申报	系列：教师
	专业：农业经济管理
	职称：教授

业绩成果材料

（申报人的业绩成果材料包括论文、科研项目、获奖以及其他成果等）

单　位（二级单位）__经济管理学院___

姓　名　　谢　琳　　

材料核对人:　　单位盖章:

核对时间:

华南农业大学制

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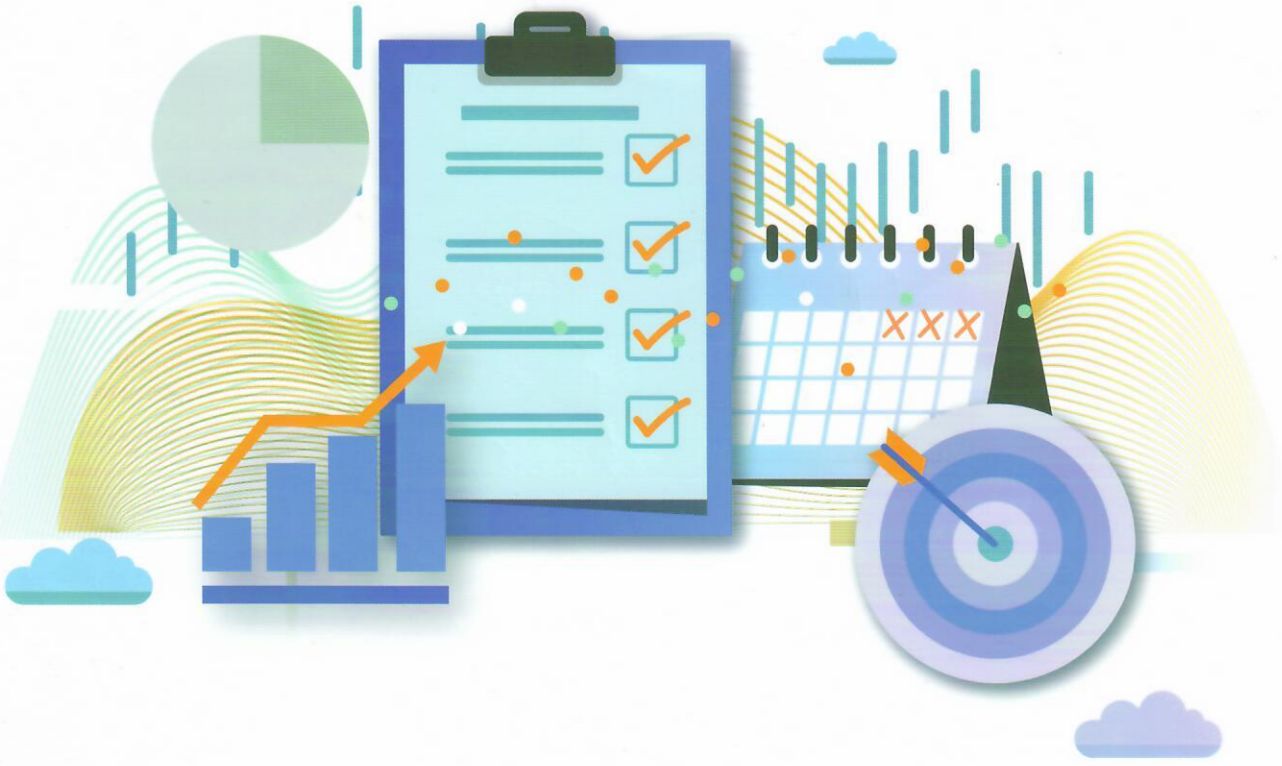
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普通高等院校工商管理类专业系列教材

管理研究方法：理论与实践

主 编◉谢 琳



北京理工大学出版社
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内容简介

《管理研究方法：理论与实践》是一本面向工商管理类本科生的教材。本科教育是培养高素质人才的重要阶段，其中研究能力的培养至关重要。随着管理学科的不断发展，工商管理类本科生不仅需要掌握学科知识，还需要具备基本的学术研究能力和素养，这就要求本科生们学习和掌握基本的管理研究方法。

本书的主要内容包括管理研究基础、研究设计、数据分析与结果呈现等。首先，本书对管理研究方法进行了全面的概述，包括研究基础与原理、科学过程与研究设计等方面的内容。其次，本书详细讲解了如何进行研究设计，包括变量测量、数据收集等方面的内容。最后，本书介绍了数据分析与结果呈现，包括假设检验、t 检验与方差分析、相关分析与回归分析、受限因变量回归模型、中介效应分析、调节效应分析、因果推断、报告结果与讨论等方面的要点。在部分涉及实操的章节，本书还给出了实例展示。

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全国哲学社会科学工作办公室

2021年度国家社会科学基金项目立项通知书

谢琳　　同志：

经国家社会科学基金学科评审组评审，全国哲学社会科学工作领导小组批准，您申请的国家社会科学基金项目数字化转型驱动农业绿色生产的机制与政策研究

获准立项，批准号 21BJY184 ，项目类别为 一般 项目，资助总额 20 万元，第一次拨款 17 万元，预留经费 3 万元。

本年度国家社会科学基金项目立项时间为2021年9月24日，立项后《国家社会科学基金项目申请书》即成为有约束力的协议，您及责任单位要按照《国家社会科学基金管理办法》承担相应责任并执行以下规定：

1. 国家社会科学基金项目研究工作要坚持正确的政治方向和学术导向，牢固树立问题意识、创新意识和精品意识，立足学术前沿，体现有限目标，突出研究重点，避免重复研究，弘扬优良学风，恪守学术规范，着力推出代表国家水准的研究成果。项目负责人要严把政治方向关和学术质量关，扎实开展研究工作，

努力维护国家社会科学基金项目的导向性、权威性和示范性。

2. 按照《国务院办公厅关于改革完善中央财政科研经费管理的若干意见》要求，我办正在修订《国家社会科学基金项目资金管理办法》。项目经费的直接费用将分为业务费、劳务费、设备费三个科目。请登录国家社会科学基金科研创新服务管理平台（网址：https://xm.npopss-cn.gov.cn/，以下简称“管理平台”）进行注册和预算填报，项目经费预算编制应科学合理、实事求是。预算填报时间为2021年10月15日-10月30日。预算填报完成后，我办将于30日内将经费拨付至责任单位，切实保障科研需要。要严格执行国家有关科研经费管理制度，按照批准预算和财务规定规范报销支出和核定票据；批准经费不再追加，不能以经费不足为由擅自缩小研究范围或变更最终成果设计。

3. 项目管理实行全过程跟踪管理、中期检查报告、阶段性成果和最终成果登记制度，科研管理部门要切实承担管理职责。要及时将最新、最有价值的成果编辑《成果要报》稿或《光明日报》、《中国社会科学报》“国家社科基金”专刊稿报我办，其采用情况、阶段性成果发表情况、作者的学风文风和治学态度等将作为验收结项的重要依据。项目执行过程中实行重要事项报告制度。如有项目名称或成果形式改变、研究内容重大调整、项目负责人或责任单位变更、项目完成时间延期，以及其他重要事项变更的，须在管理平台提交申请，按规

定逐级审核，报我办审批或备案。实施周期三年（含）以上的项目须接受一次中期检查，请根据具体通知在管理平台提交中期检查表。项目原则上要按计划完成时间申请结项，按时完成项目且成果验收达到优秀等级的负责人在申请新的国家社科基金项目时予以适当政策倾斜。国家社科基金项目实行定期清理制，本年度立项的项目清理截止日为2026年9月1日。

4.项目按计划完成后，由项目负责人在管理平台提交结项申请，但成果涉及国家秘密或重要政治敏感问题的项目应以安全方式向管理部门提交纸质结项申请。项目最终成果实行双向匿名鉴定。成果鉴定费由我办另行支付，不在项目资助经费中列支。计划出版的最终成果须先鉴定后出版；个别成果（如丛书）确需先出版的，须报我办审批。违反规定擅自出版的将视为自行终止资助协议，按有关规定追回或停止拨付研究经费。凡以博士论文或博士后出站报告为基础申报的立项课题，申请结项时须附博士论文或博士后出站报告原文，并说明结项成果与博士论文（博士后出站报告）的联系和区别；凡以在研或已结项的各级各类项目为基础申报立项的课题，不得以内容基本相同的同一成果申请多家基金项目结项。凡研究成果中存在侵犯知识产权、抄袭剽窃、弄虚作假等学术不端行为的，或观点结论有违党的理论路线方针政策、刊发后产生不良社会影响的，或在学术规范、学术道德、科研诚信等方面存在严重问题的，视情节轻重按终止研究或撤项处理并

上网通报批评。凡以“国家社会科学基金项目”名义发表成果或向有关部门报送材料，或以项目负责人、参加者等名义接受媒体采访时，若涉及政治敏感问题，事前须征得我办同意。凡以“国家社会科学基金项目”名义发表阶段性成果或最终成果，不得同时标注多家基金项目资助字样。

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7. 根据学科评审组专家的意见，部分课题名称做了修改，请以本《通知》为准。

以上规定，项目负责人及责任单位应严格遵守。如有异议，可以不接受资助（以书面形式提出申请），立项协议自行废止。

全国哲学社会科学工作办公室

2021 年 9 月 24 日

抄送：项目责任单位

广东省哲学社会科学规划领导小组办公室

2019年度广东省哲学社会科学规划项目立项通知书

谢琳同志:

经专家会议评审及省哲学社会科学规划领导小组审批，您申报的广东省哲学社会科学规划2019年度　一般项目《规模经营背景下中国化肥农药过量施用的作用机制及减量化战略研究》获准立项，批准号：GD19CYJ15，资助经费5.0万元，第一次拨款3.5万，预留经费1.5万。请认真填写立项回执，并按时交回我办。

填写立项回执后，项目申请书即成为立项协议，对项目负责人及其所在单位具有约束力。项目负责人所在单位须对立项协议的履行承担保证责任。项目负责人及所在单位须了解和执行以下规定:

1、课题组须学习并遵守《广东省哲学社会科学规划项目管理办法》。对于出现违规行为的，我办依据《广东省哲学社会科学规划

项目管理办法》的相关规定进行处理。

2、立项项目经费不再追加。课题组如不接受，我办将撤消该项目立项。而立项经费一经接受，课题组将不得以资助经费不足为由，擅自变更原设计的最终成果形式和内容。

3、项目经费分两次拨付，其中，预留经费将在项目通过鉴定结项后拨付。拨款帐号、开户行、户名如有变动，须以书面形式及时告知我办，以便准确拨款。

4、项目研究过程中，如有变更项目负责人、延长完成时间、改变成果内容或形式、变更项目管理单位、变更或增补课题组成员、中止项目或撤消项目等重要事项，项目负责人或所在单位必须按要求填写《广东省哲学社会科学规划项目重要事项变更审批表》，及时我办审批。

5、项目成果的鉴定结项由我办组织，实行匿名鉴定制度。项目鉴定结项所需材料及装印要求，详见“广东社科规划”网站。

6、成果鉴定等级分为优秀、良好、合格和不合格四个等次。不合格者即未能通过结项，不予拨付预留经费。项目成果的最终鉴定等级均通过“广东社科规划”网站予以公示，并通知项目负责人所在单位。

7、为提高成果质量，计划出版的成果必须在鉴定结项后方可出版。对于违反规定擅自出版的，视为项目负责人自行终止相关资

助协议，我办将不受理结项申请，并按有关规定扣留并追回项目研究经费。

以上规定，项目负责人及所在单位应严格遵守。如有异议，可不接受资助（在回执中注明），立项协议自行废止。

省社科规划办

地址：广州市天河北路 618 号广东社科中心 B 座 9 楼

电话：(020)83825078、37252007

邮编：510635

广东省哲学社会科学规划领导小组办公室

2019 年 12 月 14 日

广东省哲学社会科学规划项目

广州市哲学社会科学发展“十三五”规划

2020年度课题立项协议

甲　方：广州市社会科学规划领导小组办公室/广州市社会科学界联合会

地　址：广州市天河区龙口东路363号宝供大厦二楼

联系电话：020－38098424

法定代表人：曾伟玉

乙　方：华南农业大学（单位名） 谢琳（课题负责人）

地　址：广州市天河区五山路483号

课题负责人（签字）：谢琳

课题负责人手机号码：18026290568

课题负责人邮箱：xielin830163.com

二〇二〇年四月

一、经专家评审、社会公示，报广州市社会科学规划领导小组审批，同意将乙方申请的课题《 农村“厕所革命”对居民健康及其医疗负担的影响评估 》立为广州市哲学社会科学发展“十三五”规划2020年度共建课题（课题编号： 2020GZGJ73 ）。本课题负责人 谢琳 ，课题组成员 邱泽元，钟文晶，严凌霄，张禹欣，陈海婷，孟艺璇，廖佳华 。课题研究时间为2020年4月30日起至2022年4月30日。

二、该课题的研究经费原则上由课题负责人所在单位负责，参照羊城青年学人课题的经费标准提供并管理。课题完成后，由乙方所在单位科研管理部门组织专家鉴定结项，结项评审结果通报市社科规划办。如乙方无故终止课题研究，按广州市社科规划课题管理办法的相关规定进行处理。

三、课题研究和结项要求

1.以论文为最终研究成果的：论文至少发表2篇，或在市级以上报纸发表理论文章2篇。

2.以研究报告为最终研究成果的：研究报告不少于2万字。

3.以专著为最终研究成果的：专著书稿符合正式出版条件或已出版。

对应课题申请书承诺的最终研究成果形式，满足以上条件之一的即可以申请结项。

需提交单位科研管理部门的结项材料：①结题报告书；②课

题立项协议复印件；③研究成果（论文或研究报告或专著书稿）；④佐证材料（期刊相关内容复印件等）。并发送以上材料电子版至市社科规划办邮箱 gzsghb@163.com。

四、该课题的研究成果（在期刊发表或出版）原则上应标注“广州市哲学社科规划 2020 年度课题”字样和课题编号。

五、课题组必须遵守《广州市哲学社会科学发展“十三五”规划课题管理办法》和市社科规划办的其他有关规定，认真开展课题研究，合理使用课题研究经费，保证恪守学术规范，不弄虚作假，保证取得预期研究成果。

六、《课题立项协议》一式三份，一份由甲方保存，一份由乙方保存，一份由乙方所在单位科研管理部门保存。

甲方：广州市社会科学规划领导小组办公室/广州市社会科学界联合会（盖章）

通讯地址：广州市天河区龙口东路 363 号宝供大厦二楼

市社科规划办/市社科联法定代表人或委托人（签字）：

日期：2020 年 4 月 30 日

乙方：华南农业大学（盖章）　　（课题负责人）

通讯地址：广州市天河区五山路 483 号华南农业大学行政楼 631 室

课题负责人所在单位法定代表人或委托人（签字）：

日期：2020 年 4 月 30 日

结 项 证 书

项目类别：广州市哲学社会科学发展“十三五”规划2020年度共建课题（批准号：2020GZGJ73）

项目名称：农村“厕所革命”对居民健康及其医疗负担的影响评估

负 责 人：谢琳 (华南农业大学)　　主要成员：邱泽元、钟文晶、严凌霄、张禹欣、陈海婷、孟艺璇、廖佳华

结项等级：良好

证 书 号：GZSK2024273

本项目经审核准予结项，特发此证。

广州市社会科学规划领导小组办公室

2024 年 6 月 30 日

国家自然科学基金资助项目批准通知

（预算制项目）

罗明忠　先生/女士：

根据《国家自然科学基金条例》、相关项目管理办法规定和专家评审意见，国家自然科学基金委员会（以下简称自然科学基金委）决定资助您申请的项目。项目批准号：72373043，项目名称：非平衡增长理论视角下返乡创业对县域产业升级的影响：作用机理及其实现路径，直接费用：41.00万元，项目起止年月：2024年01月至2027年12月，有关项目的评审意见及修改意见附后。

请您尽快登录科学基金网络信息系统（https://grants.nsfc.gov.cn），**认真阅读《国家自然科学基金资助项目计划书填报说明》并按要求填写《国家自然科学基金资助项目计划书》（以下简称计划书）**。对于有修改意见的项目，请您按修改意见及时调整计划书相关内容；如您对修改意见有异议，须在电子版计划书报送截止日期前向相关科学处提出。

请您将电子版计划书通过科学基金网络信息系统（https://grants.nsfc.gov.cn）提交，由依托单位审核后提交至自然科学基金委。自然科学基金委审核未通过者，将退回的电子版计划书修改后再行提交；审核通过者，打印纸质版计划书（一式两份，双面打印）并在项目负责人承诺栏签字，由依托单位科研、财务管理等部门审核、签章并在承诺栏加盖依托单位公章，且将申请书纸质签字盖章页订在其中一份计划书之后，一并报送至自然科学基金委项目材料接收工作组。纸质版计划书应当保证与审核通过的电子版计划书内容一致。**自然科学基金委将对申请书纸质签字盖章页进行审核，对存在问题的，允许依托单位进行一次修改或补齐。**

向自然科学基金委提交电子版计划书、报送纸质版计划书并补交申请书纸质签字盖章页截止时间节点如下：

1. **2023年9月7日16点：**提交电子版计划书的截止时间；

2. **2023年9月14日16点：**提交修改后电子版计划书的截止时间；

3. **2023年9月21日：**报送纸质版计划书（一式两份，其中一份包含申请书纸质签字盖章页）的截止时间。

4. **2023年10月7日：**报送修改后的申请书纸质签字盖章页的截止时间。

请按照以上规定及时提交电子版计划书，并报送纸质版计划书和申请书纸质签字盖章页，逾期不报计划书或申请书纸质签字盖章页且未说明理由的，视为自动放弃接受资助；未按要求修改或逾期提交申请书纸质签字盖章页者，将视情况给予暂缓拨付经费等处理。

附件：项目评审意见及修改意见表

国家自然科学基金委员会

2023年8月24日

国家自然科学基金资助项目批准通知

（预算制项目）

钟文晶　先生/女士：

根据《国家自然科学基金条例》、相关项目管理办法规定和专家评审意见，国家自然科学基金委员会（以下简称自然科学基金委）决定资助您申请的项目。项目批准号：72173047，项目名称：互联网信息、社会网甄别与耕地质量保护技术采纳——以南方稻农为例，直接费用：48.00万元，项目起止年月：2022年01月至2025年12月，有关项目的评审意见及修改意见附后。

请您尽快登录科学基金网络信息系统（https://isisn.nsfc.gov.cn），**认真阅读《国家自然科学基金资助项目计划书填报说明》并按要求填写《国家自然科学基金资助项目计划书》（以下简称计划书）**。对于有修改意见的项目，请您按修改意见及时调整计划书相关内容；如您对修改意见有异议，须在电子版计划书报送截止日期前向相关科学处提出。

请您将电子版计划书通过科学基金网络信息系统（https://isisn.nsfc.gov.cn）提交，由依托单位审核后提交至自然科学基金委。自然科学基金委审核未通过者，将退回的电子版计划书修改后再行提交；审核通过者，打印纸质版计划书（一式两份，双面打印）并在项目负责人承诺栏签字，由依托单位科研、财务管理等部门审核、签章并在承诺栏加盖依托单位公章，且将申请书纸质签字盖章页订在其中一份计划书之后，一并报送至自然科学基金委项目材料接收工作组。纸质版计划书应当保证与审核通过的电子版计划书内容一致。**自然科学基金委将对申请书纸质签字盖章页进行审核，对存在问题的，允许依托单位进行一次修改或补齐。**

向自然科学基金委提交电子版计划书、报送纸质版计划书并补交申请书纸质签字盖章页截止时间节点如下：

1. **2021年10月22日16点：**提交电子版计划书的截止时间（视为计划书正式提交时间）；

2. **2021年10月29日16点：**提交修改后电子版计划书的截止时间；

3. **2021年11月5日16点：**报送纸质版计划书（其中一份包含申请书纸质签字盖章页）的截止时间。

4. **2021年11月25日16点：**报送修改后的申请书纸质签字盖章页的截止时间。

请按照以上规定及时提交电子版计划书，并报送纸质版计划书和申请书纸质签字盖章页，未说明理由且逾期不报计划书或申请书纸质签字盖章页者，视为自动放弃接受资助；未按要求修改或逾期提交申请书纸质签字盖章页者，将视情况给予暂缓拨付经费等处理。

附件：项目评审意见及修改意见表

国家自然科学基金委员会

2021年10月12日

受理编号：c22140500002468

项目编号：2022A1515012082

文件编号：粤基金字〔2022〕3号

广东省基础与应用基础研究基金项目

任务书

项目名称：互联网使用、信息回避与耕地质量保护技术采纳——基于广东省农户调查数据

项目类别：广东省自然科学基金-面上项目

项目起止时间：2022-01-01　至　2024-12-31

管理单位（甲方）：广东省基础与应用基础研究基金委员会

依托单位（乙方）：华南农业大学

通讯地址：广东省广州市天河区五山路483号

邮政编码：510642　　单位电话：020-85283435

项目负责人：钟文晶　　联系电话：020-85288169

（广东科技微信公众号）　　（查看任务书信息）　　（受理纸质材料二维码）

广东省基础与应用基础研究
基金委员会
二〇二〇年制

2022A1515012082

五、人员信息

项目负责人

姓名	证件号码	年龄	性别	职称	学历	在项目中承担的任务	所在单位	签名
钟文晶	362101198212070O2X	40	女	副教授	博士研究生	项目负责人	华南农业大学	钟文晶

项目组主要成员

姓名	证件号码	年龄	性别	职称	学历	在项目中承担的任务	所在单位	签名
谢琳	432503198309116517	39	男	副教授	博士研究生	理论框架与问卷设计	华南农业大学	谢琳
郭萍	362101197612060627	46	女	副教授	博士研究生	文献梳理与分析	华南农业大学	郭萍
江雪萍	441422197911270023	43	女	副教授	博士研究生	数理模型构建	华南农业大学	江雪萍
何应龙	440112198804080333	34	男	未取得	硕士研究生	计量模型	华南农业大学	何应龙
王月	14260319970429206O	25	女	未取得	本科	调研实施与数据清洗	华南农业大学	王月
薛蓓蓓	440582199712285505	25	女	未取得	本科	调研实施与数据分析	华南农业大学	薛蓓蓓
王美	130528199510027224	27	女	未取得	本科	调研实施与数据清洗	华南农业大学	王美

八、本任务书签约各方

管理单位（甲方）：　　广东省基础与应用基础研究基金委员会　（盖章）

法定代表人（或法人代理）：　曾路　（签章）

2022 年　04 月　21 日

依托单位（乙方）：　华南农业大学　（盖章）

法定代表人（或法人代理）：　刘雅红　（签章）

联系人（项目主管）姓名：　倪慧群　（签章）

Email：　kjcgxk@scau.edu.cn

电话：　020-85283435　/　15920301530

开户单位名称：　华南农业大学

开户银行名称：　广东广州工行五山支行

开户银行帐号：　3602002609000310520

2022年 05月 7日

年　月　日

联系人（项目负责人）姓名：　钟文晶　（签名）

Email：　wjzhong@scau.edu.cn

电话：　020-85288169

2022年 05月 7日

年　月　日

受理编号：c23140500001553

项目编号：2023A1515010881

文件编号：粤基金字〔2023〕2号

广东省基础与应用基础研究基金项目

任务书

项目名称： 农地确权政策如何影响政治信任？——基于基层自治组织信任的分析

项目类别： 广东省自然科学基金-面上项目

项目起止时间： 2023-01-01 至 2025-12-31

管理单位（甲方）： 广东省基础与应用基础研究基金委员会

依托单位（乙方）： 华南农业大学

通讯地址： 广东省广州市天河区五山路483号

邮政编码： 510642 **单位电话：** 020-85283435

项目负责人： 胡新艳 **联系电话：** 020-85288169

2023A1515010881

（广东科技微信公众号） （查看任务书信息） （受理纸质材料二维码）

广东省基础与应用基础研究
基金委员会
二〇二〇年制

填写说明

一、项目任务书内容原则上要求与申报书相关内容保持一致，不得无故修改。

二、项目承担单位通过广东省科技业务管理阳光政务平台下载项目任务书，按要求完成签名盖章后扫描上传到广东省科技业务管理阳光政务平台。

三、签名盖章说明。请分别在单位工作分工及经费分配情况页、人员信息页、签约各方页等地方按要求签字或盖章，签章不合规或错漏将不予受理。其中，人员信息页要求所有参与人员本人亲笔签名，代签或印章无效，漏签将不予受理。

四、本任务书自签字并加盖公章之日起生效，各方均应负本任务书的法律责任，不应受机构、人事变动影响。

五、根据《广东省科学技术厅广东省则政厅关于深入推进省基础与应严础研究基金项目经费使用“负面清单+包干制”改革试点工作的通知》（粤科规范字[2022]2号），2022年度及以后立项资助的全部省基金项目（包括省自然科学基金、省市联合基金、省企联合基金项自等）均适用“负面清单+包干制”，项目提交申请书和任务书时无需编制费用明细科目预算。

2023A1515010011

一、主要研究内容和要达到的目标

一、研究目标

（1）学术性目标：基于中国农村集体土地产权制度安排的特殊背景，将农地确权政策冲击和农户政治信任联系起来，构建“农地确权——权益保障——政治信任”的理论框架，为理解农地确权的政治信任影响效应及其作用路径提供经验证据，从而为产权的治理逻辑找到了经验证据，也将确权政策的经济影响研究拓展到政治影响层面。

（2）对策性目标：全面认识和客观评价农地确权政策在经济、政治层面蕴含的“双重效应”。为提升农户基层政治信任提供了清晰路径，有利于帮助各界理解“民心从何而来”的问题。

二、研究内容

以 “农地确权是否影响——如何影响——影响存在的条件——影响是否扩散其他政治层面”为主线，考察农地确权对政治信任的影响及其作用机理。

（1）农地确权与农户政治信任：分析框架。梳理国内外的关于农地确权、政治信任和公共政策绩效的理论研究和经验研究，厘清目前的研究现状，在已有研究的基础上，构建理论分析框架，并将通过数理模型进行推导，并提出研究假说。

（2）农地确权对农户政治信任的影响：基准模型结果分析。本部分将分别从主观认知和客观行为两个角度，实证考察农地确权对农户基层政治信任的影响。关注农地确权前后，农民基层政治信任水平是否存在变化？进一步地，考虑农地确权对农户政治信任的影响是否存在动态持续性以及同群效应。为保证研究结果的可靠性，通过更换估计方法、安慰剂检验、考虑二轮承包证书的影响和更换CFPS数据等方法检验结果的稳健性。

（3）农地确权对农户政治信任的影响：作用机制与异质性分析。尝试构建理论模型，阐明农地确权通过什么渠道影响农户政治信任，分析观察农地规模、村庄规模、区位特征等禀赋条件下农地确权对农户政治信任产生的差异化影响，为完善乡村治理发展提供决策依据。

（4）农地确权提升农户政治信任的条件。同样是农地确权，但政策执行的规范程度不同，可能会产生差异化的影响，因此尝试从“政策普及”“填写登记表”“现场指认”等关键环节考察确权程序执行规范影响的异质性，寻求提升确权政策影响的改革措施。

（5）拓展研究：确权政策与其他相关维度的政治影响。挖掘基准因果模型结论背后更丰富、可验证的相关含义，分析确权政策是否会扩散至政治信任外的其他层面，包括干群关系、农户集体行动参与以及村庄选举参与行为等。

（6）兼容性改革策略及其配套政策研究。阐明实证结果的政策内涵，按照匹配性和一致性的内在要求，提出“因地而治”的兼容性改革措施。

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二、项目预期获得的研究成果及形式

<table>
<tr><td rowspan="3">论文及专著情况</td><td colspan="2">国家统计源刊物以上刊物发表论文（篇）</td><td colspan="2">3</td><td colspan="2">科技报告（篇）</td><td colspan="2">1</td></tr>
<tr><td colspan="2">其中被SCI/EI/ISTP收录论文数（篇）</td><td colspan="2">1</td><td colspan="2">培养人才（人）</td><td colspan="2"></td></tr>
<tr><td colspan="2">专著（册）</td><td colspan="2"></td><td colspan="2">引进人才（人）</td><td colspan="2"></td></tr>
<tr><td rowspan="3">专利情况(项)</td><td colspan="2">发明专利</td><td colspan="2">实用新型专利</td><td colspan="2">外观设计专利</td><td colspan="2">国外专利</td></tr>
<tr><td>申请</td><td>授权</td><td>申请</td><td>授权</td><td>申请</td><td>授权</td><td>申请</td><td>授权</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

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三、项目进度和阶段目标

（一）项目起止时间： 2023-01-01 至 2025-12-31		
（二）项目实施进度及阶段主要目标:		
开始日期	结束日期	主要工作内容
2023-01-01	2023-03-31	（1）收集、整理文献，奠定理论基础； （2）进一步凝练形成对项目总体设计，明确研究目标、思路、重点； （3）制定阶段性工作计划，落实分工； （4）组织参加会议交流。
2023-04-01	2023-09-30	（1）总结农地确权政策的推进和实施成果与农村政治信任现状，从宏观上把握政策精神和取向； （2）建立理论逻辑框架，提出研究假说； （3）设计调研方案与调查问卷； （4）实施调研，搜集数据。
2023-10-01	2024-01-31	（1）整理调查数据和笔记； （2）将调查数据和笔记录入计算机终端； （3）进行基础数据处理，构建调查数据库。 （4）撰写工作论文。
2024-02-01	2024-08-31	（1）对研究假说进行计量模型检验； （2）根据计量结果，撰写阶段性论文和研究报告，向相关期刊投稿； （3）向有关部门报送调研报告。
2025-09-01	2025-12-31	（1）整理前期成果的修改意见，对应完善研究报告； （2）整合研究成果，形成研究报告。 （3）修改完善结题报告，做好结题工作。

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四、项目总经费及省基金委经费预算

1.省基金委经费下达总额： （大写）壹拾万圆整；（小写 ）10万元；					
2.省基金委经费年度下达计划：					
年度	2023 年	年	年	年	年
经费(万元)	10.00				

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五、人员信息

项目负责人								
姓名	证件号码	年龄	性别	职称	学历	在项目中承担的任务	所在单位	签名
胡新艳	440106197202044042	51	女	教授	博士研究生	项目负责人	华南农业大学	

项目组主要成员								
姓名	证件号码	年龄	性别	职称	学历	在项目中承担的任务	所在单位	签名
谢琳	432503198309116517	40	男	副教授	博士研究生	理论研究	华南农业大学	
洪炜杰	440583199103291332	32	男	讲师	博士研究生	理论研究	华南农业大学	
陈卓	430102199410071514	29	男	未取得	硕士研究生	计量分析	华南农业大学	
许金海	440923199509042657	28	男	未取得	硕士研究生	计量分析	华南农业大学	
张欢	440105199907291222	24	女	未取得	本科	文献收集与数据处理	华南农业大学	
黄婕	441224200007204366	23	女	未取得	本科	文献收集与数据处理	华南农业大学	
许梓缘	440902199906090423	24	女	未取得	本科	文献收集与数据处理	华南农业大学	

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六、工作分工及财政经费分配

承担/参与单位名称（盖章）	工作分工	省级财政科技资金分配（万元）
华南农业大学	负责本课题主要准备及实施工作	10.00
	合计	10.00

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七、任务书条款

第一条 甲方与乙方根据《中华人民共和国民法典》及国家有关法规和规定，按照《广东省科学技术厅关于广东省基础与应用基础研究基金（省自然科学基金、联合基金等）项目管理的实施细则（试行）》《广东省省级科技计划项目验收结题工作规程（试行）》等规定，为顺利完成（2023）年农地确权政策如何影响政治信任？——基于基层自治组织信任的分析专项项目（文件编号：粤基金字〔2023〕2号 ）经协商一致，特订立本任务书，作为甲乙双方在项目实施管理过程中共同遵守的依据。

第二条 甲方的权利义务：

1.按任务书规定进行经费核拨的有关工作协调。

2.根据甲方需要，在不影响乙方工作的前提下，定期或不定期对乙方项目的实施情况和经费使用情况进行检查或抽查。

3.根据《广东省科研诚信管理办法(试行)》等规定对乙方进行科技计划信用管理。

第三条 乙方的权利义务：

1.确保落实自筹经费及有关保障条件。

2.按任务书规定，对甲方核拨的经费实行专款专用，单独列账，并随时配合甲方进行监督检查。

3.经费使用按照广东省级财政科研项目经费使用等有关规定进行管理。

4.项目依托单位应制定经费使用“负面清单+包干制”内部管理制度并报甲方备案。

5.使用财政资金采购设备、原材料等，按照《广东省实施〈中华人民共和国招标投标法〉办法》有关规定，符合招标条件的须进行招标。

6.项目任务书任务完成后，或任务书规定的任务、指标及经费投入等提前完成的，乙方可提出验收结题申请，并按甲方要求做好项目验收结题工作。

7.若项目发生需要终止结题的情况，乙方须提出终止结题申请，并按甲方要求做好项目终止结题工作。

8.在每年规定时间内向甲方如实提交上年度工作情况报告，报告内容包含上年度项目进展情况、经费决算和取得的成果等。

9.按照国家和省有关规定，提交科技报告及其他材料。

10.利用甲方的经费获得的研究成果，项目负责人和参与者应当注明获得“广东省基础与应用基础研究基金（英文：Guangdong Basic and Applied Basic Research Foundation）（项目编号）”资助或作有关说明。

11.乙方要恪守科学道德准则，遵守科研活动规范，践行科研诚信要求，不得抄袭、剽窃他人科研成果或者伪造、篡改研究数据、研究结论；不得购买、代写、代投论文，虚构同行评议专家及评议意见；不得违反论文署名规范，擅自标注或虚假标注获得科技计划（专项、基金等）等资助；不得弄虚作假，骗取科技计划（专项、基金等）项目、科研经费以及奖励、荣誉等；不得有其他违背科研诚信要求的行为。

12.确保本项目开展的研究工作符合我国科技伦理管理相关规定。

第四条 在履行本任务书的过程中，如出现广东省相关政策法规重大改变等不可抗力情况，甲方有权对所核拨经费的数量和时间进行相应调整。

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第五条 在履行本任务书的过程中，当事人一方发现可能导致项目整体或部分失败的情形时，应及时通知另一方，并采取适当措施减少损失，没有及时通知并采取适当措施，致使损失扩大的，应当就扩大的损失承担责任。

第六条 本项目技术成果的归属、转让和实施技术成果所产生的经济利益的分享，除双方另有约定外，按国家和广东省有关法规执行。

第七条 根据项目具体情况，经双方另行协商订立的附加条款，作为本任务书正式内容的一部分，与本任务书具有同等效力。

第八条 本任务书一式三份，各份具有同等效力。甲、乙方及项目负责人各执一份，三方签字、盖章后即生效，有效期至项目结题后一年内。各方均应负任务书的法律责任，不应受机构、人事变动的影响。

第九条 乙方必须接受甲方聘请的本项目任务书监理单位的监督和管理。监理单位按照甲方赋予的权利对本项目任务书的履行进行审核、进度调查，对项目任务书变更、经费使用情况进行监督管理及组织项目验收。

说明：1.本任务书中，凡是当事人约定无需填写的内容，应在空白处划（/）。

2.委托代理人签订本任务书的，应出具合法、有效的委托书。

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八、本任务书签约各方

管理单位（甲方）：　　广东省基础与应用基础研究基金委员会 （盖章）

法定代表人（或法人代理）：　　曾路　　（签章）

2023 年　02 月　14 日

依托单位（乙方）：　华南农业大学　　（盖章）

法定代表人（或法人代理）：　刘雅红　　（签章）

联系人（项目主管）姓名：　倪慧群　　（签章）

Email：kjcgxk@scau.edu.cn

电话：020-85283435 / 15920301530

开户单位名称：　华南农业大学

开户银行名称：　广东广州工行五山支行

开户银行帐号：　3602002609000310520

年　月　日

联系人（项目负责人）姓名：　胡新艳　　（签名）

Email：huxyan@scau.edu.cn

电话：020-85288169

年　月　日

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SCAULIB202518982

检索证明

根据委托人提供的论文材料，委托人**华南农业大学经济管理学院 谢琳** 11 篇论文收录情况如下表。

序号	论文名称	发表刊物及发表的年月卷期/页码等	作者排名	论文等级	作者文中单位	收录情况	影响因子	中科院大类分区
1	Distributional effects of expressway access on rural entrepreneurial activities in China	SOCIO-ECONOMIC PLANNING SCIENCES 出版年：2024 出版日期：AUG 卷期：94 页码：- 文献号：101964 文献类型：Article	第一作者、通讯作者	T2 类	华南农业大学经济管理学院	SSCI	IF2-year=5.4 IF5-year=5.3 （2024）	经济学 1区 Top 期刊：是 （2025）
2	Smartphone access, digital economy, and pesticide use intensity: Evidence from China	SCIENCE OF THE TOTAL ENVIRONMENT 出版年：2024 出版日期：SEP 15 卷期：943 页码：- 文献号：173867 文献类型：Article	第一作者	A 类	华南农业大学经济管理学院	SCI	IF2-year=8.0 IF5-year=8.7 （2024）	环境科学与生态学 2区 Top 期刊：是 （2025）
3	Relationship between rural land titling and land transfer in China: a systematic literature review and meta-analysis	FRONTIERS IN SUSTAINABLE FOOD SYSTEMS 出版年：2023 出版日期：JUN 1	第一作者	B 类	华南农业大学经济管理学院	SCI	IF2-year=3.7 IF5-year=4.7 （2023）	农林科学 2区 Top 期刊：否 （2023）

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华南农业大学图书馆 信息检索专用章

		卷期：7 页码：- 文献号：1143595 文献类型：Review						
4	农业社会化服务组织何以促进化肥减量——基于经营主体的匹配效应研究	华中农业大学学报（社会科学版） 出版年：2022 出版日期： 卷期： 2 页码：47-56 文献号： 文献类型：期刊论文	第一作者	B 类	华南农业大学 国家农业制度与发展研究院	CSSCI	无	无
5	How Are Smallholder Farmers Involved in Digital Agriculture in Developing Countries: A Case Study from China	LAND 出版年：2021 出版日期：MAR 卷期：10 3 页码：- 文献号：245 文献类型：Article	第一作者	C 类	华南农业大学 国家农业制度与发展研究院	SSCI	IF2-year=3.905 IF5-year=4.048 （2021）	环境科学与生态学 3 区 Top 期刊：否 （2021）
6	Is Futurization the Culprit for the Violent Fluctuation in China's Apple Spot Price?	AGRICULTURE-BASEL 出版年：2021 出版日期：APR 卷期：11 4 页码：- 文献号：342 文献类型：Article	第一作者	C 类	华南农业大学 国家农业制度与发展研究院	SCI	IF2-year=3.408 IF5-year=3.459 （2021）	农林科学 3 区 Top 期刊：否 （2021）

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7	技术进步、信任格局与农业生产环节外包	农业技术经济 出版年：2020 出版日期： 卷期： 11 页码：4-16 文献号： 文献类型：期刊论文	第一作者	A 类	华南农业大学 国家农业制度 与发展研究院	CSSCI	无	无
8	农业规模经营真的有助于化肥减量吗？——来自荟萃分析的证据	中国农业大学学报 出版年：2020 卷期：25 11 页码：- 文献号： 文献类型：	第一作者	B 类	华南农业大学 国家农业制度 与发展研究院	北大核心	无	无
9	服务外包有助于化肥减量吗？——来自荟萃分析的证据	南方经济 出版年：2020 出版日期： 卷期： 9 页码：26-38 文献号： 文献类型：期刊论文	第一作者	A 类	华南农业大学 国家农业制度 与发展研究院	CSSCI	无	无
10	A Macro Perspective on the Relationship between Farm Size and Agrochemicals Use in China	SUSTAINABILITY 出版年：2020 出版日期：NOV 卷期：12 21 页码：- 文献号：9299 文献类型：Article	第一作者	无	华南农业大学 国家农业制度 与发展研究院	SSCI	IF2-year=3.251 IF5-year=3.473 （2020）	环境科学与生态学 4区 Top 期刊：否 （2020）

华南农业大学图书馆SCAULIB20251[illegible]2

11	Suburban agriculture, immigrant farmers, and access to agricultural services and resources	Journal of Agriculture, Food Systems, and Community Development 出版年：2023 出版日期：2023-01-28 卷期：12 2 页码：235-248 文献号： https://doi.org/10.5304/jafscd.2023.122.001 文献类型：	第一作者	普刊类	华南农业大学	ESCI	无	无

说明：论文等级和中科院大类分区按《华南农业大学学术论文评价方案（试行）》划分。

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检索员：卢炳卫

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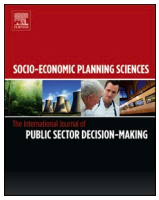
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Distributional effects of expressway access on rural entrepreneurial activities in China

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ABSTRACT

Transportation infrastructure development, such as expressways, could impact economic development in local and neighboring regions differently. However, there is limited evidence of these impacts on rural and developing areas. Here, we use Heyuan, a rural region in China, as the case to examine the effects of expressway access on entrepreneurial activity. Using detailed township-level panel data from 2004 to 2016 and a multiple-period DID model with spatial effects, we find that opening entrances and exits significantly promotes entrepreneurial activities in local towns but suppress them in adjacent towns. Furthermore, we find that the development of expressways leads to a greater concentration of firms in the provincial centers of towns with better economic development. The development of expressways has had a significant boost on tertiary industries. This study shows that the construction of highways attracts entrepreneurial activities to regions with better conditions, and this maximizes economic efficiency but at the expense of creating regional economic imbalances. Therefore, this model may be the primary model of China's economic development in the future.

1. Introduction

Transportation infrastructure, particularly expressways, primarily catalyze urban development and economic growth [1,2]. Improving transportation reduces transportation and trade costs and enables the free flow of people, capital, and other factors [3,4]. Smith [5] points out that with the development of land and water transportation, divided regions became connected, resulting in people from different places gaining the mobility to trade with each other, thereby increasing the market's size. Historical urban development experience shows that new towns are primarily concentrated in transportation hubs or along both sides of arterial roads [2]. In China, the construction of roads and canals has been closely related to urban development since ancient times.

Within China, as early as 200 B.C. (i.e., during the Qin Dynasty), straight roads were built throughout the country for the emperors' inspection tours [6]. As the economic center of gravity shifted southward, the North-South Grand Canal was opened during the Sui and Tang dynasties (581–907 A.D.) to secure supplies for the capital city. During the Yuan, Ming, and Qing Dynasties (1271–1912 A.D.), the 1794 km long Beijing-Hangzhou Grand Canal was built based on the North-South Grand Canal [7]. The improvement of the canal system promoted trade and mobility, gathering materials and population for the rise of cities and the development of industry and commerce. Chinese towns started to develop along the river then. During the Ming and Qing dynasties in China, the "Four Great Cities" (Chuzhou, Yangzhou, Suzhou, and Hangzhou) were built along the canals [8]. In the modern world, the rise of new modes of transportation, such as railroads and highways, has gradually replaced rivers. These new modes led to the development of cities along the railroad line [9]. Cities such as Zhengzhou and Shijiazhuang have steadily developed and grown, becoming railroad hub cities.

However, with the emergence of modern transportation methods such as railways and expressways, the geographical distribution of cities and economic activities began to change. The economy and population will gradually concentrate in a few areas, such as large regional cities [10]. Firms tend to develop in regions with higher demand and income and stronger inter-firm linkages. Similarly, the labor force will move to areas with better job opportunities and higher wages [11]. Economic activities are constantly concentrated in the central city, thus creating a phenomenon of economic agglomeration in geography. The New Economic Geography (NEG) theory pioneered by Krugman [12] explains such a core-periphery pattern of unbalanced spatial distribution.

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Accetturo [13] develops a New Economic Geography-Growth (NEGG) model based on the NEG. Central regions have larger market sizes and higher rates of innovation, thus attracting more new firms to enter. In central areas with high agglomeration, the innovation cost of enterprises is significantly reduced. It becomes conducive to enhancing enterprises' innovation capacity and thus promoting economic growth. In other words, with the reduction of transportation and trade costs, there is a development gradient between the central city and the areas along the high-speed railway. Resultantly, the factor resources will be gathered from the peripheral regions to the central area, and the central area will benefit at the expense of the peripheral regions, namely agglomeration shadow [14,15].

This paper explores the impact of transportation infrastructure, represented by expressways, on the distribution of entrepreneurship in China and whether a phenomenon known as the "agglomeration shadow" exists. To this end, we have collected a township-level dataset on the number of firms in each town and the registration capital of each firm in the relatively rural and remote region of Heyuan, Guangdong Province, China. This dataset is combined with information on the Chinese expressway system to estimate how the expressway affects the enterprises' layout.

The study site for this paper is Heyuan City, located in the southern province of Guangdong, China, a typical rural area. Similar to most developing countries, China has significant regional development disparities. Adjacent to Heyuan is the Guangdong-Hong Kong-Macao Greater Bay Area, one of the world's four largest bay areas and one of the most developed regions in China, with three world-class metropolises: Hong Kong, Shenzhen, and Guangzhou, all boasting very high levels of industrial and service sector development. Heyuan City, as an outer area of the Greater Bay Area, compared to that, Heyuan has a mountainous area accounting for 54 % of the total area, hilly areas accounting for 43.2 %, and plains only for 2.1 %. Its poor geographical environment makes economic development even more challenging. The Bay Area has become a significant growth pole for the world economy with its superior geographical location and role as a node connecting global markets. At the same time, it is precisely because of its strong sucking effect that it may also have adverse effects on its peripheral areas. Ultimately, talents, capital, and other factors flow into the Greater Bay Area, leading to a severe loss of talent in the Heyuan region.

The relationship between growth poles and peripheral areas is a worldwide problem many developing countries face. The Guangdong-Hong Kong-Macao Greater Bay Area (GBA) is unique in the Chinese context. It is a highly developed economic region adjacent to numerous rural areas, forming a unique urban-rural interaction model. The GBA is distinctly different from other developed countries' bay areas. For example, the other three bay areas - New York Bay Area, San Francisco Bay Area in the United States, and Tokyo Bay Area in Japan - are all concentrated in urban areas and involve less development of surrounding rural areas.

Through studying the surrounding rural areas of the GBA, this paper not only reveals the role of expressway construction in the specific socio-economic context of China but also sheds light on how to establish an effective interaction mechanism between the rapidly developing urban economic centers and the relatively backward rural areas, providing valuable references for other developing countries worldwide in handling the relationship between growth poles and the peripheral regions and promoting balanced regional development.

The remainder of the paper is organized as follows. Section 2 is the literature review and theoretical framework. Section 3 describes the identification strategies and data in detail. Section 4 reports our main empirical results. Section 5 presents discussions. Section 6 concludes.

2. Literature review and theoretical framework

2.1. Literature review

On the one hand, roads have always been considered an essential reason for promoting entrepreneurial activities and economic development [16,17] and a vital means of achieving regional economic growth [18,19]. (1) At the macro level, research based on developed countries has found that road connectivity can improve regional market access, thereby increasing regional economic effects [20,21]. In addition, Gibbons et al. [22] found that road improvements can reduce transportation and business travel costs, stimulate participation, and thus increase productivity due to business agglomeration and increased capital intensity. Studies based on developing countries have found similar results (India [19,23], Cameroon [24], Ethiopia [25], Nepal [26], and South Africa [27]). For example, studies have discovered that China's expressway and high-speed rail systems contribute to faster GDP growth in road-connected areas [16,17].

(2) At the micro level, from the perspective of individual entrepreneurship, the connectivity of roads allows people to break free from geographical constraints, shorten spatial and temporal distances, increase personnel mobility, facilitate the flow of knowledge, accelerate the flow of information, create more entrepreneurial opportunities, and thus increase the rate of individual entrepreneurship [28]. From the perspective of regional entrepreneurship, transportation infrastructure improvements affect economic entities' location choices by influencing transportation costs [29]. Reducing the distance between inter-regional expressways helps increase their trade volume and trade value [30]. Most existing studies are based on data from manufacturing enterprises, examining the transportation network's impact on manufacturing enterprises' entrepreneurship. The results show that new manufacturing enterprises cluster in areas close to expressways [31]. However, Audretsch et al. [32] found that investment in expressway infrastructure has little or no effect on entrepreneurial activities in German regions.

On the other hand, some literature suggests that the development of transportation facilities also has a sucking effect – resources are attracted from peripheral cities to core cities, thus disrupting the balance of regional economies [33,34]. Chandra and Thompson [35] proposed that constructing transportation facilities would attract economic activities from neighboring counties to counties with road access due to reduced transportation costs, resulting in inter-county disparities in economic development. In China, improvements in the transportation network have also had a similar effect. Existing research shows that increased transportation speeds have reduced people's transportation costs, leading to the transfer of economic activities from surrounding counties to central cities [36]. Specifically, improvements in the transportation network have led to population movement from peripheral areas to core areas and industrial adjustments [37], talent flow to cities with resource advantages, and employment in skill-intensive industries shifting from the periphery to the core [38], thus inhibiting economic growth in peripheral counties [34].

Although transportation facilities are directly related to entrepreneurial activities and economic development, it is worth noting that according to the above literature, there are still research gaps in the study of the entrepreneurial effects of transportation infrastructure: (1) Under the influence of the promoting and sucking effects, how does the construction of transportation infrastructure affect rural entrepreneurial activities is a question worthy of further exploration. However, existing literature rarely focuses on the impact of transportation on the spatial distribution of new ventures. (2) Research on the relationship between transportation infrastructure and rural entrepreneurship is insufficient. Although some studies have focused on farmer entrepreneurship from an individual perspective, previous research at the regional level has rarely focused on rural entrepreneurship and the entrepreneurial activities in rural areas. (3) Due to data limitations, existing research has focused chiefly on the impact of transportation on the entrepreneurial

activities of manufacturing enterprises, and research on the entrepreneurship of other types of enterprises is still lacking.

To fill these research gaps, this paper will discuss three aspects: (1) Taking Heyuan City, which has a lower economic development, as the research object and using more micro and in-depth town-level research data. This paper uses unique township expressway construction and high-resolution enterprise data to more finely understand the impact of expressways on rural entrepreneurship. (2) Considering that the impact of transportation facilities on core and peripheral areas is different, this study also incorporates spatial effects into the model using the spatial difference-in-difference (SDID) model, examining the impact of transportation infrastructure represented by expressways on the layout of Chinese entrepreneurship from a spatial transfer perspective. (3) Based on understanding the impact of transportation infrastructure on overall entrepreneurship using registered commercial enterprises, this paper further explores empirical data to examine the impact of expressway construction on the industrial and scale selection of rural entrepreneurship.

2.2. Theoretical framework

A basic consensus in entrepreneurship research is that entrepreneurial entry depends on an individual's ability to accumulate the resources needed to start a new business [39]. However, the accumulation process of factor resources is a whole of obstacles, which are even more severe for rural entrepreneurs. The flow of factor resources requires a material carrier. As an essential infrastructure, expressways can efficiently activate, integrate, and disseminate more entrepreneurial resources rural entrepreneurs need to create new businesses. For areas along the road, road connectivity can reduce trade costs [40], i.e., reduce the transportation costs of materials and goods between regions, thereby improving the transportation capacity of the areas along the way and improving regional market access [20,41], to promote the flow of factors such as talent, goods, and capital. These talents, funds, and other factors are essential resources for entrepreneurial activities [42]. Therefore, the rapid expansion of the transportation network has reduced transportation costs, making it easier for talent, capital, and other factors to flow and promote entrepreneurial activities [43,44].

However, good transportation facilities not only help to input resources from other places into the local area at low cost, but they can also transfer local resources to other places at low cost. Transportation infrastructure plays a decisive role in the spatial organization of regional economic activities [45]. New economic geography theory points out that the distribution difference in transportation infrastructure is essential for forming the "core-periphery" regional pattern [12]. The "core-periphery" theory of new economic geography shows that the changes in transportation costs caused by differences in transportation infrastructure have differential effects on the spatial distribution of economic activities in the agglomeration pattern, ultimately changing the centripetal and centrifugal forces of regions that initially have equal external conditions, shaping the agglomeration form and distribution pattern of regional economic activities [46]. Krugman [12] believes that transportation cost savings are a significant "centripetal force" for industrial agglomeration, and this "centripetal force" will have a cumulative effect under the action of path dependence and self-expectation, thereby forming a "core-periphery" spatial structure and strengthening this unbalanced development of the region [14].

Companies tend to develop in areas with higher demand and revenue, and labor tends to move to areas with higher comparative benefits [11]. A natural location advantage is formed in areas with better development levels, with more significant market potential and size, thereby impacting entrepreneurial activities [47]. Improving transportation infrastructure promotes the free flow of factor resources such as labor, capital, and information by reducing transportation costs. On the one hand, this flow has a positive agglomeration economic effect in core areas, helping to attract more labor, capital, and other production factors and inputting talents, funds, and other necessary elements for business creation [42], thereby attracting companies to concentrate and promoting local entrepreneurial activities [21,44]. On the other hand, this reduction in transportation costs does not positively affect all regions. For peripheral areas, transportation infrastructure construction may instead lead to a siphoning effect, attracting local resources and talents to core areas [34], thereby weakening the entrepreneurial potential of peripheral areas. As factor resources continue to move towards core areas, such a siphoning effect will inhibit the development of peripheral areas, benefiting core areas at the expense of surrounding areas [34,45]. New economic geography theory points out that reducing transportation costs does not always equalize economic activities between regions but may exacerbate regional development imbalance [12]. In core areas, companies continue to cluster. In areas where companies cluster, the market size continues to expand, the regional economy accumulates, and the clustering force strengthens, thereby continuously absorbing scarce resources from peripheral areas and inhibiting entrepreneurial activities and economic development in peripheral areas, further causing regional development imbalances.

It can be seen that the improvement of transportation infrastructure enhances the economic effects of core areas of agglomeration by reducing transportation costs and attracting more factors to flow in, thereby promoting local entrepreneurial activities and economic growth. At the same time, this cost reduction has a siphoning effect on peripheral areas, leading to restrictions on their entrepreneurial activities and economic growth, exacerbating economic imbalances between regions.

Fig. 1 shows the logical framework of this study.

3. Study design

3.1. Study area and data

Heyuan, Guangdong, China, is selected as the study site. Guangdong Province is in the southern coastal region of China. Heyuan, located in the northeast of Guangdong, has 15,700 square kilometers and a vast rural area with relatively lagging economic development. Nevertheless, by 2020, Heyuan's rural population is 1.46 million, accounting for 51.50 % of the region's total population.[1] Heyuan's GDP per capita is 38,860 yuan,[2] ranking 19th among 21 prefecture-level cities in the Guangdong Province.[3] The above statistics also show the urgency and importance of promoting local economic development in rural areas. Fig. 2 shows the location of Heyuan in China.

In the past 20 years, the accelerated progress of infrastructure construction in China has seen the building of several national expressways that pass through Heyuan. We obtained the expressway exit panel data of 97 towns in 6 counties and districts of Heyuan from 2004 to 2016 from the Heyuan Highway Bureau. As of 2016, Heyuan City has eight expressways passing through its administrative district, among which there are 24 towns with expressway entrances and exits (Table 1). To study the impact of expressway entrance/exit settings on entrepreneurial activities, we set a dummy variable for expressway intersections (i.e., assigning a value of 1 if a township has an expressway entrance/exit at that year and 0 otherwise).

The data on enterprise registration in Heyuan is obtained from the

[1] Heyuan City 7th National Census Bulletin: http://www.heyuan.gov.cn/zwgk/tjsj/tjnb/content/post_438675.html.

[2] From the Statistical Bulletin of National Economic and Social Development of Heyuan City in 2020 (http://www.heyuan.gov.cn/zwgk/tjsj/tjnb/content/post_428545.html) and Guangdong Statistical Yearbook 2021 (http://stats.gd.gov.cn/gdtjnj/content/post_3557537.html) are calculated.

[3] Calculated by the 2020 National Economic and Social Development Statistical Bulletin and the Guangdong Statistical Yearbook 2021 for all cities in Guangdong Province.

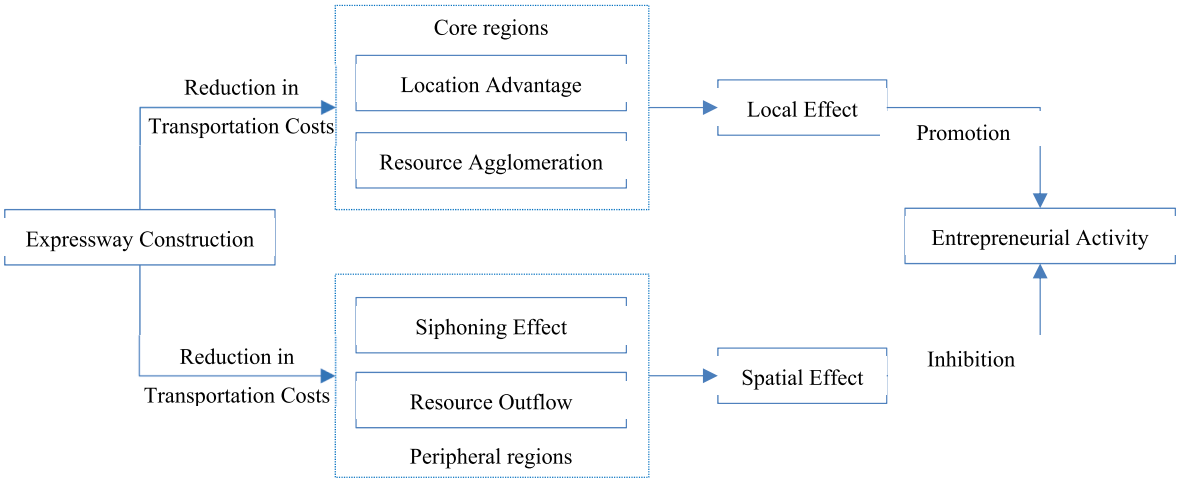


Fig. 1. Logical framework.

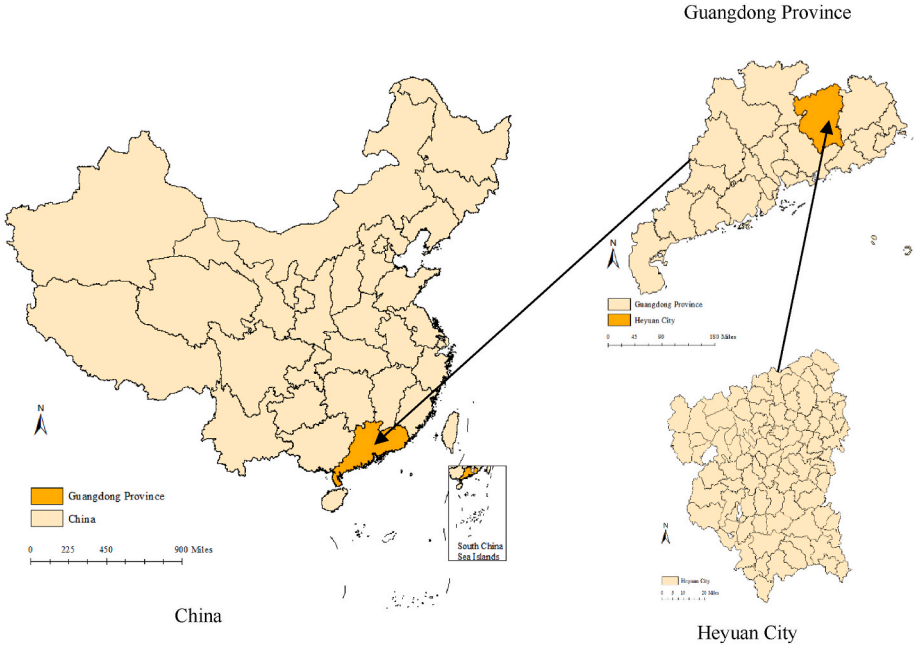


Fig. 2. Study site.

Guangdong Provincial Government Data Open Platform.[4] This comprehensive dataset includes details such as company names, unified social credit codes, registered addresses, registered capital, registration dates, and business scopes. It is important to note that the data available on this platform extends to 2016.

Since 2016, China's fundamental political and economic system has remained stable without disruptive changes. In terms of highway network planning, China has consistently prioritized infrastructure development. Beginning with the "5–7″ Expressway Construction Plan approved by the State Council in 1992, followed by the "7-9-18″ Expressway Network Plan approved in 2004 [38], and culminating in the implementation of the "National Highway Network Plan (2013–2030)" in2013,[5] China's expressway network has experienced remarkable expansion. By the end of 2003, the total length of expressways in China was approximately 29,700 km, which increased to over 131,000 by 2016, solidifying China's position as the global leader in expressway length. This growth has facilitated the connection of over 90 % of prefecture-level cities to the expressway network.

The continuity and consistency in China's approach to infrastructure development underscore the relevance of our chosen study period. Therefore, while our data may not be the most current, it aligns with our research objectives and provides valuable insights that can inform future planning and policy decisions related to China's expressway network.

Based on this data, we manually compiled information from January

[4] Source: "Open Guangdong" government data unified open platform(gd.gov.cn).

[5] Source: Ministry of Transport of the People's Republic of China (https://www.mot.gov.cn/2022wangshangzhibo/2022zt1/zhibozhaiyao/20220 7/t20220725_3661821.html).

Table 1
Expressway entrances and exits in Heyuan City by town.

Expressway Code	Towns with entrances and exits	Earliest opening year
G25441602	Puqian Town, Yuannan Town	2005
G25441622	Tuocheng Town, Laolong Town, Dengyun Town	2005
G25441625	Xiantang Town, Yihe Town, Huangtian Town, Liucheng Town	2005
G4511441623	Zhongxin Town, Dahu Town	2005
G4511441624	Heshui Town, Yangming Town, Shangling Town	2005
G4511441625	Xiantang Town, Dengta Town	2005
G35441621	Guzhu Town, Yirong Town, Lantang Town, Jiuhe Town, Zicheng Town, Shuidun Town	2015
G45441623	Longjie Town, Yuanshan Town, Shangping Town	2015

2004 to December 2016 and aggregated each newly registered enterprise to the township level. This allowed us to calculate the number of new enterprises registered in each township, providing a granular understanding of business formation patterns during our selected timeframe. This study uses the number of new enterprises registered in each township yearly to indicate the local entrepreneurial activities. Moreover, we take the number of companies registered in the logarithmic form to reduce the magnitude of data inconsistency.

We also control for other variables that would affect regional entrepreneurial activity. Variables such as the number of existing firms per capita (lag one year), total agricultural output, tax receipts, rural electricity consumption, number of social workers, number of non-agricultural populations, sown area of crops, grain acreage, and provincial roads passing through are the control variables. In addition, this study controls for time-fixed effects and area-fixed effects. Table 2 shows the descriptive statistics of the variables.

Table 2
Descriptive statistics of the variables.

Variables	Definition	Sample size	Average value	Standard deviation
Number of new firms per capita	number of new business registrations for the year in the township/population	1261	0.913	1.315
Expressway Entrance and Exit	With expressway entrance/exit = 1, Without expressway entrance/exit = 0	1261	0.157	0.364
Number of existing firms per capita (lag one year)	number of existing business registrations for the lag one year in the township/ population	1164	4.752	1.200
total agricultural output	Ln (total agricultural output)	1261	9.084	0.698
tax receipts	Ln (tax receipts)	1261	6.079	1.495
rural electricity consumption	Ln (rural electricity consumption)	1261	5.762	0.858
number of social workers	Ln (number of social workers)	1261	9.435	0.592
number of non-agricultural populations	Ln (number of non-agricultural population)	1261	7.613	1.216
sown area of crops	Ln (sown area of crops)	1261	10.353	0.644
grain acreage	Ln (grain acreage)	1261	9.994	0.714
provincial roads	With provincial roads passing through = 1, Without provincial roads passing through = 0	1261	4.907	4.483

3.2. Models

3.2.1. DID and PSM-DID model

In China, expressways are completely "closed," with strict access control and many entrances and exits along the road (i.e., expressway toll stations). Since all vehicles must pass through the entrance to enter the expressway, the expressway passing through a certain area is not necessarily of practical significance to that area, but only at the point where the expressway is located. The closer you are to the entrance, the more significant the impact of the expressway. In existing studies, such as those by Zhang et al. [16], Xu and Nakajima [48], expressway toll stations identify expressway accessibility.

Our empirical strategy also makes expressway entrance/exit (i.e., toll stations) a straightforward approximation of expressway access. This study aims to examine the effect of expressway construction on entrepreneurial activity. There is a sequential opening of expressway entrances and exits in each township. Therefore, we can view the opening of expressway accesses as a treatment effect and analyze it using a multi-period Difference-in-difference (DID) model.[6]

The model is as follows:

$$Y_{it} = \alpha + \beta D_{it} + \gamma Control_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (1)$$

Where Y_{it} is the dependent variable, i.e., the number of new enterprises registered per capita in the year, i denotes the township, t represents the time (year), α is the constant term, μ_i and ν_t represent regional and time-fixed effects, ε_{it} is the model error term, and D_{it} denotes the policy dummy variable for expressway opening. If the townships open the expressway entrance/exit in t year, D_{it} represents the entry into the treatment period and D_{it} in t and after the period t takes the value of 1; otherwise, it takes the value of 0; the dummy variable D_{it} coefficient of β denotes the overall average treatment effect. $Control_{it}$ denotes other control variables, which refer to important factors other than highways that would affect regional entrepreneurial activities.

The DID method identifies the relative differences in business registration before and after opening expressway access between regions with open expressway access and regions without. However, since the presence or absence of an expressway in an area is not a completely random selection, policymakers may decide based on each region's development and other conditions. Therefore, using the DID method makes the findings potentially subject to sample selection bias, which leads to endogeneity problems. Consequently, we also use the propensity score matching - difference-in-difference (PSM-DID) method to explore the impact of the development of expressways on regional entrepreneurial activity.

The steps of the PSM-DID model are as follows. First, we match the treatment and control group samples for each year from 2004 to 2016. Second, the control variables in Equation (1) are matching characteristic variables. Third, propensity scores are estimated by applying logit models and expressways dummy variables and matching characteristic variables. Fourth, the estimated propensity scores, the nearest neighbor matching method, the caliper matching method, and the kernel matching method are used to match the treatment and control groups. Finally, the PSM-DID estimation is performed using the matched samples and the DID model based on Equation (1).

3.2.2. SDID model

Regional economic growth may show a specific spatial dependence. For example, as the transportation infrastructure improves, businesses

[6] In this model, we assume that a town with expressway entrances and exits will be most affected and set it as the treatment group. Still, considering that other towns around the town can also enter the expressway from the nearest toll station and enjoy its service, this paper will further construct a spatial DID model to study the spatial spillover effect on the surrounding area.

may be more inclined to locate in areas with higher demand and income. As a result, transportation infrastructure development may lead to agglomeration shadows. Therefore, we use a spatial difference-in-difference model (SDID) to examine the possible spatial effects of opening expressway access on the impact of regional entrepreneurial activity.

We refer to Dubé and Legros [49], Dubé et al. [50], and Delgado and Florax [51], by including spatial effects in the DID model and choosing the spatial lag model (SAR) in the spatial econometric model. In addition, we construct the SDID, allowing the spatial effects of the treatment and control groups to be fully incorporated. Additionally, the SDID enables us to estimate the impact of expressway construction on regional entrepreneurial activity accurately.

The model is as follows:

$$Y_{it} = \rho WY_{it} + D_{it}\beta + \gamma Control_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (2)$$

Similar to Equation (1), Y_{it} is the dependent variable (i.e., the number of new enterprises registered per capita in the year), i denotes the township, t represents the time (year), μ_i and ν_t represent regional and time-fixed effects, respectively, ε_{it} is the model error term, D_{it} denotes the policy dummy variable for expressway opening , and its coefficient β denotes the overall average treatment effect. W is the spatial weight matrix. W uses a geospatial adjacency matrix to represent the spatial association, if $i \neq j$, it means that two townships are adjacent to each other, i.e.

$$W_{ij} = \begin{cases} 1 \ , \ i \neq j \\ 0 \ , \ i = j \end{cases} \quad (3)$$

Therefore WY_{it} denotes the spatial lag term of the dependent variable, and ρ is the coefficient of the spatial lag term of the dependent variable, indicating the effect brought by the business registration of the neighboring townships on that township.

4. Results

4.1. Direct effects of expressway construction on regional entrepreneurial activity

The construction of transportation infrastructure can stimulate entrepreneurial activity. This section uses DID and PSM-DID to explore the impact of expressway entrances and exits on regional entrepreneurship. In addition, we consider the differences in the effects of traffic flow at each entrance/exit on regional entrepreneurial activity. Finally, the impact of expressway development on regional entrepreneurship is discussed in terms of the installation of expressway entrances and exits and traffic flow.

4.1.1. DID results

4.1.1.1. Baseline regression. Table 3 reports the estimated results of the impact of the development of expressways on regional entrepreneurship. Columns (1) add only the key explanatory variables. Columns (2) add the control variables. The results show that the effects of opening expressway access on the region's new firms per capita are significantly positive. Therefore, the development of expressways positively affects regional entrepreneurial activity.

Appendix Table A1 shows the regression results from adding control variables item by item.

4.1.1.2. Pre-trend check. To check for a common trend between the treatment and control groups, we refer to Beck et al. [52] by including a series of dummy variables by year in the regression to control for the parallel trend test using Equation (6):

Table 3
DID results.

	(1)	(2)
	Number of new firms per capita	Number of new firms per capita
Expressway Entrance and Exit	0.947***	0.355*
	(0.119)	(0.139)
Control variables	NO	YES
year fixed effects	YES	YES
county fixed effects	YES	YES
N	1261	1164
R^2	0.3519	0.5373
Adjusted R^2	0.3420	0.5263

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels. Robust Standard Errors are shown in parentheses.

$$Y_{it} = \alpha + \beta_{-7}D_{it}^{-7} + \beta_{6}D_{it}^{-6} + \ldots + \beta_{-1}D_{it}^{-1} + \beta_{+1}D_{it}^{+1} + \beta_{+2}D_{it}^{+2} + \ldots + \beta_{+6}D_{it}^{+6} + \beta_{+7}D_{it}^{+7} + \theta Control_{it} + \mu_i' + \nu_t' + \varepsilon_{it}' \quad (7)$$

Where Y_{it} is the dependent variable (i.e., the number of new enterprises registered per capita in the year), i denotes the township, t represents the time (year), α is the constant term, μ_i' and ν_t' represent regional and time-fixed effects, respectively, ε_{it}' is an error term, and $D_{i'}'$ are a series of "event time" dummies, the pre- and post-expressway-opening year dummy variables. They are equal to zero, except as follows: D_{it}^{-T} is 1 for towns in the Tth year before the expressway opening, while D_{it}^{+T} equals 1 for towns in the Tth year after the expressway opening. The estimated β_{-T} reflects the effects in T^{th} year before treatment, and β_{+T} reflects the effects in T^{th} year after treatment.

The parallel trend hypothesis is satisfied if the coefficients of the dummy variables are largely insignificant or significantly negative before the relative time of policy implementation. In contrast, the coefficients are significantly positive and show variability after the policy implementation. Fig. 3 shows the results of the parallel trend test. The coefficients of the dummy variables before the opening expressway access are insignificant. Concurrently, they are significantly positive after the fourth or fifth year after the opening of expressway access. Over time, the positive effect between them is strengthened, showing a long-term promotion effect and satisfying the parallel trend hypothesis.

4.1.1.3. Placebo test. To exclude the effects of non-random policy shocks and county heterogeneity on the study findings, we refer to Li et al. [53] and use a placebo test. First, we obtain the interaction terms for the new stochastic simulation based on the randomly generated

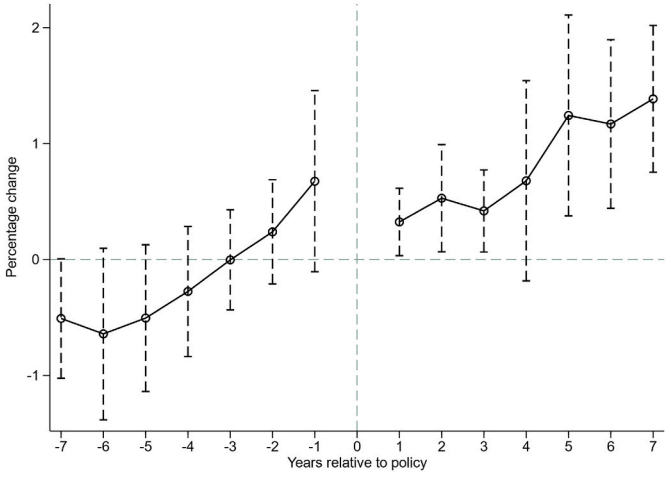


Fig. 3. Parallel trend test.

treatment group dummy variables and the dummy variables for the year of the opening expressway access. Then, we re-estimate the model by replacing the actual opening of expressway access dummy variables with randomly generated interaction terms. Fig. 4 shows the distribution of the estimated coefficients obtained after repeating the process 1000 times. It can be seen that the mean values of the coefficients obtained based on random sample estimation are in the neighborhood of 0 and are distributed normally. Also, there is a long distance from the baseline regression coefficients. Furthermore, it can also be seen that our proper estimate is a clear outlier, indicating that the effect of opening expressway access on entrepreneurial activity is not due to other policy shocks or stochastic factors. These results suggest that the baseline regression passes the placebo test, and our findings are robust.

4.1.2. PSM-DID results

Table 4 gives the results of the DID regressions based on the propensity score matched data. The results show that the effects of opening expressway access on the region's new business registrations per capita are significantly positive regardless of the matching method. The development of the expressway particularly promotes entrepreneurial activity in the area. These results are consistent with the results of the benchmark regression, which further validates the positive significance of the development of expressway in promoting regional entrepreneurship.

4.1.3. Traffic flow on entrepreneurial activity

In the base regression, we use the dummy variable of whether or not the expressway is opened to measure the effect on entrepreneurial activity, considering that the traffic flow of the expressway in different areas also affects the level of entrepreneurial activity. In this regard, we collect the average daily traffic flow at the exits and the average daily traffic flow at the expressway entrance with the expressway code "G35441621".[7] The logarithmic values of the average daily traffic flow at the exits and the average daily traffic flow at the entrances replace the opening of expressway access dummy variables in the baseline regression. They are estimated using a two-group, two-period DID model. Table 5 analyses the impact of the average daily traffic flow at the exits of the expressway on the regional entrepreneurship situation. Columns (1) add only the key explanatory variables. Columns (2) add the control variables. The results show that after adding the control variables, export traffic flow after the expressway's opening positively and significantly affects the number of new registered enterprises per capita in the region. This indicates that the increase in the flow of exit traffic from the expressway helps boost the number of new business registrations in the region. Therefore, the increase in the flow of exit traffic on the expressway positively affects regional entrepreneurship. These results are consistent with the benchmark regression results and illustrate the robustness of the previous findings.

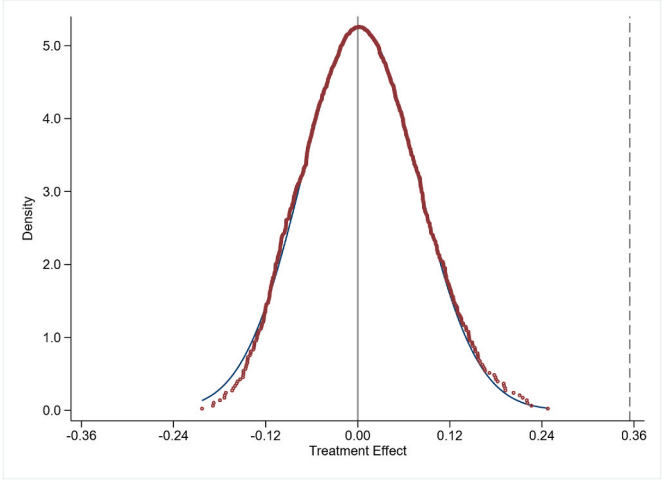


Fig. 4. Placebo test results.

Table 4
Robustness checks: replace estimation methods.

	(1)	(2)	(3)
	k-nearest neighbor matching	caliper matching	kernel matching
	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita
Expressway Entrance and Exit	0.381* (0.167)	0.406* (0.189)	0.399** (0.146)
Control variables	YES	YES	YES
year fixed effects	YES	YES	YES
county fixed effects	YES	YES	YES
N	1120	1097	1142
R^2	0.5174	0.5169	0.5224
Adjusted R^2	0.5055	0.5047	0.5108

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

Table 5
The impact of traffic flow on entrepreneurial activity.

	(1)	(2)
	Number of new firms per capita	Number of new firms per capita
average daily traffic flow at the Exit	0.143*** (0.007)	0.087** (0.025)
Control variables	NO	YES
year fixed effects	YES	YES
county fixed effects	YES	YES
N	158	158
R^2	0.4715	0.6492
Adjusted R^2	0.4432	0.6066

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

The regression results from adding control variables item by item are shown in Appendix Table A2.

The flow results at the expressway's entrance on the regional entrepreneurship also confirm the robustness of the previous finding. They are shown in Appendix Table A3.

4.2. Spatial effects of expressway construction on regional entrepreneurial activity

In this section, we use the SDID and consider the moderating role of the central town to examine further the possible spatial effects of opening expressway access on the impact of regional entrepreneurial activity.

4.2.1. Spatial correlation test

Before conducting the spatial econometric analysis, we must ensure a spatial correlation in the number of new firms per capita. For this, we use global and local spatial correlation tests. Table 6 shows the global Moran's indexes of the new number of registered enterprises per capita

[7] China's expressways are controlled throughout and are fully closed to vehicles. In addition, toll booths are set up at the exits and entrances, so the traffic flow at each entrance and exit can be monitored.

Table 6
Global Moran's index in each year.

year	Number of new firms per capita		
	I	Z	P
2004	0.1643	2.7880	0.0053
2005	0.2538	4.2555	0.0000
2006	0.2661	4.6191	0.0000
2007	0.3584	6.6837	0.0000
2008	0.4643	7.6525	0.0000
2009	0.2942	4.9398	0.0000
2010	0.4834	8.4684	0.0000
2011	0.4897	8.2757	0.0000
2012	0.4536	7.7894	0.0000
2013	0.3794	6.5450	0.0000
2014	0.5076	8.7987	0.0000
2015	0.4692	8.1065	0.0000
2016	0.2371	4.5552	0.0000

yearly. If the global Moran's index is greater (less) than 0, it indicates a positive (negative) spatial correlation. As seen from Table 6, the global Moran's indexes are all greater than 0 and significant at the 1 % level, indicating that the new number of registered enterprises per capita has a positive spatial correlation. To better reflect the local spatial correlation between the new number of registered enterprises per capita, we also plot the scatter plots for the local Moran's indexes of the number of firms for each year using the spatial weight matrix. Fig. 5 shows a scatter plot of the local Moran's indexes (taking 2016 as an example). The scatter points in the first and third quadrants represent regional business registrations' high-high and low-low aggregation characteristics. In contrast, the points in the second and fourth quadrants represent regional business registrations' low-high and high-low aggregation characteristics, respectively. Fig. 5 show that most regions are located in the third quadrant, indicating a significant positive spatial correlation between the number of business registrations. Therefore, using the spatial econometric model of Equation (3) for the analysis is reasonable.

4.2.2. *Spatial spillover effects*

Table 7 shows the estimation results based on Equation (2) and reports the regression results of the SAR model with the explanatory variables of the number of new firms per capita. Column (1) adds only the key explanatory variables. Column (2) adds the control variables. The results show that the effects of opening expressway access on the region's new registered enterprises per capita are significantly positive. These results are consistent with the previous findings. It shows that the development of expressways increases the number of locally registered enterprises and positively affects regional entrepreneurial activities.

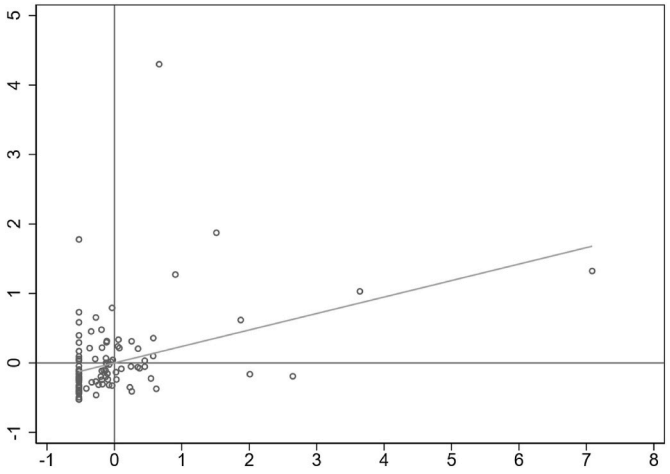


Fig. 5. The scatter plots of the local Moran's indexes of the number of new firms per capita (taking 2016 as an example).

Table 7
SDID results.

	(1)	(2)
	Number of new firms per capita	Number of new firms per capita
Expressway Entrance and Exit	0.270***	0.315**
	(0.102)	(0.142)
ρ	−0.143***	−0.149***
	(0.047)	(0.044)
Control variables	NO	YES
year fixed effects	YES	YES
county fixed effects	YES	YES
Log-likelihood	−1352.5564	−1341.7654
R^2	0.0939	0.1973
N	1164	1164

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses. The regression results from adding control variables item by item are shown in Appendix Table A4.

Table 8
The direct, indirect, and total effects results.

	(1)
	Y_{it} : Number of new firms per capita
	Expressway
direct effect	0.322**
	(0.147)
indirect effect	−0.045*
	(0.027)
total effect	0.277**
	(0.123)

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses. The direct, indirect, and total effects results of control variables are shown in Appendix Table A5.

To further analyze the direct, indirect, and total effects of opening expressway access on the number of regional business registrations, we report the direct, indirect, and total effects based on the regression results of the SAR model in Table 8. The results show that the direct effect of opening expressway access on the number of new regional registered enterprises is significantly positive at the 5 % level. That is, the development of expressways promotes the registration of local enterprises. On the other hand, the indirect effect of opening expressway access on the number of new enterprises registered in the region is significantly negative at the 10 % level. That is, the development of expressways inhibits the registration of enterprises in the surrounding areas, indicating that the "siphoning" effect of the expressway on the surrounding areas is greater than the "radiation" effect. As illustrated, there is the phenomenon of agglomeration shadow in the layout of enterprises. Besides, the total effect of opening expressway access on the number of new firms in the region is significantly positive at the 5 % level. These results indicate that the development of the expressway does promote entrepreneurial activities.

4.2.3. *the moderating role of the central town*

The different development levels of regions cause differences in the implications to their entrepreneurship situation due to the development of expressways. In this regard, we measure each region's economic and social development level by assessing whether each region is a central

provincial town in Guangdong Province.[8] The provincial central towns and economic and social development areas are identified. In contrast, non-central towns are identified as poor economic and social development areas. Table 9 shows the results. The results show that the estimation coefficient of expressway construction is significantly positive for the central town. For non-central towns, it is not significant.

Furthermore, it shows that if an area is a provincial center town with a good level of economic development, the development of the expressway has a more significant effect on the entrepreneurship situation in its region. These results mean that with the development of transportation infrastructure, enterprises are more clustered in the central town. This finding confirms the existence of agglomeration shadows of entrepreneurial activity.

4.3. The impact of expressway construction on the distribution of enterprises

The previous section focuses on the impact of expressway opening on regional entrepreneurial activity at the macro level. In this section, we further explore the effect of expressway construction on firm size and industry choice at the micro level by constructing mixed cross-sectional data with firms as the study target.

4.3.1. The impact of expressway construction on the firm size

To investigate the impact of expressways on the scale of different entrepreneurial enterprises, drawing on the research of Lin et al. [54], we first divide rural entrepreneurial enterprises into three categories according to the registered capital in the industrial and commercial registration information: small and micro enterprises with a registered capital of 0–1 million yuan, medium-sized enterprises with a registered capital of 1–5 million yuan, and large enterprises with a registered capital of more than 5 million yuan. Table 10 shows the regression results of the impact of expressways on the size of different start-ups. The results showed that the expressway significantly affected the entrepreneurship of rural small and micro enterprises but did not significantly affect the entrepreneurship of rural medium and large enterprises.

Table 9
Moderating role of the central town.

	(1)	(2)
	central towns	non-central towns
	Number of new firms per capita	Number of new firms per capita
Expressway Entrance and Exit	0.719***	0.242
	(0.070)	(0.187)
Control variables	YES	YES
year fixed effects	YES	YES
county fixed effects	YES	YES
N	228	936
R^2	0.7022	0.5677
Adjusted R^2	0.6620	0.5548

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses. Appendix Tables A6 and A7 show the regression results from adding control variables item by item.

Table 10
The impact of expressway construction on the firm size.

	(1)	(2)	(3)
	small-sized firms	medium-sized firms	large-sized firms
Expressway Entrance and Exit	0.121**	0.034	0.168
	(0.041)	(0.097)	(0.086)
Control variables	YES	YES	YES
year fixed effects	YES	YES	YES
county fixed effects	YES	YES	YES
N	1164	1164	1164
R^2	0.8564	0.5810	0.5607
Adjusted R^2	0.8530	0.5711	0.5502

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

Combined with the results of the previous analysis, it is clear that the development of the expressway promotes regional entrepreneurial activity and promotes more micro and small enterprises.

4.3.2. The impact of expressway construction on the industry choice for firms

The industrial choice of enterprises is divided into three types: primary industry, secondary industry, and tertiary industry. To investigate the impact of expressways on rural enterprise entrepreneurship in different industries, we first classify enterprises into primary, secondary, and tertiary industries according to their business scope using the National Economic Classification of China (GB/T 4754-2017)[9] and the Regulations on the Classification of the Three Industries (2012)[10]. Then, we summarize them into the primary, secondary, and tertiary industries. Table 11 shows the regression results of the impact of the expressway on rural enterprise entrepreneurship in different industries. The results show that expressway has a significant effect on the entrepreneurship of rural enterprises in the tertiary industry, but has no significant impact on the entrepreneurship of rural enterprises in the primary and secondary industries.

Combining the results of the previous analysis, it is clear that expressway development promotes local entrepreneurial activity. It also encourages the development of more micro and small enterprises, specifically in the tertiary sectors.

Table 11
The impact of expressway construction on the industry choice for firms.

	(1)	(2)	(3)
	primary industry	secondary industry	tertiary industry
Expressway Entrance and Exit	0.068	0.032	0.132***
	(0.069)	(0.049)	(0.032)
Control variables	YES	YES	YES
year fixed effects	YES	YES	YES
county fixed effects	YES	YES	YES
N	1164	1164	1164
R^2	0.6429	0.6830	0.8702
Adjusted R^2	0.6344	0.6755	0.8671

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

[8] "Centers of towns" typically refer to towns with superior locations, strong strengths, and the ability to exert significant attraction and radiation on surrounding rural and township areas. This includes county towns and some developed towns [99]. Promoting the growth of these "centers of towns" is an important measure for the Guangdong Province to promote regional economic development. Currently, Guangdong Province has identified 239 ″centers of towns", including 19 in Heyuan City.

[9] Source: "Notice of the National Bureau of Statistics on Implementing the No. 1 Amendment to the National Economic Industry Classification"http://www.stats.gov.cn/tjsj/tjbz/201905/t20190521_1666107.html.

[10] Source: "National Bureau of Statistics on 'Three Industry Division Regulations " http://www.stats.gov.cn/tjsj/tjbz/201301/t20130114_8675.html.

5. Discussion

5.1. The economic significance of opening expressways

China has long attached great importance to the construction of transportation infrastructure, considering it as an essential policy tool for promoting economic development. From a macroeconomic perspective, since the reform and opening up, China's economic growth miracle has been inseparable from the country's vigorous construction of transportation infrastructure, especially expressways [55]. A significant amount of evidence suggests that the opening of expressways can greatly promote local economic development [16,17]. Expressways can improve market access by reducing trade costs and facilitating the movement of talent, goods, and capital [20,41]. This topic holds particular significance in rural China, where previous opportunities to access broader markets and resources were limited. Local governments can focus on road construction to drive economic development, especially under a system of political competition.

At the micro-enterprise level, as one of China's high-quality transportation infrastructures, the construction of expressways can promote regional economic growth by driving the establishment and development of enterprises [56]. Most existing entrepreneurship research focuses on transportation's impact on manufacturing companies' entrepreneurship [17,57]. There is little relevant literature on the entrepreneurship of other types of companies. Moreover, research on the impact of expressways on rural entrepreneurship is still lacking. Our research builds on existing studies and uses registered businesses to gain a deeper understanding of the impact of transportation infrastructure on overall entrepreneurship.

Our study shows that opening expressways can greatly promote local township entrepreneurship and economic development, thus demonstrating the promotional role of transportation infrastructure. Our findings are consistent with previous research on the promotional role of transportation infrastructure on entrepreneurship [28,44]. Banerjee et al. [17] and Atack et al. [58] found that areas near historical transportation networks have more businesses and larger manufacturing enterprises. Our study found that developing expressways in rural areas also leads to entrepreneurship in areas along the route. In addition, expressways have promoted the establishment of micro and small enterprises in China's rural areas, especially in the tertiary industry. Our study provides factual evidence to support China's long-standing efforts to build transportation infrastructure, especially expressways, to drive economic growth.

5.2. The spatial distribution of transportation infrastructure

Economic agglomeration may develop in the spatial distribution as cities grow in size. Improving transportation infrastructure can lead to the concentration of labor, capital, and other factors in central cities due to the siphoning effect [59]. Firms tend to develop in areas with high demand and returns, and labor tends to shift employment to regions with high comparative returns [11]. As a result, factor resources and others gradually concentrate from peripheral regions with lower relative returns to central areas. Faber [34] mentions that transportation infrastructure facilitates connectivity between regions, attracting peripheral areas to core regions. The central region benefits at the expense of the surrounding area, thus creating the phenomenon of agglomeration shadowing [14,15]. Zhang and Chen [60]find that HSR plays an essential role in economic development through the agglomeration shadow phenomenon. The study investigates the impact of transportation infrastructure, represented by expressways, on the distribution of entrepreneurship in China from a spatial transfer perspective.

We find that developing transportation infrastructure promotes entrepreneurial activity in the regions along its route. For the surrounding areas, on the other hand, instead of stimulating local economic activity, the construction of transportation infrastructure reduces entrepreneurial activity. Transportation facilities exert a "siphoning effect" on their surrounding areas. Our findings are consistent with those of Zhang and Chen [60]. There is a phenomenon of agglomeration shadowing in the process of transportation infrastructure improvement that impacts regional entrepreneurship layout. Our findings also show that access to expressways significantly affects entrepreneurship in the provincial centers with better economic development. The development of expressways has led to a greater concentration of enterprises in areas with better economic growth. Therefore, expressway accesses are more likely to change the spatial layout of the economy and exacerbate regional imbalances in entrepreneurial activity. For the backward peripheral areas, expressway construction could eventually draw resources to the more developed core regions.

Throughout China, the economy and population are further concentrated in coastal areas. At the regional level, the economy and population focus more on the central cities, provincial capitals, and cities with stronger economic development momentum. Economically, from a visualization of the Gross Domestic Product of Chinese cities in2020,[11] it is clear that high GDP is mainly to the right of the "Hu Huanyong" line,[12] particularly in the urban agglomerations of the Beijing-Tianjin-Hebei, the Yangtze River Delta, the Pearl River Delta, and the Chengdu-Chongqing region,[13] where the economy is more concentrated. In terms of population, according to the seventh national census in2020,[14] the eastern region accounts for 39.93 %, the central region accounts for 25.83 %, the western region accounts for 27.12 %, and the northeastern region accounts for 6.98 %. In a visualization of the seventh national census data, it can be seen that China's population is mainly distributed to the right of the Hu Huanyong line, still concentrated around the coastal areas and the central cities inland.

At the provincial level, nine Pearl River Delta (PRD) cities account for 81.5 % of Guangdong Province's GDP in 2021, while the remaining 12 cities account for just under 20 %. This statistic shows that the PRD region has the most substantial economic dynamics. As a result, with its unique location and economic agglomeration advantages, the PRD region exerts a strong siphoning effect on other areas in Guangdong Province. Eventually, talents, capital, and other factors flow to the PRD region. From the perspective of population flow, as of 2021, the resident population of Guangdong Province is 126.84 million, of which the resident population of the PRD region is 78.606 million, accounting for more than 60 % of the entire Guangdong Province. In 2017, the resident population of the PRD region was 61.5584 million, with a 5-year

[11] Data from "China City Statistical Yearbook 2021".

[12] The "Hu Huanyong" line is a line of comparison proposed by the Chinese geographer Hu Huanyong in 1935 to classify the population density of China [99]. The Hu Huanyong Line is the dividing line between the level of population development and China's economic and social pattern. On the right side of this line is the southeast region, where most regions have higher urbanization levels than the national average. On the left side of this line is the northwest region, where most regions have urbanization levels lower than the national average.

[13] An urban agglomeration is a collection of a considerable number of cities of different nature, type and scale within a specific area, with one or two megacities as the center, and relying on certain natural environment and transportation conditions, the inner connection between cities is constantly strengthened, and together they form a relatively complete urban "aggregate". Beijing-Tianjin-Hebei, Yangtze River Delta, and Pearl River Delta city clusters are three of China's most economically developed city clusters. In 2021, the official issuance of "a master plan for the construction of the Chengdu-Chongqing economic circle in southwest China" means that the Chengdu-Chongqing region will become the fourth growth engine of China's economic growth development after the three major city clusters.

[14] China's National Census refers to a one-time survey and registration of the national population by the same method, categories, and survey forms at a set time within a defined period.The seventh national census is from November 1, 2020, and comprehensively survey the population's amount, structure, and distribution and rural and urban housing situation.

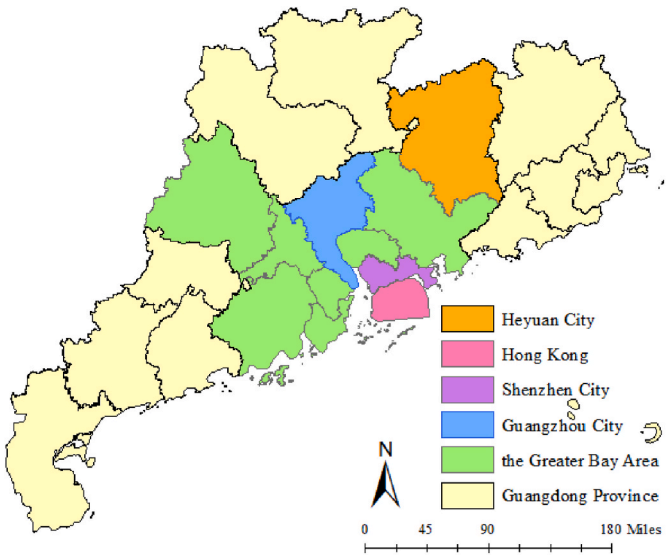


Fig. 6. Geographical location.

increment of 17.0476 million.[15] Within Guangdong Province, the economy and people are accelerating to gather in the PRD region.

Heyuan is a city in Guangdong Province. Its resources and elements are more concentrated along transportation routes and the central town, with higher comparative returns. Such a spatial distribution is consistent with the distribution of the national region and the provincial area of Guangdong Province. The economy and population are increasingly concentrated in relatively well-developed areas [10]. Meanwhile, Heyuan City, as an outer area of the Greater Bay Area, has formed a close production and marketing division system with the Bay Area in its role as a production base (see Fig. 6). It ranks among the country's top agricultural products supplied to Hong Kong and Macao. Annually, it supplies more than 200,000 live pigs to Hong Kong, accounting for over 25 % of the mainland's supply to the Hong Kong market. It consistently ranks first among cities at the prefecture level nationwide [61]. However, the Bay Area may adversely affect its periphery with its strong siphon effect. Data shows that in 2020, the permanent population of Heyuan City was 2,837,686, compared with 2,953,019 people in the Sixth National Census in 2010, a decrease of 115,333 people over ten years, a reduction of 3.91 %.[16] In contrast, the Pearl River Delta region experienced the fastest population growth in China during the same period. Therefore, research on Heyuan can provide valuable references for developing the surrounding areas of other bay areas and urban agglomerations worldwide.

5.3. The spatial agglomeration and economic growth

There is no consensus on the current conclusions regarding the relationship between agglomeration and economic growth. Some scholars believe spatial agglomeration contributes to economic growth [62,63]. Conversely, some scholars believe there is no significant relationship between agglomeration and economic growth [64] or even a negative relationship [65]. Some scholars also argue that the relationship between agglomeration and economic growth is not simply linear but non-linear, with a threshold effect [66]. That is, before reaching the threshold, agglomeration positively affects economic growth. However, after the threshold is crossed, agglomeration reduces the economic growth rate instead. Although spatial agglomeration helps promote the region's overall economic growth, it also leads to widening the income gap within the area [67].

However, we believe that the agglomeration of entrepreneurship temporarily exacerbates the imbalance in regional economic development. Nevertheless, it optimizes resource allocation and improves economic efficiency, leading to the region's high-quality development. Furthermore, improving transportation infrastructure facilitates the free flow of resources and other factors. The free movement of the population helps the regional economy "move towards balance in agglomeration" [10]. The increase in regional economic agglomeration is accompanied by an increase in population, which leads to a regional convergence in per capita income. Of course, in such a regional economic development process, the development dilemma of the relatively less developed peripheral regions is bound to appear. The question of how to break through the inherent development dilemma and seek an equilibrium for the coordinated development of relatively better and worse development-level regions is worth further investigation.

Development economics theory and empirical evidence show that with economic development progress, the core region will, in turn, drive the growth of backward peripheral areas, forming a "Polarization-Trickling down effect" [68]. For example, in the United States, local economic development was negatively correlated with proximity to large urban centers between 1840 and 1920 and positively correlated after 1920. As a result, people moved from peripheral areas to large cities in the early years. In the later years, people preferred to move from large cities to peripheral areas to commute through convenient transportation facilities [69]. Therefore, for marginal regions with relatively poor development levels, transportation infrastructure with growth centers can be accelerated to create livable commuting areas. Thus, even though transportation infrastructure may temporarily affect the economic development of the backward peripheral areas negatively, it still could have a positive effect in the long run. Therefore, the construction of expressways is still of great importance.

