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Academic achievement and mental health of left-behind children in rural China

A causal study on parental migration

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Abstract

Purpose – China's rapid pace of urbanization has resulted in millions of rural residents migrating from rural areas to urban areas for better job opportunities. Due to economic pressures and the nature of China's demographic policies, many of these migrants have been forced to leave their children with relatives – typically paternal grandparents – at home in the countryside. Thus, while income for most migrant families has risen, a major unintended consequence of this labor movement has been the emergence of a potentially vulnerable sub-population of left-behind children (LBCs). The purpose of this paper is to examine the impacts of parental migration on both the academic performance and mental health of LBCs.

Design/methodology/approach – Longitudinal data were drawn from three waves of a panel survey that followed the same students and their families – including their migration behavior (i.e. whether both parents, one parent, no parent migrated) – between 2015 and 2016. The survey covers more than 33,000 students in one province of central China. The authors apply a student fixed-effects model that controls for both observable and unobservable confounding variables to explicate the causal effects of parental migration on the academic and mental health outcomes for LBC. The authors also employ these methods to test whether these effects differ by the type of migration or by gender of the child.

Findings – The authors found no overall impact of parental migration on either academic performance or mental health of LBCs, regardless of the type of migration behavior. The authors did find, however, that when the authors examined heterogeneous effects by gender (which was possible due to the large sample size), parental migration resulted in significantly higher anxiety levels for left-behind girls. The results suggest that parental migration affects left-behind boys and girls differently and that policymakers should take a more tailored approach to addressing the problems faced by LBCs.

Originality/value – The main contributions of this paper come from the large and representative sample, as well as the causal effects analysis of being left-behind on both academic performance and mental health. First, the paper uses comprehensive panel data from a representative and populous province in China, and the sample size is the largest one among LBC-related papers to the authors' knowledge. Second, the paper separately examines the causal effects on the student outcomes of different migration strategies. Third, the paper analyzes the heterogeneous effects of different migration strategies on LBC gender. The authors believe that the paper makes a key contribution to the literature.

Keywords Mental health, Rural China, Left-behind children, Academic achievement, Parental migration

Paper type Research paper

1. Introduction

As China has undergone unprecedented urbanization over the past three decades, many parents in rural communities have migrated to cities in search of work, often leaving their children behind in the countryside (Hu *et al.*, 2008; Wen and Lin, 2012; Ye *et al.*, 2006; Huang *et al.*, 2012; Cai, 2018; Yue *et al.*, 2018). Rural parents are often forced to make this decision for two reasons: raising children in China's cities is often more costly than raising them in the countryside; and current government policy in many cities limits children from receiving social services such as access to public education or health care outside of their hometown (Chen *et al.*, 2001; Wang *et al.*, 2011). As such, the rise of migration in China has thus resulted in the emergence of a large, potentially vulnerable sub-population of more than 60m left-behind children, which henceforth we will refer to as LBCs (All-China Women's Federation, 2013).

Conceptually, however, the impact of migration on LBCs is not clear. On the one hand, parental migration might benefit the children in many ways including better educational performance. For example, the higher income that migrants almost always earn in the cities compared to what can be earned in the countryside could be used for additional support for schooling and health (Alcaraz *et al.*, 2012; Antman, 2012; Malik, 2015; Yang, 2008). On the other hand, the absence of one or both parents, and the falling level of care that would result, could impose costs in terms of educational performance and/or mental health (Zhang *et al.*, 2014; Zhao *et al.*, 2014; Su *et al.*, 2013; Moretti and Peled, 2004).

Empirical studies – which mostly have examined correlations between being left behind and poor educational performance – however, have not produced conclusive results regarding what kind of effect parental migration exerts on children. For example, in some studies research teams found that the effect of parental outmigration is negative (Zhao *et al.*, 2014; Zhang *et al.*, 2014; Liu *et al.*, 2018), mainly due to the fall in the quality of parenting (Duan and Zhou, 2005). In contrast, other studies found positive effects (Chen *et al.*, 2009; Roy *et al.*, 2015). In these studies, parental migration improves household economic circumstances and allows for more investments into the education of children (Alcaraz *et al.*, 2012; Antman, 2012; Malik, 2015; Yang, 2008). Finally, there also are studies that demonstrated that LBCs performed the same academically as children living with both parents (Zhou *et al.*, 2015).

Similarly, empirical work on the relationship between LBCs and mental health is inconclusive. Some researchers have discovered that parental migration imposes negative effects on the mental health outcomes of their children – at least relative to those of their peers (Su *et al.*, 2013; Zhao *et al.*, 2014; Shi *et al.*, 2016). For example, Su *et al.* (2013) found that LBCs have lower levels of psychological well-being (reporting lower life satisfaction and greater loneliness) than children living with both parents. Shi *et al.* (2016) also found that LBCs exhibit higher levels of anxiety and lower levels of self-esteem than non-LBCs. In contrast, other studies reported that there is no significant difference between LBCs and non-LBCs in terms of satisfaction with life and other mental health indicators (Wen and Lin, 2012; Hu *et al.*, 2011).

While there are many reasons why there are differences in findings among different studies, one methodological-based source of the inability to identify the effect of migration is

that most of the studies described above have only examined the correlation/association between parental migration and outcomes (i.e. academic or mental health outcomes). Consequently, there is little evidence of whether any of these relationships are causal. To the best of our knowledge, only one study included data that allowed the researchers to examine the causal relationship between parental migration and children's outcomes (Bai *et al.*, 2016). In this case, however, the authors focused only on academic performance and did not look at the causal effects of migration on mental health. In their study, they found that parental migration had no effect on the academic performance of LBCs. However, also like most previous studies, the study was restricted to a poor, minority autonomous region (Qinghai, an ethnic minority area in rural China – where rates of migration are relatively low: the average rate of migration across China was 18 percent in 2014, and the rate in Qinghai was only 0.4 percent (NBSC, 2015a, b).

While few studies have examined the causal impact of migration on the academic outcomes of students, even fewer have considered the difference between the effects of different types of parental migration (i.e. whether one or both parents are absent), which may be one of the key reasons for the inconclusive results in the existing literature. The past results of studies on the relationship between types of parental migration and LBC outcomes, such as academic performance and mental health, are not always consistent. While Chen *et al.* (2009) and Bai *et al.* (2016) both found that there was no significant difference between the academic performance of those children who had one parent who migrated vs those who had two parents who migrated, in terms of LBC mental health the results are more mixed. Specifically, some studies have found that there to be no significant difference between one-parent migration and both-parent migration (Zhou *et al.*, 2005). In contrast, several other studies have shown that children whose parents have both out-migrated experience higher levels of loneliness and lower levels of life satisfaction compared with children with only one-parent migrating (Sun *et al.*, 2010; Fan *et al.*, 2009). In addition, none of the mental health-related studies determined whether or not the demonstrated effect (or lack thereof) was causal.

Another reason why there is not a clear causal pathway between parental migration and child outcomes is that it is possible that there are different effects of parental migration on different types of children, such as boys and girls. Differences between the familial and societal roles held by boys and girls may result in differences in the effect of parental migration. For instance, it is possible that due to the greater role of males in supporting elderly parents in rural China (as in some other places in the world), increased remittances from migration might be used to expand educational opportunities for boys but not for girls (Hannum *et al.*, 2009; Li and Lavely, 2003; Bansak and Chezum, 2009). In such a situation, we might expect migration to more favorably influence the academic performance of boys as opposed to girls. Likewise, as girls in rural China face a higher likelihood of being called on to do household chores, the loss of a productive adult household member might result in a higher work requirement for girls (and not necessarily for boys), thereby negatively affecting their academic performance and/or mental health (Song *et al.*, 2006; Wei and Tsang, 1999).

The overall goal of this study is to estimate the causal relationship between parental migration and the academic and mental health outcomes of LBCs. To meet this goal, we have three specific objectives. First, the paper studies the causal effects of parental migration on the academic performance and mental health outcomes of children. Second, we examine the impacts of different migration types on children's academic and mental health outcomes (including both parents migrating and one-parent migrating). Third, we explore the question of whether or not there are any differences in the effects of parental migration on children's outcomes between LBC subgroups – in this case, LBC boys and girls.

To meet the paper's objectives, the present study employs a panel data set that consists of three waves of survey data covering more than 33,000 rural students in one province in

central China. To identify the effects of parental migration, we apply a student fixed-effects model that controls for both observable and unobservable confounding variables that are time invariant to explicate the causal effects of parental migration on the academic and mental health outcomes for LBC. We also employ these methods to test whether these effects differ by the type of migration or by gender of the child.

Using this approach, the main findings of this paper provide causal evidence to demonstrate that overall there is no impact of being left behind on either academic performance or mental health, reflecting the results of past correlation studies (Zhou *et al.*, 2015; Lu, 2012; Wen and Lin, 2012; Hu *et al.*, 2011). Regardless of whether we look at academic performance or mental health outcomes, we find that there is no significant impact. This is true regardless of the type of migration. Importantly, our paper also shows that the effect of being left behind is different by child gender. Specifically, left-behind girls, according to the findings, show more math anxiety than left-behind boys, relative to those children that are not left behind.

The main contributions of this paper come from the large and representative sample, as well as the causal effects analysis of being left-behind on both academic performance and mental health. First, the paper uses comprehensive panel data from a representative and populous province in China, and the sample size is the largest one among LBC-related papers to our knowledge. Second, the paper separately examines the causal effects on student outcomes of different migration strategies (including both parents migrating and one-parent migrating). Third, the paper analyzes the heterogeneous effects of different migration strategies on LBC gender. Due to these contributions, we believe that the paper offers a clearer vision of the relationship between being left behind and academic performance and mental health and makes a key contribution to the literature.

The remainder of the paper is organized as follows. Section 2 describes the data used for this paper and discusses the empirical approaches we use to conduct the causal effects analysis of parental migration on LBC academic performance and mental health. We present our results in Section 3. Section 4 concludes.