5.4. Limitations

Previous empirical studies have discussed the role of developing transportation infrastructure in economic development, and mixed results have been reported. We find a heterogeneous distributional effect when considering the spatial effect, bridging the gap in previous studies. However, this study still has several limitations. As mentioned earlier, it is possible that, in the long run, the "dual structure" of regional development will change. Thus, the role of transportation infrastructure development will become more positive. Unfortunately, due to limited data, we cannot provide evidence of whether or not such a dynamic change exists. We hope that further research will allow us to incorporate a longer span and obtain more information to explore the dynamic mechanisms of expressways on local economic activities. In addition, due to data availability, we only use one city as the study site to analyze the regional imbalance of entrepreneurial activities. We need further data from different cities to study the overall entrepreneurial layout of the entire country.

6. Conclusion

In this paper, we exploit a natural experiment to examine the effect of expressways on entrepreneurial activity in rural areas. The results suggest that the development of expressways significantly promotes entrepreneurial activity in areas along the route but has an inhibitory effect on its surrounding areas. Concurrently, the boosting effect of expressway development on regional entrepreneurial activity is more pronounced for the central provincial towns with better economic and social development levels. The improved transportation concentrates enterprises more in the central town. These results are consistent with the effect of the agglomeration shadow under the core-periphery pattern. Improvements in transportation infrastructure bring about the movement of people and promote the movement of labor to places with

[15] The data comes from the statistical bulletin of each city in previous years.
[16] Data source: The seventh national census bulletin of Heyuan City.

the highest returns. The development of transportation infrastructure changes the spatial layout of the economy and exacerbates regional imbalances in entrepreneurial activity. However, with the continuous development of the economy, this phenomenon of agglomeration shadows will gradually form a polarization-trickling effect, which will drive the development of the surrounding areas. Further research is required in this area.

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CRediT authorship contribution statement

Lin Xie: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Shaozhuang Wang:** Writing – review & editing, Writing – original draft, Software, Formal analysis, Data curation. **Lingxiao Yan:** Writing – review & editing, Methodology, Conceptualization.

Declaration of competing interest

The authors declare no conflict of interest.

Data availability

Data will be made available on request.

Appendix

Table A1
DID results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita
Expressway Entrance and Exit	0.947***	0.412***	0.407***	0.316**	0.349**	0.327**	0.359**	0.365**	0.362**	0.355*
	(0.119)	(0.090)	(0.093)	(0.085)	(0.119)	(0.103)	(0.129)	(0.137)	(0.132)	(0.139)
existing firms (lag one year)		0.573***	0.700***	0.534***	0.546***	0.581***	0.659**	0.637***	0.632***	0.636***
		(0.052)	(0.096)	(0.094)	(0.110)	(0.119)	(0.171)	(0.158)	(0.153)	(0.148)
agricultural output			−0.462*	−0.499*	−0.358**	−0.301	−0.273	−0.125	−0.125	−0.127
			(0.211)	(0.196)	(0.129)	(0.176)	(0.151)	(0.214)	(0.194)	(0.195)
tax receipts				0.217*	0.226	0.217	0.242	0.241	0.235	0.234
				(0.100)	(0.114)	(0.108)	(0.127)	(0.121)	(0.117)	(0.118)
electricity consumption					−0.217	−0.190	−0.188	−0.165	−0.177	−0.177
					(0.143)	(0.135)	(0.129)	(0.116)	(0.126)	(0.125)
social workers						−0.136	−0.122	0.003	0.036	0.042
						(0.247)	(0.225)	(0.259)	(0.275)	(0.275)
non-agricultural population							−0.126	−0.153	−0.160	−0.164
							(0.171)	(0 0.180)	(0.180)	(0.176)
sown area of crops								−0.242	0.161	0.148
								(0.282)	(0.081)	(0.088)
grain acreage									−0.392	−0.382
									(0.302)	(0.298)
provincial roads										0.006
										(0.012)
Constants	0.764***	−1.844***	1.773	1.566	1.419	1.921	1.947	2.106	1.719	1.707
	(0.019)	(0.255)	(1.501)	(1.313)	(1.301)	(1.383)	(1.351)	(1.532)	(1.219)	(1.236)
year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
county fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	1261	1164	1164	1164	1164	1164	1164	1164	1164	1164
R^2	0.3519	0.4722	0.5000	0.5195	0.5286	0.5300	0.5325	0.5354	0.5371	0.5373
Adjusted R^2	0.3420	0.4634	0.4913	0.5107	0.5195	0.5206	0.5226	0.5252	0.5265	0.5263

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

Table A2
The impact of traffic flow on entrepreneurial activity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita
average daily traffic flow at the Exit	0.143***	0.104***	0.107***	0.100***	0.100***	0.091***	0.088**	0.089**	0.087**	0.087**
	(0.007)	(0.020)	(0.021)	(0.023)	(0.023)	(0.022)	(0.027)	(0.027)	(0.025)	(0.025)
existing firms (lag one year)		0.263*	0.320*	0.238**	0.240**	0.323**	0.304**	0.320**	0.317**	0.313**
		(0.116)	(0.135)	(0.088)	(0.081)	(0.115)	(0.102)	(0.091)	(0.085)	(0.084)
agricultural output			−0.126	−0.156	−0.139	−0.021	−0.024	−0.090	−0.048	−0.039
			(0.097)	(0.106)	(0.153)	(0.135)	(0.139)	(0.169)	(0.209)	(0.201)
tax receipts				0.130	0.133	0.112	0.110	0.111	0.109	0.109
				(0.097)	(0.091)	(0.082)	(0.077)	(0.079)	(0.080)	(0.080)
electricity consumption					−0.024	−0.003	−0.018	−0.020	0.013	0.016
					(0.080)	(0.078)	(0.057)	(0.054)	(0.012)	(0.022)
social workers						−0.224**	−0.243*	−0.275*	−0.301**	−0.306**
						(0.077)	(0.098)	(0.109)	(0.097)	(0.109)
non-agricultural population							0.048	0.047	0.038	0.038
							(0.083)	(0.082)	(0.092)	(0.092)
sown area of crops								0.082	−0.276	−0.282
								(0.187)	(0.365)	(0.362)
grain acreage									0.307	0.310
									(0.311)	(0.310)
provincial roads										−0.001
										(0.005)
Constants	0.359***	−1.065	−0.177	−0.285	−0.332	0.215	0.287	0.294	0.678	0.689
	(0.002)	(0.627)	(0.857)	(0.734)	(0.695)	(0.853)	(0.897)	(0.821)	(0.414)	(0.428)
year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
county fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	158	158	158	158	158	158	158	158	158	158
R^2	0.4715	0.5812	0.5884	0.6286	0.6292	0.6411	0.6424	0.6436	0.6490	0.6492
Adjusted R^2	0.4432	0.5557	0.5605	0.6007	0.5985	0.6087	0.6074	0.6059	0.6092	0.6066

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

Table A3
The impact of traffic flow on entrepreneurial activity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita
average daily traffic flow at the entrance	0.144***	0.104***	0.107***	0.101***	0.101***	0.091***	0.088**	0.089**	0.087**	0.087**
	(0.007)	(0.021)	(0.021)	(0.023)	(0.024)	(0.023)	(0.027)	(0.028)	(0.025)	(0.025)
existing firms (lag one year)		0.263*	0.320*	0.239**	0.240**	0.323**	0.304**	0.320**	0.317**	0.313**
		(0.116)	(0.135)	(0.088)	(0.081)	(0.115)	(0.102)	(0.091)	(0.086)	(0.084)
agricultural output			−0.125	−0.156	−0.138	−0.020	−0.023	−0.088	−0.046	−0.037
			(0.097)	(0.106)	(0.153)	(0.135)	(0.139)	(0.168)	(0.208)	(0.200)
tax receipts				0.130	0.133	0.112	0.110	0.111	0.109	0.109
				(0.097)	(0.091)	(0.082)	(0.077)	(0.079)	(0.080)	(0.080)
electricity consumption					−0.024	−0.003	−0.019	−0.020	0.012	0.016
					(0.080)	(0.078)	(0.056)	(0.054)	(0.011)	(0.022)
social workers						−0.225**	−0.244*	−0.276*	−0.302**	−0.307**
						(0.078)	(0.098)	(0.110)	(0.097)	(0.109)
non-agricultural population							0.049	0.048	0.039	0.039
							(0.083)	(0.083)	(0.092)	(0.093)
sown area of crops								0.081	−0.277	−0.282
								(0.187)	(0.365)	(0.363)
grain acreage									0.307	0.309
									(0.311)	(0.311)
provincial roads										−0.001
										(0.005)
Constants	0.359***	−1.068	−0.185	−0.293	−0.340	0.210	0.283	0.290	0.674	0.685
	(0.002)	(0.629)	(0.861)	(0.736)	(0.697)	(0.854)	(0.897)	(0.822)	(0.416)	(0.429)
year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
county fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	158	158	158	158	158	158	158	158	158	158
R^2	0.4702	0.5805	0.5877	0.6279	0.6285	0.6404	0.6418	0.6429	0.6484	0.6486
Adjusted R^2	0.4418	0.5550	0.5596	0.5999	0.5977	0.6080	0.6067	0.6052	0.6085	0.6059

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

Table A4
SDID results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita
Expressway Entrance and Exit	0.270***	0.260**	0.248**	0.269**	0.255**	0.312**	0.315**	0.302**	0.302**	0.315**
	(0.102)	(0.103)	(0.101)	(0.109)	(0.111)	(0.124)	(0.124)	(0.138)	(0.138)	(0.142)
existing firms (lag one year)		0.192	0.199	0.172	0.169	0.174	0.173	0.171	0.170	0.179
		(0.146)	(0.146)	(0.141)	(0.140)	(0.133)	(0.132)	(0.135)	(0.134)	(0.133)
agricultural output			0.066	0.069	0.036	0.016	0.012	−0.015	−0.014	−0.017
			(0.140)	(0.136)	(0.123)	(0.135)	(0.133)	(0.131)	(0.168)	(0.164)
tax receipts				0.118*	0.122*	0.118*	0.119*	0.117*	0.117*	0.117*
				(0.068)	(0.068)	(0.068)	(0.067)	(0.069)	(0.069)	(0.069)
electricity consumption					0.095	0.051	0.052	0.041	0.042	0.049
					(0.066)	(0.074)	(0.073)	(0.065)	(0.071)	(0.078)
social workers						0.282**	0.282**	0.233	0.234	0.230
						(0.131)	(0.131)	(0.209)	(0.232)	(0.229)
non-agricultural population							−0.066	−0.067	−0.067	−0.081
							(0.291)	(0.293)	(0.293)	(0.291)
sown area of crops								0.081	0.095	0.112
								(0.188)	(0.621)	(0.642)
grain acreage									−0.015	−0.025
									(0.692)	(0.700)
provincial roads										−0.013
										(0.023)
ρ	−0.143***	−0.141***	−0.143***	−0.148***	−0.149***	−0.150***	−0.151***	−0.151***	−0.151***	−0.149***
	(0.047)	(0.047)	(0.046)	(0.048)	(0.048)	(0.047)	(0.046)	(0.045)	(0.045)	(0.044)
year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
county fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Log-likelihood	−1352.5564	−1350.6934	−1350.4232	−1346.7881	−1345.4077	−1342.4569	−1342.3885	−1342.1349	−1342.1332	−1341.7654
R^2	0.0939	0.2804	0.2503	0.3012	0.2750	0.2292	0.2126	0.1982	0.1990	0.1973
N	1164	1164	1164	1164	1164	1164	1164	1164	1164	1164

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

Table A5
the direct, indirect, and total effects results

	Y_{it} is the number of new firms per capita								
	existing firms per capita (lag one year)	agricultural output	tax receipts	electricity consumption	social workers	non-agricultural population	sown area of crops	grain acreage	provincial roads
direct	0.177	−0.001	0.118*	0.054	0.249	−0.079	0.159	−0.084	−0.014
effect	(0.129)	(0.157)	(0.067)	(0.078)	(0.236)	(0.291)	(0.612)	(0.682)	(0.023)
indirect	−0.025	−0.001	−0.017	−0.008	−0.036	0.008	−0.022	0.015	0.002
effect	(0.021)	(0.021)	(0.012)	(0.011)	(0.036)	(0.039)	(0.084)	(0.094)	(0.003)
total effect	0.151	−0.002	0.101*	0.046	0.213	−0.071	0.137	−0.069	−0.012
	(0.110)	(0.136)	(0.055)	(0.067)	(0.202)	(0.253)	(0.531)	(0.592)	(0.020)

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

Table A6
Moderating role of the central town

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	central town									
	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita
Expressway Entrance and Exit	2.165***	1.095***	1.153***	0.887***	0.914***	0.902***	0.768***	0.717***	0.715***	0.719***
	(0.283)	(0.148)	(0.173)	(0.180)	(0.175)	(0.183)	(0.141)	(0.083)	(0.069)	(0.070)
existing firms (lag one year)		0.846**	0.770***	0.396**	0.421***	0.432**	1.244**	1.360***	1.360***	1.382***
		(0.259)	(0.180)	(0.112)	(0.091)	(0.161)	(0.359)	(0.303)	(0.304)	(0.306)
agricultural output			−0.436	−0.356	−0.487	−0.485	−0.150	−0.726*	−0.723*	−0.723*
			(0.526)	(0.427)	(0.366)	(0.367)	(0.099)	(0.313)	(0.357)	(0.338)
tax receipts				0.451	0.446	0.441*	0.666**	0.612***	0.612***	0.605***
				(0.238)	(0.227)	(0.207)	(0.173)	(0.146)	(0.146)	(0.143)
electricity consumption					0.185	0.194*	0.109	−0.080	−0.080	−0.091
					(0.135)	(0.091)	(0.135)	(0.146)	(0.146)	(0.150)
social workers						−0.027	−0.052	−0.502*	−0.500	−0.549
						(0.299)	(0.193)	(0.243)	(0.264)	(0.282)
non-agricultural population							−0.797*	−0.698*	−0.698*	−0.679*
							(0.348)	(0.309)	(0.311)	(0.301)
sown area of crops								0.740**	0.758	0.800
								(0.264)	(0.414)	(0.412)
grain acreage									−0.018	−0.028
									(0.462)	(0.506)
provincial roads										−0.031
										(0.043)
Constants	0.963***	−3.665*	1.011	−0.872	−0.900	−0.732	−2.449	−0.325	−0.386	−0.208
	(0.102)	(1.577)	(4.248)	(3.779)	(3.644)	(3.661)	(1.427)	(2.028)	(2.938)	(3.329)
year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
county fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	228	228	228	228	228	228	228	228	228	228
R^2	0.4991	0.5832	0.5913	0.6272	0.6297	0.6297	0.6946	0.7016	0.7016	0.7022
Adjusted R^2	0.4559	0.5451	0.5518	0.5892	0.5899	0.5879	0.6584	0.6647	0.6630	0.6620

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

Table A7
Moderating role of the central town

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	non-central towns									
	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita	Number of new firms per capita
Expressway Entrance and Exit	0.276	0.203	0.204	0.186	0.238	0.234	0.259	0.219	0.224	0.242
	(0.156)	(0.158)	(0.177)	(0.176)	(0.159)	(0.159)	(0.151)	(0.174)	(0.182)	(0.187)
existing firms (lag one year)		0.233***	0.340***	0.319***	0.360***	0.389***	0.406***	0.371***	0.376***	0.363***
		(0.024)	(0.036)	(0.024)	(0.046)	(0.052)	(0.070)	(0.076)	(0.077)	(0.069)
agricultural output			−0.410**	−0.420**	−0.350**	−0.311**	−0.303**	0.026	0.031	0.035
			(0.122)	(0.127)	(0.094)	(0.091)	(0.094)	(0.096)	(0.076)	(0.075)
tax receipts				0.053	0.071	0.069	0.076	0.076	0.073	0.073
				(0.047)	(0.063)	(0.065)	(0.064)	(0.054)	(0.053)	(0.054)
electricity consumption					−0.177	−0.166	−0.152	−0.138	−0.151	−0.146
					(0.094)	(0.084)	(0.076)	(0.076)	(0.086)	(0.087)
social workers						−0.089	−0.026	0.201	0.231	0.220
						(0.063)	(0.029)	(0.142)	(0.159)	(0.159)
non-agricultural population							−0.116	−0.086	−0.091	−0.098
							(0.105)	(0.080)	(0.083)	(0.092)
sown area of crops								−0.602*	−0.264	−0.245
								(0.253)	(0.276)	(0.254)
grain acreage									−0.343*	−0.352*
									(0.145)	(0.141)
provincial roads										−0.011
										(0.011)
Constants	0.724***	−0.309**	2.896**	2.771**	2.855**	3.146**	3.130**	4.087**	3.802*	3.896*
	(0.019)	(0.115)	(0.964)	(0.907)	(0.929)	(1.042)	(1.103)	(1.505)	(1.486)	(1.565)
year fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
county fixed effects	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
N	936	936	936	936	936	936	936	936	936	936
R^2	0.4890	0.5053	0.5293	0.5309	0.5396	0.5402	0.5416	0.5644	0.5665	0.5677
Adjusted R^2	0.4789	0.4950	0.5190	0.5201	0.5286	0.5286	0.5295	0.5524	0.5541	0.5548

Note: *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Robust Standard Errors are shown in parentheses.

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Smartphone access, digital economy, and pesticide use intensity: Evidence from China

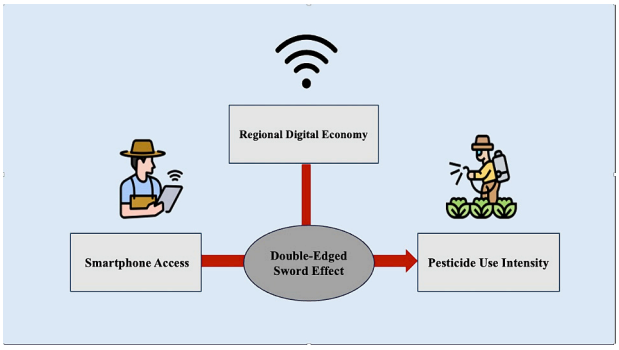
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HIGHLIGHTS

- Smartphone access has a "double-edged sword" effect on pesticide use intensity.
- Greater access led to a higher pesticide use intensity in regions with low level of digital economy.
- Greater access led to a lower pesticide use intensity in regions with high level of digital economy.
- A comprehensive social and engineering integration is needed to reduce pesticide use intensity.

GRAPHICAL ABSTRACT



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ABSTRACT

Pesticide overuse has been an increasing concern in China. Digital technology, such as smartphone access, is considered an effective way to promote proper use of pesticides. Using the Chinese Extended Family Database (2015, 2017, and 2019), this study empirically examines the impact of smartphone access on pesticide use intensity among Chinese farmers. The results show a "double-edged sword" effect of smartphone access on pesticide use intensity. In rural areas with a low level of digital economy, greater smartphone access led to higher pesticide use intensity. In rural areas with a high digital economy level, smartphone access reduced pesticide use intensity. The study results show that reducing pesticide use intensity through digital technology is not a linear process but a complicated one that involves social and engineering integration, including an increase in access to smartphones, development of a regional digital economy, reconstruction of agricultural extension systems, and enhancement of the capacity of digital technology.

1. Introduction

Proper pesticide use is a challenging issue for many developing countries that attempt to modernize their agricultural economy (Enserink et al., 2013; Popp et al., 2013; Verger and Boobis, 2013; Wu et al., 2018; Xie et al., 2020; Zhang et al., 2015a). Pesticide overuse is

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widely observed in those countries, such as China (Zhang et al., 2015a, 2015b), Thailand (Grovermann et al., 2013), Kuwait (Jallow et al., 2017), and Vietnam (Normile, 2013; Salazar and Rand, 2020). Pesticide overuse leads to environmental pollution (Hao and Yang, 2013), causes food safety concerns (Zhang et al., 2021), and increases human health risks (Enserink et al., 2013; Zhang et al., 2018; Möhring et al., 2020). Therefore, many technical supports and regulatory strategies have been introduced to reduce pesticide use intensity and promote the proper use of pesticides (Enserink et al., 2013; Normile, 2013; Möhring et al., 2020).

Digital technologies have been applied to transform agricultural systems and offer an opportunity for properly using pesticides in many developing countries. Digital agriculture integrating digital technology with agricultural production helps improve agricultural resource use efficiency and sustainability (Rotz et al., 2019; Clapp and Ruder, 2020). Digital technologies are integrated with automation technologies such as intelligent tractors, drones, and robots to implement variable rate applications that precisely deliver seeds, water, fertilizers, and pesticides and, therefore, significantly reduce the environmental impacts of agricultural production (Clapp and Ruder, 2020). Digital technologies also reduce the cost of tracking product origins, increase transparency, improve public trust on the value chain of agricultural products, and help promote environment-friendly production behaviors (Fabregas et al., 2019). Through mining big data on the Internet, digital technologies improve farmers' communication, learning, and information sharing (Nyamba and Mlozi, 2012; Baumüller, 2018; Zhong et al., 2023). In China, businesses, such as pesticide producers Bayer and Sinochem and drone manufacturers XAG technology and DJ-Innovations, are actively building online platforms to support farmers adopting new pesticide use technologies.

As a digital technology, mobile phones play a key role in the digital transformation of agriculture (Min et al., 2020). Mobile phone technology has become increasingly adopted to promote agricultural extension services in developing countries (Aker, 2011; Birke et al., 2019; Cole and Fernando, 2021; Folitse et al., 2019; Janc et al., 2019). Mobile phones help disseminate product information and increase the adoption of the recommended agrochemical application rate by 22 % in sub-Saharan Africa and India (Fabregas et al., 2019). Mobile phones also connected the ICT revolution to the smallholder cotton farmers and helped increased the adoption of pesticide use recommendations and biological pest control methods through an innovative voice-based ICT advisory service in India (Cole and Fernando, 2021). In Uganda, where resources are scarce, mobile phones help farmers to access information on agricultural inputs including pesticides and increase the likelihood of using these inputs (Freeman and Qin, 2020). In Rwanda and Uganda, mass social media campaigns involving the use of mobile phones effectively improved farmers' awareness of pesticide risks and safety measures and boosted the adoption of environmentally safer alternatives to synthetic pesticides (Tambo et al., 2023). In Ecuador, mobile phone applications helped increase the adoption of low-toxicity pesticide products among the blackberry farmers (Carrión-Yaguana et al., 2020).

The impact of mobile phones on farmers' behaviors in agricultural input use is not uniform and has been highly affected by the development of the technology itself. Early mobile technology relied on text messages in the 2G era and pictures, graphics, voice messages in the 3G era. These traditional mobile technologies were not able to provide sophisticated advice on agricultural practices or new technologies in many developing countries (Awuor and Otanga, 2019; Nakasone et al., 2014). The primary reason is that reading and interacting with text messages through mobile phones requires a high level of literacy that smallholder farmers do not have (Nakasone et al., 2014; Wyche and Steinfield, 2015), and eventually leads to the problem of information overload (Awuor and Otanga, 2019).

However, smartphone technology with video message functions in the 4G and 5G eras allows farmers with a limited literacy to obtain agricultural knowledge and information easily. Video information through smartphones helps farmers understand the advantages and disadvantages of new farm technologies, ensuring accurate application (Zheng and Ma, 2023). Empirical research shows that easily accessible videos through smartphones can deliver complex and rich knowledge and information on pesticides, increase farmers' understanding of pesticides, and help farmers make more informed decisions on pesticide use (Chowdhury et al., 2015). Many social media platforms allow some experienced farmers to be video content creators and become locally influential experts (Šūmane et al., 2018). Learning through videos allows farmers to integrate such information with their local experiences to update their knowledge and innovate their farming practices (Zossou et al., 2009).

Although mobile phone technology, especially access to smartphones, helps farmers increase their knowledge of pesticides and thus potentially reduce pesticide use, farmers in many developing countries still tend to apply more pesticides due to agricultural productivity concerns (Grovermann et al., 2013; Jallow et al., 2017; Salazar and Rand, 2020; Schreinemachers et al., 2020; Xie et al., 2020; Zhang et al., 2015b, 2015a). Pesticide overuse was especially apparent in China, where the public agricultural extension system collapsed in 1980s (Zhang et al., 2015a). Without public agricultural extension services, pesticide sellers have become the primary source of information and knowledge on pesticides to farmers in China (Fan et al., 2015; Jin et al., 2015). The profit motive often prompts sellers to oversell agricultural supplies through various tactics. Since farmers in China are generally less educated and poorly trained, frequent updates on pesticide varieties and even changes in packaging further exacerbate such information asymmetry between farmers and pesticide sellers (Jin et al., 2015). Motivated by profits, pesticide sellers often promote pesticide sales by overemphasizing the role of pesticides in agricultural production, resulting in excessive purchase and overuse of pesticides in China (Wang and Gu, 2013). Although mobile phones help farmers obtain market information about pesticides (Cole and Fernando, 2021; Freeman and Qin, 2020; Tambo et al., 2023), the same technology can also be used by pesticide sellers to directly market their products to farmers, which leads to pesticides overuse. A survey from farmers in China suggested that mobile phone technology, especially smartphone access, has a double-edged sword effect on pesticide use: smartphone access resulted in a 33 % increase in pesticide expenditure among the farmers in the lowest 20th quantile of the pesticide expenditure, and a 36–39 % reduction in pesticide expenditure among the farmers in the upper 60th and 80th quantiles of pesticide expenditure (Ma and Zheng, 2022).

However, no study has yet attempted to systematically analyze the inherent cause of such a double-edged sword effect of mobile phone technology on pesticide use. This study aims to understand the underlying impact of smartphone access on pesticide use in China. The hypothesis is that the development of a regional digital economy where mobile phones operate significantly impacts how smartphone access affects pesticide use. Digital learning through smartphones relies on the smooth operation of a local digital network characterized by an excellent digital infrastructure, a large population of internet users, and active content creation. For example, the expansion of regional mobile phone coverage induces farmers' market participation (Muto and Yamano, 2009) and increases the provision of agricultural extension services (Aker, 2011). Without the support of a well-developed local digital network, smartphones are no better than traditional feature phones, and therefore, farmers with smartphones cannot reap the benefits of digital learning. For example, in extremely remote rural communities in Papua, Indonesia, smartphones were mainly used for calls and text messages (Heimerl et al., 2015).

Based on longitudinal survey data on rural households in China, this study assesses how smartphone access and the development of the regional digital economy jointly affect farmers' decisions on pesticide use, which explains the double-edged sword effect of smartphone access on pesticide use among Chinese farmers. As a developing country where

smartphones are widely used, China provides an interesting example to understand the impacts of smartphones and mobile technology on pesticide use in agriculture. Like many other developing countries in South Asia and Africa, agriculture in China is still dominated by smallholder farmers. Therefore, the findings on the impact of smartphones on pesticide use in China can help developing countries to develop effective policies and strategies to properly use pesticides and other agrochemicals.

2. Research background

2.1. Pesticide overuse in China

In traditional agriculture in China, farmers rely on intensive cultivation techniques such as timely planting and harvesting, weeding, and deep plowing to physically prevent and control plant diseases and pests (Wen, 2016). Despite the fast growth of the "green revolution" in Western developed countries and other parts of the world, China limited manufacturing capacity and use of synthetic fertilizers and pesticides until the 1980s (Pan et al., 2020). Agrochemicals, including fertilizers and pesticides, grew in popularity in the middle of the 1980s for two reasons. First, China began to implement its "open door" policies to foreign technology and investment, significantly increasing the capacity of manufacturing and supplying agrochemicals in China. Second, China widely implemented the Rural Household Contract System to grant farmers nearly complete freedom to conduct their agricultural operations, which gave farmers the freedom to use agrochemicals to increase crop yields and farm income.

Fig. 1a presents the total amount of pesticide usage (the left axis) and the pesticide use intensity on the sown area of crops in China from 1991 to 2021. The total pesticide use in China increased from 0.77 million tons in 1991 to 1.32 million tons in 1999, a nearly 73 % increase. The total pesticide usage dropped slightly in 2000, and resumed steady growth in 2001, reaching its peak of 1.81 million tons in 2013. The intensity of pesticide use in China experienced similar changes over that period and reached its peak level of 11.14 kg/ha in 2013. The fast growth in pesticide use has become a significant concern in China. The Chinese government began to take a series of actions to reduce pesticide use in 2010. The Chinese Ministry of Agriculture issued the Action Plan on Agricultural Crop Pest Control and Disease Prevention in 2010 to prevent crop diseases and control crop damage while reducing pesticide use and enhancing agricultural product safety. The Central Government in China subsequently issued its pesticide reduction policy in the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outlook of the 2035 Long-term Development Goals. These policy changes on pesticide use and their implementation had impacts. As shown in Fig. 1a, both the total pesticide usage and the intensity of pesticide use declined steadily after 2013, and lowered to 1.24 million tons and 7.35 kg/ha, respectively, in 2021.

Fig. 1b compares the intensity of pesticide use measured by the ratio of the average weight of active ingredients per unit of farmland in kg/ha in China to the world from 1990 to 2021, based on data from FAO.[1] From 1990 to 1992, the intensity of pesticide use in China was lower than the world average, as the ratio was less than one. However, from 1993 to 2018, the intensity of pesticide use in China increased significantly and surpassed the world average level. The peak was in 2009 when the intensity of pesticide use in China was approximately 1.36 times the world average. The intensity of pesticide use in China started to drop below the world average in 2019.

[1] Source: FAO. Pesticides Use. FAOSTAT, URL. https://www.fao.org/faostat/zh/#data/RP

2.2. The growth of mobile communication in China

China launched its first commercial service of the first-generation analog mobile communication system (1G) in 1987. Over the next 35 years, China has steadily upgraded its mobile communication system from 1G to 5G and currently owns the largest 5G network in the world. According to the China Ministry of Industry and Information Technology, China had 475 million 5G mobile phone users, which accounted for >70 % of the global 5G network users by July 2022. China operates 1.97 million 5G base stations, accounting for over 60 % of the active 5G base stations worldwide. The growth of mobile communication in the past 35 years in China is further evidenced by a sharp rise in mobile phone penetration rate, a swift conversion to smartphones, and a steady increase in mobile internet speed.

Fig. 2a shows the penetration rates, i. e., the number of phones per 100 people, of hardline phones and mobile phones in China from 2000 to 2021. Over the 20 years, the mobile phone penetration rate had risen from 6.7 to 116.3, while the penetration rate for the hardline phones increased from 12.4 in 2000 to 28.1 in 2006 and then decreased to 12.8 in 2021. By the end of 2021, there were 1.82 billion telephone users in China, including 1.64 billion mobile phone users and only 181 million hardline phone users.

Fig. 2b shows the growth of smartphones with 3G/4G services in China from 2010 to 2018 in terms of the number of phone users, the ratio of the smartphone users among all mobile phone users, and the ratio of the number of 3G/4G base stations among all mobile base stations. The number of 3G/4G users was only 47.05 million, accounting for 5.5 % of the total mobile phone users in 2010. It grew to 1.3 billion in 2018, i. e., 83.4 % of mobile phone users. The number of 3G/4G base stations accounted for 32.8 % of all base stations in 2010 and had grown to 75.5 % by 2018.

As a result, the number of mobile internet users has also grown rapidly in China. According to the China Internet Network Information Center, the number of mobile internet users in China grew from 50.4 million in 2007 to 1.03 billion in 2021, corresponding to 24 % of the total internet users in 2007 and 99.7 % in 2021. In other words, smartphones have become essential for people in China who want to access the Internet.

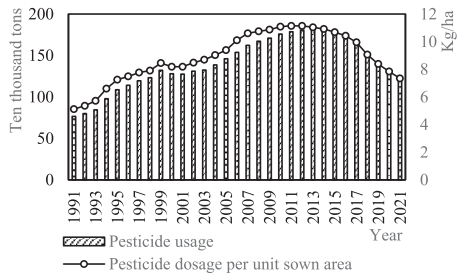
The speed of downloading and uploading mobile Internet has also increased rapidly. Fig. 2c presents the average downloading speed of the 4G network from 2016 Q3 to 2021 Q4. Mobile internet speed has skyrocketed since the launch of the 5G network in China. According to the China Information and Communication Academy, the average downloading speed for 5G users in China was 341.2 Mbps, and the average uploading speed was 71.98 Mbps in 2022, among the world's fastest mobile networks. Mobile smartphones are predominantly used for instant messaging, video sharing, and watching short movies.

Despite the staggering growth of mobile communication in China, China's rural regions are lagging. According to the China Internet Network Information Center, the internet penetration rate was 58.8 % in the rural regions and 82.9 % in urban and urbanizing regions in China in 2022. The internet speed in rural regions is far slower than in urban and urbanized regions.

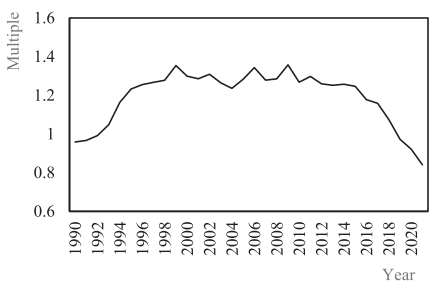
3. Method

3.1. Data

This research uses the longitudinal survey data from the Chinese Family Database (CFD) at Zhejiang University and the China Household Finance Survey (CHFS) conducted by the Survey and Research Center for China Household Finance at China Southwestern University of Finance and Economics (SWUFE). The CFD survey adopted a three-stratified probability proportion to size (PPS) sampling approach to select its household samples for the longitudinal survey (Wu et al., 2018). The selected samples include households from 29 provinces,

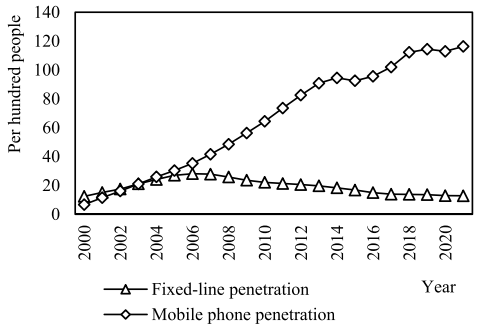


(a) Pesticide usage and use intensity in China (1991-2021)

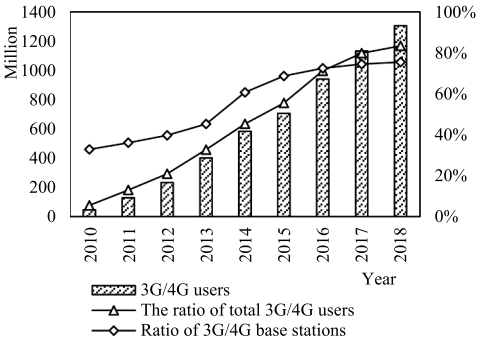


(b) Ratio of pesticide use intensity between China and the World (1990-2021)

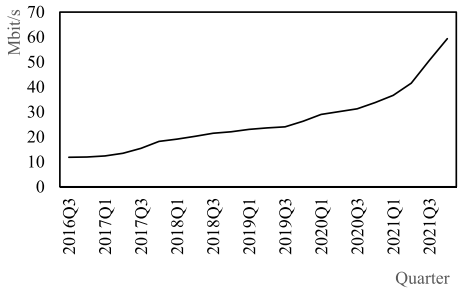
Fig. 1. Pesticide use intensity comparisons in China and the World.



(a) Penetration Rate of Hardline and Mobile Phones in China (2000-2021)[1]



(b) Development of China's smart Phones (3G/4G) (2010-2018)[2]



(c) Average Download Rate of 4G networks in China (2013- 2021)[3]

Fig. 2. The mobile communication infrastructure growth patterns in China.

autonomous regions, and metropolitan areas directly under the control of the central government in China. Through scientific sampling, modern survey techniques, and rigorous survey management, the longitudinal surveys aim to collect high-quality micro information on Chinese families to conduct in-depth research on various issues related to Chinese families. Among them, the 2015 data involved a rural sample of 22,535 households; The 2017 data involved a rural sample of 24,764 households; The 2019 data involved a rural sample of 21,815 households. This study extracted all rural household samples growing staple food and/or cash crops from the CFD database, which included 5054 in 2015, 9142 in 2017, and 8757 in 2019. We use these three rounds of survey data to form a non-equilibrium panel data. The CFD survey contains the essential information on farmers' farming operations, including pesticide use and the information on mobile phones, the Internet, and other digital technologies, and is used in this study.

3.2. Variables

3.2.1. Dependent variable

This study uses pesticide use intensity as the dependent variable. The quantity and expenditure of pesticides applied per unit area can be used to define pesticide use intensity, but the CFD survey only reported the

quantity of pesticide applied in 2015, and not in other years. Therefore, we define the pesticide use intensity as the ratio of the total pesticide expenditure to the sown area following other similar studies (Zhu and Wang, 2021). This study takes the logarithmic value of the average pesticide expenditure to reduce the impacts of those extreme values on the results.

3.2.2. Variables of interest

This study includes two independent variables as the variables of interest. The first is access to the smartphone. Farmers in China mainly access digital technology services through mobile Internet and smartphones. The CFD contains specific questions on the use of mobile phones among farmers, including the specific types of mobile phones being used. Following the similar studies (Khan et al., 2022; Ma and Zheng, 2022), this study uses a dummy variable to indicate farmers' smartphone access: one if using a smartphone and zero otherwise. The second is the digital economy index (DEI), which measures regional differences in the development in digital economy in China. DEI is derived from five indicators: internet penetration rate, internet-related employment, internet-related economic output, mobile internet users, and digital inclusive finance index. China National Bureau of Statistics compiles the first four indicators, and the last one is jointly compiled by the Digital Finance Research Center of Peking University and the Ant Financial Services Group. The five indicators were further standardized and aggregated to calculate the composite DEI of all 30 provinces, autonomous regions, and metropolitans under the control of the Central Government following Zhao et al. (2020).

3.2.3. Control variables

The control variables include the characteristics of rural households, villages, and farmland that potentially affect farmers' decisions on pesticide use. The control variables on the rural household include farmers' age (Al Zadjali et al., 2014; Huang et al., 2020; Zhou and Jin, 2009), gender (Atreya, 2007; Wang et al., 2017), education (Al Zadjali et al., 2014; Goodhue et al., 2010; Jallow et al., 2017; Zhou and Jin, 2009), agricultural employment ratio (Hedlund et al., 2020), whether the household has any agricultural loan (Rahman, 2003), and received any agricultural guidance (Huang et al., 2021), and production for self-consumption (Sharifzadeh et al., 2019). The control variables for the village include per-capita income (Li et al., 2023)[2] and the distance of the village to the nearest market (Huang et al., 2020). The control variables on farmlands include the total sown area (Wu et al., 2018), planting structure (the ratio of the sown area for food crops) (Rahman, 2016), and land ownership (farmland certification) (Migheli, 2017). The study also contains the control variables on the household and year fixed effect being surveyed using dummy variables.

Table 1 presents detailed information on those variables, including the variable type, variable name, relevant survey questions, and calculating specifications and relevant references for using the variables.

3.3. Fixed effect models

Following Greene (2003) and Wooldridge (2010), this study applies a two-way fixed effect model to assess the effect of smartphone access on pesticide use intensity in China. The two-way fixed effect model was used in other studies using the same database being used in this study (Fan et al., 2023; Zheng et al., 2023a, 2023b; Zhu and Wang, 2021). Model 1, specified as Eq. (1), considers only the impact of smartphone access on pesticide use intensity:

[2] The existing literature mainly discussed the relationship between household income level and pesticide application. However, given the endogeneity of household income, we controlled the village's annual per capita income as an alternative. This variable is a higher-level variable that helps reduce the endogeneity.

Table 1
Description of variable indicators.

Variable category and name		Questions in the CFD Surveys	Variable specification	References
Dependent variable	Pesticide use intensity	How much did your family spend on pesticides (yuan)? What is your family's sown area for staple food and cash crops?	Ln (pesticide expenditure / the sown area + 1)	(Ma and Zheng, 2022; Wu et al., 2018)
Independent variable	Smartphone	What kind of mobile phone are you using now? (1. Smartphone; 2. Non-smartphone; 3. No cell phone)	One if "1" is selected, and zero otherwise	(Khan et al., 2022; Ma and Zheng, 2022)
	Digital economy index	As described in the text	In the range between 0 and 1	(Zhao et al., 2020)
Control variable	Age	The year of birth of the farmers interviewed	The year in which the survey was conducted minus the year of birth of the farmer interviewed	(L. Fan et al., 2015; Pan et al., 2021; Zheng et al., 2021; Zhou and Jin, 2009)
	Education	What is the literacy level of the farmers interviewed?? 1. Never went to school; 2. Primary school; 3. Junior high school; 4. High school; 5. Technical secondary school; 6. Junior college; 7. Bachelors; 8. Masters; 9. Ph. D. s	The actual years of education for options 1–9 are assigned 0, 6, 9, 12, 9, 12, 16, 19, and 23	
	Gender	The gender of the farmers interviewed	Select one for female, zero otherwise	
	Ratio of agricultural employment	How many members of your family are engaged in agricultural production and operation?	The number of farm laborers/ the workforce size	
	Ratio of staple food crops	What are the sown areas for staple food crops?	The sown area for staple food crops/ the total sown area of crops	
	Agricultural loan	Does your family have outstanding bank loans for agricultural operations? (1. Yes; 2. No)	One if "1" is selected, zero otherwise	
	Farmland Certification	Does your farmland have a rural land contract right certificate?	One if "1" is selected, zero otherwise	

(continued on next page)

Table 1 (*continued*)

Variable category and name	Questions in the CFD Surveys	Variable specification	References
Production for self-consumption	What were the main uses of the agricultural products your family produced last year? 1. Direct sales; 2. Processed and sold; 3. For your use; 4. For your agricultural production; 5. Not yet produced; 6. To be sold; 7. Other.	One if "3", "4" is selected, zero otherwise	
Agricultural guidance	Has your family received any technical guidance on agricultural production? (1. Yes; 2. No)	One if "1" is selected, zero otherwise	
Total sown area	What is the sown area for both staple food crops and cash crops?	Ln (The total sown area + 1)	
Annual per capita income of the village	What is the per capita disposable annual income of the residents in this community?	ln (Per capita income of the village +1)	
Distance from market	What is the distance from the village to the nearest farmers' market or free market?	Ln (Distance from market +1), if the farmers' market or free market is in the village, the distance is 0	
Household	Household who was interviewed	Dummy variable	–
Year	The year when the survey was conducted	Dummy variable	

$$y_{it} = \alpha + \beta_1 x1_{it} + \gamma Z_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (1)$$

where i is the index for the farmers being surveyed, t indicates the year when the survey was conducted, y_{it} is the pesticide use intensity for farmer i in year t, $x1_{it}$ indicates whether farmer i uses a smartphone in year t, Z_{it} is a vector of all control variables for farmer i in year t, α is the intercept, β_1 is the regression coefficient for the independent variable $x1_{it}$, and γ is a vector of coefficients for the control variable vector Z_{it}, and μ_i is the household fixed effect, and ν_t is the time-fixed effect and ϵ_{it} is the residual term. The coefficient β_1 Eq. (1) indicates whether farmers' smartphone access impacts pesticide use intensity.

As discussed previously, smartphones rely on the availability and efficiency of the digital network to have the expected impacts on farmers' behavior change on pesticide application. We also introduce the DEI as an independent variable in the analysis to assess such effects. Model 2 considers the impacts of DEI by directly adding the DEI as an independent variable as specified in Eq. (2):

$$y_{it} = \alpha + \beta_1 x1_{it} + \beta_2 x2_{it} + \gamma Z_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (2)$$

where $x2_{it}$ is the provincial DEI where farmer i is located in year t, β_2 is the regression coefficient for independent variable $x2_{it}$ and indicates if the regional development of the digital economy impacts the pesticide use intensity. Other variables are previously defined.

Model 3 considers the compounding impacts of both independent variables by adding an interaction of the two independent variables to Model (2) and is specified as follows in Eq. (3):

$$y_{it} = \alpha + \beta_1 x1_{it} + \beta_2 x2_{it} + \beta_3 x1_{it} x2_{it} + \gamma Z_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (3)$$

where β_3 is the regression coefficient for the newly created interaction term $x1_{it}$ $x2_{it}$ and indicates the compounding impacts of smartphone access and the regional development of the digital economy on the pesticide use intensity, and other variables are previously defined.

3.4. Endogeneity test

The fixed effects model is subject to some endogeneity concerns because of the potential reverse causal relationship between smartphone access and pesticide use intensity and potential omission of other critical control factors in our model specification. We tried to address potential endogeneity concerns by incorporating an instrumental variable in our models. Following Evans et al. (1992), we introduced an instrumental variables at a higher aggregate level to our models to address the endogeneity concerns. We select the smartphone usage rate in the village level as the instrumental variable for smartphone usage. This usage rate is the result of excluding the sample itself. The smartphone rate in the area reflects the prevalence of digital technology applications. Under the influence of neighborhood effects, individuals in the areas with higher smartphone rates are more likely to access smartphones, thereby meeting the requirement of instrumental variable relevance. However, the smartphone usage rate in a village does not affect individual decision on pesticide use, satisfying the requirement of instrumental variable exogeneity.

4. Results

4.1. Descriptive statistics of all variables

In this study, we restricted the age of the surveyed farmers to 16 to 80 years, as farmers who were too young or too old could not make their own decisions. To reduce measurement error, following Wu et al. (2018), we excluded households spending less than one yuan (RMB) on pesticide inputs per mu of sown area in any given year and/or did not report any sown area. Table 2 shows the descriptive statistics of all variables used in the study based on the combined rural household samples in 2015, 2017, and 2019. The household expenditure on pesticide use per hectare of sow area in a year ranges from ¥15 to ¥28,350. On average, a rural household uses ¥1440.17 per hectare of the sown area. The average smartphone value was 0.4071, indicating that 40.71 % of rural households use smartphones. The average digital Economy index is 0.3421 on a scale of 0 to 1.

The use of mobile phones, especially smartphones, among the selected rural households steadily increased over the sampling period. Among all selected rural households in this study, only a small percentage didn't have mobile phones, i.e., 3.8 % in 2015, 3.4 % in 2017, and 2.4 % in 2019, and the number gradually declined over the sampling periods. Among the selected rural households, 70 % used non-smartphones, and only 26.2 % used smartphones in 2015. The construction of 4G network base stations and the introduction and growth of 4G smartphones accelerate the adoption among rural households after 2015. The percentage of selected rural households using smartphones increased to 44 % in 2017 and 57.6 % in 2019, while the percentage using non-smartphones was decreased to 52.5 % in 2017 and 40 % in 2019.

Table 2
Statistical description and analysis results of each variable.

Variables	Sample size	Mean	SD.	Min	Max
Pesticide use intensity (Yuan·ha^{-1})	10,255	1440.17	2667.85	15	28,350
Pesticide use intensity (Yuan·ha^{-1}, logarithm)	10,255	6.4600	1.2291	2.7726	10.2524
Smartphone	10,343	0.4071	0.4913	0	1
Digital economy index	10,343	0.3421	0.0834	0.2332	0.7727
Age	10,343	54.3781	11.3548	16	80
Education	10,338	8.3405	4.5862	0	19
Gender	10,343	0.6365	0.4810	0	1
Ratio of agricultural employment	10,343	0.6133	0.3428	0	1
Ratio of staple food crops	10,343	0.9253	0.1865	0	1
Agricultural loan	10,327	0.0620	0.2411	0	1
Farmland certification	10,343	0.6462	0.4782	0	1
Production for self-consumption	10,301	0.4615	0.4985	0	1
Agricultural guidance	10,337	0.0928	0.2901	0	1
Total sown area (ha)	10,274	0.7363	1.0735	0.0007	10.6667
Total sown area (ha, logarithm)	10,274	0.4532	0.3892	0.0007	2.4567
Annual per capita income of the village (Yuan)	10,160	9,815.179	8,751.374	0	60,000
Annual per capita income of the village (Yuan, logarithm)	10,160	8.8151	0.9876	0	11.0021
Distance from market (km)	9,065	4.9320	6.0219	0	60
Distance from market (km, logarithm)	9,065	1.4300	0.8289	0	4.1109
IV	10,213	0.4062	0.2520	0	1

Note: The raw value minus the sample mean was used for regression analyses to avoid multicollinearity problems following Balli and Sørensen (2013). The sample size is obtained after excluding observations with missing values.

4.2. Fixed effect modeling results

We further excluded the top 0.1 %, 0.5 %, 1 % or 5 % of households in pesticide use intensity and total sown area to eliminate the potential impacts of sampling outliers to run the fixed effect models. The results are consistent. Table 3 presents the modeling results for the fixed effect models excluding the top 1 % of households in pesticide use intensity and total sown area while the supplemental materials presents the results excluding the top 0.1 %, 0.5 % and 5 % of households in pesticide use intensity and total sown area. Based on Model 1, the coefficient for the independent variable smartphones is 0.077 and statistically significant at a 90 % confidence level. This result indicates that smartphone access would increase pesticide use intensity. Following the calculation methods in Kennedy (1981), the estimated coefficient of 0.077 indicates that the average expenditure on pesticide use per ha is 7.9 %[3] higher for rural households using smartphones than those not using smartphones, including non-smartphones and not having phones. The modeling results from Model 2 confirm the findings from Model 1 on the significant and positive impacts of smartphone access on pesticide use intensity. The results from Model 2 also indicate that the reverse relationship between the digital economy index and the pesticide use intensity as the model coefficient for DEI is negative at a 95 % confidence level.

As shown in the modeling results from Model 3, the coefficients for smartphone and DEI have the same signs as those from Models 1 and 2, but they are no longer statistically significant. However, the coefficient for the cross-multiplication term between smartphone and DEI, which indicates the compounding impacts of smartphone access and the development of the digital economy, is negative and statistically significant at a 99 % confidence level. In other words, smartphone access with a growing digital economy could lead to a decline in the intensity of pesticide use.

Table 3 also shows the consistent impacts of all control variables across the three models. A higher ratio of agricultural employment and a larger scale of sown areas dedicated to staple food crops lead to higher pesticide use intensity, as indicated by their positive and statistically significant coefficients. The statistically positive coefficients indicate that carrying agricultural loans prompts farmers to increase pesticide use intensity. However, farmers who consume their own products tend

Table 3
The fixed effect modeling results excluding the top 1 % of households in pesticide use intensity, total sown area, and agricultural income per capita.

Variables	Model 1	Model 2	Model 3
Smartphone	0.0770*	0.0787*	−0.0085
	(0.0412)	(0.0412)	(0.0518)
Digital economy index (DEI)		−3.4017**	−1.2794
		(1.6443)	(1.8442)
Smartphone * DEI			−3.1269***
			(1.0853)
Age	0.0000	−0.0002	−0.0003
	(0.0030)	(0.0030)	(0.0030)
Education	−0.0006	−0.0006	−0.0004
	(0.0046)	(0.0046)	(0.0046)
Gender	0.0184	0.0188	0.0141
	(0.0519)	(0.0519)	(0.0519)
Ratio of agricultural employment	0.0494	0.0581	0.0577
	(0.0571)	(0.0571)	(0.0568)
Ratio of staple food crops	0.4386***	0.4328***	0.4379***
	(0.1120)	(0.1114)	(0.1111)
Agricultural loan	0.0731	0.0696	0.0661
	(0.0795)	(0.0795)	(0.0795)
Production for self-consumption	−0.0646	−0.0673*	−0.0711*
	(0.0400)	(0.0399)	(0.0400)
Farmland certification	−0.0507	−0.0532	−0.0572
	(0.0383)	(0.0384)	(0.0381)
Agricultural guidance	0.0269	0.0271	0.0235
	(0.0554)	(0.0554)	(0.0551)
Total sown area	−1.5150***	−1.5125***	−1.5118***
	(0.1001)	(0.1000)	(0.1000)
	−0.0277	−0.0278	−0.0285
	(0.0187)	(0.0187)	(0.0186)
Distance from market	−0.0274	−0.0252	−0.0266
	(0.0195)	(0.0197)	(0.0196)
Constant	7.1688***	7.1011***	7.1705***
	(0.2711)	(0.2726)	(0.2741)
Household fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes
N	7998	7998	7998
Adjusted R^2	0.1787	0.1800	0.1824
F	25.5976	24.3475	23.2594

Note: Significance levels: * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$. The sample size is obtained after excluding observations with missing values.

[3] The calculation formula is: $g^* = exp\left(\hat{c} - \frac{1}{2}\hat{V}(\hat{c})\right) - 1$.where g^* is the relative effect on pesticide use intensity of the presence of the factor represented by the smartphones, $\hat{c}$ is the estimate of the regression coefficient, and $\hat{V}(\hat{c})$ is the variance of $\hat{c}$.

to lower pesticide use intensity, as shown by significantly negative coefficients at the 99 % confidence level. A larger scale of operation indicated by the total sown area leads to lower pesticide use intensity, as indicated by negative and statistically significant coefficients. The coefficients for other control variables, including farmers' age, gender, years of education, farmland certification, the annual per capita income of the village, and distance from the market, don't significantly impact pesticide use intensity as their coefficients are not statistically significant.

Based on the fixed effect results in Model 3, we also plot the interactive impacts of smartphone access and the DEI on pesticide use intensity in Fig. 3, where the x-axis represents smartphone access and the y-axis represents the pesticide use intensity. Following Li and Sun (2017), these impacts were evaluated at the sample means of all control variables, and the high and low digital economy development levels were defined as the top and bottom 10 % DEI levels of the samples, respectively. As shown in Fig. 3, the pesticide use intensity for farmers with smartphone access is higher than for farmers without smartphone access under the low digital economy development scenario but higher under the high digital economy development scenario. Also, the intensity of pesticide use under the high digital economy development scenario is lower than under the low digital economy development scenario. The results in Fig. 3 confirm the double-edged sword effect of smartphone access on pesticide use intensity observed by several empirical studies in China.

4.3. Endogeneity test results

Table 4 presents the endogeneity test results using the panel data. We follow the mature method and perform the first stage estimation to test the correlation between the instrumental and endogenous variable (Wooldridge et al., 2016). Based on the first stage estimation, the coefficient for the instrumental variable is 0.1331 and is statistically significant at a 99 % confidence level. This result indicates that the smartphone usage rate in the village would increase smartphone access and shows that the instrumental variable satisfies the requirement of correlation with the endogenous variable.

The second stage confirms the findings on the significant and positive impacts of smartphone access on pesticide use intensity. According to previous literature (Stock and Yogo, 2002), we utilize the squared t-statistic of the regression coefficient for the instrumental variable from the first-stage regression, denoted as the F-value, to determine whether there is a weak instrument problem. The results indicate that the F-value is 11.297,[4] which exceeds 10, suggesting that this study has no weak instrument problem.

5. Discussion

The understanding of the impacts of smartphone access on pesticide use intensity has been paradoxical. Some research argued that the integration of smartphones into agricultural production and management allows farmers to access agricultural knowledge and product information to develop smart and precision agriculture and offers opportunities to properly use pesticides and achieve pesticide reduction goals (Rotz et al., 2019; Clapp and Ruder, 2020). However, some empirical studies found that smartphone access did not reduce but, in some cases, even increased pesticide use intensity (Ma and Zheng, 2022).

Our empirical assessment results explain such a paradox. Overall, smartphone access hasn't helped reduce pesticide use in China yet: rural households with smartphone access had 8 % higher pesticide use intensity than those without smartphone access. Our findings suggest that not only smartphone access but also the development in digital economy significantly affects the intensity of pesticide use. Smartphone access in the regions with a higher level of development in digital economy helps lower the pesticide use intensity in China. The overall increase in the intensity of pesticide use associated with smartphone access in China was primarily due to the significant increases in pesticide use intensity in those regions with lower levels of development in digital economy. The results are robust, as the regression coefficients from the fixed effect models are fairly consistent.

Empirical results indicate that smartphone access must be accompanied by a high level of development in digital economy to reduce farmers' pesticide use. However, the regions with a low development level of digital economy in China generally have insufficient digital infrastructure, which results in poor network communication, weak network signal coverage, slow network speed, and nearly no existence of content creation and other supporting services. Without the public agricultural extension services, pesticide sellers have been the primary source for most farmers to gain pesticide product information and application knowledge in China (Fan et al., 2015; Jin et al., 2015). Because of the lack of digital infrastructure, the farmers with smartphone access still mainly obtain information through phone calls and SMS text messages, as in the case of Papua, Indonesia (Heimerl et al., 2015). The CFD also shows that households with smartphone access are financially better off and socially better connected than those without smartphones. Therefore, they are more willing and able to take risks and increase pesticide use intensity.

However, in regions with a high level of development in digital economy, smartphones are a new tool in agricultural operations and profoundly impact agricultural productivity. Farmers can rely on smartphones to independently search and access online information on resources and products related to agricultural production. Diverse forms of information such as text, pictures, voice, and video also help farmers break through many traditional barriers imposed by limited education, lack of social connections, and spatial isolation to learn more about crops and pesticides so that they can more properly use the products to improve the efficiency of pesticide use and, in many cases, reduce pesticide use. The flow of knowledge and information on social media then stimulates the growth of local digital services and content creation in the rural areas in those regions. Many experienced farmers become content creators to share their experiences and knowledge of using pesticides through short videos, live broadcasts, online courses, and other means (Šūmane et al., 2018). Such localized content and services have been proven to be very effective in influencing farmers' decision in pest control and disease prevention (Carolan, 2022).

The findings of this study have important implications for achieving China's pesticide reduction goals. First, smartphone access has a great potential to reduce the intensity of pesticide use; however, the potential can only be realized with the development of the local digital economy and the support of digital infrastructure. Therefore, to reduce the intensity of pesticide use, governmental policies should focus on increasing farmers' access to smartphones and other smart terminals such as tablets and investing in digital infrastructure to promote the development of the local digital economy. Second, after China decommissioned its public agricultural extension system in the 1980s, agricultural resource suppliers essentially filled the void left by the public extension system and became the sole source of agricultural knowledge and product information for farmers who seek advice, which causes pesticide overuse in China (Wang and Gu, 2013). In this digital transformation era, Chinese governments must build the public digital agricultural extension system by investing in app development, content creation and network building to disseminate scientific knowledge on pesticides and their proper uses. The governments may also encourage more experienced farmers to get involved in media content creation and become technical experts in local digital communities to promote peer learning and knowledge sharing. Third, the farmers need to be trained

[4] The calculation formula is: $F = t^2 = \left(\frac{0.1331}{0.0396}\right)^2 = 11.297$.

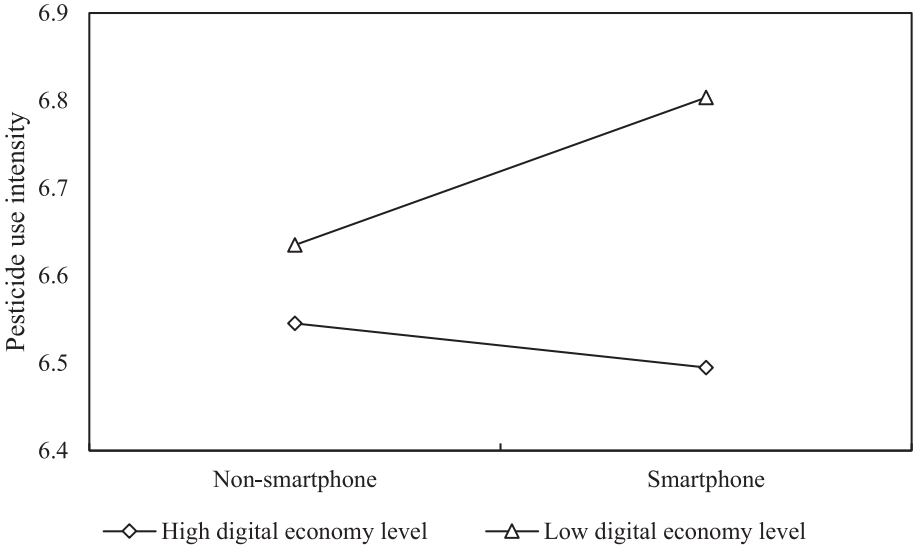


Fig. 3. The impacts of digital economy development on pesticide use intensity.

Table 4
Endogeneity test results excluding the top 1 % of households in pesticide use intensity, total sown area, and agricultural income per capita.

	(1)	(2)
	Smartphone	Pesticide use intensity
Smartphone		1.3570*
		(0.7327)
Instrumental Variable	0.1331***	
	(0.0396)	
Age	−0.0182***	0.0235*
	(0.0013)	(0.0137)
Education	0.0057***	−0.0075
	(0.0021)	(0.0067)
Gender	0.0446*	−0.0574
	(0.0228)	(0.0657)
Ratio of agricultural employment	0.0326	0.0158
	(0.0269)	(0.0699)
Ratio of staple food crops	−0.0114	0.4232***
	(0.0444)	(0.1096)
Agricultural loan	−0.0055	0.0867
	(0.0344)	(0.0847)
Production for self-consumption	−0.0153	−0.0457
	(0.0194)	(0.0491)
Farmland certification	−0.0131	−0.0267
	(0.0174)	(0.0441)
Agricultural guidance	0.0288	−0.0029
	(0.0265)	(0.0682)
Total sown area	0.0761**	−1.6134***
	(0.0349)	(0.1030)
Annual per capita income of the village	−0.0052	−0.0234
	(0.0088)	(0.0219)
Distance from market	−0.0018	−0.0247
	(0.0094)	(0.0231)
Household fixed effect	Yes	Yes
Year fixed effect	Yes	Yes
N	7900	7900
R^2	0.2843	0.0805
F	54.49	–

Note: Significance levels: * $p < 0.1$, ** $p < 0.05$, and *** $p < 0.01$. The sample size is obtained after excluding observations with missing values.

on how to use smartphones to access the necessary information since the general education level of the farmers is low in China. According to the China Internet Network Information Center, a lack of user skills, even the basic keyboard input skills, often prevents many rural residents from accessing and effectively using the Internet.

6. Conclusion

This study examines the relationship between smartphone access and pesticide use intensity among rural households in China based on the Zhejiang University Chinese Family Database in 2015, 2017, and 2019. The results show that smartphone access increased pesticide use intensity among the sampled rural households in China in those periods. However, the impacts were mediated by the level of development in regional digital economy and vary across different regions in China. In the regions with low levels of development in digital economy, smartphone access intensifies pesticide use. However, in the regions with high levels of development in the digital economy, smartphone access helps reduce the intensity of pesticide use. Rural households in rural regions with a high level of development in digital economy can use smartphones to access all different contents on pesticides and their proper use, develop knowledge on crop disease prevention and pest control, and ultimately reduce the pesticide use intensity. The study results demonstrate the potential of digital technologies, such as smartphone access, to reduce the intensity of pesticide use. However, substantial work is needed to realize such potential. This work includes developing regional and local digital infrastructure, rebuilding the public agricultural extension services, and foundational training on farmers to use smartphones.

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CRediT authorship contribution statement

Lin Xie: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Zeyuan Qiu:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Shuyin Chen:** Methodology, Formal analysis, Data curation. **Xiao Lei:** Methodology, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2024.173867.

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Relationship between rural land titling and land transfer in China: a systematic literature review and meta-analysis

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The traditional land system of rural communities in China has been an obstacle to the sustainable development of land transfer. To facilitate a more efficient allocation of resources, the Chinese government has implemented the largest rural land titling action in the world. However, there has been much debate in scholarly circles regarding the correlation between rural land titling and rural land transactions. By employing meta-analysis technology, this paper evaluates the relationship between rural land titling and rural land transactions. According to the meta-analysis results, rural land titling is only a minor contributor to rural land transfer; it only contributes to rural land transfer-out, with no effect on rural land transfer-in. Furthermore, education, age, labor force, agricultural fixed assets owned, area of contracted rural land, and publication time were identified as situational variables that affect the relationship between rural land titling and rural land transfer-out. This research provides insight into how to promote the sustainable development of agricultural land economy by promoting land transfer, as well as further topics for future study.

KEYWORDS

rural land titling, land transfer, China, meta-analysis, sustainable development

Introduction

Agricultural production in China is dominated by smallholder farms because of the Household Contract Responsibility System (HCRS), which allocates the use rights of collectively owned farmland to rural households based on long-term contracts between households and local village collectives (Ye, 2015). Under the HCRS, members of the community collective have the right to acquire the right to contract land, resulting in China becoming a country dominated by small farmers. Data from China's Third Agricultural Census show that the number of small farmers nationwide accounts for more than 98% of agricultural operators, and the area of small farmers accounts for 70% of the total cultivated land. There are 230 million households in China's current farmers, with an average operating scale of 0.52 hectares and 210 million households operating <0.67 hectares (Xinhua News Agency, 2019). The excessively small scale of operations in China's agricultural sector has hindered the application of modern agricultural technologies, and therefore, through land transfer to expand the scale of individual operators, it is helpful to reduce production costs (Xu et al., 2011); The land transfer also has promoted agricultural intensive, industrialization and standardization, as well as the improvement of production efficiency (Zhang, 2010). Therefore, as early as 1984, the Chinese government put forward the idea of encouraging the gradual concentration of land to those who are capable of farming, and taking the path

of large-scale operations. Subsequently, the concept of land transfer emerged. Land transfer denotes the process through which farmers exchange their rural land use rights, enabling those who seek to enlarge their agricultural scope to lease the rural land held by others. Land transfer-in pertains to farmers who desire to augment their agricultural scale by renting rural land from fellow farmers, whereas land transfer-out refers to farmers who lease out their own rural land holdings (Gao et al., 2020). By 2014, the State Council of China issued the "Opinions on Guiding the Orderly Transfer and Development of Rural Land Use Rights for Moderately-sized Agricultural Operations", requiring all levels of government to guide the orderly transfer of land use rights to expand the scale of agricultural operations (Xinhua News Agency, 2014).

However, as a country in transition, China has long adhered to the collective rural land ownership, with rural land owned by village collectives. Farmers have contract rights but village collectives retain the right to adjust land allocations (Zhang and Donaldson, 2013). This special property structure leads to unclear ownership of agricultural land in China and numerous rural land-related disputes, which hinders rural land transfer transactions and optimal rural land allocation (Bu and Liao, 2022). Under the influence of urbanization, there has been a rapid decrease in China's rural population as it migrates to urban areas. Additionally, under China's existing rural land system, land ownership is held by the collective of peasant communities, with the peasants merely contracted to use the land for production. As a result, ownership disputes often arise during the process of land transfer (Xie and Luo, 2013). The land system that restricts transactions leads to land abandonment and inefficient use, which determines the sustainable development of rural China (Li et al., 2018; Wang et al., 2018; Guo et al., 2019). In 2009–2018, China completed the world's largest rural land titling action at a cost of RMB60 billion. Land titling refers to the process wherein each rural household enters into a written agreement with the collective entity possessing the land, subsequently obtaining a land certificate. This certificate delineates the specific land parcel, its boundaries, and the encompassing area, with the intent of formalizing pre-existing land contracts and land use rights. Furthermore, it permits the utilization of land use rights as collateral (Cheng et al., 2019). Secure the collective and non-exclusive land rights of multiple types of land to individual farmers in an exclusive manner. Through the process of titling, the right of long-term use and transfer of land was granted to the farmers (Yan, 2010). The action clarified farmers' contract and management rights over rural land and prohibited further adjustments, greatly enhancing farmers' rural land property rights (Zhang L. et al., 2020).

In general, as indicated by Figure 1. The collective ownership of agricultural land in China has resulted in an equitable distribution of land per household. However, the country's vast population has led to a pattern of small-scale farming, wherein each household can only manage a diminutive plot of farmland. This practice has hindered the adoption of modern agricultural technologies, thereby limiting agricultural productivity. To address this issue, the Chinese government and researchers have advocated for enlarging the scale of individual households through the transfer of rural land. Nevertheless, the collective ownership of rural land poses significant legal and practical challenges to the transfer of land. To overcome these challenges, the Chinese government has implemented a land titling effort that grants farmers the right to freely transfer land. This policy weakens the rights of rural communities over the land, but it is necessary to facilitate the transfer of rural land and enhance overall agricultural productivity.

A clear definition of property rights is an important prerequisite for transactions and optimally allocated resources (Coase, 1960). Studies from various countries have shown that clear definitions of property rights promote rural land transfer by reducing transaction asymmetry, improving the perception of property rights security, and increasing credit availability for farmers (Carter and Olinto, 2003; Boucher et al., 2005; Gould et al., 2006; Holden et al., 2007; Chamberlin and Ricker-Gilbert, 2016). Some studies from China suggest that China's rural land titling action has contributed to rural land transfer (Ma et al., 2015; Cheng et al., 2016, 2019; Liu et al., 2017; Xu et al., 2017; Ye et al., 2018; Wang, 2019).

Conversely, some argue that China's land titling action hinders rural land transfer. That argument is based on the special importance of land in Chinese culture (Fei, 1998) as the personified property of farmers. Farmers' special feelings toward the farmland are further bolstered by land titling (Luo, 2019). The endowment effect is the tendency for people who own a good to value it more than people who do not (Knetsch, 1989; Kahneman et al., 1990; Morewedge and Giblin, 2015). In this case, farmers show an endowment effect when transferring rural land, that is, willingness to accept is higher than willingness to pay, which ultimately hinders rural land transfer (Zhong, 2013; Luo, 2017). This view is also supported by empirical studies (Fu et al., 2016; Cai and Xia, 2017; Lin et al., 2017).

The endowment effect has shown that the transaction of property rights for rural land is not as simple as Coase's analytical framework suggests. At the same time, the process of land titling and registration involves more complex interactions with rural communities. For example, research indicates that land titling can alter farmers' interest goals and thus affect mutual aid mechanisms in village society (Hong and Luo, 2023). Consequently, behind land titling lies not only farmers' economic calculations, but also some social issues. For instance, in the context of land titling, the number of lawsuits related to rural land property rights has not decreased, but has increased annually (Sun, 2021). Therefore, the relationship between land titling and land transfer should not only be analyzed from an efficiency perspective, but also from the perspective of equity during the titling process and afterwards (Feng et al., 2020). These factors may obfuscate the relationship between land titling and land transfer.

The foregoing implies that existing studies on the relationship between China's rural land titling and rural land transfer are ambiguous. On the one hand, this is partly because of existing studies that have referred to rural land transfer-in and transfer-out as "transfer", whereas farmers might have inconsistent behavior patterns when carrying out rural land transfer-in and transfer-out. Studies have demonstrated that land transfer-in behavior is mainly observed among farmers with higher initial income levels and better economic conditions, whereas land transfer-out behavior is mainly observed among farmers with lower initial income levels and poorer economic conditions. Moreover, land transfer-in has increased farmers' income, while land transfer-out has decreased

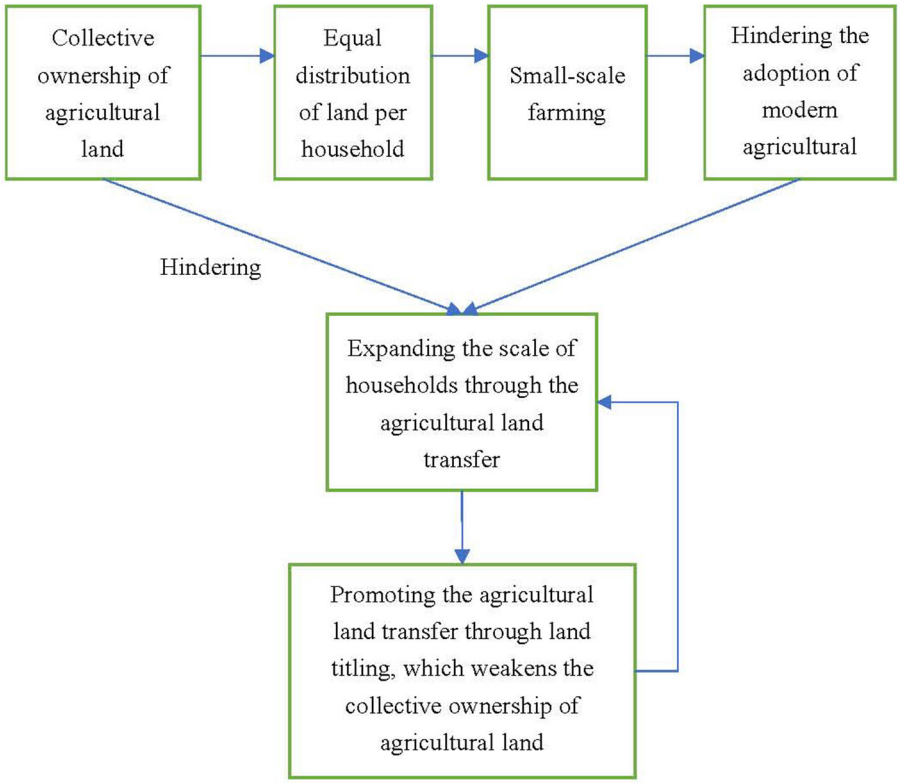


FIGURE 1
The relationship between collective ownership of agricultural land and land transfer.

farmers' income, thereby widening the income gap among rural residents in China (Du and Zhang, 2022). On the other hand, there is a moderator variable in the relationship between the variables used in different studies (Hunter and Schmidt, 2004). Most study sample data in the existing literature are limited to a certain region, so study results often apply only to a specific region. China's vast territory and wide regional disparities have led to heterogeneity of previous studies on rural areas in different regions and contexts, greatly weakening the universality of study conclusions (Xie et al., 2020). To this end, two questions remain to be clarified: (1) Has China's rural land titling action really contributed to rural land transfer? (2) What situational factors influence the relationship between the two?

As a comprehensive effect size assessment method, meta-analysis method has been widely applied in agricultural economics (Baumgart-Getz et al., 2012). As a quantitative method, meta-analysis and its derivative, meta-regression analysis method, not only assess the type and strength of the relationship between variables but also explore the moderator variable in that relationship (Miller and Toulouse, 1986). If the relationship between land titling and rural land transfer differs from one sample to another, and the samples have differing traits, those traits can be moderator variables in the relationship. In addition, meta-analysis can further explore the influence of situational factors by analyzing relevant moderating variables such as country and time based on the vast existing secondary database. Using meta-analysis technology, this study assesses the relationship between land titling and rural land transfer, transfer-in, and transfer-out in China and explores the roles of a range of moderator variables. These moderator variables include those at individual, household, and study timing levels.

(1) Individuals. Farmers' ages, education levels, and other factors significantly influence the rural land transactions in which they engage (Su et al., 2018a; Chikuni and Kilima, 2019; Peng et al., 2020). Studies have also shown that farmers of older age and lower cultural level have a deeper emotional attachment to their land, and land titling can help to further strengthen this endowment effect derived from emotion and further influence the farmers' land transfer behaviors (Zhong, 2013; Luo, 2017). However, some individual-level variables may contribute to the heterogeneity of the relevant conclusions. Therefore, this study first discusses the moderating effect of householder age and education level.

(2) Households play a critical role in China's agricultural production, based on various household-level variables such as labor force size, agricultural fixed asset value, and contracted land area (Zhang Y. et al., 2020; Ji et al., 2021). After land titling, farmers with different economic levels have various choices and the interaction between land titling and economic level has a significant impact on land transfer (Su et al., 2018b). Therefore, this study discusses the moderating effects of fixed asset value, total income, and agricultural income.

(3) Study timing. Land titling is a process of defining and confirming rights; it lasts for 10 years. During the land titling action, government behavior is "unstable" and thus affects farmers' expectations and behaviors (Ji et al., 2021), indicating

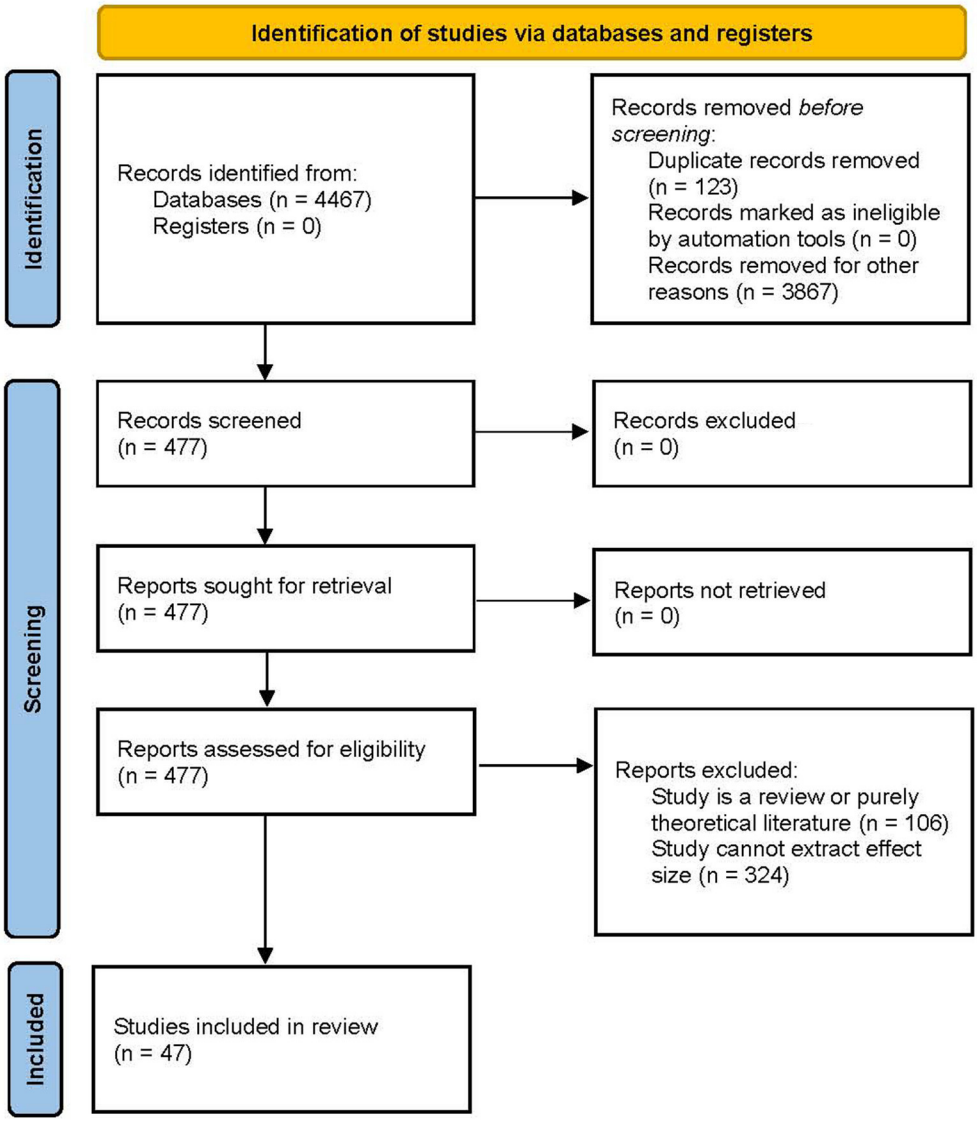


FIGURE 2
The PRISMA framework.

that the impact of a land titling varies with study timing, so the moderating effect of study timing is also discussed.

Materials and methods

Data collection

To ensure the accuracy and completeness of data, we comprehensively search both Chinese and English literature. Chinese literature is searched in CNKI's China Academic Journals Full-text Database, China Masters' Theses Full-text Database, and China Doctoral Dissertations Full-text Database, as well as the CQVIP and Wanfang databases, using the keywords "rural land titling" and "rural land transfer". English literature is mainly searched in several databases—Springer Link, Elsevier Science, EBSCO-ASP general subject full-text study literature, Emerald full-text journal, Wiley–Blackwell, ProQuest full-text journal, and ProQuest full-text master's and doctoral thesis databases—and Google Scholar using the keywords "land transaction," "land transfer," and "land titling". In order to avoid omissions in the literature, we conducted a second search on the reference literature of the searched related literature, i.e., manually searching all the Chinese and English reference literature related to the research topic in the sample literature, to ensure the comprehensiveness of the sample literature.

In combination with the requirements of the study topic and the meta-analysis method, studies included in the meta-analysis must meet the following conditions: (1) the target literature must contain keywords such as rural land titling, rural land transfer, and whether farmers have rural land titling subject to farmers' certificates of rural land titling and registration; (2) the studies must

TABLE 1 List of original studies included in the meta-analysis 1.

No.	References	Outcome variable	Sample size (*N*)	Effect size (*K*)
1	Wang (2018)	Transfer	315	−0.214
2	Liu and Luo (2018)	Transfer	1,240	0.778
		Transfer-out	1,240	0.709
		Transfer-in	1,240	0.374
3	Li (2020)**	Transfer	5,967	−0.008
		Transfer-out	5,967	0.058
		Transfer-in	5,967	−0.084
4	Ding and Zhong (2017)	Transfer	405	0.32
		Transfer-out	405	0.195
		Transfer-in	405	0.427
5	Feng et al. (2021)	Transfer	9,596	0.081
		Transfer-out	9,596	0.028
		Transfer-in	9,596	0.129
6	Zhu and Yang (2019)	Transfer-out	9,165	0.08
7	Liu and Luo (2018)	Transfer	2,738	0.036
8	Lin et al. (2016)	Transfer-out	1,444	0.05
9	He et al. (2016)	Transfer-out	9,723	0.037
10	Yu (2016)	Transfer	287	0.232
11	Li (2018)	Transfer	8,670	0.025
12	Zhou (2019)	Transfer	275	0.215
13	Li et al. (2018)	Transfer-out	5,701	0.043
		Transfer-in	5,701	−0.011
14	Xu (2019)	Transfer-out	14,260	0.014
		Transfer-in	14,260	0.014
15	Han et al. (2019)	Transfer-out	299	1.505
		Transfer-in	299	−2.161
16	Cheng et al. (2016)	Transfer-out	5,920	0.06
		Transfer-in	5,920	−0.014
17	Shi et al. (2017)	Transfer-out	612	0.006
		Transfer-in	612	0
18	Zhan and Zhang (2009)	Transfer-out	142	0.146
		Transfer-in	142	−0.014
19	Xu et al. (2017)	Transfer-out	434	0.141
		Transfer-in	420	0.059
20	Xie et al. (2017)	Transfer	231	0.031
21	Liu et al. (2020)	Transfer	1,030	0.387
22	Wang (2019)	Transfer-out	5,792	−0.061
		Transfer-in	5,792	0.029
23	Shen (2021)	Transfer	280	0.183
24	Luo et al. (2017)	Transfer	645	−0.029
25	Li (2020)**	Transfer	5,967	−0.036
		Transfer-out	5,967	−0.012
		Transfer-in	5,967	−0.048
26	Huang et al. (2018)	Transfer	14,321	0.06
		Transfer-out	14,321	0.098
		Transfer-in	14,321	0
27	Fu et al. (2016)	Transfer-out	305	0.297
		Transfer-in	305	−0.026
28	Cai (2018)	Transfer	397	0.221
29	Feng et al. (2020)	Transfer	8,199	0.936
		Transfer-out	8,199	0.879
		Transfer-in	8,199	0.965
30	Xu and Niu (2020)	Transfer-out	9,377	0.013
		Transfer-in	9,377	−0.012
31	Huang et al. (2018)	Transfer	105	0.219
32	Cai and Xia (2017)	Transfer	622	−0.285
33	Klaus et al. (2011)**	Transfer-in	1,302	−0.047
		Transfer-out	1,302	0.055
34	Ji and Qian (2018)	Transfer	7,168	0.124
35	Lin et al. (2017)	Transfer-out	5,481	−0.003
		Transfer-in	5,481	−0.026
36	Luo and Wan (2019)	Transfer-out	2,795	−0.034
37	Xu et al. (2017)	Transfer-out	4,411	0.052
38	Yang and Li (2020)	Transfer-in	4,363	0.028
39	Han and Liu (2019)	Transfer-out	294	0.15
		Transfer-in	294	−0.014
40	Feng and Zhong (2018)	Transfer-in	1,336	−0.083
41	Liu and Xu (2016)	Transfer	200	0.749
42	Chen (2006)	Transfer-out	1,001	−0.034
		Transfer-in	1,001	−0.049
43	Linxiu et al. (2019)	Transfer-out	640	−0.042
		Transfer-in	640	0.092
44	Klaus et al. (2011)**	Transfer-out	1,302	1.984
		Transfer-in	1,302	−1.7
45	Yang (2016)	Transfer	291	0.407
46	Cheng et al. (2019)	Transfer-out	10,287	0.0111
47	Yang and Wang (2022)	Transfer-out	26,397	0.01

(Continued)

TABLE 1 (Continued)

** One literature contains two different studies.

be empirical, excluding purely theoretical and literature reviews; in addition, sample size, correlation, and other data indicators that can be converted into effect size must be reported in the articles; (3)

samples for different studies must be independent of each other. If the samples for two studies are the same or overlap, the study with more detailed reports or a larger sample size is included in the analysis. We retrieved 4,467 relevant papers. After paper screening, we had finally acquired a total of 47 papers, of which 39 were in Chinese, and 8 were in English. Based on this data collection process, we drew the PRISMA framework (Figure 2).

Variables

We follow the methodology proposed by Stanley et al. to generate high-quality study data (Stanley et al., 2013). We use effect size to indicate the strength of the relationship between land titling and rural land transactions. The larger the effect size, the stronger the association between land titling and rural land transactions. Effect size in meta-analysis usually consists of a correlation coefficient between continuous variables or the mean difference between two groups of subjects in an experimental study. The calculation and coding of effect values adhere to the principle of "one sample, one effect value". If a single literature reports multiple independent and non-redundant samples, the corresponding effect values are separately calculated and coded for each sample. After coding is completed, different researchers re-calculate and code the data to ensure the accuracy of the data. Of course, some studies do not report these values but rather report *t*-test, *F*-test, or χ^2-test values—we use the tools provided by Wilson to convert them. Our meta-analysis study used Comprehensive Meta Analysis (CMA) software for statistical analysis. Table 1 lists the literature included in this study and the effect sizes obtained from it. In Table 1, columns 1 and 6 display the study numbers, while columns 2 and 7 list the authors of the studies and their respective publication years. Columns 3 and 8 present the types of land transfer analysis for each study, and columns 4 and 9 indicate the sample sizes included in the studies. Finally, columns 5 and 10 show the corresponding effect sizes of each study, as analyzed by CMA software.

In addition, Table 2 provides the moderator variable definition. "Householder" encompasses both "Age" and "Level of education;" "Household" comprises "Household labor force," "Present value of agricultural fixed assets," and "Area of household contracted land;" "Timing" refers to "Publication time".

Publication selection bias

Journals usually exhibit a preference for publishing articles with statistically significant results, while those with non-significant results are often more difficult to publish. As the majority of the literature included in this meta-analysis consists of journal articles, a potential publication bias should be taken into consideration. First, we check for serious publication selection bias by referencing the funnel plot proposed by Light and Pillemer (1984). Most studies on the effect of rural land titling on rural land transfer (Figure 3, the funnel plot for the effect of rural land titling on rural land transfer) and rural land transfer-in (Figure 4) have concentrated on the middle and upper parts of the funnel plot with left–right symmetry, indicating only a small possibility of publication bias in the studies on the effects of rural land titling on rural land transfer and rural land transfer-in. In the meta-analysis of the effect of rural land titling on rural land transfer-out (Figure 5), some studies are concentrated on the left side of the funnel plot, and the effect size of individual studies is far from the central axis of the funnel plot, indicating that some publication bias may exist in the studies on the effect of rural land titling on rural land transfer-out.

Further testing for publication bias in the studies is conducted using a classic fail-safe *N*. The classic fail-safe *N*-test refers to the number of missing papers required to reduce the cumulative effect size to an insignificant level-i.e., the greater the classic fail-safe *N*, the less likely it is that publication bias exists (Jiang et al., 2012; Xie et al., 2016). The classic fail-safe Ns for the relationships between rural land titling and rural land transfer, rural land transfer-out, and rural land transfer-in are 21,154, 3,908, and 268, respectively—i.e., the number of additional papers for the sample needed to disprove the important relationships between rural land titling and rural land transfer, rural land transfer-out, and rural land transfer-in. The three corresponding classic fail-safe Ns are much larger than the 5K + 10 standard (*K* is the total effect size included in the literature; $K = 48$) (Jin et al., 2016; Wang et al., 2016) and much different from the study sample. This result suggests that there is little possibility of publication bias in our research conclusions.

Heterogeneity test and model selection

Heterogeneity test

In a meta-analysis, to determine whether there is a moderator variable between main effects, a heterogeneity test is usually used to see how much the effect size has changed. The heterogeneity test is carried out using an I^2-test and *Q*-test in this study. An I^2—test is the effect size variation as a percentage of the total variation: $0 \leq I^2 < 25\%$ indicates the absence of heterogeneity; $25\% \leq I^2 < 50\%$ indicates low heterogeneity; $50\% \leq I^2 < 75\%$indicates moderate heterogeneity; and $75\% \leq I^2 < 100\%$ indicates high heterogeneity (Higgins and Thompson, 2002). *Q*-test is a test based on the total variation test, that is, *Q*-value obeys the chi-square distribution. If $P < 0.05$, there is heterogeneity in effect size.

The results of the heterogeneity test are set out in Table 3. The I^2 value of land titling on transfer, transfer-out, and transfer-in is 99.663, 98.552, and 99.193%, respectively, and the effect size *Q*-test is significant ($p < 0.05$), indicating high heterogeneity between rural land titling and rural land transfer, rural land transfer-out, and rural land transfer-in in the meta-analysis. There is a potential moderator variable between the effects of rural land titling on rural land transfer, rural land transfer-out, and rural land transfer-in.

Model selection

The heterogeneity test can also be used to select a meta-analysis model. The difference between the fixed-effect and random-effect models lies in their different hypotheses for reasons for the difference between conclusions: the fixed-effect model believes that there is only one real effect size in all studies, and the difference

TABLE 2 Definition of moderator variable.

Variable	Variable coding	
Householder	Age	0 = Young, age < 53.14; 1 = senior, age ≥ 53.14
	Level of education	0 = Low, primary school or below or years of education <7; 1 = high, junior high school or above or years of education ≥ 7
Household	Household labor force (aged 16–65)	0 = Less, household labor force < 1.70; 1 = more, household labor force ≥ 1.70
	Present value of agricultural fixed assets (RMB) (original value of fixed assets such as household farm vehicles, tractors, threshing machines, and harvesters)	0 = Low, present value of agricultural fixed assets <14,718.54; 1 = high, present value of agricultural fixed assets ≥ 14,718.54
	Area of household contracted land (mu) (per capita household area * household size)	0 = Small, area of contracted land < 21.47; 1 = large, area of contracted land ≥ 21.47
Timing	Publication time (year) (difference from 2022)	0 = Far, publication time <4.23; 1 = near, publication time ≥ 4.23

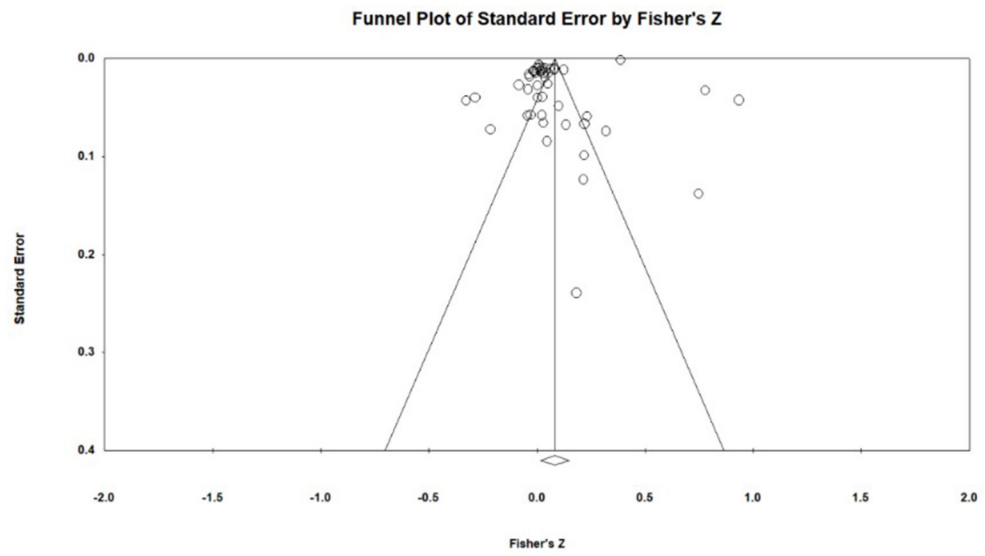


FIGURE 3
The funnel plot for the effect of rural land titling on rural land transfer.

between conclusions is solely due to sampling error; the random-effect model assumes that every study has its own real effect size and that the difference between conclusions is not solely due to sampling error (Borenstein et al., 2009). In general, if the *p*-value of the *Q*-test in the heterogeneity test is <0.01 and $I^2 > 50\%$, the random-effect model is more appropriate, and conversely, the fixed-effect model should be used (Hedges and Vevea, 1998).

Results

Main effect analysis

The results of the meta-analysis are shown in Table 4. According to the standards provided by Cohen (Cohen, 1992), a combined effect size <0.2 indicates a weak correlation between the two variables; a combined effect size between 0.2 and 0.5 indicates a moderate correlation; and a combined effect size >0.5 indicates a high correlation (Lipsey and Wilson, 2001). According to the results of the random-effect model, the combined effect sizes of rural land titling on rural land transfer and rural land transfer-out are 0.082 and 0.138, respectively, indicating that rural land titling has a slightly positive effect on rural land transfer and rural land transfer-out and is statistically significant (combined effect size < 0.2, $P < 0.05$). The results are consistent with earlier empirical study (Ye et al., 2018)—that is, there is a positive but weak correlation between rural land titling and rural land transfer and rural land transfer-out. The result is consistent with research that supports the rural land titling, which can facilitate the transfer of farmlands (Ma et al., 2015; Cheng et al., 2016, 2019; Liu et al., 2017; Xu et al., 2017; Ye et al., 2018; Wang, 2019). In addition, the combined effect size of rural land titling on rural land transfer-in is −0.03 and not statistically significant ($P > 0.1$), indicating that rural land titling has no significant effect on rural land transfer-in. The result neither supports the view that land titling promotes agricultural land transfer, nor supports the view that land titling suppresses agricultural land transfer. This might be because previous studies

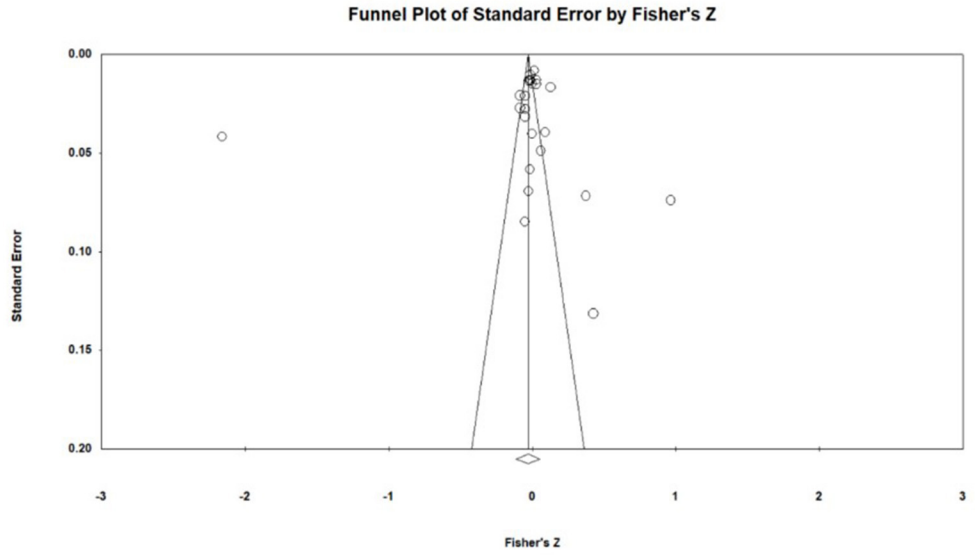


FIGURE 4
The funnel plot for the effect of rural land titling on rural land transfer-in.

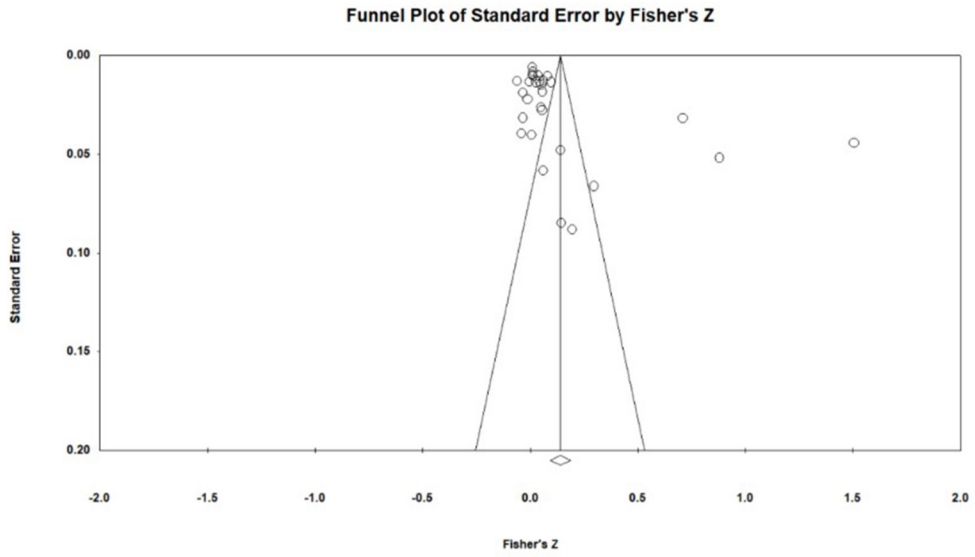


FIGURE 5
The funnel plot for the effect of rural land titling on rural land transfer-out.

have conflated land outflows and inflows without differentiating their heterogeneity.

Moderating effect analysis

The main effect in Table 4 shows a very weak correlation ($K < 0.2$) between rural land titling and rural land transfer, rural land transfer-out, and rural land transfer-in, which may be due to a potential moderator variable that affects the correlation among the three. To explore the moderating effect and sources of heterogeneity of moderator variables, we use the methods proposed by Stanley and Jarrell (2005) and Zhang and Hu (2013) to carry out a meta-regression of the relationship between rural land titling and rural land transfer, rural land transfer-out, and rural land transfer-in, respectively. The moderating variables are grouped and categorized by mean, and the moderating effects are analyzed at three levels—householders, households, and publication time—with the results shown in Table 5.

In studies concerning the effect of rural land titling on rural land transfer, the effect size (K) of all moderator variables other than the present value of agricultural fixed assets ($K = 0.184$) is

<0.1. All variables other than the area of household contracted land are significant, indicating five moderator variables with a significantly weak positive effect on the relationship between rural land titling and rural land transfer. Only the moderator variable "area of household contracted land" has no significant effect, indicating that it is the only variable that does not play a role in regulating the relationship between rural land titling and rural land transfer. This may be due to the small area of farmers' household contracted land in some study samples, resulting in a less significant moderating effect.

In the study of the relationship between rural land titling and rural land transfer-out, all moderator variables have a significant moderate positive effect on the relationship between rural land titling and rural land transfer-out ($p < 0.1$), indicating that all moderator variables have a modulating effect on the study. At the householder level, the positive correlation between rural land titling and rural land transfer-out increases with senior aging and higher education levels of farmers. The specific magnitude of effects and the number of other moderating variables remain to be tested by subgroups. In addition, we can see that the moderator variables for rural land transfer-in are not significant. This suggests that rural land titling makes no contribution to rural land transfer-in, with the relationship unaffected by other situational factors.

Robustness test: subgroup test

A subgroup test is used to study sources of heterogeneity and examine the robustness of the outcome of moderator variables to solve the problem of combined effect size in homogeneous heterogeneity and is typically used to handle heterogeneity in meta-analyses (Ding and Zhao, 2018). The operating principle of a subgroup test is to stratify each variable and establish subgroups for moderating variables. The moderating variables are generally grouped and classified by mean. At the same time, the effect sizes of all subgroups are combined, and statistical tests are conducted to verify the accuracy of the analysis of moderating variables by examining whether the combined effect sizes of all groups are significant and consistent in direction (Zhang, 2016). The subgroup test results of the effect of rural land titling on rural land transfer are shown in Table 6.

At the householder level, the effect size (K) of the senior age group = 0.036 and the effect size (K) of the low age group = 0.066 ($Q = 7.577$, $p < 0.01$), indicating that the age of farmers plays a significant role in moderating the relationship between rural land titling and rural land transfer, and the younger the householder is, the more he/she prefers to transfer rural land. The cause is that, as rural population increasingly moves into urban areas, the younger generation of farmers no longer have the same deep attachment to land as their fathers. Therefore, compared to the elderly farmers, the younger ones are more likely to transfer agricultural land after the land rights are secured.

At the household level, the present value of agricultural fixed assets ($Q = 2.877$, $p > 0.1$) indicate that the present value of agricultural fixed assets do not play a role in moderating the relationship between rural land titling and rural land transfer, and the reason may be that the farming size of sample farmers in some studies is small, there are few agricultural fixed assets, farmers mainly engage in household operations, and the quantity and use of agricultural assets tend to be consistent, leading to an insignificant moderating effect.

The area of household contracted land ($Q = 6.501$, $0.05 < p < 0.1$), the effect size (K) for farmers with more contracted land and less contracted land is 0.11 and 0.067, indicating that the more contracted farmland has a stronger positive relationship between rural land titling and rural land transfer, and a greater preference for transferring more farmland. The cause of this result might be that farmers operating on a larger scale of farmland have more incentives to further expand their operations through land transfer and thus gain more economic benefits. On the contrary, for small-scale farmers, there is no significant effect on the economic benefit either from entering or leaving after their rights are confirmed.

The household labor force ($Q = 10.485$, $p < 0.01$), and the effect size (K) of more household and less household labor forces is 0.138 and −0.045, respectively, and the significant difference between the two shows that household labor force plays a significant role in moderating the relationship between rural land titling and rural land transfer, and the more household labor force a household has, the stronger the positive relationship between rural land titling and rural land transfer is, and the more likely it is for the household to transfer rural land; however, households with less labor force play an inhibitory role in the relationship between rural land titling and rural land transfer, and are not willing to transfer rural land; and (3) publication time ($Q = 1.489$, $p > 0.1$) does not play a role in moderating the relationship between rural land titling and rural land transfer. This result implies that,

TABLE 3 Results of heterogeneity test for land titling on land transfer.

Outcome variable	Effect size	I^2	Q	df	P-value
Land titling to transfer	47	99.669	13,884.589	46	0.000
Land titling to transfer-out	30	98.552	2,003.279	29	0.000
Land titling to transfer-in	25	99.193	2,973.432	24	0.000

TABLE 4 Results of main effect analysis for land titling on land transfer.

Main effect	Effect size	Combined effect size (K)	Ll	Ul	z-statistical value	p-value
Land titling to transfer	47	0.082	0.015	0.148	2.387	0.017
Land titling to transfer-out	30	0.138	0.091	0.184	5.783	<0.01
Land titling to transfer-in	25	−0.03	−0.115	0.055	−0.695	0.487

In the main effects, the mean value of the combined multiple effects of rural land titling on rural land transfer, rural land transfer-out, and rural land transfer-in is taken.

TABLE 5 Moderating effect analysis for land transfer.

Moderator variable		Transfer					Transfer-out					Transfer-in				
		Combined effect size (*K*)	se	z	*P*	*N*	Combined effect size (*K*)	se	z	*P*	*N*	Combined effect size (*K*)	se	z	*P*	*N*
Householder	Age of householder	0.044	0.006	1.786	0.074	22	0.2	0.018	4.427	<0.01	14	−0.204	0.262	−0.958	0.338	9
	Education level of householder	0.062	0.006	2.445	0.014	24	0.188	0.018	4.145	<0.01	16	−0.113	0.091	−1.05	0.294	12
Household	Household labor force	0.082	0.006	2.929	<0.01	15	0.233	0.018	4.911	<0.01	12	−0.188	0.118	−1.504	0.133	9
	Present value of agricultural fixed assets (RMB)	0.184	0.02	2.725	<0.01	6	0.187	0.03	2.154	0.031	4	0.062	0.005	1.559	0.119	3
	Area of household contracted land (mu)	0.071	0.042	1.197	0.231	16	0.203	0.023	3.566	<0.01	11	−0.196	0.13	−1.423	0.155	9
Timing	Publication time	0.082	0.032	2.387	0.017	47	0.138	0.007	5.783	<0.01	30	−0.03	0.02	−0.695	0.487	25

in terms of the research on land transfer in relation to land titling, the publication time of the research has not changed the relationship between the two. The reason may be that the existing research has not distinguished well between land inflow and outflow. Such a conflating approach is not conducive to clearly reflecting the relationship between the two variables of our concern.

Therefore, householder age and household labor force are significant in moderating rural land titling and rural land transfer, consistent with the moderating effect analysis results.

The subgroup test results of the relationship between rural land titling and rural land transfer-out are shown in Table 7.

(1) At the senior age group level, the age of a householder will significantly influence the effect of rural land transfer; the effect size (K) of senior age group = 0.217, effect size (K) of young age group = 0.089 ($Q = 6.93$, $p < 0.01$), which indicates that the more senior the householder becomes, the more he is inclined to transfer-out rural land. The effect size (K) of high education group = 0.251, and the effect size (K) of low education group = 0.05 ($Q = 6.584$, $p < 0.01$), which indicates that the educational years have a significant role in moderating the relationship between rural land titling and rural land transfer-out, and the more years of education, the stronger the positive relationship between rural land titling and rural land transfer-out is, and the more likely it is for the household to transfer-out rural land. The aforementioned results can be attributed to the fact that younger generations of farmers have a higher level of education, are more willing, and have easier access to employment outside of the agricultural sector, thus having a weaker emotional connection to the land. After land titling, new generations of farmers are more likely to exit their agricultural land compared to their elder counterparts.

(2) At the household level, the area of household contracted land ($Q = 3.671$, $p > 0.1$), indicating that the area of household contracted land is not significant; household labor force ($Q = 7.223$, $p < 0.1$) has a significant moderating effect, with more household labor force $K = 0.16$ and less household labor force $K = 0.372$, indicating that the less household labor force a household has, the stronger the positive relationship between rural land titling and rural land transfer-out is, and the more likely it is for the household to transfer-out rural land. The result is attributed to the fact that, in China where the level of agricultural mechanization is comparatively low, farming requires more labor input. Hence, for those households with a lower labor force, it is more advantageous to seek employment in the non-agricultural sector instead of possessing more rights in agricultural land. Consequently, after the land rights were secured, these households with a lower labor force were more inclined to transfer their agricultural land.

(3) In terms of article publication time, 66% of the effect sizes are derived after 2018—i.e., the vast majority of articles on rural land titling and rural land transfer-out were published after 2018, and the effect sizes of articles published before and after 2018 are 0.047 and 0.076 ($Q = 10.58$, $p < 0.1$),

TABLE 6 Subgroup test of the relationship between rural land titling and rural land transfer 2.

Outcome variable	Moderator variable		Class	Sample size	Effect size (*K*)	LL	UL	*Q*	*p*
Transfer	Householder	Age	Senior (≥53.14)	13	0.036	−0.031	0.103	7.577	0.056
			Young (<53.14)	8	0.066	−0.013	0.144		
		Level of education	High	14	0.09	0.005	0.174	4.481	0.214
			Low	8	−0.003	−0.069	0.063		
	Household	Household labor force	More (≥1.70)	11	0.138	0.061	0.213	10.485	<0.01
			Less (<1.70)	4	−0.045	−0.126	0.037		
		Present value of agricultural fixed assets (RMB)	High (≥14,718.54)	2	0.123	0.101	0.146	2.877	0.237
			Low (<14,718.54)	4	0.201	0.02	0.369		
		Area of household contracted land (mu)	Large (≥21.47)	3	0.11	−0.07	0.283	6.501	0.09
			Small (<21.47)	12	0.067	−0.064	0.196		
	Timing	From 2018	Far	13	0.03	−0.003	0.064	1.489	0.222
			Near	35	0.076	−0.004	0.154		

TABLE 7 Subgroup test of the effect of rural land titling on rural land transfer-out 3.

Outcome variable	Moderator variable		Class	Sample size	Effect size (*K*)	LL	UL	*Q*	*p*
Transfer-out	Householder	Age	Senior (≥53.14)	12	0.217	0.121	0.309	6.93	0.031
			Young (<53.14)	2	0.089	0.006	0.17		
		Level of education	High	11	0.251	0.098	0.392	6.584	0.037
			Low	5	0.05	0.016	0.085		
	Household	Household labor force	More (≥1.70)	8	0.16	0.078	0.239	7.223	0.027
			Less (<1.70)	4	0.372	0.056	0.62		
		Present value of agricultural fixed assets (RMB)	High (≥14,718.54)	0	—	—	—	0.415	0.519
			Low (<14,718.54)	4	0.187	0.017	0.347		
		Area of household contracted land (mu)	Large (≥21.47)	2	0.084	−0.099	0.261	3.671	0.16
			Small (<21.47)	9	0.225	0.103	0.341		
	Timing	From 2018	Far	10	0.047	0.021	0.074	13.305	<0.01
			Near	20	0.076	0.112	0.237		

respectively, indicating that article publication time has a significant role in moderating the relationship between rural land titling and rural land transfer-out, and compared with early studies, articles published after 2018 show that farmers are more willing to transfer-out rural land, which is in line with the moderating effect acquired previously. The emergence of this outcome is attributable to the lagged effect of institutional influence on behavior. As a result, the effect of rights formalization on land transfer-out is more pronounced in recent studies. Therefore, the impact of land titling on land transfer-out is more significant in recent studies.

The subgroup test results of the effect of rural land titling on rural land transfer-in are shown in Table 8. The results show that education level and area of household contracted land are marginally significant ($0.05 < P < 0.1$), while all other moderator variables are marginally insignificant. The results are consistent with those shown in Table 8, indicating that the relationship between rural land titling and rural land transfer-in is not affected

TABLE 8 Subgroup test of the effect of rural land titling on rural land transfer-in 4.

Outcome variable	Moderator variable		Class	Sample size	Effect size (*K*)	LL	UL	*Q*	*p*
Transfer-in	Householder	Age	Senior (≥53.14)	7	0.217	−0.683	0.292	1.548	0.461
			Young (<53.14)	2	−0.002	−0.104	0.101		
		Level of education	High	10	−0.128	−0.356	0.113	5.399	0.067
			Low	2	−0.041	−0.09	0.008		
	Household	Household labor force	More (≥1.70)	5	0.053	−0.037	0.142	4.193	0.123
			Less (<1.70)	4	−0.472	−0.78	0.021		
		Present value of agricultural fixed assets (RMB)	High (≥14,718.54)	0	—	—	—	2.683	0.101
			Low (<14,718.54)	3	0.062	−0.016	0.139		
		Area of household contracted land (mu)	Large (≥21.47)	2	0.193	−0.218	0.545	5.278	0.071
			Small (<21.47)	7	−0.299	−0.555	0.008		
	Timing	From 2018	Far	8	−0.043	−0.063	−0.023	0.136	0.712
			Near	17	−0.021	−0.138	0.097		

by other situational factors. The result is attributed to the fact that land conversion is, in itself, an entrepreneurial behavior requiring higher capability, which is facilitated by higher education after the land titling. Meanwhile, the incentive for further land expansion is more salient for those with larger landholdings than those with smaller ones, leading to more positive land conversion after titling. Thus, concerning the impact of land titling on rural land transfer, we only need to focus on rural land transfer-in rather than rural land transfer-out.

To visualize the impact of each potential moderator variable on the relationship between rural land titling and rural land transfer, the results of the subgroup test have been visualized (Figure 6). Some obvious moderator variables are selected for analysis in the moderating effect illustrations. Specifically, the slope in the grouping illustration of each moderating variable represents the combined effect size of that moderating variable. Figure 6, which uses data from studies on the effect of rural land titling on rural land transfer, shows that farmer age, household labor force, and other moderator variables have a significant modulating effect on the main effect. Slopes in the various groups differ greatly, and the slopes of the household labor groups are opposites. This may offset the effect of rural land titling on rural land transfer and may be the main reason for only a weak positive correlation between rural land titling and rural land transfer-in the main effect analysis.

Discussion

In China's traditional rural land property rights system, land transfer is not smooth, resulting in land abandonment and hindering the sustainable development of the rural economy. The Chinese government has completed the world's largest exercise in land titling to facilitate rural land transfers. However, the impact of China's land titling action, a costly project, on rural land transfer remains controversial in academia. To clarify the above debate, we have used the meta-analysis technology to explore the relationship between rural land titling and rural land transfer: (1) Rural land titling contributes to rural land transfer with a weak effect ($K = 0.082$, $P < 0.05$). (2) Rural land titling only contributes to rural land transfer-out with no effect on rural land transfer-in. Therefore, the so-called effect of land titling on rural land transfer is limited to rural land transfer-out. (3) The higher the educational level of farmers, the more senior the age of farmers, the more labor force in a household, the more agricultural fixed assets in a household, and the larger the area of contracted rural land, the stronger the effect that land titling has on rural land transfer-out. (4) Compared with early studies, land titling has a stronger effect on rural land transfer-out, according to recent studies.

Although the results of this study seem to support the idea that land titling promotes rural land transfer, the literature defines both transfer-in and transfer-out as transfer-in general terms. However, the empirical results indicate that rural land titling only contributes to rural land transfer-out, with no significant effect on rural land transfer-in. Thus, our conclusion will help clarify future studies on land titling and rural land transfer can focus on rural land transfer-out. This study also shows that the effect of land titling on rural land transfer is affected by situational factors such as education, age, labor force, agricultural fixed assets, and area of contracted rural land. We identify the sources of heterogeneity in the conclusions of existing literature and explore the hidden mechanisms that affect the relationship between rural land titling and rural land transfer.

The conclusion of this study helps us understand the reasons for the contradictory conclusions in the existing literature. On this basis, this study's conclusion helps us identify the possibility of improving rural land transfer by changing heterogeneity factors.

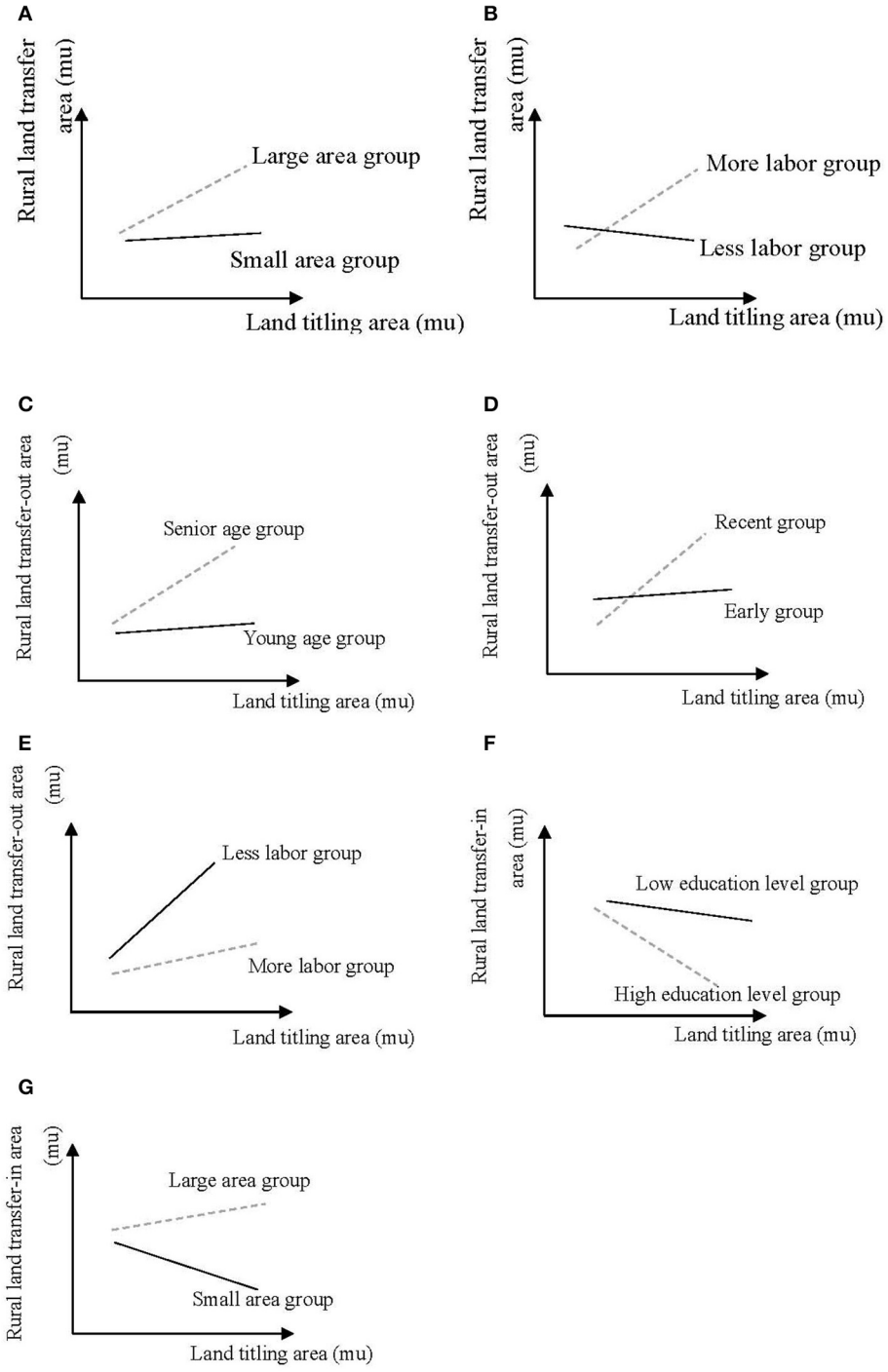


FIGURE 6
The moderating effect of rural land ownership confirmation on rural land transfer. **(A)** Area of contracted land (mu). **(B)** Household labor force. **(C)** Age. **(D)** Time of study. **(E)** Household labor force. **(F)** Level of education. **(G)** Area of contracted land (mu).

Therefore, from the perspective of policymakers, different strategies can be implemented for different groups to improve the land transfer rate and thus promote the sustainable development of the rural economy. The conclusion of this study also helps us identify topics for future studies to empirically test the effect of these situational variables by collecting data. This study also helps us treat rural land transfer dynamically—the role of land titling becomes more apparent over time, reflecting the long-term accumulation required for the definition of land titling and its implications.

Attention should be paid to the fact that both Chinese policy orientation and existing literature follow Coase's assumption, which states that the welfare growth could be achieved through the transfer of land rights among farmers. However, the literature has shown that property rights are much more complex than

the framework proposed by Coase, thus Ostrom's Bundle of Rights provides a more comprehensive framework to tackle the complexity of land rights (Ostrom, 1990; Schlager and Ostrom, 1992). Chinese rural communities are a collective, thus a diverse range of policies and a multi-level bundle of rights should be developed to satisfy the different needs of community in managing resources and land. The greatest significance of this bundle of rights lies in the fact that it takes into account aspects such as social, cultural, and environmental aspects and combines traditional laws and policies with the realities of local communities to construct a more inclusive and diversified bundle of land rights. This bundle may be beneficial to policy makers, local community members and resource managers, providing a more effective resource management system for local communities and thus helping to resolve the complexities of land rights. Therefore, when it comes to the process of land transfer in Chinese rural areas, policies that are in line with the interests of the local community should be formulated to improve the land transfer rate, taking into consideration traditional culture and social requirements, and a multi-level bundle of rights should be perfected to realize social equity and environmental sustainability.

Although this study further proves that rural land titling has a weak effect on rural land transfer, it has the following limitations. First, there is a trade-off in the selection of moderator variables. Many situational variables are discarded to obtain a greater sample size and achieve data-based manipulability. Second, most of the literature included in the meta-analysis is journal literature, with less unpublished and degree literature at home and abroad, so the unbalanced distribution of literature may affect the results of the main effect analysis.

Conclusions

This paper explored the relationship between rural land titling and rural land transactions using meta-analysis technology and identified and discussed the potential situational variables affecting the relationship. The results show that (1) rural land titling has a weak promoting effect on rural land transactions; (2) rural land titling only facilitates rural land transfer-out, with no effect on rural land transfer-in; (3) educational level, age, labor force, agricultural fixed assets owned, and area of contracted rural land are all situational variables that affect the relationship between land titling and rural land transfer; and (4) the relationship between rural land titling and rural land transfer is dynamic, and the longer that land titling takes, the more obvious the relationship between them becomes. Overall, this study contributes not only to our clarification of the true relationship between rural land titling and rural land transactions but also to our identification of topics for future studies. For example, this study has identified the moderating variables that influence the relationship between land titling and land transfer, guiding us to focus on the research of these moderating variables in the future. In addition, the conclusions of this study will help policymakers develop and implement appropriate policies to promote sustainable rural economic development by increasing land transfer rates.

This research suggests that simplifying agricultural land property rights may not support a sustainable rural agricultural production system. Instead, policies should align with local communities' interests, consider traditional cultures and social needs, and refine multi-level rights combinations. Further research on rural land rights combinations in China is still necessary.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

Conceptualization, validation, writing—review and editing, and funding acquisition: LX and LL. Methodology: LX, JZ, and DK. Software: DK, WH, and JZ. Formal analysis: JZ. Writing—original draft preparation: LX and DK. Supervision and project administration: LL. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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农业社会化服务组织何以促进化肥减量

——基于经营主体的匹配效应研究

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摘　要　现有政策希望通过促进社会化服务组织的发育和发展来推进化肥减量施用,但是其效果仍然受到质疑。基于2015年中国家庭金融调查数据的实证研究发现,社会化服务组织的发展并不必然带来化肥减量效应,而主要决定于其匹配的服务对象:当服务的经营主体为农业企业、家庭农场、合作社、大户等新型农业经营主体时,匹配效应才能达到更优,社会化服务组织的发展能有效地起到化肥减量的效果。研究也表明,在达成化肥减量目标上,发展农业社会化服务组织和培育新型农业经营主体存在协同作用。因而,中国农业的减量化有必要关注新型农业经营主体和服务主体的"匹配性发展"。

关键词　农业社会化服务组织;化肥减量;经营主体;匹配效应

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2018年,中国氮、磷、钾肥的使用量分别占全球总量的26.1%、19.4%和27.8%①。虽然化肥的使用对于保持中国高粮食产量和确保粮食安全至关重要,但有研究认为中国的施肥水平已经远高于环境安全上限[1],化肥减量化成为中国农业绿色发展的必然要求。对于化肥减量施用的途径,现有研究认为,农业社会化服务能够为经营主体提供科学的生产方法和管理方式,因而有助于化肥减量施用[2]。决策层面也逐渐注意到社会化服务组织对于化肥减量化的意义。2017年,原农业部和财政部联合下发的《关于支持农业生产社会化服务工作的通知》指出,要培育"农业生产社会化服务市场",以"促进农业绿色发展和资源可持续利用"。2018年,农业部下发的《关于大力实施乡村振兴战略 加快推进农业转型升级的意见》也指出要支持社会化服务组织开展化肥统配统施服务,以持续推进农业投入品减量。然而,有研究表明,因其商业性,农业社会化服务存在过量施用以赚取更高利润的激励动机,因此农业社会化服务反而加重了投入品的过量施用问题[3]。可以看出,对于农业社会化服务的减量效应,现有研究并未达成一致的结论。这意味着,通过扶持农业社会化服务来达到化肥减量化政策可能难以实现其预定目标。那么,厘清造成现有研究结论存在差异的异质性原因,就具有重要的现实意义。

需要关注的是,农业社会化服务需要匹配特定的对象:小农户可能根本不需要社会化服务[4],且受盈利能力约束的影响,社会化服务主体可能也不愿意服务小农户。即便服务小农户,受每笔交易的固定成本约束,社会化服务组织可能会增加化肥施用量,通过增加化肥材料费来补贴固定支出并实现盈利,但小农户也因其能力不足而处于谈判劣势地位。相反,新型农业经营主体经营规模更大,拥有更好的社会网络资源以及更高的人力资本水平,与农业社会化服务的合作更具经济性与可能

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性。也就是说,只有当农业社会化服务匹配新型经营主体时,才能达到更优的匹配效应,并体现出社会化服务在农业生产上的减量效果。

中国正处于农业经营方式大变革的时期,新型农业经营主体的发展为社会化服务的推广提供了新的发展机遇。据统计,到2020年底,全国农地流转面积5.322亿亩,其中有2.414亿亩农地转入农业企业、合作社和家庭农场等规模经营主体;全国农业农村部门名录管理家庭农场达到348.1万个,比2019年增加了262.8万个[5],这为考察不同农业经营主体与社会化服务的匹配效应提供了可能。本研究在梳理相关文献的基础上,基于微观农户调查数据检验以下几个问题:(1)农业社会化服务组织的发育是否有助于经营主体的化肥减量施用;(2)与普通农户相比,新型农业经营主体的化肥施用强度是否更低;(3)农业社会化服务组织匹配新型农业经营主体是否有助于化肥减量施用。在此基础上,本研究将根据农业绿色发展的目标选择,提出激励和促进化肥减量的对策建议。

一、理论基础

1.农业社会化服务组织的化肥减量效应

由于农业科技的发展和生产市场化程度的不断提高,农业生产环节的可分性不断提升,传统上由经营主体直接承担的生产环节越来越多地由各种专业化服务主体提供[6]。将农业生产过程的部分或者全部环节承包给农业社会化服务组织,能够有效化解农业规模化经营与经营主体资源禀赋失衡问题,为“谁来种地”与“如何种好地”问题的解决提供了破解思路与现实路径[7]。究其原因,主要在于社会化服务组织可以为农业经营主体提供科学的生产方法和管理方式——服务组织配有大量的种子包衣机、测土配方施肥仪、深松机、无人植保飞机、大型秸秆粉碎收割机等绿色生产机械,能够为经营主体提供科学、绿色生产服务,带动经营主体从事绿色生产[8]。实践中,社会化服务组织实际成为农户在施肥等农业生产环节中重要的技术指导者,为农户所提供施肥科学知识和技术,起到技术推广的作用[9]。

在实证研究方面,基于河北和山东农户调查数据的实证研究发现,获得相关农业技术服务的农户的化肥施用量更低[10]。云南洱海流域水稻种植户的问卷调查数据表明,农业社会化服务不仅能够促进农户对有机肥的认识,还能提高他们在生产中采用有机肥的意向,从而减少对化肥的使用量[11]。此外,也有研究基于农户调查数据的实证检验指出,社会化服务有助于化肥农药减量化[12]。也正是因为这个原因,研究者认为有必要利用政策工具,通过发展农业社会化服务来降低化肥施用水平[2]。

然而,也有学者注意到,在商业化潮流下,农资销售商会通过各种策略来促进农资的销售[13]。随着服务组织的商业化,社会化服务不但无助于投入品的减量化,反而导致对投入品的滥用[14]。究其原因在于:一方面,尽管农资销售商的销售策略已经转向“服务式销售”,但由于众多服务商缺乏农业技术支持尤其是种植经验积累,销售服务因缺乏精准对接而难以促进减量化;另一方面,农资服务的盈利性动机有可能诱发机会主义行为[15]。对于那些功能集中于投入品供应以及销售信息的服务组织来说,出于销售动机,它们甚至会过分强调投入品的作用,反而可能造成农户的超量购买与使用[3]。

可见,现有研究并没有就农业社会化服务的减量效应达成一致意见。究其原因,可能在于其取样大都只限于某一地,或某一经营主体,减弱了研究结论的普适性。事实上,各类情境因素会影响现象表现程度及其关系程度的大小、表现形式以及现象间关系的形式或大小[16]。因此,不同甚至矛盾的研究结论可能源于农业社会化服务匹配了不同的情境因素,这是本研究将要重点探讨的问题。

2.新型经营主体的化肥减量效应

中国农业以小农经营为主。小农是一种行为主体,这类行为主体所决定的生产方式即为小农经济,由小农经济所决定的农业形态被视为传统农业[17]。Schultz将完全以农民世代使用各种生产要素为基础的农业称之为传统农业[18]。正因为此,小农经营经常被视为一种落后的经营方式。具体来说,小农因其劳动力素质、生产能力以及农业经营规模都远在现代生产力水平所要求的底线之下,以其为基础的科技应用、产品质量、市场准入、维生收入、从农热情等都将日益变得难以为继,难以满足现

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代农业的要求。在很大程度上可以说,小农经营是中国近几十年来现代农业建设成效不显著的主要约束[19]。在鼓励绿色发展的背景下,化肥减量施用成为重要的政策选择。在保证农产品数量和质量的基础上,化肥减量施用要求科学的生产方法和管理方式。然而,正如舒尔茨所提出的,传统小农户不会自主地引进先进的技术[18]。后来的研究也认为,发展中国家的农民普遍欠缺农药施用知识,如对杂草和病虫害的种类不能合理区分,因此较难对症下药[14,20]。中国的实证研究也表明,小农户普遍存在的文化水平不高问题,是导致化肥过量施用的重要原因[21]。

和小农经营不同,新型农业经营主体一般通过土地流转进行规模经营。大型家庭农场等新型农业经营主体存在样本选择问题,即那些拥有更高社会责任和现代思维的农户更可能成为新型农业主体,并进一步使得他们减少对环境有害的化肥的投资。因而与小农户不同,新型农业经营主体因其经营规模性更容易应用测土施肥技术,因此其化肥施用水平也可能更低[22]。如针对农业企业的研究表明,农业企业往往会更科学地施用化学投入品来弥补劳动力的不足[23]。而且,农业企业经营的土地一般集中连片,这有助于农业机械的使用,在化肥施用时更可能做到机械化、精细化,从而减少施用量[24]。不过,农业企业也存在样本选择问题。黄祖辉等基于2009年对浙江省新型农业经营主体的调查数据发现,农业企业经营者相较于其他主体经营者而言更加年轻、受教育程度更高、培训经历更加丰富,其拥有更多的农业知识和管理技能,能够更加科学地制定农业投入品使用量,进而实现化肥的减量施用[25]。从农地规模角度来说,现有研究也表明,农地规模经营会降低化肥的施用强度[22,26-27]。

然而,也有研究认为新型农业经营主体的发育并不会带来化肥减量化。杨钢桥等认为,大型农场的经营目标已经从生存需求转向追逐利润,因此会导致它们增加化肥的施用强度[28]。来自诸如泰国、埃塞俄比亚、肯尼亚等发展中国家的研究同样表明,大规模经营主体可能施用更多的化肥[29]。这意味着,现有文献实质上对于新型经营主体的减量效应仍然存在争议。

3.**社会化服务与经营主体的匹配效应**

匹配理论是为了解决资源配置中的不可分问题而提出来的[30],被广泛应用于市场设计实践,并发展出了一系列关于市场匹配机制设计思路,通过科学方法帮助个人和集体在面对选择时能够选择最优策略[31]。其中,双边匹配问题起源于婚姻市场,目的在于在双方均有偏好序的前提下,如何满足双方的偏好[32]。从提升资源的配置效率来看,双边匹配理论同样适用于农业社会化服务供需匹配问题:首先,作为农业社会化服务市场的需求方,不同经营主体有不同的偏好,会针对不同的选择进行评估;其次,农业社会化服务组织会根据成本收益评估,选择合适的合作对象。在自由市场上,当社会化服务组织与合适的农业经营主体达成合作时,双方的匹配达到最优。

在农业社会化服务市场中,新型经营主体偏好选择依赖社会化服务来弥补自身在劳动力、机械等方面的短板,而普通的小农户经营规模较小,对农业社会化服务的需求并不大[13]。实践中,社会网络是经营主体交流和获取生产经营信息的主要渠道[33]。和小农户比起来,新型农业经营主体经营规模更大,拥有更好的社会网络资源,以及更高的人力资本水平,不仅更容易获得农业社会化组织的服务,也更容易理解由这些组织带来的减量技术,并降低因信息不对称带来的逆向选择和道德风险问题。

作为社会化服务组织来说,他们往往偏好规模大、拥有更多资金支持的新型经营主体,而不愿意服务普通农户:小农户普遍存在土地细碎化的问题[34],其资源禀赋决定了可能根本不需要社会化服务[4,35]。研究表明,农地细碎化程度对农业生产环节外包有抑制作用[36]。站在服务组织的角度,服务小农户的收益很低,却要投入大额的固定成本,因而也不愿意服务小农户。而且,社会化服务存在着由信息不对称引起的逆向选择与道德风险问题,例如,事后农户对土肥服务完成的质量难以监督,农业社会化服务组织可能会在服务过程中出现机会主义行为[37]。例如,在承受高额固定成本的基础上,社会化服务组织可能通过向农户出售更多的化肥来施用以获取更高的利润。

所以,当农业社会化服务匹配新型经营主体时,能够实现农业社会化服务的参与双方的意愿达

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成一致,实现更优的匹配效应,故更容易体现其化肥减量化效应。本研究的研究框架如图1所示,即主要探讨农业社会化服务组织与不同农业经营主体的匹配对化肥减量施用的影响。

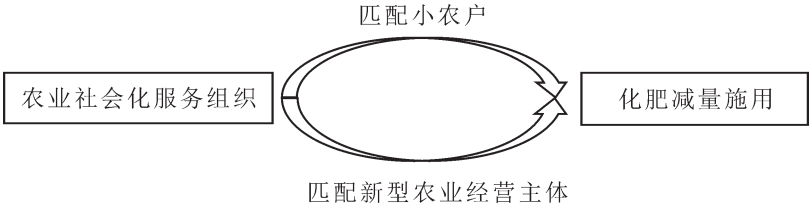


图1 理论分析框架

二、研究设计

1.数据来源

本研究使用最近一轮的中国家庭金融调查数据(China household finance survey,CHFS)①。该调查于2015年开展,数据以人口规模比例为权重,分别采用分层、三阶段、规模度量成比例(PPS)等方法进行追踪调查,样本选取29个省(自治区、直辖市),旨在通过科学抽样、现代调查技术和调查管理手段,收集中国大陆地区家庭微观信息,以便为国内外研究者研究中国家庭问题提供高质量的微观数据。该调查有专门针对农村家庭的问项,询问了被调查者属于何种农业经营主体,并较为详细地询问了农户的基本信息、农业经营情况,为本研究提供了一个具有广泛代表性、质量较好的全国性调查数据。该数据中家庭样本37289个,其中农村家庭样本11654个。在剔除缺失值和异常值②后,最终获得有效样本5735个。

2.主要变量

(1)因变量。本研究讨论社会化服务组织的发育对于化肥施用的影响。CHFS数据中没有化肥施用量的指标,但调查了农户的化肥支出。本研究借鉴纪月清等的研究,运用"亩均化肥投入支出"来刻画化肥施用强度[38]。具体来说,使用采购化肥的总费用除以耕地面积得到"亩均化肥投入支出",并对"亩均化肥投入支出"进行了对数处理。

(2)自变量。实践中,种植技术培训与指导方面的社会化服务主要由专业合作社为经营主体提供,其中,土肥服务专业合作社的发展能够带领更多经营主体采纳测土配方施肥技术[39],发挥组织优势,进而带动规模户减量施用化肥[40]。原农业部经管司编的《农村经营管理统计数据》报告了自2009年以来每个省级行政区土肥服务合作社的数量,本研究以2014年③一省土肥服务合作社的数量除以该省农作物播种面积④,得到各省区的土肥服务覆盖率作为自变量。

(3)调节变量。本研究将是否为新型农业经营主体作为调节变量,通过研究其与土肥服务覆盖率的交互效应来检验社会化服务与经营主体的匹配效应。2016年中央"一号文件"中明确指出,新型农业经营主体包括家庭农场、专业大户、农民合作社、农业产业化龙头企业等。CHFS问卷询问了被调查者属于何种农业经营主体,包括"普通农户""农业企业""家庭农场""农业合作社"和"专业大户",本研究按2016年中央"一号文件"的口径,将"农业企业""家庭农场""农业合作社"和"专业大户"定义为新型农业经营主体。

(4)控制变量。农户特征会影响农户的各种决策,进而影响农户在农业生产中的化学品投入。首先,农户的人力资本水平,如家庭人口数、学历教育水平等对农户减量施用化学投入品具有正向影响[27],因此本研究控制了家庭劳动力人数和家庭劳动力受教育程度。其次,农业收入比例高的农户家

① 虽然该调查2017年的数据已经开放申请使用,但由于缺少关键变量,本研究仍然使用2015年数据进行实证检验。

② 具体为:删去在"您家属于下列哪种农业生产经营户"题项中选择"6.其他"以及选择两个及以上选项的样本数据;删去变量"受教育水平"小于0的样本数据。

③ 2015年CHFS数据调查的是2014年的情况。

④ 农作物播种面积来源于《中国农村统计年鉴》。

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庭化学品过量施用的可能性更高[26,41],因此本研究控制了家庭非农就业比例。最后,农户的农业资源禀赋情况也会对化肥施用产生影响,其中包括种植结构与土地权利[42]、农业补贴[43]等,因此本研究控制了劳均经济作物面积、耕地是否确权和是否获得农业补贴。此外,本研究还控制了地区虚拟变量。相关变量指标说明如表1所示。

表1　变量指标说明

变量名称	问卷指标	变量设计
化肥施用强度	去年,您家采购化肥花费了多少钱?您家的耕地面积是?	ln(化肥投入/耕地面积+1)
土肥服务覆盖率	数据来源于《中国农村统计年鉴》和《农村经营管理统计数据》	土肥服务合作社数量/播种面积
新型经营主体	您家属于下列哪种农业生产经营户?(1.农业企业;2.农业合作社;3.家庭农场;4.专业大户;5.普通农户;6.其他)	若选择5,则赋值为0;否则为1
劳动力人数	您家的家庭成员有几个?您及您家人的出生年份是?	16岁以上60岁以下人数
受教育水平	您及您家人的文化程度是?(1.没上过学;2.小学;3.初中;4.高中;5.中专/职高;6.大专/高职;7.大学本科;8.硕士研究生;9.博士研究生)	高中以上人数/家庭劳动力人数
非农就业比例	去年,您的家庭成员有几个人从事农业生产经营?	(家庭劳动力人数−务农人数)/家庭劳动力人数
劳均经济作物面积	去年,您家大豆、花生、油菜的播种面积是?	ln(经济作物播种面积/务农人数+1)
是否确权	您家的耕地是否取得土地经营权证书?(1.是;2.否)	若选1则赋值为1;否则为0
农业补贴	去年,您家从事农业生产经营是否获得了补贴?(1.是;2.否)	若选1则赋值为1;否则为0
省份	被调查农户所在地	虚拟变量

3.**模型选择**

本研究主要探讨社会化服务组织发育,以及其与农业经营主体的匹配效应对化肥减量施用的影响。本研究采用调节效应模型来检验匹配效应。所谓调节效应,是指如果自变量X与因变量Y的关系受到第三个变量M的作用,那么M在X与Y之间有调节效应[44]。那么,本研究讨论的匹配效应,实质就是讨论社会化服务组织的发育对化肥施用的作用,是否受其服务的经营主体的影响。因此,本研究的回归基准模型设计如下:

$$Fertilizer_i = \alpha_i + \beta Service_i + \varphi Operator + \gamma X_i' + \varepsilon_i \quad (1)$$

$$Fertilizer_i = \alpha_i + \beta Service_i + \varphi Operator_i + \eta Service_i \times Operator_i + \gamma X_i' + \varepsilon_i \quad (2)$$

其中,"$Fertilizer_i$"为化肥施用强度,"$Service_i$"为土肥服务覆盖率,"$Operator_i$"为是否为新型农业经营主体,"X_i'"为控制变量向量,包括家庭劳动力人数、劳动力受教育水平、非农就业比例、劳均经济作物面积、耕地是否确权、是否获得农业补贴、省份虚拟变量等。上面式(1)为主效应模型,用于分析土肥服务覆盖率对于化肥施用水平的作用,以揭示社会化服务组织的发育的减量效应;式(2)为调节效应模型,用于分析社会化服务组织与新型经营主体的匹配效应。

上面的基准检验模型可以反映社会化服务组织与新型经营主体的客观匹配效应。然而,在研究农户的经营方式时,涉及农户自身的资源禀赋,从农业经营的角度,是否是经营新型主体本身就存在自选择问题——这些经营者一般拥有较好的农业知识和技能[36],可认为是农户以经营效益最大化为目标进行的内生决策,因此这一行为在很大程度上是自选择的结果,可能会出现内生性问题,导致OLS估计结果有偏且无效。为了克服自选择问题,本研究采用Heckman给出的处理效应模型进行结构建模[45],利用Heckman两步法进行估计对OLS估计结果进行修正。两步法最有效率的做法是使用最大似然估计法(MLE),同时估计所有模型参数。需要注意的是,处理效应模型要求选择方程中包含满足排他性条件的识别变量。考虑到农村中村干部家庭相比非村干部家庭拥有更多的经济资源[46],有助于农户成为新型经营主体[25],因而本研究以家庭中是否有村干部作为选择方程的识别变量①。第一阶段的Probit回归模型如式(3)所示:

① 问卷中的题项为:您家是否有家庭成员担任村干部一职?包括村支书、村主任、妇女主任等。(1.是;2.否)。本研究中,"家庭是否有村干部"的赋值方法为:若选择1,则赋值为1;若选择2,则赋值为0。

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$$Pr(Operator=1|X_n)=\Phi(\beta_0+\beta_1 Cadre) \quad (3)$$

其中,"$Pr(Operator=1|X_n)$"为成为新型经营主体的概率,"*Cadre*"为家庭中是否有村干部。根据式(3)得到估计值$\hat{\beta}$,然后再根据式(4)计算逆米尔斯比率:

$$\lambda=\frac{\Phi(X',\hat{\beta})}{\varphi(X',\hat{\beta})} \quad (4)$$

其中,"$\Phi(X',\hat{\beta})$"和"$\varphi(X',\hat{\beta})$"分别为$(X',\hat{\beta})$的标准正态分布密度函数和累计密度函数,"X'"为第一阶段模型中的解释变量集合。Heckman两阶段分析与普通最小二乘法的不同之处在于加入了逆米尔斯比率λ,以克服样本的选择性偏差。若λ显著不为0,则表明存在明显的自选择问题,也说明采用Heckman模型是合适的。

在式(3)的基础上,本研究构建式(5)和式(6)作为结果回归方程:

$$Fertilizer=\alpha+\beta Service+\varphi Operator+\gamma \boldsymbol{X}'+\omega\lambda+\varepsilon \quad (5)$$

$$Fertilizer=\alpha+\beta Service+\varphi Operator+\eta Service\times Operator+\gamma \boldsymbol{X}'+\omega\lambda+\varepsilon \quad (6)$$

其中,"*Fertilizer*"为化肥施用强度,"*Service*"为土肥服务覆盖率,"*Operator*"为是否为新型经营主体,"$\boldsymbol{X}'$"为控制变量向量,包括家庭劳动力人数、家庭劳动力受教育水平、家庭非农就业比例、劳均经济作物播种面积、耕地是否确权、是否获得农业补贴、省份虚拟变量等;"λ"为根据式(4)计算出的逆米尔斯比率。

三、实证结果

1.描述性统计

表2为各变量的描述性统计结果,可以看出,"化肥施用强度"的均值为567.011,说明样本农户家庭平均每亩耕地的化肥支出为567.011元。"土肥服务覆盖率"的均值为0.027,说明土肥服务合作社的数量仍然太少。"新型经营主体"的均值分别为0.018,说明样本农户中新型农业经营体仅占1.8%,意味着农业企业、家庭农场、农业合作社和专业大户等新型农业经营主体占总样本的比例仍然不大。

表2 各变量统计性描述分析结果 N=5375

变量	均值	标准差	最小值	最大值
化肥施用强度	567.011	3280.511	0.1	171429.4
土肥服务覆盖率	0.027	0.028	0	0.097
新型经营主体	0.018	0.132	0	1
劳动力人数	3.153	1.204	1	11
劳动力受教育水平	0.207	0.266	0	1
非农就业比例	0.339	0.261	0	0.889
劳均经济作物面积	0.316	2.131	0	65
是否确权	0.449	0.497	0	1
农业补贴	0.750	0.433	0	1

注:为方便地分析描述性统计结果,上表中的"化肥施用强度"和"劳均经济作物面积"等变量未取对数。

2.基准回归模型

表3为基准回归结果。模型1为各控制变量与因变量之间的关系,结果显示,"劳动力人数""非农就业比例"和"劳均经济作物面积"与"化肥施用强度"之间具有显著相关关系。

模型2在模型1的基础上增加自变量"土肥服务覆盖率",结果显示,"土肥服务覆盖率"的回归系数为-20.892,不具备统计显著性,说明一个地区的土肥服务覆盖率并不能显著地降低经营主体的化肥施用强度。这个结果虽然并不支持社会化服务导致化肥滥用的观点,但也未支持社会化服务有助于实现化肥减量施用的观点。换言之,仅仅提高农业社会化服务水平并不会促进化肥减量化。

模型3在模型2的基础上增加"新型经营主体"虚拟变量。结果显示,"新型经营主体"的回归系数为0.387,在5%水平上显著,说明和普通农户相比,新型农业经营主体的化肥施用强度不仅不低于普通农户,甚至更高。这个结果容易被理解为新型经营主体为追逐利润最大化,加大了化肥的施用强度或使用价格更高的化肥品种——当然,这个结果并未解决新型农业经营主体的自选择问题。

模型4在模型3的基础上增加自变量与调节变量的交互项"土肥服务覆盖率×新型经营主体",

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结果显示,交互项的回归系数为−8.817,在0.05水平上显著,说明和匹配普通农户比起来,土肥服务组织若匹配新型农业经营主体,更有可能降低经营主体的化肥施用强度。

表3　基准回归结果　　N=5375

变量	化肥施用强度							
	模型1		模型2		模型3		模型4	
	系数	标准误	系数	标准误	系数	标准误	系数	标准误
劳动力人数	0.053***	(0.015)	0.053***	(0.015)	0.051***	(0.015)	0.051***	(0.015)
受教育水平	−0.016	(0.057)	−0.016	(0.057)	−0.023	(0.057)	−0.022	(0.057)
非农就业比例	−0.272***	(0.070)	−0.272***	(0.070)	−0.266***	(0.070)	−0.267***	(0.070)
劳均经济作物面积	−0.090**	(0.038)	−0.090**	(0.038)	−0.092**	(0.038)	−0.092**	(0.039)
是否确权	−0.034	(0.031)	−0.034	(0.031)	−0.034	(0.031)	−0.036	(0.031)
农业补贴	−0.049	(0.037)	−0.049	(0.037)	−0.043	(0.037)	−0.044	(0.037)
土肥服务覆盖率			−20.892	(64.153)	−26.285	(64.119)	−27.980	(64.077)
新型经营主体					0.387**	(0.158)	0.617***	(0.203)
土肥服务覆盖率×新型经营主体							−8.817**	(3.901)
省份	控制		控制		控制		控制	
常数项	5.248***	(0.240)	5.248***	(0.240)	5.253***	(0.241)	5.253***	(0.241)
R^2	0.108		0.108		0.110		0.111	
Adjusted R^2	0.103		0.103		0.105		0.105	
F	18.501		18.501		18.017		17.623	
p	0.000		0.000		0.000		0.000	

注:*、**和***分别表示在10%、5%、1%的统计水平上显著,括号中数字为标准误,后表同。

这个结果表明,相较于普通农户,新型经营主体匹配农业社会化服务能够实现更优的化肥减量化效果:一方面,对于新型经营主体来说,农地规模更大,为了降低在化学品投入方面的支出,他们更可能选择通过社会化服务组织制定科学的生产方式来实现降低成本的需求,且新型经营主体拥有更高的知识水平和信息获取能力,能够更好地接受社会化服务组织在生产方面的建议,也能够更好地防范社会化服务组织的道德风险;另一方面,从社会化服务组织的角度来看,当服务组织服务小农户时,需要花费更多成本与多个服务对象达成交易,还要考虑不同小农户的需求调整服务,导致交易成本过高,所以服务组织也更愿意服务新型经营主体。进而,在土肥服务市场上,新型经营主体与服务组织更容易达成一致,实现最优匹配和化肥减量化。这意味着,农业社会化服务组织的发展与新型经营主体队伍的壮大在实现化肥减量化方面具有协同效应。

3.解决自选择问题:Heckman两步法

表4为Heckman处理效应第一阶段和第二阶段的回归结果。从第一阶段的回归结果可以看出,家庭中是否有村干部与新型经营主体存在显著正向相关关系,说明村干部身份能够提高农户成为新型经营主体的可能性。

在模型3的基础上加入逆米尔斯比率"λ"后,模型5的结果表明,"新型经营主体"的回归系数为−0.576,不具备统计显著性。这个结果与模型3并不一致,说明在控制经营主体的自选择问题后,虽然新型农业经营主体的化肥施用强度并不比普通农户更高,但也没有显著更低。同时,在控制自选择问题后,模型6的结果仍然与模型4具有一致性,均说明和匹配普通农户比起来,土肥服务组织若匹配新型农业经营主体,能够实现更优的匹配效应,更有可能降低经营主体的化肥施用强度。

为了直观地观察各变量之间的关系,本研究根据Heckman模型结果给出了调节效应图示。如图2所示,对于普通农户来说,土肥服务组织的发展并不能降低其化肥施用强度。不过,如果是新型经营主体,土肥服务组织的发展有助于降低其化肥施用强度。这说明,农业社会化服务组织的化肥减量效应是存在经营主体的匹配效应的,即只有在社会化服务组织服务新型经营主体时,其发育才有助于化肥减量化。

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表4 Heckman处理效应模型 N=5334

变量	化肥施用强度			
	模型5		模型6	
	系数	标准误	系数	标准误
第二阶段结果				
劳动力人数	0.051***	(0.015)	0.051***	(0.015)
劳动力受教育水平	−0.013	(0.057)	−0.011	(0.057)
非农就业比例	−0.263***	(0.070)	−0.265***	(0.070)
劳均经济作物面积	−0.089**	(0.039)	−0.089**	(0.039)
是否确权	−0.034	(0.031)	−0.035	(0.031)
农业补贴	−0.037	(0.037)	−0.038	(0.037)
土肥服务覆盖率	−26.636	(63.808)	−28.115	(63.766)
新型经营主体	−0.576	(0.790)	−0.363	(0.800)
土肥服务覆盖率×新型经营主体			−8.388**	(4.153)
λ	0.929	(0.738)	0.928	(0.738)
省份	控制		控制	
常数项	5.290***	(0.241)	5.290***	(0.241)
第一阶段结果				
家庭中是否有村干部	0.505***		(0.095)	
常数项	−2.113***		(0.034)	
R^2	0.110		0.111	
Adjusted R^2	0.104		0.105	
F	17.375		16.993	
p	0.000		0.000	

四、结论与启示

本研究建立了一个理论框架,用以解释农业社会化服务组织的发育,及其与不同农业经营主体的匹配是如何影响化肥施用水平的。基于2015年中国家庭金融调查数据的实证研究发现,从总体来说,社会化服务组织的发展并不能带来化肥减量效应,但是,如果其匹配的服务对象不同,则其对化肥施用的作用也不同:首先,如果服务的经营主体为普通农户,那么社会化服务组织的发育不能起到化肥减量的效果;其次,如果服务的经营主体为农业企业、家庭农场、合作社和专业大户等新型农业经营主体,可以达到更优的匹配效应,社会化服务的发育有助于起到化肥减量的效果。从农业经营主体的角度来看,虽然和普通农户比起来,新型农业经营主体的化肥施用强度并没有显著更低,但如果更容易获得农业社会化服务,则在化肥减量方面更具可能性。本研究结果意味着,在达成化肥减量方面,发展农业社会化服务组织和培育新型农业经营主体存在协同作用。

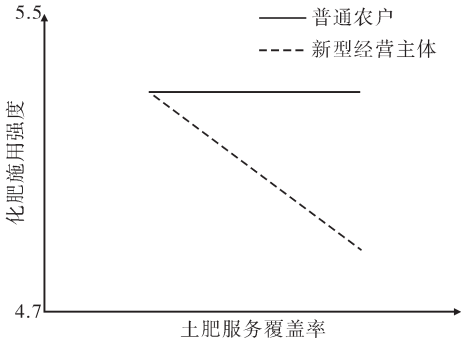


图2 新型经营主体的调节效应

本研究的启示在于:第一,虽然农业社会化服务组织在实现化肥减量施用方面存在专业优势,但是,这种优势的发挥受其他情境因素的影响,因此决策层应该注意政策的适用环境,设法引导其进行减量的努力;第二,新型经营主体虽然更可能因为应用现代农业技术而有助于其化肥减量施用行为,然而实际上,和小型的普通农户比起来,新型经营主体的经营目标可能发生改变,因而削弱了其在化肥减量方面的努力;第三,社会化服务组织与新型经营主体在化肥减量方面存在协同作用,因而决策者有必要将两者整合在同一个政策框架里来考虑,培育包含各类新型农业经营主体和社会化服务组织在内的"绿色发展"产业联合体。从现有的政策来看,中央高度重视新型农业经营主体和服务主体

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发展。农业农村部于2020年3月印发了《新型农业经营主体和服务主体高质量发展规划(2020—2022年)》,提出“支持各类服务主体与新型农业经营主体开展多种形式的合作与联合”,以促进新型农业经营主体和服务主体融合发展。本研究则表明,在“融合发展”之外,还需要关注新型农业经营主体和服务主体的“匹配性发展”。

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How Does the Development of Agricultural Social Service Organizations Promote Fertilizer Reduction

——Based on the Matching Effect with Agricultural Management Entities

XIE Lin,ZHANG Yuxin,ZHONG Wenjing

Abstract The current policy tries to promote fertilizer reduction by supporting the development of social service organizations,but its effect is still being questioned. The empirical studies based on the 2015 China Household Finance Survey data (CHFS) show that the development of social service organizations does not necessarily contribute to fertilizer reduction. Whether they work or not is determined by their matching service targets. If the business entities they offer services to are new agricultural business entities such as agricultural enterprises, family farms, agricultural cooperatives and specialized households,the matching effect can be optimal and the development of social service organizations can effectively lead to fertilizer reduction. The result of the study shows that there is a synergistic effect between the development of agricultural social service organizations and the cultivation of new agrarian business entities in terms of promoting fertilizer reduction. Therefore,China needs to pay attention to the "matching development" of the new agricultural business entities and social service organizations.

Key words agricultural social service organizations; fertilizer reduction; management entities; matching effect

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How Are Smallholder Farmers Involved in Digital Agriculture in Developing Countries: A Case Study from China

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Abstract: Digital transformation in agricultural practices may lead to a "digital divide" between small and large farms, owing to the characteristics and availability of digital technology. This paper sought to use a case study in Chongzhou County, Sichuan Province in China, to analyze how smallholder farmers in developing countries access such digital agriculture and share the benefits of digital agricultural transformation. Small farmers may own a larger scale farm through forming cooperatives; they are also indirectly involved in digital agriculture through agriculture outsourcing. The outsourcing market is expected to grow, which will allow for the evolution of a digital agricultural service platform, the development of a digital agricultural business organization consortium, and the continued expansion of a healthy digital ecology. This paper revealed important policy implications, stemming from the fact that the implementation of inclusive digital agriculture relies on two key shifts: (1) transformation from land scale operations to service scale operations and (2) from inclusive technological progress to inclusive organization innovation.

Keywords: smallholder farmers; digital agriculture; developing countries; China

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1. Introduction

About three billion rural people of two-thirds of developing countries live in small farm households, working on land plots smaller than two hectares [1]. The digital transformation of agriculture has many benefits to smallholder farmers [2], including improved market transparency [3–7], enhanced farm productivity [8–11], and more efficient logistics [12,13]. In particular, under the public health crisis created by the COVID-19 pandemic, digital agriculture has helped developing countries resist the pandemic's adverse effects on food production and supply chains [14,15].

Digitalization boosts the connectivity of all actors across the agrifood system [16]. More specifically, it helps farmers access technical information, obtain higher quality seeds, collect real-time data, improve the traceability of food, and enhance their competitiveness. Therefore, it is an innovative solution to problems of the current global food system [17]. To this end, the transmission of agricultural information through mobile technologies has increased yields by 4% in sub-Saharan Africa and India, according to a meta-analysis from six studies; it has also increased the odds of adopting the recommended agrochemical inputs by 22% [18]. Given this impact, it is clear that the digital transformation of agriculture is an essential component for developing countries.

Despite its clear benefits, it is necessary to pay attention to the possible adverse effects of digital technology on smallholder farmers. With the increase of agricultural productivity, agricultural digitalization may lead to the emergence of a "digital divide" between small farms and large farms. With the commercialization of technology, it is increasingly difficult for small farmers to obtain the support of modern agricultural technology [19]. Compared with large farms, smallholders cannot afford large investments in digital agricultural technology [18]. Given this, how to better enable small farmers to access digital technology benefits is an essential—but complicated—question [20]. A recent FAO report

showed that digital agriculture in developing countries lags behind that in developed countries [21]. Real-world practice patterns have shown that the application of digital agriculture in developing countries is still at a relatively low level. For example, the main topics of concern include the role of certain communication tools (e.g., cell phones) in accessing the information on input and commodities prices [22,23]. More advanced digital technologies (e.g., big data applications) are also being discussed in the recent literature, but are occurring primarily in Europe and North America [24]. The capacity to apply digital approaches varies greatly across different countries; critically, the agricultural systems of developing countries are often not capable of digital transformation, especially in the least developed countries [23].

Recognizing that there are obstacles to the application of digital technology by small farmers, we need to answer a fundamental question: do small farmers have to be the main entities to apply such digital technology? For instance, Young [25] discussed the application of technology from the perspective of labor division, indicating that, "The mechanism of increasing returns is not to be discerned adequately by observing the effects of variations in the size of an individual firm or a particular industry, for the progressive division of labor and specialization of industries is an essential part of the process by which increasing returns are realized. What is required is that industrial operations be seen as an interrelated whole." This gives us another way to involve smallholders in digital agriculture. Through the division of labor within the agricultural industry, smallholders can be served, rather than functioning as the main entities applying digital approaches. In this way, they share in the benefits of digital agriculture.

As a developing country, China has made great efforts to promote the integration of the internet, big data, and artificial intelligence with the development of agriculture. This has been particularly apparent in rural China, where there has been vigorous development of digital agriculture. As a result, China has accumulated useful experiences with regard to integrating and implementing digital agriculture [26]. Some areas of China have established a relatively complete outsourcing service system through the division of labor within the agricultural industry. This approach has allowed them to realize the use of modern agricultural technology by small farmers [27,28].

Given this background, we sought to conduct a long-term and extensive field survey and unstructured interview in Chongzhou County, Sichuan Province in China, from 2013 to 2020. In this region, small farmers indirectly access digital agriculture through an outsourcing service system. This work analyzed the chosen case study in detail, starting from the theory of labor division. The analysis then focused on the internal mechanism behind why the social service system worked and then proposed possible solutions for the development and regulation of digital agriculture in developing countries more broadly. After this introduction, the structure of this article is as follows: (1) a literature review regarding digital agriculture and introduction of the research background for this research; (2) research area, research methods, and data collection; (3) case study description; (4) discussion, focusing on the significance of digital agriculture access for small farmers in developing countries; and (5) research conclusion.

2. Research Background

Digitalization, or the sociotechnical process of applying digital innovations, is an increasingly ubiquitous trend across all facets of modern life [25]. Agriculture is also transforming to digital, with the definition of digital agriculture being "the use of digital technologies, innovations, and data to transform business models and practices across the agriculture value chain" [29]. Emerging technologies such as artificial intelligence, robotics, big data, the Internet of Things, gene editing, and drones are all being used to solve challenges related to food production [30,31]. The emergence of digital technologies in food systems gives farmers many benefits. For instance, soil data have formed digital maps that help farmers apply agrochemicals in a more targeted manner [32,33]. In other applications, sensors have been used to detect plant- and plot-level soil moisture, fertilizer input, weeds,

and disease [34]. Weather forecast data have also helped farmers more accurately adjust their production decisions [33,35]. Satellite imaging has provided a wealth of crop growth data, which has improved the measurement of agricultural productivity [36]. Finally, big data approaches have been used to provide predictive insights into farming operations, driving real-time operational decisions [26].

Developed countries have invested heavily in digital agriculture. For example, the British government's GBP 4.7 billion "Industrial Strategic Challenge Fund" takes artificial intelligence and data as one of the four challenge areas and has specific plans focusing on precision agriculture [37]. In 2019, Canada pledged USD 50.3 million over five years to support agricultural strategic priority plans (CASPP), including digital agriculture. The EU also pledged to provide around EUR 100 million from 2018-2020 to fund the development and application of digital agriculture [38].

The application range of digital technology is growing rapidly. In 2015, digital technology was used to manage 65% of the arable farmland in the Netherlands, compared to only 15% in 2007 [39]. In 2015, 20% of the agricultural service providers in the United States used telematics, compared to 13% two years ago [40]. McKinsey's latest report has also pointed out that if the planned agricultural interconnections are successfully achieved, the industry will add USD 500 billion additional value to global GDP by 2030 [41].

As a developing country, China's investment in digital agriculture is lower than that in developed countries; despite this, it has created a firm foundation in digital technology and economic development. In 2018, the level of network broadband accessibility is very high, with approximately 96% of China's administrative villages having been connected to fiber-optic network by the end of 2018. Rural broadband access number increased by 23.64 million households throughout the year, reaching 117 million households [42]. Moreover, data from China Internet Network Information Center shows that the rural internet penetration rate reached 55.9% by the end of 2020. Figure 1 shows the growth of China's rural internet users and rural internet penetration rate from 2016 to 2020.

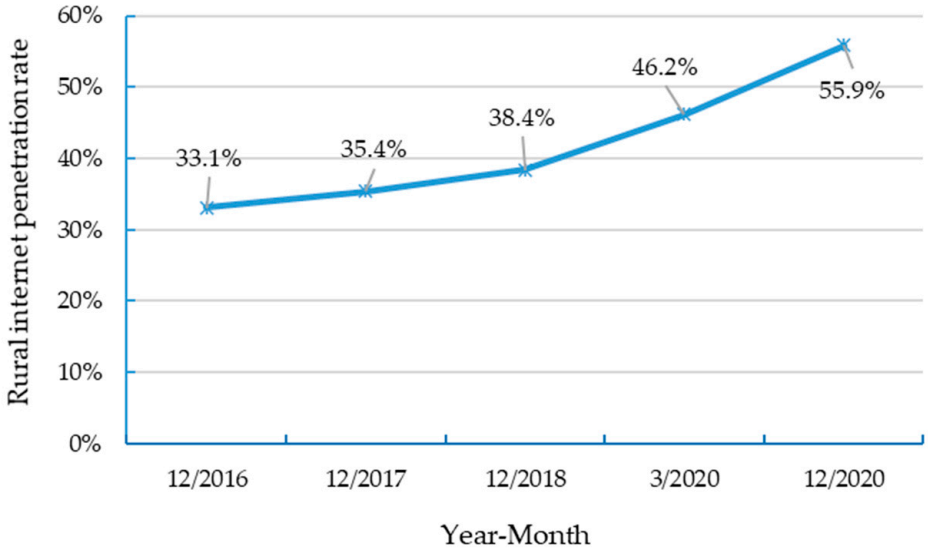


Figure 1. The rural internet penetration rate from 2016 to 2020.

In terms of mobile networks, the total number of mobile phone users in China reached 1.566 billion. The mobile phone penetration rate reached 112.2 units per 100 people at the end of 2018, of which 1.165 billion were 4G mobile phone users and 140 million were 3G mobile phone users. Even in rural areas, the 4G service coverage rate of administrative villages has reached 95%, meaning nearly all rural residents have access to relatively stable, high-speed mobile network services [42].

Considering the massive potential of digital technology, the Chinese government has paid great attention to the digital transformation of agriculture in recent years. In December

2019, the Ministry of Agriculture and Rural Affairs of China issued the "Digital Agriculture and Rural Development Plan (2019–2025)". This plan aims to fully promote the digital transformation of agricultural production and operation, including planting informatization, intelligent animal husbandry, fishery intelligence, seed industry digitization, the diversification of new business models, and the quality and safety control of food. A report of IFPRI shows the frequency of keywords used in national policy documents issued by the state council of China from 2006 to 2017. The results show that since 2006, the Chinese government has paid increasing attention to the development of internet access in rural areas. Since 2012, the Chinese government has also worked hard to promote the development of e-commerce in rural areas [43]. Figure 2 also shows that since 2010, the development of the agricultural internet of things has also received increasing attention.

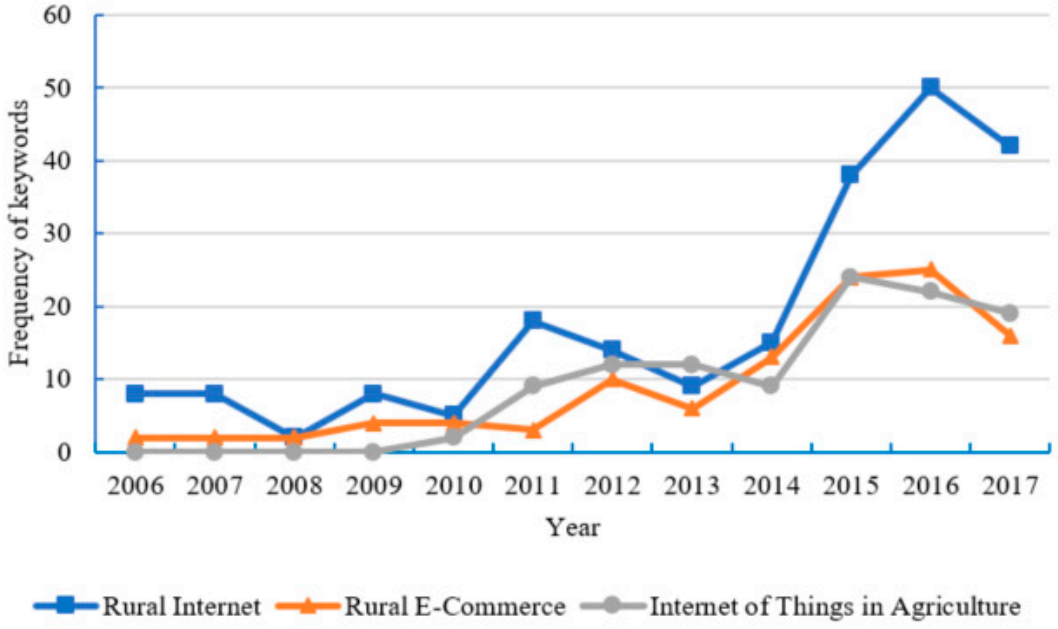


Figure 2. Frequency of key words used in national policy documents issued by the state council of the PRC., 2006–2017.

At present, China's digital agriculture focuses on two aspects: first, rural e-commerce on the consumer side, using a network platform to expand the sales market of Chinese agricultural products. According to recent statistics, in 2018, China's rural e-commerce market reached RMB 175 billion, increasing to RMB 187.36 billion in the first half of 2019. This represents a year-on-year increase of 25.3% [44]. Second, China's digital agriculture has focused on smart agricultural production that applies modern digital technologies (e.g., the Internet of Things, remote sensing). This approach uses sensors and software to control agricultural production through mobile terminals and/or computer platforms. According to recent estimates, China's smart agriculture's potential market size is expected to grow from USD 13.7 billion in 2015 to USD 26.8 billion in 2020 [45]. However, the digitization level of China's agriculture remains lower than in other industries and fields. In 2018, China's agricultural digital economy only accounted for 7.3% of the agricultural added value, which was far below the 18.3% and 35.9% of the manufacturing and service industries, respectively. This low level of agricultural digitization is partially explained by problems like technology mismatch with China's agricultural reality [44]. All of these constitute the background of this case study.

3. Study Area and Research Methodology

3.1. Study Area

Sichuan Province is one of the largest agricultural provinces in China and rice has been planted in the region for over two thousand years. Given this history, it has always

been one of the most important crop-producing areas in China. The study area in this research is Chongzhou County, a suburban county of Chengdu, which is the capital city of Sichuan Province. The study area was located at the junction of the eastern plains and western mountains in Sichuan Province. The land area of Chongzhou county is 1089 square kilometers, of which the plain area accounts for 52% of the total area, the mountainous area accounts for 43%, and the hilly area accounts for 5%. In 2019, the total agricultural output value of Chongzhou County was RMB 3.94 billion, accounting for 10.338% of the total regional GDP, and the annual grain planting area reached 467,000 mu(mu is equivalent to 0.0667 ha) with a total grain output of 218,000 tons; the oil planting area was 173,000 mu with a total output of 27,000 tons [46].

Chongzhou County is a typical rural area in China based in its characteristics of topography, industry, and population structure, and its development is influenced by rapid industrialization and urbanization. Chongzhou County is a major agricultural county and an important exporter of rural labor. In 2019, the rural population of Chongzhou County was 446,603, with only 86,772 individuals working in agriculture [46]. A large number of rural laborers have flowed into the industry and service sectors. Owing partly to this outflow of labor, Chongzhou County has achieved a very high level of agricultural mechanization. In 2019, the total power of agricultural machinery in Chongzhou County reached 420,800 kilowatts, with 70 large- and medium-sized tractors, 6363 small tractors, and 967 combine harvesters. Moreover, in 2019, the annual mechanical farming area was 42,802 hectares, the electromechanical irrigation area was 45,287 hectares, the mechanical sowing area was 34,602 hectares, the mechanical harvest area was 38,402 hectares, and the agricultural mechanization rate reached 96% of Chongzhou County [46]. Within the context of smallholder farming in China, Chongzhou County's successful adoption of modern agricultural production technology has attracted the attention of researchers.

With the continuous development of the agricultural outsourcing services, some service providers in Chongzhou County have begun to build platforms that gather various services. Ultimately, this will introduce digital technology transaction platforms to guide Chongzhou County's agriculture towards digital transformation. Chengdu, where Chongzhou County is located, has a good foundation for an agricultural and rural informatization infrastructure. For instance, Chengdu's village's optical fiber coverage and wireless communication network coverage have both reached 100%, and its mobile communication 4G network coverage ranks second in China. Moreover, Chengdu is one of China's first 5G cities. There are other important indicators for this foundation, including its leading enterprises in agricultural industrialization, the existence of specialized farmers' cooperatives and family farms, and the presence of other new agricultural business entities (e.g., computer application rate); moreover, the network coverage rate and smartphone coverage rate of employees have all reached 99% [47]. For these reasons, we chose Chongzhou County as the study area for this research. Figure 3 shows the location of Chongzhou County in China.

3.2. Research Methodology

This study used qualitative research methods, focusing on in-depth field interviews, literature, and archive research. From 2013 to 2020, we conducted a long-term and extensive field follow-up survey of organizations and individuals involved in applying digital agricultural technology in Chongzhou County, including government officials at the county and town levels, digital agricultural platform companies, cooperatives, agricultural service organizations, and ordinary farmers. We conducted the field surveys five times, each lasting an average of four days. The field surveys mainly included unstructured interviews, group discussions, participant observations, material and information selection, and cooperative case analysis. The interviewees and interview content in group discussions and unstructured interviews are shown in Table 1. We recorded or made notes for all interviews. In group interviews, we usually conducted in two phases: first, discussions with government officials for about two hours; second, discussions with the chief

operation officer (COO) of the farmland cooperatives, agricultural service organizations, and small farmers for about three hours. To reduce the possibility of interruption during the interviews, in the second phase, it was suggested that local government officials were to be avoided. The objects of the unstructured interviews were the key persons mentioned in the interview. The unstructured interview usually lasted for one to two hours and might be extended to online interviews or phone interviews in follow-up surveys when necessary. Our follow-up interviews comprised more than 20 county-level or town-level officials, two digital agriculture platform company managers, five cooperatives' managers, three service organization leaders, and approximately 30 smallholder farmers, with a total number of more than 60 interviewees. After the surveys, we obtained three main types of information: records of the interviews, the archives of the cooperatives (e.g., cooperatives' financial accounts and book sheets from 2015 to 2020), and the government statistical yearbooks, including cooperative bulletins and other statistical sources.

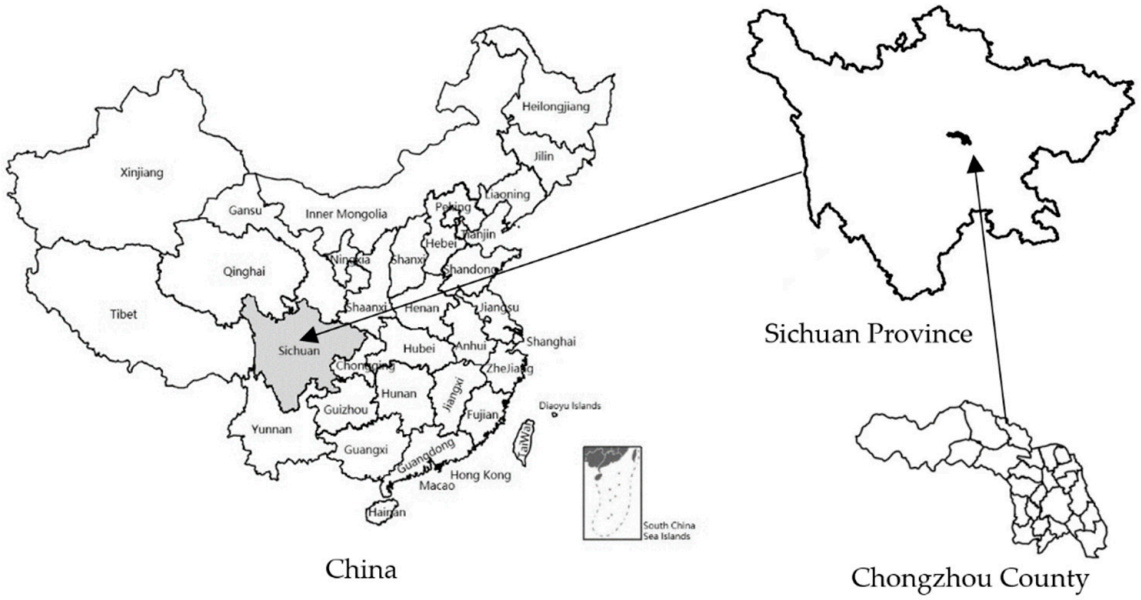


Figure 3. Location of the study area.

We conducted interviews to identify the process of smallholders' digital transformation and its influencing factors to verify the authenticity of the interview content through the identification of archive materials. The use of multiple respondents mitigates the potential biases of any individual respondent by allowing the information to be confirmed by several sources [48,49]. The use of multiple respondents also enables inducing richer and more elaborate models because different individuals typically focus on complementary aspects of major decisions [50,51]. At this stage, the questions concentrated on facts, events, and direct interpretations, rather than hearsay or vague commentary [52]. Overall, we can obtain a richer, mutually verified, and relatively accurate understanding of the phenomenon after integrating interview data and archive data. Before the analysis, we made sure that there were no theoretical preferences and prior hypotheses. We used tables and graphs to facilitate the studies [53]. The goal was to identify the theoretical constructs, relationships, and longitudinal patterns with respect to the research questions [54] and then complete the theoretical model's development.

Table 1. Interviewees and interview content.

Type of Interviewees	Number of Interviewees	Interview Content
Government officials in the agricultural department	More than 20	◆ Agricultural policy implementation performance and planning design priorities; ◆ Problems, difficulties, and countermeasures in the transformation of modern agriculture; ◆ The role of farmland cooperatives and agricultural service organizations in the development of modern agriculture; ◆ Knowledge and understanding of digital agriculture; estimation of the development of digital agriculture.
Farmland cooperative COO	5	◆ Farmland cooperative's establishment date, method, rules, and regulations, operation performance; ◆ Interest relationships with farmers, agricultural service organizations, governments, and digital platform companies; ◆ Business with digital platforms, knowledge and understanding of digital agriculture, and judgment of its application and development.
Agricultural service organization COO	3	◆ Agricultural services types, scale, and performance; ◆ The use of digital technology in the service process; ◆ Business dealings with digital platforms, knowledge and understanding of digital agriculture, and the judgment of its application and development.
Small-scale farmer	More than 30	◆ Characteristics of individual and family; - If farming, topics are about the farming scale, outsourcing services, usage of digital agriculture technology, and attitudes or opinions of digital agriculture. - If a member of a farmland cooperative, topics are about the benefit-sharing mechanism, degree of satisfaction, plans, etc.
Manager and technician of the digital agriculture platform company	2	◆ The business model of the digital platform; ◆ The service types, performance, and relationship with relevant stakeholders of the digital platform; ◆ Difficulties encountered in the promotion of digital platforms and judgements on future development.

4. Case Description

4.1. Agricultural Organization: Formation of Cooperatives and Centralized Land Management

Historically, Chongzhou County is an agricultural area dominated by small farmers; given this, it is challenging to apply advanced agricultural technology to the county's agricultural production and the production efficiency is low. In 2010, an attempt was

made to solve this problem when 30 of the 33 households in the 15 groups of Liba Village, Longxing Town registered and established the first farmland shareholding cooperative in Chongzhou County with a price of RMB 900 per mu. This cooperative was named the Yangliu Land Contract Management Cooperative (hereafter referred to as "Yangliu Cooperative"). The Yangliu Cooperative followed the principles of voluntary membership, freedom of withdrawal, and benefit/risk-sharing. The farmers used the land they owned to convert their individual shares into cooperative shares. The farmland shareholding cooperative then elected both a Board of Directors and a Board of Supervisors to undertake the decision-making and supervision functions. At the beginning of its establishment, the Yangliu Cooperative's shareholding farmland was 101.27 mu. Although it is far from the size of the large farms found in the United States, its scale is already very impressive in Sichuan, which is still dominated by small farmers.

Cooperative members without large-scale farming experience can hardly match the abilities of a farm with a scale of 100 mu or more. Given this, the Chongzhou County Rural Development Bureau hired a technician as the manager of the cooperative. According to the government officials' description, the technician was a young man with a major in agronomy, he also had local rural life experience, and practical agriculture skills. With the government's working experience, he possessed more knowledge about the agricultural policies and market information to carry out large-scale operations. Similar to the CEO of an enterprise, the manager is responsible for the operating activities of the cooperative. The manager brings scarce human capital for operation and management to the cooperative and improves the cooperative's economic benefits, such as increasing grain income and developing cash crop cultivation.

We interviewed the first manager of the Yangliu Cooperative. He believed that there were many benefits for farmers to became cooperative members. First, the cooperatives had more substantial investment capabilities and higher levels of management. The income of the members included land rental income and dividends, which was much higher than self-farming income. Second, as the manager was responsible for agricultural production, the members could seek off-farm opportunities and earn wage income. Third, members could withdraw freely, so it had a binding effect on the cooperative and the manager. By joining the cooperative, most farmers stated that the land rental income and dividends were higher than their original farming income, and the labor force of the family could earn additional off-farm income via working in the city. If they didn't want to work in the city, farmers could set up a small-scale aquaculture or be hired by the cooperatives to earn wages. Compared to working in the city, starting a small business at home or working for a cooperative could keep the farmers' rural lifestyles and fulfill their emotional needs.

After years of development, smallholder farmers in Chongzhou County formed 246 farmland shareholding cooperatives, operating across a land area of 316,000 mu and an average operating area of 1284.6 mu. By the end of 2018, the proportion of farmers participating in the cooperative exceeded 80% [28].

4.2. Deepening the Division of Labor in Agriculture: Agricultural Outsourcing Services and the Application of Agricultural Machinery

Studies have shown that owing to their inherently small scale of operations, smallholder operations hinder the application of modern agricultural technology [55,56]. The establishment of the Chongzhou County Cooperative has expanded its management scale to a more considerable extent. However, the scale is still not large enough to encourage the consumption of agricultural machines. This is because the high productivity of agricultural machinery means that the farming tasks can be completed more quickly, so the machinery becomes an idle asset.

Young [25] pointed out that the application of new technologies should be considered from an industry perspective, not just from within the organization. After developing the cooperative in Chongzhou County, managers found that compared to before, the expansion of the farms' scale was hard to match with artificial farming. It was also not possible to complete all of the production tasks by managers. This situation drove demand for

agricultural outsourcing services. Taking the Yangliu Cooperative as an example, at the beginning of its establishment, the managers searched for agricultural outsourcing service providers to provide machinery services. This would have enabled the Yangliu cooperative to achieve farming mechanization.

Another example is the local Yunfeng Farm, which purchased many batches of agricultural machinery. At the end of 2012, the farm had machinery and equipment valued at RMB 2 million, which provides mechanical services for 4000–5000 mu of farmland. The COO of Yunfeng Farm told us that they mainly served large-scale farms. They only served small-scale farmers if time permited and the price was higher. As the farmland usage was still for agricultural purposes, the government didn't interfere with cooperatives' product diversity. However, agricultural services centralized production types; thus, service prices decreased, and service levels increased. This process is the so-called service specialization leading to the concentration of production types. The concentration of production contributes to a larger scale of service market and promotes further development of service market [57]. In 2011, Yunfeng Farm's turnover exceeded RMB 2 million. The large market scale was so attractive that many of their relatives and friends came to the farm and tried to learn how to use the agricultural machinery.

Cooperatives achieve agricultural mechanization by hiring outsourcing services, which then stimulates market investment in agrarian service. Ultimately, this deepens the division of labor and self-reproduction. With the development of agricultural outsourcing service providers, the outsourcing services market gradually expand to the businesses of agricultural technology consulting, agricultural mechanization, agricultural material distribution, professional seedling, pest control, field transportation, and grain drying and storage. These services are like "nanny" services for agricultural production entities and include the entire process of agricultural production. At the end of 2019 in Chongzhou County, the amount of agricultural land benefiting from agricultural machinery services reached 300,000 mu, and the coverage of farmers reached 98% [46]. In the past few years, Yunfeng Farm continued to develop and become a cooperative. By 2020, the Yunfeng Cooperative had 85 agricultural pieces of machinery (sets) of various types, providing agricultural services for more than 30,000 mu, covering seven counties (cities, districts), including Chongzhou.

4.3. Digital Transformation of Agriculture: Integration of Digital Agricultural Service Platforms

As the demand for outsourcing services increased in Chongzhou County, a mismatch between demand and supply appeared in its agricultural outsourcing service transaction market. The seasonal characteristics of agriculture were prominent, so an agricultural service provider would often receive far more orders than its capacity in a short period. For those agricultural service providers who had received orders that exceeded their service capacity, orders were referred to other agricultural service providers with surplus production capacity. With the increasing frequency of agricultural service exchange activities, some service providers gradually transferred to specialists to exchange agricultural services and established a service supermarket specializing in providing agricultural service intermediary services.

In March 2012, Chengdu Shunonghao Agriculture Co., Ltd. was established. It is a service supermarket that had built a platform to integrate various service providers, marked service prices clearly, and provided a one-stop service. The emergence of the service supermarket had dramatically reduced the search cost of the business entities. Requiring only a phone call, the service supermarket would coordinate for customers and provided door-to-door service of agricultural services as soon as possible. At the end of August 2013, Chengdu Shunonghao Agriculture Co., Ltd. built six agricultural service supermarkets in Qiquan Town, Longxing Town, and Jixie Town in Chongzhou County. First, it integrated 22 large or medium-sized agricultural machinery service providers, which collectively had 320 sets of large- and medium-sized agricultural machinery and 662 professional employees. Second, it integrated six labor service providers with more than

1000 employees. Third, it integrated 16 plant protection professional service providers and more than 700 sets of plant protection machinery. Moreover, it integrated two professional seedling raising service providers, built a 2000-ton grain drying warehouse, and explored "grain bank" services [58].

The most important factor restricting the deepening of the division of labor is coordination cost [59]. In Chongzhou County, the establishment of the service supermarket was a revolution, which significantly reduced the coordination cost of agricultural services, greatly expanded the scale of the market, and promoted the further deepening of the division of labor in agriculture. With the application of digital technology, Chongzhou County began to use digital technology to transform and upgrade service supermarkets. In 2019, Sinochem Agriculture built a Modern Agriculture Platform (MAP) in Chongzhou County together with the BeiDou navigation system, China Meteorology, and other systems. The platform contained a precision planting system, digital operation system, and quality control traceability system. The system had been called the Space–Air–Ground Integrated Digital Agricultural Service Platform. The system relied on remote sensor monitoring, precision weather, AI recognition, online technology live broadcasts, and other technologies. Ultimately, this approach had allowed for the timely diagnosis of pests and diseases, as well as accurate services for agricultural operations. The platform had also been used in the digital transformation of services, such as seed selection, fertilizer distribution, plant protection, an inspection of grain purchasing, and storage and market information. Figure 4 shows the four phases of the digital transformation of smallholder farming in Chongzhou county.

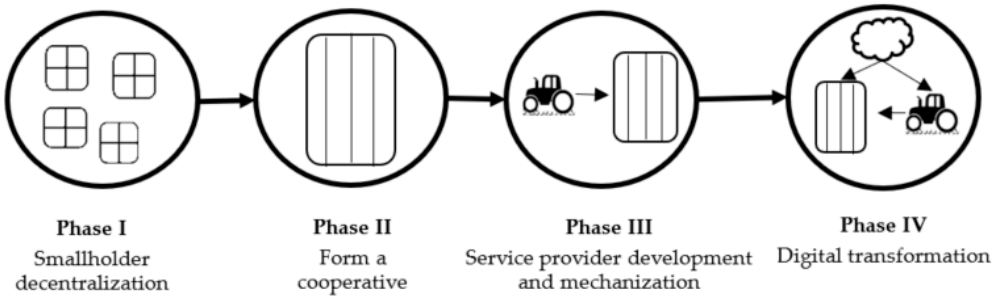


Figure 4. Four phases of the digital transformation of smallholder farming in Chongzhou county.

Chongzhou County's digital agricultural service platform's operation mode is shown in Figure 5, where the dotted line refers to the information flow. The data platform obtains market data from the finance system, inputs and products' markets, remote sensing data from satellites, and operating data from service providers' smart agricultural machinery and smart drones and soil sensing and weather station data on the cooperative farmland. These data are then integrated and analyzed using big data, resulting in assessments regarding task allocation services for the service providers and technical guidance services for the cooperatives. After receiving the platform's orders, the service providers offer different services to the cooperative according to the platform's instructions. Although the digital agricultural service platform is commercial, the government does not interfere with the daily operation of the platform. However, for supervision purposes, the government has the right to access the data of the agricultural service platform, so the data are also accumulated in the government's memory. By the end of 2019, Chongzhou County's digital agricultural service platform provided services to service providers and cooperatives across 18 counties and in 7 cities or prefectures in Sichuan Province, covering a total of 170,000 mu of farmland.

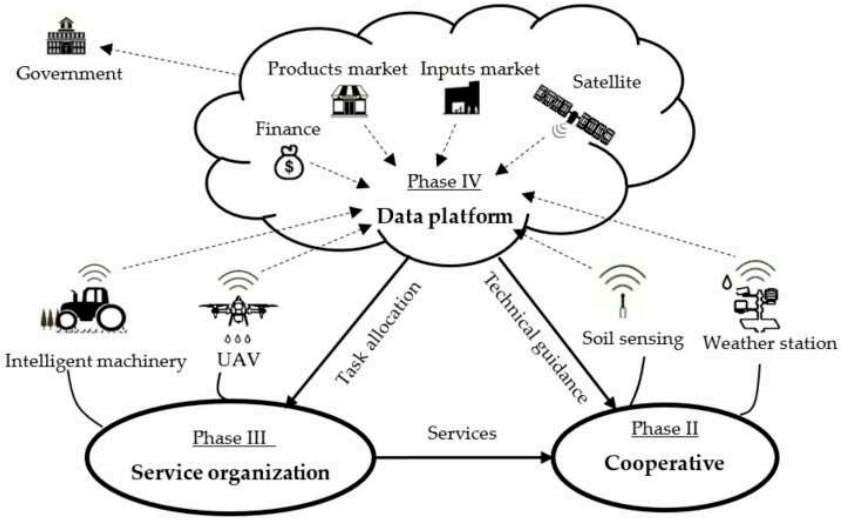


Figure 5. Chongzhou county's digital agricultural service platform. Note: The dotted line refers to the information flow.

The digital agricultural service platform integrates funds, technology, brand information, and other elements to improve resource allocation efficiency. It integrates cooperatives and agricultural service providers into a whole data system and establishes a close alliance of the agricultural operation organizations centered on the platform. The platform helps to match transactions between the cooperatives and the service providers, and reduces the transaction costs of the agricultural services. The platform also significantly improves cooperatives' efficiency for field inspections, which ultimately saves money. As mentioned above, by 2019 the Yangliu Cooperative owned farmland totaling 3850 mu. The managers supervise seedlings, diseases, and insects through the app developed by the digital agricultural service platform. In particular, during the COVID-19 epidemic, cooperative managers have relied on the app to monitor the growth of farm crops, providing a guarantee for the regular progress of the agricultural activities. In this regard, officials, platform managers and technicians all believed that with the accumulation of data, MAP would play a more important role and lead the future development of modern agriculture. Figure 6 shows the app of digital agriculture service platform (MAP).

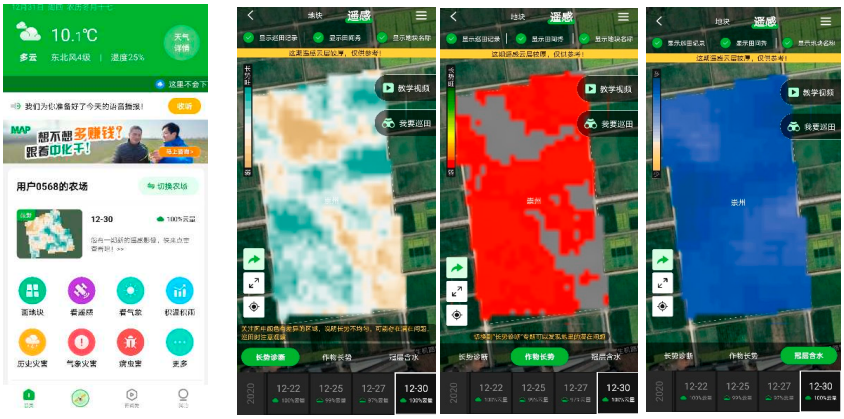


Figure 6. App of digital agriculture service platform (MAP). Note: The first picture is the entry screen of the app, and the next three pictures show how to monitor the growth of crops.

5. Discussion

Many developed countries have large-scale agricultural farms. For example, in the United States in 2019, the average farm area reached 444 acres [60]. "Large-scale farms" refers to a farm with plenty of land, and it is a concept compared to smallholder farms,

which are short of land or have around two hectares of land, as defined by FAO. In fact, according to the data from The National Bureau of Statistics of China, the average farm size in China is 0.43 ha, and the size of 92.49% of them is less than 2 ha (30 Mu). However, the service for the land scale required by digital technology is usually larger than 2 ha. For example, the digital agricultural service platform in Chongzhou County requires a scale of more than 50 mu (3.3 ha). So these large-scale farms have natural advantages in applying digital technology, and it is complex and difficult to develop digital technology that is inclusive to small farmers [19]. As a result, there is a problem of an agricultural "digital divide". Of the approximately 570 million farms in the world, more than 475 million are smaller than two hectares [61]. In the context of the digital transformation of agriculture, the "digital divide" will widen the already existing gap in agricultural productivity between developing and developed countries. This is especially realistic since developing countries are usually dominated by smallholder farmers [21].

It is likely that the direction of how digital technology's development is frustrating to small farmers. In some developing countries, agricultural policies often encourage small farmers to transfer farmland to create large-scale farms, thereby increasing agricultural productivity. For example, in China, there is a view to strengthen Chinese agriculture's competitiveness, and it is necessary to promote large-scale farms through land transfer [62]. However, compared with the United States, China has a large agricultural population and an imperfect social security system, which determines that China's agricultural production cannot rely on large-scale farms. In fact, in 2018, China's total agricultural land transfer accounted for 57.17% of the inflow of rural households, while only 10.31% were transferred to the enterprises with scale management ability [63]. In the short term, the practice of transferring and expanding farm scale is challenging to achieve.

However, in the case of Chongzhou County in Sichuan province of China, we have shown a possible path for smallholder farmers in developing countries to be involved in the development and implementation of digital agriculture through an organized way. First, establishing cooperatives allows for larger land operations. Second, agricultural mechanization is achieved by supporting the development of agricultural service providers. Third, a digital agricultural business organization consortium is formed by building a digital agricultural service platform, which evolves into a healthy, digital ecology. Collectively, this allows for improved agricultural productivity.

Given what was done in Chongzhou County, future policy should emphasize two shifts: (1) scale the economy of the land shifts to scale economy of the agricultural service; (2) inclusive technological innovation shifts to the inclusiveness of the organizational innovation. According to the website of the Ministry of Agriculture and Rural Affairs of China, the number of agricultural outsourcing service organizations in China will exceed 900,000 by the end of 2020; moreover, the agricultural production service area will exceed 1.6 billion mu, of which the food crop area will exceed 900 million mu. Agricultural production service will involve 70 million rural households [64]. Taken together, past agricultural development has already shown that the "two shifts" will have a national significance and are not just unique to Chongzhou County.

However, the digital transformation of agriculture will still bring a series of problems and challenges. First, digital agriculture reduces physical labor and improves agricultural life. However, manual labor, traditional farming lifestyles, and rich agricultural production experiences are of great significance for farmers to participate in and lead to a better understanding of their land and environment [65]. The use of digital technology may lead to the marginalization of the experience of agricultural production and a disconnection between farmers and agriculture [66], which brings challenges to the inheritance of the traditional agricultural culture [67]. Second, in the context of agricultural digitization, machinery makes autonomous decisions based on big data without manual intervention; in other words, machines replace labor. However, in China, agriculture still provides jobs for 194.45 million people [68], and remains an available job for individuals who have failed to enter urban occupations [69]. Therefore, we should pay attention to the social and

political implications of digital agriculture transformation. Third, digitization often means using large amounts of data. Consequently, privacy and security must be fully protected. In China, most farmers are not aware of this problem. However, the online equipment required for digital agriculture may open exposure to cyber threats. For example, if there are loopholes in the network security firewall settings, third parties may access sensitive data, steal data, and/or destroy equipment. Finally, when compared to small farmers and other entities with weak abilities to defend their rights, large companies with more negotiating power are more be able to integrate their data and make decisions based on the information [70–72].

6. Conclusions

As digital agriculture technology is more friendly to large-scale farms, the digital transformation of small-scale farms in developing countries has encountered significant challenges. This research discussed how small farmers might be involved in digitalization from mechanization. By analyzing the case study presented by Chongzhou County, Sichuan province in China, small farmers obtained a relatively large farmland scale by forming cooperatives. Then they outsourced agricultural production to service providers, who provided mechanized agricultural services to cooperatives. Some service providers have developed trading platforms and digitized them to create an integrated digital agricultural service platform. This platform integrates farm management systems, precision planting systems, digital operation systems, and quality control traceability systems. Ultimately, this would allow for the digital transformation of the entire industrial chain of agriculture production.

The critical findings of this research for the digital transformation of small farmers in developing countries are as follows: first, focus on the cultivation and development of outsourcing service systems is critical, rather than focusing on the scale of farmland. Second, when it is challenging to achieve inclusive digital technology progress, we should focus on inclusive organizational innovation to digitalize small farmers. Of course, this study also pointed out that the digital transformation of Chongzhou County's agriculture still had many problems, including changing the agricultural production ecology, replacing labor, agricultural data privacy and security, and the political and social ramifications of such a transformation.

The shortcomings of this research are as follows: as a case study, this research has not quantitatively evaluated the impact of digital agriculture on agricultural production or smallholders' income; this research outlined a conceptual diagram of the process and operation mode of smallholders' involvement in digital agriculture, but it has not collected data for quantitative analysis of the position and role of each participant in the digital ecology. Solving the above two problems is meaningful for future research.