2. Methods
2.1 Sampling
The sample of this study is from a longitudinal survey conducted over the course of one year in rural areas of Henan province, located in the central China. Henan covers an area of 167,000 km^2 and has a permanent population of over 94m, making it the third most populous province in China. More than 42m people, over 54 percent of the population, live in rural parts of the province. Although Henan is the fifth largest provincial economy in China, its per capita GDP of RMB 3,930.82 is low compared to eastern and some central provinces (NBSC, 2015a, b). Low per capita GDP and the large share of residents who are still living in rural areas and engaged in agriculture contribute to Henan's relative lack of development (Luo, 2010).

With the help of the education department of Henan province, we first obtained a list of junior high schools across rural Henan, which included a total of 300 schools. Then, we randomly selected one math teacher of grades 7–9 each school from these 300 junior high schools, located in 94 counties. All of the students in the class taught by each math teacher were selected to be part of the sample. If a teacher taught more than one class, one of his/her classes was randomly selected to participate in the survey. Using this sampling process, 33,492 students from grades 7–9 were ultimately included in the study.

However, there was some attrition throughout the study. Between the baseline survey in October 2015 and the midline survey in January 2016, 291 of the original 33,467 students (0.8 percent) attrited. By June 2016, there were 2,699 of the original 33,467 students (8.1 percent) who no longer participated in the endline survey. Compared to other studies conducted with LBC in rural China (Shi *et al.*, 2016), however, the rate of attrition is small and unlikely to bias the results of the study.

2.2 Data collection

The data used for this study were aggregated from three survey waves conducted during the 2015–2016 school year. The baseline survey was administered in October 2015. The midline survey was carried out in January 2016. The endline survey was held in June 2016.

Each wave of the survey consisted of three parts. The first part collected detailed information on student individual and family characteristics to use as control variables, including age, gender, grade, parental education levels (i.e. whether their father or mother graduated from junior high school), lives at home, plans to attend academic high school (as opposed to vocational high school), and has skipped class. Importantly (for this study), students were also asked whether their mother and father work and where they work. In this study, we defined parents who worked in other prefectures or provinces as migrant parents, which is the key treatment variable of the study. We also identified different parental migration strategies: only one-parent migrating or both parents migrating. This allowed us to differentiate between the effects of different parental migration types on children's outcomes.

In the second part of each survey, students took a 35 min standardized math exam. Scores on this exam were used as the key measure of academic outcomes. The exam was grade-appropriate and tailored to the national and provincial-level mathematics curriculum, and it was constructed by trained psychometricians using a multi-stage process. Items of the exam were first selected from the standardized mathematics curriculum for each grade (7, 8 and 9). The content validity of these items was checked by multiple experts, including local teachers and professors in the regional normal university. The psychometric properties of the exam were then validated through extensive pilot testing and data analysis. Students took the same exam at baseline and midline and then took a different exam at endline. In the analyses, we standardized each wave of math scores separately.

In the third part of each survey, students were asked about their attitudes toward math (including math-related anxiety, and intrinsic and instrumental motivation); responses to these questions were the key measures of mental health outcomes[1]. Math anxiety, intrinsic motivation and instrumental motivation were measured using specially designed and validated items from the 2012 Programme for International Student Assessment (OECD, 2014). These three dimensions are widely used as measurements of mental/psychological health across the world (Caputo, 2014; Ho *et al.*, 2000; Lee, 2009). We summarized student responses to the items into a single measure of math anxiety, intrinsic motivation and instrumental motivation using the GLS weighting procedure described in Anderson (2008).

2.3 Statistical analysis

We conducted four different types of analyses in this study: a descriptive analysis, a correlational analysis, a causal analysis (overall and by migration type) and a heterogeneous analysis. In the correlational part of our first analysis, OLS multivariate regression analyses were used to estimate the correlation between parental migration and LBC academic performance and mental health outcomes. In order to further explore the relationship according to different parental migration strategies, two sets of model specifications were constructed. While the first set of models includes a single treatment variable – parental migration – that incorporates all migration strategies, the second set of models further divides parental migration into two treatment variables: both parents migrating and only one-parent migrating. The same outcome and control variables were included in both sets of models. Standardized endline math test scores were used as the academic performance outcome variable and math anxiety and motivation as the mental health outcome in both sets of models.

The two regression models are as follows:

$$Y_{is} = \beta_0 + \beta_1 \mathrm{MP}_i + \beta_2 \mathrm{X}_i + \varepsilon_i, \tag{1}$$

where Y_{is} represents educational or mental outcomes for individual i in schools; MP_i is a treatment dummy variable indicating parental migration (1 = migrant parents, including both parents migrating and one-parent migrating, 0 = otherwise); X_i is a vector of controls (student's gender, student's age, grade, lives at home, plans to attend academic high school, has skipped class, parental educational levels, teacher's gender, teacher's experience, teacher's educational level and class size); and ε_i is an idiosyncratic error term:

$$Y_{is} = \beta_0 + \beta_1 MS_i + \beta_2 X_i + \varepsilon_i, \quad (2)$$

where MS_i is a treatment dummy variable indicating different migration strategies, including both-parent migration and single-parent migration. X_i is a vector of controls (student's gender, student's age, grade, lives at home, plans to attend academic high school, has skipped class, parental educational levels, teacher's gender, teacher's experience, teacher's educational level and class size); and ε_i is an idiosyncratic error term.

For the causal analysis, a student fixed-effects model was applied to estimate the impacts of different parental migration strategies on the academic and mental health outcomes of LBC. The causal analysis used the following model:

$$Y_{is} = \beta_1 MS_i + \beta_2 X_i + \beta_3 FE_i + \varepsilon_i, \quad (3)$$

where MS_i is a treatment dummy variable indicating different migration strategies including both-parent migration and single-parent migration; X_i is a vector of controls (student's gender, student's age, grade, lives at home, plans to attend academic high school, has skipped class, parental educational levels, teacher's gender, teacher's experience, teacher's educational level and class size); FE_i is student fixed effects, and ε_i is an idiosyncratic error term.

Finally, we carried out the heterogeneous analysis segment of our study. We did this in order to compare the causal impacts of parental migration on female and male LBCs using the fixed-effects model specified above.

3. Results
3.1 Descriptive results
Descriptive statistics for the sample at the baseline year 2015 are presented in Table I. Among the 33,467 participants in the baseline survey, 15,848 are female and 17,628 are male. The mean age of the participants is 13, indicating that our sample consists largely of students in their adolescent stage of development. Given that adolescence is a unique developmental phase of life during which psychosocial neural pathways evolve and mature, it is possible that we find upwardly biased results since adolescents are already at a heightened risk of mental disorders and consequently school failure (McGorry *et al.*, 2007).

As our sample is representative of rural Henan province, China's third most populous province, it is also representative of rural China as a whole. Henan has a large population size of over 94m persons, making it the third most populous province in China – if it were a country, it would rank it as the 14th largest in the world. The rural population also exceeds 50m, making it the province in China that has the largest rural population in the nation (NBSC, 2015a, b). The per capita GDP in China also ranks it fifth in the nation. In this sense, we are studying a large and important and representative in the sense of our income metric.

The histograms in Figure 1 demonstrate the distribution of different parental migration types among our sample during the three survey periods. Similar to the migration phenomena in many other rural areas of China (Rozelle *et al.*, 1999), more than half of households included in our study had members in the migrant labor force. The total number of migrants from our sample province (Henan) is over 21m, which makes the province the largest sender of any province in China (NBSC, 2010). Of the 29,695 households in our sample, 22,236 (74.9 percent) had at least one parent who had out-migrated. Within the

	Mean	SD
Demographic, family and teacher characteristics at baseline		
1. Female students (1 = yes)	0.473	0.499
2. Grade	7.623	0.691
3. Student age (in years)	13.790	1.098
4. Plan to attend vocational high school after JH (100 = yes)	30.654	23.045
5. Plan to attend academic high school after JH (100 = yes)	48.052	28.976
6. Ever skipped class (1 = yes)	0.145	0.352
7. Father graduated from junior high school (1 = yes)	0.560	0.496
8. Mother graduated from junior high school (1 = yes)	0.466	0.499
9. Live home (1 = yes)	0.335	0.472
10. Teacher gender (1 = male)	0.448	0.497
11. Teaching experience (in years)	14.860	9.085
12. Teacher education level (1 = college or above)	0.333	0.471
13. Class size	59.301	16.259
Endline measures of outcome variables		
13. Standardized value of endline math test score	0	1
14. Standardized value of endline math anxiety	0	0.726
15. Standardized value of endline intrinsic motivation	0	0.854
16. Standardized value of endline instrumental motivation	0	0.870

Table I.
Summary statistics
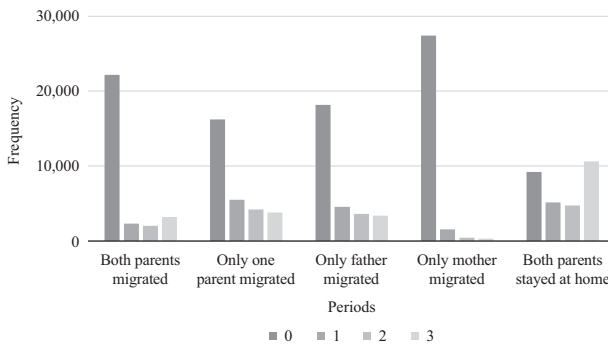
Figure 1.
Treatment frequency
patterns across three
survey time periods
(October 2015,
January 2016
and June 2016)

sample of migrant households, there are differences in the prevalence of different types of migration. Only one-parent migrating was the most commonly employed migration strategy, with 45.3 percent of all sample households (13,464 out of 29,695) experiencing the outmigration of a single parent during the three waves of our study; only 25.3 percent (7,504 out of 29,695) of sample households had both parents migrating during at least one wave of the survey.