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技术进步、信任格局与农业生产环节外包*

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摘　要: 技术进步使得部分农业生产环节可以外包给服务商。文章认为,在家庭内部组织生产或将生产环节外包实质都是合作行为。特殊信任有助于降低合作中的监督成本,使农业家庭经营具有成本优势。但是,随着规模的扩张,由特殊信任带来的成本节省可能不足以弥补由于家庭成员代理能力有限而带来的成本增加,农民此时将选择将生产环节外包。实证研究表明,更高的普遍信任水平有助于农民的外包行为,但服务商与家人之间的信任差值越大,农民越倾向于在家庭内部组织生产。对于家庭经营的未来,文章认为,即便是技术进步使生产活动实现机械对劳动的替代,但由于统筹各个生产环节难以标准化,特殊信任机制仍然使得家庭经营方式难以被替代。

关键词: 技术进步; 普遍信任; 特殊信任; 外包
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一、引　言

发挥农业家庭经营的比较优势并使之成为中国现代农业发展的积极因素与重要组织资源具有重要的实践意义(张露等,2018)。从全球层面来看,在美国等发达经济体中,尽管家庭农场的平均耕地规模持续扩大,但平均用工人数却长期稳定,保持着家庭经营特性(韩朝华,2017)。实际上,农业的家庭经营是一个全球性现象,家庭农场的数量占全球农场总数的比例超过了 90%(FAO,2014)。也正因为此,有必要提出一个一般化的理论逻辑来解释这一全球性问题。

农业生产特性是家庭经营在农业生产领域具备“天然合理性”的原因之一: 农业生产活动中的主体往往处于“照料者”和“侍弄者”的地位,必须根据生命节律及生物需要指令采取行动,而不能以自己为中心。同时,农业活动的时间性极强,具有生命的不可逆性,做出的反应不仅要灵敏,而且必须严格遵守有机界的规律。因此,农业活动主体必须及时而充分地获得巨量的不规则信息,并且立即做出有效反应。由于信息的分散性、反应的灵敏性及处置的随机性,从而导致农事活动中的劳动监督成本过大。家庭经营对此具有比较优势。维系家庭的纽带不限于经济利益,还包括血缘、感情、心理、伦理和文化等一系列超经济因素。因此,家庭成员往往把家庭其他成员的要求、利益和价值取向,自愿地当成自己的要求、利益和价值取向。家庭成员努力工作,贡献智慧和力气,无需以内部精密的劳动计量并和报酬挂钩来激发,家庭内部的偷懒和搭便车行为要远远低于一般的经济组织(中国农村发展问题研究组,1984)。中国历史上不乏雇工农场,但这些农场最终逐渐转化为以佃农家庭经营为基础的租佃农场(赵冈,2003)。历史经验表明,若不改变农业生产的高计量、高监督成本特征,那么背离

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家庭经营终将带来失败(谢琳等,2017) 。由此,农业生产特性和家庭的“非理性”的血缘、感情、心理、伦理和文化等超经济纽带可以用于解释农业的家庭经营。这似乎印证了亚当·斯密在《国富论》中提出的“农业不能采用完全的分工制度”的论断(斯密,1776) 。

不过,技术进步能够在一定程度上改变农业的生产特性,如农业机械的应用能改善劳动的可监督性,并实现生产过程的工艺规范(杨汉明等,2001) 。工艺规范有助于农民将生产活动外包给外部服务商——以水稻生产为例,收割环节机械化程度高,生产相对标准,农民对外包服务的接受程度较高(孙顶强等,2019) 。其他农业技术,如温室栽培与无土种植技术能够改善对生命节律的控制; 种苗的栽培生产和生物抑制剂技术能够缓解农业生产过程中的生命连续特性。由此,技术进步收窄了农业中的核心技术范围,从而增加生产过程中操作环节的可分离程度,有助于提升农业可分工性,并进一步使得农民将那些经技术改进的整地、收获等生产环节外包给服务商,实现农业的产业内分工(胡新艳等,2015) 。

将部分农业生产环节外包,意味着家庭从这些生产活动中退出,即农民选择非家庭经营方式进行生产活动。因此,技术进步是农民选择将这些生产环节外包,还是继续采用家庭经营组织生产的重要因素。不过,研究表明,即便是整地、收获等可以实现机械化生产环节,农民是否选择外包仍然存在个体差异(申红芳等,2015; 胡新艳等,2015; 李宁等,2019) 。本文关注的一个核心问题是: 当技术条件能够满足生产环节的分开并大大降低监督成本时,哪些因素决定了农民的外包行为?

本文的贡献在于: 第一,构建一个风险占优博弈模型,以便深化对信任在形成农业家庭经营格局中的作用的理解; 第二,分析家庭经营面临的困境,以及普遍信任在农民是否将生产环节外包中的作用,并提出家庭经营的边界问题; 第三,基于微观调查数据,实证检验信任在生产环节外包中的作用; 第四,讨论在技术不断进步的将来,农业家庭经营生产方式发展演化的可能性。本文的结构安排如下: 第二部分讨论特殊信任与组织治理之间的关系,构建一个协调博弈模型,用于分析家庭经营的独特优势,并提出家庭经营的困境及其边界问题; 第三部分是本文的研究设计,详尽介绍了数据来源和变量测量方法; 第四部分是实证结果,在描述性统计的基础上,通过回归分析检验普遍信任和信任差值对生产环节外包的影响; 第五部分是本文的研究结论。

二、理论分析

(一) 信任与经营方式选择: 一个协调博弈模型

无论是将生产环节外包,还是在家庭内部组织生产活动,实质都是合作行为: 农民将生产环节外包,意味着合作对象为外部服务商; 若在家庭内部组织生产,则合作对象为家庭成员。经典研究已经表明,信任对促进合作有着极为重要的意义,如信任能使合作更有效率,高度的信任能降低组织运行成本,那些享有一致伦理与价值观的组织,并不需要严谨的法律条文来规范成员之间的关系(福山,1998) 。甚至在某些情境下,信任关系能够取代第三方执行,成为达成交易的保证(如 Grief,1989,1993; Grundmann 等,2015) 。从信任格局来看,信任可以区分为普遍信任与特殊信任。相比于西方的普遍信任原则,中国人信奉特殊信任(李新春,2002) 。特殊信任意味着个体对于家庭成员和非家庭成员的信任程度存在“内外有别”。韦伯(1995) 提出,中国人的信任是建立在血缘基础之上,是一种难以普遍化的特殊信任。费孝通(1998) 认为中国人际关系的“差序格局”: 如同把一个石头扔进湖水里,在石头周围形成一圈一圈的波纹,由波纹的远近来标示关系的亲疏。Redding(1993) 对华人的信任状况进行了描述,认为华人在无所不在的不信任之中强调对家庭的忠诚,由此形成内外有别的信任体系。这些思想多被学者们用于解释华人世界中社会交往与组织治理的家族主义特征,并认为特殊信任是将家庭或家族凝聚在一个生产组织中的内在原因(如福山,1998; 杨宜音,1999; 李新春,2002;

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储小平等,2003; 罗家德等,2013) 。

假设某个农业生产环节由于技术进步而可以外包出去,那么农民的信任格局将在一定程度上决定了农民是否将这些生产环节外包。为了说明该问题,本文借用 Carlsson 等(1993) 和李新春(2002) 提出的风险占优模型{ g(x) 博弈} 进行分析。假设某个生产环节的生产活动的参与者有农民 A 与其合作者 B,其中 B 有可能是 A 的家庭成员,也可能是外部服务商,两者的策略空间为{ 不合作,合作} 。如果 A 和 B 均选择“合作”策略,则 A 和 B 均会为农业生产活动提供高质量的劳动,而不存在机会主义行为。然而现实中,即便是农业机械的应用大大降低了劳动的监督成本,参与者仍然存在机会主义行为的空间,如耕地深度不够、收获过程中的浪费等,因此对局者也可能选择“不合作”策略。

博弈的收益函数如图 1 所示。g(x) 博弈的均衡取决于 x 的值。若 x<0,则 A 和 B 都选择“合作”策略的均衡就是最优均衡。类似地,如果 x>4,那么“不合作”策略对于 A 和 B 来说就是最优策略。然而,绝大部分的时候 $x \in (0,4)$,此时存在多个纯策略均衡,且这些均衡按照帕累托排列。支付占优均衡的策略为{ 合作,合作} ,但这是有风险的,如 A 选择合作但 B 选择不合作,那么 A 的收益只有 0。最终,均衡一般取决于 x 的取值以及对局人对于对手选择“不合作”或“合作”的概率估计。

		合作者 B (家庭成员/服务商)	
		不合作	合作
农民 A	不合作	(x, x)	(x, 0)
	合作	(0, x)	(4, 4)

图 1　g(x) 博弈收益函数

假设 B 以 s 的概率选择“不合作”策略,则 A 选择“不合作”策略的净收益 $V(s) = x-(1-s)\times 4$,令 $V(s) = 0$,则可得 $s^* = (4-x)/4$。此时,如果 A 认为 B 选择“不合作”策略的概率(s) 小于等于 s^* ,则 A 将选择“合作”策略,反之应选择“不合作”策略。x 是可以给定的,如当 x=2 时,则 $s^* = 1/2$,即如果 A 认为 $s \leqslant 1/2$,他将选择“合作”策略。相反,如果 A 认为 $s>1/2$,他将选择“不合作”策略。

A 对于 B 的选择的判断是存在风险的。科尔曼(Colman,2008) 认为信任的行动是“诸种风险行动的一种,个人在这类行动中承担的风险程度取决于其他行动者完成交易的情况”。威廉姆森(Williamson,1993) 将这种算计风险的信任称之为“精心算计的信任”,认为其对于合作行为具有重要意义。Gambetta(1988) 指出当 A 信任 B 时,意味着 A 认为 B 采取对 A 有利的,或至少无害的行动的概率很高,由此足以使得 A 考虑与 B 进行某种形式的合作。家庭内部存在的偷懒和搭便车行为要远远低于一般的经济组织(中国农村发展问题研究组,1984) 。如果合作行为仅限于家庭内部,对局者 A 和 B 被置于特殊信任空间内。李新春(2002) 认为,当 $x \in (0,4)$ 时,在特殊信任的文化空间下,对局者 B 是 A 的家庭成员,其选择“不合作”的概率(s) 几乎为 0,要远小于 s^* 。因为信任程度较高,A 也相信 B 更可能采取“合作”策略,因此 A 将选择“合作”策略,此时,策略组合{ 合作,合作} 就是帕累托最优均衡,均衡结果是(4,4) 。对此,正如 Bryan 等(2015) 所指出的,家庭成员之间互相信任拥有较高的信任水平,由此可以降低经营成本。

在普遍信任空间下,农民 A 面对的是服务商 B,此时农民 A 选择何种策略同样取决于 x 的值和农民 A 对服务商 B 选择“不合作”策略(s) 的概率的判断。农民的普遍信任水平存在差异,其策略选择也相应不同。对于普遍信任水平较高的农民来说,他们更倾向于相信服务商会采取“合作”策略,因此自己也采取“合作”策略,此时策略组合{ 合作,合作} 就是帕累托最优均衡,均衡结果是(4,4) 。然而,对于普遍信

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任水平较低的农民来说,他们更倾向于认为服务商会采取“不合作”策略,因此自己也采取“不合作”策略,从而拒绝服务商的服务,此时策略组合{不合作,不合作}就是帕累托最优均衡,均衡结果是(2,2)。也就是说,普遍信任水平较高的农民与服务商之间的合作更可能获得(4,4)这个支付占优且风险占优的均衡结果,农民选择将生产环节外包;普遍信任水平较低的农民与服务商之间的合作更可能获得(2,2)这个支付并不占优的均衡结果,农民将选择不把生产环节外包,而在家庭内部组织生产活动。

(二)家庭经营的困境及其边界

普遍信任水平一般低于特殊信任水平,因此农民总是会倾向于选择家庭经营方式。但是,农业家庭经营虽然能降低因机会主义带来的代理成本,却仍然面临能力约束。特殊信任能带来最优的合作,但由于最具代理能力的人可能是非家庭成员,所以这种合作并不是最有效率的,因此造成家庭经营不能同时实现代理成本和代理能力的最优配置,形成“家庭经营困境”:如技术进步和专业化发展要求作业者懂得现代农艺技术、操作现代农业机械,并通过对市场信息的搜集与判断,实现农户与市场的对接,但是家庭成员并不一定满足该要求。尤其在较大规模的农业生产组织中,家庭经营所节省的代理成本有可能要低于因代理能力有限而导致的经营成本增加。

图2给出了由于组织规模成长导致的家庭经营困境的几何模型。其中横轴表示组织规模的成长率S,纵轴表示作为经营方式的成本C。本文假设组织规模和经营成本之间是线性关系,即随着组织规模的扩大,经营成本增加。在组织规模较小的时候,代理能力对经营带来的负面效应较小,此时由特殊信任带来的代理成本削减使家庭经营具有较大的成本优势。然而,和普遍信任空间比起来,随着组织规模的扩大,由特殊信任带来的代理能力约束增加得更快一些。这一性质在图2中表现为特殊信任下的经营成本曲线的斜率更大。

在特殊信任空间下,不同农民的家庭成员的努力程度是一致的,因此图2中特殊信任空间下的经营成本曲线只有一条。但是,不同普遍信任水平的农民,在外包过程中拥有不同的成本曲线:普遍信任水平I要高于普遍信任水平II,相应地,普遍信任水平I的农民与服务商的合作成本低于普遍信任水平II的农民,因此其成本曲线位于普遍信任水平II的农民的下方。

在S_1点,普遍信任水平I的经营成本曲线与特殊信任相交;在S_2点,普遍信任水平II的经营成本曲线与特殊信任相交。农民将根据组织规模在横轴的区间来相机选择经营方式:

1. 当$S<S_1$时,不管是普遍信任水平I还是普遍信任水平II的农民,家庭经营的成本都低于外包,或者说在组织规模较小时,家庭经营具有独特的优势,此时经营者当然选择家庭经营方式。

2. 当$S>S_2$时,不管是普遍信任水平I还是普遍信任水平II的农民,家庭经营的成本都高于外包,或者说在组织规模较大时,表现出家庭经营的困境,此时经营者当然选择服务外包。

3. 当$S_1<S<S_2$时(如在S_0点时),普遍信任水平II的农民的家庭经营成本仍然低于外包,但普遍信任水平I的农民的家庭经营成本却高于外包。此时,普遍信任水平I的农民选择外包,但普遍信任水平II的农民选择家庭经营方式。可以看出,S_1为普遍信任水平I的农民选择家庭经营的边界,而S_2为普遍信任水平II的农民选择家庭经营的边界。

总的来说,理论分析表明,信任格局在一定程度上决定了农民是将农业生产环节外包,还是选择在家庭内部组织生产,且特殊信任是农民选择家庭经营的深层次原因,而对于那些因技术进步而可能可以外包出去的生产环节,普遍信任水平越高,农民越有可能选择外包,而非内部化的家庭经营方式。那么,不同普遍信任水平的农民,其在各个生产环节上的家庭经营边界也相应存在差异。本文基于农户调查数据实证检验两个问题:(1)各生产环节的技术发展进度不同,农民对待各生产环节的外包策略也不同;(2)农民的外包决策受信任格局的影响,即普遍信任水平更高的农民,更可能将农业生产环节外包给服务商,而不是在家庭内部组织生产。

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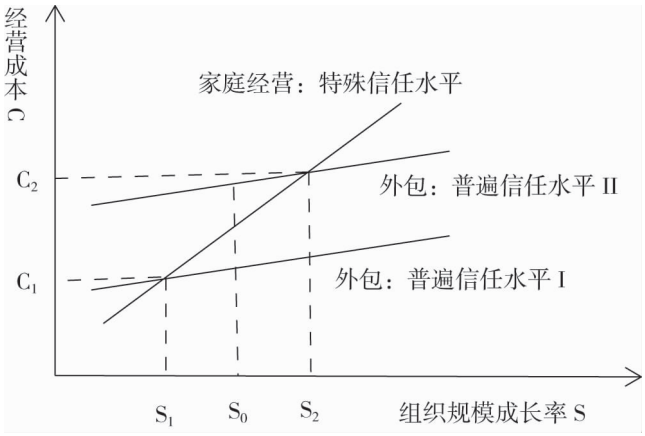


图 2　家庭经营的困境与经营方式的相机选择

三、研究设计

(一) 数据来源

本文数据来源于华南农业大学国家农业制度与发展研究院于 2016—2017 年在广东省阳山县和新丰县组织的农户抽样问卷调查。在抽样技术方面,课题组首先将阳山县 149 行政村进行汇总,随机抽取 80 个行政村,从新丰县 140 个行政村中随机抽取 60 个行政村。在确定行政村后,在每个行政村分别随机抽取 2 个自然村,并在每个自然村随机挑选 10 户样本农户进行调查。本次调查要求回答问卷的人为户主或可以做出农户生产决策的人,因此问卷填写人的信任格局是可以对该农户的生产环节外包行为产生影响的。本次调查总计发放农户问卷 2802 份,回收 2802 份,回收率 100%。

(二) 变量测量

1. 因变量。课题组使用的问卷询问了农户在整地、育秧、插秧、施肥、防治病虫害和收获等生产环节是否外包。本文构造了各个生产环节外包变量,例如,如果农户将整地生产环节外包,则“整地外包”赋值为 1,否则赋值为 0,以此类推。

2. 自变量。世界价值观调查(WVS 6) 开发了一套问卷测度人们的信任状况,其中包括普遍信任和特殊信任(Delhey 等,2011) 。本文参考世界价值观调查的办法,使用“总体来说,您觉得与您打交道的人很可信”来测量农民的普遍信任。此外,Fukuyama(1995) 提出信任半径(Trust radius) 的问题,认为信任半径意味着人们乐意把自己的信任扩展到的范围大小,决定了人们愿意和谁去合作。Delhey 等(2011) 提出由于个体对不同群体的信任半径不同,因此可以区分为特殊信任和普遍信任。Priest 等(2003) 提出信任差值(Trust gap) 的概念,即个体对不同对象的信任值的差值,并以此来预测态度与行为。本文参考 Priest 等(2003) 的方法,以信任差值作为自变量之一。考虑到除家庭成员外,其他主体提供的服务均可视为外包,因此本文以样本对家人的信任值减去所有其他可能提供服务的主体的信任值的均值来刻画信任差值。

3. 控制变量。为了给自变量“信任差值”提供一个“锚”,本文首先控制了样本的特殊信任值,以样本对家人的信任值作为代理变量。土地规模和家庭收入水平对于农户选择是否通过社会化服务实现机械化具有重要影响(谢琳等,2017) ,因此本文控制了农户经营的土地面积和家庭收入水平。以产品销售为主要目的的农户,为了提升其生产经营效率和产品质量,会倾向于生产环节之间的分工(刘晗等,2017) ,因此农户销售农产品的数量有可能影响其引入专业化服务的行为,故本文控制了农户销售的农产品总值。关系网络能帮助个体获取稀缺的资源,作为农村中社会网络的占优者,村干部

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更容易获取农业社会化服务服务(谢琳等,2017) ,因此本文控制了家庭成员的村干部身份。家庭的劳动力特征,包括劳动数量、性别结构、文化水平、非农就业情况都对农业经营产生影响,也是农户需要获得社会化服务进行生产活动的重要前置因素(罗必良,2014) ,因此本文控制了农户劳动力人数、劳动力比例、家庭性别结构、家庭文化水平、农业就业人口比例、非农就业人口比例。交通条件与农业生产服务外包有正相关关系(胡新艳等,2015) ,因此本文控制了村庄的机耕路情况。乡村的互助往往也是基于家族网络的,由此在家庭难以完成所有工作的时候,也能获得宗族成员的帮助(如费孝通,1998; 费孝通,2001) ,因此拥有更强、更大家族网络的农户更容易获得农业社会化服务,故本文控制了农户姓氏在村庄中的地位。此外,为了消除村庄的固定效应和调查年度效应,本文还控制了样本所在村庄的虚拟变量和调查年份虚拟变量。本文的变量测量与定义如表 1 所示。

表 1　变量测量与定义

变量	问卷指标	变量赋值
生产环节外包	是否雇佣机械服务(整地、育秧、插秧、施肥、防治病虫害、收获) : 0=否,1=是	只要有一个环节外包,赋值为 1; 否则为 0
普遍信任	您觉得与您打交道的人很可信: 1=不同意,2=不太同意,3=一般,4=比较同意,5=非常同意	根据选项赋值
特殊信任	分别对其信任程度进行打分: 亲人(指父母、兄弟) : 最低 1 分,最高 10 分	根据打分赋值
信任差值	分别对其他主体的信任程度打分: 亲戚、朋友、本村农户、村外农户、专业合作社、本地企业、外地企业、村集体。最低 1 分,最高 10 分	亲人信任分值-其他八类主体分值的平均值
经营面积	农作物经营面积(亩)	Ln(1+所填数值)
家庭收入	2016 年家庭总收入(元)	Ln(1+所填数值)
农业销售收入	2016 年出售自家农产品收入(元)	Ln(1+所填数值)
村干部家庭	农户是否有村干部: 0=否,1=是	选择 1 的人数除以报告是否村干部的人数
劳动力人数	农户各成员出生年份	所填数值大于 1951 年且小于 2000 的人数
劳动力比例	农户各成员出生年份	劳动力人数除以报告出生年份的人数
家庭性别结构	0=女,1=男	选择 1 的人数除以报告性别的人数
家庭文化水平	0=不识字(文盲) ,1=小学及以下,2=初中,3=高中(或中专) ,4=大专及以上	小于 3 的人数除以报告文化程度的人数
农业就业人口比例	家庭各成员在家劳动时间(月数,≤12)	填写 12 的人数除以报告劳动时间的人数
非农就业人口比例	家庭各成员在家劳动时间(月数,≤12)	填写 0 的人数除以报告劳动时间的人数
机耕路	您村最近三年,是否有投资建设田间机耕路: 1=否,2=是	若选择 2 则赋值为 1; 否则赋值为 0
姓氏	您家姓氏是村里: 1=第一大姓,2=第二大姓,3=一般小姓	以第一大姓为基组生成第二大姓和一般小姓 2 个虚拟变量
调查村庄	被调查农户所在村庄	以第一个村庄为基组,生成 139 个村庄虚拟变量
调查年份	访问年份	以 2017 年为基组生成 2016 年虚拟变量

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四、实证结果

(一) 描述性统计

本问卷利用题项“请分别对下列对象的信任程度进行打分(按 1~10 打分)”调查了农民的信任格局。表 2 给出的是被调查样本的信任格局状况。可以发现,在对个体对象的信任方面,被调查样本对于亲人、亲戚、朋友、本村农户和村外农户的信任均值分别为 9.3876、8.6580、8.0250、7.5018 和 6.0889,很明显,被调查样本对于亲人、亲戚、朋友、本村农户和村外农户的信任呈现出费孝通(1998)指出的“差序格局”,且对于亲人的信任均值与对于村外农户的信任均值之间的差距比较大。同样地,在对组织对象的信任方面,被调查样本对于村集体和专业合作社、本地企业和外地企业的信任同样呈现出“差序格局”。

表 2　被调查样本的信任格局

信任对象-个体	样本总数	均值	标准差	信任对象-组织	样本总数	均值	标准差
亲人(指父母、兄弟)	2794	9.3876	1.3610	村集体	2707	7.7159	2.2313
亲戚	2792	8.6580	1.7542	专业合作社	2720	6.3255	2.6127
朋友	2796	8.0250	2.0237	本地企业	2705	5.6835	2.4348
本村农户	2790	7.5018	2.0642	外地企业	2784	5.2377	2.4360
村外农户	2767	6.0889	2.4081				

进一步考察农户根据生产环节的不同选择经营方式的情况(见表 3)。农户一般只能在家庭经营与市场外包之间进行选择,因此课题组考察了农户雇佣服务的情况。如表 3 所示,农户在整地、育秧、插秧、施肥、防治病虫害和收获等环节中雇佣服务的比例分别为 28.4934%、0.1622%、0.6894%、0.0812%、0.0406%和 39.2746%,与信任格局一样,呈现明显的差序格局——整地和收获环节的雇佣服务最多,而育秧、插秧、施肥、防治病虫害等环节几乎没有雇佣服务。其原因就在于,由于技术进步,整地和收获生产环节已经基本可以实现机械化,劳动的监督成本比较低,因此农户可以选择外包,而非家庭经营方式。与之相反的是,其他生产环节难以进行有效识别,农户选择外包将承担巨额的监督成本。

表 3　各生产环节的雇佣服务情况

生产环节	样本总数	雇佣服务频数	雇佣服务比例(%)
整地	2562	730	28.4934
育秧	2466	4	0.1622
插秧	2466	17	0.6894
施肥	2464	2	0.0812
防治病虫害	2464	1	0.0406
收获	2564	1007	39.2746

可以发现,和人际信任呈现出的“差序格局”相映成趣,农户的生产环节雇佣服务上同样出现了“差序格局”。在这个“差序格局”里,收获和整地因为雇佣服务的比例大,而其他生产环节则难以被外包出去。这意味着,农户可以根据生产环节特性的不同,对不同生产环节采取了差异化的外包策略,由此形成一个生产环节间多样的经营方式组合:整地和收获生产环节可能通过外包安排生产活动,而其他生产环节则采用家庭经营生产方式安排生产活动。

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表 4 给出了各变量的描述性统计结果。考虑到将育秧、插秧、施肥、病虫害防治等 4 个生产环节外包的农户很少,因此本文只关注整地和收获等 2 个生产环节外包变量。普遍信任的均值为 3.7383,虽然其与家庭内部信任的量纲不同,但仍然可以看出其数值比家庭内部信任要小。信任差值的均值为 2.4919,说明被调查对象对外部人的信任均值为 6.8957,那么,被调查样本对家庭内部对象的信任水平要比对外部人的信任水平高 36.1370%。这说明,被调查对象对家庭内部的信任水平要显著高于对外部人的信任水平。

表 4　各变量的描述性统计结果

变量	样本量	均值	标准差	最小值	最大值
整地外包	2562	0.2849	0.4515	0	1
收获外包	2564	0.3927	0.4885	0	1
普遍信任	2797	3.7383	0.8700	1	5
信任差值	2642	2.4919	1.7005	−7.7500	9
家庭内部信任	2794	9.3876	1.3610	1	10
经营面积	2767	1.3160	0.8097	0	7.3658
家庭收入	2797	10.4687	1.6816	0	16.379
出售农产品总值	2784	2.1443	3.7525	0	16.195
村干部家庭	2793	0.1797	0.3840	0	1
劳动力人数	2802	3.6767	1.6330	0	9
劳动力比例	2800	0.7387	0.2381	0	1
家庭性别结构	2802	0.5417	0.1791	0	1
家庭教育结构	2802	0.8739	0.1993	0	1
农业就业比例	2788	0.4635	0.2961	0	1
非农就业比例	2788	0.4934	0.2850	0	1
机耕路	2799	0.3984	0.4896	0	1

注: 其中经营面积、家庭收入、出售农产品总值等 3 个变量是取对数后的值

(二) 回归分析与结果

表 5 给出的是回归结果,其中: 模型 1~3 的因变量为整地外包,探寻普遍信任与信任差值与整地外包之间的关系; 模型 4~6 的因变量为收获外包,探寻普遍信任与信任差值与收获外包之间的关系。因为上述 6 个回归模型的因变量均为虚拟变量,故使用 Probit 模型进行回归。

模型 1 的结果表明,普遍信任的回归系数显著为正($\beta=0.0844$, $p<0.05$),说明农民的普遍信任越高,农民越可能将整地生产环节外包出去。该模型中普遍信任的边际效应为 0.0255,说明普遍信任每提高 1 个单位,则整地生产环节被外包出去的概率提升 2.55%。模型 2 的结果表明,信任差值的回归系数显著为负($\beta=-0.0470$, $p<0.05$),说明家庭内部信任与外部信任之间的差值越大,农民越不可能将整地生产环节外包出去。该模型中信任差值的边际效益为−0.0142,说明信任差值每提高 1 个单位,则整地生产环节被外包出去的概率减少 1.42%。模型 3 同时控制普遍信任和信任差值 2 个变量,以检验模型 1 和模型 2 的稳健性。结果表明,普遍信任的回归系数显著为正($\beta=0.0674$, $p<0.1$),信任距离的回归系数显著为负($\beta=-0.0380$, $p<0.1$),同样说明农民的普遍信任水平与整地外包正相关而信任差值与整地外包负相关。两个变量的边际效应分别为 0.0204 和−0.0115,说明普遍信任每提高 1 个单位,则整地生产环节被外包出去的概率提升 2.04%; 信任差值每提高 1 个单位,则整地生产环节被外包出去的概率减少 1.15%。与模型 1 和模型 2 比起来,模型 3 中普遍信任和信任差值的系数虽然变小,显著性也有所下降,但趋势未变,说明模型 1 和模型 2 的结果比较稳健。

模型 4 的结果表明,普遍信任的回归系数显著为正($\beta=0.0993$, $p<0.01$),说明农民的普遍信任

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越高,农民越可能将收获生产环节外包出去。该模型中普遍信任的边际效应为 0.0282,说明普遍信任每提高 1 个单位,则收获生产环节被外包出去的概率提升 2.82%。和整地外包的结果不同,模型 5 的结果表明,信任差值的回归系数不具备统计显著性(β = -0.0243, p>0.1) ,说明家庭内部信任与外部信任之间的差值与收获生产环节的外包没有显著相关关系。不过,模型 5 中信任差值的回归系数小于 0,说明与模型 2 的回归结果仍然具有一致性。模型 6 同时控制普遍信任和信任差值 2 个变量,其结果与模型 4 和模型 5 具有一致性: 普遍信任的回归系数显著为正(β = 0.0835, p<0.05) ,信任距离的回归系数不具备统计显著性(β = -0.0149, p>0.1) 。模型 6 中普遍信任的边际效应分别为 0.0239,说明普遍信任每提高 1 个单位,则收获生产环节被外包出去的概率提升 2.39%。

回归分析表明: (1) 普遍信任水平高的农民更可能将整地、收获等 2 个生产环节外包出去; (2) 信任差值水平高的农民更不可能将整地生产环节外包出去。值得关注的是,虽然在以收获外包为因变量的回归中,信任差值的系数不显著,但系数符号为负,说明信任差值与收获生产环节外包之间仍然存在负向关联。总的来说,基于农户调查数据的分析表明: 一方面,技术进步在不同生产环节之间进度不同,使得农民在生产环节间进行多样化的经营方式组合; 另一方面,普遍信任水平和信任差值在一定程度上决定农民是选择内部化的家庭经营还是外包。

表 5　回归分析结果

变量	整地外包(Probit 模型)			收获外包(Probit 模型)		
	模型 1	模型 2	模型 3	模型 4	模型 5	模型 6
普遍信任	0.0844**		0.0674*	0.0993***		0.0835**
	(0.0363)		(0.0381)	(0.0371)		(0.0381)
信任差值		-0.0470**	-0.0380*		-0.0243	-0.0149
		(0.0221)	(0.0228)		(0.0227)	(0.0231)
特殊信任	控制	控制	控制	控制	控制	控制
经营面积	控制	控制	控制	控制	控制	控制
家庭收入	控制	控制	控制	控制	控制	控制
出售农产品总值	控制	控制	控制	控制	控制	控制
村干部家庭	控制	控制	控制	控制	控制	控制
劳动力人数	控制	控制	控制	控制	控制	控制
劳动力比例	控制	控制	控制	控制	控制	控制
家庭性别结构	控制	控制	控制	控制	控制	控制
家庭文化水平	控制	控制	控制	控制	控制	控制
农业就业人口比例	控制	控制	控制	控制	控制	控制
非农就业人口比例	控制	控制	控制	控制	控制	控制
机耕路	控制	控制	控制	控制	控制	控制
姓氏	控制	控制	控制	控制	控制	控制
调查村庄	控制	控制	控制	控制	控制	控制
调查年份	控制	控制	控制	控制	控制	控制
常数	-1.7242***	-1.5583***	-1.7335***	-1.8095***	-1.6467***	-1.8613***
	(0.5894)	(0.5929)	(0.6026)	(0.5643)	(0.5667)	(0.5740)
N	2040	1939	1937	2128	2037	2035
Pseudo R^2	0.1721	0.1717	0.1731	0.2724	0.2671	0.2693
Log pseudolikelihood	-1086.6375	-1035.3420	-1032.8513	-1066.6421	-1030.3174	-1026.1746
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

注: 括号中为标准误; * 表示 p< 0.10, ** 表示 p< 0.05, *** 表示 p< 0.01。下同

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(三) 稳健性检验

若实证结果随着数据、参数或计量方法的变化而变化,则说明该实证结果并不稳健,于是需要寻找问题所在。一般来说,可以根据具体情况选择稳健性检验的方法: 第一,可以从数据出发,利用其他可以反映研究问题的数据进行计量分析,看结果是否一致; 第二,可以从变量出发,使用其他测量方法来刻画变量,看结果是否一致; 第三,从计量方法出发,如使用不同计量模型,看结果是否一致。由于难以获得相似的数据,因此本文在改变变量测量方法的基础上,改变计量分析模型进行稳健性检验。

本文前面以虚拟变量分别刻画了"整地外包"和"收获外包"2 个因变量。为了进一步刻画农民将生产环节外包的程度并进行稳健性检验,本文将 2 个变量的数值求和,构造一个新的变量"外包程度"作为因变量,即如果 2 个生产环节均未外包则赋值为 0,若外包 1 个生产环节则赋值为 1,若外包 2 个生产环节则赋值为 2。该变量的赋值存在高低顺序,但数值之间的距离并不相等,是典型的排序数据,此时采用排序模型(ordered probit model) 进行回归。此外,为了更全面刻画生产环节外包,本文还构造了新变量"是否外包"作为因变量,即对于"整地外包"和"收获外包",只要其中 1 个生产环节外包,则赋值为 1,否则为 0。该变量是一个虚拟变量,因此采用 Probit 模型进行回归。稳健性检验结果如表 6 所示。可以看出,表 6 中普遍信任的系数的显著性和表 5 保持高度一致,说明普遍信任的结果非常稳健。对于信任差值的系数,模型 8 和模型 2 的结果具有一致性。和模型 3 的结果比起来,模型 9 中信任差值的系数不显著。但 2 个回归模型中信任差值的系数符号一致,模型 9 中信任差值的系数的 t 检验值也达到了-1. 244,因此结果还是具有一致性。总的来看,计量分析结果具有较好的稳健性。

五、结论与讨论

(一) 研究结论

特殊信任有助于将家庭成员凝聚在一个农业生产组织中。本文构造了一个风险占优博弈模型用于分析特殊信任和农业家庭经营之间的关系。理论分析发现: (1) 信任意味着风险,博弈均衡取决于对局人对于对手选择"不合作"或"合作"的概率估计; (2) 在特殊信任的文化空间下,对局者之间的偷懒和搭便车行为要远远低于在普遍信任空间下,因此特殊信任是农民选择家庭经营的深层次原因; (3) 随着组织规模的扩大,家庭经营所节省的代理成本有可能要低于因代理能力有限而导致的成本增加,农民将根据组织规模在横轴的区间来选择经营方式; (4) 对于那些因技术进步而可能可以外包出去的生产环节,普遍信任水平越高,农民越有可能选择外包,而非家庭经营方式。

基于农户调查数据的实证研究为理论分析提供了实证支持,实证分析表明: 农民会根据技术进步水平的差异,在生产环节间进行多样化的经营方式组合。随着技术不断进步,部分生产环节可以进行外包,则普遍信任水平高的农民更可能通过外包来安排这些生产环节的生产活动,而信任差值水平高的农民更可能通过家庭经营方式来安排生产。

(二) 进一步的讨论: 技术进步与家庭经营方式的演化可能性

信任格局或许短期内难以改变,但技术进步却有可能重塑农业经营方式。许多生产环节因为未能实现机械替代劳动,因此家庭经营成为农民合意的选择。然而,和人工打药被无人机喷药替代一样,随着技术的不断进步,当农业生产的各个环节都可以实现机械对劳动的替代,各个生产环节都被外包,那么农业的家庭经营是否将被非家庭经营方式的外包所替代呢?

或许不断有新的生产环节由于技术进步的原因可以从家庭经营方式转变为通过外包安排生产。不过,生产的各中间环节同最终产量之间的联系,由于各种自然条件的复杂影响而不稳定,需要劳动者在整个生产过程中做出随机反应。这意味着,作为生物的"照料者"和"侍弄者",经营者不但必须

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安排每个生产环节本身的生产活动，还必须统筹所有的生产环节。经营者必须及时而充分地获得生产过程中巨量的不规则信息，并且立即做出有效反应。经营者还必须对各个生产环节进行监督，小心翼翼地最大化最终产量（中国农村发展问题研究组，1984）。也就是说，由于统筹各个生产环节本身难以标准化，由特殊信任机制决定的家庭经营方式仍然难以被替代，印证了列宁（1901）所说的“农业有许多绝对不能消除的特点。由于这些特点，农业中的大机器生产永远也不会具备工业中的大机器生产的全部特点。”

表 6　稳健性检验结果

变量	外包程度（Orderedprobit 模型）			是否外包（Probit 模型）		
	模型 7	模型 8	模型 9	模型 10	模型 11	模型 12
普遍信任	0.0971***		0.0795**	0.1079***		0.0888**
	(0.0312)		(0.0324)	(0.0359)		(0.0372)
信任差值		−0.0340*	−0.0245		−0.0328	−0.0223
		(0.0194)	(0.0197)		(0.0222)	(0.0226)
特殊信任	控制	控制	控制	控制	控制	控制
经营面积	控制	控制	控制	控制	控制	控制
家庭收入	控制	控制	控制	控制	控制	控制
出售农产品总值	控制	控制	控制	控制	控制	控制
村干部家庭	控制	控制	控制	控制	控制	控制
劳动力人数	控制	控制	控制	控制	控制	控制
劳动力比例	控制	控制	控制	控制	控制	控制
家庭性别结构	控制	控制	控制	控制	控制	控制
家庭文化水平	控制	控制	控制	控制	控制	控制
农业就业人口比例	控制	控制	控制	控制	控制	控制
非农就业人口比例	控制	控制	控制	控制	控制	控制
机耕路	控制	控制	控制	控制	控制	控制
姓氏	控制	控制	控制	控制	控制	控制
调查村庄	控制	控制	控制	控制	控制	控制
调查年份	控制	控制	控制	控制	控制	控制
常数				−1.5083***	−1.2904**	−1.5109***
				(0.5632)	(0.5665)	(0.5745)
cut1	1.4238***	1.2425**	1.4513***			
	(0.5337)	(0.5324)	(0.5415)			
cut2	2.3403***	2.1503***	2.3602***			
	(0.5355)	(0.5340)	(0.5432)			
N	2409	2311	2308	2267	2152	2150
Pseudo R^2	0.2409	0.2401	0.2413	0.2840	0.2766	0.2788
Log pseudolikelihood	−1832.6429	−1762.9771	−1758.2086	−1123.9664	−1078.6038	−1074.3547
p	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

当然，在某些设施农业中，人们不但可以标准化各个生产环节，还通过控制温度、湿度和光照的方式来标准化生产环节的统筹。此时，不但监督和计量单个生产环节的成本低廉，而且容易将单个生产环节的成果同最终产量联系起来，因此也降低了统筹各个生产环节的难度，此时决定农业的生产经营方式主要是代理能力而非因信任带来的代理成本，因此非家庭经营更合意。这和 Allen 等（1998）所指出的“当能控制农业生产的季节性和不确定性时，农场组织将趋于工业化与公司化”的结论是一致

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的。事实上,这也是为什么标准化的蘑菇生产组织一般是企业组织形式的原因。此外,韩朝华(2017)注意到,家庭经营的优势只限于农业中的直接生产环节,而在与直接生产相衔接的诸产前、产后环节中,非家庭经营更具优势。韩朝华(2017)采纳了 Valentinov(2007)的解释,认为经营主体在面对上下游贸易伙伴时能力有限,因此处于弱势地位,因此需要合作社来抗衡。在本文的模型里,其原因仅仅在于产前、产后各环节更容易标准化,因此劳动的监督与计量成本都偏低,而面对大市场又要求代理人拥有较高的能力,因此表现为产前、产后环节大都采用非家庭经营的生产方式。所以,如果在标准化各个生产环节的同时,还能够标准化生产环节的统筹,则农业生产将趋于工业化与公司化。

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Technical Progress, Trust Pattern and the Outsourcing of Agricultural Production Links

XIE Lin, HU Xinyan, LUO Biliang

Abstract: Technological progress has enabled some agricultural production links to be outsourced. The article argues that organizing production within the family or outsourcing is essentially a cooperative behavior. Special trust helps reduce the supervision cost in cooperation and make agricultural household management have a cost advantage. However, with the expansion of the scale, the cost savings brought about by special trust may not be sufficient to make up for the cost increase brought about by the limited agency capacity of family members. Farmers will choose to outsource the production process at this time. Empirical research shows that a higher level of general trust is conducive to farmers' outsourcing behavior, but the more significant the trust difference between service providers and their families, the more farmers tend to organize production within their families. As for the future of family business, the article holds that even if technological progress enables production activities to replace labor with machinery, the special trust mechanism still makes it challenging to replace family business because it is challenging to standardize all production links.

Keywords: Technical progress; General trust; Special trust; Outsourcing

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农业规模经营真的有助于化肥减量吗？
——来自荟萃分析的证据

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摘 要 旨在利用荟萃分析的研究方法，分析农业经营规模与化肥施用强度之间的关系，以及导致现有实证文献研究结果异质性的原因。结果表明：1)农业经营规模与化肥施用强度之间存在微弱的负相关关系；2)这种负相关关系受到农户受教育程度、年龄、研究所在国别和研究时间等因素的显著影响，即这4种因素是现有实证文献研究结果异质性的重要来源。综上，从现有的实证文献来看，农业规模经营确实有助于化肥减量化，但仍然需要深入讨论其调节变量的隐性作用机制。

关键词 农业规模经营；化肥施用强度；荟萃分析；荟萃回归分析
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Does agricultural scale management help reduce fertilizer use? Evidence from meta-analysis

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Abstract The purpose of this paper was to determine whether big farm contributes to fertilizer reduction, and to identify sources that lead to heterogeneity of research results in the existing empirical literature by meta-analysis. The results showed that: 1) There was a weak negative correlation between the farm size and the intensity of fertilizer use; 2) The empirical findings of this negative correlation were significantly affected by the degree of education of farmers, age, research country, and time of the research published. The four factors were relevant sources of heterogeneity of the existing empirical literature research results. In conclusion, agricultural scale management does contribute to reduce fertilizer, but the recessive mechanism of its regulatory variables still needs to be discussed in depth.

Keywords agricultural scale management; fertilizer use intensity; meta-analysis; meta-regression analysis

作为世界上最大的化肥消费国，中国存在严重的化肥过量施用问题[1]。在中国农业向规模经营与绿色经营“双转型”的背景下，经营规模与化肥施用强度之间的关系成为许多研究者关注的焦点问题。但是，已有研究的结论却往往并不一致：大量基于中国的研究认为，经营规模和化肥施用强度之间存在负向相关关系，即规模经营有助于化肥减量化[2-7]。然而，也有研究显示经营规模和化肥施用强度之间的关系并不显著[8-10]，甚至有研究表明两者之间存在正向相关关系[11-14]。基于其他发展中国家数据的

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实证研究也表明：经营规模和化肥施用强度之间存在正向相关关系[15-17]。究其原因，可能在于已有研究的取样多数只限于某一地，或某一作物，减弱了研究结论的普适性。事实上，各类情境因素均会影响到变量之间相关关系程度，甚至符号方向[18]。因此，不同甚至矛盾的研究结论可能源于不同的情境因素。为此，学术界仍然有待厘清以下 2 个问题：(1)农业规模经营真的有助于降低化肥施用强度吗？(2)两者之间的关系受到哪些情境因素的影响？

作为一种文献综述方法，荟萃分析已由最初的医学领域拓展至经济学和管理学等多个学科领域[19-20]。传统文献综述方法整理以往研究文献得出结论，但作为定性研究，其自身会存在不足，如研究者的主观意识对所得结论有较大影响，而且在综述过程中往往会忽视所得结论是否具有统计意义[21]。荟萃分析为定量研究方法，能弥补传统叙述性文献综述上述的不足，即通过量化文献，得到更为客观准确的结论。而且荟萃分析以及由其衍生出的荟萃回归分析技术不仅可以评估变量之间的关系及其强度，还能探寻变量关系中的调节变量。如果现有研究中经营规模和化肥施用强度之间的关系在不同样本之间存在差异，且这些样本在某些特质方面存在不同，那么这些样本特质就可以成为两者之间关系的调节变量[22]。鉴于此，本研究基于荟萃分析技术，评估农业经营规模和化肥施用强度之间的真实相关性，并进一步利用荟萃回归分析方法深入探究种植结构、教育、年龄、国别和时间等潜在调节变量的作用。

1　关于农业规模经营的化肥减量效应的争论

自 Feder 等[23]识别出规模经营是决定发展中国家农户化肥施用行为的关键因素之一以来，规模经营的化肥减量效应引起了众多研究者的注意。针对中国情境，许多研究认为随着经营规模的扩大，中国农户的化肥施用强度也随之降低。蔡颖萍和杜志雄[2]基于 1 322 个家庭农场的问卷指出，大型家庭农场更容易应用测土施肥技术，因此化肥施用水平更低。他们还认为，大型家庭农场存在样本选择问题，即那些拥有更高社会责任和现代思维的农户更可能成为大型农场主，并进一步使得这些农场主减少施用对环境有害的化肥。而且，随着经营规模的扩大，大型家庭农场因考虑成本控制而加大应用先进科学和管理技术力度，进而降低化肥施用强度。Zhang 等[3]基于湖北省梁子湖区的 300 户农户调查数据也发现，化肥施用强度与经营规模存在负向相关关系，其中那些经营规模较小的农户倾向于寻找非农就业机会，在农业生产中花费更少的时间，因此忽视了先进施肥技术在农业生产中的应用，并由此导致更高的化肥施用强度。这与 Wu 等[4]使用浙江大学“中国家庭数据库”的实证研究结果一致。此外，还有很多实证研究表明经营规模与化肥施用强度之间存在负向相关关系[5-7]，说明化肥施用存在“规模经济”效应。

然而，一些实证研究却发现经营规模与化肥施用强度之间存在正向相关关系。杨钢桥和靳艳艳[11]研究指出，大型农场的经营目标已经从生存需求转向追逐利润，由此导致化肥施用强度的增加。徐卫涛等[12]基于 375 户农户调查问卷数据的实证研究发现，在农业技术推广缺失的中国农村地区，播种面积更大的农户更可能增加化肥施用强度。田云等[13]发现，经营规模越大，农户越不可能以低于标准或按标准施肥。当经营规模扩大时，农户将通过加大化肥的投入以获得更多的收益。Hu 等[14]则从化肥施用效率出发，基于 2004—2006 年 4 281 户农户调查数据的实证分析得出，经营面积最小的农户群体的化肥施用效率最高，从侧面说明经营规模越大，化肥的施用强度越大。此外，也有研究认为，经营规模与化肥施用强度之间并没有显著相关关系[8-10]。

2　引起争论的原因：调节作用分析

现有文献关于经营规模与化肥施用强度之间的关系并未得出统一的结论，究其原因，可能在于不同研究存在异质性因素：某些调节变量会影响经营规模与化肥施用强度之间的关系，由此导致两者之间的关系在不同样本之间存在差异。首先，现有研究已经表明不同的作物所要求的化肥施用量不同[24]，那么经营规模与化肥施用强度之间的关系可能受种植结构的影响；其次，农户的知识、经验对于农户规模经营的能力和化肥施用行为密切相关[2]，因而农户的受教育程度和年龄等人力资本特征也可能是重要的异质性来源。此外，每个不同研究都存在各种特定的情境因素，如研究的地点、时间等[18]，因而研究的国别和时间也可能是潜在异质性的来源。现有关于经营规模与化肥施用强度之间关系的研究多数报告了种植的作物品种、农户受教育程度、农户年

龄、研究所在国别和研究时间等信息，为荟萃分析探讨调节作用提供了可能性，因而本研究将这些变量作为调节作用分析的重点。

2.1 种植结构的调节效应

经济作物的经济价值比粮食作物大。受潜在产出价值增加等心理预期的激励，农户对经济作物的化肥施用强度要显著高于主粮作物[5]。实证研究也表明，经济作物的化肥施用量普遍高于粮食作物[24]。实践中，经济作物播种面积比例的逐步增长，是导致中国化肥施用强度增加的重要原因[25-27]。以经济作物苹果为例，农民会通过增加化肥投入以获得更大的产量来提高收入[7]。因而，种植结构的变化会导致化肥施用强度的变化[28]。纪月清等[29]基于中国农村固定观察点的农户调查数据也发现，种植的作物不同，经营规模与化肥施用强度的关系也不同。Rahman[30]基于孟加拉国17个地区的2 083户农户数据的实证研究同样表明，经营规模与化肥施用强度之间的关系受农作物种植品种的影响。

2.2 农户受教育程度的调节效应

人力资本积累是现代农业发展的重要前提[31]。发展中国家的农民普遍欠缺农业化学投入品施用知识，因此较难按要求施用[1,32]。诸多基于中国数据的研究发现，农民缺乏科学知识是导致化肥滥用的关键原因之一[1,33]。而农资市场的差异化发展更是加重了这种趋势[29]。

农技推广体系的商业化浪潮使得其难以提供合适的农业技术培训[1,4]，因此农民自身的教育水平显得更为重要。研究表明，受教育程度较高的农民知识储备丰富，更注重施肥效果[34]；懂得更多合理施肥的知识与技术要点[35]；接受新事物的能力较强，见识与视野更宽阔，更有远见，更愿意选择生态生产行为，并通过减少化肥投入强度来保护耕地质量与农村环境[2]。相反，教育程度较低的农户缺乏基本知识，仅靠务农经验耕作，不愿接受外界新的信息，也不愿学习节肥技术等科学种植技术[36]，追求眼前小利，往往通过增加化肥的施用来获取更多收益[37]。多项实证研究也表明，农户受教育程度与化肥施用强度之间存在负向相关关系[2,35,38-39]。和小农户相比，大规模农场更容易应用现代施肥农业技术[4]。如水肥一体化、无人机施肥技术都对经营规模提出了要求。那么，高人力资本的优势在大规模农场能够获得更好的发挥，即教育能够帮助大农户更好地实现化肥减量化。

2.3 农户年龄的调节效应

在中国，农户的施肥行为是一个相对稳定的经验行为，很少存在恶意增大化肥投入的现象[5]。随着年龄的增长和务农年限的增加，农户可以积累更多农业经验，能更好地判断作物对化肥的要求并合理施肥[13]。由于农户认知与经验的积累，他们更容易接受新颖的农业技术，更愿意采用现代施肥技术[40]。在其他发展中国家，Fufa等[41]基于埃塞俄比亚农户调查数据的实证研究表明，农户年龄是影响化肥施用强度的重要因素。随着年龄的增长，农民对新兴技术有更多的了解，能有效率地使用新技术来减少化肥投入。Akpan等[42]基于尼日利亚农户调查数据的研究同样发现，化肥施用强度随农户年龄增加而减少。可见，农户年龄不同，会对规模经营与化肥减量化行为之间的关系产生影响，导致实证结果的异质性。

2.4 国别的调节效应

发展中国家的农业大都以小农户经营为主[23]。但中国与许多发展中国家不同：中国的农业技术相对先进，市场上化肥供应充足，价格相对低廉。在劳动力成本不断攀升的情况下，中国农民普遍存在化肥滥用问题。来自FAO的数据显示，中国已经成为世界上最大的化肥和农药消费国，2016年，中国大陆的氮肥、磷肥和钾肥施用量分别占全球的27.647%、32.230%和35.428%，氮肥、磷肥、钾肥施用强度分别为138.64、49.81和38.22 kg/hm^2，分别是同期全球水平的2.01倍、1.63倍和1.57倍[5]。这与其他发展中国家化肥短缺，小农户化肥施用量不够甚至少施化肥的情况形成了鲜明的对比，如撒哈拉以南非洲地区2005—2014年平均化肥消耗量14 kg/ha^2，而全球为127 kg/ha^2[43]，差距十分明显。实际上，早期关于发展中国家农户化肥施用行为的研究是在“绿色革命”的背景下进行的，认为农户采纳化肥技术是其接受现代农业技术的重要表现方式。许多来自诸如泰国、埃塞俄比亚和肯尼亚等发展中国家的研究表明，经营规模与化肥采纳之间存在正向相关[15-17]。在这些较落后的发展中国家，较大的农场可能无需依赖信贷计划就有较多现金购买化肥并投入农业生产[16]，而普通小农户则因信贷约束缺乏资金购买。因此农户的农地规模越大，其获得并使用化肥的能力越强。可见，其他发展中国家和中国农业生产中化肥施用的出发点是不同

的，前者仍然希望通过“绿色革命”来提高农业生产率，而中国农业则向化肥减量化的发展阶段转型。

一些发达国家的经验也可以在侧面印证上面的问题。许多发达国家的农业集约化发展早于发展中国家，自 20 世纪 80 年代末以来，欧美发达国家开始重视对农业面源污染的研究和治理，积极开展化肥减量化行动，降低化肥施用强度[44]。Wu 等[4]研究也发现，化肥施用与经济增长的环境库兹涅茨曲线(EKC)一致，化肥施用强度会随人均 GDP 的提高先增加再减少，呈倒 U 型变化趋势，即人均 GDP 较高的国家，农业科学技术与专业管理的广泛应用有助于提高化肥施用效率。可见，国别不同，处于不同经济发展阶段的农业政策也会导致规模经营的化肥减量效应出现差异。

2.5　研究时间点的调节效应

本研究纳入荟萃分析的文献的时间跨度长达 35 年，在此期间农业生产条件发生了巨大变化。以中国为例，早期在土壤质量条件较低与向地要粮的时代背景下，中国制定的化肥施用标准高于世界标准[5]，期望通过化肥施用弥补农地质量的不足。在过去的几十年里，中国逐步建立起较为完整的化肥工业体系，化肥施用量直线上升。然而，随着科学技术的发展，农业生产要求机械化、专业化和科学化，化肥的施用也更追求合理化、科学化和环境保护。为此，中国出台了多项政策，以推动化肥减量化。随着时间推移，各国的化肥施用政策在不断改变，农民也会根据政策环境的变化对其化肥施用行为进行调整。这意味着，农户的化肥施用行为还可能受到时间因素的影响。尤其是经营规模更大的农户，其人力资本水平更高，且更具社会责任和现代思维，因而更容易接受最新的施肥技术和政策[2]，那么，随着时间的推移，不同经营规模的农户的施肥行为变化幅度也将不同。

3　研究方法

3.1　文献搜索

为确保数据的准确性与完整性，本研究较为全面地搜索了中文和英文文献。中文文献主要通过中国知网(CNKI)期刊数据库、中国优秀硕士论文全文数据库、中国博士学位论文全文数据库、维普数据库、万方数据库进行搜索。中文文献搜索关键词包括化肥施用行为、经营规模、化肥投入水平和农业化学品使用等。英文文献主要在 Springer Link、Elsevier Science、EBSCO-ASP 综合学科研究文献全文库、Emerald 期刊全文库、Wiley-Black-Well、ProQuest 期刊全文库与 ProQuest 硕博士论文全文数据库和 Google scholar 中搜索，英文文献搜索关键词为 farm size and fertilizer、chemical fertilizer use、determinants of fertilizer use、fertilizer application intensity、fertilizer use strength 和 influencing factors of fertilizer use 等。为了避免文献遗漏，本研究还对搜索到的相关文献的参考文献进行第二次搜索，即对样本文献中所有涉及研究主题的中英文参考文献进行手工搜索，确保样本文献的全面性。

3.2　文献筛选

结合研究主题和荟萃分析方法的要求，纳入本研究荟萃分析的文献符合以下条件：(1)必须包含农业经营规模与化肥施用强度等 2 个变量。(2)必须是实证研究，排除纯理论与文献综述类文献，并在论文中报告了样本量、相关系数或者其他可转换为效应值的数据指标。(3)各研究之间的样本必须是独立的。若 2 个研究之间的样本相同或存在交叉重叠，则选择报告内容更详细或者样本更大的研究纳入分析。本研究从中英文数据库中搜索出 550 篇相关文献，通过上述条件进行筛选，最终有 45 篇文献符合荟萃分析的要求，其中中文文献 17 篇，英文文献 28 篇(表 1)。

3.3　文献编码

本研究根据 Lipsey 和 Wilson[45]的步骤进行文献编码，研究特征主要包括文献作者、出版年份、样本量、研究国别、经营规模、化肥施用强度及研究对象等。效应值包括各相关变量的相关系数、回归系数及其显著性水平等指标。文献效应值以每一样本一个效应值进行编码，如文章中同时报告了多个样本，对效应值进行分开编码。当编码步骤完成后，由另一位研究者对随机抽取出的部分研究重新编码，以保证编码的准确性，如编码出现内容不同，则回到文献原文进行比对。在本研究中，2 位研究者编码一致性为 91.5%，说明在文献编码过程中人为误差较小，编码较为准确。最终，本研究获得 63 个独立效应量，总样本量达到 148 411 个。

3.4　效应值计算

本研究使用 CMA2.0(Comprehensive meta-analysis 2.0)软件进行荟萃分析，并以相关系数作为效应量对经营规模与化肥施用强度的关系进行研究。在编码时，有些文献没有直接报告相关系数，而

表1 纳入荟萃分析研究的文献资料目录

Table 1 Catalog of literature materials included in meta-analysis research

编号 Number	作者 Author	发表时间 Issuing time	国家 Country	样本量 Sample size	编号 Number	作者 Author	发表时间 Issuing time	国家 Country	样本量 Sample size
1	Mandac & Flinn	1985	菲律宾	476	24	Wiredu 等	2015	加纳	820
2	Daramola	1989	尼日利亚	122	25	Huang 等	2015	中国	481
3	Mbata	1994	肯尼亚	133	26	玛衣拉·吐尔逊等	2015	中国	446
4	Coady	1995	巴基斯坦	1 351	27	Emmanuel 等	2016	加纳	470
5	Bacha 等	2001	埃塞俄比亚	97	28	Jiang & Li	2016	中国	432
6	Freeman & Omiti	2003	肯尼亚	399	29	尹晓宇	2016	中国	293
7	Waithaka 等	2007	肯尼亚	253	30	Danso-Abbeam & Baiyegunhi	2017	加纳	838
8	Fayaz 等	2008	巴基斯坦	60					
9	Msuya	2008	坦桑尼亚	113	31	Pan 等	2017	中国	386
10	Akpan & Aya	2009	尼日利亚	130	32	Zhang 等	2017	中国	283
11	Olwande 等	2009	肯尼亚	1 275	33	陈黎 & 仇蕾	2017	中国	182
12	Marenya & Barrett	2009	肯尼亚	243	34	李宾等	2017	中国	316
					35	刘甜	2017	中国	91
13	Zhou 等	2010	中国	349	36	杨万江 & 李琪	2017	中国	678
14	郑鑫	2010	中国	223	37	诸培新等	2017	中国	79
15	Chibwana 等	2011	马拉维	380	38	Haider 等	2018	布基纳法索	517
16	杨慧	2011	中国	325	39	Pan & Zhang	2018	中国	687
17	Akpan 等	2012	尼日利亚	150	40	Wu 等	2018	中国	202
18	项诚等	2012	中国	342	41	黎孔清 & 马豆豆	2018	中国	203
19	庄钠	2012	中国	236	42	宁运旺等	2018	中国	442
20	Isaac Nunoo 等	2013	加纳	200	43	陈俭军	2019	中国	179
21	A. A Obisesan 等	2013	尼日利亚	110	44	高晶晶等	2019	中国	116 613
22	Gurara & Larson	2013	埃塞俄比亚	4 126	45	刘静 & 连煜阳	2019	中国	598
23	周智炜等	2013	中国	202					

是报告了 t 检验值、F 检验值，或者 χ^2 检验值，本研究根据郑凤英和彭少麟[46]的公式将相关指标转换成相关系数。有部分文献只报告了回归系数，本研究根据 Peterson 和 Brown[47]所提供的公式对回归系数进行转换，其中回归系数的适用范围为(−0.5，0.5)。随后将文献中报告的，或者通过上述计算出的 r 值进行 Fisher's Z 值转换，得出研究分析所需数据。

3.5　出版偏差

多数期刊更愿意发表实证结果显著的文章，而结果不显著的文章发表较少。因此，纳入荟萃分析的文献可能会存在出版偏差问题。为此，本研究首先采用漏斗图(Funnel plot)(图 1)对是否存在严重的出版偏差进行检验。可以看到，研究样本基本分布在总效应两边，说明不存在严重的出版偏差。

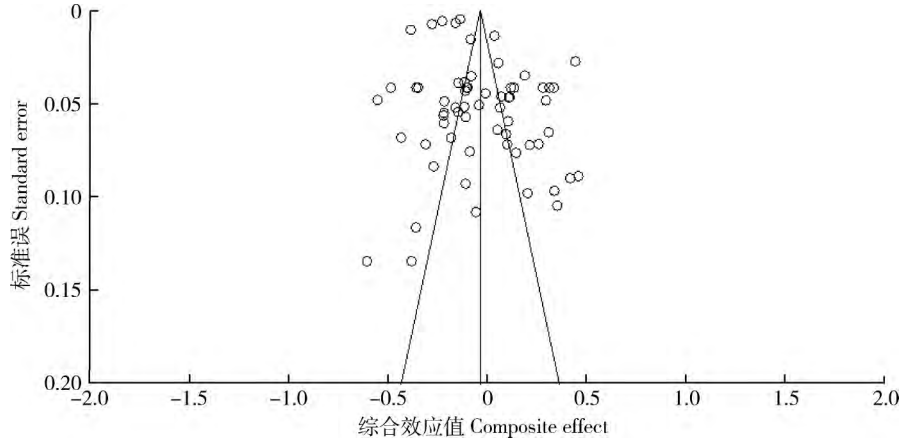


图 1　主效应的漏斗图

Fig. 1　Funnel plot of main effect

然后，本研究通过失安全系数 N(Classic fail-safe N)对出版偏差问题进行进一步检验。所谓失安全系数 N 是指研究中要包含多少未出版的研究才能把本次研究中累积效应量减低到不显著水平[48]。若计算出来的系数 N 与研究样本数量相差较大，则说明本研究的出版偏差小，不存在严重的出版偏误。结果表明，本研究的失安全系数 N 为 8 723，即要额外增加 8 723 篇文献作为样本进行分析才能否定经营规模与化肥施用强度之间的关系，说明本研究不存在严重的出版偏差。

3.6　异质性检验

异质性检验(Heterogeneity test)用于研究效应值的变化程度，目的在于判断主效应之间是否存在调节效应。如存在异质性，那么主效应间存在潜在的调节变量。本研究使用 I^2 检验和 Q 检验来进行异质性检验。I^2 检验即效应值的变异占总变异的百分比：$0 \leqslant I^2 < 25\%$ 表示不存在异质性；$25\% \leqslant I^2 < 50\%$ 表示存在低异质性；$50\% \leqslant I^2 < 75\%$ 表示存在中度异质性；$75\% \leqslant I^2 < 100\%$ 表示存在高异质性[49]。Q 检验值则符合卡方分布，如 $P<0.05$，即说明效应值存在异质性。

异质性检验结果见表 2 所示。可以看出，I^2 值为 97.819%，表示效应值的变异占总变异的 97.819%；各样本研究效应值的 Q 检验也具备统计显著性($Q=2\,842.743$，$P<0.001$)，说明荟萃分析中效应值存在高度异质性，即主效应间存在潜在调节变量。

异质性检验结果还可以用于判断荟萃分析应该采用固定效应模型还是随机效应模型。固定效应模型和随机效应模型的不同点在于对文献研究结论之

表 2　异质性检验

Table 2　Heterogeneity test

结果变量 Outcome variable	效应值数量 Number of effect values	Q	df	P	I^2
经营规模与化肥施用强度	63	2 842.743	62	<0.001	97.819

间差异的原因持不同的假设：固定效应模型认为，全部研究只有一个真实效应值，研究结论的不同仅因为抽样误差；随机效应模型则假设每个研究都有其真实效应值，结论的差异不仅仅是由于抽样误差[50]。一般来说，如果异质性检验中 Q 检验值的 P 值<0.01 且 $I^2>50\%$，则使用随机效应模型更为合适，反之，则使用固定效应模型[51]。本研究的异质性检验表明，I^2 为 97.819%（$I^2>50\%$）且 Q 检验值为 2 842.743（$P<0.001$），因此本研究应采用随机效应模型进行调节效应分析。

4 结果与分析

4.1 主效应分析

荟萃分析结果见表 3。Cohen[52] 认为，综合效应量在 0.1 以下说明相关性较弱。本研究的随机效应模型结果表明，综合效应量为 −0.042（$P<0.05$），表明经营规模与化肥施用强度之间存在负向相关关系。这与 Wu 等[4] 和 Sun 等[6] 的实证研究结果一致，即农地经营规模与化肥施用强度存在负相关关系。这意味着，综合现有实证文献的证据表明，农业规模经营确实有助于化肥减量化，尽管这种作用比较微弱。

4.2 调节效应分析

异质性检验表明，效应值之间具有高度异质性，说明存在潜在调节变量对农户经营规模与化肥施用强度之间的主效应产生影响。实际上，主效应分析中显示经营规模与化肥施用强度之间的相关关系过于微弱，其原因可能就在于潜在调节变量的影响。本研究通过荟萃回归分析方法进一步来探索异质性来源与调节变量的作用，即借鉴 Stanley 和 Jarrell[53]，以及张晓和胡丽娜[20] 的方法，把各样本研究中农户经营规模与化肥施用强度的相关系数作为被解释变量，将潜在调节变量赋值并作为解释变量进行荟萃回归处理。潜在调节变量的赋值方法及荟萃回归分析结果见表 4。

表 3 主效应的荟萃分析

Table 3 Meta-analysis of main effect

方法 Method	总样本 Total sample	效应值数量 Number of effects	综合效应值 Composite effect value	LL	UL	Z 统计值 Z statistics	P 值 P value
随机效应	148 411	63	−0.042	−0.082	−0.003	−2.097	0.036

注：LL、UL 分别表示 r 的 95%置信区间下限与上限。

Notes: LL and UL represent the lower and upper limits of the 95% confidence interval of r, respectively.

表 4 调节变量的荟萃回归分析

Table 4 Meta-regression analysis of moderators

调节变量（变量定义） Moderator (variable definition)	效应值数量 Number of effects	系数 Coefficient	标准误 Standard error	Z 统计值 Z statistics	P 值 P value
种植结构（1=经济作物，0=粮食作物）	39	−0.048	0.083	−0.570	0.567
农户受教育程度（1=受教育年数≥7 年，0=受教育年数<7 年）	39	−0.192	0.069	−2.790	0.005
农户年龄	31	−0.030	0.010	−2.990	0.003
国别（中国=1，非中国=0）	63	−0.169	0.059	−2.840	0.004
研究时间（2020—文献发表时间）	63	0.009	0.004	2.160	0.031

（1）种植结构的调节效应。各样本研究涉及的作物可以分为经济作物和粮食作物，其中经济作物包括水果、蔬菜、烟草、可可、油料作物等，而粮食作物主要包括水稻、玉米、小麦等。此外，有 24 个效应值所在的样本研究没有明确划分作物类型，因此未包含在种植结构潜在调节变量的分析中。由表 4 可

知，种植结构的回归系数不具备统计显著性（$\beta=-0.048$，$P>0.1$），说明种植结构未在经营规模与化肥施用强度之间的关系中起调节作用。原因可能在于，在一些研究中样本农户种植规模偏小，主要以自给为主，区分经济作物与粮食作物对他们意义不大，在施肥的过程中，农户为了便利会一视同仁，化肥施用行为存在一致性。

（2）农户受教育程度的调节效应。考虑到不同研究中对农户受教育程度的测量指标并不一致，因此本研究对农户受教育程度进行了重新编码。大多数国家为 6 年制小学教育，故本研究将受教育年份≥7，或者接受过小学以上教育的农户视为受教育水平较高的农户，并赋值为 1，否则负值为 0。对于那些没有报告受教育程度的研究，本研究并未纳入关于教育程度潜在调节变量的分析。荟萃回归结果显示，农户受教育程度的回归系数显著为负（$\beta=-0.192$，$P<0.01$），说明农户受教育程度越高，经营规模与化肥施用强度之间的负向关系将增强。这与蔡颖萍和杜志雄[2]、史常亮等[35]的实证研究结果一致。他们认为教育提升了思维方式，有助于农户接受新技术，认识到作物产量的增加不仅依靠化肥的使用，也可以通过调整作物间距、种植优良品种等其他方式来实现。而且，文化水平较高的农户更具长远思维，不过分追求通过施用大量化肥来获取短期收益，而会合理施用化肥，强化土壤健康，重视面源污染问题以实现长期稳定收益。

（3）农户年龄的调节效应。样本文献一般报告了农户户主年龄的均值，本研究以其作为自变量进行回归，来探寻农户年龄的调节效应。在删除没有报告农户年龄的样本后，本研究最后获得 31 个效应量。荟萃回归结果显示，农户年龄的回归系数显著为负（$\beta=-0.030$，$P<0.01$），说明随着农户年龄的增长，经营规模与化肥施用强度之间的负向关系将增强，与田云等[13]的实证结果一致。

（4）国别的调节效应。在纳入荟萃分析的文献中，样本涉及中国、菲律宾、肯尼亚、尼日利亚、加纳、埃塞俄比亚、巴基斯坦和坦桑尼亚等多个国家。为了研究国别的影响，本研究构造了国别虚拟变量，即将基于中国的研究赋值为 1，否则赋值为 0。荟萃回归结果表明，“中国”虚拟变量的回归系数显著为负（$\beta=-0.169$，$P<0.01$），说明和其他发展中国家比起来，中国农户经营规模与化肥施用强度之间的负向关系更强，进一步印证了 Demeke 等[16]、Olwande 等[17]对于其他发展中国家中规模经营促进化肥施用的研究结论；但在中国，正如 Zhang 等[3]、高晶晶等[5]表明的，规模经营有助于减少化肥施用。类似于撒哈拉以南的非洲国家，发达程度较低，甚至有的还未进行农业“绿色革命”，农业生产力低[54]，面临的国民温饱与国家粮食安全问题较严重，加上经济较弱、科学技术落后，农业难以提过专业化、科学化生产来提高产量，更多地希望增加化肥使用量以实现增产。但是在中国，随着社会经济的不断进步，人们更注重农业生产的科学化，并推进化肥减量化工作。

（5）研究时间的调节效应。由于有的样本研究没有报告明确的研究时间点，所以本研究将 2020 年与文献发表年份的差值作为研究时间变量进行荟萃回归分析。结果显示，研究时间变量的系数显著为正（$\beta=0.009$，$P<0.05$），说明距离 2020 年时间越远的研究，经营规模与化肥施用强度越可能正相关，即相比早期的研究，时间越近的研究中经营规模与化肥施用强度之间的负向关系将增强。这一结果反映出，随着社会与技术不断进步，化肥的施用更加追求合理化。

4.3　稳健性检验

4.3.1　改变因变量刻画方式

为检验实证结果的稳健性，本研究变换了被解释变量的刻画方式重新进行荟萃回归分析。本研究构造了一个新的被解释变量：若经营规模与化肥施用强度显著正相关则赋值为 1，若无显著相关关系则赋值为 0，若显著负相关则赋值为 −1。考虑到被解释变量为排序变量，因此使用 Ordered Logit 模型进行回归分析。在本研究中，虽然被解释变量被刻画为排序数据会丢失一部分信息，但可以将那些不能将效应值转换为相关系数的研究纳入回归分析里面来，因此增加了样本研究的数量。在稳健性检验中，样本研究的效应量数量最多的回归达到 108 个。由表 5 可以看出，各潜在调节变量的回归系数符号和显著性与表 4 具有高度的一致性，说明实证结果非常稳健。

4.3.2　亚组检验

亚组检验（Subgroup analysis）是荟萃分析中分析主效应调节变量的常用方法之一[55]。亚组检验按潜在调节变量的大小进行分组，并对各组的综合效应值是否相等进行统计检验，以解释是否存在异质性[56]。亚组检验结果如表 6 所示，结果表明：

(1)经济作物与粮食作物的效应值没有显著区别($Q_b=0.182$,$P>0.1$),说明种植结构未在经营规模与化肥施用强度之间的关系中起调节作用;(2)高教育组的效应量为-0.142,低教育组的效应量为0.055,且两者差异显著($Q_b=12.064$,$P<0.01$),说明农户受教育程度越高,经营规模与化肥施用强度之间的负向关系越强;(3)以研究样本的年龄均值(51.010)分组,高年龄组的效应量为-0.153,低年龄组的效应量为0.034,且两者差异显著($Q_b=13.433$,$P<0.01$),说明农户年龄越大,经营规模与化肥施用强度之间的负向关系越强;(4)中国组的效应量为-0.105,非中国组的效应量为0.066,且两者差异显著($Q_b=16.453$,$P<0.01$),说明和其他发展中国家比起来,中国农户经营规模与化肥施用强度之间的负向关系更强;(5)以1985年至2019年的中间年份2002为界分组,近期研究的效应量为-0.065,早期研究的效应量为0.235,且两者差异显著($Q_b=8.457$,$P<0.01$),说明与早期研究相比,时间较近的研究中经营规模与化肥施用强度之间的负向关系更强。可以看出,亚组检验的结果与调节效应分析的结果具有高度一致性,进一步说明了实证结果的稳健性。

表5 稳健性检验

Table 5 Robustness test

调节变量(变量定义) Moderator (variable definition)	效应量数量 Number of effects	系数 Coefficient	标准误 Standard error	Z统计值 Z statistics	P值 P value
种植结构(1=经济作物,0=粮食作物)	63	0.147	0.520	0.280	0.778
农户受教育程度(1=受教育年数≥7年,0=受教育年数<7年)	59	−1.791	0.556	−3.220	0.001
农户年龄	46	−0.187	0.086	−2.180	0.029
国别(中国=1,非中国=0)	108	−1.330	0.399	−3.330	0.001
研究时间(2020—样本研究时间)	108	0.107	0.034	3.100	0.002

表6 亚组检验

Table 6 Subgroup analysis

调节变量 Moderator	类别 Category	效应量数量 Number of effects	综合效应值 Composite effect	LL	UL	Q_b	P value
种植结构	经济作物	16	−0.057	−0.170	0.057	0.182	0.670
	粮食作物	23	−0.031	−0.072	0.011		
农户受教育程度	高	19	−0.142	−0.187	−0.096	12.064	0.001
	低	20	0.055	−0.046	0.156		
农户年龄	高(≥51.010)	14	−0.153	−0.202	−0.102	13.433	0.000
	低(<51.010)	17	0.034	−0.057	0.124		
国别	中国	39	−0.105	−0.146	−0.065	16.453	0.000
	非中国	24	0.066	−0.006	0.138		
研究时间	近期(时间>2002年)	58	−0.065	−0.102	−0.027	8.457	0.004
	早期(时间≤2002年)	5	0.235	0.038	0.414		

注:采用随机效应模型;Q_b表示组间异质性的Q检验。

Notes: Using random-effects model; Q_b is the Q test for heterogeneity between groups.

为更直观地观察各潜在调节变量对于经营规模与化肥施用强度之间关系的影响，本研究基于亚组检验结果，画出了大致的调节效应图示（图2）。其中，各分组的斜率为所在组的综合效应值[①]。可以看出，在教育程度、农户年龄、国别和研究时间等各变量的图中，不同分组的斜率相反，在一定程度上抵消了经营规模对于化肥施用强度的作用。这可能就是主效应分析中，经营规模与化肥施用强度之间仅仅存在微弱负相关关系的主要原因。

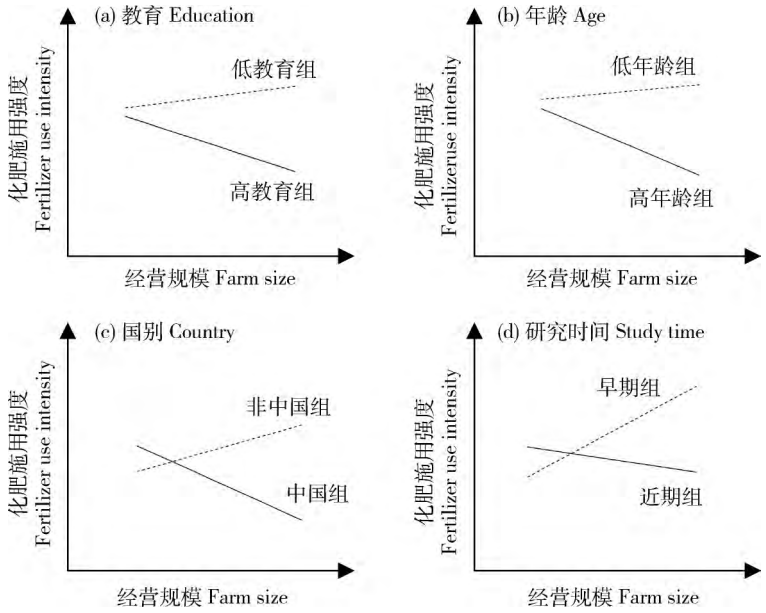


图 2　各调节变量的调节效应图示

Fig. 2　The diagram of moderating effect of the moderators

5　结论与展望

对规模经营是否有助于化肥减量化，现有文献并未得出统一的结论。为探寻经营规模与化肥施用强度之间的真实关系，本研究搜集了大量实证文献，基于荟萃分析技术系统总结了两者之间的关系，并对影响两者关系的潜在调节变量进行识别和讨论。

研究表明：(1)经营规模与化肥施用强度之间存在微弱的负向相关关系；(2)虽然有文献认为经营规模与化肥施用强度之间的关系受种植的农作物品种的影响，但基于大样本文献的分析则表明，至少在经济作物与粮食作物之间，这种影响并不显著；(3)农户受教育程度越高，年龄越大，则经营规模与化肥施用强度之间的负向关系越强，说明受教育程度更高和年龄更大的农户更可能在规模经营背景下推动化肥的减量施用；(4)和其他发展中国家相比，中国农户经营规模与化肥施用强度之间的负向关系更强，其原因可能在于，和中国的化肥减量化战略的出发点不同，很多发展中国家仍然希望通过“绿色革命”来提高农业生产率，而大规模农场本身意味着拥有更强的能力来获得更多的化肥；(5)与早期研究相比，时间越近的研究中经营规模与化肥施用强度之间的负向关系越强，说明和早期“绿色革命”的背景不同，随着时间的推移，化肥的施用也更追求科学化和绿色化，而大规模农场更容易应用最新科技。

本研究针对前人的研究进行更深层次的总结和检验，是对现有经营规模与化肥施用强度关系研究的重要补充：(1)应用荟萃分析技术，在更大样本量的基础上明确了经营规模与化肥施用强度之间的关系，并提供了更为可靠的研究结论，有助于平息现有争议；(2)在调节效应中引入农户受教育程度、年龄、国别和时间等因素，寻找现有文献中研究结论的异质性来源，回答了主效应如何因情境不同而变化的问题，挖掘了经营规模与化肥施用强度之间关系的隐性机制；(3)本研究还有助于研究者用一种动态的思维看待化肥施用问题——或许许多发展中国家正

① 为表示方便，示意图并没有考虑截距。

将化肥看作是现代农业的重要标志，但若没有较好地规划和管理，将来可能和中国一样，面临化肥施用过量问题。

本研究仍然存在一定的局限性：(1)纳入荟萃分析的多数都是期刊文献，国内外未发表文献与学位文献较少，文献分布不平衡可能会影响主效应分析结果；(2)由于纳入荟萃分析的文献没有报告，或者报告方式不同，使得本研究没有涉及诸如农户性别、家庭收入、社会化服务水平、农地细碎化和化肥价格等情境因素；(3)部分实证研究表明，经营规模与化肥施用强度之间存在非线性相关关系[57-58]，但得到相似结论的研究较少，因而本研究难以对非线性关系进行深入分析。

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服务外包有助于化肥减量吗？
——来自荟萃分析的证据

谢　琳　廖佳华　李尚蒲*

摘　要：对于服务外包与化肥施用强度之间的关系，学术界虽积累了大量研究文献，但并没有得出一致的结论。文章运用荟萃分析方法，探究两者之间真实关系及其异质性来源。结果表明：(1)服务外包与化肥施用强度之间具有微弱的负相关关系；(2)农户经营规模、受教育程度以及研究所在国别等因素作用于这种负向相关关系，并成为现有实证研究结论不一致的重要异质性来源。基于现有文献数据来看，尽管服务外包有助于化肥的减量化，但是不能忽视两者间的调节变量与隐性作用机制。

关键词：服务外包　化肥施用强度　荟萃分析　荟萃回归分析

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一、问题提出

中国农业生产高度依赖化肥，存在严重的过量施用问题(Zhang et al.，2015)。来自世界粮农组织(FAO)的数据显示，中国已经成为世界上最大的化肥和农药消费国。2016 年，中国大陆的氮肥、磷肥和钾肥施用量分别占全球总量的 27.65%、32.23% 和 35.43%，三者的施用强度分别达到 138.64、49.81 和 38.22 kg/hm^2，是同期全球平均水平的 2.01、1.63 和 1.57 倍①。生态环境部的数据则显示，2017 年水稻、小麦和玉米的化肥利用率仅为 37.8%(生态环境部，2019)。现阶段，中国的施肥水平已经远高于发达国家所公认的环境安全上限(张维理等，2004)。化肥的过量施用是农业污染的主要原因(Fischer et al.，2010)，不仅增加农业生产成本、浪费资源，还造成耕地板结、土壤酸化(诸培新等，2017)，而且导致地表水富营养化，并引发地下水的硝酸盐污染(朱兆良等，2006；张军伟等，2018)。为此，农业农村部早在 2015 年就提出了《到 2020 年化肥使用零增长行动方案》，强调化肥高效利用，推动化肥减量施用。

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① 数据来源：根据世界粮农组织数据库数据计算。见 http://www.fao.org/faostat。

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对于化肥减量的途径，现有研究认为，随着农业生产过程中纵向分工的不断深入，越来越多的化肥施用环节可以外包给服务商（江雪萍，2014；陈思羽、李尚蒲，2014）。服务外包意味着施肥环节由经营主体内部分工转换为产业内部分工，而专业化分工有助于农户享受到专业、科学的施肥服务，并由此降低化肥施用水平（如刘锐，2013；杨万江、李琪，2017；孙小燕、刘雍，2019；张露、罗必良，2019；杨高第等，2020）。然而，也有研究发现服务外包与化肥施用强度之间没有显著相关关系（如郑鑫，2010；Obisesan et al.，2013；Marenya and Barrett，2009）。甚至还有研究发现，服务商可能与农资经销商合谋，通过过量施肥获得高额回报，因此服务外包反而加重了化肥过量施用问题（如王常伟、顾海英，2013；Zhang et al.，2015）。这说明，现有文献并未就服务外包和化肥施用强度之间的关系得到一致结论。究其原因，可能在于已有研究的取样大都只限于某一作物，某一时间，或某一地，减弱了研究结论的普适性。实践中，许多情境因素会改变某些变量之间相关关系的大小和符号，故情境因素往往会导致变量之间的相关关系不同，甚至是矛盾的内在原因（陈晓萍、沈伟，2018）。基于上述分析，本文关注两个尚未厘清的问题：第一，服务外包真的有助于降低化肥施用强度吗？第二，两者之间的关系受到哪些情境因素的影响？

荟萃分析以及由其衍生出的荟萃回归分析技术，不仅可以定量评估变量之间的关系，还能探寻变量关系中的情境变量，挖掘主效应之间的隐性机制（Miller and Toulouse，1986）。为此，本研究首先基于荟萃分析技术，评估服务外包与化肥施用强度之间的真实相关关系，并进一步利用荟萃回归分析技术探究经营规模、农户教育程度、农户年龄、国别和研究时间等潜在调节变量的作用，以识别影响服务外包与化肥施用强度之间关系的情境依赖性。

二、关于服务外包化肥减量效应的争论

（一）已有的争论

服务外包被认为是实现化肥减量施用的重要途径。从农户角度来看，降低化肥施用水平具有正外部性，其所得成果为全社会共享，但成本却由农户自己独自承担，因而农户减量施用化肥的激励不足（Arriagada et al.，2010）。而且，化肥减量施用等绿色生产技术具有投资大、收益期长等特点，进一步降低了农户的积极性（孙小燕、刘雍，2019）。即便是存在补贴的情况下，以生存安全为首要目标的理性农户仍然倾向于通过较高的化肥施用量来规避产量风险（仇焕广等，2014；杨高第等，2020）。不过，服务外包有助于改变农户要素投入组合，例如服务商为农户提供更科学、更专业的施肥服务，如更先进的机械装备、测土施肥等，克服农户“绿色生产意愿低及意愿与行为悖离”的难题（孙小燕、刘雍，2019）。站在服务商的角度来看，他们会基于成本考虑而节约化肥投入，并通过化肥减量施用积累声誉，并获得政策优惠（张露、罗必良，2019；杨高第等，2020）。张露、罗必良（2020）基于湖北省水稻主产区的 1752 户农户调查数据就发现，服务外包能促进专业化分工和精准化生产，有助于减少化肥施用量。而且，服务商对化肥的质量辨别能力与肥效信息收集能力也都优于个体农户，可以根据农地质量、作物类型，运用专业知识因地制宜地进行科学施肥。可见，服务外包有助于实现化肥减量，即服务外包与化肥施用强度之间存在负向相关关系。

然而也有学者注意到，随着服务组织的商业化，服务外包不但无助于投入品的减量化，反而导致对投入品的滥用（Zhang et al.，2015）。陈义媛（2018）注意到，在商业化浪潮下，农资销售商与服务商合

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谋，通过各种策略来促进农资的销售。尤其在土地流转大背景下，许多城市过剩资本投入农业但并无种植经验。由此，农资销售商转向“服务式销售策略”，即通过给农户提供种植技术、病虫害防治等服务来吸引和维系客户，使服务商与农资提供商之间形成紧密的合作关系。于鸷隆、刘玉铭(2011)已经指出，农业服务人员可能会存在机会主义行为。最后导致如王常伟、顾海英(2013)提到的现象：对于那些功能集中于投入品供应以及销售信息的服务组织来说，出于销售动机，它们甚至会过分强调投入品的作用，反而可能造成农户的超量购买与使用。此外，也有研究发现服务外包与化肥施用强度之间没有显著相关关系(如郑鑫，2010; Obisesan et al.，2013; Marenya and Barrett，2009)。

(二)引发争论的原因：调节作用分析

现有文献关于服务外包与化肥施用强度之间的关系并未得出统一的结论，究其原因，可能在于不同研究存在情境因素，即存在一些变量在服务外包与化肥施用强度之间起调节作用。考虑到服务外包需要一定的农地规模进行匹配(杨子等，2019)，且农户的知识、经验与化肥施用行为密切相关(蔡颖萍、杜志雄，2016)，所以经营规模、农户受教育程度和年龄等变量都可能是重要的情境因素。此外，研究的地点和时间一直以来都是很多研究典型的情境因素(陈晓萍、沈伟，2018)。现有关于服务外包与化肥施用强度之间关系的研究大都报告了经营规模、农户受教育程度、农户年龄、研究所在国别和研究时间等信息，为荟萃分析中的调节作用分析提供了较为丰富的数据材料，因而本研究的调节作用分析聚焦于这些变量。

1. 经营规模的调节效应。小农户普遍存在土地细碎化的问题(罗必良、李玉勤，2014)，资源禀赋决定了其可能根本不需要服务外包(王钊等，2015; 杨子等，2019)。实证研究也表明，农地细碎化程度对农业生产环节外包有抑制作用(陈昭玖、胡雯，2016)。站在服务商的角度，服务小农户的收入低，却要投入大额的固定成本，故不愿意服务小农户。而且，服务外包存在着由信息不对称引起的逆向选择与道德风险问题。由于农户对施肥服务完成的质量难以监督，服务商就可能在服务过程中出现机会主义行为(马九杰等，2019)。例如，在承受高额固定成本的基础上，服务商可能通过向农户出售更多的化肥以获取合意的利润。在这种情况下，服务外包不但不会带来化肥减量化，甚至带来相反的效果。

实践中，社会网络是经营主体交流和获取生产经营信息的主要渠道(刘亚，2012; Ramirez，2013)。与小农户相比，经营规模较大的农户拥有更好的社会网络资源，以及更高的人力资本水平，更容易理解及采用现代化肥减量技术(蔡颖萍、杜志雄，2016)，并降低因信息不对称带来的逆向选择和道德风险问题。基于此，当服务外包匹配的是小农户时，其减量效应可能难以发挥，甚至存在过量施肥的风险。但是，当服务外包匹配大规模经营农户时，则更容易实现化肥减量化。

2. 农户受教育程度和年龄的调节效应。在人力资本理论看来，农民的知识和经验是支撑现代农业发展的重要要素(舒尔茨，1990)。已有研究表明，发展中国家的农户普遍对化肥施用技术缺乏了解，导致化肥施用水平难以符合要求(Zhang et al.，2015; Khan and Damalas，2015; 林源、马骥，2013)。此外，有研究显示，农资产品差异化竞争的加剧进一步使得农户拥有的知识越来越难以满足要求(纪月清等，2016)。对于农户来说，其受教育程度越高，越容易接受、采纳现代施肥技术(史常亮等，2015)，有助于合理施肥(Zhou et al.，2010)，而且接受新知识和新技术的能力越强，也越容易接受服务外包的生产方式。相似地，随着农户年龄的增长，务农经验越来越丰富，对农业生产环节与作物生长习性更为了解，能更好地判断作物对化肥的要求并合理施肥(田云等，2015; 蔡颖萍、杜志雄，

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2016)。更重要的是,更高的人力资本水平能够帮助农户实现对服务商的监督,并由此降低逆向选择和道德风险问题。这意味着,和教育程度低和年龄小的农民比起来,教育程度更高、年龄更大的农民与服务外包商之间的合作更顺畅,并抑制服务商的机会主义行为,实现化肥减量施用。

3. 国别的调节效应。虽然发展中国家在农业经营方面存在相似性,如大都以小农户为主、现代农业要素稀缺等(Feder et al.,1985)。但是,不同国家之间仍然存在异质性。以化肥为例,中国已建立起全球最大的化肥工业,其消费量和生产量都排名全球第一。来自 FAO 的数据显示,2019 年,中国农用氮、磷、钾化肥产量 5842 万吨,占全球生产总量的 26.55%①,不仅可以满足国内需求,还能有富余供出口。与之相应的是中国化肥的过量施用,由此使得化肥减量化成为中国现代农业的重要指标。然而,更多的发展中国家仍然面临化肥短缺问题,正力图通过"绿色革命"来提高农业生产率,大力提倡农户施用化肥。那么,和中国农户通过获得专业化的服务来实现化肥减量不同,许多发展中国家却希望通过获得外部技术服务支持以提高化肥施用水平,实现增产增收。基于埃塞俄比亚、加纳等发展中国家的实证研究发现,社会化服务与化肥施用强度之间是正向关系(Mbata,1994; Beshir et al.,2012; Miheretu and Yimer,2017)。如 Beshir et al.(2012)基于加纳水稻种植农户数据的实证研究表明,服务商会鼓励农户增加化肥施用水平来提高产量,所以农户在获得服务后,化肥施用量会相应增加。这意味着,国别也是使服务外包与化肥施用强度之间关系产生差异的潜在调节变量。

4. 研究时间点的调节效应。化肥施用行为存在时间效应。以中国为例,在"绿色革命"背景下,为了解决因土壤质量低下造成的单位产量低的问题,中国早期制定的化肥施用标准高于世界标准(高晶晶等,2019)。随着化肥工业体系逐步完善,化肥供给逐渐充足且价格低廉,农户倾向于通过施用更多的化肥来实现单位产量的提高,最终导致化肥过量施用。然而在新的"绿色生产"背景下,政策发生了转向,开始提倡化肥减量化。对此,服务商也将做出相应调整。因而,研究的时间点也可能是导致服务外包与化肥施用强度之间关系存在不一致的潜在调节变量。

三、研究设计

(一)文献搜索

纳入荟萃分析的中文文献主要通过中国知网(CNKI)期刊数据库、中国优秀硕士论文数据库、中国博士学位论文全文数据库、万方数据库、维普数据库搜索获得,搜索关键词包括化肥施用、化肥施用强度、服务外包、社会化服务、测土配方施肥、化肥投入水平等;英文文献主要通过 Springer Link、Elsevier Science、EBSCO - ASP 综合学科研究文献全文库、Emerald 期刊全文库、Wiley - Black - Well、ProQuest 期刊全文库、ProQuest 硕博士论文全文数据库、Google scholar 搜索获得,搜索的关键词包括 determinants of fertilizer use、chemical fertilizer use、fertilizer application intensity、fertilizer use strength、agricultural extension services、access to extension service 等。为了减少文献的遗漏问题,本研究还对所得文献中的参考文献进行了手动搜索。

(二)文献筛选

本研究进行文献筛选的要求包括:(1)必须为实证分析文献,排除文献综述和纯理论类文献,且

① 数据来源:根据 FAOSTAT 数据计算得出。

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实证结果报告了样本量、相关系数，或者可转换为研究所需效应值的其他数据指标；(2) 实证结果中包含农业服务外包与化肥施用强度变量；(3) 各文献的实证研究涉及的样本相互独立，若 2 个或 2 个以上研究的样本范围相同或存在相互交叉重叠现象，选择报告内容更为详细或者样本更大的研究。本研究总计搜索到 130 篇符合研究主题的文献，在进行文献筛选后，最终有 16 篇文献纳入本次荟萃分析研究，其中有 13 篇中文文献，3 篇英文文献(表 1)。对于荟萃分析的样本文献量，Valentine et al. (2010) 指出，只要存在能识别的异质性，2 篇文献即可，因而本研究的文献量是符合要求的。

表 1　纳入荟萃分析研究的文献资料目录

编号	作者	发表时间	国家	样本量	编号	作者	发表时间	国家	样本量
1	Ouma et al.	2002	肯尼亚	111	9	尹晓宇	2016	中国	293
2	郑鑫	2010	中国	223	10	Donkor et al.	2016	加纳	470
3	张峰、胡浩	2012	中国	353	11	朱哲毅、周力	2016	中国	526
4	Hassen et al.	2012	埃塞俄比亚	252	12	杨万江、李琪	2017	中国	678
5	周智炜等	2013	中国	202	13	陈黎、仇蕾	2017	中国	182
6	罗小娟等	2013	中国	221	14	于元赫	2019	中国	137
7	姜太碧	2015	中国	361	15	杨高第等	2020	中国	856
8	李志朋	2016	中国	2028	16	梁志会等	2020	中国	983

(三) 文献编码

本研究根据 Lipsey and Wilson(2001) 给出的方法对文献进行编码，其中研究特征为文献相关作者、文献出版年份、研究样本数量、研究地区、服务外包、化肥施用强度以及研究对象的相关指标。效应值所需数据包括实证结果中各变量的相关系数、回归系数及其系数检验值等。文献效应值的计算与编码遵循“一个样本一个效应值”原则，若某一文献中同时报告了多个独立不重复样本，则相应的效应值分别对应各自样本分开计算和编码。当完成编码后，另一位研究员对数据进行重新计算编码，以保证数据的准确性。若两人编码出现差异，则返回文献原文进行逐一比对。本研究中，两位研究员的编码数据一致性为 90.3%，说明编码过程中人为造成的误差较小。最后，本研究共获得 19 个关于服务外包与化肥施用强度的独立效应值，总样本量达到 7694 个。

(四) 效应值计算

本研究使用 CMA2.0(Comprehensive Meta - analysis 2.0) 软件进行荟萃分析，并以相关系数作为效应值来梳理服务外包与化肥施用强度之间的关系。在编码时，有些文献只报告了研究所得的 t 检验值、F 检验值，或者 χ^2 检验值，而没有报告相关系数。为此，我们根据郑凤英、彭少麟(2001) 的公式将相关数据指标转换成所需的相关系数，具体公式如下：

$$r = \sqrt{\frac{t^2}{t^2 + df}} \tag{1}$$

$$r = \sqrt{\frac{F^2}{F^2 + df}} \tag{2}$$

$$r = \sqrt{\frac{\chi^2}{\chi^2 + df}} \tag{3}$$

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其中公式(1) -(3) 中的 $df = n_1 + n_2 - 2$ 。

有部分文献只报告了回归系数,为此,本研究根据 Peterson and Brown(2005) 提供的方法将回归系数转换为相关系数,具体公式如下:

$$r = \beta \times 0.98 + 0.05(\beta \geq 0) \tag{4}$$

$$r = \beta \times 0.98 - 0.05(\beta < 0) \tag{5}$$

其中系数 β 的适用范围为 $\beta \in (-0.5, 0.5)$ 。

随后将文献中报告或者通过上述计算得出的 r 值进行 Fisher's Z 值转换。具体公式如下:

$$F_z = 0.5\ln\left[\frac{1+r}{1-r}\right] \tag{6}$$

(五) 出版偏差

期刊一般存在发表偏好,如更喜欢发表实证结果显著的文章,而那些不显著的文章通常更难发表。本研究纳入荟萃分析的文献绝大部分为期刊文章,可能存在出版偏差问题。为此,本研究采用漏斗图(Funnel plot) 对是否存在出版偏差进行初步检验。由图 1 所示,研究样本基本对称分布在综合效应值两侧,说明本研究不存在严重出版偏差。

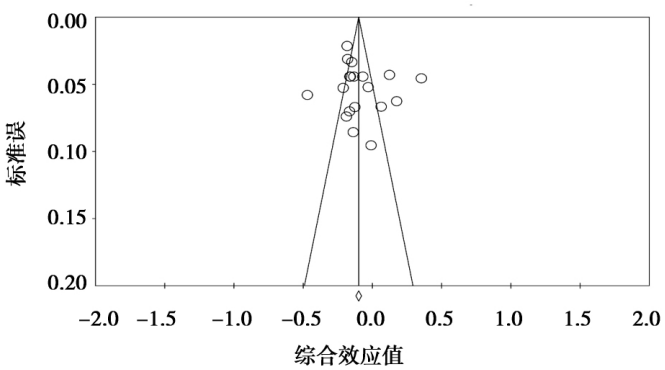


图 1 主效应的漏斗图

进一步地,本研究通过失安全系数 N(Classic fail - safe N) 对是否存在出版偏差进行进一步的检验。失安全系数 N 是指需包含多少未出版的研究文献才有可能使本次研究的效应值降低到不显著的结果(Rosenthal,1978) 。若计算出的失安全系数 N 与本次研究样本数量相差较大,则说明不存在严重的出版偏差问题。结果表明,本研究的失安全系数 N 为 271,意味着需要额外纳入 271 篇研究文献才能否定本研究中服务外包与化肥施用强度之间的关系,进一步说明本研究的出版偏差问题较小。

(六) 异质性检验

为了判断主效应是否存在调节效应,本研究进行了异质性检验(Heterogeneity test) 。Higgins and Thompson(2002) 指出,异质性检验通过 I^2 检验和 Q 检验进行。I^2 检验主要分析效应值的变异程度占总变异的比值,其中 $0 \leqslant I^2 < 25\%$ 时表示不存在异质性,$25\% \leqslant I^2 < 50\%$ 时表示存在低异质性,$50\% \leqslant I^2 < 75\%$ 时表示存在中度异质性,$75\% \leqslant I^2 < 100\%$ 时表示存在高异质性。Q 检验中的 Q 值符合卡方分布,如 $p < 0.05$,说明效应值之间存在异质性。异质性检验结果如表 2 所示,其中 I^2 值为 91.900% ,且 Q 检验也显著($Q = 222.232$,$p < 0.001$) ,说明本研究的效应值之间存在高度异质性,即

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服务外包与化肥施用强度之间存在潜在调节变量。

表2　异质性检验

结果变量	效应值数量	I^2	Q	df	P 值
服务外包与化肥施用强度	19	91.900	222.232	18	0.000

荟萃分析还要判断是利用固定效应模型还是随机效应模型进行估计。Borenstein et al.（2009）指出，固定效应模型假设所有研究只有一个真实效应值，研究结论存在的不一致只是由抽样误差造成的；随机效应模型则假设每个研究都有其真实效应值，结论的差异不仅仅是由于抽样误差造成，还可能存在其他方面的原因。I^2 检验和 Q 检验还可以为荟萃分析应选用固定效应模型还是随机效应模型提供判断依据：如果 Q 检验值的 $p<0.01$ 且 $I^2>50\%$ 则使用随机效应模型，反之使用固定效应模型（Hedges and Vevea，1998）。异质性检验结果已经表明 $I^2>50\%$（$I^2=91.900\%$），且 Q 检验值为 222.232（$p<0.001$），因此本研究采用随机效应模型进行荟萃分析。

四、研究结果

（一）主效应分析

Cohen（1992）指出，综合效应值反映变量之间的相关性程度，若在 0.1 以下说明变量之间相关性较弱。荟萃分析的结果（表3）显示，服务外包与化肥施用强度的综合效应值为 -0.079（$p<0.05$），说明服务外包与化肥施用强度之间具有微弱的负向相关关系，即服务外包确实有助于化肥减量施用，但其作用非常微弱。

表3　主效应的荟萃分析

方法	总样本	效应值数量	综合效应值	LL	UL	Z 统计值	P 值
随机效应	7694	19	-0.079	-0.153	-0.004	-2.069	0.039

注：LL、UL 分别表示综合效应值的 95% 置信区间下限与上限。

（二）调节效应分析

异质性检验已表明服务外包与化肥施用强度之间存在潜在调节变量。本研究利用荟萃回归分析方法进行调节变量分析，并借鉴 Stanley and Jarrell（2005）与张晓、胡丽娜（2013）给出的方法，以研究样本中主效应的相关系数作为被解释变量，对潜在调节变量进行分类赋值并作为解释变量分别进行荟萃回归分析。表4为潜在调节变量的赋值方式与对应的荟萃回归结果。

（1）经营规模的调节效应。各样本文献一般会报告农户经营规模，但不同研究的计量单位可能存在差异，因此本研究以亩为面积单位重新编码。对于没有报告农户经营规模的研究，本研究不将其纳入经营规模的调节效应分析中。结果显示，经营规模系数显著为负（$\beta=-0.006$，$p<0.05$），说明农户经营规模在服务外包与化肥施用强度之间的关系中起调节作用，即与经营规模较小的农户相比，经营规模大的农户其服务外包与化肥施用强度之间的负向关系更强，意味着服务商在服务大规模农户的时候，更能发挥其减量效应。

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表 4　调节变量的荟萃回归分析

调节变量	效应值数量	系数	标准误	Z 统计值	P 值
经营规模	11	-0.006	0.003	-2.230	0.026
农户受教育程度	16	-0.173	0.089	-1.940	0.052
农户年龄(样本均值)	12	0.002	0.011	0.170	0.866
国别	19	-0.350	0.085	-4.120	0.000
研究时间	19	0 .014	0.010	1.310	0.189

注: 经营规模为样本均值; 农户受教育程度为 1 = 受教育年数≥7 年,0 = 受教育年数 <7 年; 农户年龄为样本均值; 国别为 1 = 中国,0 = 非中国; 研究时间为 2020 - 文献发表时间。下同。

(2) 农户受教育程度的调节效应。考虑到样本文献对农户受教育程度的测量方法存在差异,本研究也进行了重新编码。由于大多数国家为 6 年制小学,故本研究将受教育年份大于等于 7 或小学以上教育程度定义为较高教育程度,并赋值为 1,否则赋值为 0。对于没有报告农户受教育程度指标的文献,本研究将其剔除出受教育程度的调节效应分析。荟萃回归结果显示,农户受教育程度的回归系数显著为负($\beta = -0.173$, $p = 0.052$),表明农户的教育水平越高,服务外包与化肥施用强度之间的负向关系越大。

(3) 农户年龄的调节效应。农户年龄的回归系数不具备统计显著性($\beta = 0.002$, $p > 0.1$),即农户年龄在服务外包与化肥施用强度之间的关系中没有起调节作用。

(4) 国别的调节效应。样本文献使用的数据涉及中国、肯尼亚、埃塞俄比亚、加纳等 4 个国家。为了研究国别的调节作用,本研究构造了国别虚拟变量: 除中国外,其余国家均位于撒哈拉以南的非洲,故将基于中国数据的样本文献赋值为 1,否则赋值为 0。从表 4 可知,"中国"的回归系数显著为负($\beta = -0.350$, $p < 0.01$),说明和撒哈拉以南的非洲国家比起来,中国的服务外包与化肥施用强度之间的负向相关关系更强。

(5) 研究时间的调节效应。本研究将文献发表年份距离 2020 年的时间跨度作为研究时间变量,并以此为自变量进行荟萃回归分析。结果显示,研究时间的系数为正,但不具有统计显著性($\beta = 0.014$, $p > 0.1$)。不过从实际意义来看,研究时间变量系数大于 0,说明与时间较为早期的研究相比,近期的研究中服务外包与化肥施用强度间的负向关系更强。考虑到 p 值并不大($p = 0.189$),故荟萃回归分析的结果也能够在一定程度上说明研究时间的调节效应。

(三) 稳健性检验

1. 改变因变量刻画方式。为了检验调节效应分析的实证结果是否稳健,本研究通过更换因变量刻画方式进行稳健性检验: 若服务外包与化肥施用强度之间关系显著正相关则赋值为 1,若不显著则赋值为 0,若显著负相关则赋值为 -1。由于新构建的因变量为排序变量,所以选择 Ordered Logit 模型进行回归分析。通过改变被解释变量的刻画方式,可将之前不能转换为相关系数而被剔除的文献样本纳入本次回归分析中,因而可以增加研究样本数量,使得效应值最多的回归达到 29 个。表 5 为稳健性检验结果。可以看出,除农户年龄变量存在一定差异外,其他变量的系数检验结果与表 4 的结果基本一致,说明实证结果具有较好的稳健性。需要指出的是,在变换因变量刻画方式后,农户年龄的系数显著为负($\beta = -0.196$, $p < 0.1$),说明农户年龄越大,服务外包与化肥施用强度之间的负向关系越强。

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表5　稳健性检验

调节变量	效应值数量	系数	标准误	Z 统计值	P 值
经营规模	15	-0.155	0.090	-1.710	0.087
农户受教育程度	21	-2.249	1.199	-1.880	0.061
农户年龄	16	-0.196	0.113	-1.730	0.084
国别	29	-5.029	1.481	-3.400	0.001
研究时间	29	0.092	0.083	1.100	0.272

2. 亚组检验。为了进一步检验实证结果的稳健性，本研究利用丁凤琴、赵虎英(2018)给出的方法进行亚组检验(subgroup analysis)。张世洪(2016)指出，所谓亚组检验是通过对潜在调节变量进行分组，然后检验各组综合效应量是否相等来解释异质性问题。亚组检验结果如表6所示：(1)以经营规模均值(21.800)分组，大规模组的效应值为-0.184，小规模组的效应值为-0.016，两者存在显著差异(Q_b=3.092，p<0.1)，说明经营规模越大，服务外包与化肥施用强度之间的负向关系越强；(2)高教育组的效应值为-0.166，低教育组的效应值为0.000，两者存在显著差异(Q_b=4.435，p<0.05)，说明农户受教育程度越高，服务外包与化肥施用强度之间的负向关系越强；(3)以农户年龄均值(51.259)分组，高年龄组与低年龄组的效应值没有显著区别(Q_b=0.083，p>0.1)，即农户年龄在服务外包与化肥施用强度之间的关系中没有起调节作用；(4)中国组的效应值为-0.127，非中国组的效应值为0.193，两者存在显著差异(Q_b=9.734，p<0.01)，说明在中国，服务外包和化肥施用强度之间存在负向相关关系，但在撒哈拉以南的非洲国家，服务外包和化肥施用强度之间是正向相关关系；(5)样本文献的发表年份为2002-2020年，以年份均值(2015)分组，近期组的效应值为-0.096，早期组的效应值为-0.039，两者不存在显著差异(Q_b=0.500，p>0.1)，说明研究时间未在服务外包与化肥施用强度之间的关系中起调节作用。可以看出，亚组检验结果与荟萃回归分析结果具有高度一致性，进一步说明了实证结果十分稳健。

表6　亚组检验

调节变量	类别	效应值数量	综合效应值	LL	UL	Q_b	P 值
经营规模	大(≥21.80)	5	-0.184	-0.294	-0.069	3.092	0.079
	小(<21.80)	6	-0.016	-0.164	0.133		
农户受教育程度	高	7	-0.166	-0.254	-0.076	4.435	0.035
	低	9	0.000	-0.125	0.125		
农户年龄	高(≥51.259)	7	-0.098	-0.165	-0.029	0.083	0.773
	低(<51.259)	5	-0.126	-0.300	0.056		
国别	中国	16	-0.127	-0.182	-0.071	9.734	0.002
	非中国	3	0.193	0.001	0.371		
研究时间	近期(时间>2015年)	13	-0.096	-0.186	-0.005	0.500	0.480
	早期(时间≤2015年)	6	-0.039	-0.168	0.091		

注：采用随机效应模型；Qb表示组间异质性的Q检验。

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五、结论与展望

对于服务外包是否有助于降低化肥施用强度，现有文献仍然存在争议。为探寻服务外包与化肥施用强度之间的真实关系，本研究搜集大量实证研究文献，基于荟萃分析方法系统总结了两者之间的关系，并对影响两者之间关系的潜在调节变量进行识别与分析。研究表明：（1）服务外包与化肥施用强度之间存在微弱负相关关系；（2）农户经营规模负向调节服务外包与化肥施用强度之间的关系，即农户经营规模越大，服务外包与化肥施用强度之间的负向关系越强，说明当服务外包匹配大规模农户时，更能发挥其减量效益；（3）农户受教育程度负向调节服务外包与化肥施用强度之间的关系，即农户受教育程度越高，服务外包与化肥施用强度之间的负向关系越强，说明受教育程度更高的农户能够更好地与服务商合作，推进化肥减量施用；（4）和撒哈拉以南的非洲国家比起来，中国的服务外包与化肥施用强度之间的负向关系更强，说明和中国化肥减量的战略出发点不同，撒哈拉以南的发展中国家仍然处于“绿色革命”背景下，希望通过增加化肥投入提高生产率。

本研究运用荟萃分析对前人的实证研究进行了更深层次的总结与分析，是对现有关于服务外包与化肥施用强度关系研究的重要补充：（1）运用荟萃分析技术，基于更大的研究样本量系统地分析服务外包与化肥施用强度之间的关系，提供了比以往研究更有说服力的研究结论，有助于平息学术界的争论；（2）识别出农户经营规模、农户受教育程度、国别等因素是导致现有文献研究结论存在异质性的主要来源，回答了服务外包与化肥施用强度之间的关系以及在不同情境中如何变化的问题，挖掘了其隐性机制；（3）本研究还有助于我们用一种动态发展的思维看待化肥施用问题。尽管现阶段许多发展中国家把化肥看作是现代农业的重要标志，但若缺乏良好的规划和管理，将来可能会与中国一样面临化肥过量施用问题。

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Does Agricultural Service Outsourcing Help Reduce Fertilizer Use: Evidence from Meta－Analysis

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Abstract: The past researches on the relationship between service outsourcing and fertilizer use intensity has not reached a consistent result. This study uses meta－analysis to explore the real connection between the two variables and the source of their heterogeneity. The results show that：(1) there was a weak negative correlation between agricultural service outsourcing and the intensity of fertilizer use. (2) Through meta－regression analysis research，it is found that factors such as the farm size，education level，and research country have a moderating effect on the main effect. The three factors were relevant sources of heterogeneity of the existing empirical literature research results. In conclusion，based on the current literature data，service outsourcing is helpful to the implementation of fertilizer reduction，but the moderating variable and its recessive mechanism cannot be ignored.

Keywords: Agricultural Service Outsourcing；Fertilizer Use Intensity；Meta－Analysis；Meta－Regression Analysis.

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A Macro Perspective on the Relationship between Farm Size and Agrochemicals Use in China

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Abstract: Agrochemicals are overused in China. One strategy to reduce agrochemical use is to increase farm size because of the potential effect of economy of scale. Existing studies at a micro scale present mixed and often conflicting results on the relationship between agrochemical use and farm size. This study aimed to assess that relationship from a macro perspective using an aggregated panel dataset in 30 provinces in China from 2009 to 2016. The empirical results confirm the existence of both economy and diseconomy of scale effects on agrochemical use in China. The agrochemical application rates decreased as the proportion of farms between 0.667 and 2 ha increased. The diseconomy of scale existed when significantly larger farms, such as the farms larger than 3.34 ha, continued to emerge. Given the fact that 78.6% of farms are under 0.667 ha in China, our results suggest that the reduction strategy based on only expanding farm size might achieve some initial success in reducing agrochemical use, but the effect would fade away and be reversed as significantly large farms continue to emerge. These results have significant policy implications as China is proactively developing and implementing various policies and strategies to modernize its agriculture toward achieving its sustainability goals.

Keywords: farm size; agrochemical use; scale effect; fixed-effect model; smallholder agriculture

1. Introduction

China is the largest agrochemical user in the world. In 2018, China used 26.1%, 19.4%, and 27.8% of the global nitrogen, phosphate, and potassium fertilizers, respectively, and 43% of the total global pesticides (http://www.fao.org/faostat). Although agrochemical use is essential to maintain high grain productivity and ensure food security in China [1–4], it is generally realized that agrochemicals have been overused in China [1,4–8]. The Ministry of Ecology Environment of China estimated that the utilization rate was only 37.8% for fertilizers and 38.8% for pesticides in rice, corn, and wheat production in 2017 [9]. Previous research reported °, 64, and 17% of pesticide overuse for rice, cotton, and maize production in China, respectively [10]. Agrochemical overuse wastes resources, increases agricultural production costs, and causes agricultural pollution [11]. Excessive fertilizer degrades soil and causes land compaction and soil acidification [12]. Fertilizer overuse also causes eutrophication of surface waters and nitrate pollution of groundwater in China [13]. Pesticide overuse in China has also been related to environmental pollution [8,14], food safety [15], and human health risk [2,16,17]. There is an urgent need to develop and implement effective strategies to reduce agrochemical use in China [7,13,18].

Agrochemical use and use efficiency in China have been subject to extensive research. There are significant variabilities in agrochemical use and use efficiency across different regions due to great spatial variations in biophysical conditions such as climate, soil and topography in China and agrochemical use should adapt to these specific conditions [3,4,19,20]. Agrichemical use is also crop-specific and a significant amount of research is dedicated to improving agrochemical use efficiency of specific crops [1,8,10]. Research found that cash crops such as fruits and vegetables generally used more agrochemicals than grain crops such as maize, wheat, and rice [8,21,22]. With the economy in China growing, the planting structure is undergoing substantial changes: more farmlands are switched from grain production to cash crop production, which has contributed to the increase in agrochemical use [23]. Studies have also suggested that fertilizer overuse and fertilizer use efficiency varied significantly among farmers across China [4,22,24], which implies significant room for improvement in agrochemical use. Research suggested that farmer education and training on agrochemical use has helped reduce both fertilizer and pesticide use [7,25,26]. Climate change has significant impacts on crop yields and farm income [27]. Studies were also dedicated to understanding the root-causes of agrochemical overuse in China [1,28]. The fertilizer overuse in China was the result of the artificially low fertilizer prices caused by the agricultural support policies in conjunction with massive subsidy programs to the fertilizer industry to ensure food security [1]. A recent study found that many direct and indirect agricultural support policies significantly contributed to the increased use of fertilizers in China with a few exceptions and called for agricultural support policies using "green box" measures to reduce agrochemical use and increase agricultural sustainability in China [29].

Agricultural production in China is dominated by smallholder farms because of the Household Contract Responsibility System (HCRS), which allocates the use rights of collectively owned farmland to rural households based on long-term contracts between households and local village collectives [30]. According to the China Rural Statistics Yearbook, the per capita arable land area in rural China was only 0.234 hectares (ha) in 2017. One way to reduce agrochemical use is to increase farm size because of the potential effect of economy of scale [6,7,31]. A study based on the China Agricultural Census in 2006 observed the economy of scale effect between farm size and fertilizer use in China and suggested that the fertilizer use reduction and efficiency improvement can be achieved by increasing the farm size [6]. The same strategy was echoed by a recent study, which argued that increasing large-scale farms could reduce agrochemical uses for two main reasons. First, it is more cost-effective for large-scale farms to adopt modern agricultural technology and management. Second, large-scale farm operators are the self-selected individuals who generally possess better agricultural knowledge and skills [7]. Other empirical studies also suggested a negative correlation between farm size and the level of agrochemical use in China [22,31,32].

However, the economy of scale of farm size on agrochemical use is not universally observed in China. Some empirical studies dismissed the significant correlation between farm size and agrochemical use [33]. Other empirical studies even suggested a diseconomy of scale, i.e., a positive relationship between farm size and agrochemical use [29,34,35]. The diseconomy of scale on agrochemical use was attributed to the short-term profit motive of farmers, planting structure change, farmers' willingness to increase agricultural inputs, capital intensive farming operation, and farmers' inability to efficiently use agrochemicals on large farms [34,36–38]. Moreover, most farmers who operate those large farms were evolved from smallholder farmers, and their knowledge and skills were inadequate to operate large scale farms, which results in low efficiency in agrochemical use [38]. Furthermore, one study suggested a U-shaped relationship between the farm size and the intensity of agrochemical use, i.e., agricultural chemicals use intensity decreased first, became flat, and then increased as the farm size increased [12].

In general, these empirical assessments present mixed results on the relationship between farm size and agrochemical use in China. Such mixed results might be attributed to a sample selection bias as these studies were based on surveys at an individual farm level. The samples being used might be limited to certain geographic regions and/or certain types of farming operations. Local biophysical

conditions such as soil and climate, and socioeconomic factors such as availability of agricultural services and agrochemical prices, could affect farmers' decision on agrochemical use [2,39]. The average farm sizes in those empirical studies were generally small and less than 1 ha, and therefore their findings regarding the economies of scale effect on agrochemical use might not represent the whole spectrum of farms in China. Particularly, they might not capture the effect on agrochemical use due to the changes in planting structures experienced by large-scale farms [40,41].

The objective of this study is to assess the relationship between farm size and agrochemical use using aggregated provincial data at a macro scale. The aggregated panel dataset contained the annual information on agrochemical uses, farms, and farmers in 30 provinces in China from 2009 to 2016, which was compiled from several national statistical databases, including China Statistical Yearbooks, China Population and Employment Statistics Yearbooks, China Rural Statistical Yearbooks compiled and published by the National Bureau of Statistics of China, and the Statistical Database on Rural Operations and Management distributed by the Ministry of Agriculture of China. The use of aggregated provincial data that contains all farms in China eliminates the sample selection bias embedded in other empirical studies as discussed above. There is no other study that has attempted to study the relationship between farm size and agrochemical use from a macro perspective using the aggregated provincial data in China.

2. Methods

A linear fixed-effect model was applied to a panel data from 30 provinces in China during the 2009–2016 period. Following Greene (2000) and Wooldridge (2010) [42,43], the model was specified as follows:

$$lny_{it} = \alpha_i + \boldsymbol{\beta X'_{it}} + \boldsymbol{\gamma Z'_{it}} + \varepsilon_{it} \quad (1)$$

where the dependent variable y_{it} is the agrochemical use intensity in Province i at Year t, the vector $\boldsymbol{X_{it}}$ represents the independent variables on farm size in Province i at Year t, the vector $\boldsymbol{Z_{it}}$ are the control variables in Province i at Year t, $\boldsymbol{\beta}$ and $\boldsymbol{\gamma}$ are the vectors of the regression coefficients, and ε_{it} the error term. The fixed-effect model was estimated by calculating the ordinary least square (OLS) estimate with cross-time demeaning variables [43–45]. More specifically, the estimation was implemented by applying the fixed-effect model estimate function PanelOLS in statsmodels.linearmodles package Version 4.17 under the Python 3.7.6 environment [46].

The robustness of the model was validated using a bootstrap method, a powerful nonparametric statistical tool [47–49]. The bootstrap method has become increasingly popular in economics [50], and medical research [51], where observations are noisy, and modeling results might be sensitive to a few outliers. The bootstrap method uses resampling data and tests the sensitivity of modeling results without additional assumptions. We took 10,000 iterations in the bootstrap analysis. In each iteration, we resampled the observations uniformly with replacements. Each bootstrap data set had the same size as the original data. We fitted the fixed-effect model on the bootstrap data and estimated the coefficients. The 10,000 estimates of the coefficients from the fitted models were used to form a "bootstrapped" distribution of the coefficient and assess its significance and robustness.

The dependent variable for this study was specified as agrochemical application rates in kilograms per hectare (kg/ha) derived from the data on agrochemical uses and sowing area in the China Statistical Yearbooks between 2009 and 2016. This study considered two categories of agrochemical uses: chemical fertilizers and pesticides. The chemical fertilizer and pesticide application rates were calculated by dividing the total amount of annual chemical fertilizer and pesticide use by the sowing area in each province, respectively.

Most micro-scale studies used per capita farmland to represent farm size [7,38]. This study included two types of independent variables on fam size at a macro scale. The first one was the farm size measured by average arable land per rural household in each province each year. While the data on the total number of rural households was extracted from the Statistical Database on Rural Operations and Management, the data on the total arable lands were from the China Statistical

Yearbooks. The second one was the farm composition with different farm sizes in each province extracted from the Statistical Database on Rural Operations and Management. The database contained the total number of rural households and the number of households in five different categories of farm size, namely, below 10, 10–30, 30–50, 50–100, and over 100 mu in each province each year from 2009 to 2016. The unit, mu, is the unit for measuring the land area in China, and one mu is equivalent to 0.0667 ha. The Statistical Database on Rural Operations and Management reported the number of farms with arable land less than 10, 10–30, 30–50, 50–100, 100–200 and above 200 mu. This study combined the last two categories into one since the numbers of farms with arable land of 100–200 mu and above 200 mu was small. The farm composition variables were specified as the percentages of farms in the five farm size categories, i.e., the total number of households in each of the five farm size categories divided by the total number of farm households in each province each year.

The control variables included rural labor migration, farmers' education, planting structure, and farm household income. Under the current Household Registration System called Hukou in China, the rural residents may migrate to live and work in cities, but still maintain their use rights to farmland in their rural village collectives. Such labor out-migration from rural China results in an increase in agrochemical use [7,52]. The Statistical Database on Rural Operations and Management recorded the total numbers of three types of households with varying degrees of rural labor migration. Type 1 are the households whose primary income comes from farming with supplementary income from non-farm employment. Type 2 are the households that operate farms but derive income primarily from non-farm employment. Type 3 are the households that no longer operate farms and are employed in non-farm-related occupations. The control variables on rural labor migration were the percentages of these three types of households among the total number of rural households.

Agrochemical overuse is attributed to farmers' lack of understanding of the detrimental effects of those chemicals [7,53–55], and of scientific knowledge on appropriate use of agrochemicals [2], which are closely tied to farmers' education. Thus, this study also included the control variables on farmers' education level. The control variables on education were the percentages of farmers with primary school, junior high school, senior high school, and some college education in each province per year, which were derived from the China Population and Employment Statistics Yearbook. Planting structure influences the use of agrochemicals [40], and was specified as the percentage of arable land planted with grains, vegetables, or fruits. Studies also show that agrochemical overuse is related to farmers' income [7,56]. Therefore, this study included a control variable on farmers' income, which was specified as the average disposable per capita income of rural households. The data on both disposable per capita income and planting structure were all derived from the China Rural Statistical Yearbook. Consider the significant efforts being taken by the Chinese government to reduce agrochemical use in recent years, which might have a systematic impact on agrochemical use in China. This study also included control variables on years using dummy variables.

3. Results

The descriptive statistics for each variable were presented in Table 1. The average fertilizer application rate in China was 365.12 kg/ha but varied significantly by province across different years, ranging from 150.99 kg/ha to 637.55 kg/ha. The average pesticide application rate in China was 12.42 kg/ha ranging from 1.96 kg/ha to 56.32 kg/ha. The average farm size in China was 0.43 ha, and 92.49% of farms were less than 2 ha (30 mu). The farms greater than 6.67 ha (100 mu) accounted for only 2.38% of farms in China. Off-farm employment is widespread in China. Among rural households, 35.11% generated some of their disposable income from non-farm employment. In terms of education, 91.18% of farmers in China had some level of education, which were mostly at primary (35.67%) and junior high (43.83%) school levels. The majority (65%) of farms in China were on grain production. The average rural disposable income in China was $1300 (9224 RMB Yuan) per capita.

Table 1. Descriptive statistics of variables.

Variables		Obs.	Mean	Std. Dev.	Min	Max
Agrochemical Use (kg/ha)	Fertilizer use	240	365.12	114.89	150.99	637.55
	Pesticide use	240	12.42	9.57	1.96	56.43
Farm size (ha)		240	0.43	0.37	0.10	1.70
Farm Composition (%)	p_under_10	240	78.62	21.07	17.22	99.27
	p_10_30	240	13.87	12.10	0.49	43.68
	p_30_50	239	3.80	5.61	0.06	23.17
	p_50_100	237	1.39	2.65	0.00	12.59
	p_over_100	237	2.38	7.88	0.00	75.35
Disposable Per capita Income (RMB)		240	9224.43	4249.24	2980.10	25520.40
Labor Migration (%)	p_farm_I	240	16.81	5.60	0.81	29.09
	p_farm_II	240	8.53	5.12	1.09	23.27
	p_farm_III	240	9.78	10.13	0.45	52.63
Education (%)	p_primary	240	35.67	7.10	17.13	56.02
	p_junior	240	43.83	7.45	23.25	56.47
	p_senior	240	9.03	3.12	3.69	23.92
	p_college	240	2.65	1.64	0.67	11.97
Planting Structure (%)	p_grain	240	65.00	12.58	40.90	95.70
	p_vegetable	240	15.01	8.29	1.50	36.60
	p_fruit	240	1.78	1.37	0.10	6.90

3.1. Effects on Chemical Fertilizer Use

Table 2 presents the effects of farm size on the chemical fertilizer application estimated by six fixed-effect models. All six models included the dependent variable, i.e., the natural log of average fertilizer application rate, the independent variable on farm size, and the control variables including dummy variables on years, natural log of the disposable per capita income, labor migration, farmers' education, and planting structure. Models 1–5 included one additional independent variable on farm composition, which was the percentage of farms under each of five different types of operation scales among all farms. Model 6 included all these farm composition variables except the percentage of farms less than 0.667 ha (10 mu) to avoid the collinearity.

The coefficients of farm size were negative in Models 1–5 and positive in Model 6, but were statistically insignificant, which implies no clearly observable scale effect on fertilizer use from a macro perspective. However, there were some interesting observations on the coefficients of farm composition variables. The coefficient of p_under_10 in Model 1 was small and negative, but insignificant. The coefficient of p_10–30 in Model 2 was negative and significant with $p < 0.01$. The average chemical fertilizer application rate would decrease by 1.29% as the percentage of farms with a farm size of 0.667–2 ha (10–30 mu) increased by 1%. That result signifies a potential effect of economy of scale on chemical fertilizer application.

However, the economy of scale effect on fertilizer application did not last as larger farms emerged. The coefficient of p_30–50 in Model 3 was small, positive, and also statistically insignificant, which indicates that the average fertilizer application rate might not be affected as the percentage of farms of 2–3.34 ha (i.e., 30–50 mu) increases. The positive and statistically significant coefficient of p_50–100 in Model 4 indicates a diseconomy of scale effect on fertilizer application. The fertilizer application rate would increase by 4.84% for an 1% increase in the percentage of farms of 3.34–6.67 ha (i.e., 50–100 mu). Similarly, the diseconomy of scale effect did not last as larger farms continued to emerge. As demonstrated by the results from Model 5, the effect was positive but small and statistically insignificant as the percentage of farms greater than 6.67 ha (100 mu) increased.

Table 2. The fixed-effect modeling results between fertilizer use and farm size.

Variables	Model_1	Model_2	Model_3	Model_4	Model_5	Model_6
Farm Size	−0.1578 (0.1932)	0.0734 (0.1945)	−0.1534 (0.1945)	−0.1814 (0.1668)	−0.1454 (0.1951)	0.0502 (0.1852)
p_under_10	−0.0003 (0.0006)					
p_10–30		−0.0129 *** (0.0029)				−0.0126 *** (0.0031)
p_30–50			0.0010 (0.0103)			−0.0168 ** (0.0067)
p_50–100				0.0484 ** (0.0210)		0.0575 ** (0.0223)
p_over–100					0.0008 (0.0007)	0.0006 (0.0006)
Years	X	X	X	X	X	X
Ln (income)	X	X	X	X	X	X
p_farm_I	X	X	X	X	X	X
p_farm_II	0.0159 ** (0.0078)	0.0157 ** (0.0070)	0.0162 ** (0.0076)	0.0140 ** (0.0067)	0.0133 * (0.0080)	0.0121 * (0.0072)
p_farm_III	−0.0192 *** (0.0062)	−0.0178 *** (0.0053)	−0.0195 *** (0.0063)	−0.0183 *** (0.0063)	−0.0182 *** (0.0068)	−0.0161 *** (0.0056)
p_primary	X	0.0057 * (0.0033)	X	X	X	0.0063 * (0.0034)
p_junior	X	X	X	X	X	X
p_senior	X	X	X	X	X	X
p_college	0.0121 * (0.0070)	X	0.0123 * (0.0071)	X	0.0123 * (0.0073)	0.0107 * (0.0062)
p_grain	−0.0110 *** (0.0035)	−0.0094 *** (0.0035)	−0.0110 *** (0.0036)	−0.0109 *** (0.0036)	−0.0112 *** (0.0037)	−0.0078 ** (0.0031)
p_vegetable	X	X	X	X	X	X
p_fruit	X	0.0283 * (0.0146)	0.0323 ** (0.0162)	0.0294 * (0.0160)	X	X
intercept	7.0583 *** (1.2992)	6.8117 *** (1.1089)	6.9459 *** (1.3737)	6.8501 *** (1.2669)	7.1282 *** (1.3432)	6.2723 *** (1.0965)
N	240	240	239	237	237	237
R-square	0.4647	0.5328	0.4645	0.4957	0.4646	0.5733
F-stat	8.2467	10.832	8.1956	9.1897	8.1124	10.747
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$. X—The variables included as a control but with statistically insignificant coefficients.

Model 6 confirmed all of the findings based on Models 1–5 discussed above with a few twists. First, the coefficient of p_30–50 became negative and statistically significant at p-value < 0.05. A 1% increase in the percentage of farms of 2–3.4 ha (30–50 mu) could result in an 1.68% reduction in fertilizer application rate. This result indicates that the economy of scale effect of farm size on fertilizer application could continue at that specific scale of farm size. Second, although the coefficients p_50–100 in both Models 5 and 6 were positive and significant at p-value < 0.05, the co-efficient in Model 6 was larger than in Model 5. This further confirms the diseconomy of scale effect on fertilizer application when the percentage of these large farms increased. Third, Model 6 had the highest R^2 value among the six models, which indicates that Model 6 was the best fit model.

Figure 1 compares the histogram of the bootstrap coefficients of those farm composition variables with the derived normal distribution of the coefficients via central limitation theory and resulting *p*-values for testing the statistical significance of the coefficients in Models 1–6. The bootstrap analysis confirmed that the results presented above are robust. First, the histogram of the bootstrap coefficients followed a normal distribution pattern around the coefficients of the farm composition variables discussed above. Second, the *p*-values for significance testing whether the bootstrap coefficients were different from zero were consistent with the *p*-values reported in Table 2.

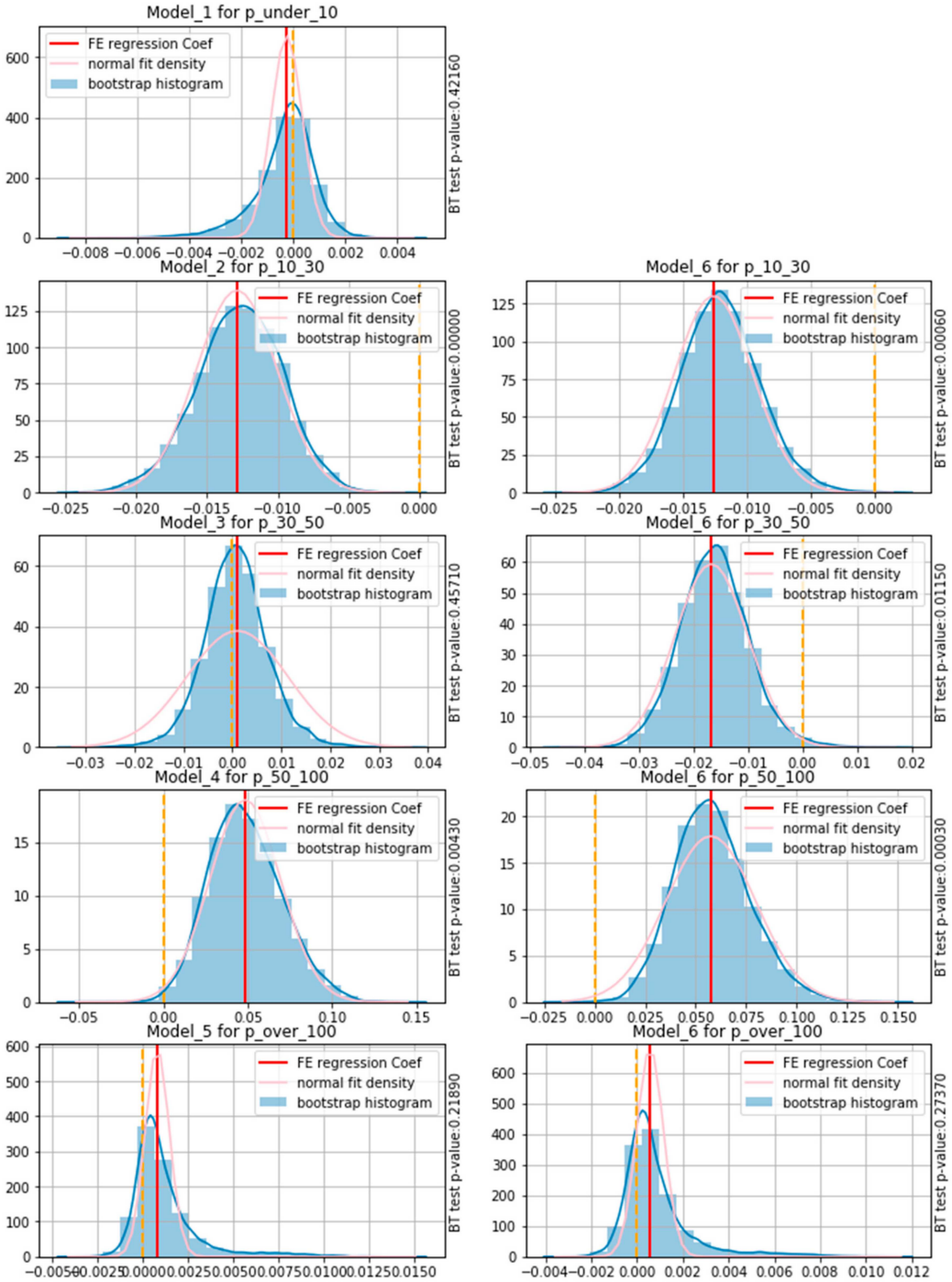


Figure 1. The bootstrap distribution of the estimated coefficient of the farm structure variables in Models 1–6 for fertilizer use.

3.2. Effects on Pesticide Use

Table 3 presented the effects of farm size on pesticide application using Models 7–12. The specifications for Models 7–12 were similar to Models 1–6, except the dependent variable for Models 7–12 was the natural log of the pesticide application rate. The coefficients of farm size were negative but also statistically insignificant for Models 7–12, which indicates the economy of scale effect on pesticide use was not observable based on the aggregated data at the provincial level.

Table 3. The fixed-effect modeling results between pesticide use and farm size.

Variables	Model_7	Model_8	Model_9	Model_10	Model_11	Model_12
Farm Size	−0.5701 (0.4244)	−0.1833 (0.4287)	−0.5592 (0.4210)	−0.5934 (0.3852)	−0.5503 (0.4179)	−0.1908 (0.4038)
p_under_10	−0.0005 (0.0010)					
p_10–30		−0.0215 *** (0.0047)				−0.0217 *** (0.0053)
p_30–50			0.0031 (0.0171)			−0.0189 (0.0158)
p_50–100				0.0575 * (0.0308)		0.0563 * (0.0335)
p_over_100					0.0012 (0.0009)	0.0010 (0.0009)
Years	X	X	X	X	X	X
Ln (income)	X	X	X	X	X	X
p_farm_I	X	X	X	X	X	X
p_farm_II	X	X	X	X	X	X
p_farm_III	−0.0324 *** (0.0067)	−0.0301 *** (0.0068)	−0.0334 *** (0.0072)	−0.0333 *** (0.0073)	−0.0328 *** (0.0070)	−0.0297 *** (0.0069)
p_primary	0.0192 ** (0.0084)	0.0201 ** (0.0090)	0.0204 ** (0.0088)	0.0209 ** (0.0091)	0.0200 ** (0.0085)	0.0214 ** (0.0091)
p_junior	0.0181 *** (0.0069)	0.0185 *** (0.0069)	0.0190 *** (0.0070)	0.0185 ** (0.0073)	0.0190 *** (0.0068)	0.0197 *** (0.0069)
p_senior	X	X	X	X	X	X
p_college	0.0342 ** (0.0149)	0.0299 ** (0.0146)	0.0352 ** (0.0150)	0.0335 ** (0.0154)	0.0349 ** (0.0154)	0.0319 ** (0.0146)
p_grain	−0.0128 ** (0.0062)	−0.0102 * (0.0060)	−0.0131 ** (0.0064)	−0.0129 ** (0.0061)	−0.0133 ** (0.0062)	X
p_vegetable	X	X	X	X	X	X
p_fruit	0.0836 * (0.0452)	0.0819 * (0.0419)	0.0891 ** (0.0419)	0.0858 ** (0.0426)	0.0759 * (0.0453)	X
intercept	4.1909 * (2.4437)	X	X	X	4.2080 * (2.5393)	X
N	240	240	239	237	237	237
R-square	0.2811	0.353	0.282	0.2995	0.2852	0.3759
F-stat	3.7152	5.1832	3.7115	3.9981	3.7315	4.7993
P-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$. X—The variables included as a control but with statistically insignificant coefficients.

The coefficient of p_under_10 in Model 7 was small, negative, but statistically insignificant. The coefficient of p_10–30 in Model 8 was negative and statistically significant at p-value < 0.01, which indicates an economy of scale effect on pesticide use. More specifically, an 1% increase in the proportion of farms of 0.67–2 ha (10–30 mu) would decrease the pesticide application rate by 2.15%. This result was similar to the result of Model 2 for chemical fertilizer application. However, such an economy of scale effect on pesticide use would disappear when larger farms continued to emerge. The coefficient of p_30–50 in Model 9 was small but positive and statistically insignificant. The coefficient of p_50–100 in Model 10 was positive and statistically significant at p-value < 0.10, which indicates a diseconomy of scale of farm size on pesticide application. An 1% increase in the percentage of farms of 3.34–6.67 ha (i.e., 50–100 mu) could result in a 5.75% increase in the pesticide application rate. However, the diseconomy of scale effect was not observed for farms greater than 6.67 ha as the coefficient of the p_over_100 in Model 11 was small and positive, but statistically insignificant. The results of Model 12 confirmed all observations made in Model 7–11. Similar to Model 6, Model 12 was the best fit model for assessing the impacts on pesticide use with the highest R^2 value.

The results from the bootstrap analysis presented in Figure 2 confirm that these coefficients in Models 7–12 discussed above were robust. Furthermore, the t-test from the bootstrap analysis indicated the coefficients of p_30–50 and p_50–100 in Model 12 could be statistically significant at $p < 10$ and $p < 5$, respectively.

3.3. Effects of Control Variables

The modeling results showed that rural labor migration had multi-layered effects on agrochemical application. The percentage of Household Type I had insignificant impacts on both fertilizer and pesticide application rates. This result is expected as these households derive their income primarily from agriculture, and their impacts on agrochemical use were already captured by the modeling results discussed above. The percentage of Household Type II had positive and significant impacts on fertilizer application, but insignificant impacts on pesticide application. The positive and significant impacts on fertilizer use are consistent with others' observations at the micro scale in the literature since Type II households derive their income primarily from non-agricultural employment and substitute labor shortages by increasing chemical fertilizer use [7,52]. The percentage of Household Type III had negative but significant impacts on both fertilizer and pesticide applications. Recall Type III households derive their income entirely from non-agricultural employment. A higher percentage of Type III households implies more large-scale farms as those households would transfer their lands to other farmers. As demonstrated above, there were economy of scale effects on both fertilizer and pesticide applications as the percentage of middle-sized farms, specifically farms of 0.67–2 ha (10–30 mu) and even of 2–3.34 ha (30–50 mu), increased.

The modeling results showed that farmers' education levels had limited impacts on fertilizer application in China while other studies reported mixed results [12,57,58]. Most coefficients of the percentages of farmers with different education levels across Models 1–6 were statistically insignificant except the coefficients for the percentage of farmers with some college in Models 1, 3, 5, and 6; and for the percentages of farmers with primary school in Models 2 and 6, which were positive, but only significant at $p < 0.1$ (Table 2). These results imply that the impacts of fertilizer use on agricultural production might have been well understood by farmers across different education levels. Therefore, the education levels have less impact on farmers' decisions on fertilizer. The positive and significant impacts of farmers with some college might be due to the fact that those farmers might simply operate the over-sized large farms, which were experiencing diseconomy of scale on fertilizer application as observed above. The farmers with some college might also choose to grow cash crops that generate higher returns but require higher agrochemical usage. However, the impacts on pesticide application rate seemed to be positive across different education levels. The significant impacts for farmers with primary and junior high school education just confirm the findings by other studies: the lack of knowledge on the impacts of agrochemical use contributes to the increase in chemical use [54,55], as the

knowledge on pesticide use is more sophisticated than on fertilizer use. Similar to the positive impacts observed on fertilizer application rate, the positive and significant coefficients for the percentage of farmers with some college education might be due to the fact those highly educated farmers tended to operate large-scale farms of cash crops such as fruits and vegetables, which require higher usage of pesticides.

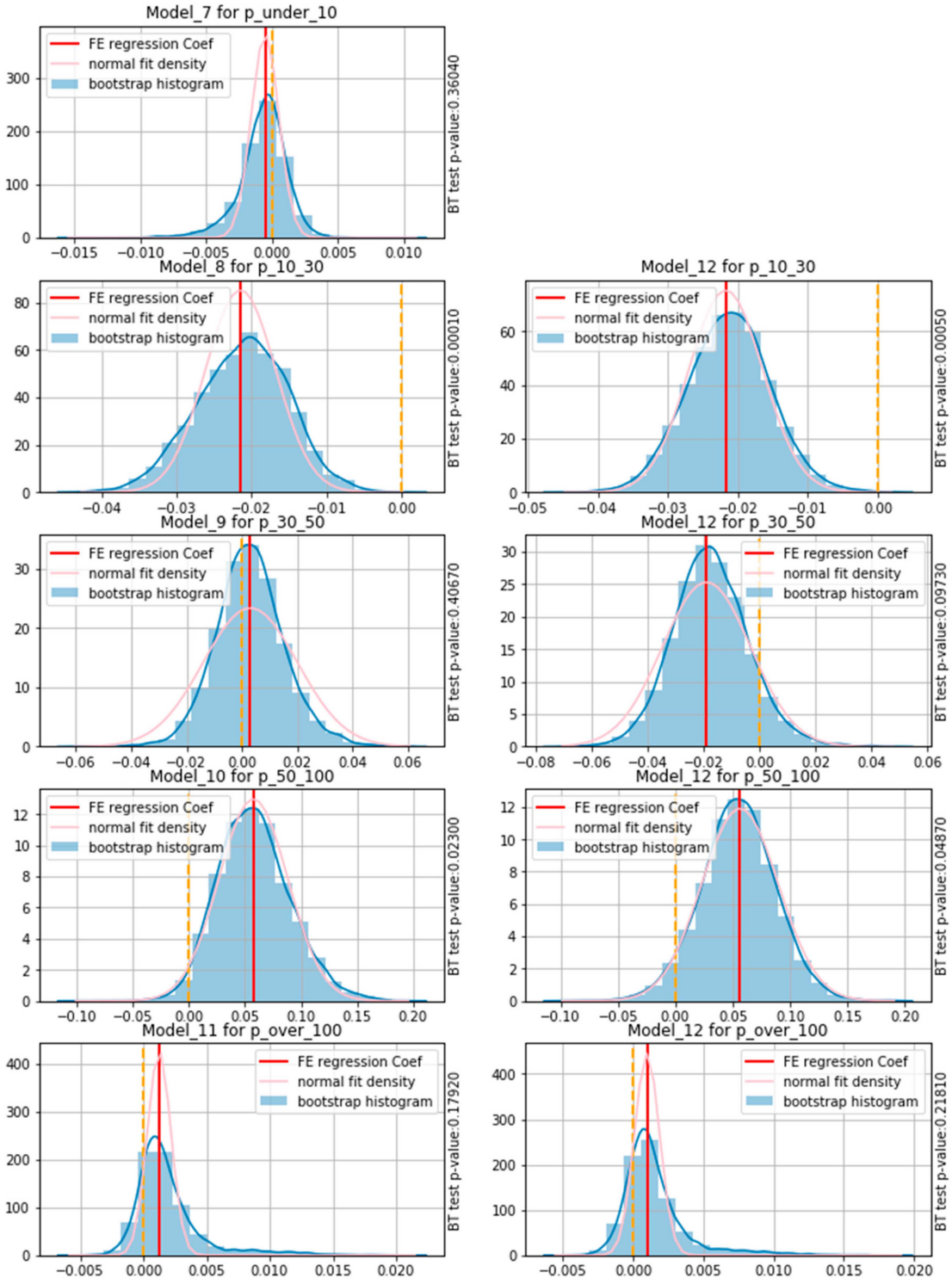


Figure 2. The bootstrap distribution of the estimated coefficient of the farm structure variables in Models 7–12 for pesticide use.

The impacts of planting structure on agrochemical use are consistent with the existing findings [40,58]. The increase in the proportion of arable lands in grain production tended to lower both chemical fertilizer and pesticide application rates as indicated by the negative coefficients of p_grain with a significance at $p < 0.01$ or 0.05 for Models 1–11. On the other hand, the large proportion of arable lands in fruit production would increase both chemical fertilizer and pesticide application rates, which was indicated by the positive coefficients of p_fruit with a significance at $p < 0.1$ for Models 2–4 and 7–11. The impacts of the proportion of arable lands in vegetable production on agrochemical uses were not statistically significant.

There were a few other interesting observations. First, the coefficients for all dummy variables on years were statistically insignificant across all models, although the coefficient value was increasing yearly from 2010 to 2015, reached its peak in 2015, and then became lower in 2016. These results indicate that the tremendous efforts from the central government are helpful but not effective in reducing agrochemical uses. Second, the disposable per capita income among rural households seemed to have no impact on agrochemical use as the relevant coefficients were negative but statistically insignificant across all models.

4. Discussions

Farm size has profound impacts on farm performance and farmers' behaviors toward the adoption of various innovative farming practices and technologies [59–62]. The knowledge of the relationship between agrochemical use and farm size is critical to the development and implementation of the agrochemical use reduction strategies and policies in China. However, the findings from the existing literature are mixed and often conflicting. While most empirical studies observed the economy of scale effect on agrochemical use, some found diseconomy of scale effect on agrochemical use and even dismissed the relationship between farm size and agrochemical use altogether. Our results using the provincial data at a macro scale confirmed the complexity of such relationships. Therefore, the results from empirical assessments based on specific sample farm survey data at a micro scale cannot be simply extrapolated to describe the relationship in other regions and/or at a macro scale.

The economy of scale effect on agrochemical use would be ideal. The decreases in agrochemical application rates in many developed countries such as the U.S. and western European countries could be partially attributed to the increase in farm size in those countries due to the economy of scale [63–65]. The HCRS and Hukou systems have distorted the allocation of rural labor across the different sectors and farmland across rural households in China [7]. By eliminating these two distortions, the average farm size in China would increase to 4.1 ha, and fertilizer and pesticide use and fertilizer loss would fall by 28%, 45%, and 50%, respectively [7]. However, our assessment found the existence of the diseconomy of scale effect on agrochemical use in China. The diseconomy of scale occurred only when larger farms such as the farms larger than 3.34 ha (50 mu) continued to emerge. Furthermore, other researchers also observed a similar relationship between farm size and agrochemical use in China [29,36–38]. Such findings are inconveniently contrary to the economy of scale effect, as observed by other notable studies [6,7]. The differences might be due to the different data being used. Ju et al. [6] used the aggregated macro data from the Second China Agricultural Census in 2006 and compared fertilizer use between traditional smaller farms and collective farms. However, the nature and structure of large farms have changed substantially since then. Moreover, Ju et al. [6] only analyzed the agrochemical use of wheat, rice and corn. They did not analyze the farms which produce cash crops (e.g., sugar, vegetables and fruits) which have relatively large agrochemical consumption. Wu et al. [7] used the 2015 China Rural Household Panel Survey, which included 20,000 rural households. Despite being nationally representative, the households in that survey primarily produced staple crops such as wheat, rice, corn, soybean, and peanut. That survey did not include farms that primarily produced sugar, vegetables, and fruits and therefore tended to apply more fertilizer. Xin et al. [23] have shown that large-scale farms are more likely to product cash crops than small-scale farms. Our macro analyses were based on the aggregated provincial data from 2009 to 2016

that included all farms that conducted all kinds of farm operations and therefore our results were more balanced without the explicit biases mentioned above.

The positive correlation between an increase in agrochemical application rate and an increase in farm size is not unique in China. Similar relationships were observed in other developing countries such as Thailand [66], Ethiopia [67], Kenya [68], and Bangladesh [69]. Despite the similarity in terms of the diseconomy of scale effect on agrochemical uses in both China and other developing countries, the underlying rationales may be different. First, the farm size in China is smaller than in many developing countries such as Ethiopia, Ghana, Niger, Cambodia, and Nicaragua, according to the Smallholders Data Portrait database maintained by FAO. Second, China is the largest agrochemical producer in the world. According to FAO, China produced 26.55% of the total fertilizer in the world in 2019. While more intensive agrochemical use by large farms in these developing countries was attributed to farmers' ability to acquire and use agricultural chemicals and willingness to take risks [66–69], the underlying reasons for more intensive agrochemical use by large farms in China might be very different as agrochemicals are readily available to all farmers. Previous studies suggested various plausible reasons including the short-term profit motive of farmers [35], planting structure change [41], and farmers' willingness and ability to use more agricultural inputs [70]. Third and most importantly, the diseconomy of scale on agrochemical use among large farms might be related to the distortions in labor and farmland allocation by the HCRC and Hukou systems, two powerful institutional policies unique to China [7]. Because of the Hukou system, rural residents are reluctant to give up the use right to their allocated farmlands even after they have migrated to cities in China. As such, most large farms formed through the transfer of the use right are based on short-term land contracts between the large farms and the migrated residents [38]. A rural land survey from 17 provinces in China showed that only 52.6% of farmers negotiated the lease duration in a lease contract for receiving the use right of farmland, and only 15.9% of farmers received the use right of land with a lease duration greater than ten years [71]. Short-term land lease contracts discourage long-term farmland investments and encourage short-term farm operation behaviors that result in a significant reduction in organic fertilizer application and an increase in agrochemical use in China [38,72]. As such, many large farms formed under the current institutional structure tended to be fruit, vegetable, and other cash crop farms [73], whose agrochemical application rates were higher than most grain crop farms.

The existence of the diseconomy of scale effect on agrochemical use among the larger farms is extremely troubling to the agricultural policy-makers. In the past decade, China has been implementing various programs and policies such as farmland consolidation programs to form larger farms to improve agricultural productivity and to reduce agrochemical use. Our results suggest those programs might have had some initial success but have entered into the bottleneck where the diseconomy of scale effect occurs and therefore do not provide a straight path to achieve the ideal outcomes related to the reduction in agrochemical uses. The institutional restrictions under the current HCRC and Hukou systems cause instability in the land rental markets, through which large farms obtain land use rights. The unstable land market leads to widespread short-term land lease contracts, making it difficult to achieve the economy of scale effect in reducing agrochemical use [38]. Therefore, the future rural policy reform on the HCRC and Hukou systems themselves are needed to facilitate the flows of rural resources and labor to break down the bottleneck and achieve the economy of scale effect on agrochemical uses as envisioned by others [6,7].

The public agricultural extension and education programs had been successful in supporting farmers in their farm operations [74,75]. One alternative way in China is to establish and strengthen the agricultural extension and education services available to farmers to improve agricultural productivity while reducing agrochemical uses. The specific training of farmers through agricultural extension and education programs is proven to be very effective in reducing agrochemical use without decreasing crop yield [76,77]. The examples include the Science and Technology Backyard platform [5], the Integrated Soil-crop System Management program [25], and the Soil Testing and Fertilizer Recommendation

Project [26]. While China has been active in encouraging the formation of large farms, little guidance was provided to support the operation of large farms. As such, many large farms are left alone in dealing with many operational and technical issues in their operations, which prompt them to maximize their short-term profits by over-applying agrochemicals. Our results indicate that there is an urgent need to implement such programs to support the growth and development of large farms in China, including reducing agrochemical use and improving efficiency. Another alternative is to nurture the development of the agricultural service industry in agrochemical use in China [78]. As a service entity, an agricultural service firm can achieve the economy of scale and reduce agrochemical use by serving a large number of farms [79,80].

5. Conclusions

Agrochemical overuse in China has been generally recognized. One potential mitigating strategy is to increase farm size in order to achieve a reduction in agrochemical use. This study examined the relationship between farm size and agrochemical use from a macro perspective using a panel dataset aggregated for 30 provinces in China from 2009 to 2016 and found no universal economy of scale on agrochemical use in China. Given the fact that 78.6% of farms are under 0.667 ha in China, any increase in slightly larger farms such as the farms that are greater than 0.667 but less than 2 ha would reduce agrochemical use. However, the potential economy of scale effect would not last when larger farms continued to emerge. The study found that the agrochemical application rates would increase when the percentage of large farms, especially the farms greater than 3.34 ha but less than 6.67 ha, increased, implying a diseconomy of scale.

Many empirical studies aimed to understand the relationship between farm size and agrochemical use in China using sample farm surveys at a micro scale and reported mixed and often conflicting results that were most likely dictated by the samples being used. Our empirical assessment using the aggregated data at a macro scale provided an additional perspective to understand this complicated relationship. Our results confirmed the existence of both economy and diseconomy of scale effects on agrochemical use in China. We further identified where those effects would take place.

Our results suggest that the strategy based on increasing farm size alone might achieve some initial success in reducing agrochemical use, but the effect could fade away and be reversed as significantly large farms continue to emerge. A plausible explanation for such a bottleneck situation is that HCRC and Hukou systems define the fabric of rural society in China, and large farms formed under those two institutional policies tend to focus on short-term profit maximization, which leads to an increase in agrochemical use. These results have significant policy implications as China is developing and implementing various policies and strategies to modernize its agriculture. In the long-term, reforms on HCRC and Hukou systems should be carried out to eliminate their negative impacts on agricultural development. In the short term, some alternative measures can be implemented to overcome the bottleneck and achieve a reduction in agrochemical use. These alternative measures may include (1) developing technical assistance programs and agricultural extension programs that train and educate farmers, especially farmers who operate large scale farms, to properly use the agrochemicals and guide them to adopt the production methods that use less agrochemicals with minimal impacts on net profits, (2) nurturing the development of agricultural service industry, in which the professionally trained individuals would conduct agrochemical applications for farmers through business contracts, and (3) strengthening the legal procedure of the farmland use right transfer and protecting the use rights of farmlands to encourage large farms to make long-term investments and reduce agrochemical use.

Despite these interesting results, the study has its limitations especially related to the data being used and leaves room for improvement. The study used a panel dataset in 30 provinces in China during the 2009–2016 period, which resulted in limited observations. Research can be further developed by expanding the observations to include data from recent years and/or collect data at a county level to test the robustness of the results. Research can also be conducted by combining the data at both micro and macro scales to test the robustness of the results. Future research can explore these ideas.

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Suburban agriculture, immigrant farmers, and access to agricultural services and resources

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Abstract

While agricultural services are shrinking, the number of nontraditional farms run by immigrant farmers is rising in U.S. suburban regions. This study attempts to understand Chinese immigrant farmers' experience accessing agricultural services and resources in the New York metropolitan area and explores the need for changes in agricultural services to meet changing demand. Thirteen Chinese immigrant farmers in the region were recruited to participate in a semi-structured interview to understand their shared experiences of accessing agricultural services and resources. The study identified diverse ways of accessing agricultural services and

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resources in four critical areas of farming operations: agricultural technology, financial services, farm labor, and farming machinery; and also revealed the existence of "liability of newness" among those new immigrant farmers in operating farms. Most participants felt that they were isolated, with limited access to available services as new immigrant farmers, which constitutes the liabilities to their success in farming. Language barriers, cultural differences, distrust, and isolation were the main obstacles to access adequate services and resources. As farms and farmers are becoming more diverse in U.S. suburban regions, the provision of agricultural services needs to adapt accordingly to meet the growing needs of groups of farmers with varying farming experiences and demographic backgrounds and help them to overcome the liabilities as new immigrant farmers. This study contributes to understanding the farming experiences of minority farm groups, which help develop more inclusive agricultural services.

Keywords
Suburban Agriculture, Chinese Immigrant Farmers, Farming Experiences, Agricultural Services and Resources, Qualitative Research, Liability of Newness, Descriptive Phenomenology

Introduction

The demographic composition of farmers in the U.S. is changing. According to the U.S. Department of Agriculture Census of Agriculture, while 95.4% of farm operators in 2017 were white, non-white farmers increased significantly, by 20% from 2007 to 2017 (Census of Agriculture 2017 Highlights, 2019b). Although Asians were only 9.4% of non-white farmers in 2017, the number of Asian principal operators had increased 24.2% from 2012 to 2017 (Census of Agriculture 2017 Highlights, 2019a). More than half of Asian-operated farms are in suburban regions and produce specialty crops (Li, 2013; Census of Agriculture 2017, 2019a). Farms operated by Chinese immigrants are increasing for several reasons. First, the demand for ethnic and better-quality food products from the immigrant communities is expanding (Aldrich & Waldinger, 1990) as acceptance of Chinese culture and foods increases. (Coe, 2009). As discussed by Imbruce (2016), the development of the ethnic food network in New York City's Chinatown has been sustained by a global food and farm network that includes immigrant farms across the U.S. and global food supply chains. Second, there have been limited employment opportunities for low-skilled immigrants (Aldrich & Waldinger, 1990; Sanders & Nee, 1996), so self-employment through small-scale farming became a practical way of living because of inherited entrepreneurship, readily available human capital, and lower barriers to entering farming in terms of skills and investment (Hightower & Brennan, 2013; Salaff et al., 2003; Zhang, 2016). Third, farming is increasingly considered a leisure and investment opportunity in many suburban regions where farmlands have become scarce and their value has appreciated (Nickerson et al., 2012), attracting some high-skilled and affluent Chinese immigrants to farming.

Immigrant farmers tend to run smaller operations that grow specialty crops and have direct access to markets, and that use alternative farming techniques such as multi-cropping and low agrochemical inputs, differing from U.S. industrial agriculture (Imbruce, 2016; Minkoff-Zern, 2018, 2019). Thus, despite strong governmental support for farming through provisions of the U.S. Farm Bill and from U.S. Department of Agriculture agencies such as the Farm Services Agency and the Natural Resources Conservation Service, Latino immigrant farmers, for example, are often left out of various governmental programs; the lack of standards in their farming practice and their racialized identities are attributed to racial exclusion (Minkoff-Zern & Sloat, 2017; Zabawa et al., 2007). The fast growth of farms operated by immigrants re-ignites the debate on racial identity, immigration, and sustainability in a new perspective challenging not only conventional agrarian development theories, but also U.S. agricultural programs and policies (Agyeman & Giacalone, 2020; Horst & Marion, 2019; Imbruce, 2016; Minkoff-Zern, 2018, 2019; Minkoff-Zern et al., 2020; Ploeg, 2018; Reynolds, 2002; Seda, 2020). However, there is limited knowledge of the unique experiences of minority immigrants as farmers rather than as farm laborers. More research is needed to understand the lived

experiences of racialized farmer groups. (Minkoff-Zern, 2018).

The objective of this study is to explore the farming experiences of Chinese immigrant farmers, specifically their experiences accessing U. S. agricultural services and resources. It is expected that the number of farms operated by the Chinese and other immigrants will continue to increase and play an increasing role in the future agricultural economy. Their growth depends on their ability to access essential resources such as farming knowledge and technology, financial and farm labor services, and farming machinery. Some studies have explored the experiences and contributions of Chinese immigrants as farm labor (Leung & Ma, 1988; Tsu, 2013) or agents in the ethnic food network (Imbruce, 2016), but there is no study specifically dedicated to investigating the farming experiences of Chinese immigrant farmers as principal. A thorough understanding of their farming experiences would help develop more effective sustainable and inclusive agricultural extension and education services.

Theoretical Framework

In his seminal discussion of the "struggle for survival" in the evolution of organizations, Stinchcombe (1965) introduced the "liability of newness" concept to explain the high failure rate of organizations in the early stages of their life cycles. Lack of knowledge, experience, capital capacity, and lack of cooperation with and trust of "strangers"—i.e., older organizations—could potentially contribute to organization failure; therefore, social and economic supports are critical to enhance the survival chances of emerging organizations (Abatecola et al., 2012; Stinchcombe, 1965). Despite its significant impact on research on organizational evolution, the liability of newness concept has rarely been applied to study the evolution of agricultural enterprises. This study applies the liability of newness concept to assess the experiences of Chinese immigrant farmers in accessing agricultural services and resources to operate their farming enterprises. As with any early-stage enterprises, the emerging farms run by Chinese immigrants possess many liabilities that could lead to failure, such as lack of farming knowledge and experiences, financial resources, and a well-established social network to access agricultural resources and services. More extensive understanding of these liabilities will help construct social, economic, technical, and political "macro-structure," especially provision of agricultural extension services that better support the healthy growth of these immigrant agricultural enterprises.

Methods

This study applied a descriptive phenomenology approach to understand the lived experiences of the Chinese immigrant farmers in accessing services and resources in the broad U.S. agricultural production system. Understanding the farming experiences of Chinese immigrant farmers would help provide evidence for future policy changes and additional research to enhance the provision of agricultural resources and services. Phenomenology is a qualitative research method aimed at understanding the explicit and implicit structures and meanings of human experience (Conklin, 2007; Sokolowski, 2000). Descriptive phenomenology explores individuals' experiences of everyday life, describes the structure of such experiences, and provides a thorough understanding of shared experiences (Sokolowski, 2000). Phenomenology has been applied in various agricultural research settings, describing, for example, farmer experiences of being environmental stewards (Hanson, 2001), growing organic produce (Marabesi & Kelsey, 2019), pursuing agritourism entrepreneurship (Ainley, 2014), and even understanding perceived barriers to fertilizer use in Uganda (Mulvaney & Kelsey, 2020). This study followed the essential principles of Husserlian descriptive phenomenology (Husserl, 1962): "natural knowledge begins with experience and remains within experience" (p. 45), "every experience…has intentionality" (p. 222), "essential universality" (p. 47), or "essential generality" (p. 53) and "can be exemplified intuitively in the data of experience" (p. 50).

The study was conducted in the New York metropolitan area (NYMA), a popular destination for Chinese immigrants. NYMA is the largest metropolitan region in the U.S. and is comprised of New York City and surrounding counties in New York, New Jersey, Connecticut, and Pennsylvania.

Chinatown in Manhattan, New York, was one of the earliest settlements for Chinese immigrants in the U.S. Flushing, in Queens, is a newly developed Chinatown and is expanding in size. New Jersey is also a popular home for Chinese immigrants. Mott Street in Chinatown is a regional distribution center and hosts wholesalers and retailers of agricultural products preferred by Chinese immigrants and their families. Although suppliers of the agricultural products include farms in Florida, California, and even South America, most seasonal agricultural products sold on Mott Street are produced in New Jersey. As such, all participants in the study but one were Chinese immigrant farmers from New Jersey; the remaining participant was from New York.

Data Collection

The number of farms operated by Chinese immigrants is still relatively small in the NYMA. Therefore, we adopted a snowball approach to recruit participants for the study. We secured the first group of participants through immediate personal and professional contacts. We followed the recommendations of the first group of participants to secure the second group of participants and so on until the threshold number of participants was reached. All participants met the following criteria: (1) first- or second-generation immigrants from China Mainland, Taiwan, Hong Kong, and Macao, (2) primary farm operators themselves at least 21 years old, and (3) ability to communicate in Mandarin Chinese.

Following a descriptive phenomenological approach (Dory et al., 2017; Fu et al., 2008), semi-structured interviews were conducted with the Chinese immigrant farmers to understand their farming experiences of accessing agricultural services and resources. A key step in applying descriptive phenomenology is not to introduce bias and preconceptions to participants. Therefore, the phenomenological reduction strategy of "bracketing" was adopted in the interview question design and interviewing process, in which existing knowledge and researchers' personal understanding of farming experiences was intentionally bracketed out (Denzin, 1989; Dory et al., 2017; Fu et al., 2008, 2009). The interview questions were carefully designed without directly asking the participants whether they can access agricultural services and resources. Instead, we elicited their experiences using such open-end inquiries as "please introduce yourself," "please describe your farm," "please describe your experiences of accessing agricultural services in the local area," and "please describe your experience of accessing agricultural services and resources from governments."

The interview questionnaire and guide were first developed in English for evaluation and approval by the Institutional Review Board (IRB) at New Jersey Institute of Technology in Newark, New Jersey and then professionally translated into Chinese for interviews after IRB approval. The interviews were conducted in Mandarin Chinese. Informed consent was secured from all participants following approved IRB guidelines to ensure privacy. A nominal one-time payment was given to each participant to compensate for the time spent for the interview. All interviews were conducted in private settings. A coding system with numbers instead of participant names was used to ensure confidentiality. Participant recruitment and interviews occurred between June and August 2017. Following Dory et al. (2017), each interview lasted from 40 to 120 minutes and was recorded using a digital audio device. Observational data for each participant were also recorded. All the interviews were professionally transcribed in Chinese and checked for accuracy. The researchers are fluent in both Chinese and English.

Thirteen participants, one woman and 12 men, were interviewed (Table 1). Age of the participants ranged from 27 to 73 and was 51.5 years old on average. Five participants immigrated from Taiwan, seven from the Chinese mainland, and one was born in the U.S. and inherited the farm from his father. All participants, except one, had higher education degrees: Five bachelors, five masters, and two Ph.Ds. Ten participants worked on farming full-time and three part-time. Most were first-time farmers with limited farming experience. They grew a variety of products, including vegetables, flowers, mushrooms, oysters, grapes, and edamame. The average size of their farms was 41.5 hectares (ha); the smallest farm was 2.4 ha and the largest was 161.9 ha.

The sample size for this descriptive phenome-

nological study, i.e., the threshold number of participants, was "determined by the richness and saturation of the interview data, that is, when the same information has been repeated by the participants…regarding the description of their experiences" (Dory et al., 2017, p. 3). Strong convergence emerged when interviewing the 13th participant. To ensure that all important information was captured, we conducted a second-round interview using the same interview questions with one of the 13 participants. Data saturation was assured as no new information emerged in the second-round interview.

Data Analysis

The transcribed interview data were analyzed with a descriptive qualitative method based on intuitive reflections and strategies of continuously "comparing and distinguishing, collecting and counting, presupposing and inferring" (Husserl, 1962, p. 93). Crucial to this method is systematically classifying data into fewer content-related themes that share the same meaning, which are coded in color and text (Dory et al., 2017). We followed the seven-step data analysis procedure described by Dory et al. (2017) and Fu et al. (2008, 2009) to examine data, compare codes, challenge interpretations, and inductively develop themes. We first individually read the transcripts in Chinese several times to gain a broad understanding of the text, and then met to identify significant quotations and discuss key codes related to the research question. The first author took the initiative to combine the coded quotations into one file and confirm the accuracy of the code and quotation by comparing to the original transcript. Then we individually analyzed the quotation files and identified major themes by putting key coded quotations together for each research question. We then met as a group to review major themes and discuss them to resolve any discrepancies, and to review the transcripts and validate the structure of themes alongside interview data. Multiple discussions were followed until consensus was achieved about each aspect of data analysis. The specific themes, codes, and quotations were translated from Chinese to English and reported in the Results section. Efforts were made to differentiate and compare the experiences of the 13 subjects, with careful selections of text demonstrating the true meaning of their experiences.

Results

The 13 participants represented the diversity of farms operated by immigrants in the region. First,

Table 1. Participants and Their Demographics and Farm Characteristics

ID	Gender	Age	Education	Farming Career	Starting Year	Size (ha)	Products	Organic Farming
P1	M	39	Ph.D.	Part-time	2015	25.9	Vegetables	Yes
P2	M	69	Bachelor	Full-time	1991	16.2	Nursery/Vegetables	Yes
P3	M	50	Bachelor	Full-time	2000	121.4	Vegetables	Yes
P4	F	50	Master	Part-time	2013	9.3	Vegetables	Yes
P5	M	73	Master	Full-time	2010	2.4	Nursery	—
P6	M	66	Master	Full-time	2005	8.1	Nursery	—
P7	M	45	Bachelor	Full-time	2000	61.1	Vegetables	No
P8	M	53	Bachelor	Full-time	2016	13.6	Mushrooms	Yes
P9	M	27	Master	Full-time	2001	19.0	Mushrooms	Yes
P10	M	31	Ph.D.	Full-time	2016	161.9	Edamame	Yes
P11	M	63	K–12	Full-time	2008	40.5	Vegetables	No
P12	M	53	Bachelor	Full-time	2001	20.2	Oysters	—
P13	M	50	Master	Part-time	2010	40.1	Vineyard	—
Average		51.5				41.5		

their personal backgrounds were diverse, ranging from high-skilled immigrants, such as computer programmers, newspaper reporters, and entrepreneurs to low-skilled immigrants who had previously worked in Chinese restaurants and grocery stores in New York City. Four participants were highly educated in agriculture and aquaculture and immigrated to the U.S. as agricultural specialists. Second, the organizational form of those farms was diverse. Three farms were corporations that operated like most modern enterprises: the owners did not directly operate the farm but entrusted it to professional farmers or farm managers. The other ten, family farms, were mainly operated by family members. Third, their business objectives were diverse. Most participants made a living by farming, but some operated farms for leisure and investment purposes. Such diverse personal backgrounds, organizational forms, and business objectives resulted in diverse ways to access agricultural resources and services.

Theme 1: Accessing farming knowledge and agricultural technology

Regardless of prior background in farming, it is a new undertaking for immigrants to operate a farm in the U.S., which involves new knowledge, including of plants, soils, climate, diseases, rules and regulations, and farming technologies. Agriculture is driven by advances in agricultural technology, and access to agricultural technologies is important for improving agricultural productivity and profitability. This study identified four ways of accessing farming knowledge and technology by the participants.

Obtaining technical support from public service agencies

The agricultural experiment stations and cooperative extension services have offices with experienced staff to offer science-based education programs and bring the wealth of knowledge of state land-grant universities to farmers and communities. Out of the 13 participants, two had obtained support from public or university extension service. They found that science-based education programs were useful and the extension agents helpful. Participant P2 stated that he had participated in various workshops organized by county agricultural extension agents, who were "between governments and farmers and help spread information from governments to farmers, and also help introduce new products or technologies to farmers." Participant P2 added: "If you have any problem or any difficulty, you can always call them. They will help you sort the problem out." Participant P5 agreed: "If you have any problems such as pest and disease issues and don't know what to do; or you don't even know what the problem is, then you can just take some samples and sit down with an agricultural extension agent."

Learning from other farmers

In the peer learning practice, farmers interact with other farmers in a community to obtain farming knowledge, which has proven to be one of the most effective ways for farmers to learn and master agricultural technology (Faysse et al., 2012; Foster & Rosenzweig, 1995). Many participants maintained good relationships with neighboring farmers and gained knowledge and skills from them. For example, one participant learned pest control techniques from a farmer neighbor. To gain knowledge and technology from other farms, some farmers "visited and consulted with other farmers" (P7), "temporarily worked for other farms or greenhouses" (P5), or "collaborated with a local large organic farm" (P10). In addition to direct learning from others, some participants relied on social media to gain knowledge. For example, participant P4 mentioned a WeChat (a popular social media platform among Chinese immigrants) group for communication on agricultural technology that included a professor of agronomy and other local Chinese immigrant farmers.

Relying on prior personal farming experiences

Experience is an essential dimension of human capital and critical to the operation of an enterprise (Ainembabazi & Mugisha, 2014). Farming experience is a process through which farmers perceive and participate, accumulate knowledge, and adopt technologies. Five participants clearly indicated that they or their family members had farming experiences prior to immigration, which were helpful in their farm operations in the U.S. Participant P1 said, "My parents were vegetable farmers in China.

They have worked on vegetables their whole life in China and still love growing vegetables. During their visit to the U.S., they converted my backyard into a vegetable garden." He eventually bought a farm so that his experienced parents could work on it. Participant P11 said that he had been growing corn, sorghum, and hybrid rice for over ten years before coming to the U.S. Four participants have advanced degrees in agriculture-related fields, such as a master's degree in agronomy (P5, P6 and P9) and a doctorate degree in food science (P10). Participant P12 said, "I majored in fishery in college and came to the U.S. as an expert working in aquaculture."

Learning by doing

Regardless of their farming backgrounds, all participants had gone through the process of learning by doing, which plays a critical role in helping farmers to overcome technical barriers, learn agricultural technology, and accumulate farming knowledge (Foster & Rosenzweig, 1995). Participant P7 claimed he "did not know anything about farming at the beginning, had to gradually figure it out." Participant P6 described his whole farming experience as a learning by doing process: "From how to build a greenhouse to what to plant and how to plant, I had to figure it out gradually." Learning by doing is important not only for the less experienced farmers, but also for those experienced ones because farming practices, scales of production, and natural and socioeconomic environments differ considerably between their original countries and the U.S. One of the most experienced participants said, "For nearly 20 years, I have been gradually learning and improving" (P3). As a part of learning by doing, some participants would get agricultural knowledge by reading books and searching for information. "If I didn't know, I would try to find an answer from books" (P5). Most participants relied on "the internet to learn; whenever I had a technical issue, I would go online" (P1). Another participant said, "I could find solutions from books on most technical problems."

Despite diverse ways of accessing farming knowledge and agricultural technology, participants still had a lot to learn and needed support. For example, farmers in the region of the study generally control weeds using landscape fabric, mulch, and herbicides. However, many Chinese farm operators in the U.S. had just begun their farming career, and their knowledge of farming was very limited. Weed control was one of the biggest challenges they faced, as seven of 13 participants were specifically practicing organic farming. To manage organic farming, they "spent a lot of time to pull out the weeds" just as traditional Asian farmers have done; "pulling out the weeds is daily work" (P1). They also have limited knowledge for dealing with insects. To avoid pesticides, some participants sometimes used "tobacco and white vinegar to treat visible insects" (P4).

Theme 2: Accessing financial resources

Farming is a capital-intensive business. Capital is needed to upgrade farm equipment and pay for labor and materials, such as seeds and agrochemicals, often before any harvest. Flexible access to financial resources is critical to operating farms and improving productivity (Fakowski et al., 2010). The Chinese immigrant farmers in this study had diverse ways to access financial resources to support their operations.

Obtaining financial support through informal channel

Seven participants funded their operations through personal and family savings. Participant P7 "started from scratch and have gradually accumulated year after year." Another participant shared the same experiences of saving and reinvesting: "started from zero, saved dollar by dollar; and then slowly reinvest" (P5). To cover temporary shortage, many participants turned to relatives and friends to borrow "[US]$3,000 from one and [US]$5,000 from another" (P11) to maintain operations.

Accessing external financial services

To support farming operations, there are a variety of formal financial services, such as commercial banks and government-backed agricultural loan programs. For example, the Farm Service Agency (FSA) offers various loan programs to help start, expand, or maintain a family farm. In this study, only a few participants obtained government-backed, no-interest loans for farming machinery

purchases. Participant P1 "bought a tractor with a no-interest loan, which is helpful; it incurs no interest; I have five or six years to pay it off." Some participants participated in the Environmental Quality Incentive Program, with technical and financial assistance offered by Natural Resources Conservation Service (NRCS) and FSA, respectively. Discussing a high tunnel system built with such support, Participant P1 said, "It is very practical. The thousands of dollars subsidized by NRCS is very helpful." Participant P6 used a low-interest loan from a commercial bank to start and operate his greenhouse, but the bank was a foreign commercial bank that supports immigrants' entrepreneurship in the U.S.

Most participants are reluctant and/or unable to finance their farm operations through external and formal financial services. Participant P5 said that "local farmers may borrow government-backed agricultural loans from the U.S. banks, but we are not familiar with these loans and lending procedures. We have to rely on our own gradually accumulated savings." Eight participants clearly indicated that they had never applied for any governmental funding support. Some participants said that they even "did not know" the existence of such funding support. Participant P2 thought that "governmental assistance is very important…but I have been not aware of any assistance from agricultural department or farm bureau."

Theme 3: Accessing farm labor

Farming is a labor-intensive business. Stable access to farm labor is critical to operate a farm. However, demand for farming labor is often seasonal, making it difficult to maintain a stable labor force, especially for small farms. Two participants were content with their access to farm labor. Participant P6 had maintained a stable team of workers over many years. Participant P13 contracted all the farm work to a service company by signing a labor contract in advance. However, the labor shortage was the biggest problem encountered by all other participants; they had to be creative to obtain farm labor.

Relying on personal networks

Most participants simply engaged themselves and their family members more and intensified their labor to overcome the shortage. Participant P4 said, "I am the laborer, and so is my husband." Participant P5 gave a more specific account: "My work is equivalent to three hired laborers…a typical laborer works 40 hours a week, but I work 80 hours a week. Additionally, my work efficiency is 50% higher than theirs." Participant P7 gave a specific example of stretching themselves to overcome the labor shortage: "At the busiest harvest time, we had to work overtime to prepare the shipment until one or one thirty in the morning. My father then drove to Chinatown. After coming back, he would sleep for a few hours before repeating the process again. At some point, he only slept eight hours in three days." Some participants would turn to their relatives and friends for help when immediate family labor was not sufficient. Participant P3 asked "Godmother's brothers, and Godfather and his relatives for help." Participant P1 pointed to a worker on the field on his farm: "She is my neighbor's mother. I asked her to work for me a few hours a day." Some participants sought help directly from their home country: "This is the farm owned by an elder of a family clan…Ten to twenty of his family members and/or relatives would visit the farm temporarily and provide timely help during the harvest season" (P3).

Go through formal channels

Some participants "put job advertisements in Chinese newspapers" to recruit labor from Chinese immigrant communities, and some used labor agencies to obtain temporary workers. Participant P7 said, "We hired temporary workers through a labor agency to do some low-skilled work like shipment preparation. There are minor skill requirements for temporary workers. They can come and go without big impacts on the operation."

Sharing labor force

Labor demand is seasonal, but timing varies by farms and their products. Some participants drew on timely availability to meet labor needs. Participant P3, who runs a vegetable farm, said that he often borrowed workers from a nearby friend who operated a horticultural farm: "We each have our own hired labor. When I am busy, I would ask him to send his workers to help. I do the same when he

is in high demand." Labor sharing is a creative way to overcome the conflict between seasonal labor demand and the desire to maintain a stable labor force.

Theme 4: Accessing farming machinery

Farming machinery improves agricultural productivity (Edgerton, 2009). However, our study found that participants generally had limited access to farming machinery.

Relying on self-service

Some participants pointed out that they had no money to buy machinery and had to use hand tools to work on the fields during the initial period of farming. Participant P1 said, "Local farmers found it funny. My neighbor, a local farmer, would imitate the way of using a hoe to remove the weeds every time he saw my father." Many participants gradually learned to purchase and use farming machinery to replace human labor. Participant P1 continued his story: "We initially bought a small tractor for my parents to use…I bought a tractor last fall…and this year I bought several used equipment and prepared the fields all by myself using those machines."

Obtaining external support

The participants also tried to access farming machinery services through their social networks. When necessary, participants would ask other farmers, especially neighboring farmers, for help. One participant asked his neighbor to prepare his fields for planting. His neighbor helped prepare the initial three-acre field of his vegetable farm with plowing and ridge making. Participant P4 turned to a farmer friend for timely use of heavy machinery: "A friend rented a bulldozer for a week, but finished his work early. Since we are not far away, I wanted to use it on my farm."

Although some participants such as P6, P10, and P13 were content with their needs for farming machinery and services, most participants encountered difficulties in obtaining services suitable to their small-scale operations. Participant P4 said, "I had a hard time to find a service provider who offers small combine or bulldozer. I don't need the big one. I finally found one, but they didn't want to lease it to me only for a few days." As farming is a seasonal operation, some participants complained they could not get timely services from others: "These seeds had to be planted early, but the local farmer who provided me machinery services was busy with his work during the early planting season. He came to help me only after he finished all his work. Last year, it was in late May and early June when he came to build the ridges for planting" (P1).

Theme 5: Obstacles to Accessing Services and Resources

Despite growing interest in farming, Chinese immigrant farmers had practical difficulties in accessing necessary services and resources, largely due to their status as immigrants.

Isolation in production

Despite the diverse ways of operating farms and accessing services and resources, most participants generally are isolated when conducting their farming operations and rarely deal with broader farming communities. Most Chinese farms primarily produce special vegetables and oriental flowers to serve the growing demands of Chinese immigrant communities. As Participant P1 said, "Mexican goes to Mexican farms, Chinese goes to Chinese farms, and American goes to American farms." Therefore, his farm cultivates "Chinese produce that local American does not eat, and the consumers are mainly Chinese." Participant P3 said, "We came from Taiwan, and all things we knew were Taiwanese produce. Thus, we started our farm to produce Taiwanese produce." Some participants "do not like" (P7) and "are afraid of strangers" (P11) to visit their farms.

Language and communication barriers

Some participants considered their poor English a barrier to communicating with others and accessing information on resources and services. Participant P11 said, "I don't have any experience dealing with the government. I don't know English. Whatever I need, I tell my son. He helps out." NRCS programs were often brought up in the interviews. Participant P1 said, "NRCS does not proactively communicate the information on those programs

with me while local American farmers know it well." Some participants visited the governmental websites for more information but often experienced "language obstacles because that vocabulary is difficult to understand" (P4). Some participants complained that the information on those websites was incomplete; when they called for additional inquiries, "no one picked up the phone. There is no specially designed website that hosts all agriculture-related information" (P4).

Cultural difference

There are cultural differences between the Chinese immigrant farming community and American society. Most Chinese immigrant farms focus on agricultural products exclusively for Eastern Asian immigrant consumers rather than the local American consumers. Some Chinese immigrant farms do serve American consumers, but they must overcome some cultural barriers. Participant P6 gave a vivid example, "The taste of local American is different from ours. Chinese like red, and everything is red, but Americans don't like red. **…** Yellow and light blue flowers were the best seller during Easter, and I thought Americans like yellow and light blue. Therefore, I prepared such color flowers on Mother's Day but couldn't sell them at all."

Distrust

The cultural difference can lead to mistrust. Participant P1 said, "Local Americans sometimes came to visit my store on my farm, but usually didn't buy anything. A local American visitor once told me that my tomato did not have tomato flavor, but my tomato seed were from my neighbor, an American farmer." Distrust extended to the government, with some participants feeling that they were treated differently by government organizations. Participant P1 said, "Most people who work at NRCS are white. White farmers always get funding when they apply, but I didn't get it when I first applied for it. I waited for two years to get it**…**local American farmers got more funds than I did." Some participants did not want to be "involved in politics because we are disappointed with the government**…**we just follow the rules to do our business. We are immigrants. We need to keep reminding ourselves about that. No matter what you do, the government would see you differently. We work harder than others because we are the first-generation immigrants" (P6). Participant P6 cited an example of a harsh treatment from a local government: "I applied for a permit for my greenhouse. Although no issue was found during the inspection, the township refused to issue the permit for its operation. The township fined me [US]$2,000 a day after its opening. It took three years and numerous efforts and resources to win the lawsuit against the township. The case was finally settled by paying [US]$8,000 fee instead of the accumulated fine of [US]$2 million." Some participants simply believe that "the government does not bring benefits, but always tries to find your faults; therefore, we are not willing to deal with the government" (P7).

It should be noted that some young farmers have opposite opinions about government agencies. The second-generation immigrant farmer said, "It is quite smooth to deal with the government. They tell us what to do, and we do it" (P9). Participant P10, who has a Ph.D., said, "Agricultural extension helps us collaborate with other farms and introduces us to some government programs." Participant P12 said, "The state agencies liked my operation very much and were helping me expand my business."

Discussion, Implications, and Recommendation

Agriculture in U.S. suburban regions is experiencing a transformation. Large-scale industrial agriculture has been fading away in the suburbs, and pockets of small-scale farms that produce specialty products and are often run by immigrants have emerged to fill the niche and take advantage of proximity to consumers and markets. It is expected the trend will continue, since most suburban regions have adopted aggressive farmland preservation programs to retain it for agricultural operations (Hellerstein et al., 2002). However, new immigrant farmers face numerous obstacles for entering the farming business as a newcomer, which can be characterized as liability of newness. The findings from this study confirmed the existence of the liability of newness among these Chinese immigrant farmers. First, studies show that

immigrant farmers face many obstacles including inadequate English communication skills, insufficient social networks, and lack of technical knowledge and resources that often prevent immigrants from successfully operating farms (Asiedu et al., 2012; Jensen, 2006; Salaff et al., 2003; Sanders & Nee, 1996; Smithers & Sethuratnam, 2013). Our study finds that those obstacles are real among Chinese immigrant farmers and had significantly affected their access to services and resources. Second, this study also found that Chinese immigrant farmers primarily used informal channels to obtain financial resources to operate and expand their farming operations. The predominant use of informal channels for financial services often implies significant barriers to formal financial services (Banerjee & Duflo, 2007; Madestam, 2014; Tsai, 2004). Third, although the network of food supply chains in Chinatown, New York, is global, as described by Imbruce (2016), the operation of farms by Chinese immigrants was conducted locally and often in isolation, forming an enclave economy on the production side. Similar experiences of liability of newness were recorded among other immigrant farmers, such as Latinos (Gonzalez & Jeanetta, 2013; Minkoff-Zern & Sloat, 2017; Zabawa et al., 2007).

Public investment in food and agricultural research and various agricultural education and extension programs has successfully supported farm operations and spurred U.S. agricultural productivity growth (Pardey et al., 2013). These programs help improve farmer decision-making and raise productivity, contributing to agricultural development and prosperity (Anderson & Feder, 2004). Jin and Huffman (2016) estimated a real internal rate of return of 67% for public agricultural research with a productivity focus, and a rate of return of over 100% for narrowly defined agricultural and natural resource extension. Public agricultural education and extension are closely linked to a decentralized and state-based university research system with additional support from state and local government (Norton & Alwang, 2020). As the share of the agricultural economy in suburban states like New Jersey shrinks, so does the federal and state funding for these programs, resulting in a significant decline in agriculture education and extension programs in the region. This further hurts the community of immigrant farmers as they have been already experiencing difficulties and barriers to access these services traditionally provided.

Despite isolation and many obstacles, the immigrant farmers are resilient in dealing with difficulties in their farm operations to overcome the "liability of newness." In many cases, their farming businesses are expanding and flourishing. However, to facilitate further growth in farms operated by immigrants, the agricultural education and extension programs in suburban regions need to adapt to the transformational changes in suburban agriculture to meet the new kind of demands (Brown, 1981; Calo, 2018; Knutson, 1986; van den Ban & Hawkins, 1996). First, as more immigrants, including Chinese and Latino, are engaged in farming, language barriers and cultural differences are limiting their abilities to access services and resources. Agricultural extension and governmental service agencies can adapt to such situations by providing multi-lingual supports in their programs. Second, immigrants generally have a limited understanding of agricultural and relevant regulatory policies. The governmental agencies can take a proactive approach to improve communication and reduce distrust with immigrant farmers. Third, local governments and community groups can play more active roles in organizing and/or hosting multi-cultural festivals to strengthen communication and exchange between immigrant farmers and their communities and to understand cultural differences. Fourth, agricultural extension services could develop a one-stop service platform that consolidates multiple services to help farmers to obtain services more effectively. Fifth, more innovative financial services can be created to better serve the financial needs of immigrant farmers to support their farm operations.

Limitations and Future Research

This is the first study to investigate the farming experiences of the Chinese immigrant farmers as principal operators in terms of their access to agricultural resources and services for overcoming the liability of newness and operating farms. This qualitative study has some inherent limitations. First, the experiences described here are limited to

Chinese immigrant farmers in the New York metropolitan area. Second, the number of participants is relatively small. Third, most of the participants are first-generation farmers, and the experiences of more long-term Chinese immigrant farmers in other regions such as California may be quite different. More in-depth research is needed to understand Chinese immigrant farmers' obstacles to accessing services and resources, such as the language barriers, cultural difference, distrust, and isolation described in this study. In-depth research is also needed to understand how their racial identity may help expand their farming operation, integrate with the broader, even the global agricultural and food system, and develop a market-oriented yet sustainable agricultural system. The growth of small-scale immigrant farmers in an industrial agricultural system also calls the conventional agricultural development theories into question. More research and theoretical development are also needed to understand the increasing presence of small-scale immigrant farmers and to facilitate their growth.

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How does internet use promote joint adoption of sustainable agricultural practices? Evidence from rice farmers in China

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ABSTRACT

Climate change and public health emergencies have severely threatened world food security. In response, the Chinese government has actively promoted sustainable agricultural practices (SAPs) and emphasized the importance of integrated packages to enhance the development of high-quality agriculture. However, due to information failure, farmers' adoption rate of SAPs is still very low. Meanwhile, internet use can effectively reduce the cost of information barriers and catalyze farmers to promote the joint adoption of SAPs. This paper aims to theoretically elucidate the logic of how internet use impacts farmers' joint adoption of SAPs. Empirical analysis based on data from 844 rice farmers in southern China reveals that internet use can significantly promote the joint adoption of SAPs, and adoption behaviours are complementary across multiple technologies. Furthermore, internet use in the group of rice farmers with more farmlands or those receiving subsidies is more inclined to adopt SAPs jointly. These findings suggest that developing countries should prioritize public investment in rural internet infrastructure to facilitate joint adoption of SAPs through farmers' internet use. The moderate scale of farmland usage and targeted agricultural subsidy policies can further enhance the effectiveness of ICT-based joint adoption of SAPs.

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Highlights

- Internet use significantly promotes the joint adoption of sustainable agricultural practices (SAPs) among farmers in southern China.
- Complementary adoption across three technologies indicates that new seeds or seedlings technology adoption can be driven if the farmer adopts the other two SAPs.
- Larger farmland scale or receiving subsidies contribute to a higher inclination towards farmers' joint adoption of SAPs through internet use.
- Developing countries should prioritize public investment in rural internet infrastructure to overcome limited access to information and foster the adoption of SAPs.
- Targeted policies, including agricultural subsidies and encouraging appropriate management scale of farmland, can further enhance the effectiveness of ICT-based joint adoption of SAPs, ensuring sustainable agricultural development.

1. Introduction

Global food security suffers severe shocks due to climate change and public health emergencies. The number of people affected by hunger globally rose to as many as 828 million in 2021, an increase of about 46 million since 2020 (FAO et al., 2022). The 2030 Agenda for Sustainable Development is already off-track, reframing sustainable food systems is urgent. Sustainable Agricultural Practices (SAPs) are strategies that can enhance productivity

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sustainably by addressing the degradation of ecosystem services and improving the ability of smallholder farmers to adapt to climate variability and change (Teklewold et al., 2013a). To address the issue of food security, the Chinese government emphasized that joint adoptions of SAPs should be promoted to facilitate sustainable agricultural development in an integrated and complementary manner.[1] The rationale of those policies is clear. First, agricultural production is a continuous process, and joint adoption is inevitable in agricultural production activities (Dorfman, 1996). Second, SAPs appear to be independent, but it is still inherently systematic, as SAPs can interrelate with different technologies (Oyetunde-Usman et al., 2021); adopting multiple technologies is more effective than adopting a single technology (Ehiakpor et al., 2021). Third, Farmers' technology adoption decisions are determined by the characteristics of agricultural technology innovation (Morgan et al., 2023). So, considering synergistic effects, farmers may change the internal components of SAPs integration, deepen the structure of SAPs integration, generate innovation decisions (Arthur, 2009) and allow them to achieve agricultural productivity gains with the joint adoption of SAPs. However, Chinese farmers' willingness to engage in joint adoption was low (Zeng et al., 2019). For example, 42.77% of rice farmers adopted only one kind of Pro-environmental Agricultural Practice (PEA), 31.03% chose to adopt two PEAs, and only 6.5% chose to adopt three or more PEAs (Zeng et al., 2020).

So far, a few studies have researched the impacts that influence farmers' joint adoption of SAPs. Due to constraints in resources, ability, and information, farmers face limitations in their behavioural capacity, making it challenging to meet the conditions for the joint adoption of SAPs (Bakker et al., 2021; Gao et al., 2020). Also, since farmers are risk-averse when making decisions (Ellis, 1993), their attitudes regarding new technologies can lack motivation. The rapid development of information and communication technology (ICT) has effectively reduced the cost of information access and dissemination, which can increase the willingness of farmers to adopt SAPs jointly (Ma & Wang, 2020). Research has also demonstrated that many farmers worldwide already use internet search results to make agricultural production decisions and improve production efficiency (Deichmann et al., 2016; Michels et al., 2020; Zhai et al., 2020). Many farmers have internet access, especially in China, the largest developing country (Li et al., 2022). Until June 2022, the internet penetration rate in rural areas of the country was 58.8%. With the rapid development of ICT, agricultural sectors, including farming, aquaculture, fisheries, and forestry, are actively embracing ICT technologies such as IoT and AI to enhance production efficiency and product quality. This growing trend has prompted research into the relationship between internet use and joint adoption of SAPs (Ali et al., 2019; Kuhlmann et al., 2023; Lim et al., 2022; Ma, 2020; Steinke et al., 2021; Tham et al., 2022; Van et al., 2022). Sørensen et al. (2019) argue that farmers can directly engage in the joint adoption of ICT with other technologies. Moreover, farmers can utilize ICT to provide agricultural production information, indirectly assisting them in making joint adoption decisions (Hasanuzzaman, 2019; Khan et al., 2022a; Sørensen et al., 2019). Sheng Tey et al. (2018) argued that ICT could reduce uncertainty in technology adoption among SAPs. Others have argued that ICT enhances the willingness of farmers to adopt SAPs jointly (He et al., 2021). Moreover, ICT can contribute to agricultural productivity (Khan et al., 2022b) and achieve sustainable and high-quality agricultural development (Chandio et al., 2022; Symeonaki et al., 2019). However, literature on theoretical analyses of how internet use influences farmers' SAPs adoption is still inadequate, and only Ma and Wang (2020) have made a relatively comprehensive and detailed analysis at the farm level. Furthermore, the latest research notices the digital divide among different groups of farmers in technology adoption (Ma, 2020). According to the findings, smaller farming households can suffer from 'technophobia' and be reluctant to adopt new technological devices such as smartphones (Marescotti et al., 2021), thus less likely to adopt SAPs; larger farmers were more likely to experiment with new conservation farming technologies on parts of their land (Arslan et al., 2014). Moreover, the government tends to use subsidies policy to promote the adoption of new agricultural technologies. Consequently, the effectiveness of internet use in promoting the joint adoption of SAPs may be constrained by internal and external factors, including endowment characteristics and policy conditions. However, due to the lack of empirical evidence to support them, these perspectives require further exploration (Lankoski & Lankoski, 2023).