We also examine only one-parent migrating in further detail, looking at situations when only the father migrated and only the mother migrated separately. We find that it was more frequent for a father to migrate while the mother stayed at home. Of the 22,236 households with out-migrants, in 11,495 the father migrated while the mother stayed at home during at least one wave of the study, which constitutes 38.7 percent of all the households. Finally, of all the households in which one-parent migrated, in 85.4 percent of these it was the father who migrated.

It was significantly less common for mothers to migrate. The mother migrated while the father stayed at home in only 2,198 households, which accounts for 7.4 percent of all the households or 9.9 percent of the migrant households.

3.2 Correlational results

The results of the correlation analysis are presented in Tables II and III. We first show the overall correlation between parental migration and LBC outcomes. We then examine the correlations between different migration strategies and LBC outcomes.

Our results show that, overall, LBCs had significantly lower math scores ($p < 0.1$) and higher anxiety levels ($p < 0.1$) than their peers at endline. However, these differences did not hold for the other mental health outcomes. In fact, the differences between LBCs and non-LBCs in terms of intrinsic and instrumental motivation were relatively small and statistically insignificant (Table II).

To better understand the differential effects of migration practices, we further divide the treatment variable parental migration into both parents migrating and only one-parent migrating (see Table III). The results show that the average correlation of the migration strategy only one-parent migrating on math score is negative and statistically significant ($p < 0.1$); it is also positively correlated with math anxiety ($p < 0.1$). However, the results from the comparisons among math score, intrinsic and instrumental motivation between children who had both parents migrating and non-LBC were not statistically significant, indicating that there are no significant differences between these two groups in terms of academic and mental health outcomes.

At least, one of these findings has been previously documented in the existing literature. Our finding that non-LBC outperforms LBC in both academic and mental health outcomes is in line with past research (Hu, 2013; Meyerhoefer and Chen, 2011). Taken together, these results suggest that different migration strategies may correlate with both academic and mental health outcomes for the children of migrating parents. Specifically, when single-parent migration is linked with poorer child outcomes, situations when both parents migrate seem to not have such a correlation. In order to investigate these different outcomes with higher validity, we next used fixed-effects models to explore the causal impacts of parental migration on LBC.

Table II.
Correlational relationships between parental migration status and children's math achievement and mental health

	Math score (endline)	Math anxiety (endline)	Intrinsic motivation (endline)	Instrumental motivation (endline)
Parental migrating	−0.0335*** (0.0117)	0.0210** (0.0090)	−0.0057 (0.0113)	0.0101 (0.0113)
Constant term	0.2026 (0.1367)	−0.2764*** (0.0628)	−0.1097 (0.0908)	0.1495 (0.0906)
No. of observations	29,262	28,953	29,132	29,135

Notes: Robust standard errors are in parentheses adjusted for 299 clusters in schools. Controlling for student gender, student age, grade, whether lived at home, whether wanted to go to vocational/academic high school, whether had skipped class, parents' educational levels, teacher gender, teacher experience, teacher educational level and class size. **$p < 0.05$; ***$p < 0.01$

Table III.
Correlational relationships between two parental migration types and children's math achievement and mental health

	Math score (endline)	Math anxiety (endline)	Intrinsic motivation (endline)	Instrumental motivation (endline)
Both parents migrating	−0.0269 (0.0183)	0.0257* (0.0137)	−0.0105 (0.0168)	0.0066 (0.0166)
Only one-parent migrating	−0.0370*** (0.0119)	0.0175* (0.0094)	−0.0024 (0.0122)	0.0108 (0.0167)
Constant term	0.2042 (0.1367)	−0.2486*** (0.0662)	−0.1025 (0.1024)	0.1308 (0.0954)
No. of observation	29,262	28,953	29,132	29,135

Notes: Robust standard errors are in parentheses adjusted for 299 clusters in schools. Controlling for student gender, student age, grade, whether lived at home, whether wanted to go to vocational/academic high school, whether had skipped class, parents' educational levels, teacher gender, teacher experience, teacher educational level and class size. *$p < 0.1$; ***$p < 0.01$

3.3 Causal results

In order to examine the impact of parental migration on the academic and mental health outcomes of LBCs, we used the student fixed-effects model presented in Equation (3), which allows us to estimate the impact of the time-varying covariate on each student. Table IV presents the academic and mental health outcomes for LBCs and non-LBCs.

In contrast to the correlational analysis in the previous sub-section, the results of the causal analysis do not provide strong evidence that parental migration negatively influences the academic and mental health outcomes of LBCs. When pooling across the migration strategies, the difference between LBC and non-LBC outcomes in both outcome measures is small and insignificant (Table IV, Row 1, Columns 2 and 3).

We also find that this holds true regardless of the parental migration type. Although the migration of only one parent does have a larger negative effect on LBC math score as well as a larger positive effect on LBC math anxiety compared to when both parents migrate (Table V, Row 2, Columns 2 and 3), the effects are still small and statistically insignificant.

3.4 Heterogeneous results

Do the effects of migration differ by the gender of the children? We next explore this question by examining the heterogeneous effects of parental migration across subgroups of LBC by gender, as these effects may better explain the differences in endline outcomes that were found in the correlational analysis (though not found in causal analysis). To estimate the effects, we run regressions analogous to Equation (3), and we also divide the sample into left-behind girls and left-behind boys. Table VI presents these results.

	Math score (endline)	Math anxiety (endline)	Intrinsic motivation (endline)	Instrumental motivation (endline)
Parental migrating (both parents or only one-parent migrating)	−0.0169 (0.0163)	0.0074 (0.0140)	−0.0006 (0.0146)	−0.0015 (0.0159)
Constant term	0.0699*** (0.0121)	−0.0259*** (0.0111)	0.0281** (0.0117)	0.0412*** (0.0134)
No. of observations	58,766	58,411	58,612	58,614
R^2	0.773	0.656	0.695	0.625

Notes: Robust standard errors are in parentheses adjusted for 299 clusters in schools. For math scores, controlling for math scores in the previous period and parental migration status in the previous period; for mental health outcomes, controlling for mental health scores in the previous period and parental migration status in the previous period. $**p < 0.05$; $***p < 0.01$

Table IV. Impacts of parental migration on left-behind children's math achievement and mental health

	Math score (endline)	Math anxiety (endline)	Intrinsic motivation (endline)	Instrumental motivation (endline)
Both parents migrating	0.0089 (0.0249)	0.0053 (0.0205)	0.0015 (0.0212)	−0.0167 (0.0227)
Only one-parent migrating	−0.0235 (0.0166)	0.0079 (0.0147)	−0.0011 (0.0159)	0.0022 (0.0171)
Constant term	0.0650*** (0.0126)	−0.0252** (0.0114)	0.0276** (0.0120)	0.0447*** (0.0137)
No. of observations	58,766	58,411	58,612	58,614
R-squared	0.773	0.656	0.695	0.625

Notes: Robust standard errors are in parentheses adjusted for 299 clusters in schools. For math scores, controlling for math scores in the previous period and parental migration status in the previous period; for mental health outcomes, controlling for mental health scores in the previous period and parental migration status in the previous period. $**p < 0.05$; $***p < 0.01$

Table V. Impacts of two parental migration types on left-behind children's mental health and math achievement

	Female students				Male students			
	Math score	Math anxiety	Intrinsic motivation	Instrumental motivation	Math score	Math anxiety	Intrinsic motivation	Instrumental motivation
Parental migrating (both parents or only one-parent migrating)	−0.0079 (0.0200)	0.0304* (0.0170)	0.0050 (0.0197)	0.0169 (0.0212)	−0.0248 (0.0238)	−0.0140 (0.0201)	−0.0057 (0.0231)	−0.0195 (0.0248)
Constant term	−0.1677*** (0.0156)	0.0422*** (0.0137)	−0.0163 (0.0162)	0.0863*** (0.0179)	−0.0253 (0.0170)	0.0960*** (0.0156)	0.0702*** (0.0176)	0.0049 (0.0203)
No. of observations	28,798	28,632	28,726	28,722	29,883	29,695	29,801	29,807
R^2	0.761	0.696	0.717	0.637	0.780	0.616	0.678	0.613

Notes: Robust standard errors are in parentheses adjusted for 299 clusters in schools. For math scores, controlling for math scores in the previous period and parental migration status in the previous period; for mental health outcomes, controlling for mental health scores in the previous period and parental migration status in the previous period. $*p < 0.1$; $***p < 0.01$

Table VI.
Impacts of parental migration on math achievement and mental health of left-behind girls and left-behind boys

We find that although parental migration does not seem to influence the intrinsic or instrumental motivation of LBCs regardless of gender, we do find that parental migration significantly impacts girls more in terms of mental health. Although it is beyond the scope of this paper to identify the exact reasons behind the different effects on boys and girls, one possible reason is that these gender disparities already exist in general and that once migration occurs the absence of parents exacerbates the problem. Past research in rural China has shown that in general girls are more susceptible than boys to mental health issues like anxiety (Zhou *et al.*, 2016) and that emotional support from parents may have a stronger impact on the mental well-being of girls than boys (Cross and Madson, 1997; Ma and Huebner, 2008). Thus, the psychological well-being of girls therefore might be more negatively impacted when they lose the emotional support of their parents. Girls with migrant parents might also be more at risk for mental health issues due to the gender-biased labor division in rural China. As mentioned in the introduction of this paper, when parents migrate, oftentimes the burden of household chores falls upon the girls they leave behind (Song *et al.*, 2006; Wei and Tsang, 1999). Thus, girls might be forced to sacrifice their own independence and freedom and thus unwillingly take on more responsibility in order to take care of the household. This could in turn promote their feelings of anxiety.

4. Conclusions

Based on a quasi-experimental framework, our study examined the impact of parental migration on the academic and mental health outcomes of LBC in rural China. By comparing the math scores as well as math anxiety and motivation of children with different parental migration status, this paper provides evidence on whether the academic and mental outcomes of LBC suffer when one parent or both parents migrate elsewhere for work. Specifically, this paper fills the gap in the existing literature by using rich longitudinal data of a large sample to explicate the causal effect of parental migration on the academic and mental health outcomes for LBC in rural China and by showing the impact of migration type as well as the heterogeneous effects between LBC subgroups (boys vs girls).