The objective of this paper is to cover the gaps mentioned above. First, this paper provides a rationale for internet use as 'ICT information' input which drives agricultural production and theoretically analyses how it affects farmers' joint adoption of SAPs. Then, by utilizing survey data from rice farmers, it

empirically analyzes the impact of internet use on the joint adoption of SAPs in intensity perspective, verifies the complementary relationship between the three SAPs' adoption from a decision correlation perspective, and finds out larger-scale farmers and farmers receiving agricultural subsidies are more likely to adopt SAPs jointly when using the internet. Finally, based on the research findings, it proposes policy recommendations for promoting farmers' joint adoption of SAPs. This study provides a theoretical and practical reference for improving the ICT-based joint adoption of SAPs in developing contexts.

This paper is organized as follows. After this introduction, section 2 is the theoretical framework and research hypotheses. Section 3 outlines the study sites, data collection and empirical models. Section 4 presents the main results and heterogeneity analysis. Section 5 includes a synthesis of the results, policy and practice recommendations, and research limitations.

2. Theoretical analysis and research hypotheses

Yoav and Shchori-Bachrach (1973) proposed the Diffusion Theory of Technological Innovation for business firms, and Feder and Slade (1984) argued that it was also applicable in the agricultural sector. Their study of technology adoption by Indian farmers underscored the role of information accumulation in agricultural production while distinguishing between active information gathering and passive information acquisition. On this basis, Zheng et al. (2022) included 'ICT information' as an input factor in farmers' agricultural production functions. They found that internet use could promote farmers' technology adoption in agricultural production.

This paper incorporates 'ICT information' as a driver of agricultural production and theoretically analyses farmers' joint adoption of SAPs. It is assumed that farmers obtain new technology to improve their production utility through passive and active learning, while the most common active learning is from ICT information, and the acquisition of ICT information involves low costs such as time or money. This means that if the farmer uses internet, the more information of SAP farmers can get through the internet, the more likely they would adopt a new SAP. Since the technology adoption of SAPs varies across farmers, farmers with more ICT information of SAPs accumulation will continue to adopt SAPs to maximize utility if the marginal productivity of ICT information is positive. The first hypothesis of this paper is:

> H1: Internet use promotes farmers' joint adoption of SAPs.

Feder (1982) has argued that agricultural innovations usually show higher perceived risk than traditional technologies. Joint adoption by farmers is usually an information-based rational choice (Ryan & Subrahmanyam, 1975): although farmers maximize expected profits by joint adoption, they tend to adopt technologies in some order over time (Atanu et al., 1994) until full joint adoption is achieved, thus maximizing expected utility (Leathers & Smale, 1991). However, Feder (1982) has also argued that the selection patterns of innovations are interrelated. Assume that two innovations are introduced simultaneously: one innovation is scaling neutral, and the cost of the other decreases with increasing farm scale. Using certain technology-to-technology combinations may be more favourable for some farmers, while other farmers actively avoid using them. There are clear complementarities and alternatives between different agricultural technologies (Teklewold et al., 2013b).

In the process of ICT information dissemination, farmers' information decision-making behaviours on different SAPs may also be correlated with each other. High-volume, low-cost, and rapid internet information may induce farmers to adopt combined innovations for increasing production, income, and efficiency. Moreover, they may integrate and combine other SAPs to maximize the profit of the agricultural output. This leads to the second hypothesis of this paper:

> H2: In the internet use promoting the joint adoption of farmers' SAPs, SAPs complement each other.

Heterogeneity also exists in technology adoption (Foster & Rosenzweig, 2010). The effectiveness of ICT information for the joint adoption of SAPs may be limited by both exogenous and endogenous constraints on farmers' decision-making (Feder, 1982). On the one hand, farm scale is the main factor of agriculture production and may impact farmers' joint adoption of SAPs. Smaller farmers have less ability to search for technology information and are usually more risk-averse and psychologically resistant to new technologies. In comparison, larger farmers with higher levels of information accumulation can hold more positive attitudes toward the joint adoption of new technologies. So, these farmers are more likely

to use ICT for the joint adoption of SAPs with the help of the internet compared to smaller farmers.

On the other hand, official institutions usually extend agricultural innovations, and subsidy policies can reduce the investment cost of SAPs for farmers and enhance their willingness for technology adoption. Farmers who receive subsidies are more likely to adopt SAPs jointly through the internet. As such, our third hypothesis is:

H3-1: Compared to small-scale farmers, large-scale farmers are more inclined to adopt SAPs jointly when they use the internet.

H3-2: Compared to the farmers who have no subsidies, farmers who received subsidies are more inclined to joint adoption of SAPs when they use the internet.

3. Materials and methods

3.1. Data

The sample of this study is rice farm households in Xinfeng County, Shaoguan City, Guangdong Province, Southern China, as it shown in Figure 1. Xinfeng County has a mild subtropical monsoon climate, high rainfall, abundant light, long frost-free periods, and four distinct seasons. Hills and basins dominate the topography, making it suitable for growing traditional crops such as rice Meanwhile, telecommunication optical ports and mobile signal base stations were constructed to cover all administrative villages in the county in 2019.[2]

The research group conducted the survey in 2019. Considering Xinfeng county had 142 administrative villages in 7 towns, we adopted the following sampling principles. First, 60 villages were randomly selected from the entire administrative villages; then, 2 natural villages were randomly selected from each administrative village, and 10 farmer households were selected from each natural village. As a result, a total of 1200 farmer households were surveyed, and after excluding non-rice farmer households, the final sample size in this paper is 844.

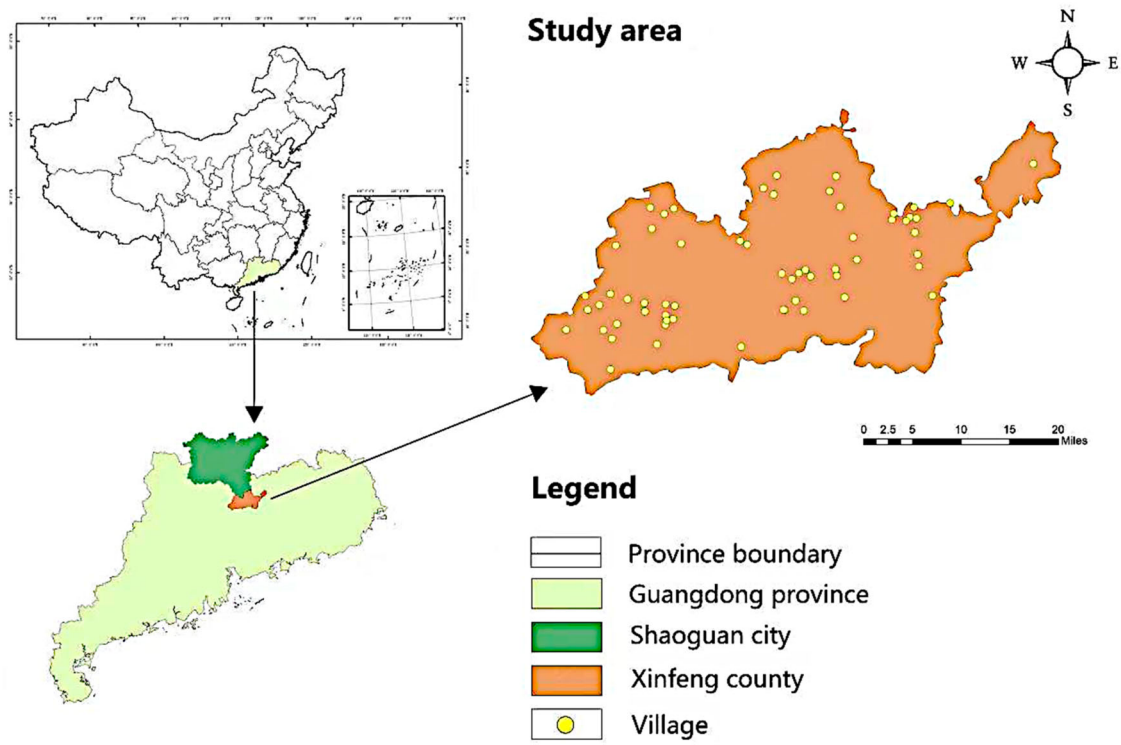


Figure 1. Study area in Chinese territory.

Note: This figure is based on a standard map downloaded from the standard map service system of the Ministry of Natural Resources of the People's Republic of China with approval number GS(2019)1822. The base map has not been modified.

3.2. Variables

3.2.1. Dependent variables

Joint adoption of SAPs is the dependent variable; it refers to the adoption of the number of SAPs by rice farmers for agricultural production activities (Dorfman, 1996). And each SAP adoption is measured as follows: (1) Whether rice farmer adopts new seeds or seedlings (SAP_S). (2) Whether rice farmers adopt green and environmentally friendly agrochemical technology for production (SAP_PF). (3) Whether rice farmers adopt modern machinery for farmland preparation, planting, or harvesting (SAP_M) (Akram et al., 2020). So, we can construct an ordinal variable to reflect SAPs' joint adoption. Based on Ehiakpor et al. (2021), we assign a value of 0 to rice farmers who do not adopt SAP, 1 to rice farmers who adopt one SAP, 2 to rice farmers who adopt two SAPs, and 3 to rice farmers who adopt three SAPs.

3.2.2. Independent variable

The independent variable is whether rice farmers use the internet via WIFI or a mobile network, which is assigned a value of 1 if the condition is satisfied and 0 otherwise.

3.2.3. Control variables

To control for external influences on the joint adoption of SAPs by rice farmers (Conley & Udry, 2010; Teklewold et al., 2013b; Wainaina et al., 2016; Zhang et al., 2020), we included control variables as follows: householder characteristics include age, gender, education, training, and risk; household characteristics include family size, farm labourers, and agricultural income; agriculture management characteristics include area, plots, and farming type; policy characteristics include subsidies; and social characteristics include clan, migrant, trust, and associations.

3.3. Descriptive statistics

Table 1 shows the statistical description of the variables used in this paper.

A description of technology adoption by rice farmers is shown in Figures 2–4. The adoption of each SAPs by rice farmers is shown in Figure 2, in which 68.60% of rice farmers adopted SAP_S, 27.25% adopted SAP_PF, and 74.41% adopted SAP_M. Figure 3 shows the joint adoption by rice

Table 1. Variables definition and description.

Variables	Definition	Mean	S.D.	Min	Max
Dependent variables					
SAP_S	=1 if the rice farmer adopts the new seeds and seedlings, 0 otherwise	0.686	0.464	0	1
SAP_PF	=1 if the rice farmer adopts the green and environmentally friendly pesticide and fertilizer technologies, 0 otherwise	0.273	0.446	0	1
SAP_M	=1 if the rice farmer uses machinery for land preparation, seeding or harvesting, 0 otherwise	0.744	0.437	0	1
Joint adoption	adoption number of SAPs (none = 0; one = 1; two = 2; three = 3)	1.703	0.908	0	3
Independent variable					
Internet_use	=1 if the rice farmer uses the internet, 0 otherwise	0.705	0.456	0	1
Control variables					
Age	Age of the rice farmer(years)	57.564	9.713	21	91
Gender	=1 if the rice farmer is male, 0 otherwise	0.897	0.304	0	1
Education	Education of the rice farmer(below primary school = 1; primary school = 2; junior high school =3; senior high school = 4; above high school = 5)	2.737	0.759	1	5
Training	=1 if the rice farmer has been trained in agricultural technology, 0 otherwise	0.168	0.374	1	0
Risk	The risk appetite of the rice farmer (1–5, risk averse = 1, risk preference = 5)	1.633	1.107	1	5
Family size	Number of family members	5.072	1.982	1	15
Farm_labourers	Number of family farming labourers	1.977	1.251	0	11
Agri_ income	Total household farm income (in natural logarithm)	2.444	3.878	0	12.543
Area	The area of arable land on which the rice farmer cultivates rice (mu)	3.703	4.727	0.4	110
Plots	Number of rice plots	8.515	7.532	1	55
Farming_type	=1 if the rice farmer is growing double-season rice, 0 otherwise	0.765	0.424	0	1
Subsidies	=1 if the rice farmer receives agricultural subsidies, 0 otherwise	0.823	0.382	0	1
Clan	=1 if the rice farmer is a member of a clan, 0 otherwise	0.722	0.448	0	1
Migrant	=1 if the rice farmer is working outside the village, 0 otherwise	0.791	0.406	0	1
Trust	Level of trust of rice farmers in village collectives (very high = 5; very low = 1)	3.874	1.070	1	5
Associations	=1 if the rice farmer is a member of an agriculture technology association, 0 otherwise	0.123	0.329	0	1

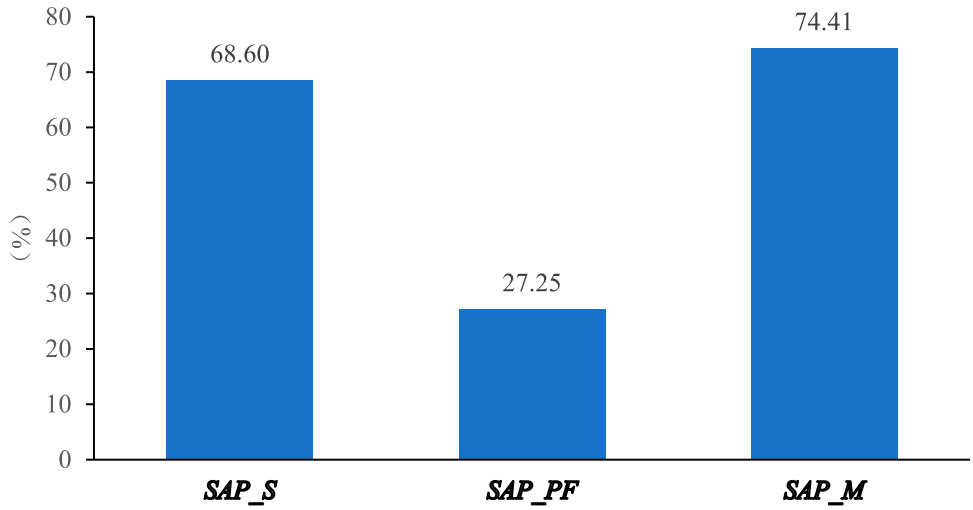


Figure 2. Adoption rate of each SAP by rice farmers.

farmers. A significant proportion of rice farmers opted for joint adoption (60.19%).

Figure 4 shows the internet use of rice farmers. Most rice farmers (70.50%) had chosen to use internet.

3.4. Estimation strategy

The dependent variable is farmers' joint adoption of SAPs. In our study scenario, there are four possible

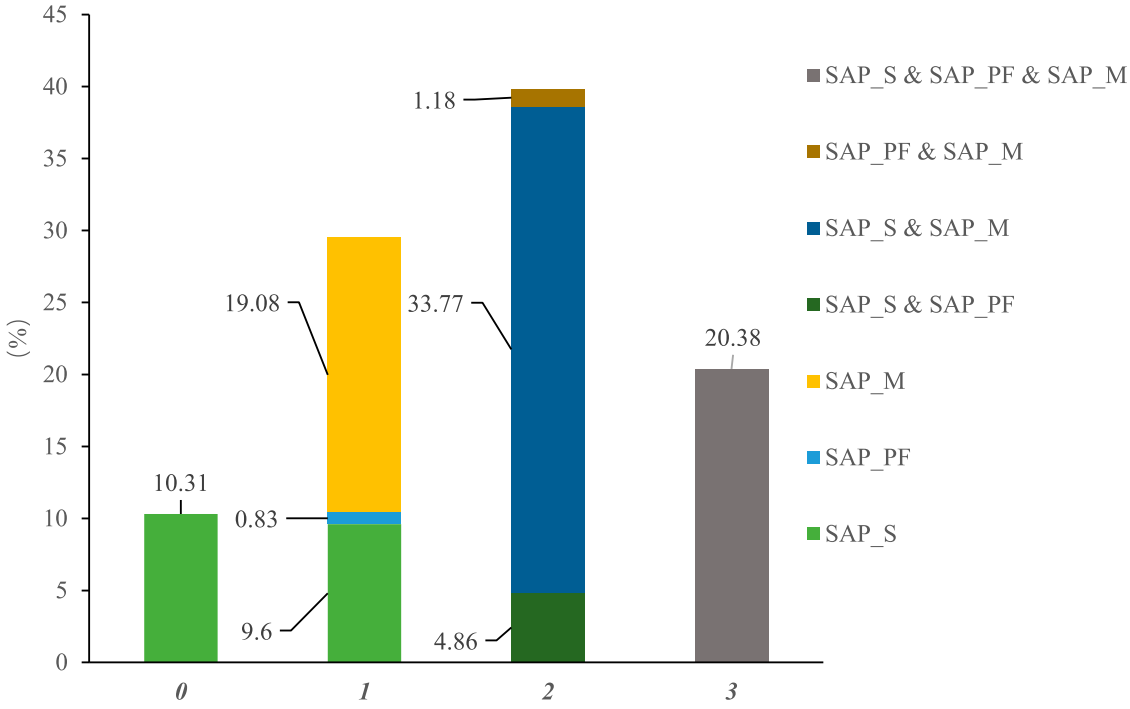


Figure 3. Adoption intensity of different types of SAPs by rice farmers.

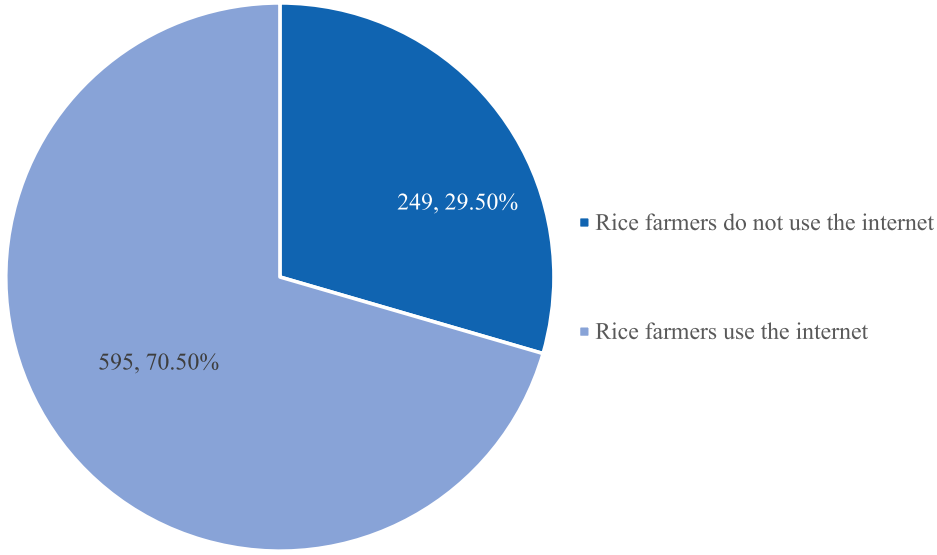


Figure 4. Percentage of internet use by rice farmers.

adoption outcomes: no adoption, adoption of one technology, adoption of two technologies, and adoption of three technologies. Here, the joint adoption behaviour of farmers towards SAPs is coded as an ordinal variable. We use the Ologit model as the benchmark model, and it's shown in the following equation (Greene, 2012):

$$J\_\text{adoption}_i^* = \beta \text{internet}_i' + \varepsilon_i \tag{1}$$

$$J\_adoption_i = \begin{cases} 0 & \text{if} \quad J\_\text{adoption}_\text{i}^* \le r_0 \\ 1 & \text{if} \quad r_0 < J\_\text{adoption}_i^* \le r_1 \\ 2 & \text{if} \quad r_1 < J\_\text{adoption}_i^* \le r_2 \\ 3 & \text{if} \quad J\_\text{adoption}_i^* > r_2 \end{cases} \tag{2}$$

In Equations (1) and (2), $J\_\text{adoption}_i^*$ is an unobservable latent variable, indicating the intensity of joint adoption of farmer *i*. $\text{internet}_i'$ indicates the *i*th farmer' internet use affecting the joint adoption of SAPs. β is a parameter to be estimated. ε_i is the random error term which follows a standard normal distribution. The farmer' s joint adoption of SAPs is categorized into four outcomes: (1) none, (2) one, (3) two, and (4) three. In Equation (2), 0,1, 2 and 3 are the different intensity of joint adoption(none, one, two, three), $r_0 < r_1 < r_2$ are the cut points to be predicted for any joint adoption intensity.

Further, referring to Wainaina et al. (2016) and Koppmair et al. (2017), the MVP model is constructed to analyze the effect of internet use on the interrelationship of SAPs for testing H2. the MVP approach simultaneously models the influence of the set of explanatory variables on each of the different practices, while allowing for the potential correlation between unobserved disturbances, as well as the relationship between the adoption of different practices (Belderbos et al., 2004). Failure to capture unobserved factors and interrelationships among adoption decisions regarding different practices will lead to bias and inefficient estimates (Greene, 2012).

The observed outcome of SAP adoption can be modelled following a random utility formulation. The general model can be written as Equations (3) and (4):

$$y_{ik}^* = \beta_k \text{Internet}_i + \sigma_{ik} (k = S, PF, M). \tag{3}$$

$$y_{ik} = \begin{cases} 1, & \text{if } y_{ik}^* > 0 \\ 0, & \text{otherwise} \end{cases} \quad (k = S, PF, M). \tag{4}$$

In Equation (3), y_{ik}^* is an unobservable latent variable that captures the unobserved preferences or demand associated with the *k*th choice of SAP, k denotes choice of new seeds and seedlings (*S*), green and environmentally friendly pesticide and fertilizer technologies (*PF*), and modern agricultural machinery (*M*). The independent variable is $Internet_i$, a dummy variable indicating whether *i*th farmers use the internet. β_k is the vector of parameters to be estimated. Unobserved characteristics captured by the stochastic error term σ_{ik}. Using the indicator function, the unobserved preferences in

Table 2. Joint adoption regression: Benchmark model estimation.

Variables	Model 1: Ologit model		Model 2: Logit model					
			SAP_S		SAP_PF		SAP_M	
	Parameter	*P*-values	Parameter	*P*-values	Parameter	*P*-values	Parameter	*P*-values
Internet_use	0.422**	0.031	0.020	0.924	0.647**	0.012	0.433**	0.030
	(0.195)		(0.211)		(0.256)		(0.199)	
Age	0.007	0.311	−0.001	0.861	0.016*	0.071	0.003	0.697
	(0.007)		(0.008)		(0.009)		(0.009)	
Gender	0.186	0.425	0.148	0.512	−0.140	0.585	0.558**	0.023
	(0.233)		(0.225)		(0.257)		(0.246)	
Education	0.077	0.453	0.064	0.629	0.219**	0.040	−0.142	0.171
	(0.102)		(0.133)		(0.107)		(0.104)	
Training	0.181	0.354	0.043	0.805	0.395*	0.074	−0.051	0.829
	(0.196)		(0.174)		(0.221)		(0.235)	
Risk	−0.014	0.782	−0.025	0.714	0.022	0.709	−0.004	0.959
	(0.051)		(0.068)		(0.060)		(0.078)	
Family size	0.054	0.175	0.029	0.493	0.036	0.430	0.044	0.295
	(0.040)		(0.042)		(0.046)		(0.043)	
Farm_labourers	0.073	0.139	0.131**	0.039	0.074	0.239	−0.023	0.690
	(0.049)		(0.063)		(0.062)		(0.058)	
Agri_income	0.024	0.227	0.026	0.265	0.004	0.886	0.034	0.194
	(0.020)		(0.023)		(0.026)		(0.027)	
Area	0.002	0.884	−0.006	0.730	0.000	0.987	0.016	0.436
	(0.014)		(0.019)		(0.015)		(0.021)	
Plots	−0.032**	0.016	−0.017	0.187	−0.021	0.138	−0.039***	0.004
	(0.013)		(0.013)		(0.014)		(0.014)	
Farming_type	−0.235	0.126	−0.360**	0.037	−0.114	0.618	−0.092	0.692
	(0.154)		(0.173)		(0.228)		(0.232)	
Subsidies	0.071	0.700	0.169	0.449	−0.431*	0.054	0.474**	0.021
	(0.184)		(0.223)		(0.224)		(0.205)	
Clan	0.296*	0.062	0.372**	0.050	0.095	0.692	0.192	0.324
	(0.159)		(0.190)		(0.239)		(0.194)	
Migrant	0.316*	0.078	0.441**	0.023	0.170	0.531	0.157	0.424
	(0.179)		(0.194)		(0.271)		(0.196)	
Trust	0.132**	0.030	0.069	0.346	0.171**	0.046	0.088	0.289
	(0.061)		(0.073)		(0.086)		(0.083)	
Associations	0.265	0.265	0.136	0.620	0.379	0.217	−0.020	0.933
	(0.238)		(0.274)		(0.307)		(0.235)	
Constant			−0.460	0.578	−3.622***	0.000	−0.393	0.655
			(0.826)		(0.855)		(0.880)	
Observation	844		844		844		844	
R^2/Pseudo R^2	0.021		0.023		0.042		0.033	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets.

Equation (1) translate into the observed binary outcome equation for each choice as in Equation (4).

In the multivariate model, where the adoption of several SAPs is possible, the error terms in the model jointly follow a multivariate normal distribution with zero conditional mean and variance normalized to unity. The model generates a variance-covariance matrix Ω is given by:

$$\begin{bmatrix} 1 & \rho_{SPF} & \rho_{SM} \\ \rho_{PFS} & 1 & \rho_{PFM} \\ \rho_{MS} & \rho_{MPF} & 1 \end{bmatrix} \quad (5)$$

Of particular interest are the off-diagonal element in the covariance matrix represents the unobserved correlation between the stochastic component of SAPs. The results of the MVP model in Equation (5) enable the representation of the unobserved characteristics that influence the SAPs to make decisions, thus reflecting the adoption of correlation between

Table 3. Joint adoption marginal effects: Benchmark model estimation.

Variables	$Y = 0$	$Y = 1$	$Y = 2$	$Y = 3$
Internet_use	−0.037**	−0.064**	0.034**	0.067**
	(0.016)	(0.030)	(0.016)	(0.032)
Control variables	Yes	Yes	Yes	Yes
Observation	87	249	336	172

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets. The control variables of all these models are the same as in Table 2.

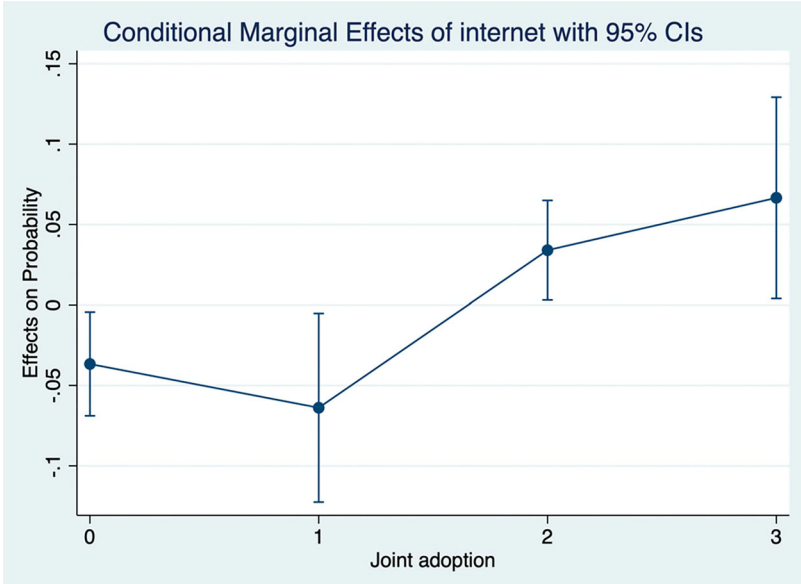


Figure 5. Marginal effects of joint adoption of SAPs.

the decision error terms of the three specific technologies (Kassie et al., 2013).

4. Results

4.1. Joint adoption of SAPs: intensity perspective

4.1.1. Benchmark model

The Ordered Logit model benchmark regression revealed that the internet use positively affected the joint adoption of SAPs and was statistically significant at the 5% level (Table 2, Model 1). Furthermore, the Logit model regression showed that the coefficients of internet use for each of the three different SAPs are all positive (Table 2, Model 2). Rice farmers using the internet were more likely to adopt SAP_PF and SAP_M, which were statistically significant at the 5% level; however, internet use did not significantly affect SAP_S (Coefficient = 0.020, *P*-value = 0.924).

In addition, we reported the marginal effects of the joint adoption of SAPs in Table 3 (Wollni et al., 2010; Teklewold et al., 2013b). We observed that the probability of joint adoption of two technologies increased by 3.4% while the likelihood of joint adoption of three technologies increased by 6.7% if rice farmers used the internet. The result indicates an increasing tendency for the intensity of joint adoption of SAPs among rice farmers through using the internet (Figure 5).

4.1.2. Robustness check

The underlying assumption of the Poisson regression model was that events occurred independently over time (Cameron & Trivedi, 1986). Therefore, we tested for potential overdispersion in the count-related variables (Cameron & Trivedi, 1990). The results showed that the response variance of the model was less than the mean, and there was no potential overdispersion in the count-related variables (Mean = 1.702, Response Variance = 0.824). Then, we dropped the negative binomial regression model in favour of a Poisson model. Considering there might have been more zeros in the dependent variable than expected (Thinda et al., 2020), we also evaluated whether a zero-inflated Poisson regression produced a better fit. As the evaluation result was not the case (Vuong

Table 4. Joint adoption robustness check: Poisson model estimation.

Variables	Poisson		Marginal effects
	Parameter	*P*-values	
Internet_use	0.119**	0.032	0.196**
	(0.055)		(0.090)
Control variables	Yes		Yes
Constant	−0.091	0.646	
	(0.197)		
Observation	844		844

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets. The control variables of all these models are the same as in Table 2.

Table 5. CMP method: IV-Oprobit model estimation.

Variables	First stage		Second stage	
	Parameter	*P*-values	Parameter	*P*-values
Internet_use			1.330***	0.000
			(0.225)	
Communication expenses (ln)	0.215***	0.000		
	(0.040)			
Control variables	Yes		Yes	
Atanhrho_12			−0.847***	0.000
			(0.180)	
Constant			−0.214	0.578
			(0.384)	
Observation	844		844	

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets. The control variables of all these models are the same as in Table 2.

test, *P*-value = 0.500), we used a standard Poisson model for robustness checking (Table 4).

We found that internet use promoted increased intensity of joint adoption of SAPs among rice farmers, which was statistically significant at the 5% level. The marginal effects of the Poisson model indicate that internet use was positively correlated with the joint adoption of SAPs among rice farmers. Rice farmers using the internet were 19.6% more likely to adopt SAPs jointly than those not.

4.1.3. Endogeneity analysis

In the technology adoption process by rice farmers, there was a possibility of endogeneity problems between the independent and dependent variables due to reverse causality. Specifically, for the joint adoption of new SAPs, rice farmers would seek adequate information through various means, which could effectively contribute to developing information dissemination channels and increase rice farmers' internet usage (Bi et al., 2022). Therefore, the endogeneity problems would lead to biased results of the benchmark model.

We adopted an instrumental variable approach to deal with potential endogeneity problems for more rigorous results. We chose the logarithm of rice farmers' communication expenses in 2018 as an instrumental variable for internet use (He et al., 2021). So, the rice farmers' decision was made given that: (1) higher communication expenses of rice farmers were correlated with lower digital divide problems faced by households (Ma et al., 2020) and (2) higher communication expenses of rice farmers were essential household expenses that do not directly affect their joint adoption of SAPs. After weak-instrument tests, We found that communication expenses were not a weak instrumental variable, meeting the requirements for the exogenous variable (F-value = 36.911).

We used a conditional mixture process (CMP) to deal with potential endogeneity problems (Roodman, 2011), the results were shown in Table 5. The endogeneity test parameter Atanhrho_12 was significant at the 1% statistical level. It indicated the endogeneity problem in the benchmark model. In the first stage of regression, there was a positive correlation between instrumental variables and endogenous explanatory variables, which was statistically significant at the 1% level. In the second stage regression, internet use was positively correlated with the joint adoption of SAPs and was statistically significant at the 1% level. The CMP approach was mainly consistent with the benchmark regression results, supporting H1.

4.2. Joint adoption of SAPs: decision correlation perspective

We chose to use the MVP model considering the decision complexity when rice farmers' Internet use affects the joint adoption of sustainable agricultural production technologies. It allows further analysis of the correlation between unobserved factors among adoption decisions and error terms in the adoption

Table 6. Correlation test: MVP model estimation.

Variables	SAP_S		SAP_PF		SAP_M	
	Parameter	*P*-values	Parameter	*P*-values	Parameter	*P*-values
Internet_use	0.005	0.967	0.397***	0.007	0.270**	0.023
	(0.129)		(0.147)		(0.118)	
Control variables	Yes		Yes		Yes	
Constant	−0.359	0.465	−2.063***	0.000	−0.224	0.669
	(0.492)		(0.505)		(0.524)	
Observation	844		844		844	

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets. The control variables of all these models are the same as in Table 2.

Table 7. SAPs correlation matrix: MVP model estimation.

Variables	SAP_S		SAP_PF		SAP_M	
	Parameter	*P*-values	Parameter	*P*-values	Parameter	*P*-values
SAP_S	1		0.557***	0.000	0.212***	0.000
			(0.066)		(0.056)	
SAP_PF			1		0.123*	0.062
					(0.066)	
SAP_M					1	

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets. The control variables of all these models are the same as in Table 2.

equation (Koppmair et al., 2017). Table 6 shows the regression results of the MVP model. The results show that the coefficient of rice farmers' internet use on SAPs is positive. Internet use on the adoption of SAP_PF technology by rice farmers is statistically significant at a 1% level, which means using the internet increased the odds of SAP_PF adoption by 39.7%. Internet use on the adoption of SAP_M technology by rice farmers was statistically significant at the 5% level, which means using the internet increased the odds of SAP_M adoption by 27.0%.

SAP adoption is not mutually exclusive, the adoption of one technology does not mean that other technologies cannot be adopted. There may be complementary and alternative relationships between different technologies such that it may make more sense for rice farmers to adopt certain combinations of technologies according to local conditions. This can lead to synergistic relationships that can lead to a '1 + 1 > 2' effect (Koppmair et al., 2017).

Although the internet was not significant for SAP_S in the benchmark regression, there were complementary relationships between SAP_S & SAP_PF, SAP_S & SAP_M and SAP_PF & SAP_M in the correlation matrix, which were statistically significant at the 1%, 1%, 10% level (Table 7), supporting H2. As the 'chips' of agriculture, seeds play a critical role in rice production, the results indicated that the adoption of SAP_PF or SAP_M promoted the adoption of SAP_S.

4.3. Heterogeneity analysis

However, the above results are tested for the whole sample level, ignoring differences in SAPs technology adoption that might be caused by different endowment and institutional characteristics. Here, we analyze the heterogeneous effects of joint adoption of SAPs via internet use based on rice farmers' farmland scale and subsidies. On the one hand, the sample of rice farmers was divided into two groups, '≥3' and '<3', using the median farm size as the cutoff (Zhao et al., 2022); On the other hand, the whole sample was divided into two groups based on whether they received subsidies. When the rice farmer received subsidies, he or she was in the 'yes' group; otherwise in the 'no' group.

As the results shown in Table 8, we found that rice farmers with larger farmland scales that use the internet for joint adoption of SAPs were more favourable. In addition, internet use by rice farmers who received subsidies significantly promoted the joint adoption of SAPs technology relative to rice farmers who did not receive subsidies.

Adopting all three technologies positively benefited rice farmers with more farmland or received subsidies (Table 9). With the result of correlation matrix in Table 10, we found that the complementary relationships between SAP_S & SAP_PF and SAP_S & SAP_M existed in both large-scale rice farmers and

Table 8. Heterogeneous effects tests: Ologit model estimation.

Variables	Farmland scale				Subsidies			
	≥3		<3		Yes		No	
	Parameter	*P*-values	Parameter	*P*-values	Parameter	*P*-values	Parameter	*P*-values
Internet_use	0.519**	0.018	0.377	0.157	0.462**	0.020	0.135	0.718
	(0.219)		(0.267)		(0.199)		(0.373)	
Control variables	Yes		Yes		Yes		Yes	
Observation	432		412		695		149	
Pseudo R^2	0.033		0.027		0.022		0.048	

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets. The control variables of all these models are the same as in Table 2.

Table 9. Heterogeneous effects tests: MVP model estimation.

Variables		SAP_S		SAP_PF		SAP_M	
		Parameter	*P*-values	Parameter	*P*-values	Parameter	*P*-values
Farmland scale	≥3	0.100	0.514	0.474**	0.013	0.207	0.208
		(0.153)		(0.190)		(0.164)	
	<3	−0.092	0.609	0.275	0.120	0.356**	0.026
		(0.179)		(0.177)		(0.160)	
Subsidies	Yes	0.016	0.896	0.518***	0.001	0.209	0.102
		(0.126)		(0.160)		(0.128)	
	No	−0.073	0.800	0.014	0.947	0.424*	0.083
		(0.290)		(0.214)		(0.245)	
Control variables		Yes		Yes		Yes	

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets. The control variables of all these models are the same as in Table 2.

Table 10. Heterogeneous effects of farmland scale: SAPs correlation matrix.

≥3	SAP_S		SAP_PF		SAP_M	
<3	Parameter	*P*-values	Parameter	*P*-values	Parameter	*P*-values
SAP_S	1		0.511***	0.000	0.188**	0.040
			(0.098)		(0.092)	
SAP_PF	0.748***	0.000	1		0.045	0.569
	(0.115)				(0.080)	
SAP_M	0.189**	0.027	0.088	0.346	1	
	(0.085)		(0.093)			

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets. The control variables of all these models are the same as in Table 2.

small-scale rice farmers (Table 10). It seems inconsistent with literature, suggesting that small-scale rice farmers are more likely to integrate combinations of SAPs according to their local conditions to maximize the profitability of agricultural production (Cacho et al., 2020; Wale & Yalew, 2007). Some research discussed that they did not jointly adopt specified technologies regarding local governments, agricultural cooperatives, or agricultural extension organizations to achieve economies of scale, as large-scale rice farmers did (Zheng et al., 2022). With the results of Table 11, we found a complementary relationship between joint SAP_S and SAP_PF adoption by rice farmers who receive subsidies but not among those who do not. This situation may be due to risk aversion, as non-subsidized rice farmers were more likely to use farmyard manure in rice cultivation instead of the more expensive SAP_PF, as demonstrated in a study of Tanzanian farmers (Kassie et al., 2013).

In summary, we found that large-scale rice farmers were more likely to adopt multiple SAPs jointly, while small-scale rice farmers were more likely to adopt different types of SAPs in combination. This may be because larger rice cultivation areas create a cost advantage, and large-scale agricultural production may give rice farmers more time and money to pursue new technologies (Hu et al., 2022). We also found that rice farmers who received subsidies were more inclined to joint adoption of SAPs if they used the internet. The subsidy

Table 11. Heterogeneous effects of subsidies: SAPs correlation matrix.

Yes	SAP_S		SAP_PF		SAP_M	
No	Parameter	*P*-values	Parameter	*P*-values	Parameter	*P*-values
SAP_S	1		0.595***	0.000	0.207***	0.001
			(0.073)		(0.061)	
SAP_PF	−0.009	0.949	1		0.123*	0.077
	(0.135)				(0.070)	
SAP_M	0.685***	0.000	0.365***	0.001	1	
	(0.194)		(0.108)			

Note: *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Robust standard errors adjusted for clustering at village level in brackets. The control variables of all these models are the same as in Table 2.

incentive appears to mitigate the perceived risk of joint adoption of SAPs by rice farmers. These results support hypothesis H3: using the internet to promote joint adoption of SAPs among rice farmers is more likely in large-scale rice farmers or rice farmers who receive subsidies.

5. Conclusion

This study offers valuable insights into the role of internet use in promoting rice farmers' joint adoption of SAPs. The study theoretically revealed that the internet serves as a new type of farm implement for farmers to acquire adequate information in a fast, low-cost, timely way and facilitate the joint adoption of SAPs. This study draws results from Guangdong province, employing field survey data collected from 844 rice farmers. The empirical analysis using the Ologit model testified internet use facilitation of joint adoption intensity and using MVP verified complementary relationships among the adoption of three types of SAPs. The heterogeneity analysis revealed that ICT-based joint adoption of SAPs is more likely among rice farmers with a larger farmland scale or those receiving subsidies, indicating the influence of resource endowment conditions and institutional incentives on the adoption behaviour.

The findings of this study have three important implications for future practice. Firstly, governments in developing countries should prioritize internet infrastructure in rural areas. Secondly, governments should promote the integration of internet use and the adoption of SAPs in a way that aligns with local conditions. Thirdly, bridging the digital divide in the joint adoption of SAPs is crucial. Governments should promote the moderate-scale operation of agriculture. Finally, incentive policies for SAPs and establish a subsidy policy system to overcome potential market failures.

There are two main limitations of this study. First, the sample was recruited in 2019. Although the data was collected in 2019, the technology adoption in Chinese agriculture has not undergone rapid and drastic changes in recent years. Several studies have indicated that factors such as farm scale, farmers' technological capabilities, and the overall state of agricultural technology adoption have remained relatively stable over the years (Li et al., 2023; Lin et al., 2022; Liu et al., 2023; Zhang et al., 2023). Meanwhile, in 2019, the internet had rapid development, and the influence of the internet was prevalent during the data collection period (Ding et al., 2022). Therefore, the insights and findings obtained from this survey still hold relevance and significance in understanding the current state in China. Second, the mechanisms of how farmers' internet use influences their joint adoption of SAPs can be explored in future research.

Notes

1. Here we referred to two important official policy issued by the Chinese government. First, in 2016, the Ministry of Agriculture and seven other departments promulgated 'Plan for the construction of national Experimental Demonstration zones for sustainable agricultural Development'. It pointed to promoting sustainable agricultural development and a need for the innovation of integrated technologies. For more information, please visit the official website of the Central People's Government of the People's Republic of China: http://www.gov.cn/xinwen/2016-08/30/content_5103492.htm;Second, in 2022, the General Office of the Ministry of Agriculture and Rural Affairs promulgated the 'Guidance on Promoting the Construction of Ecological Farms'. It pointed out that local governments should strengthen the integration of ecological agriculture technology, promote the integration and support the maturation of individual technologies, products, and equipment.For more information, please visit the official website of the Ministry of Agriculture and Rural Affairs of the People's Republic of China: http://www.moa.gov.cn/nybgb/2022/202203/202204/t20220401_6395140.htm.
2. This data came from the Xinfeng County Statistical Yearbook. It was a comprehensive, systematic, and continuous record of the development of the local economy and society in all aspects. Interested readers can view more detailed information online at this website: https://www.xinfeng.gov.cn/attachment/0/78/78676/1770546.pdf.

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财经问题研究

RESEARCH ON FINANCIAL AND ECONOMIC ISSUES

伍晓光，孙文莉.“一带一路”倡议下的人民币国际化及影响因素研究
罗兴良（主持人）.中国式现代化的地权制度改革效应研究
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——基于双重差分模型的实证研究
万丛颖，等.自贸区设立的区内企业绩效：制度红利还是政策红利?

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地权稳定性、非正式治权与务工农民性别差异

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摘　要：地权稳定性对农村劳动力非农转移的影响已经备受关注，但对外出务工农民性别差异的讨论尚不多见。基于宗族非正式组织在乡村治权中的重要作用，本文利用中国劳动力动态调查（CLDS）2016年和2018年两期面板数据，采用固定效应模型分析了地权稳定性与不同性别劳动力非农转移之间的内在关联性。研究结果表明：首先，基准回归结果表明，农地调整表征的地权不稳定对男性劳动力外出务工具有显著的抑制作用，对女性劳动力外出务工影响不显著。其次，机理分析结果表明，村落宗族非正式治权的强弱是影响男性劳动力外出务工选择的关键情境。其一，宗族绝对势力的强弱使得地权稳定性对男性劳动力外出务工的影响产生分化。其二，与宗族相对势力对比非均衡相比，宗族相对势力对比均衡可以有效弱化地权不稳定对男性劳动力外出务工的抑制作用。其原因在于，相互制衡的宗族非正式治权在一定程度上弱化了地权变动对农地纠纷产生的影响，确保农地调整中土地分配相对公平，从而起到维护地权稳定的作用。本文的结论对于理解劳动力转移过程中的性别差异现象，以及如何发挥非正式组织在乡村治理中的积极作用具有重要的政策含义。

关键词：地权稳定性；非正式治权；务工农民性别差异

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一、问题的提出

随着工业化和城市化的快速发展，中国农村劳动力涌向城市的非农转移已成为重要的社会经济现象。最近十多年来，中国外出务工的农村劳动力总量每年持续高达1.5亿人，且总体稳中有升。其中，一个值得关注的重要现象是，外出务工劳动力中的男性与女性的数量存在显著差异，尤其是2009年以后男女性别对比更为明显。国家统计局数据显示，2009年之前外出务工劳动力中男性约为女性的1.60—1.70倍，2020年则增加为2.32倍，呈现出性别差异不断扩大的态势。

王汉生等[1]指出，基本政策和制度框架，以及这些政策和制度框架所提供的特定机会、渠

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道或限制，对农村人口向城市迁移具有主导作用。事实上，回顾中国农村的变革历程不难发现，劳动力的非农转移并非是要素市场发育的独立事件，而是与农村土地产权制度紧密相关[2]。中国于2009年开展了新一轮的农地确权，目的在于进一步提高农地产权的稳定性。这恰好与劳动力外出务工性别分化的突变阶段相契合。Janvry等[3]的研究表明，在农村劳动力非农转移过程中，地权不稳定对劳动力非农转移具有显著的抑制作用。孟晓志和李尚蒲[4]认为，农地产权稳定性提高，则会促进劳动力非农转移。尤其是，农地产权稳定性的提高能够有效释放农村男性劳动力。由此可以推断，农地产权稳定性的改善可能是劳动力外出务工性别分化的重要诱因。

中国现行的农地制度是以农户为产权主体的家庭联产承包责任制，其在一定程度上带有“均田制”的色彩。在土地集体所有的前提下，保障公平性的地权均分成为地权制度实施的一个重要层面。既然土地要素在农户之间是按家庭人口或劳动力数量平均分配，所以当人地关系发生增减变化时，原有的土地分配均衡被打破，往往诱发频繁的农地调整以满足农户对地权平等的诉求[5]。因此，农地调整一度成为中国农村普遍发生的现象。农地调整隐含着农地产权弱化并使农户地权排他性降低，诱发村庄内部地权博弈与竞争的周期性现象，由此决定了村庄必须通过自发的行动秩序来维护土地权益，而这种自发的行动秩序又源于村社和家户两个层面。

从村社层面看，村社自治和乡村非正式规范对于维持村社行动秩序具有重要作用。由于乡村法治建设不完善，农户对法律的认可度较低，乡村非正式制度安排成为一种有效的自我治理模式，从而也使得非正式的乡村治理规范在地权配置中发挥着重要作用[6]。一直以来，村落宗族在维持乡村秩序、形塑乡村文化和供给乡村公共产品等方面扮演着重要角色。尤其是宗族内部的族规和习俗已成为配置土地资源的内在约束，使得宗族与土地产权的界定紧密相关，由宗族传统形成的村庄资源配置方式也成为与村庄地权自发变更相关联的重要实现机制[7]。由此可见，地权变更中村社行动秩序的表达将在一定程度上取决于宗族这一非正式治权。从家户层面看，自发的行动秩序的表达也表现为产权主体行为能力的强弱[5]。产权经济学对产权赋权和产权行使两个概念进行了区分，明晰的赋权是重要的，但产权主体行使产权的行为能力的强弱同样重要[8]。家庭联产承包责任制对农户的赋权及权利边界的法律规定是清晰的，保证了农户所拥有的相对独立的排他性产权。但体现主体产权行使及其行为能力的一个重要方面是其对产权的实际使用和操作，受法律成本和知识不完备的影响，农地产权界定往往是不完全的，总是存在界定模糊的部分权利。针对这部分权利，产权主体的行为能力对产权由谁来行使具有决定性作用。即使产权在法律上能够明确界定清楚，产权主体能否完全地行使其赋权也取决于其行为能力的大小[9]。

然而，在隐含产权不稳定的农地调整中，宗族在地权分配中的身份却具有双重性，既可能成为维护公平性的“代理人”，亦可能转变为破坏地权稳定性的利益“攫取者”[10]。在乡村社会，村落可能由多个宗族共同组成，每个宗族都是由血缘关系所构成的紧密共同体，对处于宗族内的个体家庭而言，宗族可以对每个家庭关系进行整合形成“公”的权威，但在宗族之外或与其他宗族的交往中，宗族又带有“私”的性质[11]。在宗族对内“公”而对外“私”的关系下，从单个宗族的绝对力量看，由宗族形成的绝对势力对内部成员的诸如土地等资源起到了良好的保护作用。但从多个宗族对比情形看，一个村落内部只有存在相对力量对比均衡的多个宗族，或许才能实现村落治权的平衡。具体到地权保护层面，村落内部存在相互制衡的宗族，可以实现村落治权的平衡，并对地权起到保护作用。但如果宗族力量对比不均衡，则会对农地调整中的赋权公平性构成威胁，甚至可能更易引发农地纠纷。村落中的农户往往以家庭为基本单位，在村落复杂的宗族关系之外，地权博弈的结果同样取决于农户家庭整体的行为能力。换言之，当宗族力量对比不均衡而不能对地权公平性产生有效保护时，农地调整中形成的竞争性的地权将更多地表达为农户彼此之间家庭力量的对比与角逐[4]。传统村落社会中的男性相对于女性往往在地位、力量和权利等方面更有优势，故单个家庭在经济社会活动中的排他性和谈判能力的强弱通常由男性表

达[12]。显而易见，家庭中男性群体成为农地调整过程中对结果具有决定性作用的核心力量，男性的“在位”数量也就成为一个家庭在地权博弈和竞争中行为能力强弱的体现。

基于产权不稳定和其竞争结果主要依赖于男性“在位”参与的特性，村落家庭中的男性将与农业生产紧密“捆绑”。同时，男耕女织的传统所形成的家庭分工使女性主要从事料理家务、照顾老人和抚育子女等家庭内部事务。村落中男性与女性所处境遇的不同将可能使女性的个体决策与男性有所区分，从而导致地权稳定性变化对男性劳动力和女性劳动力的外出务工决策产生不同的影响。本文所使用的中国劳动力动态调查（China Labor-Force Dynamics Survey，CLDS）2016年和2018年数据也显示，相比于未经历农地调整的农户，有农地调整经历的农户男性外出务工的比例更低，而女性的变动趋势则相对较小，且并未表现出统计意义上的显著性。

刘晓宇和张林秀[13]指出，面对表征地权不稳定的农地调整，农户往往会采用自己“占有耕种”的行为以捍卫地权，导致劳动力锁定于农业生产，从而对农户非农转移产生抑制作用。可以进一步推断，由于男性在农地调整中所扮演的重要角色，地权稳定性主要作用于男性劳动力的就业选择，由此解释了中国农村劳动力非农转移过程中出现的性别分化现象。然而，已有研究忽略了地权稳定性对农村劳动力非农转移影响的性别差异，且未将宗族这一对地权分配具有重要影响的非正式制度安排纳入分析框架。本文利用中国劳动力动态调查（CLDS）2016年和2018年两期面板数据，构建了地权稳定性—非正式治权—务工农民性别差异的分析框架，探究在宗族非正式治权下，地权稳定性对不同性别劳动力转移的异质性影响，以期为农地产权政策的调整及乡村治理中如何更好地利用乡村非正式力量提供经验证据。

二、理论分析

（一）传统乡村视域下的宗族及其与农地调整的关系

“皇权不下县，县下惟宗族”。宗族自古以来在中国乡村治理中发挥着不可替代的作用。中国的宗族制度最早源于氏族社会的父权制，以血缘、婚姻等关系组成的具有严密等级的家长式共同体形成了宗族组织的最初样态。随着历史的演进和社会的发展，宗族组织形式及其在乡村治理中的作用历经嬗变，到明清时期，宗族在乡村社会中发挥的作用达到鼎盛。这一时期的乡村社会更趋于血缘与亲缘叠加关系上的熟人社会，最突出的特征是稳定与封闭共存。宗族在组织生产、村社公共产品供给和乡村建设等方面发挥着重要的规范和调节作用，是乡村治理和乡村经济发展中的主导者[14]。新中国成立后，集体合作式生产方式对以血缘为基础的宗族组织产生了巨大冲击，使得宗族力量日渐式微。改革开放后，“全能主义”的人民公社瓦解，国家行政命令逐步被市场经济所取代[15]。此时，在基层政权中，国家权力“收缩”留下的部分“功能空白”被乡村宗族等非正式治权所占据，这一时期的宗族承担了维护乡村秩序的重要功能。尤其是村庄自治和村民一票制“海选”的制度化推进，使得宗族在现代乡村中持续发挥作用[16]。可以说，宗族是贯穿中国乡村历史不可或缺的重要主体，对乡村治理的诸多方面产生了深远影响。

在中国农地集体所有的制度框架内，农户因集体成员权而被赋予参与地权分配决策的权利，这反映了农地调整具有公共选择的性质。农地调整是对集体成员所拥有的地权的再分配，同时也是合约的重新缔结。此过程既是集体共同意志的反映，同时也取决于参与者的策略互动。然而，在正式制度缺位的乡村社会，非正式制度作用尤为突出。已有研究关注到，相对于正式的法律制度，地权实施中非正式制度安排的影响不容忽视[17]。显然，在村落社会结构中，地权的界定及实施在经过多方博弈后将达到均衡状态。宗族固有的组织性和文化地域性深刻地影响着村落的社会结构，而基于血缘和地缘关系的聚村而居的村落传统使得“权利文化网络”在农村要素配置中发挥了重要作用[18]。法律层面的农地产权是通过村集体实施的，而村庄治权本身就与族权关系密切[19]。尤其是在现代乡村治理中，宗族所具有的组织动员和自我治理功能在为基层治理提供

积极补益的同时，也将在村庄产权治理中发挥重要作用。从社会意义来看，农地调整通常是为了增加村庄人口生存空间的帕累托改进而私立的产权规则，是在法律规范和社会保障缺失状态下，村民自发的集体行动，具有非正式制度安排的典型特征。而作为传统村居格局下（自然村或自然组）重要的非正式制度安排，宗族的存在有助于资源配置自我实施，并与地权变更紧密相关。

（二）农地调整中的宗族博弈和农户选择

与西方的农地私有产权制度相异，中国的农地属于集体成员共有，农户凭借其集体成员身份无偿获得农地的承包经营权。在这样的地权制度安排下，农户拥有的是一种有限排他性的非完全地权。集体产权天然存在的模糊性为地方政府或乡村组织干预农户地权提供了可乘之机[20]。当考察宗族作为重要的非正式组织对地权稳定性产生影响时，农地作为村落重要的生产资料，其产权界定与实施必然受到宗族的影响。若村落内部宗族彼此之间能够相互制衡，那么农地产权的界定将能够依据农户达成的协议进行，地权分配将处于相对公平状态。反之，如果宗族间因竞争力量强弱差距悬殊而出现彼此约束失衡，那么资源或将被更强大的宗族所攫取。因此，在农地调整中，农户的非农转移决策将受到宗族非正式治权对比所形成的现实情境的影响。为此，本文借鉴仇童伟和罗必良[17]的研究，构造了农地调整中基于宗族博弈的农户选择策略模型。

为简化分析，笔者提出两个前提假定：一是村落只存在两大宗族且双方目标都为收益最大化。二是宗族双方无地权竞争之外的休闲活动或其他非创造收益的活动，且不存在偏好异质性。经济学家将交易框架内的努力分为生产性努力和分配性努力，前者指的是人们对财富的创造，后者指的是将别人的财富转化为自己的财富的付出。当产权存在约束力不足、排他性较弱，或者相比较于生产性努力，分配性努力的成本更低而收益更高时，人们就会更加偏向于作出分配性努力或产生机会主义行为[8]。假定宗族1和宗族2均把当前持有资源r_i用于生产性投入m_i和分配性投入d_i。其中，生产性投入是指在农地中用于农业生产的投入，分配性投入是指与其他宗族进行地权竞争的投入。在不区分由于地权竞争的进攻和防御活动的情况下，两个宗族资源分配情形如下：

$$r_i = a_i m_i + b_i d_i \tag{1}$$

其中，假定资源总量为常量，即$r_1+r_2=r$，这表示村庄土地总量恒定，不随宗族双方博弈行动而变化。a_i和b_i也恒为常量，分别表示资源转化为生产投入和竞争投入的单位转换成本。那么，生产强度和地权竞争强度的定义为：

$$M_i=m_i/r_i \tag{2}$$

$$D_i=d_i/r_i \tag{3}$$

其中，$a_i m_i + b_i d_i = 1$，且处于稳态条件中的两大宗族都作出一次性的最佳选择。否则，若存在多次无休止的博弈，则村庄将陷入冲突且这种冲突最终会把其中一方“挤出”，这显然是不现实的。假定两个宗族获取农地资源只有通过地权竞争这一途径，且双方竞争获胜的概率分别为p_1和p_2（$p_1 + p_2 = 1$）。由此，可以得出宗族获得的资源为：

$$r_i = p_i r \tag{4}$$

参照Hirshleifer[21]的竞赛成功函数设定，可以推出宗族1和宗族2竞争获胜的概率由二者投入地权竞争的资源之比和代表资源重要性的参数w（$w>0$）共同决定：

$$p_1/p_2 =(d_1/d_2)^w \tag{5}$$

在式（5）中，随着w的增加，竞争成功概率p_i对d_i的敏感度随之提高。显而易见，由农地资源稀缺性决定的人地关系紧张使农地成为村庄重要的生产资料，当农地成为宗族唯一的生产资料且资源只能通过竞争的方式取得时，资源重要性w将显著增加，宗族间的竞争亦将愈发激烈。宗族竞争实力的强弱与d_i正相关，d_i为宗族整体竞争资源的投入，是构成宗族所有成员投入的合集。很显然，在宗族整体竞争资源投入一定的条件下，宗族规模越大，单个成员的投入就会越

少，这使得竞争获胜的概率p_i对个体成员竞争投入十分敏感。假定w不变，随着宗族成员的增加，产生的规模优势将增加竞争获胜的概率，从而形成对其他宗族农地的“挤出”。由式（2）、式（3）、式（4）和式（5）推导得出：

$$p_1/p_2=(D_1/D_2)^{W/(1-W)} \quad (6)$$

其中，p_1/p_2为均衡成功比率。当w趋近于1，即土地资源对村落内部的宗族及农户极其重要时，均衡成功比率对宗族的竞争投入将极为敏感。此时，竞争结果取决于双方竞争资源的投入，或者说取决于宗族规模的对比。村落内部宗族力量对比越不平衡，大宗族的博弈优势越明显，而小宗族或村内其他非宗族成员的权益将受到损害。进一步在两大宗族博弈均衡基础上扩展到村落整体，宗族间的博弈使得地权稳定性变化对劳动力非农转移的影响将存在于村落宗族力量均衡和非均衡两种情境。

一种情境是，宗族力量对比均衡。在地权博弈中，各个宗族投入的资源趋于一致，或者说用于竞争资源投入较少甚至趋近于零。此时，地权的界定与实施基本满足村民的公平诉求。那么，村落内部无论是大小宗族，还是其他非宗族农户个体，都会摆脱地权竞争的束缚，农户不再担心失去地权，并作出向非农部门转移的决策。另一种情境是，宗族力量对比处于非均衡状态，村落内部存在激烈的博弈与竞争：大宗族利用其组织规模优势形成对小宗族或者其他非宗族农户地权的挤占。换言之，在农地调整中，宗族产生对地权的保护，但是这种保护在一定程度上取决于村庄内部各个宗族之间势力的均衡程度，即宗族之间是否形成了一定的权力制衡，而农户对非农转移的选择也取决于宗族力量对比达成的均衡程度。

（三）农地调整、非平衡治权与劳动力转移的性别差异

纵观古代中国，从奴隶社会到封建社会建立了男尊女卑的性别意识形态。男性对女性的绝对统治成为社会的基本法则，并体现在三纲五常等级体系中[22]。这种意识形态在历史上长期传承并固化于观念、习俗和生活方式中，对乡村社会农业生产资料分配，特别是土地配置产生了重大影响。在农村乡土社会中，人均资源禀赋极少的小农经济现实决定了理性原则下的农户追求的首要目标是保障生存安全[23]。土地自然成为农户最为重要的生产资料，甚至被誉为农民的“命根子”。传统小农经济体系下农户外出的机会少、风险大，固守于土地，依托于土地的以村庄为基本单位的内卷化生产成为农民的必然选择。人地关系的紧张程度决定了村落中农户的双重性：一方面，土地资源的稀缺性使得农户之间基于血缘和地缘进行互助合作以谋求生存；另一方面，土地资源的稀缺性又使得农户为获得土地而相互竞争，竞争结果往往取决于家庭势力的对比。显然，家庭势力的对比决定了男性的比较优势。在传统农户家庭的分工格局中，女性常从事料理家务、照顾老人和抚育子女等家庭内部事务，而男性则负责出门耕种和处理家庭对外事宜等。长此以往，逐渐形成了“男主外，女主内”的家庭分工格局，产生了男性与女性角色的差异。

中国农村收入来源的单一性决定了土地成为农民不可或缺的生产资料，而人多地少的国情更意味着土地资源的相对稀缺。在中国农村土地集体所有的前提下，土地资源的稀缺性也直接加剧了因农地调整而产生的地权博弈与竞争。尤其是，在力量对比均衡性不确定的宗族治权情境下，地权博弈与竞争的结果将取决于竞争者“在场”对地权的保护，或者说演化为多方参与主体行为能力的强弱。就单个农户的行为能力而言，一方面，由于个体排他能力受空间边界的约束，当农户从事远距离非农就业时，农户家庭的排他能力将会被削弱；另一方面，当农户更多地在村落内部活动时，其对土地的在位控制及排他能力更强。更为重要的是，处于宗族治权非平衡下的村落中地权的重新界定与分配平衡的达成，往往又取决于以家庭为基本单位的农户间的力量对比。此时，由于性别角色差异，男性在社会和家庭中处于主导地位，维护家庭权利的力量和声望更大。在地权分配的竞争中，男性则成为农户家庭实力的代表。故在隐含产权不稳定的农地调整中，家庭中的男性成为农户保证自身地权的关键，从而导致男性被束缚于农业生产而不能自由地实现非

农转移。对于女性，虽然法律规定女性与男性地权并无显著差异，但传统农村的女性地权却缺乏保障，且这种情况主要发生在土地产权的动态调整中[24]。按照此逻辑，地权得不到保障的女性更应去外面寻找就业机会。但是，家庭作为一个整体，女性主要从事料理家务、照顾老人和抚育子女等家庭内部事务，对外事务或经济责任主要由男性承担。因此，总体而言，在农地调整中，地权不稳定对不同性别劳动力的影响存在异质性，即地权不稳定产生了对男性的束缚，从而抑制其外出务工，而对于女性的影响较小，甚至可能并不存在显著的影响。

三、研究设计

（一）数据来源

本文使用的数据来源于中山大学国家治理研究院社会科学调查中心的中国劳动力动态调查（CLDS）。该调查采用多阶段、多层次、与劳动力规模成比例的概率抽样方法，主题涉及中国劳动力的生活、教育、收入、消费、就业、健康和社会保障等诸多方面，也对农村社区的政治、经济、社会文化及家庭结构特征等进行了详细调查。该调研样本覆盖中国29个省份，这些省份人口占全国总人口的90%以上，具有很强的代表性。鉴于研究目的和变量数据的可获得性，本文选取CLDS2016和CLDS2018两期数据并构造平衡面板进行经验分析。结合研究主题，在剔除缺失严重的样本后，最终得到6 730份农户有效样本。

（二）变量设置及说明

1.被解释变量

本文的被解释变量为男性外出务工占比和女性外出务工占比，数据来源于问卷中对家庭成员状况的描述，定义为男性或女性外出务工数占家庭成员总数的比重。同时，本文计算的劳动力性别占比均采用劳动力数量与家庭总人数之比，原因在于劳动力转移并不是一个独立的个体行为，而通常是家庭的共同决策。

2.解释变量

本文的解释变量为农地调整，此变量来源于问卷问项“2003年以来是否经历过农地调整”的回答结果。若回答是，则赋值为1，反之，则赋值为0。

3.机制变量

探究地权稳定性对务工农民性别差异的影响时，必须考虑到的关键情境是宗族非正式治权。本文衡量宗族非正式治权的变量设定为村落内宗族势力的强弱，并将其分为宗族绝对势力和宗族相对势力。一方面，对宗族绝对势力的衡量来源于村庄问卷中第一大宗族和第二大宗族的人口总和占村庄总人口的比重，若宗族人口占比超过50%，代表宗族绝对势力强，赋值为1；反之，则表示宗族绝对势力弱，赋值为0。另一方面，对宗族相对势力的衡量来源于问卷中第一大宗族和第二大宗族人口数量的对比关系。若村庄中前两大宗族的人口数量比高于所有村庄中前两大宗族数量比的均值，则定义为宗族势力对比均衡，赋值为1，反之，归为非均衡组，赋值为0。

4.控制变量

由于本文采用的样本数据为家户层面，为了提高回归拟合的可信性，参照刘晓宇和张林秀[13]与洪炜杰和罗必良[25]的研究，将同时影响农地调整和劳动力务工的控制变量划分为家庭层面和村庄层面。其中，家庭层面主要包含农户的人力资本禀赋和农业资源禀赋，村庄层面则涉及村庄的经济、人口、地理和交通条件等多个方面。具体设定为：（1）家庭层面控制变量：选取人均受教育程度、健康状况、农业收入占比和耕地总面积来反映家庭特征。（2）村庄层面控制变量：选取村庄经济情况、村庄人口情况、村庄少数民族占比、村庄地形、村庄交通条件和村庄所在地区来控制村庄特征。变量定义及描述性统计结果如表1所示。

表1 变量定义和描述性统计结果

变 量	定 义	均 值	标准差
男性外出务工占比	男性外出务工数/家庭成员数	0.137	0.217
女性外出务工占比	女性外出务工数/家庭成员数	0.088	0.187
农地调整	2003年以来是否经历过农地调整：是=1；否=0	0.149	0.357
宗族绝对势力	前两大宗族人口占比是否超过50%：是=1；否=0	0.730	0.444
宗族相对势力	前两大宗族的人口数量对比是否均衡：是=1；否=0	0.720	0.449
人均受教育程度	家庭成员平均受教育年限	7.211	3.253
健康状况	家庭成员平均健康水平	3.466	0.907
农业收入占比	农业收入/家庭总收入	0.374	0.437
耕地总面积	家庭拥有的承包地总面积的自然对数	1.401	1.010
村庄经济情况	村庄是否有信用社：是=1；否=0	0.214	0.410
村庄人口情况	村庄户籍人口数	4 357	11 000
村庄少数民族占比	少数民族人口/村庄总人口	0.121	0.293
村庄地形（是否山区）	是=1；否=0，平原为参照	0.258	0.438
村庄地形（是否丘陵）	是=1；否=0，平原为参照	0.284	0.451
村庄交通条件	村委会距县政府的距离（千米）	24.350	22.620

（三）模型设定

为了分析农地调整对务工农民性别差异的影响，本文考虑构建面板数据的适用模型。笔者参照陈强[26]与众多学者们的做法，进行Hausman检验，结果显示，P值为0.000，强烈地拒绝原假设，应采用固定效应模型。由此，本文的模型设定如下：

$$Y_{it} = \beta_0 + \beta_1 X_{it} + \beta_2 D_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (7)$$

其中，Y_{it}为农户i家庭在t期男性或女性外出务工占比；X_{it}为农户i在t期是否经历过农地调整；D_{it}为包含了农户家庭层面和村庄层面的所有控制变量；α_i为个体固定效应；λ_t为年份固定效应；ε_{it}为随机扰动项，假设其满足正态分布。

既往研究表明，由于反向因果或者遗漏变量等而产生内生性问题，导致估计结果存在偏误。本文的解释变量为农地调整，在模型设定中，虽然控制了农户家庭层面和村庄层面的变量，但仍有可能会遗漏与农地调整和劳动力非农转移都相关的变量，导致解释变量不满足与随机扰动项不相关的假定，由此带来内生性问题。工具变量法能够很好地解决由反向因果和遗漏变量而引起的内生性问题。因此，本文借鉴已有的研究，根据农户周围地区农地调整情况，选取“地级市内除本村农户外其他村农户是否经历农地调整的均值”作为本文的工具变量，其满足与解释变量农地调整相关而外生于农村劳动力非农转移的要求，工具变量回归的模型设定如下：

$$Y = \alpha \hat{X}_1 + \beta_1 X_2 + v_1 \quad (8)$$

$$\hat{X}_1 = \delta_1 X_1 + \delta_2 X_2 + v_2 \quad (9)$$

其中，Y为劳动力非农转移；X_1为农地调整的工具变量；X_2为可能同时与农地调整和劳动力非农转移相关的控制变量；$\hat{X}_1$为两阶段最小二乘法第一阶段的拟合值；v_1和v_2为随机扰动项。

四、实证结果与分析

（一）基准回归分析

表2展示了基准回归结果。其中，列（1）和列（3）是采用面板数据的混合回归结果；列（2）和列（4）是采用双向固定效应模型的回归结果。列（1）和列（2）的结果显示，农地调整对男性劳动力外出务工具有抑制作用，且都在1%水平上显著；列（3）和列（4）的结果显示，

农地调整对女性劳动力外出务工并未产生显著影响。此回归结果检验了农地调整对劳动力非农转移影响的性别差异。

表2　农地调整与务工农民性别差异的基准回归结果

变　量	（1）	（2）	（3）	（4）
	男性外出务工占比		女性外出务工占比	
农地调整	−0.024***（0.007）	−0.029***（0.010）	0.005（0.006）	0.004（0.008）
人均受教育程度	0.007***（0.001）	0.007***（0.002）	0.003***（0.001）	0.002（0.002）
健康状况	0.022***（0.003）	0.004（0.004）	0.010***（0.003）	0.007（0.004）
农业收入占比	−0.094***（0.006）	−0.032***（0.009）	−0.021***（0.006）	−0.005（0.009）
耕地总面积	−0.017***（0.003）	−0.001（0.005）	−0.010***（0.003）	−0.002（0.005）
村庄经济情况	0.006（0.006）	−0.011（0.011）	0.014**（0.006）	−0.015（0.010）
村庄人口情况	0.000***（0.000）	0.000***（0.000）	−0.000***（0.000）	−0.000***（0.000）
村庄少数民族占比	−0.001（0.010）	0.018（0.027）	0.005（0.009）	0.049*（0.026）
村庄地形（是否山区）	−0.012**（0.006）	−0.018*（0.010）	−0.006（0.006）	0.012（0.010）
村庄地形（是否丘陵）	−0.007（0.007）	−0.003（0.013）	−0.017***（0.006）	−0.005（0.012）
村庄交通条件	−0.000***（0.000）	0.000***（0.000）	−0.000***（0.000）	−0.000***（0.000）
个体/年份FE	不控制	控制	不控制	控制
常数项	0.104***（0.013）	0.091***（0.023）	0.086***（0.012）	0.059**（0.023）
观测值	6 730	6 730	6 730	6 730
R^2	0.136	0.093	0.038	0.008

注：***、**和*分别表示在1%、5%和10%的统计水平上显著，括号内为稳健标准误，下同。

（二）内生性问题处理

1.工具变量法

工具变量可以有效缓解因内生性问题而产生的估计偏误。为了更进一步证明基准回归结果是稳健的，本文使用“地级市内除本村农户外其他村农户经历农地调整的均值”作为工具变量进行估计，回归结果如表3所示。第一阶段回归结果显示，工具变量与内生变量的回归系数为0.236，且在1%水平上显著，表明工具变量与农地调整之间存在较强的相关性，满足了二者相关的假定。此外，F值为29.087，远大于弱工具变量检验的临界值10，这说明不存在弱工具变量问题。使用工具变量法的回归结果显示，农地调整对男性外出务工有显著负向影响，而对女性外出务工无显著影响，与基准回归结果保持一致。

表3　工具变量法检验结果

变　量	男性外出务工占比	女性外出务工占比
农地调整（第一阶段拟合值）	−0.237**（0.118）	0.142（0.113）
控制变量	控制	控制
地区/年份FE	控制	控制
常数项	0.136***（0.022）	0.064***（0.020）
观测值	6 730	6 730
第一阶段回归结果	0.236***（0.044）	
Under-Identification Test	29.087***	
Weak Identification Test	25.368	
R^2	0.025	

2.倾向得分匹配

为了避免自选择而引起的内生性问题，本文使用倾向得分匹配（PSM）方法重新进行估计。笔者将经历过农地调整的农户设定为实验组，而将未经历过农地调整的农户设定为对照组，采用三种不同的匹配方法估计农地确权的平均处理效应（ATT），如表4所示。由表4可知，三种匹配方式均显示，农地调整对男性外出务工具有显著的抑制作用，而对女性外出务工无显著影响，与前文的回归结果保持一致，再次说明本文研究结论是稳健的。

表4 倾向得分匹配检验结果

变 量	匹配方式	ATT	S. E.	t值
男性务工占比	近邻匹配	−0. 025**	0. 011	−2. 280
	卡尺匹配	−0. 020**	0. 008	−2. 350
	核匹配	−0. 022***	0. 007	−3. 040
女性务工占比	近邻匹配	0. 005	0. 010	0. 512
	卡尺匹配	0. 004	0. 008	0. 480
	核匹配	0. 005	0. 007	0. 700

（三）稳健性检验

为了验证基准回归结果的可靠性，本文采用重新定义被解释变量的方式进行稳健性检验，分别用男性外出务工人数和女性外出务工人数占家庭所有男性和女性数量的比重来替换基准回归的被解释变量，使用面板双向固定效应模型进行估计，估计结果如表5列（1）和列（3）所示。同时，考虑到劳动力外出务工占比是介于0—1之间的连续变量，具有双受限特征，故另采用面板Tobit随机效应模型进行估计，估计结果如表5列（2）和列（4）所示。表5的回归结果显示，农地调整对男劳动力外出务工和对女劳动力外出务工的影响与基准回归结果一致，证明基准回归结果的稳健性。

表5 重新定义被解释变量与变换估计模型检验结果

变 量	（1）	（2）	（3）	（4）
	男性外出务工占比		女性外出务工占比	
农地调整	−0. 035**（0. 014）	−0. 080***（0. 029）	0. 001（0. 015）	−0. 022（0. 044）
控制变量	控制	控制	控制	控制
个体/年份FE	控制	不控制	控制	不控制
常数项	0. 102***（0. 033）	−0. 600***（0. 057）	0. 101**（0. 040）	−0. 866***（0. 089）
观测值	6 730	6 730	6 730	6 730
R^2	0. 027		0. 010	

五、机理分析

（一）农地纠纷的传导效应

农地调整之所以对劳动力非农转移存在抑制作用，源于农户在地权变更时需要进行地权的博弈与竞争。男性作为博弈与竞争结果的关键，自然而然地受到地权稳定性的影响。原因在于，在地权博弈过程中，不稳定的地权更容易引发土地承包权益纠纷，由此形成对男性的束缚。为了验证这一逻辑，本部分引入农地纠纷作为农地调整作用于男性劳动力非农转移选择的传导变量。变量的定义来自问项“农户是否产生过因农地承包或土地权益问题而发生农地纠纷”，若回答是，则赋值为1，否则赋值为0。

表6的回归结果显示，农地调整所表征的地权不稳定增加了农地纠纷，而农地纠纷的增加显

著地抑制了男性劳动力外出务工。同时，对女性外出务工的影响依然不显著。

表6　农地纠纷的传导效应检验结果

变　量	农地纠纷	男性外出务工占比	女性外出务工占比
农地调整	0.149***（0.012）		
农地纠纷		−0.062***（0.023）	0.011（0.024）
控制变量	控制	控制	控制
个体/年份FE	控制	控制	控制
常数项	−0.082***（0.017）	0.084***（0.023）	0.061***（0.023）
观测值	6 730	6 730	6 730
R^2	0.059	0.065	0.008

（二）宗族非正式治权下农地调整与农地纠纷关系的讨论

为了厘清宗族非正式治权在农地调整时对男性外出务工的作用机理，本文进一步探讨宗族非正式治权在缓解农地纠纷中发挥的作用。

表7的回归结果显示，在宗族绝对势力强时，农地调整表征的地权不稳定性更易引发农地纠纷。这说明，强大的宗族绝对势力在农地调整中发挥了作用，但是可能发挥的是与维护地权公平相悖的“负面”作用，即对内部成员地权维护和对外部成员地权破坏的“负面”作用。进一步地，本文探究宗族相对势力对比情境下农地调整与农地纠纷的关系。结果表明，无论宗族相对势力对比均衡与否，农地调整都会增加农地纠纷。但是，在宗族相对势力对比不均衡时，农地调整对农地纠纷的作用更强，而当宗族相对势力对比均衡时，这种作用明显减小。这个结果说明，相对于势力对比不均衡的宗族，相互制衡的宗族能够弱化农地调整对农地纠纷的影响，起到维护地权公平的作用。

表7　宗族非正式治权下对农地调整与农地纠纷关系的检验结果

变　量	农地纠纷			
	宗族绝对势力弱	宗族绝对势力强	宗族相对势力对比不均衡	宗族相对势力对比均衡
农地调整	−0.006（0.006）	0.171***（0.016）	0.228***（0.033）	0.105***（0.014）
控制变量	控制	控制	控制	控制
个体/年份FE	控制	控制	控制	控制
常数项	0.234***（0.035）	−0.087***（0.019）	−0.154***（0.036）	−0.050**（0.022）
观测值	2 215	4 515	1 885	4 845
R^2	0.500	0.283	0.502	0.119

（三）对宗族非正式治权的分组检验

村落宗族的存在直接影响农地调整中地权分配的公平性，村落宗族非正式治权的大小对地权博弈的结果也起到关键作用。现有文献已经指出，宗族在地权博弈中扮演双重角色，既可能形成对地权的保护，亦可能破坏地权分配的公平性。一方面，由于宗族的显著特征是对内“公”而对外“私”，这可能会导致在村落中具有绝对力量的宗族产生对土地资源的攫取，破坏地权分配的公平性，对内部成员产生主动束缚和对宗族之外成员产生被动束缚；另一方面，从宗族相对力量来讲，当村落内部宗族之间的势力不均衡而使得地权分配不能按照村民意愿进行公平分配时，宗族内部成员规模成为地权博弈与竞争的关键因素，从而形成对劳动力的束缚。当村落内部宗族之间的势力能够形成相互制衡时，或许在一定程度上也能够形成对地权的保护，弱化对劳动力所形成的束缚。但是，无论是从宗族绝对势力还是从宗族相对势力来讲，非稳定产权下的男性作为农户家庭整体力量的代表，在地权博弈中扮演的角色意味着其成为地权竞争结果的关键，从而影响

其外出务工。因此，本文将农地调整对务工农民性别差异的影响从两个层面进行分组检验，其一是宗族绝对势力情境，其二是宗族相对势力情境。

1.对宗族绝对势力情境的考察

表8为在宗族绝对势力情境下，农地调整与务工农民性别差异的检验结果。其中，列（1）和列（2）为对男性外出务工影响的分组考察，列（3）和列（4）为对女性外出务工影响的分组考察。回归结果显示，当宗族绝对势力弱时，农地调整对男性外出务工并未产生显著影响；当宗族绝对势力强时，农地调整对男性外出务工产生了显著的抑制作用。这说明，当宗族绝对势力强时，宗族内部成员在地权的博弈与竞争中能够获得土地资源优势，进而使其在农地调整中获得更大的益处，从而抑制其外出务工；而宗族外部成员为了保护自己拥有的地权，同样会选择留守并进行地权竞争。由此，农地调整所表征的地权不稳定形成了对男性外出务工的抑制。对女性外出务工而言，与基准回归结果相一致，即无论宗族绝对势力强还是弱，农地调整对女性外出务工都不产生显著影响。

表8　对宗族绝对势力情境的检验结果

变　量	（1）	（2）	（3）	（4）
	男性外出务工占比		女性外出务工占比	
	宗族绝对势力弱	宗族绝对势力强	宗族绝对势力弱	宗族绝对势力强
农地调整	−0.013（0.013）	−0.033***（0.008）	−0.003（0.015）	0.003（0.008）
控制变量	控制	控制	控制	控制
个体/年份FE	控制	控制	控制	控制
常数项	0.122***（0.024）	0.105***（0.017）	0.067***（0.019）	0.093***（0.015）
观测值	1 816	4 914	1 816	4 914
R^2	0.131	0.197	0.061	0.055

2.对宗族相对势力情境的考察

前面考察了在宗族绝对势力强或弱的情形下，农地调整对外出务工性别差异的影响，且得出当宗族绝对势力强时，农地调整对男性外出务工具有显著的抑制作用。那么，宗族在乡村中作用的发挥不仅与其绝对势力有关，同时也取决于其相对势力的大小，即上文中所提到的宗族间能否形成村落权力的制衡。表9为对宗族相对势力分组考察的检验结果。

表9　对宗族相对势力情境的检验结果

变　量	（1）	（2）	（3）	（4）
	男性外出务工占比		女性外出务工占比	
	相对势力对比不均衡	相对势力对比均衡	相对势力对比不均衡	相对势力对比均衡
农地调整	−0.038***（0.014）	−0.016**（0.008）	0.006（0.015）	0.003（0.008）
控制变量	控制	控制	控制	控制
个体/年份FE	控制	控制	控制	控制
常数项	0.093***（0.024）	0.116***（0.017）	0.091***（0.025）	0.087***（0.014）
观测值	1 885	4 845	1 885	4 845
R^2	0.214	0.169	0.061	0.062

由表9可知，列（1）和列（2）同样是农地调整对男性外出务工影响的考察，列（3）和列（4）是对女性外出务工影响的考察。由表9可知，当宗族相对势力对比不均衡时，农地调整对男性外出务工产生了显著的抑制作用；而宗族相对势力对比均衡时，农地调整对男性劳动力外出务

工的抑制作用明显减弱。这一结果说明，宗族只有在力量相互制衡时，才会起到对地权公平的维护作用。当相对力量对比不均衡时，力量相对强的一方可能通过地权的重新分配攫取利益，进而产生对地权公平性的破坏。此外，本文也考察了在宗族相对势力对比情形下，地权不稳定对女性劳动力外出务工的影响，结果发现无论是宗族相对势力对比均衡还是不均衡，农地调整对女性外出务工都未产生显著影响。

六、结论与启示

在中国农村土地集体所有制下，追求地权分配公平决定了农地调整存在的合理性。农地调整作为农村界定地权的重要方式，虽然能够体现集体成员权公平，但也可能会破坏经营权的稳定性[27]。学术界通常将农地调整作为地权不稳定的衡量指标，来探究其隐含的行为发生学意义。其中，地权稳定性与劳动力外出务工之间的关系历来受到学术界的关注。典型的主流文献从经营权不稳定的观点出发，指出农地调整会抑制农村劳动力外出务工[3]。这些研究认为，面对农地调整所表征的地权不稳定，农户往往会采用留守来实施对地权的保护，从而影响其非农转移决策。但是，现有文献并未考虑乡村非正式治权的作用，也并未对劳动力的异质性进行区分。地权变更引发的产权不稳定及地权中“公共领域”的广泛存在，为农地权利的竞争留下了空间，致使农户普遍被卷入了对地权讨价还价的博弈之中。同时，宗族等非正式组织在中国乡村资源分配中发挥着重要作用，从而产生了土地产权实施中农户家庭成员非农转移决策不确定性的问题。因此，本文拓展了已有研究，构建了地权稳定性—非正式治权—务工农民性别差异的分析框架，结合乡村非正式治权情境，探寻劳动力转移的性别差异及其作用机理，以便更好地解释中国农村劳动力转移过程中出现的性别差异现象。

本文基于中国劳动力动态调查（CLDS）2016年和2018年两期面板数据的研究结果表明，农地调整对劳动力非农转移的影响存在明显的性别差异。由于男性在地权竞争中发挥主导作用，故农地调整对男性劳动力非农转移具有显著的抑制作用，但对女性劳动力外出务工的影响却不显著。机制分析结果显示，农地调整引发的地权博弈与竞争产生农地纠纷，并由此抑制男性劳动力外出务工。同时，当宗族绝对势力弱，或者宗族相对势力对比均衡时，农地调整对农地纠纷的影响更小。这个结果说明，农地调整对男性外出务工产生了较强的抑制作用，但当宗族绝对势力弱，或者宗族相对势力对比均衡时，这种抑制作用被明显地弱化了。

与劳动力流动相伴随的人地关系变化是中国乡村治理现代化过程中不可回避的现实问题。为了处理好产权变更与劳动力流动之间的关系，优化农村劳动力配置，提升农业生产效率，劳动力转移性别差异所隐含的产权经济学含义理应引起足够重视。农地调整是体现集体成员权公平的重要方式，在看到农地调整在保障公平方面发挥的作用时，也应充分重视传统道德习俗等非正式治权在保障产权公平性方面所发挥的重要作用，并由此对产权实现更好的保护。“乡土中国”存在着根深蒂固的自治文化[28]。宗族是社会变迁中存在的一种适应能力极强的社会组织。正如费孝通所说，“活生生的生活中有许多是从过去传下来的，但这些传下来的东西之所以传下来就因为他们能满足当前人们的生活需要”[29]。笔者发现了宗族组织对于地权分配和非农就业的重要影响，那么，以宗族组织在地权分配中的作用为出发点，扩展到乡村治理的全局来看，非正式制度发挥的作用成为正式制度的积极补益。

在任何社会或者社会阶段，都不存在纯粹的现代性，也不存在纯粹的传统性[30]。现代化进程是在传统制度和价值观念上的延伸与发展。因此，在乡村振兴战略实施进程中，有必要对宗族等非正式治权进行改造或者适应性重塑，以充分发挥其在维持乡村秩序、保护村庄安定、维护村落公平等方面的正面功能，由此拓展乡村善治的可能性路径。

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Effects of Land Rights Institution Reform in Chinese Modernization

Presenter: LUO Bi-liang[1,2]

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Summary: The path to China's agricultural modernization is closely related to the reform of the agricultural land Institution. From the establishment of the household responsibility system under the contract responsibility system, to the new round of land rights confirmation, and then to the "separation of three rights" involving collective ownership of rural land, household contracting rights, and farmers' management rights, land rights reforms all affect various aspects of farmers' production and life, and have a profound impact on the transformation of China's agricultural modernization. The three articles selected for "A Special Column on Effects of Land Rights Institution Reform in Chinese Modernization" led by professor Luo Bi-liang focus on the incentive effects of land rights on farmers' fertility behavior, the influence of land rights stability on the gender differences of migrant workers, and the behavioral economics significance of the impact of land property rights stability on farmers' path choice to urbanization. This special column analyzes the functions of land rights in the transformation of China's agricultural and rural modernization, with the hope of further stimulating academic enthusiasm and deepening research on rural land Institution.

In their article titled "Does Land Rights Stability Strengthen Farm Households' Fertility Incentives: Quasi-Natural Experimental Evidence From the Leizhou Peninsula", Hong Wei-jie and Luo Bi-liang utilize farm household questionnaire data and employ OLS and 2SLS methods to investigate this issue. The study reveals that farmers residing in ancestral land exhibit lower birth incentives, and as the proportion of ancestral land in a village increases, the number of new members within farm households decreases. In the article "Land Rights Stability, Informal Governance and Fender Differences Among Migrant Farmers" by Meng Xiao-zhi and Xie Lin, the authors explore the role of clan informal organizations in rural governance and its impact on gender-specific labor migration. Based on data from the 2014 and 2016 CLDS, Weng Yi-qing and Hu Xin-yan's article titled "How Does the Stability of Land Rights Affect Farmers' Choice to Move to Cities?" analyzes the influence of land rights stability on farmers' decisions to migrate to nearby cities using a two-way fixed model. It contributes to a better understanding of the new urbanization development strategy based on the county economy.