One main finding should be highlighted. Specifically, we find that parental migration caused a significant increase in math anxiety for left-behind girls. In other words, when the effect on LBCs is not examined separately by gender, we do not find that parental migration significantly impacts LBC outcomes overall. Although the effect of only one-parent migrating is larger than the effect of both parents migrating, neither is significant. This could be the result of the economic benefits (achieved through remittances) that accrue from parental migration, which may help offset the potentially negative impacts on the mental health outcomes of LBCs, such that the overall impact of parental migration on LBCs becomes negligible.

Several limitations of this study require careful consideration when interpreting its results. First, there are methodological shortcomings: when measuring the impact of parental migration, it was not feasible to randomly assign parents to participate in the intervention and migrate away from home. Biased results could be produced if the parents who ended up in the treatment group systematically differ from those that did not undergo the intervention in characteristics associated with both the treatment and the outcome. Although the student fixed-effects design attempts to overcome this bias by looking at changes within each student, which by design controls for observable and unobservable characteristics that are time invariant, the estimates could still be affected if there are unobservable confounders that change over time.

Moreover, this study only examines the effects of parental migration during one school year, which lasted for eight months. It is possible that impacts could change significantly over a longer period of time. It could be the case, for instance, that the longer the period of time that parents are away, the more severe the effects are on the LBC experience. However, it is also possible that the negative effects of family disruption might diminish in subsequent periods,

as household dynamics might stabilize after a parent's initial move. Moreover, any positive effects due to remittances sent back home from migrant parents are likely to increase as time goes on; if these positive effects are larger, LBC outcomes may improve over time.

Nevertheless, even with the abovementioned limitations, our results have some important implications. Our findings, which suggest that migration affects LBCs in different ways depending on child gender, call to attention the need for a more focused policy approach tailored toward the specific needs of boys and girls. As for left-behind girls, who may be more susceptible mental health issues, schools should broaden access to additional psychological counseling.

The effects found during the relatively short time period of this study could imply more significant effects of migration in the long run and therefore suggest the need for more long-term research in the future. Future research should also examine in finer detail the mechanisms by which parental migration affects LBC academic outcomes and mental health. A deeper understanding of LBC's mental health as a mediator for student academic outcomes is also needed. Not only would such investigations contribute to more accurate depictions of the impacts of parental migration on LBC, but they would also shed light on effective interventions that can be used to target the very core of the problem.

Note

1. The mental health outcomes were measured by survey questions based on a four-point scale. For example, one of the survey questions about math anxiety asked "I worry about studying math all the time: 1 = strongly agree; 2 = agree; 3 = disagree; 4 = strongly disagree."

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Urban segregation and food consumption
The impacts of China's household registration system

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Abstract

Purpose – The purpose of this paper is to investigate the impacts of China's urban segregation caused by *hukou* restrictions on food consumption.

Design/methodology/approach – Based on the 2007–2009 Urban Household Survey data from six China provinces conducted by the National Bureau of Statistics of China, the authors adopt a propensity score matching (PSM) method to correct for potential selection bias. A Rosenbaum bounds test is applied to evaluate the sensitivity of the PSM results to unobserved variables.

Findings – The results show that holding rural *hukou* (RHs) reduces the consumption of livestock products and vegetables and fruit by 8.8 and 4.8 percent, respectively. The status of *hukou* does not affect the consumption of grain and edible oil. *Hukou* impacts on food consumption are heterogeneous across income levels, with low-income and middle-income households more vulnerable to urban segregation and *hukou* discriminations. A stronger motivation for precautionary saving and higher welfare expenditures that not compensated by social security lead to the lower food consumption by migrant households with RHs.

Originality/value – This paper advances the research frontier by investigating the impacts of *hukou* system on the structure of food consumption, which accurately reflects the household welfare.

Keywords Food consumption, Migrants, *Hukou* system, Urban segregation

Paper type Research paper

1. Introduction

Urban segregation is the result of economic restructuring and is relevant to social welfare (Musterd and Ostendorf, 1998). Since the economic reform launched in 1978, the urbanization rate in China has increased from 17.9 to 58.5 percent (National Bureau of Statistics of China (NBSC), 2018a). The population of rural–urban migrants grew from 25m in 1990 to 287m in 2017,

with an annual increase of 9.1 percent (NBSC, 2018b). The rural–urban migrants can obtain legal temporary residence in urban areas, but due to the constraints of China's household registration (*hukou*) system, they cannot gain full access to urban services and thus are segregated from the local urban residents (Cai *et al.*, 2016).

Introduced by the Chinese Government in the 1950s, the *hukou* system initially identified rural and urban households based on the place of residence to control internal migration. Rural residents started to work in cities and became "migrant workers" in the 1980s along with China's rapid economic growth. Despite efforts to remove barriers to labor mobility across regions, the current *hukou* system prevents rural–urban migrants from staying in urban areas permanently[1]. Households living in urban areas thus are divided into two segmented groups by *hukou* status: local households with urban *hukou* (UHs) and migrant households with rural *hukou* (RHs). Without UHs, RHs are discriminated against in education, health care, employment opportunities and public services (Chen *et al.*, 2013; Fang and Sakellariou, 2016; Gersovitz, 2016; Meng, 2012; Whalley and Zhang, 2007; Zhu, 2004). For instance, RHs are generally employed on short-term contracts by government offices and state-owned enterprises (SOEs) in cities. They face both hiring and wage discrimination especially in the high-wage SOEs (Song, 2016). RHs are not entitled to fringe benefits ranging from subsidized housing, state pension, medical insurance and enrolling children in public schools[2].

The previous literature of *hukou* system has focused on *hukou*-related inequalities in occupational attainment, wages, health status, happiness and subjective well-being (Afridi *et al.*, 2015; Jiang *et al.*, 2012; Lee, 2012; Liu, 2005; Meng and Zhang, 2001; Song, 2016). Afridi *et al.* (2015) show that making *hukou* identity salient significantly reduces the performance of rural migrant students, and potentially exacerbating income inequalities in urban areas. Jiang *et al.* (2012) find that subjective well-being of people living in cities is negatively correlated with *hukou*-related inequality. This paper advances the research frontier by investigating the impacts of *hukou* system on food consumption. Comparing to income and wages, food consumption measures the household welfare more accurately, since it reflects households' basic needs as well as expenditure planning on expected lifetime income (Cutler and Katz, 1992; Deaton and Zaidi, 2002). The limited access to urban services may substantially restrain RHs' food consumption and welfare gains.

Our study focuses on comparing the consumption behavior between UHs and RHs, rather than that between urban and rural households, or between rural-to-urban migrant and rural households. UHs hold urban *hukou* and RHs hold rural *hukou*, but they both live in cities. Urban living may remove the divergences in food access, tastes and lifestyles of rural migrants from local urban residents (Huang and Bouis, 2001). Since tastes and lifestyles affect food consumption, by comparing the two groups of similar urban lifestyles we are able to identify the impacts of discriminations against RHs on food consumption, not confounded with the location effects.

Different from previous studies of the *hukou* system and consumption expenditures, we directly compare the structure of food consumption between the UHs and RHs. Chen *et al.* (2015) demonstrate that *hukou* constraints reduce the total consumption expenditure of migrants in comparison with local urban residents. Fang and Sakellariou (2016) and Chen (2018) explore the underlying causes for the reducing effect of the *hukou* system on migrant household consumption expenditure. These studies focus on the total consumption level without examining the consumption structure. This paper directly compares consumed quantities across a range of food categories between UHs and RHs, which not only rules out price effects, but also reveals the disparities in household basic welfare between the two groups caused by the *hukou* system.

A propensity score matching (PSM) method (Dehejia and Wahba, 2002; Heckman *et al.*, 1997) is used to correct for selection bias with *hukou* status. Data come from the 2007–2009

Urban Household Survey conducted by NBSC, which covers 19,648 urban and migrant households from six provinces. We apply a Rosenbaum bounds test to evaluate the sensitivity of the PSM method to unobserved variables as a robustness check. The channels through which the *hukou* system affects food consumption are empirically tested.

Our results indicate that holding RHs rather than UHs reduces the consumption of livestock products and vegetables and fruit by 8.8 and 4.8 percent, respectively, whereas *hukou* status does not affect the consumption of gain and edible oil. The *hukou* impacts on food consumption are heterogeneous across income levels: they are significant for low- and middle-income groups but insignificant for high-income groups. RH's stronger motivation for precautionary saving and higher welfare expenditures especially on basic education lead to their lower food consumption.

The remainder of this paper is organized as follows. Section 2 describes the data. Section 3 introduces the PSM method, followed by the empirical results and a robustness check. Section 6 discusses the implications of the results. The final section concludes.

2. Data

We obtained data from the 2007–2009 Urban Household Survey from the NBSC[3]. It covers 19,648 households with urban or RHs from 80 cities in six provinces, with Hebei and Guangdong from the eastern economic zone, Jilin and Henan from the central zone and Sichuan and Xinjiang from the western zone, representing a variety of economic areas in China. The sampled cities account for up to 87.9 percent of the total number of cities in the six provinces, covering the full range from big cities (e.g. Guangzhou and Shenzhen), medium-size cities (e.g. Chengdu and Zhengzhou), to small cities.

The NBSC Urban Household Survey is of high quality and has been used in the food consumption studies of urban China (Gould and Villarreal, 2006; Zheng and Henneberry, 2011; Han and Chen, 2016). The survey sample includes households living in urban areas for at least six months with either UHs or RHs. Unlike most consumption surveys that record only a short period of time, the NBSC survey data are compiled from diaries kept by the household over the course of a 12-month period (Zheng and Henneberry, 2010). Therefore, the data used for this analysis reflect the actual consumption patterns of a household living in cities during an entire year.

The treatment group consists of 865 migrant households with RHs, identified using the "UHs classification" indicator[4]. The remaining households with UHs are treated as the control group. The relatively large sample for the control group ensures that there are enough untreated households to match the treated households. Following the food classification criteria from NBSC, we disaggregate food into four categories: grain, livestock products, edible oil, and vegetables and fruit. We further classify livestock products into red meats (i.e. pork, beef and mutton), poultry, eggs and milk[5].

Table I summarizes our data. The per capita food consumption of RHs is 286.87 kg, which is significantly lower than the 317.55 kg of UHs. The consumption of livestock products and vegetables and fruit of RHs is 65.15 and 145.09 kg per capita, respectively, both of which are significantly lower than the values for UHs. The grain and edible oil consumption of RHs is not significantly different from that of UHs. With regard to household characteristics, RHs tend to have lower per capita real disposable income, larger family size, a higher proportion of seniors and children[6], and are less likely to own housing property than UHs. The average real disposable income of RHs is 11,600 yuan per capita, which is significantly lower than that of UHs (14,500 yuan per capita). The average family size of RHs, 3.30, is significantly larger than the size of 3.01 for UHs, indicating that RHs have more family members. This result partially reflects the impact of the One Child Policy in China implemented prior to 2015: UHs are generally subject to the one-child limit; RHs are allowed a second child if the first child is a daughter.

Variables	Full sample Mean	SD	RHs Mean	SD	UHs Mean	SD	Difference in means Mean
Quantities (KG per capita per annum)							
Food	316.20	113.25	286.87	113.58	317.55	113.05	−30.68*
Grain	67.83	36.87	67.09	40.85	67.87	36.68	−0.78
Livestock products	75.26	36.28	65.15	33.97	75.72	36.32	−10.58*
Red meat	25.37	14.89	22.18	14.51	25.52	14.89	−3.34*
Poultry	10.18	8.67	9.22	7.71	10.23	8.71	−1.01*
Egg	9.82	6.09	9.30	6.33	9.85	6.08	−0.55*
Milk	20.09	17.71	15.80	14.57	20.29	17.82	−4.49*
Edible oil	9.60	6.02	9.55	6.12	9.61	6.02	−0.06
Vegetables and fruit	163.51	62.33	145.09	60.28	164.36	62.29	−19.28*
Household characteristics							
Real disposable income per capita (10,000 yuan)	1.43	1.03	1.16	0.80	1.45	1.03	−0.28*
Family size	3.09	0.83	3.30	0.98	3.01	0.82	0.22*
Proportion of seniors and children (%)	0.57	0.68	0.74	0.76	0.58	0.67	0.18*
Owning house property (Y = 1, N = 0)	0.40	0.49	0.21	0.41	0.40	0.49	−0.19*
Household head characteristics							
Age	43.80	8.08	39.97	8.35	43.97	8.02	−4.01*
Duration of residency in the city	31.05	15.93	16.74	13.42	31.71	15.73	−14.96*
Education	12.20	2.87	10.02	2.48	12.30	2.85	−2.28*
Living area characteristics							
Hebei (Y = 1, N = 0)	0.16	0.36	0.19	0.39	0.15	0.36	0.04*
Jilin (Y = 1, N = 0)	0.07	0.25	0.03	0.17	0.07	0.25	−0.04*
Henan (Y = 1, N = 0)	0.19	0.39	0.17	0.37	0.19	0.39	−0.02*
Guangdong (Y = 1, N = 0)	0.19	0.39	0.38	0.49	0.30	0.46	0.08*
Sichuan (Y = 1, N = 0)	0.30	0.46	0.14	0.34	0.20	0.40	−0.06*
Xinjiang (Y = 1, N = 0)	0.20	0.40	0.09	0.29	0.09	0.29	0.00
City population density (1,000 persons/km^2)	1.56	1.25	1.60	1.26	1.55	1.25	0.05
Sample size	19,648		865		18,783		

Note: *Significant at the 5 percent level

Table I.
Summary statistics

Compared with UHs, RHs have significantly more seniors and children to care for and raise, with a 74 percent proportion of family members over 65 or under 14 years old. Approximately, 21 percent of RHs own housing property, which is significantly less than the value for UHs, of which 40 percent have housing property. The household head of RHs is likely to be younger, to have a shorter period of residency in cities and to have received less education than UHs.

3. Empirical method

Hukou status is determined upon birth and thus almost exogenous for individuals. However, the identification of urban segregation impacts on food consumption caused by *hukou* is confounded with the impacts of education, income and other demographic characteristics correlated with *hukou* status[7]. To correct for selection bias, we use a PSM method (Dehejia and Wahba, 2002; Heckman *et al.*, 1997) to match UHs with similar observed characteristics to RHs.

The propensity score, defined by Rosenbaum and Rubin (1983), is the conditional probability of assignment to a particular treatment given a vector of observed covariates. It is proposed as a balancing score to characterize the similarity between treated and control groups. Controlling for propensity scores, the control households can provide a

plausible counterfactual for the treated households. Rather than characterizing the similarity conditional on multiple covariates, PSM allows households to be compared based on the propensity score alone. This method has been widely applied in impact evaluation studies (Abate *et al.*, 2016; Abebaw and Haile, 2013; Lechner, 2002; Liu and Lynch, 2011). In this study, RHs are the treatment group and UHs are the control group. The treatment thus is the RHs assignment for households living in urban areas.

We construct a probit model to estimate the propensity score:

$$P(X_i) = \text{prob}\left(H_i = 1 | X_i\right) = \int_{-\infty}^{\beta' X_i} \phi(z)dz = \phi\left(\beta' X_i\right), \tag{1}$$

where $P(X_i)$ is the probability of an urban household i possessing rural *hukou*; H_i is an *hukou* index with $H_i = 1$ indicating rural *hukou* and H_0 indicating urban *hukou*; X_i is a vector of relevant factors correlated with the *hukou* status, including all characteristic variables for household, household head and living areas in Table I; β is a parameter vector to be estimated.

Since the PSM estimators are relatively sensitive to matching algorithms for finite samples, we iteratively apply the algorithms of nearest neighbor, kernel and radius, the three commonly used algorithms, to match UHs and RHs (Caliendo and Kopeinig, 2008). The nearest neighbor algorithm matches treated households with untreated households with the closest propensity score. Kernel matching constructs the counterfactual using a weighted average of all untreated units, with the highest weight placed on those with propensity scores that are closest to the treated group. The radius algorithm searches untreated households for matching within a certain caliper.

The average treatment on the treated (ATT) is estimated based on matched samples. Rosenbaum and Rubin (1983) has demonstrated that through pair matching on the propensity score, the difference between treatment and control means is an unbiased estimate of the average treatment effect. We use the logarithm form to obtain the percentage changes in food consumption and derive the ATT as:

$$\text{ATT} = E\left[\ln Y_i^T - \ln Y_i^C | H_i = 1, P(X_i)\right]$$

$$= E\left[\ln Y_i^T | H_i = 1, P(X_i)\right] - E\left[\ln Y_i^C | H_i = 1, P(X_i)\right], \tag{2}$$

where Y_i^T and Y_i^C are food consumption for treatment and control group, respectively.

To ensure that the matching estimators correctly identify the treatment effects, the matching balancing condition and the conditional independence condition must be satisfied. Under these two conditions, a treatment assignment is strongly ignorable; thus, pair matching based on the propensity score can produce unbiased estimates (Rosenbaum and Rubin, 1983). Matching balancing requires that UHs and RHs with the same propensity score have similar or at least not very different characteristics (Becker and Ichino, 2002; Wendimu *et al.*, 2016). We test the matching balancing through a *t*-test (Rosenbaum and Rubin, 1985) and a pseudo R^2 statistics (Sianesi, 2004). The condition of matching balancing cannot be rejected if the means for the two groups or the distribution of covariates between the two groups are not significantly different.

Conditional independence implies that the RHs assignment is independent of the potential outcomes after controlling for the observed covariates. It requires that all variables relevant to the treatment and outcomes are observable (Li, 2013; Rosenbaum and Rubin, 1983; Wendimu *et al.*, 2016). If there are unobserved characteristics that simultaneously affect the treatment assignment and the outcome variables, the PSM estimates for the

treatment effect may be biased. Since conditional independence cannot be directly tested, we apply the Rosenbaum bounds approach (Rosenbaum, 2002) to evaluate the sensitivity of our PSM method to unobserved variables, if they exist.

4. Results

Propensity scores are estimated using the probit model[8]. As shown in Table II, households with lower disposable income per capita, larger family size, smaller proportion of seniors and children, and no house property are more likely to hold RHs. Household heads below the age of 45 are more likely to get UHs as age grows, whereas the probability declines over the age of 45. Household heads with RHs live in cities for a shorter period and are less educated than household heads with UHs.

We match the household samples using three alternative algorithms, including the five-nearest neighbors, kernel (bandwidth = 0.06) and radius (caliper = 0.05). As shown in Figure 1, the propensity scores of the treatment and control groups before matching are significantly different, but they converge after matching.

The test results of matching balancing are presented in Table III. The t-tests show that after matching using the nearest neighbor algorithm, the hypothesis of no difference in means between the treated and control groups cannot be rejected. This result suggests that matching balancing condition is satisfied using the nearest neighbor algorithm. For the other two algorithms, this hypothesis is rejected for at least one covariate. According to Sianesi (2004), the pseudo R^2 statistics should be low if there are no systematic differences in the distribution of the covariates after matching. Our results indicate that matching using the five-nearest neighbor algorithm is preferred among all of the algorithms.

The impacts of *hukou* on food consumption are estimated using Equation (2)[9]. Table IV (columns 2) reports the estimation results based on the nearest neighbor algorithm. RHs' food consumption is significantly lower than that of UHs, indicating that RHs reduce food consumption by 4.7 percent.