Key words: land rights Institution; birth incentives; rural-urban migration; nearby urbanization

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RESEARCH ON FINANCIAL AND ECONOMIC ISSUES

罗兴良(主持人). 农地确权专题研究
白让让. 行政权力与市场支配地位的双重滥用行为研究
——理论分析与多案例比较
张先治,李 苗. 双重成本匹配影响企业集团管控模式选择的机制
——基于海尔集团的探索性案例研究

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值班编辑：刘 艳 英文目次：李 姝

农地调整经历、劳动力非农转移与农业生产绩效

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一、问题的提出

制度变迁主要表现为两种方式：一是政策制定者以法律或命令等形式自上而下推行的强制性变迁；二是个人或团体受到潜在的利益驱使，通过自发组织和倡导等形式自下而上形成的诱致性变迁[72]。制度实施及其绩效与人们的制度信念紧密关联，而这种信念的形成往往受到行为主体历史经验的影响。所以，制度安排不能忽略历史的作用[73]。行为心理学的研究表明，基于小概率事件的记忆与信息处理，在人们面对现实环境进行决策时仍然发挥着特别重要的作用[74]。正如弗洛伊德[41]强调的，人类的行动受过去经验记忆及知识积累的影响，通过条件反射和学习形成信念，从而指导当前和未来的行动。因而社会的经济绩效不仅与制度安排有关，同样也会受到个体经历或记忆的影响。

制度对经济增长的决定论已成为学术界的基本共识[75]。明晰而稳定的产权通过规范经济主体的行为预期，并由此激励其长期投资，进而提高整个社会的经济绩效。在农业生产领域，有效的制度安排以及由此内生出的产权激励和经济主体的稳定预期同样是改善农业生产绩效的根源[76]。对此，中国政府为赋予农民长久而稳定的土地承包权作出了持久的努力。其中，2009 年开始试点并于 2014 年全面推进的农村土地承包经营权确权登记颁证工作，对于妥善解决农户承包地块面积不准、“四至”不清等问题，具有重要的基础性制度意义。农业农村部的数据表明，截至 2018 年底，农村土地承包经营权确权登记颁证基本完成，颁证率已超过 96%，覆盖全国 2 838 个县（市、区）、3.4 万个乡镇、55 万多个行政村、两亿多个农户。①

作为一项维护地权稳定和产权安全的制度安排，农地确权的社会经济效应已受到学术界的广泛关注。然而，已有研究大多聚焦于从地权不稳定到农地确权的政策转变所引发的行为效果[21,77-78]，却鲜有研究关注在农地确权工作完成之后，农户的农业生产绩效是否存在差异以及差异生成的根源。笔者推测，农地确权对农业生产绩效的影响并非是独立事件，而是具有重要的情境依赖性。其中，农户过往经历的农地调整及其产权不稳定记忆具有重要作用。

本文以农地确权登记颁证工作的收官之年 2018 年作为研究起点，通过构建“农地调整经历—劳动力非农转移—农业生产绩效”的分析框架，并采用中国劳动力动态调查（CLDS）2018 年数据，利用线性回归模型、倾向得分匹配模型和中介效应模型，分析农地确权背景下农户的农地调整经历对农业生产绩效的影响及其内在的传导机制，并进一步从代际分布、经营禀赋以及经济区位等多个角度，考察农户的农地调整经历对农业生产绩效影响的异质性，由此揭示行为主体的过往经历对制度绩效的决定机理。

本文的边际贡献在于：首先，在技术层面，突破已往文献从“是”“否”二分法来刻画农地调整，而是按调整程度将其细化为无调整、小调整和大调整三种不同情形予以刻画。其次，在理论层面，通过分析农地确权背景下农户的农业生产绩效差异，由此阐明同样的制度安排并不一定导致同样行为效果的理论机理。

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① 数据来源：https：//www. chinanews. com. cn/sh/2020/11-03/9329635. shtml。

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二、理论基础与研究假设

（一）农地确权背景下农业生产绩效的决定：农地调整经历

农地确权不仅使农户承包权“四至”的空间边界得以明晰，更是固化了“生不增、死不减”的集体成员身份[16]。因此，随着2018年农地确权颁证登记制度的全面落实，地权趋于稳定已成为基本事实。理论上，农地确权通过提升农户的行为预期，改善农业生产绩效。但是，已有研究仍然表明，制度变迁和制度绩效与社会信念、制度目标和制度遗产等有关，具有情境依赖性[25]。农地确权是在土地调整的情境中实施的，因而农地确权的实施效果必将受其影响[79]。行为心理学强调，过往的经历往往会形成对某一事件的先验态度[22]，并影响人们的行为选择。因此，在同等赋权强度下，确权主体的绩效差异可能与其过往的农地调整经历密切相关。

在中国农村，农地集体所有决定了地权均分的必然性。尽管政府一直致力于强化地权稳定性，但是农地调整在较长一段时期内依然普遍存在。原因在于：一方面，从土地革命战争时期的“耕者有其田”，到农业集体化时期的绝对平均地权，再到土地家庭联产承包责任制下的农地“均包”，都充分体现出土地的“均权”特征，而土地承包经营权的调整，多数是在人地关系发生变化后对要素不平等的响应；另一方面，自中华人民共和国成立以来，无论是对农地私有制的集体化改造运动，还是家庭联产承包责任制在全国范围的普遍推广，均是国家意志选择的结果。特殊的农地初始赋权方式意味着，农地调整在一定程度上也是按照国家意图变更的结果[32]。然而，学术界就农地调整是否会引起微观经营主体“消极怠农”是存在分歧的[80]。从心理学角度看，当行为主体处于非常平衡的状态，更容易陷入舒适区，并难以产生改善现状的内驱力，而农地调整是打破农地持有者原有“平衡状态”的一种方式。由地权变动诱发的失地风险，更有可能使行为主体形成严格的自我约束，并在一定程度上刺激行为主体的生产性努力。因此，农地调整表面上是国家基于公平原则自上而下赋予村集体的产权再界定，但从心理学角度出发，还在一定程度上表达为规范农民生产行为的一种“约束机制”。显然，不同的农地调整方式（无调整、小调整和大调整）隐含着不同的地权损失程度，由此所形成的约束强度和激励效果也有所差异。

损失规避理论强调，与等量的收益相比，损失会带给人更强烈的心理效应[40]。正如斯密[81]所描述的：状况由好变坏时，人们所承受的痛苦往往要比由坏变好时所体验到的快乐多。由此可以认为，无调整经历的农户由于从未体会过失去农地的“痛苦”心理，轻易获得并持续拥有的农地剩余控制权反而会弱化其对农地的珍惜程度，并由此形成农地“低价值”的心理定位，从而诱发“持有型懈怠”，造成农业生产绩效损失[79]。对比之下，在农地调整经历中遭受损失的农户对于农地产权有着更强烈的感受，并更有可能珍惜已获取的资源，由此形成的“先验态度”在获得确权的政策补偿后，将激励农户优化要素配置结构，提高农业生产绩效。但值得注意的是，尽管“约束机制”在某种程度上可以激发农民的生产性努力，但如果农户面临的损失程度过大，反而会过犹不及。换言之，具有大调整经历的农户，其产权的安全性感知是最低的，大调整意味着一旦在农地上进行跨期投资，就有可能面临“竹篮打水一场空”的局面。因此，大调整经历会显著弱化农户对农地确权政策的制度信任，形成较弱的制度可信性预期。农户由于担心以农地确权为标志的法律意义上的产权无法保护自身权益，导致其改善农业生产的动机较弱，很难产生农业生产的激励作用[82]。基于此，笔者推断：在不同的调整经历下，农户面临的损失经历以及由此引发的产权约束强度并不相同。无调整和大调整分别由于“安于覆盂”“过犹不及”并不利于农业生产，对比之下，农户的小调整经历对于农业生产绩效的改善更为有利。据此，笔者提出如下假设：

假设1：农户的农地调整经历与农业生产绩效之间存在倒U型关系，即与无调整和大调整相比，经历农地小调整的农户是农业生产绩效最高的经营主体。

（二）机制分析：对“约束机制”的行为响应

1. 基于劳动力转移的行为响应

对于无调整经历的农户，产权的“约束机制”是近乎失效的。因为这部分群体的生产行为从未受到来自产权变动的约束，因而其改善农业生产的动机是最弱的。正如行为主义心理学所强调的，人

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的行为主要通过后天习得，并且因奖惩机制而得到强化或者削弱[83]。农地无调整意味着，珍惜农地并不会使经营主体获得更多的土地，不珍惜也不会因此而失去。因此，这部分群体无论是否表现出珍惜的举动，都不会受到任何奖惩，由此将很难激发起该群体对于土地的珍惜心理。换言之，无调整经历的农户之所以难以产生改善农业生产的内驱力，本质上是因为“珍惜”行为与“奖惩”之间并没有建立有效的联结机制，这也是“约束机制”失效的主要原因。农地确权代表着地权的赋能和集体成员权身份的固化，地权的高度稳定与农地的低价值定位的现实矛盾为农户离农提供了可能的空间。因此，当农户的生计选择空间不断扩大，无调整经历的农户有可能策略性地选择离农。由此可以推测：“安于覆盂”的地权经历将导致“约束机制”失效，那么在非农劳动力市场释放出较高的价格信号时，无调整经历的农户将倾向于向非农领域转移。

农地大调整意味着所有农户的土地边界及产权均会受到影响，因而其背后所蕴含的约束程度是最大的。虽然农地调整“约束机制”在某种程度上可以激发农民的生产性努力，但如果约束过度，就容易在行为主体身上形成超限效应 。① 对于经历大调整并承受较大损失的农户，在大调整中所形成的“先验态度”使其衍生出对于农地确权政策的不信任心理，并由此引发两种可能：一是逃离农业以避免地权再次变动所造成的损失。农地产权的不稳定意味着对农地未来收益的不确定，一旦农地被重新调整，附着在土地上的中长期投资将一并失去。因此，频繁的土地调整相当于对农民征收随机税[28]。大调整经历的农户为了避免遭受失地损失，可能选择改变从业方式，进入非农生产领域。二是调整种植结构以避免地权再次变动所造成的损失。地权不稳定所导致的投资预期稳定性的降低，往往会影响农业生产的连续性。显然，对于偏好农业生产却又经历大调整的确权农户而言，应对产权风险的一个重要表现就是缩短农作物的种植周期以适应农地调整，从而形成劳动力非农转移的挤出效应[84]。由此推断：“过犹不及”的地权调整经历将导致部分农户逃离农业或调整种植结构，从而促进劳动力的非农转移。

小调整通常只发生在人口发生变化的农户家庭。换言之，如果家庭人口并未改变，农户依旧可以拥有原来的承包地。人口减少使得家庭在小调整中失去部分土地，人口增加则有助于家庭新增部分土地。在小调整中，原有承包地块位置发生大幅度变化的可能性较小，由此所隐含的农地产权不稳定程度往往介于不调整与大调整之间。所以，对比其他两种调整情形，小调整经历对劳动力非农转移的影响也因此存在一定的差异。与无调整相比，经历小调整的农户获得了来自基层政府（村集体）关于农地的“奖励”或“惩罚”，由此所形成的“先验态度”将在农地确权政策的补偿效应下强化该群体对于农地的珍惜程度，并表现为减少农业劳动力向非农领域的过度转移。因此，农户的农地小调整经历对劳动力非农转移的影响并没有无调整明显。与大调整相比，小调整借助适度的产权管制可以激发农民的生产性努力，同时由于承包地块边界和位置的变化幅度较小，农地长期投资的预期较为稳定，对农业经营连续性的影响程度也可能低于大调整。因此，农户的农地小调整经历对劳动力非农转移的影响也没有大调整明显。由此可以推测：在不同的调整经历下，农户的行为响应强度并不相同，经历无调整和大调整的农户分别由于“安于覆盂”和“过犹不及”的产权经历，更有可能促进劳动力非农转移，对比之下，经历小调整的农户的劳动力非农转移程度较低。据此，笔者提出如下假设：

假设 2：与无调整和大调整相比，经历农地小调整的农户家庭劳动力非农转移程度较低。

2. 不同响应强度下的农业生产绩效差异

新迁移经济学（NELM）理论强调，劳动力转移对家庭生产的影响是极其复杂的：一方面，劳动力转移会造成农业劳动力要素的短缺；另一方面，由劳动力转移产生的汇款可以帮助家庭克服流动性约束限制，并提高风险应对能力[85]。检验 NELM 假说的计量分析结果也表明，由于迁移汇款的流向具有不确定性，劳动力非农转移对农业生产的影响并没有一个确切的结论[86-87]。但是在劳动力转移过程中存在的一个基本事实是，农业的生计地位会伴随劳动力转移而发生动态变化。当少量的家庭劳动力流向非农产业时，意味着农民对于农业仍然具有较高的生存依赖性。此时劳动力转移将对农业生

① 超限效应是指刺激过多、过强或作用时间过久，从而引起极不耐烦或逆反的心理现象。

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产带来两种可能性：一是通过生产要素替代（如农业机械化）弥补家庭务农劳动力不足。二是将务工收入投入到投资回报率相对较高的经济作物。但已有文献指出，劳动力转移更有可能引发种植结构的趋粮化[88]。因为粮食作物属于土地密集型产品，在农业分工上更具优势，所以理性的小农会遵循要素的配置逻辑，优先种植劳动生产率高的粮食作物[89]。因此，劳动力转移是否会通过增加经济作物种植来提高农业生产绩效还有待商榷。由此可以推测：家庭内部小规模的劳动力非农转移可能通过生产要素替代对农业生产带来积极影响。

当家庭劳动力大多流向非农产业时，农业可能副业化。可以认为，土地所承担的生存保障功能已经大大降低，不再像历史上任何时期那样是农民的命根子。按此逻辑，务工农户家庭将选择流转经营权以获得土地的财产性收益。但由于土地要素市场的扭曲和发育不足，以及土地本身所凝聚着的乡土情怀与情感关联，使得大部分农民继续持有土地成为了占优选择[90]。因此，农业生计地位的改变并不足以使农户放弃经营权，但此时农户的生产积极性可能会由于农业生计地位的下降而骤减，并表现为通过减少农业资本投入，只维持土地最基本的生产功能。由此可以推测：当家庭成员大多外出务工时，劳动力非农转移可能对农业生产造成不利影响。据此，笔者提出如下假设：

假设 3：与家庭内部大规模的劳动力非农转移相比，小规模的劳动力非农转移更有利于农业生产绩效的提高。

综上，农户的农地调整经历不仅对农业生产绩效具有直接影响，还通过影响劳动力非农转移水平间接影响农业生产绩效，由此形成“农地调整经历—劳动力非农转移—农业生产绩效”的分析线索。

三、研究设计

（一）数据来源

本文所用数据来源于中山大学社会科学调查中心开展的中国劳动力动态调查（CLDS）。该数据涵盖中国 29 个省份（西藏、海南、港澳台除外）。其中，2018 年调研数据共涉及样本 16 537 个劳动力个体、13 501 个受访家庭以及 368 个社区。在剔除非农村户口居民和关键变量严重缺失的样本后，将农户家庭问卷、个体问卷以及村居问卷进行匹配合并，最终获得 2 259 个农户家庭样本。鉴于 2018 年中国已经基本完成农村土地承包经营权的确权登记颁证工作，所以在 CLDS 问卷中这些样本农户均被视为农地确权农户。

（二）变量选取

1. 被解释变量：农业生产绩效

笔者借鉴李宁等[91]的研究，以 2017 年单位土地农业产出值的自然对数作为农业生产绩效的测度指标。

2. 解释变量：农地调整经历

主要包括 2003 年至今农地是否无调整、小调整和大调整三种情形。其中，根据李尚蒲和罗必良[32]对农地调整的划分，将“村组内部分农户土地小调整”“利用村里的机动土地进行调整”视为农地小调整；将“村组内土地打乱重分”视为农地大调整。

3. 中介变量：劳动力非农转移

用家庭非农劳动力数/家庭劳动力总数衡量。

4. 控制变量

本文参照林文声等[21]的研究，控制变量包括家庭特征（家庭成员平均年龄、家庭女性占比和家庭成员受教育水平）、生产特征（农业生产人数、家庭耕地面积、弃耕比重、作物类型和农业生产方式）以及外部特征（惠农服务、村庄地形和地理区域）。主要变量定义及描述性统计如表 1 所示。

（三）模型选择与说明

1. 基准回归模型

为考察农户的农地调整经历与农业生产绩效之间的关系，设定模型如下：

$$Y_i = \alpha_0 + \alpha_1 D_{i2} + \alpha_2 D_{i3} + \sum_{j=3}^{13} \alpha_3 Controls_i + \varepsilon_i \quad (1)$$

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其中，Y_i表示农业生产绩效，D_{i2}和D_{i3}分别表示农户的无调整和大调整经历的虚拟变量，D_{i1}作为小调整经历的虚拟变量不加入模型，$Controls_i$表示控制变量组，ε_i为随机误差项。

2. 中介效应模型

为考察农户的农地调整经历对农业生产绩效的内在作用机理，本文采用逐步回归法对影响机制进行检验，在模型（1）的基础上设定模型如下：

$$M_i=\beta_0+\beta_1 D_{i2}+\beta_2 D_{i3}+\sum_{j=3}^{13}\beta_j Controls_i+\varepsilon_i \quad (2)$$

$$Y_i=\gamma_0+\gamma_1 D_{i2}+\gamma_2 D_{i3}+\gamma_3 M_i+\sum_{j=4}^{14}\gamma_j Controls_i+\varepsilon_i \quad (3)$$

其中，M_i表示中介变量劳动力非农转移。

3. 关于内生性问题。

由于农户的农地调整经历与农业生产绩效之间可能存在内生性问题，因此，本文选择“同一省份内其他村庄不同农地调整情形的均值”作为农地调整的工具变量。原因在于：一是农地调整是以村为单位开展的，同一省份的政策在不同村落之间的执行进程具有相对一致性的特点，满足相关性条件。同时，农户农业生产绩效通常由所在村庄的农地调整情况所决定，并不会受到外部村落的影响，满足外生性条件。二是本文在稳健性检验部分将采用倾向得分匹配法构造农地调整经历对农业生产绩效影响的反事实框架来纠正可能存在的自选择问题。三是由于 CLDS 数据中缺乏耕地细碎化程度和地块位置等影响农业生产绩效的控制变量，本文还增加了外部特征变量来控制遗漏变量问题。

表 1 **变量定义及描述性统计**

变　量	定义及赋值	均　值	标准差
农业生产绩效	2017 年单位土地农业产出值的自然对数	6. 806	1. 012
农地无调整经历	2003 年至今农地是否无调整：是=1；否=0	0. 781	0. 009
农地小调整经历	2003 年至今农地是否进行小调整：是=1；否=0	0. 170	0. 375
农地大调整经历	2003 年至今农地是否进行大调整：是=1；否=0	0. 050	0. 217
劳动力非农转移	家庭非农就业劳动力数/家庭劳动力总数	0. 342	0. 360
家庭成员平均年龄	家庭成员平均年龄（年）	43. 853	12. 448
家庭女性占比	女性成员占比	0. 473	0. 177
家庭成员受教育水平	高中以上学历成员占比	0. 174	0. 218
农业生产人数	家庭从事农业生产 3 个月以上成员数量（人）	1. 746	0. 740
家庭耕地面积	家庭承包地总面积的自然对数	1. 989	0. 808
弃耕比重	耕地弃耕面积/家庭承包地总面积	0. 024	0. 110
作物类型	粮食作物播种面积/种植业总面积	0. 955	0. 133
农业生产方式	传统农耕=1；半机械化=2；全程机械化=3	1. 980	0. 158
惠农服务	本村获得的惠农服务项目数量（项）	1. 957	1. 261
村庄地形	平原=1；丘陵=2；山地=3	1. 650	0. 818
地理区域	东部=1；中部=2；西部=3	1. 932	0. 018

四、实证结果与分析

（一）农地调整经历对农业生产绩效的影响

表 2 是农户的农地调整经历影响农业生产绩效的回归结果。先进行的识别不足检验和弱工具变量检验结果表明，本文选取的工具变量不存在识别不足和弱工具变量问题。再进行杜宾—吴—豪斯曼的检验结果表明，基准模型并不存在严重的内生性问题。因此，本部分主要以 OLS 的估计结果作为解释的依据。

列（1）显示，与农地小调整经历相比，农户的农地无调整经历和农地大调整经历均负向影响农业生产绩效，且分别在 1% 和 10% 水平上显著。这意味着，经历农地小调整的农户是农业生产绩效最高的经营主体。列（2）中的 2SLS 估计结果和列（1）中的 OLS 估计结果具有一致性。此外，本文采用 2003 年至今农地的调整程度（无调整=0，小调整=1，大调整=2）作为农地调整经历的代理变

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量，并在模型中引入农地调整程度的平方项，进一步考察农地调整程度对农业生产绩效的影响。列（3）显示，农地调整程度及其平方项均在1%水平上显著，这说明随着农地调整程度的增加，农户的农业生产绩效将出现先上升后下降的倒U型变化。上述结果为假设1提供了实证支持。

表2 农户的农地调整经历对农业生产绩效影响的回归结果

变 量	OLS	2SLS	OLS
	（1）	（2）	（3）
农地小调整经历（对照组）			
农地无调整经历	-0.157*** （0.056）	-0.155*** （0.058）	
农地大调整经历	-0.207* （0.107）	-0.174* （0.096）	
农地调整程度			0.339*** （0.116）
农地调整程度的平方			-0.182*** （0.070）
家庭成员平均年龄	-0.004** （0.002）	-0.004** （0.002）	-0.004** （0.002）
家庭女性占比	-0.068 （0.115）	-0.070 （0.121）	-0.068 （0.115）
家庭成员受教育水平	-0.017 （0.094）	-0.018 （0.102）	-0.017 （0.094）
农业生产人数	0.092*** （0.028）	0.092*** （0.027）	0.092*** （0.028）
家庭耕地面积	-0.311*** （0.027）	-0.310*** （0.028）	-0.311*** （0.027）
弃耕比例	-0.084 （0.191）	-0.086 （0.234）	-0.084 （0.191）
作物类型	0.149 （0.158）	0.146 （0.191）	0.149 （0.158）
农业生产方式	0.014 （0.031）	0.013 （0.030）	0.014 （0.031）
惠农服务	0.001 （0.017）	0.000 （0.017）	0.001 （0.017）
丘陵（相对于平原）	-0.269*** （0.055）	-0.267*** （0.059）	-0.269*** （0.055）
山地（相对于平原）	-0.461*** （0.058）	-0.461*** （0.060）	-0.461*** （0.058）
中部地区（相对于东部）	-0.278*** （0.052）	-0.275*** （0.050）	-0.278*** （0.052）
西部地区（相对于东部）	-0.336*** （0.053）	-0.333*** （0.055）	-0.336*** （0.053）
常数项	7.782*** （0.210）	7.781*** （0.235）	7.625*** （0.210）
观测值	2 259	2 259	2 259
R^2	0.108	0.107	0.102
识别不足检验		570.026***	
弱工具变量检验		4 301.404***	
DWH检验（P值）		0.140	

（二）稳健性检验

1. 替换研究方法：倾向得分匹配（PSM）法

为了解决可能存在的自选择问题，本部分采用PSM法对样本进行稳健性检验。本文依次将“2003年至今农地未进行调整”“2003年至今农地进行大调整”的样本设置为处理组，将“2003年至今农地进行小调整”的样本设置为对照组，分别采用最近邻匹配、半径匹配和核匹配三种方式进行检验，结果表明，在三种匹配方式下，与农地小调整经历相比，农户的农地无调整经历和大调整经历依然对农业生产绩效具有抑制作用。这说明，本文的实证结果具有较好的稳健性。

2. 替换研究样本：CLDS2016年数据

为了进一步检验结果的稳健性，本部分采用CLDS2016年数据样本重新进行估计。CLDS2016年数据中有效农户样本为2 476个，其中，已确权农户样本为1 361个。回归结果表明，无论是全部样本农户还是已确权样本农户，农地调整程度及其平方项均在5%的统计水平上显著，再次说明农地调整程度与农业生产绩效之间的倒U型关系具有较好的稳健性。

（三）机制分析

上述实证结果已经表明，在农地已经确权的情境下，不同的农地调整经历引发了农户的农业生产绩效差异。理论分析表明，与农地小调整经历相比，农户的农地大调整和无调整经历主要通过增加劳

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动力非农转移水平而降低农业生产绩效。中介效应模型检验结果如表 3 所示。

表 3 中列（2）显示，与小调整经历相比，农地无调整和大调整经历均在 5% 的显著性水平上正向影响农户的劳动力非农转移。进一步地，将农地调整经历和劳动力非农转移两个变量同时纳入回归方程后，列（3）显示，劳动力非农转移在 10% 的显著性水平上负向影响农户的农业生产绩效。由此得出，与农地小调整经历相比，农户的农地无调整和大调整经历主要通过增加劳动力非农转移降低农业生产绩效。这进一步说明，农地小调整经历的农户之所以是最有效率的经营主体，主要是由于该群体的非农劳动力转移水平相对较低。这个结果为假设 2 和假设 3 提供了实证支持。

表 3 **农地调整经历—劳动力非农转移—农业生产绩效作用机制检验**

变 量	农业生产绩效	劳动力非农转移	农业生产绩效
	（1）	（2）	（3）
农地小调整经历（对照组）			
农地无调整经历	−0. 157 *** （0. 056）	0. 038 ** （0. 019）	−0. 153 *** （0. 056）
农地大调整经历	−0. 207 * （0. 107）	0. 085 ** （0. 037）	−0. 198 * （0. 107）
劳动力非农转移			−0. 105 * （0. 061）
控制变量	控制	控制	控制
常数项	7. 782 *** （0. 210）	0. 750 *** （0. 073）	7. 861 *** （0. 215）
观测值	2 259	2 259	2 259
R^2	0. 108	0. 144	0. 109

（四）异质性分析

理论与实证部分表明，农地小调整经历的农户是最有效率的经营主体，且该群体主要通过减少劳动力非农转移从而提高了农业生产绩效。但值得关注的是，这种影响可能具有情境依赖性：第一，代际分布。新生代劳动力凭借人力资本积累的优势，在城市中更容易获得就业机会和稳定的工资性收入，因而新生代劳动力具有更高的非农偏好。第二，家庭禀赋。农业经营规模过小意味着农业很难满足生计需求，因而更可能向非农转移。第三，经济区位。城郊地区凭借经济优势更有可能为劳动力提供较多的非农就业机会。因此，本部分将从农户家庭的代际分布、家庭禀赋和经济区位三个角度进行异质性分析。需要说明的是，鉴于本部分主要是考察经历过小调整对确权农户的农业生产绩效的异质性影响，故均将农户的小调整经历赋值为 1，其余调整情形赋值为 0。

1. 代际分布情境下农户的农地小调整经历对农业生产绩效的影响

本文参照刘炎周等[92]的研究，将 1975 年以前出生的家庭户主视为老一代家庭，1975 年及以后出生的家庭户主视为新生代家庭。将其划分为新生代家庭和老一代家庭两组，分别检验不同代际分布情境下农户的农地小调整经历对农业生产绩效的影响，检验结果如表 4 所示。由表 4 可知，对于新生代家庭，农地小调整经历对农业生产绩效的影响并不显著，但影响系数为负；对于老一代家庭，农地小调整经历在 1% 的显著水平上正向影响农业生产绩效。究其原因，新生代家庭与老一代家庭相比：一方面，由于“少不更事”对农地调整带来的地权不稳定缺乏深刻的感知，因而其行为影响相对有限；另一方面，新生代劳动力的受教育水平普遍偏高，就业空间的广泛性和较少的务农经历强化了非农就业的偏好，从而衍生对农地的“低价值”心理。

2. 家庭禀赋情境下农户的农地小调整经历对农业生产绩效的影响

本文以样本农户的家庭耕地面积（均值为 10. 41 亩）作为划分依据，将经营规模划分为经营规模小和经营规模大两组，分别检验不同经营规模下农户的农地小调整经历对农业生产绩效的影响（估计时剔除了原有控制变量中的“耕地规模”）检验结果如表 4 所示。由表 4 可知，在不同规模的样本组中，农地小调整经历均在 1% 的水平上显著为正，但经营规模较大的样本组边际效应更大。可见，农地小调整经历更有利于提高大规模农户的农业生产绩效。从生计角度来看，耕地经营规模较大的农户一般采取“以农为生”的生计策略，因而这类群体对于农地的生存和情感依附通常较高，其非农转移水平也相对较低。

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3. 经济区位情境下农户的农地小调整经历对农业生产绩效的影响

本文将“农户所在村庄是否属于城郊”作为区位特征的代理变量，并将其划分为城郊区位和非城郊区位两组，分别检验不同区位情境下农户的农地小调整经历对农业生产绩效的影响，检验结果如表4所示。由表4可知，当农户家庭所在村庄属于城郊区位时，农地小调整经历在5%的显著性水平上抑制了农业生产绩效的提高；当所在村庄属于非城郊区位时，农地小调整经历在1%的显著性水平上正向影响农业生产绩效。之所以如此，是因为城郊区位在经济发展水平、资源和信息获取以及非农务工机会等方面与非城郊区位的差距在不断扩大，区位经济优势更有可能削弱约束机制的反向激励效果，促使经历农地小调整的农户向比较收益更大的非农领域转移。

表4 异质性分析结果

变 量	代际分布情境		家庭禀赋情境		经济区位情境	
	新生代家庭	老一代家庭	经营规模小	经营规模大	城郊区位	非城郊区位
农地小调整经历	-0.033（0.140）	0.192***（0.061）	0.173***（0.066）	0.304***（0.107）	-0.816**（0.386）	0.173***（0.056）
控制变量	控制	控制	控制	控制	控制	控制
常数项	7.604***（0.467）	7.327***（0.212）	7.333***（0.235）	5.277***（0.499）	6.733***（1.041）	7.690***（0.215）
观测值	318	1 941	1 735	524	115	2 144
R^2	0.167	0.103	0.055	0.192	0.262	0.120

五、结论与启示

已有研究大多聚焦于从地权不稳定到农地确权政策转变引发的行为效果，较少关注在农地确权工作完成之后，农户的农业生产绩效是否存在差异以及这些差异生成的根源。笔者认为，农户所经历的农地调整及其地权不稳定经历或许是重要诱因。为此，本文以农地确权登记颁证工作的收官之年作为研究起点，构建“农地调整经历—劳动力非农转移—农业生产绩效”的分析框架，并利用中国劳动力动态调查（CLDS）2018年数据，采用线性回归模型、倾向得分匹配模型和中介效应模型，实证检验了农地确权背景下农户不同情形的农地调整经历对农业生产绩效的影响。得出以下主要结论：首先，在农地确权以后，农户所经历的农地调整程度与农业生产绩效呈倒U型关系，即与农地无调整经历和大调整经历相比，经历农地小调整的农户是农业生产绩效最高的经营主体。其次，对比农地无调整和大调整，经历农地小调整的农户主要通过减少劳动力非农转移提高农业生产绩效。但这种影响具有情境依赖性，如果农户的家庭禀赋过小，会显著弱化农地小调整经历对农业生产绩效的影响；对于新生代和城郊区位的确权农户，农地小调整经历对农业生产绩效将不再具有显著的促进作用。

基于上述分析本文得到如下启示：首先，个体的经历和记忆会影响制度实施的效果。以往文献认为，农业生产绩效大多与农地确权制度安排有关，本文则从农地调整的角度讨论农户的农地调整经历如何引发农业生产绩效的差异，从而为农地确权后农业生产绩效出现差异提供一个可能的逻辑性解释。农地调整所隐含的“约束机制”会影响农户对于农地确权的“先验态度”，并引发农户不同强度的行为响应，从而使农业生产绩效出现差异。换言之，制度是重要的，行为主体的过往经历及记忆同样重要。其次，农村土地在赋权强能的同时，不能忽略“约束机制”的有效匹配。从土地第二轮延包时强调的“土地承包关系三十年不变”到土地确权，以及“三权”分置改革，都在试图形成更稳定的地权关系，在这种情况下，缺乏约束机制的匹配措施将很难激发起农户对农地的“高价值”定位心理，从而导致农业生产绩效的损失。正如本文研究表明，对比农地无调整和大调整，经历农地小调整的农户才是农业生产绩效最高的经营主体。但本文并非主张农地调整的合理性，而是强调在农地赋权强能的过程中辅之以产权“约束机制”的必要性。

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The persistence of China's great famine on individuals' choice to pursue self-employment

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The persistence of China's great famine on individuals' choice to pursue self-employment

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ABSTRACT

Self-employment is a field of special importance to developing countries in view of its positive role on socio-economic development. This study exploits a unique nationally representative database using the 1949–1985 China Demographic Data, the 2016 China Labour Force Dynamic Survey, and the 1959–1999 China Drought Disaster Data. Through a difference-in-differences estimation, we reveal that the Great Chinese Famine bear significantly upon individuals' self-employment decisions. Specifically, a 1% increase in famine intensity results in a 3.89% and 2.31% decrease in the probability of self-employment and self-employed entrepreneurs entering the agricultural sector, respectively. Using rainfall as an instrument, we further show that the documented relationship is causal. Overall, we provide strong empirical evidence that famine exposure significantly affects one's self-employment decisions, and can help design policies aiming to promote self-employment and the development of small businesses.

KEYWORDS

Self-employment; famine; difference-in-differences; instrumental variable

JEL CLASSIFICATION

C13; C87; J43; N55; N95

1. Introduction

Self-employment, as one kind of entrepreneurship (Blanchflower and Oswald 1998), unquestionably the oldest way by which individuals offer their labour in a market economy (Aronson 2019). This is a significant field for developing countries, given its positive role in socio-economic development (Caceres and Caceres 2017), a premise that dates from the work of Schumpeter (1934). Following a long-term decline, the issue of self-employment has received considerable attention in recent years because of its critical role in the reduction of unemployment (Thurik et al. 2008). It has been argued that self-employment has a positive association with economic growth in the developing world (Van Stel 2006; Sánchez 2018), given its tangible positive economic effects not only on wage but also on per capita income growth and poverty reduction (Goetz, Fleming, and Rupasingha 2012). China is an indispensable case study of self-employment. As the largest developing country, China still has many poverty-stricken regions, with an estimated 62.04 million marginalized population in 2016 alone.[1] Its

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steady growth, business opportunities, and venture phenomenon boost may benefit the governance for poverty alleviation.

People's motivation to become self-employed varies. One, 'pull' theory indicates that individuals choose to become self-employed for times of economic prosperity, given the fair business opportunities provided by a free market and economic dynamism (Smith 1979). The other, 'push' theory maintains that due to the deterioration of the economy, unemployment forces individuals into self-employment to make a living (Danson, Galloway, and Sherif 2020). Both theories have emphasized the external conditions, and other associated literature has focused on psychological traits, such as the bearing of uncertainty (Leibenstein 1968), innovation (Schumpeter 1934), leadership, and motivation. Among them, the character of risk-taking has received the most attention (Fairlie and Holleran 2012).

Previous literature argues that early-life experience profoundly shapes individuals' risk preferences (Cameron and Shah 2015; Brown et al. 2018), which in turn influence their decisions (Korosi et al. 2012). The Great Famine of 1959–1961 is considered one of the top ten major events since the founding of new China in 1949 (Weigelinsch-wiedrzik 2003). People in China do maintain a strong memory of this famine tragedy (Cao 2005). On this basis, the current study aims to determine whether the Great Famine will make a difference to survivors' self-employment decisions.

Our research contributes to the existing literature in several ways. First, considerable research has documented that the Great Chinese Famine negatively affected its survivors' later economic decisions (Zhang 2017; Feng and Johansson 2018), such as bearing fewer debts and holding more cash and higher household saving rates. However, its effect on self-employment remains underexplored. Thus, we bring insight into the traumatic early-life experience and its consequence on later self-employment decisions, which is a theme that has not been analyzed in-depth in China. We also prove that famine significantly alleviates its survivors' self-employment rate and discourages self-employed entrepreneurs from entering the agricultural sector. Our study adds to the literature that examines how major historical events can persist in the development process (Ager et al. 2020; Ambrus, Field, and Gonzalez 2020).

Second, our careful measurement of the famine and the formulated nationally representative dataset provide a precise causality identification. The empirical strategy of this paper is a difference-in-differences framework in that it compares self-employed behaviour for cohorts born before and after the famine, between regions with different degrees of excess death rate during the famine period. To account for the persistent effect of the great famine on self-employment, we adopt the interaction of excess death rate and birth cohorts. We also draw upon three nationally representative datasets: the 1949–1985 China Demographic Data, the 2016 China Labour Force Dynamic Survey, and the 1959–1999 China Drought Disaster Data. This proposed method alleviates sampling error in the first place.

Finally, the variation in self-employment across China is subject to many endogenous forces, with the omitted variable bias being our primary concern, such as 'culture'. Given the influence of Confucianism for thousands of years, the disdain for

commerce was founded on occupational discrimination among Chinese people until recent decades. Therefore, we utilize rainfall as an instrument. Droughts are widely considered hydroclimatic hazards and have a strong connection with the occurrence of famine (Chantarat et al. 2007; Speranza, Kiteme, and Wiesmann 2008). However, in the context of China's famine, we are facing the challenge by using rainfall as the instrument—whether three successive years of bad weather is correlated with the outbreak of famine. Following Sen's entitlement approach (Sen 1981), researchers argued that the great famine is a manmade catastrophe to a large extent, which was attributed to an urban-biased system (Lin and Yang 2000; Kung and Lin 2003). While the food availability decline thesis postulates that death rates would be higher in response to a grain output decline and provides another perspective from which to understand the cause of China's famine. We collected information from China agriculture yearbook in 2018, and find that China's grain production experienced a sharp fall from 197.65 million tons to 136.5 million tons between 1958 and 1961 after years of steady growth. A careful study of a panel data concludes that weather conditions contribute to 12.9% of the collapse in grain production (Li and Yang 2005). Contrary to Lin's argument (Lin 1990), Yao (1999) also argued that bad weather was an important factor responsible for the sharp grain output decline in the famine.[2] Therefore, bad weather did play a role in China's famine (Chinn 1980; Lavely, Lee, and Feng 1990). Sum up, the poor policies and bad weather definitely both contributed to the severity of the catastrophe; however, bad weather was only secondary reason for this crisis (Lin 1990). That is, our instrument satisfies a suitable relevance condition, but there appears to be reason for concern about weak instruments in this case. To address this, we also conduct several empirical checks to verify the validity of our instrument empirically in Section 5. Moreover, our instrumental variable satisfies the exclusion restrictions requirements. On the one hand, the regional disparity of rainfall is exogenous as it is a natural phenomenon, and individuals are unlikely to predict or control the rain capacity. On the other, rainfall between 1959–1961 is unlikely to affect later outcomes; since it is not practically possible for the survivors to recall the rain capacity during the famine period but via the channel of famine.

The remainder of this study proceeds as follows. We propose our theoretical hypothesis and introduce our data and empirical strategy in Sections 2 and 3. Then, we examine the persistent effect of the famine on individuals' self-employment decision-making in Section 4. Next, we identify the Great Famine's causal effect by conducting an instrumental variable (IV) approach and a pre-trend test in Section 5. Section 6 concludes.

2. Historical background and hypotheses

2.1. China's great famine: 60 years later

Between the spring of 1959 and the end of 1961, China was in the middle of the world's largest famine wherein millions of Chinese people starved to death (Kung and Chen 2011), and about the same number of births were lost or postponed. The tragedy's true extent remained a mystery to the world until the publication of the first highly reliable population census in 1982 (Smil 1999). On the basis of these data, the

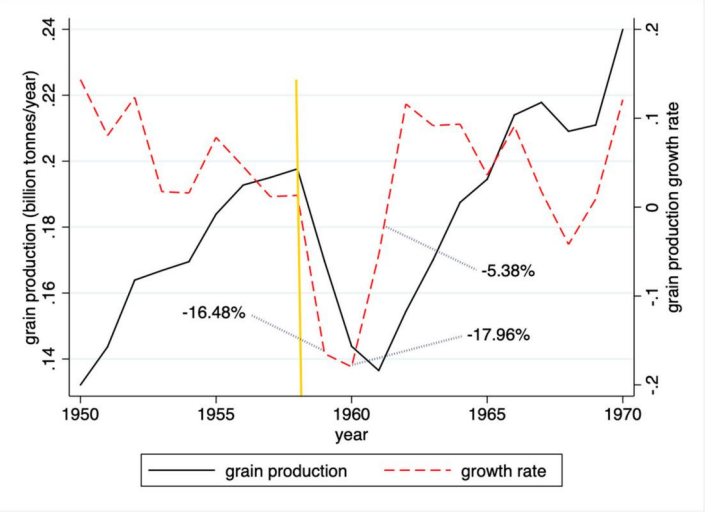


Figure 1. Total grain production and growth rate in China, 1950–1970 (*Source: China agriculture yearbook in 2018*).

earliest calculations by Aird (1982) put the toll at between 16.5 and 23 million. Subsequently, Ashton et al. (1984) suggested that the famine led to 23–30 million excess deaths. Another non-negligible aspect of this famine is the steep fall in the grain harvest, as shown in Figure 1. China's grain production experienced a sharp fall from 197.65 million tons to 136.5 million tons between 1958 and 1961 after years of steady growth. Its growth rates in 1959 and 1960 even went critical to −16.48% and −17.96%, respectively. Without a doubt, the Great Famine was the worst of modern times in terms of human suffering and excess deaths. The unpredictable way the tragic famine occurred and its disparity in excess mortality across China provides a unique opportunity to quantify the persistence of early-life trauma on economic decisions. One, it is logical to assume that the Great Famine was an exogenous shock, since the majority did not anticipate such an outbreak of tragedy; the other, the famine's severity ultimately varied across regions. Given that, we employ a DID method to proxy the famine's persistence by adopting the interaction terms between birth cohorts and excess death rate.

2.2. Famine exposure and self-employment

People are affected the most by the negative events occurred in their early lives, and the following endogenous preferences stay with them even into adulthood (Malmendier and Nagel 2011). This logic is consistent with developmental psychology. It identifies childhood and adolescence as key phases for an individual to recognize and understand the world, preserve permanent memories, and develop character (Shaffer and Kipp 2010). Previous research also suggested that life experiences can shape individuals' behaviour (Callen et al. 2014). However, the literature has obtained mixed results regarding whether major negative shocks alleviate or increase risk preference (Voors et al. 2012; Cameron and Shah 2015; Hanaoka, Shigeoka, and

Watanabe 2018). Given this, we aim to contribute by providing additional evidence by developing a nationally representative dataset and carefully measuring the indicators. In addition, the correlation between China's Great Famine and one's economic decision is clear and sound (Zhang 2017; Feng and Johansson 2018). While the analysis of how famine exposure persists on people's behaviours remains insufficient and the investigation into self-employment decision is relatively scarce.

Famine is always associated with the scarcity of food. According to Mullainathan and Shafir (2013), scarcity captures the mind and changes one's way of thinking and behaving. 'Minnesota Starvation Experiment' showed that starving men spontaneously focus on food and are not interested in other things, such as entertainment and career. The subconscious reflex may also bring about irrational risk aversion when individuals face expected profit opportunities (Scott 1977). The famine exposure may have a long-lasting effect on one's decision to start a business and become self-employed by the process of not risking 'a decent meal'. Accordingly, we hypothesize that the scarcity of 'subsistence means everything' captures famine survivors' minds (childhood and adolescence exposure to famine), making them less risk-tolerant and reluctant to become self-employed.

2.3. Famine exposure and self-employed field

Freud (1915) argued that individuals' decisions are always subject to prior knowledge and life experiences. Prior knowledge is not only one's cognition upon fact but rather the fact itself (Wang and Jiang 2002). People may easily create projection bias by overextending the meaning of limited facts, especially the painful experiences (Redelmeier and Kahneman 1996), and overestimate the probability and effect of the particular traumatic event (Weinstein 1980). Given the massive economic losses and deaths caused by food shortages, individuals exposed to famine may create certain stereotypes on agriculture. Such a group of entrepreneurs may self-select out of agriculture in the first place.

In addition, agriculture involves the interrelation of natural and economic reproduction and has limitations caused by climate change, land characteristics, and potential threats, such as epidemics and pests. In the process of transaction, it also faces market risks. As a weak industry, agriculture is affected by nature and the market, whereas the non-agricultural sector deals with market risk for the most part. Entrepreneurs who experienced famine with higher risk aversion may prefer to set up their business in non-agricultural fields.

3. Data and empirical strategy

3.1. Data collection

Our nationally representative dataset for empirical analyses contains comprehensive information collected from publicly available databases and statistical publications. The dataset is assembled from three separate sources as follows.

China Demographic Data. The 1949–1985 China Demographic Data is the first formal collection of demographic statistics released to the public since the founding of

the People's Republic of China in 1949, which is mainly based on three major national population censuses, namely, the 1953 population census, the 1964 population census and the 1982 population census. Although Lavely, Lee, and Feng (1990) described China as the largest and the least known of any human population before 1970s, since domestic politics in the People's Republic of China precluded any serious study of population within China. Later under Deng Xiaoping's rule, China swung away from an attitude of hostility to 'Malthusian' theories and embraced economic pragmatism and empiricism in 1978. At the same time, China's government has modernized its demographic data collection apparatus, established new institutions for training and research, and made public a broad range of demographic information (Lavely, Lee, and Feng 1990). In this sense, the demographic data should be reliable theoretically. We use its longitudinal data to calculate the normal and famine population index as a proxy for the severity of the famine.

China Labour Force Dynamic Survey. China Labour Force Dynamic Survey, launched by Sun Yat-Sen University, national representative, is a longitudinal survey of the labor force, and is a forerunner to conduct a rotation panel survey in China. Using a rotating panel design, the survey is conducted every two years and has released three waves of data to public until now (2012, 2014 and 2016). The survey focuses on the existing labor force situation and its changes, gathering a wealth of information covering various topics such as education outcomes, working experiences, migration, health, social participation, and grassroots organizations. To make sure that the sample of the survey can be regarded as a nationally representative sample, it is drawn from 29 provinces/cities/autonomous regions in China excluding Hong Kong, Macao, Taiwan, Tibet, and Hainan. The sampling is based on a probability-proportional-to-size approach, and population size, administrative units, and socio-economic status are used as the main stratification indicators. We utilize the individual-, family-, and community-level longitudinal data of the 2016 China Labour Force Dynamic Survey to construct the key explained variables, birth cohorts, and a set of covariates.

China Drought Disaster Data. The 1959 to 1999 China Drought Disaster Data is a official collection of demographic statistics released by the National Meteorological Science Data Center of China, which covers the regional disparities of drought and rainfall across China. We take the index of precipitation anomaly percentage ($PAP = \frac{(V-V_0)}{V_0} * 100\%$, where V represents the precipitation in the current period, and V_0 represents the local regular precipitation) from 1959 to 1961 as a proxy for rainfall during the famine period and use it as an IV.

3.2. Proxying the famine

To construct an appropriate variable to quantify the individuals' traumatic famine exposure, we first measure the excess death rate using the 1949–1985 China Demographic Data. Then we obtain the birth cohorts by setting year dummies. Finally, we use the interaction of excess death rate and birth cohorts as the proxy for the famine.

Table 1. Birth cohorts.

Age (at time of survey)	Year of birth	Age (during famine period)	Life stage (during famine period)	Birth cohorts
<58	(1958 and after)	<3	Unborn and infancy	cohort1
[58, 62)	(1954–1958]	[3, 7)	Early childhood	cohort2
[62, 75)	(1941–1954]	[7, 18)	Childhood and adolescence	cohort3
≥75	before 1941	≥18	Adulthood	cohort4

We measure the excess death rate during 1959–1961 by referring to Huang and Martorell (2009). First, we obtain the normal population index (N_{normal}) by calculating the average population of the three years before (1956–1958) and after (1962–1964) the famine. Then, we acquired the famine population index (N_{famine}) by calculating the average population during the famine period (1959–1961). Finally, we propose the following measure of GCF to capture the excess death rate during the famine at the provincial level:

$$GCF = \frac{(N_{normal} - N_{famine})}{N_{normal}} \tag{1}$$

A crucial step in understanding the nature of effects of early-life events entails the study of events during childhood and adolescence; the impact of early events may be more pervasive than events occurring during adulthood (Compas 1987). In developmental psychology, Shaffer and Kipp (2010) argued that childhood and adolescence experiences are critical for humans' psychological development and preference formation. Scholars from behavioural economics also suggested that early life experiences have some major effects on individuals' risk-taking preferences and behaviours (Malmendier and Nagel 2011; Bernile, Bhagwat, and Rau 2017). Life stages are commonly divided into infancy (before 3 years old), early childhood (3–6 years old), childhood (7–11 years old), adolescence (12–18 years old), and adulthood (after 18 years old). Among these different life stages, we focus on childhood and adolescence and put them into one cohort (Table 1).

3.3. Empirical strategy

To examine whether the famine exposure has a long-lasting effect on self-employment decisions, we construct the following DID model:

$$SE_{icp} = \alpha_0 + \sum_{c=2}^{4} \beta cohort_{ic} + \delta gcf_p + \sum_{c=2}^{4} \gamma cohort_{ic} * gcf_p + \alpha controls_{icp} + e_{icp} \tag{2}$$

$$BF_{icp} = \theta_0 + \sum_{c=2}^{4} \beta_1 cohort_{ic} + \delta_1 gcf_p + \sum_{c=2}^{4} \gamma_1 cohort_{ic} * gcf_p + \theta controls_{icp} + \varepsilon_{icp} \tag{3}$$

We use Equation (2) to estimate the effect of the famine on self-employment. SE_{icp} represents the self-employment choice of individual i who lives in province p and belongs to birth cohort c. $cohort_{ic}$ is a dummy variable, representing individual i

Table 2. Summary statistics.

Variables	Definition	Obs.	Mean	Std. Dev
Self-employment	Self-employed = 1; Otherwise = 0	11408	0.152	0.359
Self-employed field	Agricultural = 1; Non-agricultural = 0	1363	0.093	0.291
Age	/	14923	45.906	13.530
Age squared	/	14923	2290.424	1221.061
Gender	Male = 1; Female = 0	14971	0.482	0.500
Marital status	Married = 1; Unmarried = 0	14951	0.853	0.354
Education level	Illiterate = 1 to Ph.D. = 8	14943	2.957	1.311
Religious belief	Have religious belief/s = 1; None = 0	14958	0.105	0.306
Ln (income)	Yuan	11654	9.756	1.241
Health status	Poor = 1 to Fit = 5	14950	3.592	0.999
Self-employment experience	Yes= 1; No = 0	13640	0.074	0.262
Ln (family income)	Yuan	20155	10.217	1.951
Ln (property value)	Yuan	20402	4.736	5.942
Road coverage	Coverage of roads for vehicles to travel on (%)	14836	71.190	25.237
Local government	Near the seat of local government = 1; or = 0	14836	0.208	0.406

belonging to birth cohort c. The coefficient β denotes the fixed effect of the birth cohort. gcf_p represents the excess death rate of province p during the famine period, measuring the excess death rate in province p. The coefficient γ represents the long-term effect of the famine on self-employment. $controls_{icp}$ and e_{icp} are the control matrix and error terms, respectively. Then, we employ Equation (3) to estimate the effect of the famine on the self-employed field. BF_{icp} represents the self-employed field of individual i who is in province p and belongs to birth cohort c. The remaining settings are consistent with Equation (2).

Our key explained variables of interest are self-employment and the self-employed field. We define self-employment as individuals who perform some work for profit or family gain, in cash or in kind. Included in this category are employers, own account workers and persons in production of goods and services. In practice, we use the question 'What is your current type of occupation?' to measure self-employment with two corresponding options: 'If the respondent is self-employed' (coded as 1) and 'otherwise' (coded as 0). We also analyze the long-term effect of the famine on individuals' self-employment decision-making. We use the question 'What business field do you involve in on your current self-employed decision?' to measure the self-employed field with two corresponding options: 'agricultural sector' (coded as 1) and 'non-agricultural sector' (coded as 0).

In addition, the estimation model is also incorporated with a number of covariates. We classify the covariates into three categories: individual characteristics—age, age squared, gender, marital status, education level, religious belief, income, health status and self-employment experience; household characteristics—family income and family property value; community characteristics—road coverage and location of residence. Table 2 shows the definition and summary statistics of the variables.

To determine whether the samples have lived through the famine period or not, we use 1961 as the boundary. Table 3 shows the mean difference between the two groups in self-employment and the self-employed field. The sample group born before the famine presents a lower probability of being self-employed and starting a business in the agricultural field than the sample group born after the famine. This finding suggests that there may be a potential correlation between the famine and

Table 3. T-test estimator.

		Self-employment		Self-employed field	
		Mean	P-value	Mean	P-value
Born before the Great Chinese Famine	Yes	0.081	0.000***	0.073	0.089*
	No	0.174	—	0.099	—

Note: $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

later individual self-employment decisions. And when it comes to the causality, we need more empirical evidence to prove it.

4. Empirical results

4.1. Famine persistence on self-employment

We find that exposure to famine in childhood and adolescence attenuates individuals' choice to pursue self-employment. At the ages of approaching adulthood, people are mentally dependent on the outside world (Shaffer and Kipp 2010). They require considerable nutrition physiologically, and negative shocks at this period may be even far-reaching (Compas 1987) and leads to irrational risk aversion. As a result, they will unlikely choose self-employment with great potential risks, consistent with previous studies (Chen and Chen 2016). In practice, we include a series of personal characteristics in the first place. Among the interaction terms, only the coefficient of interaction between gcf and cohort3 is negatively significant at the 1% level, as shown in Column (1). To allay the concern that the missing features of the local labour markets may lead to estimation bias when looking at self-employment. We exploit the detailed breakdown of regional information by including regional fixed effects, and held the estimates in Column (2), Column (3), Column (4), and Column (5) at a province level, city level, county level, and community level, respectively. The resulted estimates of gcf*cohort3 are consistent with Column (1).

As shown in Column (5), the interaction between gcf and cohort3 is significant at the 1% level, suggesting a strong correlation between childhood and adolescence famine exposure and low self-employment selections. The marginal effect result shows an association between famine intensity and entry rate to self-employment in the childhood-adolescence stage. Specifically, a 1% increase in famine intensity results in a 3.89% decrease in the self-employment entry rate. Such individuals are less risk-tolerant and prefer low-risk ways of making a living other than starting a business and becoming self-employed.

4.2. Famine persistence in the self-employed field

In this section, we further examine the long-term effect of the famine on self-employment decisions. We adopt the self-employed field as a new explained variable, and Table 5 shows the results. Among all control variables included, only the coefficient of interaction between gcf and cohort3 is negatively significant at the 1% level, as shown in Column (5). Specifically, a 1% increase in famine intensity can lead to a 2.31% decrease in the possibility of starting a business in the agricultural field. On the one hand, compared to non-agricultural field, the agriculture industry faces dual

Table 4. Persistence of the famine on self-employment.

	Self-employment				
	(1)	(2)	(3)	(4)	(5)
cohort2	−0.186	−0.168	−0.109	−0.081	−0.072
	(0.133)	(0.140)	(0.147)	(0.151)	(0.149)
cohort3	−0.072	−0.049	−0.015	−0.001	0.009
	(0.147)	(0.153)	(0.159)	(0.164)	(0.167)
cohort4	0.452	0.442	0.629	0.623	0.775
	(0.470)	(0.494)	(0.487)	(0.481)	(0.499)
gcf	−6.874***	−18.873***	−3.344	−15.511	−23.643*
	(1.333)	(5.272)	(5.997)	(10.489)	(12.384)
gcf*cohort2	−3.073	−5.015	−7.130	−8.064	−9.812
	(6.178)	(7.014)	(7.410)	(7.527)	(7.338)
gcf*cohort3	−10.984*	−11.848*	−15.117**	−17.689**	−19.386***
	(5.957)	(6.890)	(6.882)	(7.092)	(7.301)
gcf*cohort4	11.013	13.589	7.310	7.050	1.752
	(18.283)	(20.039)	(19.102)	(18.582)	(19.779)
Age	0.075***	0.076***	0.081***	0.083***	0.082***
	(0.015)	(0.015)	(0.015)	(0.016)	(0.016)
Age squared	−0.001***	−0.001***	−0.001***	−0.001***	−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Gender	0.329***	0.324***	0.353***	0.360***	0.369***
	(0.033)	(0.033)	(0.035)	(0.036)	(0.036)
Marital status	0.053	0.064	0.055	0.029	0.009
	(0.059)	(0.059)	(0.061)	(0.063)	(0.063)
Education level	−0.091***	−0.087***	−0.122***	−0.116***	−0.140***
	(0.015)	(0.015)	(0.016)	(0.018)	(0.018)
Religious belief	0.253***	0.149***	0.133**	0.143**	0.128**
	(0.049)	(0.052)	(0.058)	(0.060)	(0.062)
Ln (income)	0.031***	0.027***	0.023**	0.023**	0.024**
	(0.010)	(0.009)	(0.010)	(0.010)	(0.010)
Health status	0.066***	0.061***	0.044**	0.030	0.035
	(0.018)	(0.019)	(0.020)	(0.020)	(0.021)
Self-employment experience experience	−0.889***	−0.905***	−0.937***	−0.983***	−1.004***
	(0.085)	(0.086)	(0.087)	(0.089)	(0.090)
Ln (family income)	0.091***	0.070***	0.048***	0.051***	0.046***
	(0.020)	(0.018)	(0.018)	(0.018)	(0.018)
Ln (property value)	0.001	0.001	0.001	−0.001	−0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Road coverage	0.007***	0.006***	0.003***	0.005***	0.024**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.010)
Local government	0.172***	0.227***	0.319***	0.292***	1.402**
	(0.038)	(0.039)	(0.052)	(0.068)	(0.644)
Constant	−4.237***	−3.870***	−3.557***	−3.258***	−3.963***
	(0.326)	(0.389)	(0.419)	(0.545)	(0.716)
Province fixed effects		Yes			
City fixed effects			Yes		
County fixed effects				Yes	
Community fixed effects					Yes
Obs.	10,945	10,945	10,262	9,840	9,541
Pseudo R^2	0.092	0.105	0.145	0.165	0.192
			Marginal effect		
gcf*cohort3	−2.264*	−2.409*	−3.043**	−3.570**	−3.884***
	(1.228)	(1.400)	(1.384)	(1.429)	(1.460)

Note: Robust standard errors in parentheses; $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

risks of market and nature, entrepreneurs who experienced the famine have a higher chance to develop risk aversion. On the other hand, painful memories resulting from the famine may lead to a certain degree of projection bias toward agriculture. As a result, the self-employed ones who experienced famine in their childhood and adolescence are more likely to start up business in the non-agricultural sector.

Table 5. Persistence of the famine on self-employed field.

	Self-employed field				
	(1)	(2)	(3)	(4)	(5)
cohort2	0.117	0.309	0.610	0.901*	1.638
	(0.416)	(0.448)	(0.488)	(0.523)	(1.030)
cohort3	1.260***	1.639***	2.477***	2.840***	3.153***
	(0.425)	(0.468)	(0.572)	(0.613)	(0.710)
cohort4	−0.195	−0.197	−0.340	−0.344	−0.331
	(5.194)	(5.154)	(10.578)	(11.570)	(8.750)
gcf	1.547***	0.872	2.179	1.182	2.438
	(0.436)	(1.233)	(1.585)	(2.063)	(4.585)
gcf*cohort2	−3.486	−4.424	−3.219	−4.076	−14.651
	(2.671)	(3.009)	(3.142)	(3.569)	(14.910)
gcf*cohort3	−6.438**	−7.891***	−10.111***	−10.699***	−10.075**
	(2.539)	(2.729)	(3.273)	(3.324)	(4.222)
gcf*cohort4	41.942	43.291	69.069	71.267	70.508
	(98.515)	(97.791)	(196.796)	(216.617)	(164.554)
Age	−0.026	0.023	0.074	0.113*	0.174**
	(0.045)	(0.050)	(0.061)	(0.066)	(0.077)
Age squared	0.000	−0.000	−0.001	−0.001	−0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender	0.573***	0.561***	0.698***	0.708***	0.725***
	(0.116)	(0.128)	(0.166)	(0.178)	(0.197)
Marital status	−0.066	−0.220	−0.526**	−0.723***	−0.795***
	(0.177)	(0.191)	(0.239)	(0.267)	(0.303)
Education level	−0.218***	−0.188***	−0.165**	−0.133	−0.059
	(0.056)	(0.060)	(0.077)	(0.082)	(0.094)
Religious belief	−0.325**	−0.213	−0.184	−0.104	−0.535*
	(0.154)	(0.172)	(0.211)	(0.225)	(0.274)
Ln (income)	−0.020	−0.010	−0.043	−0.036	−0.030
	(0.025)	(0.028)	(0.032)	(0.035)	(0.041)
Health status	−0.098*	−0.046	0.025	0.008	−0.010
	(0.054)	(0.059)	(0.072)	(0.076)	(0.086)
Self-employment experience experience	0.060	0.165	−0.027	−0.084	−0.167
	(0.158)	(0.174)	(0.212)	(0.229)	(0.264)
Ln (family income)	−0.045	−0.026	−0.004	0.002	−0.011
	(0.032)	(0.036)	(0.044)	(0.046)	(0.055)
Ln (property value)	−0.006	−0.001	−0.002	0.004	0.004
	(0.008)	(0.009)	(0.012)	(0.013)	(0.016)
Road coverage	−0.001	−0.007**	−0.010**	−0.011**	−0.043
	(0.002)	(0.003)	(0.004)	(0.005)	(0.116)
Local government	0.188	0.024	−0.187	−0.127	−0.387
	(0.118)	(0.131)	(0.197)	(0.264)	(2.022)
Constant	0.550	−0.689	−1.395	−1.826	−1.557
	(0.945)	(1.168)	(1.407)	(1.581)	(6.605)
Province fixed effects		Yes			
City fixed effects			Yes		
County fixed effects				Yes	
Community fixed effects					Yes
Obs.	1,126	1,119	816	672	541
Pseudo R^2	0.128	0.231	0.248	0.235	0.244
			Marginal effect		
gcf*cohort3	−1.290**	−1.394***	−1.912***	−2.309***	−2.309**
	(0.506)	(0.477)	(0.608)	(0.700)	(0.952)

Note: Robust standard errors in parentheses; *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

4.3. Pre-trend test

The identification strategy in this study assumes that the changes of excess death caused by the great famine are not related to other potential factors that could also affect the self-employment decision. To alleviate this concern, we test the assumption

of DID estimation, also known as the pre-trend test. Following Chen and Zhou (2007), we utilize the subsample of individuals born after the famine to construct another group of birth cohorts. If our potential concerns do exist, the estimates will be consistent with Tables 4 and 5. Otherwise, we cannot observe any significance in the interactions of excess death rate and the new birth cohorts.

We exploit a subsample of individuals born after 1961 and divide them into four birth cohorts: birth cohort 5 (50–55 years old), birth cohort 6 (45–50 years old), birth cohort 7 (40–45 years old), and birth cohort 8 (35–40 years old). We take birth cohort 5 as the control group. None of these birth cohorts were ever directly exposed to the famine. Thus, we expect that the Great Famine would not produce any negative effects on them. Table 6 reports the results. The effects of post-famine (gcf∗cohort6, gcf∗cohort7, and gcf∗cohort8) are not significant in Column (1) and Column (2) and have the wrong sign. This approach suggests that our DID estimator satisfies the pre-trend assumption.

5. Sensitivity analysis

5.1. Famine vs. the reform and opening up policy on self-employment

Over the past 40 years, China has experienced spectacular economic growth since the initiation of the economic reform and opening up policy in 1978. The GDP of China has increased from $149.5 billion in 1979 to $12.24 trillion in 2017, achieving an annual growth rate of 9.5%,[3] thereby, millions of paid jobs were created. Therefore, famine-exposed individuals may look for other forms of employment such as paid employment since higher economic growth increases the number of paid jobs. In this case, the observed correlation between famine exposure and self-employment may reflect economic growth rather than the causal effect of relative famine exposure on self-employment.

Differences in policy shock by regions allow us to disentangle the effect of famine from that of the reform and opening up policy. As the pioneer of China's reform and opening up policy, the coastal China plays a significant role in promoting China's rapid economic growth, namely, 'Beijing-Tianjin-Hebei', 'Yangtze River Delta' and 'Pearl River Delta'. Therefore, we run regressions based on two subsamples in Table 7. One is 'eastern coastal China', which covers 10 provinces or municipalities: Beijing, Tianjin, Hebei, Shandong, Shang-hai, Jiangsu, Zhejiang, Fujian, Guangdong and Hainan; the other is 'other parts of China'.

We find that economic factors do partially explain individuals' lower preference for self-employment as the famine effect (gcf∗cohort3) in column (1) is larger than that in column (2). While the coefficient estimate is still significant in column (2), suggesting that the observed effect cannot be fully absorbed by economic factors. These findings reveal that the reform and opening up policy does not confound the effect of famine.

5.2. Using selection on the observables to assess selection bias

The baseline estimates may trigger another major concern: the documented negative correlation between famine exposure and self-employment could also be explained by omitted variables that are correlated with self-selection into self-employment. For example, if

Table 6. Pre-trend test.

	Self-employment (1)	Self-employed field (2)
cohort6	−0.165	−0.343
(45–50 years old)	(0.151)	(0.468)
cohort7	−0.090	−0.452
(40–45 years old)	(0.207)	(0.704)
cohort8	0.014	1.469
(35–40 years old)	(0.281)	(1.074)
gcf	−26.234	33.590
	(57.732)	(25.219)
gcf*cohort6	4.740	2.734
	(5.619)	(17.048)
gcf*cohort7	6.184	17.384
	(6.158)	(20.453)
gcf*cohort8	5.975	10.749
	(6.401)	(22.631)
Community fixed effects	Yes	Yes
Control var.	Fixed	Fixed
Obs.	4416	345
Pseudo R^2	0.176	0.247

Note: Robust standard errors in parentheses; $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

Table 7. Famine versus the reform and opening up policy.

	Self-employment	
	Eastern coastal China (1)	Other parts of China (2)
cohort2	−0.015	−0.451
	(0.175)	(0.290)
cohort3	−0.032	0.099
	(0.216)	(0.255)
cohort4	0.687	0.722
	(0.598)	(0.914)
gcf	−2.861	−132.274***
	(45.687)	(42.581)
gcf*cohort2	−13.208	5.251
	(8.161)	(13.908)
gcf*cohort3	−21.192**	−13.451**
	(9.217)	(5.251)
gcf*cohort4	0.702	8.139
	(26.292)	(32.398)
Community fixed effects	Yes	Yes
Control var.	Fixed	Fixed
Obs.	5,532	4,009
Pseudo R^2	0.171	0.235

Note: Robust standard errors in parentheses; $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

individuals that are inherently more risk aversion have a lower preference for self-employment. In this subselection, we assess the likelihood that the estimates are biased by unobservables.

Following Altonji, Elder, and Taber (2005) and Nunn and Wantchekon (2011), we present a closely related way to use the relationship between the observables and famine exposure as a guide to selection bias. We measure the amount of selection on the index of observables in the baseline specification and then calculate a ratio of how large selection on unobservables would need to be in order to attribute the entire effect of famine exposure to endogeneity bias. Specifically, we run two two

Table 8. Using selection on observables to assess the bias from unobservables.

Controls in the restricted set	Controls in the full set	Self-employment (1)	Self-employed field (2)
None	Full set of baseline controls	36.31	68.28
Individual characteristics	Full set of baseline controls	10.41	26.46

Note: The reported ratios in each cell of the table is calculated as $\beta^F/(\beta^R-\beta^F)$. β^R denotes the coefficient for the variable of interest under restricted-set specification, and β^F denotes the coefficient for the variable of interest under full-set specification. In both regressions, community fixed effects are included.

regressions: one with a restricted set of control variables, where β^R denotes the famine effect under restricted-set specification; and one with a full set of controls, where β^F denotes the famine effect under full-set specification. We then define the ratio as: $\beta^F/(\beta^R-\beta^F)$. A large ratio would imply that the estimates cannot be plausibly explained entirely away by the unobserved inherently traits of individuals.

The results are presented in Table 8. We consider two restricted-set specifications: one with no controls; one with only control for individual characteristics in baseline specification. The ratios range from 10.41 to 68.28, suggesting that selection on unobservables would need to be at least 10.41 times larger than selection on observables to attribute our baseline estimates to selection bias, which seems highly unlikely. These results make it less likely that the estimated effect of the famine exposure is largely driven by unobservables.

5.3. Using China's 1990 population census to reconstruct GCF

Despite the discussions on the reliability of the China's population census in Section 2, our identification may still be confounded with the validity of data. In particular, the sensitive statistics on population that could related to mortality in the famine period (1959–1961). As argued by Smil (1999), the official Chinese figures for the three famine years greatly underestimate both the fall in fertility and the rise in mortality. While he also added that the lack of accuracy is as expected since all death tolls cited for major famines have large margins of error, such as the 1991–1992 famine in Somalia. In this subsection, we assess the likelihood that the baseline estimates are biased by the validity of data in an empirical way.

The strategy that we use exploits the insight from Huang and Martorell (2009). We utilize 1% sample China's 1990 population census to derive an alternative measure of excess death rate using demographic information at provincial level. Similar with our calculation process in equation (1), to proxy the excess death rate, we collapse the data by province and birth year. For each province, we first calculate the mean cohort size of people born during the three years right before the famine (1956–1958) and the three years right after the famine (1962–1964), labeled as normal, as well as the mean cohort size of people born during the famine period (1959–1961), labeled as famine. Then we define the excess death rate as the difference between normal and famine divided by normal. We label it as 'newgcf' and present the estimates in Table 9. For self-employment and self-employed field, the estimated famine exposure coefficients remain negative and highly significant.

Table 9. Famine intensity based on 1% sample of China's 1990 population census.

	Self-employment (1)	Self-employed field (2)
cohort2	−0.228**	1.014*
	(0.102)	(0.560)
cohort3	−0.250*	1.770***
	(0.134)	(0.637)
cohort4	0.757**	1.136
	(0.350)	(31.840)
newgcf	−17.453**	1.800
	(8.656)	(3.177)
newgcf*cohort2	−0.337	−3.080
	(2.181)	(2.391)
newgcf*cohort3	−4.141**	−3.094**
	(1.749)	(1.521)
newgcf*cohort4	2.981	−27.649
	(3.671)	(83.083)
Community fixed effects	Yes	Yes
Control var.	Fixed	Fixed
Obs.	9,541	541
Pseudo R^2	0.192	0.233

Note: Robust standard errors in parentheses; *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

5.4. Measurement validity of GCF

Another possible concern is that the measured value of excess death rate is far from the true value, which may result in a biased estimation. Drawing on previous literature on China's famine (Huang and Martorell 2009; Hu et al. 2022), we utilized the average of pre famine and post famine population to proxy the normal population. While the famine bears negative consequences upon both actual and desired fertility even when it ends, namely, postponed births (Smil 1999). In this case, there is reason to doubt that our measurement approach in equation (1) may obtain an invalid value of excess death rate since we take into account the post famine population. In this subsection, we run two empirical tests to alleviate such a concern. First, we adopt Chen and Zhou's method (Chen and Zhou 2007) to measure the excess death rate, which does not involve post famine population. Specifically, we use excess death rate in 1960 as a proxy of the severity of the famine. The excess death rate in 1960 is calculated as the gap between the death rate in 1960 and the average death rate in the three years before 1959, labeled as 'egcf'. Second, we redefine the normal population index using a longer five-year window, namely, five years before and after famine. And we obtain a new measure of GCF and label it as 'fgcf'. Huang and Martorell (2009) found that the famine births (born in 1959–1961) are significantly smaller in size compared to earlier and later births, thereby, a recovery on actual fertility after the disaster. Table 10 reports the regression results. Again, the estimated famine exposure effects on self-employment and self-employed field both are consistent with our baseline estimates.

5.4. IV Estimation

One's decisions on self-employment are likely associated with a complex myriad of factors. Although we have controlled for possible confounding ones, the omitted variables are still our major concern. Together with the analysis in Section 1 and Section 3, the empirical challenge we face in this study is that the variable of interest may be

Table 10. Measurement validity of GCF.

	Self-employment (1)	Self-employed field (2)	Self-employment (3)	Self-employed field (4)
cohort2	−0.095	0.472	0.040	3.062*
	(0.141)	(0.594)	(0.183)	(1.856)
cohort3	−0.253	0.101	0.209	2.782***
	(0.162)	(0.065)	(0.215)	(0.729)
cohort4	0.744*	0.248	0.722	0.259
	(0.449)	(6.172)	(0.588)	(7.284)
egcf	0.039	−0.021		
	(0.026)	(0.077)		
egcf *cohort2	−0.005	0.003		
	(0.007)	(0.038)		
egcf *cohort3	−0.015*	−1.189*		
	(0.009)	(0.671)		
egcf *cohort4	−0.001	−2.598		
	(0.017)	(74.283)		
fgcf			27.041	−4.569
			(17.230)	(15.190)
fgcf*cohort2			−11.560	−19.889
			(12.245)	(15.306)
fgcf*cohort3			−21.710***	−5.406*
			(8.042)	(2.824)
fgcf*cohort4			1.190	−17.414
			(18.256)	(55.207)
Community fixed effects	Yes	Yes	Yes	Yes
Control var.	Fixed	Fixed	Fixed	Fixed
Obs.	9,405	616	9,405	616
Pseudo R^2	0.194	0.225	0.195	0.233

Note: Robust standard errors in parentheses; *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

correlated with the omitted variables, such as culture. To address this issue, we employ the IV method to alleviate the endogeneity of our estimation.

Rainfall is closely related to the occurrence of drought. An undeniable cause of the Chinese Great Famine is natural catastrophes (Kane 1988). Natural catastrophes can badly harm agriculture because of their various types, high frequency, and strong seasonality. A unique advantage of using rainfall as an instrument is that, as climate, its geographic distributions are exogenously given. Artificial interventions into rainfall are not practical due to climate change. Moreover, the famine survivors are unlikely to have a deep memory of rain capacity between 1959–1961. Even if the memory exists, it can only be perceived indirectly through the famine tragedy. In this sense, we adopt rainfall as our IV by calculating the precipitation anomaly percentage between 1959–1961 at a provincial level.

Limited by low technology and management levels, most peasants in 1960s China lived in the weather, however, a dry area with crop failure does not have to be poor and experience famine as the inhabitants could produce non-food commodities and purchase food from other areas. The fact that, China was always an agricultural nation before and right after the foundation People's Republic of China in 1949. During Mao Zedong's rule of China, the planned economy prevailed; investment and production activities are strictly restricted by the central and local governments; private sector investment is even illegal. Thus, the majority's livelihood depends largely on agriculture at that period. Based on these, rainfall may a good instrument for the famine.

Table 11. IV estimation results.

	gcf∗cohort3 (1)	Self-employment (2)	gcf∗cohort3 (3)	Self-employed field (4)
gcf∗cohort3		−36.237***		−8.647*
		(9.280)		(4.814)
gcf	0.049***	−22.148**	0.009	8.440
	(0.016)	(11.287)	(0.011)	(12.393)
cohort3	0.034***	0.281	0.021***	1.709***
	(0.000)	(0.194)	(0.001)	(0.594)
cohort2	0.001***	−0.028	0.0001	0.312
	(0.000)	(0.145)	(0.000)	(0.448)
cohort4	0.001	0.837*	−0.001	−2.061
	(0.001)	(0.497)	(0.004)	(8.235)
gcf∗cohort2	−0.076***	−12.451*	−0.029	−4.456
	(0.009)	(6.670)	(0.018)	(3.013)
gcf∗cohort4	−0.081***	−2.001	0.026	45.156
	(0.024)	(20.145)	(0.884)	(156.058)
rainfall∗cohort3	−0.002***		−0.001***	
	(0.000)		(0.000)	
Community fixed effects	Yes	Yes	Yes	Yes
Control var.	Fixed	Fixed	Fixed	Fixed
Obs.	9,541		541	
Adjusted R^2		0.841		0.786
F-statistic	186		119	
		Marginal effect		
gcf∗cohort3	—	−5.759***	—	−3.166***
	—	(1.474)	—	(0.227)

Note: Robust standard errors in parentheses; $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

Table 11 reports the ivprobit estimation results. The first-stage results show that the coefficient of interaction between rainfall and cohort3 are −0.002 and −0.001 in Columns (1) and (3) respectively, and both are significant at the 1% level. This finding suggests that the reduction in rainfall is related to a high excess death rate. The first stage F-statistics are 186 and 119, much higher than 10. By the rule of thumb, concerns on the weakness and ineffectiveness of our instrument can be excluded. The second-stage results show that the coefficients of the interaction term (gcf∗cohort3) are −36.24 and −8.65 and significant at the 1% and 10% levels, as shown in Columns (2) and (4), respectively. These values are consistent with our baseline estimation in Section 4. The marginal effect results show that a 1% increase in famine intensity can lead to a 5.76% and 3.17% decrease in the chance for individuals to become self-employed and further choose the agricultural field, respectively. We also test the interaction terms (gcf∗cohort3) of interest in the self-employment and self-employed field models.

5.5. Exclusion restrictions

Although the regional rainfall is exogenously determined, it may still be correlated with other omitted variables. However, we can only adopt an over-identification test if we have more than two IVs. Following Fang and Zhao (2011), we apply an alternative method to test the exogenous hypothesis for rainfall. In Table 12, we put gcf∗cohort3 and rainfall∗cohort3 into regression. If rainfall∗cohort3 only indirectly affects one's self-employment decisions through gcf∗cohort3, under the condition of controlling gcf∗cohort3, the coefficient of rainfall∗cohort3 should have no statistical significance. The estimates in Column (1) and Column (2) are in line with our expectations.

Table 12. Exclusion restrictions.

	Self-employment (1)		Self-employed field (2)
gcf*cohort3	−19.386***		−10.075**
	(7.301)		(4.222)
rainfall*cohort3	0.011		−0.075
	(0.058)		(0.148)
gcf	−23.643*		24.376
	(12.384)		(45.853)
cohort3	0.009		3.153***
	(0.167)		(0.710)
cohort2	−0.072		1.638
	(0.149)		(1.030)
cohort4	0.775		−3.314
	(0.499)		(8.750)
gcf*cohort2	−9.812		−14.651
	(7.338)		(14.910)
gcf*cohort4	1.752		70.508
	(19.779)		(164.554)
Community fixed effects	Yes		Yes
Control var.	Fixed		Fixed
Obs.	9,541		541
Pseudo R^2	0.192		0.244
		GDP	
Rainfall		−0.004	
		(0.003)	

Note: Robust standard errors in parentheses; *$p < 0.10$, **$p < 0.05$, and ***$p < 0.01$.

Even with the above estimates, we still cannot say that our IV meets exclusion restrictions. Many reasons might have caused the IVs to be insignificant in Table 12. We ought to further exclude other possible paths: most notably, economic prosperity, which describes the local entrepreneurial environment. In rural China, ideal climate and plentiful rainfall always lead to high agricultural yield, and such a region is likely prosperous. To confirm such a claim in a robust fashion, we regress provincial average GDP between 1959 and 1961 on rainfall. The results show that they are not significantly correlated (bottom of Table 12).

5.6. Further explanation: accounting for the mechanism of famine persistence

As discussed in Section 2, we hypothesis that famine experience profoundly shapes individuals' risk preferences, which in turn influence their self-employment decisions. In this subsection, we put it down to empirical analysis by examining whether risk tolerance is affected by famine exposure. It is documented that risk aversion increases savings (Bommier and Grand 2019). In practice, we utilize the question 'I would like to save more even if I am not short of money' to proxy individuals' risk tolerance.

The estimates are presented in Table 13. As shown in column (1), the coefficient of the variable of interest (gcf*cohort3) is −9.27 and significant, suggesting that childhood and adolescence famine exposure would lead to changes in individuals' risk tolerance. Our empirical evidence adds to the literature on the persistence of traumatic experience on risk preferences (Voors et al. 2012; Cameron and Shah 2015; Hanaoka, Shigeoka, and Watanabe 2018). Our findings support the claim that major negative shocks may increase risk aversion in the long run.

Table 13. The mechanism of famine persistence: risk tolerance.

	Risk tolerance (1)
cohort2	−0.106
	(0.108)
cohort3	0.042
	(0.117)
cohort4	−0.022
	(0.335)
gcf	21.834**
	(10.860)
gcf*cohort2	3.615
	(3.946)
gcf*cohort3	−9.265**
	(3.737)
gcf*cohort4	0.123
	(12.132)
Community fixed effects	Yes
Control var.	Fixed
Obs.	5,703
Pseudo R^2	0.099

Note: Robust standard errors in parentheses; $^{*}p < 0.10$, $^{**}p < 0.05$, and $^{***}p < 0.01$.

6. Conclusion

Self-employment is considered an engine of economic development for its potential as an alternative source of employment. However, the knowledge on the long-term effect of personal early-life experiences on entrepreneurial behaviour remains scarce. This study adopts the Great Famine in 1959–1961 as a natural experiment and explores the relationship between China's Great Famine and individuals' self-employment decisions. We adopt a rich individual-level database that assembles consistent data on climate changes and surveys across China. We also provide strong empirical support that childhood and adolescence famine exposure significantly affects one's self-employment decisions in adulthood. Specifically, a 1% increase in famine intensity results in a 3.89% and 2.31% decrease in the possibility of self-employment and the agricultural sector entry rate. Using rainfall as an instrument, we further show that the documented relationship is causal.

Our findings support that famine exposure attenuates individuals' self-employment decisions by profoundly altering their personality traits and preferences. Our results have two major implications for policymakers. For long-term development, the governments should build disaster prevention facilities and relief systems in disaster-prone areas with poor natural conditions. Such a social security network may effectively prevent major disasters from negatively affecting people's risk preferences in the long term, which can inhibit their innovation and entrepreneurship behaviour. Moreover, determining appropriate interventions for the scarcity and risk aversion of famine survivors is significant in the short run.

Finally, religious beliefs rationally promote individuals to become self-employed, which is consistent with the findings of Audretsch, Bönte, and Tamvada (2013), and negatively attenuates the entrepreneurs' entry rate into the agricultural sector. For the sake of poverty reduction in developing countries, more self-employed entrepreneurs should be encouraged to set up businesses in the agricultural sector to improve food

security. Thus, further evidence upon religions and self-employment may be an equally promising endeavour for future research.

Notes

1. The approximate number of marginalized populations is calculated using the poverty headcount ratio and total population reported in China from the World Bank Open Data.
2. Yao (1999), 'Poor weather and reduced acreage alone left little room for other factors to explain the sudden drop in grain production in 1959. In 1960 and 1961, a further decline in grain output was accelerated by an unusually high proportion of sown area hit by natural disaster. The average proportion of sown areas hit by natural disasters was 15.3% in 1960 and 18.6% in 1961, compared to an average of 6.6 percent for the period 1949–66 (with 1959–61 excluded). Poor weather was a much more important factor responsible for a reduction in output in 1960–61 than in 1959. Although sown acreage rose by 5.52% in 1960 from 1959, total grain output dropped by 15.59%, implying that the average yield in 1960 was more than 21% less than in 1959'.
3. Data source: China profile from the World Bank Open Data.

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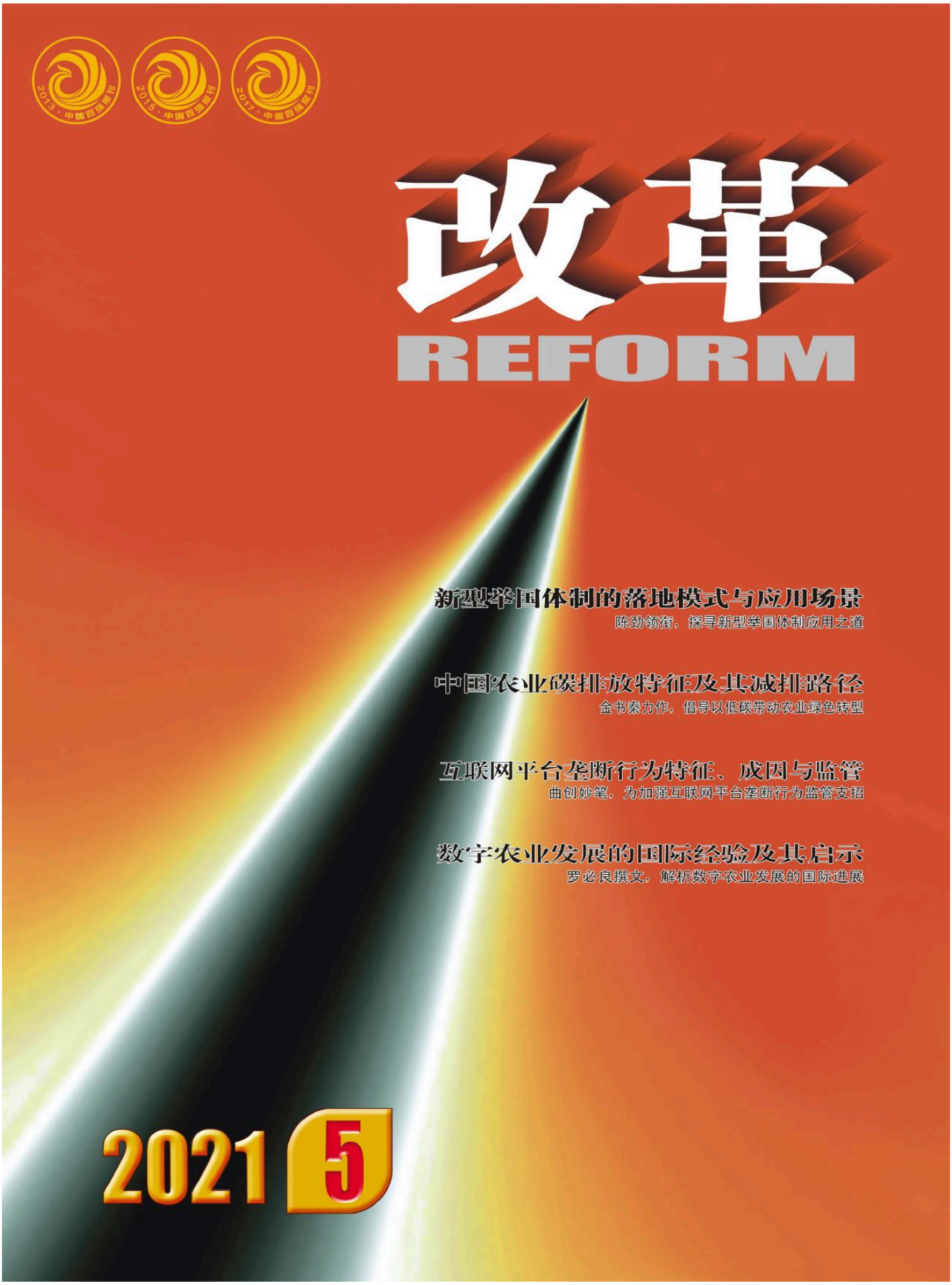
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数字农业发展的国际经验及其启示

钟文晶　罗必良　谢　琳

摘　要：气候变化和资源利用不可持续带来了较大的粮食安全压力，通过数字化技术推进农业的转型与高质量发展变得愈加迫切。数字农业具有技术依赖性、数据中心性和能力匹配性等特性，容易引发投资不足、失业、数字鸿沟和侵犯数据隐私等问题。现阶段，我国数字农业发展水平还不够高，有必要借鉴国际经验，以实现包容性数字农业转型，具体应采取如下措施：加大数字转型基础设施建设；诱导有利于降本增效的农业数字技术创新；设计有助于发挥数字红利的多元主体享益机制；提升利益相关者的参与能力；构建激励相容的数据产权规制体系。

关键词：数字农业；农业数字技术；包容性发展

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气候变化和资源利用不可持续威胁着全球粮食安全，可持续地生产足够的健康食物是21世纪全世界面临的最为关键的长期性挑战之一。应对此挑战，要求农业粮食与食物体系尽快转型。数字技术创新可能是转型方案的重要组成部分，即通过引入一套自动化的、数据密集型的“精准”技术，用更少的土地、更节约的用水和其他投入生产出更多的健康食物[1]。这就意味着数字化将是农业转型发展的重要路径。数字农业也被称为智慧农业、精准农业、农业产业的第四次技术革命等[2]。数字农业利用丰富而详细的数字信息指导农业价值链上各个主体的决策，其应用并不局限于农业生产，而是涉及整个或部分价值链，包括生产过程、收获后处理、市场准入、融资以及供应链管理等多个方面[3]。已有研究表明，数字农业的功能性作用在于：第一，通过减少化学投入品和劳动力需求，提高农业生产力和效率，创造新的市场机会来提升经济效益；第二，通过增进沟通和包容性，带来社会与文化效益；第三，通过优化资源利用，适应气候变化，带来环境效益[4]。

在世界范围内，以农业物联网、农业大数据、精准农业、智慧农业、人工智能等五大核心模块为代表的数字农业技术已经被广泛应用于农业领域且发展迅速[5]。与此同时，发达国家还在数字农业上进行了大量投资，如英国政府“产业战略挑战基金”将人工智能和数据作为四个挑战领域之一，计划聚焦于精准农业[6]；鉴于数字农业的广阔前景，麦肯锡的最新报告指出，如果在农业中成功实现互联互通，到2030年将为全球GDP增加5000亿美元的额外价值[7]。

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值得重视的是,尽管数字农业在经济效率方面的潜在好处被予以充分肯定,但现有研究大都忽视了从社会、习俗、政治和生态维度进行深入讨论。从全球来看,虽然部分地区存在食物的过量生产,但与此同时,仍然有数十亿计的人们在忍受饥饿和营养不良。因此,技术进步本身并不能完全解决未来全球性的粮食安全问题。而且,数字技术可能对小农经营带来"双刃剑"效应:在带来农业生产率提升的同时,农业数字化可能导致小型农场与大型农场之间出现"数字鸿沟",因为与大型农场相比,大多数小农难以获得数字农业技术,难以承受数字技术的大额投资以及由这些投资带来的风险;数字农业还会引发企业权力和农民自治之间的冲突、数据隐私和可持续发展等一系列的问题;新技术甚至可能导致市场集中度的提高,进而引发投入品价格上涨,使小农陷入更加困难的境地。

可以预期的是,数字农业或将意味着农业生产系统、农村经济、社区和自然资源管理的重大转型。理解农业数字化转型的条件与挑战,并制定因应策略,已成为重要的研究议题。本文试图对数字农业的技术特征、发展困境及国际经验进行研究和分析,以期为中国数字农业转型和发展提供借鉴和启示。

一、数字农业的技术特性与发展困境

数字农业对现代农业体系转型的作用机制,来源于其技术特性,主要包括技术依赖性、数据中心性和能力匹配性三方面。与此同时,数字农业的技术特性决定了其发展可能面临的一系列困境。

(一)数字农业的技术特性

1.技术依赖性

对于推进数字农业来说,数据、平台与连通性缺一不可。数字农业的实现依赖电力供应、移动网络覆盖和互联网连接等基础设施建设。在此基础上,数字农业的应用依赖数字技术发展,比如地理信息系统(GIS)、全球导航卫星系统(GNSS)、遥感(RS)、卫星图像、地面传感器、移动计算处理技术和通信技术等[8]。数字技术结合程序映射到耕作、播种、施肥、除草剂和农药的使用、灌溉、收割等农业实践中。图1(下页)以信息技术(ICT)为例展示了农业数字技术在农业循环中的应用[9]。数字技术将大大拓展农业发展的空间,例如,移动技术和网络设备将农民接入供应链,使其有机会获得更优质的种子和肥料,从而提高产量和质量[10];区块链技术有助于提高食品的可追溯性和供应链效率,从而减少浪费并增进价值链的透明度和信任度;深度学习、机器学习和人工智能有助于进行先进的作物管理、病害检测、物种识别以及水、土壤和林业管理,保障粮食安全;数字解决方案有助于提高监测、报告和验证农业和土地利用方面的准确性[11]。

2.数据中心性

数字农业中的关键要素是数据,由地理空间技术、现场生产信息、天气和气候以及市场动态汇集而成。其中,地理空间数据通常是特定站点与精准农业相关的信息,如特定地点的土壤特性和产量信息等;有关管理实践和技术的元数据,包括播种深度,种子位置,品种,机械诊断、时间和运动,耕作、播种、搜寻、喷洒的日期及投入品使用等;决策者无法控制的环境数据,包括降雨量、蒸发量和热量单位累积值等。图2(下页)展现了数字农业的农场数据流,根据生成地点以及参与者的潜在使用情况来表达数字农业相关数据生成的过程[12]。由此可见,大数据在农业中的价值取决于是否有足够数量的农民提供其农场的相关信息,进而聚合形成农业大数据。这类数据是一种信息资产,必须通过具有成本效益和创新性的信息处理,增强对农业的洞察力并发挥强大的预测能力,最终实现服务于农场管理决策的功能[13]。

3.能力匹配性

数字农业虽强调数据价值和智能决策的强

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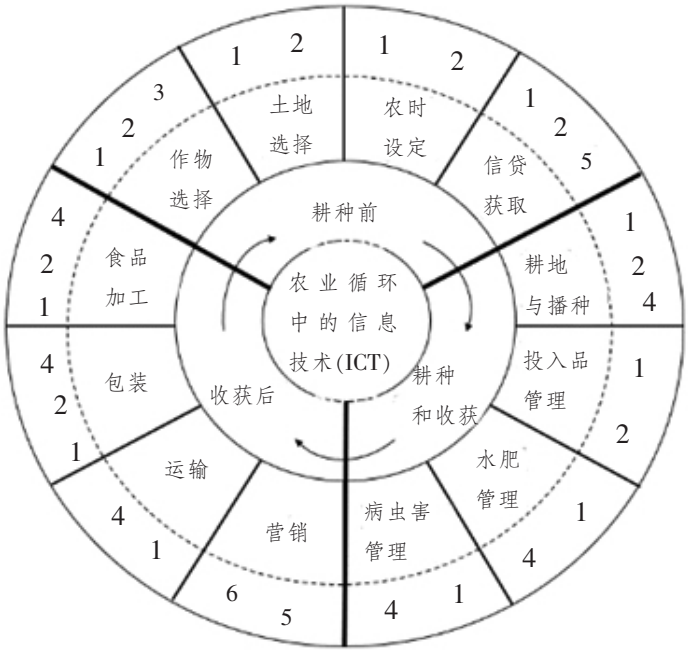


图 1 农业循环中数字技术的应用

注：图 1 中的数字对应技术为：1=信息系统(DSS,MISS,GIS 等)；2=支持 ICT 的学习和知识交流；3=建模解决方案；4=传感器和邻近设备；5= ICT 联网方案；6=在线商业工具

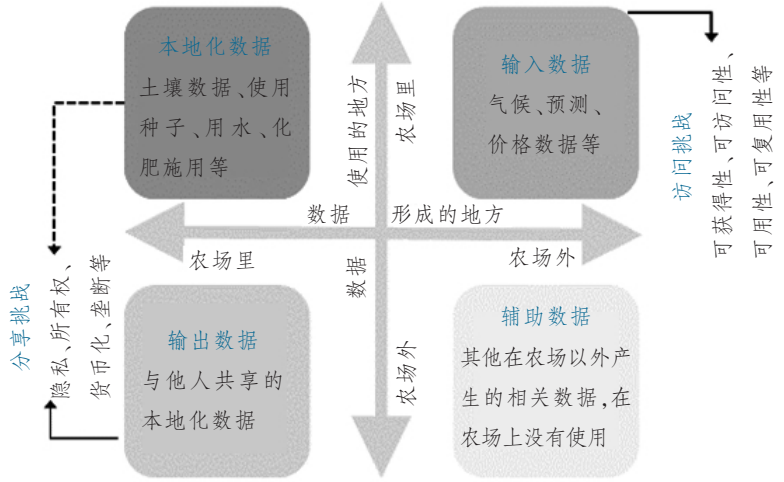


图 2 数字农业的农场数据流

大功能，但根据数据产权和服务“委托—代理”原则，最终进行决策的主体还是农业经营者。经营者在学习和经济能力上与技术的匹配，能够更好地支持数字农业转型。

一是主体学习能力的匹配。农民的学习和适应能力对其从数据驱动的农业机遇中获益至关重要。随着高速互联网和智能手机的兴起，手机应用程序、社交媒体、基于 IP 的语音传输(VoIP)以及数字参与平台在改进农村地区人口获取信息和服务方面具有巨大潜力，这不仅要求他们具备基本的读写和数学能力，而且要求其掌握数字处理和通信技能[14]。对于农民而言，数据需要经

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过一系列的过程才能转化为信息,且这些信息与经验结合才能作为知识使用。而每个阶段的学习过程并不是线性的,农民使用、分享和交换来自不同来源且各具特性的数据、信息和知识,并根据自己的知识基础进行应用或调整。例如,当向农民提供原始天气数据时,他们可能不知道这些数据对农业操作意味着什么,因为数据的使用必须从农学的角度来解释,如降雨模式对于在特定时间开始播种某种特定作物是否足够;对于不同作物,降雨数据的应用也可能会存在差别。因此,对农民来说,数据、信息和知识的使用是相互关联的,无法单独加以处理[12]。

二是主体投资能力的匹配。从技术上讲,大数据可为田间和农场管理实践提供量身定制服务,使得数字农业技术具备较大的灵活性,并被应用于各种农场规模,如:机器人和传感技术的进步对小农户比较友好,有助于改变农业的生产模式,使小农户能够重新发挥其优势。而且,数字化有助于农业价值链中的不同主体在可持续的农业生态系统中进行合作。正因如此,数字农业可能会被视为规模中性的技术。然而,无论是网络接入设备还是操控平台,都需要成本投入,尤其在数字农业发展的初期,与小农场相比,大型农场具有规模经济性,连通性使得对大片土地的监控更加便捷,更容易抵消数字农业投资的固定成本。

(二)数字农业的发展困境

数字农业的发展前景令人期待,但隐含的风险与挑战不容忽视。“颠覆定律”(The Laws of Disruption)指出,经济社会的变化速度难以跟上呈指数级发展的技术[15]。由于基础设施薄弱、获取机会不公、成本高昂、技能不足和资本有限,农业向数字化转型仍然面临一系列问题。在经济因素之外,社会、政治、生态层面的问题越发值得重视。

1.数字农业投资不足

虽然数字农业相关设备和硬件的成本正在迅速下降,投资回报周期在不断缩短,但仍然不足以释放农业数字化转型的所有潜在价值。风险资本正在投资于数字农业革命,但相对于其他行业,农业数字化吸引的资金依然是最少的。2010—2015 年,全球对金融技术的投资年增长率为 65%,达到 220 亿美元,而对数字农业的投资明显滞后,仅为 46 亿美元。在数字化发展进程中,农业仍是最落后的行业[16]。

2.挑战农业与农村文化

数字农业可以减少体力劳动,改善农民生活。但是,这一“改善”有时候并非人们所希望的。研究表明,体力劳动、传统的农场生活方式和丰富的农业生产经验对于农民了解其土地和生活环境具有重要意义[17]。农业的生命特性及其现场感,能够让农民在与自然交往的过程中获得智慧与感悟。而数字技术的使用可能导致农业生产经验的边缘化,以及农民与农业的脱节,降低农民对农业生产的满意度,加重农村社区普遍存在的心理健康问题。工作方式的改变将挑战农业文化的一些核心原则,而这些原则对农民的幸福感至关重要。农业的数字化及其智能化处理,不仅可能撕裂人与自然的互动,而且可能导致许多农民(尤其是小农场主)厌恶并离开农业[18]。

3.引发失业问题

在数字农业的大量应用场景中,基于大数据,机器可以在无需人工干预的情况下作出自主决策。因此,农业数字化无疑会创造新的就业机会,但这并不适合许多已经被边缘化的农场工人,尤其在高失业率的地区,是否有必要采用节省劳动力的技术一直存在着争议。除非农民调整技能并专攻新工种,否则,机器人技术和人工智能的出现将造成劳动力被替代。现实是,农业生产系统仍是全球 28%的劳动力的就业来源,数字农业可能会引发技术性失业,并对农村社区造成重大的连锁影响[4,19]。

4.造成产权争议和隐私风险

农民需要与第三方共享大量数据,才可能将

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信息转化为有价值的工具,但这一过程增加了数据权属纠纷和隐私泄露的风险。与此同时,数字农业所需的联机设备也可能暴露在网络威胁之下,如网络安全防火墙设置存在漏洞,第三方有可能访问敏感数据、窃取资料,甚至摧毁设备。此外,数据共享也并不是平等的,对于小农等维护自身利益能力较弱的群体来说,数据往往在更有谈判能力的大公司手中整合并用于信息决策[11]。研究表明,农民在共享农业数据时存在数据许可使用条款缺乏透明度、数据所有权不清、隐私问题、议价能力不平等、与农民之间缺乏利益共享等一系列问题。由此产生的可能后果是:一方面,数据权属、隐私和责任方面出现诚信缺失等问题,导致农业经营主体对数字技术的应用缺乏信任[20],如担心无人机会捕获其工作和私人生活的图像等;另一方面,在数字农业市场起步阶段,农民可能有机会选择任何一个服务提供商,并具有一定的议价能力,但随着市场的发展,少数大公司占据大部分市场,农民可能会失去议价能力与选择空间。

5.形成"数字鸿沟"

一是国家(地区)之间的"数字鸿沟"。从基础设施和资源可得性来看,亚洲、拉丁美洲和非洲国家(地区)的互联网使用仍然落后于北美和欧洲等地区。在许多非洲国家,只有不到40%的农户能上网,而且成本高昂。高速网络服务在北美和欧洲占主导地位;而在整个非洲大陆,农田的3G网络覆盖率仅占33%,4G网络覆盖率仅占9%;在亚洲,农田的3G网络覆盖率为46%,4G网络覆盖率为29%。家庭的手机拥有率方面也存在差异,亚洲和拉丁美洲许多地方的农户手机拥有率接近100%,但非洲国家(地区)的手机拥有率大大落后于世界其他地区[21]。

二是经营规模上的"数字鸿沟"。信贷约束会限制新技术的可负担性,自给型的小农难以从数字化转型中受益。即便是在农业比较发达的澳大利亚,小型农场经营者相对于大型农场经营者的数字化水平也普遍更低。

三是经营主体能力上的"数字鸿沟"。农民的数字技术素养存在差异,尤其是发展中国家的小农更难获得农业信息和数据,以及处理这些信息和数据的技能,从而阻碍了数字农业生态系统的形成与发展。不仅如此,新的数字服务往往会缺少本地化内容,技术的深度创新与差异性扩展均需要科研投入和重复性的实地试验,在缺乏公共和市场投入的背景下,主体的能力约束将导致农户获得本地化信息和服务的机会非常有限。

四是不同性别之间的"数字鸿沟"。研究发现,妇女等弱势群体的上网机会更少,全球女性手机拥有率比男性低14%,而在南亚,这一差距甚至上升至38%;女性使用数字设备和技术的能力也可能更低。这导致了女性的农业生产绩效和收入与男性相比存在差距[21]。

二、中国数字农业的发展状况

中国高度重视数字农业转型发展问题,试图从政策指向、公共投资、市场引导、主体激励等多维度出发,着力打造中国现代农业的未来图景。

(一)中国关于数字农业发展的相关政策

中国自2015年就开始规划数字农业的实施方案,制定了一系列旨在推动数字农业转型发展的政策文件,以促进数字乡村和数字农业协同发展(见表1,下页)。其核心路径在于,从基础设施的大力推进,到数字技术的推广应用,再到大数据体系和平台的建立,以实现数字技术和农业生产的深度融合。

各地方政府积极响应中央政策,出台本地数字农业农村发展的行动计划,因地制宜创新数字农业的实现机制与实现路径。如:浙江省印发《浙江省数字乡村建设实施方案》,强调推进生产管理数字化应用,建设一批省级数字农业园区和数字农业强镇。推广智能设施装备,推进数字化农业气象服务系统在现代农业中的应用,推进数字化监管,发展智慧农机装备和设施农业,开展数

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表 1 中国数字农业发展的相关政策文件及主要内容

时间	政策文件及主要内容
2015 年 12 月	《农业部关于推进农业农村大数据发展的实施意见》提出的主要目标是，立足中国国情和现实需要，未来 5—10 年内实现农业数据的有序共享开放，初步完成农业数字化改造。到 2025 年，实现农业产业链、价值链、供应链的联通，大幅提升农业生产智能化、经营网络化、管理高效化、服务便捷化的能力和水平，全面建成全球农业数据调查分析系统。
2018 年 1 月	《中共中央、国务院关于实施乡村振兴战略的意见》提出，大力发展数字农业，实施智慧农业林业水利工程，推进物联网试验示范和遥感技术应用。实施数字乡村战略，做好整体规划设计，加快农村地区宽带网络和第四代移动通信网络覆盖步伐，开发适应“三农”特点的信息技术、产品、应用和服务，弥合城乡数字鸿沟。提升气象为农服务能力。
2018 年 9 月	中共中央、国务院印发的《乡村振兴战略规划(2018—2022 年)》提出，大力发展数字农业，实施智慧农业工程和“互联网+”现代农业行动，鼓励对农业生产进行数字化改造，加强农业遥感、物联网应用，提高农业精准化水平。发展智慧气象，提升气象为农服务能力。实施数字乡村战略，加快物联网、地理信息、智能设备等现代信息技术与农村生产生活的全面深度融合，深化农业农村大数据创新应用。
2019 年 1 月	《中共中央 国务院关于坚持农业农村优先发展做好“三农”工作的若干意见》提出，实施数字乡村战略。深入推进“互联网+农业”，扩大农业物联网示范应用。推进重要农产品全产业链大数据建设，加强国家数字农业农村系统建设。继续开展电子商务进农村综合示范，实施“互联网+”农产品出村进城工程。全面推进信息进村入户，依托“互联网+”推动公共服务向农村延伸。
2019 年 5 月	中共中央办公厅、国务院办公厅印发《数字乡村发展战略纲要》，重点任务中指出要推进农业数字化转型。加快推广云计算、大数据、物联网、人工智能在农业生产经营管理中的运用，促进新一代信息技术与种植业、种业、畜牧业、渔业、农产品加工业全面深度融合应用，打造科技农业、智慧农业、品牌农业。建设智慧农(牧)场，推广精准化农(牧)业作业。
2019 年 12 月	农业农村部、中央网络安全和信息化委员会办公室印发《数字农业农村发展规划(2019—2025 年)》，规划预期到 2025 年中国农业数字经济占农业增加值的比重将达到 15%，农村互联网普及率达到 70%；建立健全农业农村数据采集体系，基本建成天空地一体化观测网络、农业农村基础数据资源体系、农业农村云平台。
2020 年 1 月	《中共中央 国务院关于抓好“三农”领域重点工作确保如期实现全面小康的意见》指出，加强现代农业设施建设。依托现有资源建设农业农村大数据中心，加快物联网、大数据、区块链、人工智能、第五代移动通信网络、智慧气象等现代信息技术在农业领域的应用。开展国家数字乡村试点。
2020 年 7 月	农业农村部印发《全国乡村产业发展规划(2020—2025 年)》，指出以信息技术带动业态融合，促进农业与信息产业融合，发展数字农业、智慧农业等。
2021 年 1 月	《中共中央 国务院关于全面推进乡村振兴加快农业农村现代化的意见》提出，实施数字乡村建设发展工程。推动农村千兆光网、第五代移动通信(5G)、移动物联网与城市同步规划建设。加快建设农业农村遥感卫星等天基设施。发展智慧农业，建立农业农村大数据体系，推动新一代信息技术与农业生产经营深度融合。完善农业气象综合监测网络，提升农业气象灾害防范能力。

字农业工厂建设。推进农产品加工、农资生产企业数字化改造，建成一批数字化生产线。到 2022年，建成 250 个数字农业工厂。广东省实施《广东数字农业农村发展行动计划(2020—2025 年)》，夯实广东数字农业新基建基础，争创优势形成数字农业示范标杆效应，积极创建国家数字经济创新发展试验区，打造“数字农业硅谷”；湖南省发布的《湖南省数字乡村发展行动方案(2020—2022年)》提出，到 2022 年，数字乡村建设取得明显成效，推动农业物联网应用，打造数字农业产

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业新优势。

不仅如此,国家还通过项目建设和补贴结合的激励机制大力推进数字农业的应用。农业农村部从2017年起组织开展数字农业建设试点项目,以县为单位组织实施,实施主体为区域内具有数字农业建设需求的农民合作社、家庭农场、农业产业化龙头企业等新型经营主体。同时,支持国家农业遥感应用等公益性科研单位开展农业遥感数字农业建设试点。中央财政对符合条件的数字农业建设试点县市予以投资补助。

(二)中国数字农业发展状况及其存在的问题

第一,农村互联网的快速普及与城乡和区域差距并存。中国互联网信息中心发布的第47次《中国互联网络发展状况统计报告》显示,截至2020年12月,中国网民规模达9.89亿,互联网普及率达70.4%,其中,手机网民规模达9.86亿,使用手机上网的比例达99.7%。城镇地区互联网普及率达79.8%,农村地区互联网普及率为55.9%。农村网民规模3.09亿,占比仅为31.3%;城镇网民规模达6.8亿,占比68.7%。由此可见,在互联网普及率上存在较大的城乡差距。与此同时,农业农村数字经济发展存在区域差距。2020年,北京大学新农村发展研究院数字乡村项目组发布的《县域数字乡村指数(2018)》指出,中国县域乡村经济数字化整体水平较低,且呈现明显的东西部差异。从县域乡村经济数字化指数分布来看,以"胡焕庸线"为界,乡村经济数字化指数值较高的县域主要集中在东部沿海地区,以及少量的中西部地区中心城市。

第二,农业产业数字化发展与产业内差异。中国信息通信研究院发布的《中国数字经济发展白皮书(2020年)》显示,2019年,中国农业数字经济增加值占行业增加值的比重为8.2%, 同比提升0.9个百分点;工业为19.5%,同比增长1.2个百分点;服务业为37.8%,同比增长1.9个百分点。与工业和服务业相比,农业数字经济增加值仍然较低,增长速度也相对较慢,还存在较大的提升空间。《2020年县域数字农业农村发展水平评价报告》显示,2019年经营主体农业生产数字化水平为23.8%,还存在巨大的发展潜力。有调查研究表明,家禽养殖业是中国畜牧业的支柱产业,也是规模化集约化程度最高、与国际先进水平最接近的产业,其主要环节数字化应用水平在20%以上;新型农业经营主体大田耕种管收主要环节的数字化应用水平约为25%,近90%的主体开展了测土配方施肥,40%的主体应用了水肥一体化技术,精准施药、病虫害监测预警系统、无人机植保等技术装备也得到了不同程度的应用[22]。可见,不同的数字技术在农业内部不同行业之间的应用存在较大差异。

第三,数字农业应用创新发展迅猛与数字技术研发瓶颈并存。农业农村部从2018年开始,通过推进苹果大数据发展应用,打造示范样板,为整个农业农村大数据建设提供可学习、可借鉴、可复制的机制、模式和经验。2020年,世界数字农业大会发布了十大创新案例,全面展示了数字农业创新模式,推动农业全面转型升级的应用场景,包括极飞智慧农业系统技术及实施模式、华为数字农业农村智能体、联通现代数字农业产业园、大疆智慧农业系统、京东农场"谷语"数字农业管理平台等。与此同时,市场投资热情高涨,如2020年中化农业MAP与阿里数字农业签署合作协议,计划未来3年内,围绕大米、苹果、柑橘、葡萄、草莓、猕猴桃、沃柑等品类,在全国建立10~15个数字农业基地,展开基于数字农业的战略合作。但需要重视的是,中国农业软件、农业传感器、智能农机装备的设计、加工、制造、研发与发达国家差距较大,动物生长模型、高端智能农机核心芯片绝大部分依赖进口,尚未形成自主可控的技术产品与装备[22]。

因此,总体而言,中国数字农业还比较薄弱,数字资源分散,天空地一体化数据获取能力较弱、覆盖率低,生产信息化、精准化水平与发达国家相比还有一定的差距[23]。

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三、数字农业发展的国际经验

面对数字农业转型过程中存在的问题与挑战，已有研究将重点放在改善可达性上。国际组织和各国政府试图制定数字包容议程，以期让更多的农民利用数字农业技术。尤其是制定相关法规和政策，对于未来农业的长期发展非常关键，且能够帮助重要参与者在数字农业的发展中处于中心位置。具体而言，数字农业发展的国际经验主要体现在四个方面。

（一）加强基础设施建设

基础设施和业务模式的创新有利于降低“最后一公里”的成本，因为移动互联网接入的普及可能让农民使用应用程序（APP）的边际成本接近为零。因此，有两方面的努力是值得尝试的：第一，为了缩小网络覆盖范围的差距，持续地建设和更新基础设施。欧盟国家的经验表明，提高电信领域的自由度有助于实现广泛的互联互通。高效的频谱管理可以降低建设费用，为终端用户带来更好的信息通信技术服务。政府使用的许可证管理框架的类型和频谱分配的效率对于鼓励私营部门在偏远地区投资移动网络十分重要[4]。第二，增强数字农业技术的可达性，降低使用成本。在国家、金融机构、移动网络运营商、设备制造商和服务提供商之间创造融合价值的业务，创新商业模式，降低农业经营主体的使用成本。尤其是政府农业研究与推广组织可以发挥重要作用，协助设计针对本地化的解决方案[24]。

（二）激励低成本包容性的技术创新

数字农业带动下的可持续粮食生产有益于整个社会，对于能力不足的弱势群体尤为重要。一方面，最贫困的农民无力支付互联网接入、设备或者数据的费用，于是公益基金便致力于将移动宽带作为一种公共物品提供给非洲最贫困的家庭[21,25]，还可以通过开放数据，让所有主体都能享益并且降低垄断的风险；另一方面，受能力和渠道的约束，许多农民获得本地化信息和服务的机会有限，但应用程序的技术创新有望改变这一局面。如2016年由德国的AI初创企业PEAT GmbH开发的名为Plantix的应用程序，旨在专门帮助农业生产者或者专业农技人员判断病虫害与营养缺乏等问题，到2020年，该程序已经有超过18种语言的1000万下载量。每天世界各地的用户平均上传5万幅图片，Plantix通过人工智能技术对农作物生长情况进行诊断，以此提升农民的生产效率。不同于其他类似平台，这个平台是经营规模中性的，可以适应于不同经营规模的生产者[26]。数字农业发展可为技术创新提供补贴与融资机会。如，欧洲联盟委员会建立了欧洲农业创新伙伴关系项目（EIP-AGRI），为数字农业创新提供资金，并开发与公共和私人利益相关者共享知识的网络，还通过担保计划对农民和研究人员进行补贴以支持数字农业；日本政府实施“战略创新促进计划（SIP）”，旨在促进数字农业创新技术的应用和交叉学科的资助政策。

（三）农业数据和平台企业的规制与监管

数字农业技术可以帮助农民，但这种帮助是有成本的，数字平台增加了农民对大型公司的依赖性。无论是陶氏与杜邦的合并、中国化工对先正达的收购，还是拜耳对孟山都的收购，都受到了政府和利益相关者的严格审查，目的在于确保合并不会损害市场竞争[27]。这一系列事件意味着，数字农业可能影响竞争，导致市场力量失衡，因而对数字农业进行更仔细的评估是合理的。欧盟为了解决市场力量可能导致的市场失灵，引入了包括《欧盟并购条例》等一系列关于竞争的法律规则，并在2013年设立了特别的高层论坛，为食品供应链设定了一套“良好实践原则”，以实现可自我监管的机制运行[28]。与此类似，2014年，美国的主要农业数据技术提供商、政府以及其他行业利益相关者就核心原则达成共识，通过“数据隐私和安全原则”纲要对数据的所有权、收集、透明性、便携性、披露、使用、销售和储存进行了规范，其中一项旨在解决反竞争行为的原则明确

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指出,农业技术提供者“不应将这些数据用于非法或反竞争活动,如农业技术提供商被禁止使用农场数据在商品市场进行投机”[29]。不仅如此,美国还制定了《2018 年美国农业数据法案》等专门的农业数据共享法案,旨在促进美国农业部收集农业种植数据,并在兼顾农民隐私的基础上,将数据收集和分析的结果提供给学术机构和研究人员。2020 年,日本农林水产省(MAFF)在研究农田信息的集中化管理方法及其有效利用方法的报告中强调,在建立个人信息时,需要格外注意个人信息的处理系统的操作。广泛地研究和考虑如何匹配耕地信息和个人信息,以及如何匿名和隐藏信息等方面的问题,防止利用个人信息数据进行身份识别[30]。

(四)构建包容性数字农业生态

构建支持农民的数字生态需要以下条件:第一,通过农业组织数字化转型实现农民的数字赋权和赋能。在收集农民数据的过程中,要赋予农民权利并给予他们表达的机会。合作社、生产者组织、农民组织等在管理、分享和使用数据信息以及促进和提升农民主动性方面具有重要作用。因此,探索可持续的经营模式,并让农民和农民组织从数据中受益是最紧迫的问题。可能的实现途径是,农民组织向数字智能组织或“数据合作社”过渡,以构建成员之间及与各种外部组织之间基于数据驱动的交互关系。第二,建立信托中心或信托机制与平台,促进和规范公开数据在不同层面(产品细分、价值链环节细分、国家、地区等)的共享。信托中心由公共部门推动和支持并依托价值链的某个环节建立起来,是代表农民的组织,或由农民和行业代表组成的联盟。这类中心可能成为公共和私营部门、农民和大企业一起讨论和制定实现互利性激励措施的理想场所。第三,制定数据访问管理和数据所有权及其流动的国际协议。农业和营养有关的数据往往被视为与全球粮食安全、可持续发展和减贫等目标有关的公共产品,因此需要在国家或国际机构之间达成具有强制性的协议。这些协议不仅约定分享数据的好处和机会,而且要促进数据公平、合理且合乎道德地流动和使用[12]。

四、对中国数字农业转型发展的启示

数字农业发展的国际经验,可为中国数字农业转型发展提供如下政策启示:

第一,大力推进农村基础设施建设。完善政府引导、市场主导、社会参与的协同推进机制,通过“新基建”推进农村互联网、5G 网络等公共基础设施建设,通过公私合营的方式推进农业数字平台建设,引导农业经营主体接入平台和采纳数字化应用场景。此外,在农业数据的采集、利用与开发上充分考虑产业特性导致的数据的复杂性,提升数据存储方式和使用效率,构建完善的基础数字资源体系。

第二,通过农业组织化促进包容性数字农业转型。与欧美发达国家相比,中国在经济发展阶段、农业用地和劳动力要素禀赋上存在显著差异,农业仍然是劳动力就业岗位的重要来源,虽然通过农地流转、服务托管等方式扩大了农地经营规模,但仍无法与欧美的大农场相比。在积极拓宽农外就业渠道的同时,要强调包容性发展目标的重要性,农业领域可以进一步通过农业组织创新,将小农户通过组织化卷入农业数字转型过程。组织化的小农户将具有双重优势,一方面增强与数字技术服务组织或农业数据平台的谈判能力,另一方面通过组织的分享机制获得数字转型带来的收益。

第三,激励“卡脖子”技术的创新研发,推进全产业链数字生态的构建。聚焦数字农业“卡脖子”技术,大力推进自主创新、协同攻关,进一步降低数字农业设备和硬件成本,将有利于数字技术供应商为农业生产经营主体提供更加有效的转型方案。中国农业销售端已经广泛使用数字化技术(如直播、电商等)拓宽农产品销售渠道。但需要重视的是,生产端仍然是农业价值链的核

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心，精准、智能、可溯源等数字技术应用有助于农产品质量的提升。因此，可以通过农业技术推广体系进行技术信息传播，通过政府补贴诱导产业链中各环节数字技术的应用，通过构建农业生产组织与数据平台之间合作享益联盟关系，最终打造健康的农业数字生态。

第四，建立数字农业经营主体的培养体系。在国家鼓励农民工、大中专毕业生、退伍军人、科技人员等返乡下乡创业的政策引导下，以新型农业经营主体为核心，同时加强对小农户具有包容性的数字农业人才培养体系建设。通过农技推广体系、商业企业培训服务和院校研究人员授课等线上或者线下的灵活形式，结合对数字农业技术采纳的定向资金支持等方式，开展数字农业人才培养工作。对于新型农业经营主体，提供数字农业转型方案，激励其从环节改造开始，进行全产业链化的数字农业转型；对于分散细碎化经营的小农户，激励其使用具有规模中性的数字技术（如通过手机使用ICT信息技术），帮助其改善在关键生产环节进行科学决策的可能性。此外，还要培训一批具有数字农业相关设备管护、数据调用与存储和平台维护等能力的人才队伍，以保障数字农业运行的安全性与可靠性。

第五，加快农业数据立法，防止平台垄断，维护数据主体的合法权益。实际上，中国第一部专门针对数据安全法律的立法过程已经正式启动，2020年7月2日，《中华人民共和国数据安全法（草案）》经十三届全国人大常委会第二十次会议初次审议公布，面向社会公众征求意见。农业数据立法的意义在于明晰农业数字产权边界，保障主体隐私权，降低数据被非法使用的风险。通过国家立法对市场行为进行规制，有利于在尊重数据主体权益、符合有关法律法规的前提下，推进数据连通融合，鼓励合法的互联网数据挖掘与利用，防止由数据非竞争性使用产生的平台垄断等问题。与此同时，除国家规定的涉密数据外，应加快政府数字政务平台建设，推进农业农村数据资源在相关利益主体之间的协同管理和价值融合。Reform

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International Experience and Enlightenment of Digital Agriculture Development

ZHONG Wen-jing LUO Bi-liang XIE Lin

Abstract: Climate change and unsustainable use of resources have brought greater pressure on food security, and it is increasingly urgent to promote the transformation and high-quality development of agriculture through digital technology. Digital agriculture has the characteristics of technology dependence, data centrality and capability matching, which easily leads to the problems of underinvestment, unemployment, digital divide and data privacy violation. At the present stage, the development level of digital agriculture in China is not high enough, so it is necessary to learn from international experience to realize inclusive digital agriculture transformation. Specific measures should be taken as follows: increase the infrastructure construction of digital transformation; induce agricultural digital technology innovation which is conducive to cost reduction and efficiency improvement; design a multi-agent benefit mechanism which is conducive to digital dividend; enhance the participation ability of stakeholders, and build an incentive compatible data property rights regulation system.