Variable	Coefficients	Bootstrap SE	Marginal effect
Household characteristics			
Real disposable income per capita	−0.110***	0.029	−0.008
Family size	0.121***	0.029	0.009
Proportion of seniors and children	−0.080**	0.035	−0.006
Owning house property (yes = 1, no = 0)	−0.275***	0.042	−0.020
Household head characteristics			
Age of household head	−0.090***	0.020	−0.007
Age of household head sq.	0.001***	0.000	0.000
Duration of residency in the city of household head	−0.030***	0.002	−0.002
Education of household head	−0.167***	0.007	−0.012
Living area characteristics			
Hebei (yes = 1, no = 0)	−0.051	0.096	−0.004
Jilin (yes = 1, no = 0)	−0.218*	0.119	−0.016
Henan (yes = 1, no = 0)	−0.159*	0.089	−0.012
Guangdong (yes = 1, no = 0)	−0.044	0.077	−0.003
Sichuan (yes = 1, no = 0)	−0.316***	0.078	−0.023
City population density	0.021	0.020	0.002
Cons.	3.281***	0.438	−0.008
Log likelihood = −2,699.513			
Pseudo R^2 = 0.239			
Notes: *,**,***Significant at 10, 5 and 1 percent levels, respectively			

Table II.
Results of
probit model

(a)

(b)
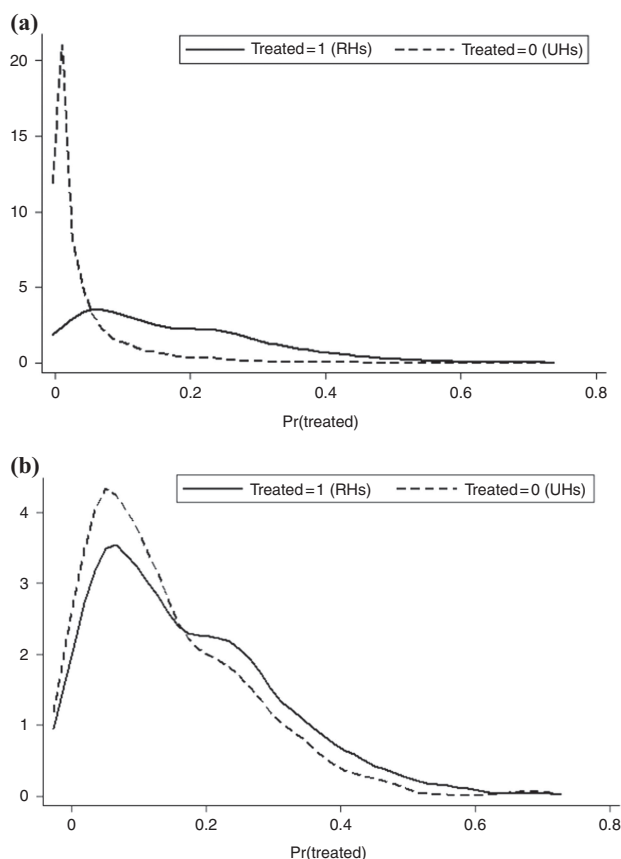
Notes: RHs represent migrant households with rural *hukou*, and UHs
represent urban households with urban *hukou*. (a) Distribution of
propensity scores before five-nearest neighbor matching;
(b) distribution of propensity scores after five-nearest neighbor
matching

Figure 1.
Propensity score
distribution of
treatment and control
groups before and
after matching

For the main food categories, the consumption of livestock products and vegetables and
fruit is significantly different between UHs and RHs, while the consumption of grain and
edible oil is not significantly different between the two groups. RHs reduce the consumption
of livestock products by 8.8 percent, and vegetables and fruit by 4.8 percent. The sub-
category consumption of livestock products is significantly different between UHs and RHs,
except for egg consumption. RHs significantly decrease the consumption of red meat,
poultry and milk by 9.8, 9.5 and 9.8 percent, respectively. These results imply that *hukou*
cause disparities in food consumption between urban and migrant households. Méjean *et al.*
(2008) found that food consumption eventually will converge for local and migrant residents
along the path of acculturation. We add a different perspective that migration alone does not
fill the gap in food consumption between the two groups as long as urban segregation and
discrimination against migrants exist.

To further capture the impact heterogeneity across households, we partition the
distribution of real disposable income for RHs into three equal proportions, i.e., low, medium

Variables	NN5 matching[a]	% Bias after KN matching[b]	RD matching[c]
Household characteristics			
Real disposable income per capita (10,000 yuan)	−0.5	−1.3	−1.5
Family size	−5.6	−1.2	−0.8
Proportion of seniors and children (%)	1.1	4.6	4.8
Owning house property (yes = 1, no = 0)	−2.0	−7.6	−8.0
Household head characteristics			
Age	−3.8	−9.6	−9.9*
Duration of residency in the city	−4.0	−16.2*	−17.1*
Education	4.6	−2.5	−3.3
Living area characteristics			
Hebei (yes = 1, no = 0)	−0.6	1.6	−4.3
Jilin (yes = 1, no = 0)	−1.1	−4.2	−0.4
Henan (yes = 1, no = 0)	2.7	−0.5	3.6
Guangdong (yes = 1, no = 0)	−1.9	3.5	−3.1
Sichuan (yes = 1, no = 0)	−1.4	−3.0	2.4
City population density (1,000 persons/km^2)	0.9	2.4	−4.3
Pseudo R^2	0.002	0.007	0.008

Notes: [a]Matching using five-nearest neighbor algorithm; [b]matching using kernel algorithm with bandwidth of 0.06; [c]matching using radius algorithm with caliper of 0.05. *Significant at 5 percent level

Table III.
Tests of matching quality

			Income level	
Consumption	Full sample	Low	Middle	High
Food	−0.047*	−0.057*	−0.069**	−0.015
Grain	−0.017	0.003	−0.011	−0.041
Livestock products	−0.088***	−0.147***	−0.148***	0.006
Red meat	−0.098**	−0.138***	−0.161***	0.060
Poultry	−0.095*	−0.117*	−0.090	0.078
Egg	0.005	−0.077	−0.065	0.031
Milk	−0.098*	−0.262***	−0.230***	−0.084
Edible oil	0.009	0.047	0.055	0.058
Vegetables and fruit	−0.048**	−0.064*	−0.077***	−0.005

Notes: *,**,***Significant at 10, 5 and 1 percent levels, respectively

Table IV.
Estimated effects of *hukou* on food consumption

(with threshold of 9,090.43 yuan) and high levels (with threshold of 15,347.73 yuan). We estimate the ATTs for each group using nearest neighbor algorithm and present the results in Table IV.

In contrast to the full sample, high-income RHs are not significantly different from UHs in the consumption of total food. However, RHs in the low- and middle-income groups consume significantly less food than their counterparts, which are most pronounced in food categories with relatively high-income elasticity, i.e., livestock products and vegetables and fruit (Han and Chen, 2016). Specifically, for the middle-income group, RHs consume 6.9 percent less food than UHs. The gap is 14.8 and 7.7 percent for livestock products and vegetables and fruit, respectively. For the sub-categories of livestock products, the RHs' consumption of red meat and milk is lower than that of UHs by 16.1 and 23.0 percent, respectively. For the low-income group, RHs consume 5.7 percent less food than UHs, which is smaller than the consumption gap for the middle-income group. The consumption gaps in

livestock products and vegetables and fruit between low-income UHs and RHs are 14.7 and 6.4 percent, respectively. Among livestock products, RHs consume significantly less red meat, poultry and milk than UHs. These results indicate that low-income and middle-income households are more vulnerable to *hukou* discriminations. Growth in income may help to reduce disparities in food consumption between UHs and RHs.

We also stratify the entire sample into quantiles based on the level of total food consumption. The estimated results from the quantile-based PSM are shown in Table V. Our finding that *hukou* status does not affect the consumption of grain and edible oil is consistent across quantiles. For the consumptions of livestock products and vegetables and fruits, the quantile-based PSM provides a more differentiated picture. The *hukou* impacts on the consumption of livestock products are insignificant at the two lowest quantiles, but become significant at and above the median. The gap in the consumption of vegetables and fruits between UHs and RHs is significant at the 90th percentile, but insignificant at all lower quantiles.

5. Robustness check

The PSM method provides reliable estimates if there are no unobservable factors simultaneously related to *hukou* status and food consumption decisions. Given the data set, we have included as complete a set of household and living area characteristics as possible to ensure that the conditional independence assumption is satisfied. With a comparison of UHs and RHs who both live in cities, the potential unobserved confounders in this study are embodied mainly in individual traits, such as food habits, cultural values and customs, which may influence households' demand for food but are not fully captured by the observed covariates.

To examine the robustness of the PSM results to possible unobserved confounders, we use the Rosenbaum bounds test, which directly measures the magnitude of hidden bias. This test relies on the sensitivity parameter Γ, which represents the departure degree from a random assignment of treatment. For example, the value $\Gamma = 1$ ensures random treatment, while $\Gamma = 2$ indicates that for households with identical observed characteristics, one may be twice as likely as the other to receive RHs because they differ in unobserved covariates (Rosenbaum, 2005). We test for hidden bias from unobserved factors through a sensitivity analysis on Γ. When the *p*-value reaches the threshold of 0.05, higher values of Γ indicate that larger differences in unobserved characteristics are needed to change the inferences; thus, the results are more robust.