Key words: digital agriculture; agricultural digital technology; inclusive development

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粮食直补、农地市场结构与农地租金决定*

李尚蒲 仇童伟 谢 琳

[摘 要]我国农业已经进入高成本时代，其中农地租金的快速增长备受关注。采用 2015 年和 2016 年对广东与江西两省进行抽样问卷的 4172 个农户样本数据，考察不同类型农地市场结构和粮食直补政策对农户农地转出租金的影响发现：（1）农地租金上涨既是自发流转市场的必然结果，同时也是村集体主导或者村集体经济组织参与推动的结果；（2）当粮食直补分配给承租方时，不同类型的农地市场均会将粮食直补资本化为农地租金；（3）当粮食直补分配给承包者时，自发流转的农地市场会降低农地租金，而村集体主导的市场格局会推动农地租金上涨。因此，应妥善运用村集体和基层政府在农地流转中的“有形之手”，厘清政策目标间的冲突，适当调整农业补贴资本化为农地租金的政策倾向。

[关键词]农地流转 市场类型 粮食直补 农地租金

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一、引言

近年来，伴随工业化和城镇化进程加速，我国农业生产成本不断上涨，已进入高成本时代。其中，土地成本的上涨备受关注。杜挺、朱道林（2018）根据调查数据测算表明，2009—2017 年中国土地流转租金上涨了 33.3%。① 农地租金上涨是若干因素的函数。其中，农业补贴资本化为农地租金是国内外研究关注的一个重点。新古典理论假设农地市场为完全竞争，农地供给缺乏价格弹性，农地所有者通过调节租金获得全部的补贴收益。但在现实经济中，农地市场结构会影响农业补贴在农地所有者和租赁者之间的分配。已有研究表明，欧美等发达国家的农地租赁市场大体呈以下基本特征：一是随着农地租赁市场竞争性提高，农地承租者获得农业补贴的比例增大，欧盟和美国的农地所有者只能获得 6%—38% 的“脱钩补贴”。② 二是随着农地租赁规模扩大和契约期限延长，农地租赁方具有更好的谈判能力和信息优势，同等条件下可以享受到更低的农地租金。美国农业部 2006—2007 年的调查数据表明，农地租赁规模每增加 1 英亩，边际农业补贴资本化率下降 5%—15%。③ 三是农业补贴发放对象的差异影响着农业补贴资本化为农地价值（或租金）的比率。以欧盟为例，2005 年约有 20%—100% 的挂钩型补贴资本化

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① 杜挺、朱道林：《中国土地流转价格时空演化与宏观机制研究》，《资源科学》2018 年第 11 期。

② Kirwan B. E., “The Incidence of US Agricultural Subsidies on Farmland Rental Rates”, *Journal of Political Economy*, vol.117, no.1, 2009, pp.138-164.

③ Kirwan B. E., Roberts M. J., “Who Really Benefits from Agricultural Subsidies? Evidence from Field-Level Data”, *American Journal of Agricultural Economics*, vol.98, no.4, 2016, pp.1095-1113.

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为农地价值，脱钩型农业补贴仅为 6%—10%。[①]

在国内，自发流转的农地市场存在着土地细碎化、粮食生产兼业化和粗放化等一些缺陷。自 2013 年的中央一号文件首次提出鼓励和支持承包土地向专业大户、家庭农场、农民合作社流转，发展多种形式的适度规模经营和培育新型农业经营者主体就成为了重要政策导向。于是，各地在操作上更加依赖行政力量主导农地流转，打造规模经营主体。一种做法是村集体（包括乡镇基层地方政府）主导农地流转。部分村集体采取了强制性主导方式参与农地流转，村集体或基层乡镇政府代理农户统一与规模经营主体进行谈判、签约，农户间接参与农地流转。部分村集体将农户的农地进行集中整理，完善农田基础设施，再按照一定的准入条件发包给农地经营主体。[②] 另一种做法是村集体经济组织间接参与农地流转，即通过建立网络化的土地流转平台、土地信托服务、土地合作社等土地中介开展。村集体的直接主导或者间接参与行为改变了农地租赁双方的谈判能力。一方面村集体在选择交易主体、拟定合同、决定价格等方面对农户决策产生重要影响，另一方面村集体主导和参与使得转入主体之间的竞争加剧，增大了农地需求。也即是说，村集体的介入已经改变了我国原有自发流转的农地市场结构。

按照主流文献的观点，不同类型的农地市场结构将会影响农业补贴资本化为农地租金，并影响农业补贴在农地所有者和租赁者之间的分配。2004 年我国已经全面取消农业税，并构建了以粮食直接补贴（简称“粮食直补”）为主要内容的农业生产补贴政策体系。那么，村集体介入的新农地流转市场结构将会如何影响我国粮食直补资本化为农地租金？本文拟采用 2015 年和 2016 年对广东与江西两省进行抽样问卷的 4172 个农户样本数据，实证考察农地市场结构变化和粮食直补发放对我国农地转出租金的影响。

二、数据来源与模型设定

（一）数据来源

数据来源于本课题组在 2015 年和 2016 年对广东与江西两省进行的农户抽样调查。抽样方法为：随机在广东抽取 24 个县，在江西抽取 31 个县，按经济发展水平在各县再各随机抽取 15 个乡镇，在每个乡镇随机选取 1 个行政村，在各行政村依据收入水平各选取 10 个农户。最终回收问卷数为 4172 份，其中，有效问卷数为 4156 份，有效率为 99.6%。表 1 是抽样调查的统计数据，我们可以发现：（1）不同类型的农地市场在农地租金和农地转出规模上存在着较大差异。村集体主导或村集体经济组织参与的农地市场租金较高，农地转出面积较小；自发流转农地市场的租金均值较低，农地转出面积较大。（2）粮食直补发放给承租者时的转出租金较高，发放给承包者时的转出租金较低。

表 1　粮食直补分配与不同类型农地流转市场的租金情况

	粮食直补分配给承包者		粮食直补分配给经营者	
	转出面积（亩）	转出租金（元/亩•年）	转出面积（亩）	转出租金（元/亩•年）
自发流转	5.9723	216.59	2.9470	562.99
村集体主导	3.5184	437.19	2.4281	630.95
村集体参与	5.3868	268.71	2.7877	607.81

注：（1）本计算剔除了租金的异常值；（2）村集体经济组织间接参与是指转出户依托村土地合作社等中介组织进行流转；（3）在农地转出样本中，对于粮食直补发放对象回答“不清楚”选项暂不予讨论。

（二）模型设定

当前关于农地租金的计量分析多采用 Heckman 模型或两阶段最小二乘法。Heckman 模型能够有效解决自选择问题，但缺点是将第二阶段的“数量决策”进行最小普通二乘法估计，对零租金的重视程度不够。本文调研数据中约 1/3 的农地转出租金为零，这使得传统的计量方法估计可能存在着较大误差。

① Ciaian P., Kancs D., Espinosa M., “The Impact of the 2013 CAP Reform on the Decoupled Payments’ Capitalisation into Land Values”, *Journal of Agricultural Economics*, vol.69, no.2, 2018, pp.306-337.

② 诸培新、张建、张志林：《农地流转对农户收入影响研究——对政府主导与农户主导型农地流转的比较分析》，《中国土地科学》2015 年第 11 期。

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两阶段最小二乘法解决自选择问题较好，但缺点是忽视了农户租金决策的阶段性特征。为了避免这些缺陷，本研究选择 Cragg 提出的 Double-Hurdle 模型。[①] Double-Hurdle 模型采用不同的参数来反映上述不同的决策阶段。第一阶段为货币租金决策阶段，即农地转出是否为非零租金；第二阶段为农户转出的租金决策阶段。第一个阶段参与决策模型的因变量（d_i）是二元变量，由潜变量 d_i^* 决定。

$$d_i^* = z_i\alpha + \mu_i, \mu_i \sim N(0,\ 1) \tag{1}$$

$$d_i = \begin{cases} d_i^* & if\ d_i^* > 0 \\ 0 & if\ d_i^* = 0 \end{cases} \tag{2}$$

在式（1）中，z_i 表示影响转出户非零租金决策的变量，α 表示方程系数，μ_i 表示残差项，服从均值为 0、方差为 1 的正态分布。结合式（2），当 d_i^* 的观测值为 1 时，表示农户进行了货币租金的决策，当 d_i^* 观测值为 0 时，表示农户进行了零租金的决策。

第二个阶段数量决策模型的因变量 y_i^* 是零或者正数，对其估算类似于 Tobit 模型。

$$y_i^* = x_i\beta + \gamma_i, \gamma_i \sim N(0, \sigma^2) \tag{3}$$

$$\begin{cases} y_i = y_i^* & if \quad d_i^* > 0 \quad and \quad y_i^* > 0 \\ y_i = 0 & else \end{cases} \tag{4}$$

在式（3）中，y_i^* 表示潜在的数量变量，y_i 表示农地转出租金，x_i 表示影响农地转出租金的变量，β 表示方程系数，γ_i 表示残差。由于农地租金的最小值是零，且假设式（1）和式（3）中的残差项相互独立，因此本研究采用 Low-Hurdle 双栏模型，[②] 其似然函数如下式（5）。

$$\log L = \sum_0 \ln\left\{1 - \phi(z_i'\alpha)\phi\left(\frac{y_{\max} - x'\beta_i}{\sigma}\right)\right\} + \sum_+ \ln\left\{\phi(z_i'\alpha)\frac{1}{\sigma}\phi\left(\frac{y_i - x'\beta_i}{\sigma}\right)\right\} \tag{5}$$

表 2　变量定义与统计描述

变量	定义	均值	标准差
货币租金	货币租金 =1，零租金 =0	0.7121	0.4530
农地租金	亩均农地转出租金的对数值（含零租金）	4.1413	2.8649
自发市场	村级农地市场转出面积均值	2.4076	1.8681
村集体主导	村集体主导 =1，其他 =0，求村均值	0.0594	0.1377
村集体参与	参加土地合作社、土地银行等 =1，其他 =0，求村均值	9.8178	0.3720
粮食直补 I	粮食直补给承租方 =1，其他 =0	0.1984	0.3988
粮食直补 II	粮食直补给承包者 =1，其他 =0	0.5538	0.4972
性别	户主性别为男性 =1，其他 =0	0.6252	0.4841
年龄	户主年龄	49.8566	14.3392
受教育程度	户主完成义务教育 =1，其他 =0	0.7994	0.4005
承包地肥力	肥力评价为较好及以上 =1，其他 =0	0.3650	0.4815
承包地灌溉	灌溉评价为较好及以上 =1，其他 =0	0.4181	0.4933
承包地连片	承包地距离比较近 =1，其他 =0	0.4068	0.4913
承包地面积	农户家庭承包地面积（亩）	4.9325	15.3111
村农业受灾	农业受灾较多及以上 =1，其他 =0，求村均值	0.3530	0.2865
村庄农地确权	承包地确权颁证 =1，其他 =0，求村均值	0.5532	0.1846
村庄务农比	农业劳动力占家庭劳动力之比，求村均值	0.5369	0.4987
村庄交通	对村交通评价较好及其以上 =1，其他 =0	0.7784	0.2453
村庄地形	山区 =1，其他 =0	0.1289	0.3351
村庄地形	丘陵 =1，其他 =0	0.6051	0.4889

① Cragg J. G., “Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods”, *Econometrica*, vol.39, no.5, 1971.

② Garcia B., “Implementation of a Double-Hurdle Model”, *The Stata Journal*, vol.13, no.4, 2013, pp.776-794.

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（三）变量选择与描述

1. 因变量是农地租金。为解决异方差问题，将农地租金取对数处理，同时保留农地零租金。对于部分农地流转租金为实物（如粮食）的，本研究按照当地出售价格进行折算。

2. 核心解释变量。（1）考虑到农地市场的区域性，市场结构按照村级农地市场识别。其中，自发流转市场结构选择村级农地转出规模表征。将村集体主导市场和土地合作社等村集体经济组织参与的市场均设置为二元变量，并分别求村庄均值。（2）将粮食直补分配对象设置为二元变量，粮食直补 I 表示补贴给承租方，粮食直补 II 表示补贴给农地承包者。

3. 控制变量。一是人口特征，包括性别、年龄和受教育程度等变量。二是农地特征，包括土壤肥力、灌溉条件和地块连片程度、承包地面积。三是村庄特征，包括村庄农业受灾情况、村庄农地确权情况、村庄务农劳动力占比、村庄交通状况。考虑到村庄地形、土壤特征及农业生产条件会影响农地租金，本文对其亦予以控制。此外，本文还控制了调研时间和区域等虚拟变量。

三、计量结果分析

（一）不同类型农地流转市场对农地租金的影响

表 3 汇报了基于 Hurdle 模型测算的不同类型农地流转市场结构对农地租金的影响程度，结果表明，在不同类型的农地市场中，自发流转的市场规模、村集体主导、村集体参与均显著正向影响了农地转出租金。第 1 列和第 2 列分别估算了在自发流转农地中市场结构对农地转出和农地转出租金的影响。其中，以转出面积表征的市场份额变量显著正向影响农地租金。该计量结论与 Kirwan 等的研究结论类似，[①] 当农地承包者在农地流转市场中转出较大规模的农地时，其具备更强的市场谈判能力和市场定价能力，容易获得更高转出租金。第 3 列和第 4 列分别估算村集体主导市场的情况发现，村集体主导的

表 3　不同类型农地流转市场结构对农地租金的影响

变量	（1）		（2）		（3）	
	决策模型	数量模型	决策模型	数量模型	决策模型	数量模型
自发市场	-0.002(0.001)	0.021**(0.009)				
村集体主导			0.553***(0.155)	2.680***(0.322)		
村集体参与					0.681***(0.141)	0.589***(0.219)
性别	0.167*(0.088)	-0.034(0.101)	0.147**(0.065)	-0.060(0.091)	0.145**(0.065)	-0.107(0.088)
年龄	-0.004(0.003)	0.003(0.004)	-0.003(0.003)	0.004(0.004)	-0.001(0.003)	0.006*(0.003)
受教育程度	-0.077(0.121)	0.043(0.131)	-0.103(0.092)	0.043(0.120)	-0.094(0.091)	0.057(0.117)
承包地肥力	0.161(0.103)	0.2180*(0.125)	0.151*(0.083)	0.230**(0.117)	0.157*(0.082)	0.274**(0.115)
承包地灌溉	-0.068(0.099)	-0.047(0.120)	-0.058(0.080)	-0.054(0.113)	-0.082(0.080)	-0.118(0.110)
承包地连片	-0.087(0.087)	0.165(0.102)	-0.062(0.065)	0.150(0.093)	-0.081(0.065)	0.133(0.090)
承包地面积	0.0003(0.008)	0.020*(0.012)	-0.001(0.006)	0.026**(0.011)	-0.004(0.006)	0.026**(0.011)
村农业灾害	-0.446***(0.164)	-0.381**(0.185)	-0.475***(0.131)	-0.163(0.172)	-0.523***(0.129)	-0.391**(0.166)
村农地确权	0.118(0.120)	-0.069(0.140)	0.253***(0.097)	-0.234*(0.131)	0.217**(0.096)	-0.173(0.130)
村庄务农比	-0.441*(0.256)	0.170(0.277)	-0.132(0.195)	0.393(0.255)	-0.202(0.182)	-0.135(0.239)
村庄交通	-0.136(0.092)	0.126(0.103)	-0.189***(0.069)	0.126(0.094)	-0.163**(0.069)	0.147(0.090)
村庄地形 I	-0.367**(0.175)	-0.465**(0.183)	-0.138(0.138)	-0.360**(0.169)	-0.080(0.137)	-0.293*(0.168)
村庄地形 II	-0.259**(0.106)	-0.130(0.129)	-0.219***(0.084)	-0.059(0.118)	-0.172**(0.084)	0.041(0.117)
常数项	6.313***(0.275)	-0.359(0.292)	6.036***(0.221)	-0.451(0.276)	6.044***(0.213)	-0.128(0.267)
时间	控制	控制	控制	控制	控制	控制
地区	控制	控制	控制	控制	控制	控制
观测值	783	783	1053	1053	1053	1053

注：*** p < 0.01，** p < 0.05，* p < 0.1，括号内为稳健的标准误。下同。

① Kirwan B. E., Roberts M. J., “Who Really Benefits from Agricultural Subsidies? Evidence from Field-Level Data”, *American Journal of Agricultural Economics*, vol.98, no.4, 2016, pp.1095-1113.

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农地市场促进了农地转出，同时推高了农地转出租金。第 5 列和第 6 列估算村集体经济组织参与的情况发现，村集体经济组织参与促进了农地转出，同时有助于提高转出租金，但其对租金的推动作用弱于村集体主导市场。控制变量的计量结果也符合对现实的观测。首先，承包地土壤肥力在不同的农地流转市场中均显著正向影响农地租金，连片的土地也显著提高了农地转出租金，这符合极差地租理论。其次，从村庄特征变量看，农地受灾程度显著负向影响农地转出租金，村庄所处地形是山区时农地租金相对较低。此外，我们还做了稳健性检验。基准模型可能忽略了农地转出户会随行就市自动调整农地租金水平，这会导致自选择问题。借鉴前期研究，本文选择采用村庄其他转出户的均值作为工具变量的思路进行重新估算。[①] 表 4 回归结果表明，不存在严重的内生性问题，引入工具变量的估计结论依旧稳健。进一步地，我们剔除农地互换样本，仅使用农地净转出户样本进行估计，并对农户家庭是否有外出打工的子样本进行再估计。同时，为消除可能存在的选择性偏误问题，核心变量转换为村庄其他转出户的均值估算。结果表明，子样本均得到稳健结论（省略汇报）。

表 4　稳健性检验

变量	（1）		（2）		（3）	
	决策模型	数量模型	决策模型	数量模型	决策模型	数量模型
自发市场	-0.046***(0.011)	0.363***(0.062)				
村集体主导			0.445***(0.170)	2.873***(0.365)		
村集体参与					0.577***(0.144)	0.645***(0.239)
控制变量	控制	控制	控制	控制	控制	控制
观测值	752	752	1053	1053	1053	1053

（二）农地市场类型与粮食直补资本化为农地租金

1. 粮食直补发放给承租方对补贴资本化为农地租金的影响。表 5 的实证结论表明：（1）自发流转的农地市场结构显著正向影响农地转出租金。（2）村集体主导的农地市场结构对农地租金有着显著正向影响。交互项显著为负，且估算系数的绝对值低于村集体主导市场结构的估算系数，则说明在村集体主导市场结构中，补贴发放给承租方提高了农地租金水平。（3）在村集体经济组织参与的市场中，估算结论与村集体主导市场的结论类似，但对农地租金上涨的影响程度较弱。我们同样采取前述的两种方案进行稳健性检验（省略汇报）。当选择村庄其他转出户的均值作为工具变量时，发现自发流转农地市场的计

表 5　市场类型、粮食直补发放给承租方对农地租金的影响

变量	（1）		（2）		（3）	
	决策模型	数量模型	决策模型	数量模型	决策模型	数量模型
自发市场	-0.0015 (0.0015)	0.0809*** (0.0233)				
村集体主导			0.7493*** (0.1808)	3.6757*** (0.4147)		
村集体参与					0.6474*** (0.1719)	0.7858*** (0.2597)
粮食直补 I	0.3922*** (0.1273)	0.2274 (0.2440)	0.3528*** (0.0997)	0.4543*** (0.1450)	0.2396** (0.1070)	0.4437*** (0.1573)
交互项	-0.0405*** (0.0093)	0.0263 (0.0766)	-0.7419** (0.3180)	-3.1939*** (0.6169)	0.0300 (0.2771)	-0.7759* (0.4538)
控制变量	控制	控制	控制	控制	控制	控制
观测值	783	783	1053	1053	1053	1053

① Ma X., N. Heerink, E. van Ierland, M. van den Berg, X. Shi, “Land Tenure Security and Land Investments Northwest China”, *China Agricultural Economic Review*, vol.5, no.2, 2013.

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量结果为正向不显著，其他市场类型与表 5 回归结论基本一致，更换子样本再估算的结果稳健。

2. 粮食直补发放给承包者对补贴资本化为农地租金的影响。表 6 的实证结论表明：（1）交互项显著为正且系数绝对值小于前者，说明在自发流转市场中粮食直补发放给承包者降低了农地租金水平。（2）村集体主导的农地市场结构对转出租金影响显著为正。交互项显著为正，且估算系数绝对值高于市场结构估算系数，则说明在村集体主导市场中补贴发放给承包者推高了农地租金水平。（3）在村集体经济组织参与的市场中，计量估算结果与村集体主导市场的结论类似，但对农地租金上涨的影响程度较弱。同样做稳健性检验（省略汇报）。当选择村庄其他转出户的均值作为工具变量时，自发流转市场与补贴给承租方的交互项不显著，其他两类市场情况与表 6 回归结论基本一致，更换子样本再估算的结果稳健。

表 6　市场类型、粮食直补发放给承包者对农地租金的影响

变量	（1）		（2）		（3）	
	决策模型	数量模型	决策模型	数量模型	决策模型	数量模型
自发市场	0.0010 (0.0019)	0.0046 (0.0089)				
村集体主导			0.0908 (0.1865)	1.0264*** (0.3470)		
村集体参与					0.7775*** (0.1605)	0.1285 (0.2505)
粮食直补 II	-0.2409** (0.1066)	-0.4632*** (0.1505)	-0.3863*** (0.0900)	-0.5540*** (0.1283)	-0.1328 (0.0926)	-0.5256*** (0.1320)
交互项	-0.0054** (0.0027)	0.0502** (0.0244)	1.1444*** (0.2856)	3.8462*** (0.6466)	-0.4986* (0.2937)	1.2984*** (0.4642)
控制变量	控制	控制	控制	控制	控制	控制
观测值	783	783	1053	1053	1053	1053

四、结论与讨论

农地流转市场结构如何影响农业补贴资本化为农地租金尚有待研究，本文基于 Double-Hurdle 模型的实证结果表明：（1）在村民自发流转市场中，农地转出规模对农地转出具有显著正向影响，即当出租较大规模的农地时，承包者具备更强的市场谈判能力和市场定价能力，更容易获得高租金。（2）在村集体主导和参与的流转市场中，村集体或基层乡镇政府直接介入或者村集体经济组织间接参与均改变了农地流转双方的谈判能力，提高了农地租金。（3）粮食直补发放给承租方时正向影响农地租金，且村集体主导比参与的农地流转市场结构对农地租金上涨的推动作用更大。（4）粮食直补发放给承包者时降低了农地租金，村集体主导的农地流转市场结构对农地租金的影响依旧显著为正。

可见，在农地流转市场中，村集体与农业补贴政策都具有“双刃剑”的性质。对于前者来说，农村基层组织出面推进农地流转，一方面有助于农地的连片流转，改善农业的规模经营，并有助于维护农民的土地财产权益；另一方面却助推了农地租金上升，加剧了农业的高成本压力。对于后者而言，尽管以粮食直补为重点的农业补贴政策有助于调动经营主体的种粮积极性，但补贴发放的方式不同却有着不同的效果，其中粮食直补资本化为农地租金的情况应该引起高度重视。本文隐含的政策意义在于，应妥善运用村集体和基层政府在农地流转中的“有形之手”，设计切实可行的农村土地流转市场化工具；厘清政策目标间的冲突与最优解，综合权衡推进农地流转、实现规模经营、提高农民租金收入、确保粮食安全、控制农产品成本等各类政策，改善政策目标的相容性。

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本期责任主编　吕拉昌　毛　卉　　**执行编辑**　常宗广

农地确权方式与农户投资激励效应
——基于 IPWRA 模型的比较分析

胡新艳，许金海，陈相泼，谢 琳
(华南农业大学 国家农业制度与发展研究院，广州 510642)

摘要：基于广东省阳山县土地常规确权、整合确权的准自然实验调查数据，利用双稳健的 IPWRA 模型识别两种不同地权界定方式的投资激励效应及其作用机制。结果表明：不同确权方式对农户长期投资意愿的影响有着显著差异。相比常规确权方式，整合确权使农户的农田机械和有机肥投资意愿分别提高 78.7% 和 52.6%。其异质性的投资激励效应源于两种确权方式给农户带来不同的产权稳定性预期和地块资源属性改善。对于农田机械购置的投资意愿，产权稳定、资源改善两种中介效应占比分别为 15.93% 和 35.81%；对于有机肥投入意愿，产权稳定、资源改善则为完全中介效应。中国农业政策有必要从“以地权为本”转向统筹“资源与产权”的匹配协调，从而最大程度上激活和释放确权政策的制度红利。

关 键 词：确权方式；投资激励；IPWRA 模型；中介效应
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0 引言

产权理论关注经济运行的制度基础[1-2]，确权登记的重要性经过 H. De Soto[3] 的研究而广为所知。理论上，有保障的土地产权能激励农户投资行为，促进土地要素流动，增加正规信贷获取，确权带来的这三项地权安全效应可以总结为“保证”“实现”和“抵押”[4]。基于确权政策可能引致的经济激励效应，很多发展中国家启动了土地确权颁证计划。

土地制度改革一直是中国农村改革发展所关注的核心议题。改革以来，国家政策一再强调农地产权的稳定性，但实践中很多村庄普遍存在农地调整现象[5]，导致显著的效率损失。基于主流产权理论范式所形成的改革重点在给农民“确实权，颁铁证”。2009 年中国启动农地确权登记颁证试点工作，2014 年全面推广。然而，已有研究并没有完全一致的实证证据支持中国土地确权对投资激励具有重要意义，甚至出现相反的结论。黄季焜等[6] 研究发现农地确权提高了土地使用权的稳定性，从而促进农户的长期投资意愿；钟甫宁等[7] 认为土地制度改革带来的产权稳定性提升对农户生产投资的促进作用有限，农地规模经营产生的规模报酬才是激励农户农业投资的根本。另外，该领域实证研究面临自选择、反向因果等内生性问题的挑战。目前学界对农地确权政策与投资激励之间的因果关系仍存在质疑。

农地确权政策影响的经验研究结论的分歧与研究使用的数据和方法的严谨性不够有关。已有确权对投资激励影响的研究，惯常的分析起点是农地“是、否”确权，很少关注到实践中地权界定方式的多样性。国外的研究已经注意到此问题，G. D. Libecap 等[8] 基于 19 世纪美国俄亥俄州的自然实验，发现两种土地划界制度(界标界限法和矩形法)的经济效应存在显著差异，其原因是两种制度带来的交易成本存在异质性。显然，如果不对确权制度进行归类细分，易导致研究结论受到干扰。事实上，确权政策在中国不同区域的执行中并非是同质的制度安排。其中，常规操作是按照二轮承包土地台账对农户承包地进行“四至”确权。广东省阳山县等地创新性实施了“整合确权”方式，即进行土地整治、调整并块之后再确权。比较而言，这两种确权方式同中有异。相同的是：都将承包地地块、面积、合同、权属以证书落实到户；不同的是：整合确权匹配了土地整治、调整并块等改革措施。因此，整合确权是相对集中、规整化的产权界定方式，而常规四至确权是相对分散、非规整化的产权界定方式。目前很少有文献细致地分析两种确权方式带来的经济影响，这一研究领域往往被针对是否确权的集中讨论所忽视。目前国内仅查阅到一篇关于两种确权方式农地流转效应比较分析的文献，研究结论是整合确权更能促进农户参与农地流转[9]，但并未分析不同确权方式异质性农地流转效应的作用机制。

综上，农地确权的政策影响评估是一个理论问题，更是一个经验验证问题。产权界定概念及其影响研究需进一步拓展，不仅要考虑产权权利是否界定，而且要重视产权如何界定，归类分析不同产权界定方式下产权权利特性以及土地资源价值属性变化的投资激励效应。鉴于此，本研究重点关注两种不同确权方式的投资激励

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效应，尝试回答以下问题：常规确权、整合确权对农户土地投资激励有着怎样不同的影响？其生成机理是什么？有着怎样的政策含义？

1　理论基础和研究假设

中国地权制度设计与改革具有相当的复杂性，对不同产权界定方式及其影响的探索本身就是其中的必要过程。广东省阳山县同时存在整合确权和常规确权为识别确权方式的制度效应提供准自然实验条件。以下将从产权稳定性和土地资源改善效应作用逻辑出发，揭示不同农地确权方式作为制度协调装置对农地投资激励的异质性及其作用机制。

1.1　确权方式、产权稳定性与投资激励效应

稳定的农地产权能够保护资产拥有者的未来收益不受他人剥夺，激发农户长期投资动机，促进投资及资本形成[10]。目前主流研究多强调自上而下地通过国家法律对农民赋权以稳定地权，提升地权强度，往往忽视产权界定之后相互分离产权的实施问题。政治学家阿奎那在探讨资本主义私人财产制度起源问题时，明确区分权利和权利的行使，认为这是两个完全不同的、相互独立的观念[11]。巴泽尔区分了法律权利和经济权利两个概念，认为法律权利会强化经济权利，但经济权利可以在法律权利缺位的情况下存在，法律可能被架空于文字[12]。本质上，巴泽尔的法律权利指的是法律赋权，而经济权利则是指产权的实际运行和实施。D. C. North 等[13]指出产权权利是法律规则、实施行为以及行为规范的函数。基于上述理论，罗必良[14]认为法律赋权、社会认同和行为能力三者共同决定了地权稳定性。依此逻辑，即使同样是国家法定层面的农地确权，但农地产权在实施中依然可能存在产权强度差异。从法律赋权看，不管是整合确权还是常规确权，农户最终都能获得土地承包经营权证，产权能得到国家法律赋权的保障。换言之，农户最终在法律赋权维度上的农地产权稳定性是相同的。但是，不同确权方式下，农户社会认同、行为能力维度的产权稳定性是否一致呢？社会认同表现为一套产权的意识形态，是社会成员主观博弈的均衡[14]。对于中国农地产权制度而言，一个广为社会认同的规范是：为保障农户生存安全、维护地权公平（包括数量和质量）进行农地调整[15]。因此，尽管国家政策一再强调农地产权的稳定性，但村庄的农地调整现象依然普遍[5]。但是，不同确权方式下，农户对农地调整诉求的社会规范可能发生变化。比较两种确权方式可知，在整合确权下，基础设施作为技术资本的投入，促使地块规整化和标准化，能最小化村庄内各个地块之间的质量差异。这使得将全部农地打乱重分的“大调整”净收益很小，自然弱化了农户的调地需求，有利于实现农地产权的“大稳定”目标。即使村庄需要根据人口变化进行农地“小调整”，由于地块基本是同质标准化的，因此，可以切割边缘地块进行“多退少补”，由此保障农户原有绝大部分承包地地块位置、面积的基本稳定，提升产权稳定性预期。

从行为能力维度看，尽管赋权及其产权界定会对个人行为产生约束，但这并不排除人类主观能动性及其行为能力的客观存在[16]。即使拥有法律保护农民地权，他们仍面临土地产权实施的不确定性。农户可能不遵守法律规定的产权规则，侵害地块相邻农户的利益（如破坏田埂，侵占土地）；产权不安全意味着个人可能无法实现其投资和努力的成果，会导致农户维持或提高农地价值的投资激励减弱[17]。比较两种确权方式可知，常规确权锁定了二轮承包时期固有的农地细碎、分散的占有格局；整合确权通过农田整治能以相对规整的直线边界及标准化地块更明晰地界定产权，且通过调整并块减少农户地块数，这对行为能力维度的产权稳定性产生两方面的影响：有利于减少农户地权边界的测量争议以及纠纷；农户进行农业种植经营时，所需打交道、讨价还价的农户对象减少，因用水、施肥等引致的地权纠纷减少。总之，它便于协调农民利益关系，降低农地遭受破坏的风险和监督成本，减少产权执行的外部性，从而强化农户对具体地块的产权权利，增强产权稳定性。

可见，以确权改革为契机匹配基础设施等技术资本投入的整合确权进一步改善了农民的土地财产权，是提高地权稳定性的“工具”，导致地权权利对农户更有价值。换言之，不同的确权方式下地权制度安排的稳定性及其投资激励效应可能是不同的。

1.2　确权方式、资源属性与投资激励效应

农户投资不仅考虑产权稳定性对预期收益的保障效应，还要考虑与之相匹配的土地资源属性条件[18-19]。中国农业家庭经营面临的核心问题在于分散化、细碎化的小规模经营引发的规模不经济、分工不足所造成的低效率[20]。随着农村青壮年劳动力持续外流以及机械化程度逐步提高，规模化经营需求强烈，耕地细碎化、分散化逐渐成为导致农业生产效率损失的关键因素[21-22]，是妨碍和抑制农户农业投资的重要因素[23]。可见，农地的资源属性作为生产活动的实际载体对农业投资激励有着重要的影响。两种确权方式对农地资源属性产生了不同的影响，可能进一步放大其投资激励效应差异。

整合确权通过土地资源属性改善，降低农业生产成本[24]，激励农户进行长期投资。在实际生产投资过程中，农户作为一个理性的投资者[25]，不仅需要考虑产权稳定预期，还要权衡投资的成本与产出的关系。本研究主要从投资成本的角度分析确权方式之间可能存在的差异。一是相比常规确权，整合确权通过调整并块，提高了农户的平均地块面积及地块规整程度。这在原有总承包面积不变的基础上，直接扩大了农户的农地经营规模，有利于机械技术引入，优化要素配置，降低单位农产品生产的成本[26]。二是在农业生产作业过程中，整合确权提高了农地集中度，使农户往返各地块之间的时间

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成本明显降低。尤其在农业劳动力成本迅速上涨的背景下[27]能节省一笔昂贵的劳动力成本。因此,在单位农产品生产成本和劳动力成本降低的双重作用下,促进农户进行农地投资。

整合确权通过土地资源属性改善,降低农户潜在的失地损失,激励长期投资。常规确权并没有改变农田的土地资源属性,即农地的细碎化程度和质量差异化没能得到缓解。而整合确权通过农田整治并块,使得不同地块的机耕、灌溉条件基本得到相同的提升,从而降低地块之间的异质化程度。相比整合确权,常规确权(农地之间质量相差较大)的农户进行长期投资(有机肥等)可能面临的失地损失更大,即农户在土地调整中重新分配到比之前更差的地块。因此,整合确权降低了农户可能面临的失地损失,从而促进农户对农地的长期投资。

2 数据来源、研究方法与变量选取

2.1 数据来源

数据来源于课题组 2017 年 1 月对广东省阳山县进行的入户调查。一是整合确权试点村的调查。调查点为黎埪镇升平村,包括前锋、四新、联合、东风和中心 5 个村小组,共发放问卷 150 份,剔除无效及尚未完成整合确权的问卷,得到整合确权的有效样本为 91 户。二是全县(升平村除外)的常规调查。在县内随机抽取 80 个行政村,每个行政村抽取 2 个自然村,每个自然村抽取 10 个农户,共发放 1 600 份问卷。剔除无效及尚未完成确权的问卷,得到已完成确权的有效问卷 748 份,其中整合确权、常规确权的样本量分别为 86,662 份。最终总样本量为 839 份,包含 177 份整合确权样本,662 份常规确权样本。相对于整体随机抽样而言,数据可能存在一定程度的样本自选择问题,即在试点村小组分层抽取的样本数与阳山县(升平村除外)其他村小组的有所差异。为此,将通过计量模型进行修正,并做稳健性检验。

2.2 研究方法

选取 IPWRA(inverse-probability-weighted regression adjustment)模型来估计不同确权方式的投资激励效应差异,该模型可通过逆概率赋权来修正样本自选择偏差,并且,只需 IPW 模型和 RA 模型其中之一被正确设定,即可获得一致估计。具体设定见 J. M. Robins 等[28]和 J. M. Wooldridge[29]的研究。同时,借助逐步回归法检验产权稳定性和资源改善两条作用路径[30]。

2.3 变量选取及描述性分析

各关键变量的选取如下:(1)被解释变量。参照许庆等[31]的研究,使用“是否购置更多农田机械”衡量与特定地块不相连的长期投资;使用“是否投入更多有机肥”衡量与特定地块相连的长期投资。(2)核心解释变量。整合确权为 1,常规确权为 0。(3)中介变量。一是产权稳定效应,采用“土地确权是否相当于生不增,死不减”衡量农户的产权稳定性预期。二是资源改善效应,参考同类研究[9],使用农户的平均地块面积进行度量。(4)控制变量。包括户主特征、家庭特征、社会资本、地形特征和地块特征。

各变量定义及描述性统计见表 1。全部样本农户中,购置更多农田机械、投入更多有机肥的农户占比分别为 26.2%,30.5%,说明农户整体投资意愿较低,存在较大的提升和激励空间。整合确权与常规确权两组农户的长期投资意愿存在显著差异。相比常规确权,整合确权农户购置农田机械、投入有机肥的意愿分别高出 16.8%,14.3%,且在 1% 置信水平上显著。可初步判断,不同确权方式对农户长期投资意愿的激励效应存在差异。同样地,两类确权方式农户的产权稳定性感知和土地资源属性均存在明显不同。整合确权农户的产权稳定性比常规确权农户高 20.8%,且其平均地块面积为常规确权农户的 2.3 倍,两者均在 1% 置信水平上显著。由此可知,确权方式对农户长期投资意愿的效应差异很可能是由两类农户在产权稳定性与农地资源属性的不同所致。

表 1 描述性统计与组间均值差异分析
Tab.1 Descriptive statistics and mean difference test between groups

变量定义	样本均值			均值差异
	全样本	整合确权	常规确权	
农田机械购置(是=1,否=0)	0.262	0.395	0.227	0.168***
有机肥投入(是=1,否=0)	0.305	0.418	0.275	0.143***
地权稳定性(是=1,否=0)	0.514	0.678	0.470	0.208***
平均地块面积(承包地总面积÷总地块数)	0.533	0.959	0.419	0.540***
户主年龄/岁	55.602	55.362	55.666	-0.304
户主受教育程度(受教育年限)	6.321	7.390	6.035	1.355***
家庭总收入(家庭总收入取对数)	10.590	10.406	10.639	-0.233**
农业收入占比(农业收入÷总收入)	0.082	0.092	0.079	0.013
家庭总人口/人	5.372	5.181	5.423	-0.242
劳动力人数/人	2.129	2.102	2.136	-0.034
抚养比(16 岁以下和 70 岁以上人数÷总人数)	0.212	0.197	0.217	-0.020
政府补贴(有=1,无=0)	0.517	0.373	0.556	-0.183***
受到公平对待(是=1,否=0)	0.862	0.887	0.855	0.032
第一大姓(是=1,否=0)	0.700	0.797	0.674	0.123***
有无党员(有=1,无=0)	0.221	0.277	0.205	0.072**
总地块面积(承包地总面积取对数)	0.905	0.643	0.975	-0.332**
地块肥力(较差=0,一般=1,较好=2)	1.532	1.435	1.557	-0.122***
山地(是=1,否=0)	0.360	0.441	0.338	0.103**
丘陵(是=1,否=0)	0.487	0.339	0.527	-0.188***

说明:***,**,* 分别表示显著性水平为 1%,5% 和 10%。下表同。

3 计量结果与分析

3.1 基准模型结果分析

IPWRA 模型的估计结果见表 2。RA 模型与 IPW 模型的估计结果也一并在表 2 中给出。由IPWRA模型的

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表 2　两种确权方式的投资激励效应差异对比

Tab. 2　Differences in investment incentive effect between two methods of land titling

模型	被解释变量	
	农田机械购置	有机肥投入
RA	0.170*** (0.042)	0.141*** (0.045)
IPW	0.168*** (0.038)	0.139*** (0.039)
IPWRA	0.174*** (0.051)	0.144*** (0.063)
PSM	0.395*** (0.052)	0.418*** (0.051)

ATT 估计结果可知,不同确权方式的激励效应存在显著差异。从农田机械购置看,相比常规确权,整合确权对农户的激励效应高出 0.174,且在 1% 水平上显著; 对常规确权农户购置农田机械意愿估计的均值为 0.221,且在 1% 水平上显著; 这意味着整合确权使农户购置农田机械的投资意愿提高 78.7%。从投入有机肥意愿看,整合确权对农户的激励效应要比常规确权高 0.144,且在 1% 水平上显著; 对常规确权农户投入有机肥意愿估计的均值为 0.274,且在 1% 水平上显著; 这意味着整合确权使农户投入有机肥的意愿提高 52.6%。IPWRA,RA 和 IPW 3 个模型的估计结果基本一致。总之,整合确权能够显著提高农户两种不同类型的长期投资意愿。IPWRA 估计的有效性与重叠假定的满足程度有关。标准化差异越趋向于 0,方差比率越趋向于 1,则平衡性越高[32]。结果显示,仅有少数协变量的标准化差异与方差比率出现偏离。这说明模型的有效性相对较高(限于篇幅,检验结果省略) 。

3.2　作用机制分析

表 3 为产权稳定效应估计结果。从表 3 看出,模型 1、模型 2 的回归系数均为正,且在 1% 的水平上显著,说明确权方式对农户长期投资的激励效应差异是由产权稳定性的不同所导致。购置农田机械意愿、投入有机肥意愿的产权稳定效应分别为 0.018(0.209 × 0.084) ,0.025(0.209 × 0.119) 。购置农田机械意愿的产权稳定效应占总效应比例为 15.93%(0.018/(0.018 + 0.095)) ,而投入有机肥意愿的产权稳定效应为完全中介。值得注意的是,不同类型的投资意愿其产权稳定效应存在差异。相比与特定地块不相连的长期投资,产权稳定性在与特定地块相连的长期投资中发挥更大的作用。投入有机肥的产权稳定效应约为购置农田机械的 1.39 倍。这是因为土地调整给与特定地块相连的长期投资带来的损失几乎为投资全部,而对与特定地块不相连的长期投资(农田机械) 造成的损失则要小得多。因此,农地产权稳定效应得到验证。

表 3　产权稳定效应估计结果

Tab. 3　The results of estimating property stability effect

变量	模型 1			模型 2		
	农田机械购置	产权稳定性	农田机械购置	有机肥投入	产权稳定性	有机肥投入
整合确权	0.112*** (0.043)	0.209*** (0.045)	0.095** (0.045)	0.090** (0.045)	0.209*** (0.045)	0.065 (0.046)
产权稳定性			0.084*** (0.030)			0.119*** (0.032)
其他控制变量	是	是	是	是	是	是
常数项	0.011 (0.174)	0.424** (0.204)	−0.025 (0.174)	0.429** (0.182)	0.424** (0.204)	0.379** (0.182)

说明: 括号内为稳健标准误。下表同。

资源改善效应的估计结果见表 4。模型 1、模型 2 的回归系数均为正,且在 1% 的水平上显著。具体而言,购置农田机械意愿、投入有机肥意愿的资源改善效应分别为 0.053,0.049。购置农田机械意愿的资源改善效应占总效应比例为 35.81%,而投入有机肥意愿的资源改善效应则为完全中介。从两种不同类型投资意愿的资源改善效应的数值大小看,与特定地块不相连的长期投资意愿其资源改善效应相对更大些,即农田机械类长期投资对农地规模的要求更高。总之,地块资源属性改善的中介效应得到验证。

3.3　稳健性检验

换用倾向得分匹配(PSM) 模型的估计结果见表 2。可以发现,其估计系数方向与基准模型基本一致。因此,基准模型结果相对稳健。PSM 的有效性需满足重叠假定和匹配假定。重叠假定检验结果显示,样本匹配前处理组与控制组的协变量均值存在明显差异; 而匹配后

表 4　资源改善效应估计结果

Tab. 4　The results of estimating resource improvement effect

变量	模型 1			模型 2		
	农田机械购置	平均地块面积	农田机械购置	有机肥投入	平均地块面积	有机肥投入
整合确权	0.149*** (0.045)	0.528*** (0.074)	0.095** (0.045)	0.114*** (0.043)	0.528*** (0.074)	0.065 (0.046)
平均地块面积			0.101*** (0.026)			0.092*** (0.025)
其他控制变量	是	是	是	是	是	是
常数项	0.003 (0.179)	0.283 (0.336)	−0.025 (0.174)	0.404** (0.185)	0.283 (0.336)	0.379** (0.182)

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处理组与控制组的协变量均值差异基本在 0 附近波动，仅个别变量的均值差异仍较大，即重叠假定得到基本满足。匹配假定检验结果表明，仅控制组少量个体无法匹配上，不存在匹配过程中样本大量丢失的情况（限于篇幅，检验结果省略）。

4 结论与建议

4.1 结论

两种确权方式对农户长期投资的激励效应存在显著差异。不同确权方式下，农地产权稳定效应和资源改善效应不同。相对于常规确权，整合确权使农户购置农田机械和投入有机肥的投资意愿分别提高了 78.7%，52.6%。农户购置农田机械的产权稳定效应与资源改善效应占比分别为 15.93%，35.81%；投入有机肥的产权稳定效应与资源改善效应均为完全中介。

4.2 建议

整合确权对提升农户的投资意愿有重要的创新性实践价值，对完善农地确权制度具有重要的启示。全国各地普遍推行的常规确权方式强调保障农户土地产权，但几乎完全忽视产权以外其他与之协调联动的作用因素。整合确权不仅通过颁证提高农户的产权稳定性，还实施农田整治、调整并块等改革措施，有效改善土地的资源属性，从而更好地激发农户的投资意愿。因此，在农地确权制度改革的实践中，不仅要重视确权改革内在含义的统一性，强调产权是否界定，更应关注不同产权界定方式所隐含的制度效应差异，针对性地引导鼓励各地进行合理地探索，因地制宜选择确权方式，最大化激活和释放其制度红利。由此认为，中国农业政策应从仅仅以地权为本转向统筹资源与产权的匹配协调。需要指出的是，整合确权作为一种源自基层的创新性实践，未在全国得到普遍推广，原因可能在于其实施成本相对较高，产生了土地整治等多项额外成本。因此，整合确权需要配套国家土地整治等财政支农资金，分阶段、分批次、分区域地有序推进。

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Methods of Land Titling and Farmer Investment Incentive Effect: Comparative Analysis Based on IPWRA Model

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Abstract: Based on the quasi-natural experimental data of Yangshan County, used the IPWRA model to identify the impact of two land titling on farmers' investment incentive and its mechanism. The results show that methods of land titling had significantly different effects on farmers' long-term investment willingness. Compared with conventional land titling, farmland machinery and organic fertilizer investment willingness for farmers with land consolidation titling increased by 78.7% and 52.6%, respectively. The two methods of land titling have brought farmers different property rights stability expectation and resource attributes improvement. For the investment in farmland machinery, the mediating effect of property rights stability and resource improvement is 15.93% and 35.81% of the total effect, respectively. For the input of organic fertilizer, they were all full mediating effect. Therefore, China's agricultural policy reform should shift from property-right-based to coordination of resources and property rights, maximizing the land titling effect.

Key words: methods of land titling; investment incentive; IPWRA model; mediating effect

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Analysis of Farmers' Ecological Farming Behavior Based on Social Embedded Theory: A Case Study of Jiangxi Province

ZHANG Yuqin , CHEN Meiqiu , XIE Xianxin , ZHANG Shuxian , LAI Zhaohao

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Abstract: According to the theory of social embeddedness, the orderly logistic model was used to analyze the impact of various factors embedded in rural society on the ecological farming behavior of farmers. The results show that the level of part - time employment and the proportion of agricultural income positively affect the ecological farming behavior of farmers, and the total family population negatively affects the ecological farming behavior of farmers; cognitive embedding, relationship embedding and structural embedding help to increase the likelihood of farmers' ecological behavior. In view of this, the popularization of ecological farming behavior should start from the three dimensions of farmers, different groups and local governments: farmers should improve their cognitive and technical level, strengthen exchange and interchange between farmers, farmers and other rural entities. Agricultural business entities actively share resources and information, and move toward standardization and scientificization, local governments improve their own management and organizational capabilities, and provide relevant technical incentives and financial support for different groups according to local conditions.

Key words: social embedded; farmer behavior; ecological farming; ordered logistic; Jiangxi Province

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● 政策研究

美国土地确权登记管理及其对中国的启示

◈ 钟文晶 谢 琳 罗必良

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摘要：本文基于美国首次土地确权登记管理的调查数据，从交易费用理论的角度构建“产权界定—登记与服务市场—土地交易”的分析思路，从产权界定、产权管理和产权转让 3 个方面剖析美国土地登记管理与市场交易的运作机制，并由此得到启示。通过明确政策目标、构建交易型的农地登记与管理服务平台、结合大数据技术构建共享信息机制，促进中国农地确权完成后的登记管理工作及其相关市场发育。

关键词：土地确权登记；交易费用；土地交易；美国；中国

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1 引言

中共十九大报告明确了中国将实施乡村振兴战略，继续强调巩固和完善农村基本经营制度、深化农村土地制度改革以及完善承包地“三权分置”制度的重要性。作为农村土地改革重要基础的全国农地确权工作也将在 2018 年年底前完成。此轮改革的具体特征为，在原有土地承包界定方式的基础上，通过测量技术改进，精准明确农户承包地的物理边界，并通过农地的法律赋权进行落实和强化。一方面明确不再进行农地调整，确定将农地承包期限在这一轮结束后再延长 30 年；另一方面赋予农地“继承权”，与此同时拓展了农地使用的自由性，放松农业企业等工商资本和非农户籍人口等务农人员对农地经营权的进入，降低土地流转管制程度。

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制度变迁可以区分为自发演进与理性建构，卢瑟福认为“自发的看不见的过程与设计过程的主要根据是意识在产生社会结果中的作用”[1]。由此观察中美两国土地确权制度的变迁方式，中国农地确权改革是在二轮农地承包制度基础上，在市场分工加深与要素流动性加强的背景下，针对产权细分的内在需求而产生的变迁，政府的“干预”在于强化和完善秩序并以此激活市场，这是自发演进和理性建构的结合；而作为私有产权代表的美国的土地制度则是建构式的，其制度最初是沿袭英国产权制度，在科学测量进行产权界定的基础上，国家通过土地确权管理部门的职能发挥，保障私人通过法令分配或者市场交易获得土地权利。中美土地所有制形式的不同并不影响其政府作为制度选择的主体身份，“赋权于民”都是对于产权制度带动经济发展的路径选择。因此，总结和分析美国土地确权登记管理制度，能够为中国农地确权制度及其绩效发挥提供重要的借鉴。

实际上，对于美国土地制度及其发展经验的研究已经引起了很多中国学者的关注，相关成果主要集中在 3 个方面：第一，美国初始土地法令的历史背景以及后续影响，体现了土地政策发展的连续性和稳定性，并保证财产关系秩序的稳定。第二，美国土地测量方式和出售原则。土地测量的高技术性有效地避免了产权纠纷，为买卖、继承和转移提供了极为简单方便和有力的手段。第三，产权界定与交易秩序的关系。美国的土地是具有所有权限制的，禁止所有权人恣意行使所有权。所有权是相容的，允许绝对所有权人将小于自己权利的权利转让他给人，将剩余部分保留给自己或赋予受让人以外的第三人[2-4]。

但是，现有研究在强调美国产权制度建立、确权管理与交易的关系上，缺乏统一框架下的理论分析和数据支撑；而关于中国农地确权与制度绩效的研究，侧重于从微观到微观的个体研究，缺乏对政府作为实施主体的管理职能及其重要作用的阐释。因此，本文将基于“产权界定—登记与服务市场—土地交易”的分析思路，结合历史统计数据，剖析美国土地确权登记管理与土地市场交易的关系，为更好地理解中国农地确权的意义及其对农地流转的推动路径提供可行的建议。

2　土地确权登记管理及其交易成本：以 1974 美国问卷调查数据为例

美国在建国之初，掌握了大约 1.5×10^4 亿英亩（1 英亩≈0.405hm^2）的公共土地。1785 年的土地法令确定了出售西部公共土地，将其作为国家收入来源的公共土地政策。美国的土地确权管理体系是一种典型的正式制度设计，直接为土地市场交易服务而构建。从制度经济学角度研究土地市场时，可以把“交易”作为基本的分析单位。当土地“跨过某个技术上可分的界面而被让渡时，交易就会发生”，但是这个运行系统不是零摩擦的，交易必然会引发与此相关的费用，且交易成本贯穿交易的整个过程。首先，交易双方达成协议需要获得足够的对方信息，而信息的获取和传递是需要成本的，如果双方中间还有代理人，会产生更多的决策成本；其次，达成协议后，会形成执行成本，也即控制和监督成本[5]。随着交易成本理论向前发展，为了实证“对各种组织安排的选择始于对每笔交易的成本的比较”，学者将交易成本的大小与交易的可观测属性联系在一起[6]。因此，在对贯穿美国 20 世纪 70 年代的土地确权登记制度的研究中，本文将该制度涉及的交易成本分为土地产权界定成本、管理成本和转让成本 3 个部分，具体而言，通过土地确权登记的基础信息建立成本、登记和查询程序成本以及转让成本 3 个方面来测量。

本研究使用的资料和数据来源于 1974 年美国农业部和自然资源经济部出版的《美国土地确权登记——统计报告》[7]。在美国国家层面搜集不动产权利登记信息的调查是没有先例的，因此，此次调查是最早的以数据为基础，全面了解美国不动产尤其是土地登记情况的契机。调查于 1971 年开展，通过邮寄调查问卷反馈获得数据，问卷对象涉及美国本土 48 个州和哥伦比亚地区（不包括阿拉斯加和夏威夷州）的 3 584 位确权登记转让的登记员、办事员和注册员，回收的问卷来自于 2 364 个行政辖区，占全部被调查人数的 66%。反馈的行政辖区占全国人口的 71%，覆盖了 70%的土地面积。

2.1　产权界定成本：美国土地确权登记的基础信息建立

一个土地市场已经发展起来的明显标志是，可

以取代当地自然演化出来的单位的、准确而恒定的测量单位的出现[8]。美国的私有土地产权的获取通过在土地测量和登记基础上的书面形式的交易来实现。这种方式沿袭自英国，并具有时代和社会适应性，作为有保障的产权获取方式很好地实现了产权的可转让性。英国在 1536 年通过立法，部分土地转让才开始有书面凭据。直到 1676 年，欺诈法令规定，形式化书写是转让交易必备要素。与此形成鲜明对比的是，美国的土地转让从一开始就在书写凭据上做出了规定。除了装备现代测量工具、使用科学数学方法的测量员这一技术因素外，还有两个重要现实原因：一是相对稀缺的移民人口希望获得可转让权，以避免类似英国的佃农圈地运动的遭遇；二是当地的印第安部落并不会经常参与到地块划分中去，这使得美国人相对容易地使用先进测量和登记技术去界定土地。

早期的美国定居者把寻找有保障的确权方式作为第一要务，这一做法有利于开荒所有者获取有保障的土地产权，并由此得到基于信用的抵押贷款和财产价值保护、新受让人有保障地更改等权利。因此，美国通过将土地登记管理规定为政府功能之一，促进了买卖双方对确权的普遍认同，在严格的管理体系下，实现简单易行的土地产权可转让性。到 1700 年左右，土地转让登记在大西洋沿岸地区普遍起来，登记制度成为西部扩张的重要组成部分。到 1833 年，西部 53 个公地区每区均设登记员 1 人和出纳 1 人。此外，土地管理人员还包括 8 名测量主任、126 名代理测量员，以及在各个土地局领导下数量庞大的职员。杰克逊任职期间，每年的土地管理经费高达 33 万多美元，约占年度 GDP 的 6.26%[9]。到 1974 年，土地登记办公室的支出估算达到 147.9 万美元。

2.2 产权管理成本：美国土地确权登记和查询程序

美国当时的登记与公开程序已经规范化，并且在登记方法上根据区域不同而有所区别，但其核心都是确权检验。具体管理过程包括以下两个方面。

一方面，在登记管理程序上强调时间优先，登记信息和格式以便于公开查询为导向，信息保存手段完备。第一步，在地块确权文件中记录登记时间、文件编号、确权案件系列号。其中，最重要的是时间，因为基本上整个美国法律都建立在登记时间优先的优先权基础上。与此同时，还要收取登记费和相关的转让税。第二步，向社会公布必要信息。公开文件依照 3 类索引：一是收费登记索引，包含的信息包括文件、系列号、收集的登记费和登记地点；二是让与人—受让人索引；三是地带索引，它是用地理上的区域（如街区或者镇区）来进行组织的。每类索引在确权查验的时候都必须被检查。第三步，在文件索引制定好之后，会同时制作一份副本，存放在行政辖区的永久登记处。作为防止损坏的预防措施，每个文件还会微缩胶卷化，并被存放在另一个地方。根据登记辖区的反馈，登记方法分为普通书写或者打字机准备的副本、复印件、胶片、穿孔卡片、磁带等。

另一方面，通过委托代理和保险等机制设计，保障确权检验的可靠性，有利于交易的顺利完成。确权检验主要有代理人、代理人—摘要和确权保险 3 种方式，都是基于登记体系这一基本的信息来源。它们之间的本质区别在于占优势的特殊职业或者说是“技能”差别。在第一种方式下，买者雇佣代理人进行“个人”公共登记（转让代理人可以去雇佣专业的确权检验员协助）查询。使用让与人—受让人或者地带索引构造“确权链”，延伸至法令规定的年份，或者回溯到最初授权的年份，同时也要查验文件副本。在检查完资料之后，代理人会准备一份意见书，以确定对于卖者提供的产权信息是否可用于出售。第二种代理人—摘要方式与代理人方式类似，只是信息是由摘要人搜集。摘要本身是所涉及地块的确权历史的总结，通过检查摘要，代理人可以确定这个确权是否适合交易，指出任何存在的缺陷，一般不用回溯到最初的文件。在检验完之后，代理人同样会发布一份意见书。第三种方式是确权保险。1876 年，第一家产权保险公司成立，随后直到第二次世界大战之后，确权保险才规范化。在有些地区，确权承保人根据代理人的意见发布保险；在另外一些地方，确权承保人自己在公共记录中检查确权的情况。购买确权保单的目的在于保障所有人、放款人或者双方的公平性，保险费支付后保单立即生效。一旦保单所覆盖的损害发生时，保险无法返还一个有保障的确权，而是以现金形式进行赔偿。

至今，不动产和保险市场仍旧保持紧密的关系，

确权保险是完成一项不动产交易的基本要求，以此保证交易合同完成。在完成彻底的确权查验之后购买保险能提供产权保证，同时保险也能增强财产所有权的流动性和保障所有权转让的顺利完成[10]。确权保险公司的报告是确权公共信息正确性的反应，因为报告质量会直接影响保险公司的偿付能力[11]。

2.3　产权转让成本：转让率和转让费用的影响因素

美国第一份土地立契转让的登记于 1661 年发生在英属卡罗来纳州。在部落同意的前提下，印第安自耕农的首领 Kilcocanen 转让了 Perquimans 河的部分土地。在土地确权制度建立之后，买者或者卖者每次在确权转让的时候都要付钱评估土地的确权情况。有时候，卖者会将他获得产权时所掌握的摘要给买者，这样，买者只需要更新摘要。相对于准备完整的摘要而言，这是值得考虑的更加划算的替代方案。由于确权保险是不可转让的，新的保单伴随着每次转让的发生而出现。一般来说，买者支付保险金，从而得到承保人的协助。在有些地方，州法律规定卖者提供最新摘要或者给买者购买一份确权保单来保护买者。不动产转让市场带来的不仅是工作机会，还有财产数量和周转率。根据美国农业部（USDA）农场不动产市场数据和城镇不动产市场的不完全数据可知，美国每年的周转率为总宗数的 5%～10%，且转让率呈现增长态势（表 1）。

表 1　美国农业部 1956—1971 年不动产市场征税宗数和周转率

单位：万个，%

年份	地方拥有的可征税不动产的宗数	周转率
1956	6 120	5.5
1961	6 740	5.0
1966	7 480	4.5
1971	8 300	6.8

数据来源：宗数估计除了 1971 年来自可征税财产价值，1956、1961 和 1966 年的数据分别来自 1957、1962 和 1967 年的政府调查。所有其他估计的数据基于出版的和未出版的数据。

国家每年支出经费给管理办公室，州平均转让支出有明显的不同。例如，当全国平均的转让费为每次 17.16 美元时，州平均则从亚利桑那的 6.25 美元到罗德岛（哥伦比亚排除外）的 61.10 美元不等。转让费的差异主要受以下几方面因素的影响。

第一，确权办公室职能与容量。有些州的确权办公室还要兼顾其他职能，而总的办公支出是被计算在确权支出内的，平均成本自然会更高。另外，办公室容量的大小也会影响平均成本的高低，低容量的办公室会有更高的平均成本。这两个因素又会影响转让数量。这些因素部分解释了每笔转让平均支出的差异。从地域来看，西部地区每笔转让平均支出 10.70 美元，东北部地区为 26.13 美元，中北部和南部地区分别为 14.49 和 20.85 美元。

第二，雇员数量，即劳动力的规模会影响行政辖区的支出。中西北部地区的行政辖区雇佣更少人员。大西洋中部地区的登记办公室报告显示，每个行政辖区有 15 个工作人员，是中西北部地区平均支出的 5 倍。大西洋中部地区的单位也拥有按照行政辖区来计算的最高平均支出，是中西北部地区平均支出的 7 倍。

第三，生产特定部件的成本。这些部件包括信息储存媒介，如微缩胶卷轴和盒子、穿孔卡片以及精装书。5%的办公室中，作为存储工具的精装书的成本高于 500 美元，而大约 1/8 的行政辖区面临的成本是每本精装书少于 50 美元。对于大部分办公室来说，价格为每本 100～200 美元。

第四，登记费。绝大部分州立法机构对各个行政辖区收取的登记费做出了规定。登记费一般分为两部分，基本费是用于登记的第一页费用，另外还要加上每个附加页的费用，后者的费用一般更低。以州为统计单位，第一页费用为 1～8 美元不等，每个附加页的费用为 0.4～3 美元不等。

第五，转让税。到 1968 年，联邦税已经影响了大部分的不动产转让。税收盖章必须粘贴在每个立契转让中，用以显示收取税费的金额。在联邦转让税被废止之后，很多州和地方政府将此类税费立法，至今至少有 38 个州还在使用。转让税不仅是重要的

收益来源，取决于税率和转让价值；而且是信息来源，便于政府官员了解不动产转让和销售价格，以及税收评审员迅速得到销售价格和税收支付数据等。在国家水平上，大概有 72%的行政辖区报告指出了转让税的有效性。一般来说，转让税由各州征收，但在部分地区，县和镇被授权立法，和州税结合在一起。1969 年 1 174 个行政辖区报告显示，收取的转让税总额达 1.09 亿美元，其中东北部地区收取 41%、南部地区收取 27%、西部地区收取 25%、中北部地区收取 7%。

2.4 美国土地确权管理制度降低交易成本的途径

第一，普及电子化存储和电脑。通过私人、企业和政府登记和储存土地确权信息，实现对公众的需要具有明显的经济和社会效益，因为信息对称有利于降低交易成本。在当时的技术条件下，管理工作最显著的困难是存储成本问题。由于尚未电子化，纸质版的确权档案文件如何永久保存成为难题，其防火、防水成本高，且面临储存空间、资料使用的灵活性等难题，当时普遍认为通过微缩胶片可以解决 95%的存储空间问题。此外，人力也是主要的花费，确权检查工作耗费时间、精力并直接产生管理费用。因此，电脑的使用越发具有优势。电脑化的记录、微缩胶片文件和阴极射线管显示系统可以大大提升速度和减轻确权检查工作。但事实上，这种具有积极意义的改善工作很少得到地方确权管理部门的响应，只有 9%的登记员反映他们辖区有计划去改善相关体系。

第二，改进确权登记机制，降低信息转换成本与传递成本。由于需要遵守登记的安全性、登记录入的准确性、信息的可达性、辖区内外标准和定义的统一化，检索的便捷性，生产和管理的经济性等原则，如何提高登记机制从地方自治到国家层面在土地市场上的实施能力成为挑战。尽管国家范围的土地市场、州际信息系统在技术上是可行的，但是在地区政府和商业需求驱动下，土地登记体系仍然是地方性的，这些地方特征经常植根于传统和习惯性的认同。其结果是，地方自治有益的时候，可能对地区和国家经常是不利的。因此，为了满足未来的信息需要，土地登记应该整合成一个大的系统。土地权利和使用的信息应与经济活动、征税、公共服务、人口和计划、金融利益联合起来，形成一个完整的数据体系。同时，可以引入遥感技术，但事实上大部分辖区还没有做此类变化。

3 美国土地确权登记管理对中国农地确权与登记管理的启示

3.1 农地登记政策的目标导向和运行方式会直接影响交易成本及其效率的发挥

美国土地登记管理目标从开始就在于服务市场交易，这点与中国的情况有很大不同。中国历史上也有过土地调查，清康熙年间在全国进行过大规模的土地测量，其目的主要是为了核实土地面积，以便对土地进行征税[3]。近年来，中国土地登记信息来源不断完善。1999 年，作为国土资源大调查工作之一的中国农村集体土地产权调查试点工作在 11 个省份正式启动，投入专项经费 700 多万元[12]。2014 年，全国铺开利用遥感技术和信息化手段进行农地确权的工作，这一改革解决了数据准确性和存储高效性的问题，实现了动态监控土地利用情况，降低了土地民事纠纷和市场欺诈行为，也为征收土地税提供了准确资料。但是，农地登记信息的公众开放程度还很低。事实上，国土资源部于 2000 年才开始在全国 30 个省份开展土地登记公开查询试点工作。现有的农地确权数据仍然存在开放周期长、信息量少、可达性较弱等问题，农地转入方无法真实、准确、快速掌握农地产权信息，进而影响达成农地流转交易的政策目标。

3.2 农地登记和交易服务市场有利于降低交易成本，促进交易

服务市场的建立可以降低交易风险，减少交易纠纷的产生，确权代理人、保险公司是保证登记后的资料信息在交易过程中发挥作用的重要桥梁。尤其是后者，通过二级市场促进土地交易的完成。确权保险重在损失预防而不是损失赔偿[10]。此外，保险成本的主要组成部分不是损失赔偿，而是确权搜索和检查、其他服务以及文件报告制定等费用[13]。因此，确权保险是劳动密集型的，保险索赔少，所以实际的损失很小，一般是由搜索过程的遗漏造成的[14]。国外较早确立确权保险机制，且在机制运行方面有深入研究。中国相关市场的建立还在初始阶段。2014 年，国务院办公厅《关于引导农村产权流转交易市场健康发展的意见》指出，这类市场是政

府主导、服务“三农”的非盈利性机构，可以是事业法人，也可以是企业法人。2016 年开始施行的《农村土地经营权流转交易市场运行规范（试行）》指出，该市场是依照市场规律、为交易双方提供服务的平台，主要遵循“提出申请—进场交易—签订合同—配套服务”的顺序。应交易双方要求，市场可以组织提供法律咨询、资产评估、会计审计、项目策划、金融保险等服务。在现有实践中，多数土地流转交易市场是依托农业系统经营管理部门成立的事业单位或国有企业，也有一些是民营企业利用互联网等技术建立的流转交易平台[15]。因此，如何激励更多个人和组织规范加入服务市场并且持续发展，从而使土地流转市场更好发展是长期需要关注的问题。

3.3　大数据技术有利于降低交易成本，全国范围内农地登记管理体系构建及其功能延伸是发展方向

美国现有的土地查询系统有纽约、新泽西、得克萨斯等 18 个州支持在线查询，并且通过不同索引可以对部分地区和确权内容实现免费自主查询。就中国土地登记查询而言，国内学者认为，建立统一的平台既是政府工作需要，也是公开查询需要。这个平台可以支撑不动产登记业务、实现多行业主管部门的业务联动、实现与相关部门的信息共享、为社会提供依法查询服务[16]。事实上，中国现在的土地登记为县级政府管理，根据《土地管理法》第 11 条：“农民集体所有的土地，由县级人民政府登记造册，核发证书，确认所有权。”2003 年实施《土地登记资料公开查询办法》，目的是规范土地登记资料的公开查询活动，保证土地交易安全，保护土地权利人的合法权益。单位和个人查询土地登记资料，可以自己查询，也可以委托代理人或者土地登记代理机构查询，各地依照成本设定收费标准，查询时需要提供相关证明并向管理机构申请。可以预计，随着法律配套和服务机构配套的不断完善、市场需求的增加，各地相关部门在缩短反馈查询结果时间、简化查询程序、降低查询成本、纠错程序等方面，仍然有较大的提升空间。

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（责任编辑　肖时花　段丽君）

广东省科技进步奖

证 书

为表彰 2021 年度广东省科技进步奖获得者，特颁发此证书。

项目名称：**中国特色农业现代化道路模式选择的理论创新及其应用**

奖励等级：**二等奖**

获 奖 者：**谢琳**

粤府证【2022】0689 号

项目编号:J18-2-03-R04

广东省人民政府

2022 年 3 月

第九届高等学校科学研究优秀成果奖

（人文社会科学）

成果名称：分工经济、服务外包与农业规模经营方式创新

中国农业出版社 2021 年 8 月

主要作者：胡新艳，罗必良，谢琳，朱文珏，洪炜杰

奖项类别：著作论文奖

获奖等级：三等奖

教社科证字（2024）第 0880 号

中华人民共和国教育部

二〇二四年七月二十日

广东省哲学社会科学
优秀成果
奖励证书

为表彰第十届广东省哲学社会科学优秀成果奖获得者，特颁发此证书。

成果名称：分工经济、服务外包与农业规模经营方式创新

成果形式：著作

奖励等级：三等奖

获 奖 者：胡新艳、罗必良、谢　琳、朱文珏、洪炜杰、吴小立、陈文晖、刘　恺、钟文晶、王梦婷、罗锦涛、吕　佳

粤府证〔2024〕327

证书号：2023-A-3-327

广东省人民政府

2024年6月

广东省社会科学界联合会

（内部文件 妥善保管 不得外传 不得公开发布）

证 明

华南农业大学：

贵校报送的决策咨询报告《关于加快发展广东农业生产性服务的建议》（作者：罗必良、胡新艳、钟文晶、谢琳、罗明忠、米运生、洪炜杰），已在《南方智库专报》（第 559 期，2021 年 7 月 14 日）刊发上报广东省领导，获得广东省委常委、广州市委书记张硕辅同志批示。

特此证明。

广东省社会科学界联合会

2021 年 7 月 29 日

广东省人民政府办公厅领导批示办理表

紧急程度:　　密级:内部　　收文编号:信 202400434

来文单位	华南农业大学	收文日期	2024-08-13	办文编号	信息〔2024〕310号
来文标题	以全域土地综合整治为切入口推动社会资本下乡：从化经验与启示				

批示内容：

8月19日，张少康同志批示：请省自然资源厅阅。

办理意见：

呈**厉海帆、范世尧**同志阅。转请省自然资源厅办理，抄送华南农业大学，本厅综合二处。

政务信息处（杨松青、何飞琏）20/8

20/8　20/8

广东省人民政府办公厅政务信息处　　经办人：何飞琏　　电话：83132527

华南农业大学
智库研究成果要报

2024（第 50 期）

科学研究院　　2024 年 08 月 12 日

以全域土地综合整治为切入口 推动社会资本下乡：从化经验与启示

【摘要】土地整治有助于资源整合与集约使用、引导社会资本下乡。广州市从化区于 2021 年 9 月获批为全国首个以县域为实施单元的全域土地综合整治试点，坚持规划引领，统筹城乡发展；生态修复，促可持续发展；制度创新，多元引入资本，成效明显。同时，仍有四个问题需要引起重视：整治目标需要继续厘清，避免片面追求经济效益；财政资金难以覆盖整治需求，存在地方隐性债风险；整治项目融资面临系列难题，社会资本引入有难度；用地权益保障不足，社会资本参与的投融资受阻。为此，华南农业大学课题组建议，要平台蓄水，精准投放；试点叠加，形成合力；以地聚财，筑巢引凤；拓宽渠道，引导参与。

土地作为生产生活生态的基本空间载体，是乡村经济、社会和生态发展的关键资源，也是推动乡村全面振兴的重要切入点。

土地整治作为一项针对乡村发展要素流失、土地使用效率低下问题的综合民生工程，通过规划设计和工程技术，有助于实现资源整合与集约使用、优化乡村空间布局等目标。为此，2019年自然资源部公布了全域土地综合整治试点。广州市从化区于2021年9月获批成为全国首个以县域为实施单元的全域土地综合整治试点，几年来，从化以全域土地综合整治为切入口，探索“百县千镇万村高质量发展工程”的实施路径，以科学规划为前提，以乡镇为基本实施单元，通过“山水林田湖草沙”的综合治理，在耕地连片、设施完善、环境优化等方面取得了显著成效，有效整合了“人口—土地—产业”三大关键要素及“三生”空间，建设人与自然和谐共生的和美乡村，促进城乡融合高质量发展，具有重要借鉴和启发意义。

一、广州市从化区全域土地综合整治的主要做法与经验

广州市从化区作为全国唯一县域土地综合整治试点，探索“1+4”差异化整治模式（“1”为流域治理的国土空间规划实施模式；“4”是“源头修复和生态价值实现”、“城乡融合发展”、“老城市新活力”、“区域协同与产城融合”等四种模式），建立“1+1+8+X”组织体系（1个领导小组办公室+1个工作专班+8个镇街专班+X个具体项目部），确保整治工作高效推进。具体的做法和经验是：

（一）规划引领，统筹城乡发展。从化区坚持规划先行，坚持“统一规划、统一立项、统一实施、统一监管”，以国土空间规划为引领，统筹农业、城镇、生态空间布局优化，实现“增耕地、腾空间、强活力、优生态”目标。**一是**“增田”，高标准整理农业空间，推进耕地成片。以鳌头镇万亩良田示范项目为代表，

打造岭南田园综合体。**二是**“数智”，农业的科技赋能。以街口街的艾米稻香小镇为代表，为永久基本农田提供了整套数字化解决方案。**三是**“添绿”，践行绿水青山就是金山银山的理念，形成“良田连片、村庄集中、产业集聚、生态优美”的土地保护利用新格局。**四是**“兴村”，推进人居环境改善。以吕田镇为代表，深入挖掘村庄资源禀赋和历史文化内涵，讲好狮象岩古人类遗址的故事，打造以“狮象文化”带动的农文教融合发展。

（二）生态修复，促可持续发展。从化全域土地综合整治“源头修复与生态价值实现”模式得到了自然资源部的高度肯定，并纳入“统筹生态保护修复，改善农村人居环境”的典型案例。**一是**实施生态保护，推进绿色发展。从化区特别重视生态修复工作，通过整合河流整治、林下改造、村庄整治等，促进生态环境的持续改善。以流溪河为脉络，结合国家水系连通及农村水系综合整治试点，完成鸭洞河、溉江河等生态修复治理50公里，连通形成1350公里蓝脉。**二是**推动一二三产融合发展。结合片区和市场需求，发展农产品展销、科研、文旅等产业，为经济发展注入新动力。**三是**发展绿色产业，推进结构升级。南部地区依托高埔创智谷吸引高新技术企业，发展绿色建材产业等，推动产业结构升级。

（三）制度创新，多元引入资本。**一是**以少量财政资金撬动专项债与政策性金融工具。从化区整合“农、林、水、路、村”相关财政资金形成“组合资金池”[1]约3000万元，重点投入乡村生态保护修复和基础设施完善。从化区还申请了全域土地综合整

[1] 包括：①省、市、区专项资金，即：高标准农田建设、耕地开垦、垦造水田、乡村振兴相关资金等；②国家试点资金，即：国家水系连通及农村水系综合整治试点资金、国家级田园综合体试点资金、国家和省对现代农业产业园的资金支持、宜居宜业和美乡村专项资金等。

治专项债与政策性金融贷款。2023-2024年从化区依托全域土地综合整治项目发行的专项债约46600万元。鳌头镇使用专项债资金开展了河道清淤疏通、河堤建设、水土流失治理与碧道建设，解决了洪涝灾害隐患以及水利功能不足的问题，为万亩良田示范基地提供了重要保障。**二是**土地制度创新与国有企业带动。以盘活城乡建设用地为抓手，吸引越秀集团、区属城投集团等社会资本参与。越秀田园综合体按照自愿有偿的原则开展闲置低效建设用地整治，腾退的建设用地规模和指标保障辖区内农民安置、乡村产业发展、乡村公共服务和基础设施建设等，有效支撑了项目范围内龙潭旧墟风情街、风行牧场奶牛产业园、乡村振兴产业创业孵化园、溉江水系休闲观光带、乡村振兴培训基地等项目建设。**三是**“投、融、设、建、管、营”的一体化项目开发模式。通过“政府出一点、银行贷一点、社会投一点、指标卖一点”等多种方式，构建“政府引导资金+专项债+政策性金融+社会资金”的多元资金参与模式，实现政府、企业、村户三方共赢。探索建立三方联动机制，属地政府作为业主单位负责前期土地流转、宣传沟通等工作，引入社会资本作为实施主体，统筹推进产业策划、方案设计、项目融资、开发建设和后续运营等工作，注重导入优质产业形成“整治—增值—再投资”的正向循环，着力构建全域土地综合整治良性循环的“自我造血”发展模式。

二、广州市从化区全域土地综合整治的启示

土地全域综合整治是一项资金量需求巨大的系统工程，社会资本的引入对于全域土地综合整治的持续性和项目的全面推进至关重要。由此，必须多渠道引入社会资本参与，才能有效缓解财政资金紧张的局面，提高项目的资金保障能力，确保整治工作的

顺利进行。同时，社会资本的参与还可以带来更多的专业经验和先进的管理模式，提升整治项目的运营效率和效果。基于从化的实践，在推进全域土地综合整治中，至少有以下四个方面的关键问题需要引起重视。

（一）整治目标需要继续厘清，避免片面追求经济效益。全域土地综合整治旨在促进城乡融合发展，缩小城乡差距，实现资源优化配置和生态环境的修复。从化根据不同区域的自然条件、社会经济发展需求，对全域土地综合整治项目进行差异化设计：北部主抓生态修复，西部主打城乡融合发展，中部着重都市综合提升，南部重点在产业转型提质。在执行过程中，各区域都强调了全域土地综合整治的不同分目标，而且主要着眼于经济效益，导致整治工作的重点还有待进一步突出，效果有待进一步提升。同时，与不同区域的多样化相对应，各区域的监督考核机制的针对性也有待加强。例如，针对耕地保护目标，应重点监督考核土地平整和灌溉设施建设，以及耕地面积增加量；针对生态修复目标，应重点监督考核植被恢复和水土保持，生态环境改善等指标；针对集体建设用地整理盘活目标，应重点考核建设用地利用效率等。

（二）财政资金难以覆盖整治需求，存在地方隐性债风险。由于整治项目的复杂性和规模性，前期需要大量的资金投入，但全域土地综合整治投资回报周期长。尽管区财政和专项债为全域土地综合整治提供了初始资金支持，但这些资金远不足以覆盖整治项目的全部需求。而且，财政资金紧张和专项债发行未来面临不确定性，使得从化区在推进全域土地综合整治的过程中面临着巨大的资金压力。特别是专项债、政策性贷款等依靠项目经营性

收益（比如农业种植、停车、广告等经营性收益）作为还款来源，但这些项目经营性收益的不确定性太大，据此测算进行贷款，容易造成隐性债务问题。

（三）整治项目融资面临系列难题，社会资本引入有难度。**一是**与高速公路、地铁等项目相比较，全域土地综合整治的项目投资回报周期较长，难以形成稳定的现金流，投资风险较大，融资有难度。**二是**全域土地综合整治的项目规模大，融资门槛较高，叠加行业认知度较低，融资渠道受限。**三是**面临国际、国内经济增长的不确定性，叠加土地价格下降等因素，投资环境不确定性增加，导致社会资本在投资决策上更加谨慎，招商引资进度较慢。**四是**全域土地整治需要各部门积极协调，九龙治水的情况下，潜在成本较高。**五是**全域土地综合整治项目未来主要依靠区属国企运营，但是，区属国企土地整治项目运营管理经验不足，难以有效吸引社会资本积极参与。**六是**全域土地综合整治涉及多个领域，相关产业体系尚未成熟，吸引社会资本参与的配套产业不够健全，市场基础不够牢固。

（四）用地权益保障不足，社会资本参与的投融资受阻。**一是**集体经营性建设用地的权益保障问题。从化区不属于集体经营性建设用地入市试点，由此，在集体经营性建设用地上建设的厂房及其它附着物等产权证件均归村集体所有，企业无法为这些厂房及其它附着物单独办理产权证，更难以用作融资抵押，影响投资项目的顺利开展。**二是**缺乏产权保障和融资支持，投资风险评估偏高。土地是良好的质押品，由于集体建设用地缺乏产权保障，加剧社会资本融资困难，进一步影响社会资本的投资意愿，进而影响全域土地综合整治项目的招商引资进度。如何唤醒农村

沉睡资产，破解农村土地融资难题，促进全域土地综合整治项目的顺利实施和预期目标的实现，亟需“顶层设计”进行改革和创新。

三、以全域土地综合整治为切入口推进社会资本下乡的建议

（一）平台蓄水，精准投放。政府要划分好整治单元，系统谋划有一定收益率的整治项目包，促进项目统一谋划、统一立项、统一实施、统一监管。要以全域土地整治为平台，整合各类资源，设定全域整治专项资金，对地方政府谋划的项目包择优配套专项资金。比如，可以借鉴海南省琼中黎族苗族自治县的做法，采取“信息公开+实施方案评选+土地超市”方式，为优质项目包公开遴选社会资本投资主体，促进社会资本精准投放。同时，对遴选出的优质项目包，要明确项目投资回报机制，委托专业机构研究成立全域土地整治公益基金，形成公众可广泛参与、灵活退出的项目融资机制。

（二）试点叠加，形成合力。推进全域土地综合整治试点与“三块地”改革试点叠加，积极探索农村集体经营性建设用地入市试点同等权利，最大限度发挥全域土地综合整治的积极效应，有效激发市场主体参与土地整治的积极性，为有效化解融资难题提供支持，强化发展保障，实现长期稳定经营。例如，鼓励社会资本按照EOD（生态导向开发）理念参与乡村生态公益林建设、乡村人居环境整治、水环境治理等，在合法合规的前提下向社会资本配置一定的集体经营性建设用地等资源，实现产业发展对公益性投入的反哺。

同时，根据国土空间规划编制的要求，开展拆旧的闲置建设用地均为“三调”的村庄建设用地（203），腾退后的建设用地用

于新区建设时，也应规划为村庄建设用地。该规定一定程度上限制了用地的使用范围和项目的准入，也一定程度降低了全域土地综合整治中镇村对拆旧和建新工作的积极性及社会资本参与的热情。为此，需要制度创新，对全域土地综合整治中通过实施增减挂钩腾退的建设用地，允许其可统一按城镇用地进行管理和使用。

（三）以地聚财，筑巢引凤。要按照区域发展定位与功能分区，坚持产业规划先行。将产业招商环节前置，按照产业发展需求进行土地整备，为优质产业量身定制用地，更加合理有效地利用和盘活土地资源，促进产业集聚。厘清各类用地产权，充分运用留白用地、点状供地等机制，更加灵活地保障乡村产业多元用地需求，促进乡村一二三产融合发展。更加充分利用属地政府的产权交易服务平台，承担全域土地综合整治项目的产业招商信息公开发布、行业动态跟踪以及交易撮合等市场化服务。通过在平台上发布招商意向信息，吸引各类社会资本参与投资，并依托农村产权交易平台开展统一规范、高效便捷、阳光透明的交易服务。平台同步展示全域土地综合整治相关政策文件及解读，以及全域土地整治、乡村振兴等工作开展的最新动态等，以更加充分的信息公开，吸引更多的“凤凰”进驻。

（四）拓宽渠道，引导参与。拓展全域项目新的收益来源，真正实现“投、融、设、建、管、营”一体推进，实现“有为政府”和“有效市场”相结合。积极探索建立绿色金融机制，支持金融机构创新金融产品和金融服务。充分利用开发性金融机构、政策性银行和其他金融机构对全域土地综合整治的支持政策，拓展资金来源渠道。依托金融创新，为政府、企业和镇村提供多元

化的多种债权和股权融资渠道。债权融资渠道包括土地融资信托、土地银行、土地资产证券化及土地售后回租等。股权融资渠道包括产业投资基金（REITS等）、土地“类房地产投资信托基金”。强化政府部门间的协同治理，提供信用背书，共担监管职责。设立专项资金，完善全域土地整治贴息贷款政策，建立全域土地综合整治互助基金，避免贷款坏账、资金链断裂对项目推进带来的负面影响。

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