The results of Rosenbaum bounds test indicate that estimated ATTs from the PSM method are relatively robust to unobserved factors. As shown in Table VI, *hukou* effects on

Consumption	10th	25th	50th	75th	90th
Food	−0.018	−0.040	−0.034	−0.019	−0.047**
Grain	0.018	−0.033	−0.022	0.024	−0.013
Livestock products	−0.050	−0.042	−0.058*	−0.048*	−0.071***
Red meat	0.015	−0.019	−0.054	−0.041	−0.074**
Poultry	−0.092	0.003	−0.040	−0.028	−0.047
Egg	0.048	−0.027	−0.019	0.017	−0.008
Milk	−0.186	−0.073	−0.078	−0.072	−0.114**
Edible oil	−0.063	0.007	−0.005	0.030	0.008
Vegetables and fruit	−0.009	−0.033	−0.033	−0.026	−0.050**
n	1,965	4,912	9,824	14,737	17,864

Notes: The thresholds of total food consumption are 177.83, 237.67, 309.22, 391.63 and 461.23 (KG per capita per annum), respectively at the five quantiles. *,**,***Significant at 10, 5 and 1 percent levels, respectively

Table V.
Estimated effects of
hukou on food
consumption across
quantiles

Food categories	Γ
Food	1
Grain	1
Livestock products	> 1.6
Red meat	> 1.6
Poultry	> 1.6
Egg	1.5[a]
Milk	> 1.6
Edible oil	1.6[a]
Vegetables and fruit	1

Notes: Rosenbaum bounds are tested based on the five-nearest neighbor matching. Γ is the sensitivity parameter when p-value reaches the 0.05 threshold. [a]Indicates the p-value is on upper bound, otherwise are on lower bound

the consumption of livestock products, red meat, poultry, eggs, milk and edible oil are robust to unobserved factors. The estimated result $\Gamma > 1.5$ suggests that the conclusions from the PSM will change only if an unobserved covariate caused the odds ratio of treatment to differ between the treatment and control groups by more than 1.5. With $\Gamma = 1$, the ATTs of total food, grain, and vegetables and fruit are relatively sensitive to unobserved factors, if any. As consumption habits and customs have little impacts on the consumption of grain and vegetables and fruit compared with livestock products, the hidden bias related to these two categories may be negligible. In addition, as emphasized by DiPrete and Gangl (2004), the Rosenbaum bounds provide the worst possible scenarios.

6. Discussion
Based on the PSM results that RHs consume less food than UHs after controlling for the level of income, RHs either save more or spend more on non-food categories than UHs[10]. We propose two channels through which RHs may reduce food consumption: a precautionary saving channel and a welfare expenditure channel. Testable hypotheses for each channel are constructed as follows:

H1. A stronger precautionary saving motivation may lead to a higher savings rate, and thus decreases food expenditures. Uncertainties in income significantly affect household consumption and saving decisions (Chamon *et al.*, 2013; Giles and Yoo, 2007; Ravallion and Chen, 2005). With discrimination in the local labor market and exclusion from urban social insurance (including pension, medical, work-related injury, unemployment and maternity insurance) programs, RHs have less secure jobs and higher income risk; thus, they are likely to save a higher proportion of their income for precautionary purposes[11]. The precautionary saving motivation may therefore be inversely related to insurance participation. Because RHs are not covered by urban welfare benefits, their food consumption may be squeezed out in order to maintain a minimal level of well-being.

H2. Higher expenditures on basic education and medical care reduce food consumption. Because RHs are excluded from enrolling children in urban public schools and urban insurance system, expenditures on education and medical care that are not compensated by the social insurance programs may account for a large share of their disposable income. This may lead to a reduction in the food consumption.

These two hypotheses are empirically tested. Using the propensity score from the PSM method, we control for income, household characteristics and other factors that may

confound the test results. Hypothesis tests are conducted based on the matched samples. To test *H1*, we examine whether RHs have a lower level of insurance participation than UHs. The ratio of insurance payment to total income is used as a proxy for insurance participation rate. The test result in Table VII shows that the insurance participation of RHs is 3.00 percent lower than that of UHs, indicating that the disparities in social security coverage between UHs and RHs lead to a precautionary saving motivation. *H1* is strongly supported.

Expenditures on basic education and medical care are treated as proxies for welfare expenditures not compensated by the social insurance system. Education incorporates basic education, personal tutoring, training courses and adult education. We choose basic education in the percentage of total expenditure as it directly reflects the discrimination in welfare coverage related to the *hukou* system. We find that the RHs' expenditure ratio of basic education is 1.10 percent higher than that of UHs. This result indicates that RHs have to spend more on basic education due to their RHs, which had been proved by Liu (2005) and Garnaut (2016). Differences in medical expenditures between RHs and UHs are insignificant. This may due to the reimbursement mechanism in the medical care system. UHs are covered by urban resident medical insurance, but they pay same amounts as RHs, and these amounts are recorded in the NBSC survey. After paying their medical bills, UHs covered by insurance can apply for reimbursement. The insignificant differences in medical expenditures between the two groups imply that UHs who are covered by urban welfare benefits may actually spend less than RHs. Thus, *H2* is partially supported.

Our tests of the two hypotheses suggest that a stronger motivation for precautionary saving and higher welfare expenditures result in lower food consumption of RHs.

7. Conclusions

The *hukou* system in China favors local urban residents and discriminates against the rural–urban migrants through resource allocation. Migrant households with RHs are restricted to obtaining UHs and gaining access to urban welfare benefits. We empirically investigate the impacts of urban segregation caused by *hukou* on food consumption. A PSM method is used to address selection bias with data from the NBSC Urban Household Survey that covers 19,648 households living in urban areas in six provinces.

We find that RHs consume 4.7 percent less food than UHs. For the main food categories, RHs consume 8.8 percent less livestock products and 4.8 percent less vegetables and fruit than UHs. For the sub-categories of livestock products, the RHs' consumption of red meat, poultry and milk is 9.8, 9.5 and 9.8 percent less than that of UHs, respectively. There is no significant difference in the consumption of grain, edible oil and eggs between the two groups. These results indicate that *hukou* cause disparities in food consumption between urban and migrant households. Holding RHs significantly reduces migrants' food expenditures.

Channels	Difference	SE
H1		
Precautionary saving motivation (%)	2.996*	0.333
H2		
Basic education expenditure (%)	1.102***	0.374
Medical care expenditure (%)	0.237	0.303

Notes: Precautionary saving motivation is measured as the negative ratio of insurance fees to income, a proxy of social insurance participation; education and medical care expenditures are expressed as the percentages of total expenditures. Hypotheses are tested using the propensity score from the PSM method. *,***Significant at 10 and 1 percent levels, respectively

Table VII.
Channels of *hukou*
impact on food
consumption

Hukou impacts on food consumption vary with income level. High-income RHs are not significantly different from UHs in their food consumption. Low-income and middle-income households are more vulnerable to urban segregation and *hukou* discriminations. For the middle-income group, RHs consume 6.9 percent less food than UHs. The differences in consumption are particularly pronounced with regard to livestock products and vegetables and fruit. Low-income RHs consume 5.7 percent less food than low-income UHs, particularly including 14.7 percent less livestock products and 6.4 percent less vegetables and fruit.

Our estimates are relatively robust to unobserved factors. The estimated effects regarding total food, grain, and vegetables and fruit are relatively sensitive to hidden bias. Our hypothesis tests indicate that compared with UHs, RHs' stronger motivation for precautionary saving and higher welfare expenditures especially on basic education lead to their lower food consumption levels.

To improve the welfare of RHs and reduce the disparities in food consumption between UHs and RHs, we suggest decouple the *hukou* status from the basic welfare system. Furthermore, as *hukou* status substantially affects food consumption, undertaking reform of the *hukou* system may bring challenges to China's food security. If RHs are fully covered by the urban social security, the quantities of their food consumption are likely to increase. It is necessary to promote the "vegetable basket project" and increase food supply, especially with regard to livestock products and vegetables and fruit.

Admittedly, this study is subject to limitations. We investigate the *hukou* effects on the quantity of household food consumption without considering sources of nutrition or food consumption away from home. As RHs consume significantly less nutritious foods (livestock products) and micronutrient-rich foods (vegetable and fruits) than UHs, it is likely that RHs' intakes of nutrition and calories may differ from those of UHs. Future studies with data on nutrition and food quality may provide insights into these issues. In addition, we only examine the static impacts of *hukou* discriminations on food consumption using the cross-section data. With the rapid urbanization process and gradually relaxed *hukou* system, it is necessary to study the dynamics of *hukou* impacts on consumption behaviors between UHs and RHs.

Notes

1. The *hukou* status is inherited at birth and RHs–UHs conversion is only possible through limited channels, i.e., enrollment in higher education institutions, receiving a sponsorship (e.g. artist or employer), land expropriation and investing in real estate.

2. Public schools should provide free education to all children in China. However, this free education is only guaranteed for the children whose *hukou* match the school's location (Sa, 2004). Children with RHs should pay steep out-of-district tuition fees to enroll in urban public schools or pay much more fees to enroll in tuition-funded, for-profit migrant schools (Ma *et al.*, 2008; Lai *et al.*, 2014).

3. Due to the limited access to official statistics, we obtained data from NBSC for a relatively short period and conducted a static analysis. The *hukou* system recently has been gradually relaxed. For example, some small cities have relaxed the *hukou* conversion criteria and offer local UHs to investors, homebuyers and those having a formal job. However, these reforms are not fundamentally enough to totally remove *hukou* restrictions, especially in big cities where the majority of rural migrants are living and working. It remains difficult to change *hukou* status and thus most rural migrant households still maintain their RHs (Song, 2014).

4. The NBSC survey recorded four types of *hukou* status, i.e., local and non-local UHs, and local and non-local RHs. In this study, local and non-local UHs are aggregated as UHs, and local and non-local RHs are aggregated as RHs.

5. The milk category is aggregated using fresh milk, milk powder and yogurt, with milk = fresh milk + 7 × milk powder + yougurt.

6. We define children as population with age lower than 14, and seniors with age higher than 65.

7. This paper identifies the impacts of urban segregation on food consumption caused by the *hukou* system, i.e., discrimination against RHs holders in labor market, unequal access to social insurance, and all other discriminations against households living in cities with RHs.

8. Estimated results from using a simple ordinary least square (OLS) model are reported in Table AI. Comparing with the PSM results, the OLS model overestimates *hukou* impacts on food consumption for each food category.

9. We also use another propensity score method, the inverse probability weighting (IPW), to correct for the selection bias. Results are reported in Table AII. IPW uses weighted means rather than simple unweighted means to disentangle the *hukou* effects from other confounders, where weights are constructed as the reciprocal of the probability score. It produces an efficient estimate of the ATT and performs as well as most matching estimators when overlap condition is satisfied (Hirano *et al.*, 2003; Busso *et al.*, 2014; Alem and Broussard, 2018). The IPW results are generally consistent with the PSM results. All estimates have the same signs. Differences are found only in the significance level for the consumption of poultry, milk, and vegetables and fruit.

10. It is widely observed that rural migrants tend to send part of their income back to rural areas. It may be one of the important factors leading to the lower food consumption of RHs. We are unable to test this hypothesis, since we do not have remittance data of RHs. The remittance of RHs can be considered as their regular expenditures, which are consumed by other family members and relatives in the rural area. If we take RHs' remittance into account and replace the disposable income in the probit model with the adjusted income (i.e. real disposable income net of remittance), the divergences in food consumption between UHs and RHs may decrease.

11. Social insurance programs in urban China are employment based. Employees generally will be enrolled in social insurance programs when signing labor contracts. The majority of migrant workers, however, lack formal contracts with employers and are not entitled to such job-related benefits (Gao *et al.*, 2012).

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Appendix

Consumption	*Hukou*
Food	−0.118***
Grain	−0.037
Livestock products	−0.172***
Red meat	−0.190***
Poultry	−0.101***
Egg	−0.079***
Milk	−0.266***
Edible oil	0.009
Vegetables and fruit	−0.140***
Note: ***Significant at 1 percent level	

Table AI.
Results of ordinary least square model

Consumption	Full sample
Food	−0.029*
Grain	0.001
Livestock products	−0.059***
Red meat	−0.058**
Poultry	−0.024
Egg	0.016
Milk	−0.109***
Edible oil	0.031
Vegetables and fruit	−0.032*
Notes: *,**,***Significant at 10, 5 and 1 percent levels, respectively	

Table AII.
Results using inverse probability weighting

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Exchange rate effects on agricultural exports
A firm level investigation of China's food industry

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Abstract

Purpose – The purpose of this paper is to extend empirical investigations of the relationship between real exchange rates and agricultural exports to the firm-product-country level with the use of disaggregated panel data of China's food industry. In particular, the study aims to explore heterogeneities in the export response to real exchange rates across firms, destinations and products, as well as to differentiate responses on the intensive and extensive margins.

Design/methodology/approach – This paper utilizes a merged panel data set of firm-product-country level transaction records of China's agricultural exports with firm-level survey data of the food industry. Panel regression models are constructed to identify empirical relationships.

Findings – Real appreciations are found to reduce export quantities and the probability to enter destination markets. These impacts are enhanced in 2005 when China unexpectedly depegged yuan from the USD. In addition, real appreciations in 2005 also reduced the yuan-denominated export price and increased firms' probability to exit destination markets. Taking the exchange rate reform as a natural experiment, evidence suggests that the negative exchange rate effects on exports are robust to the endogeneity issue. Finally, heterogeneous export responses are identified with respect to firm productivities and ownerships, income levels and locations of destination markets, as well as product groups.

Originality/value – This paper provides first-hand evidence on how real exchange rates influence agricultural exports at the firm-product-country level. A featured contribution is that China's exchange rate reform in 2005 is utilized to alleviate the typical concern of endogeneity. Findings may benefit policy makers, for example, by identifying firms most vulnerable to real appreciations.

Keywords Agricultural trade, Food industry, Real exchange rate, Exchange-rate pass-through

Paper type Research paper

1. Introduction

After joining the WTO, China's agricultural export value has rapidly increased from \$16bn in 2001 to \$70bn in 2015[1]. Since 2010, China has overtaken Canada to be the world's fourth largest agricultural exporter, just behind the EU, the USA and Brazil[2]. With a deep integration into the world, the export performance of China not only influences the country's agricultural sector that still accounted for 9 percent in GDP and its 220m agricultural employees, but also exerts notable impacts on competing industries of other economies (Fuller *et al.*, 2003; Cheng, 2004; Huang *et al.*, 2007; Veeck, 2008).

An undervalued currency has been widely alleged to contribute to the international competiveness of Chinese products (United States International Trade Commission, 2011). Understanding the exchange rate effects on China's agricultural exports is thus of particular interest to both researchers and policymakers. However, most previous studies use aggregate trade data[3], which not only makes the task to distinguish price responses from volume responses difficult, but also overlooks firm level heterogeneities, as well as firm entries and exits on extensive margins. In this paper, a detailed panel data set of Chinese firms in the food industry has been merged with the transaction level census data of

agricultural exports to fill this gap. Thanks to these unique data sets, trade flows could be analyzed at the firm-product-country level.

Particularly, we first examine exchange rate effects on intensive margins of agricultural exports at the country, country-product and firm-product-country levels. At the last two levels, responses of export quantities are distinguished from those of unit values which serve as a proxy of export prices. We then investigate the effects on extensive margins with a focus on firm probabilities to enter and exit destination markets. Though real exchange rate changes are arguably exogenous to firm level decisions, the concern of endogeneity remains if real exchange rate changes are expected. To alleviate this concern, we utilize the year of 2005 when China suddenly announced to abolish its decade-long fixed exchange rate regime against the USD, which could serve as a natural experiment. We also explore heterogeneities of exchange rate effects regarding productivities and ownerships of firms, income levels and locations of destinations, as well as product groups[4].

Recently, the literature of exchange rate effects on firms has been rapidly growing mainly as a result of increased data availability. Current empirical studies have revealed abundant evidence that the response to real exchange rate changes differs across exporters (Berman *et al.*, 2012). Dornbusch (1987) considered a model featuring Cournot competition to explain differential responses between foreign and domestic firms. The "new-new trade theory" provides a framework to formally consider firm heterogeneities in the response from the standpoint of pricing-to-market strategies. For instance, using three different models, Berman *et al.* (2012) consistently demonstrated that the heterogeneous response depends on firm productivity. In contrast, Amiti *et al.* (2014) developed a theoretical model to illustrate that the market share and import share influence the export response.

Despite the increase of disaggregated data, firm-level studies on agricultural exports are limited. Agricultural exports are special in that the products are relatively homogeneous and less storable, which tends to cause more market competitions and larger exchange rate effects (Cho *et al.*, 2002; Wang and Barrett, 2007). The export performance is not only a critical determinant of the international price movement of agricultural commodities (Piesse and Thirtle, 2009; Headey, 2011), but also has a notable impact on the domestic agricultural sector, poverty situations and nutrition levels (Pauw and Thurlow, 2011; Barrett *et al.*, 2001; Kwon and Koo, 2009). Hence, a firm level investigation of exchange rate effects on agricultural exports is a valuable attempt to enrich the knowledge about the "macro-agricultural nexus" (Kwon and Koo, 2009).

The rest of this paper is organized as follows. Section 2 describes our data and presents stylized facts. Benchmark empirical models and estimation results are reported in Section 3, at the country, country-product and firm-product-country levels. Section 4 re-examines the results for the year of the exchange rate reform, and explores heterogeneous effects across firms, destinations and products. Section 5 concludes the paper.

2. Data
2.1 Data description
Our data is a subsample of the Annual Survey of Industrial Firms (ASIF) during 1998 and 2007. The ASIF is conducted by the National Bureau of Statistics of China and covers all Chinese industrial SOEs as well as above-scale non-state-owned industrial firms with the main operating revenue exceeding 5m yuan (approximately $731,614 under the current exchange rate) over the sample year. It can well represent China's industrial sector, because the sum of sales made by these firms accounted for 90 percent of the sector's total sales according to China's National Economic Census. For the purpose of this study, we only keep firms in the food industry based on their two-digit Chinese Standard Industrial Classification (CSIC) codes[5]. Observations in violation of accounting rules are excluded following Guariglia *et al.* (2011). We also drop observations with

annual growth rates of export quantities and unit values in the top or bottom 1 percent of the distribution following Berman *et al.* (2012). Since firm IDs may change upon occasions such as restructuring, merger and acquisition, the sequential matching procedure of Brandt *et al.* (2012) is adopted to link firms over time when matching based on firm IDs fails.

To precisely characterize the export performance of these firms in all product and destination markets, we merge the ASIF subsample with transaction level trade data reported by the General Administration of Customs of China (GACC) during 2000 and 2006. The original GACC data documented the (free on board) *f.o.b.* export value which we denote by *EXP* and volume which we denote by *q* per product (HS eight-digit) of all Chinese firms to each destination market on a monthly basis. To be consistent with the frequency of the ASIF data, monthly records are aggregated by year. We also aggregate products to the HS six-digit level seeing the potential coding error at lower levels (Li *et al.*, 2015). Given such disaggregated data, we can use the unit value defined as $uv = EXP/q$ as the proxy for the *f.o.b.* export price. Since in our data, the unit of quantity is non-missing for 99.4 percent transaction records and among them 99.8 percent have the same unit being used throughout the sample period for the same product category, we can calculate unit values for more than 99 percent of observations[6]. Such firm-product (HS six-digit)-destination-year level GACC data are then merged with our ASIF subsample in two steps as in Yu (2015). Particularly, the two data sets are first merged according to the Chinese names of these firms. For those unmatched, we identify firms that share the same postal codes and the last seven digits of phone numbers between these data sets to be matched. The reason is that in each postcode area, firm numbers are unique (Yu, 2015). In the ASIF data, the total export value is reported for all exporters in the food industry, though not distinguished by products or destinations. We thus derive that the rate of successful merging is around 83 percent, which is comparable to Yu (2015).

It shall be noted that most exports to Hong Kong were eventually re-exported to other destinations. But since we do not have access to Hong Kong's transaction level trade data, food exports to Hong Kong cannot be precisely decomposed by final destinations. We thus follow Park *et al.* (2010) to assume that an export flow of any firm to Hong Kong was re-exported to each destination market according to the fraction that Hong Kong exported the same HS six-digit product to that destination. The fraction was calculated using the UN Comtrade data. Estimation results remain similar if export flows to Hong Kong are simply excluded.

Bilateral real exchange rates and other country level variables are then merged with the above data according to firms' destination markets. Data of bilateral real exchange rates, which are denoted by *RER*, is obtained from the Penn World Table 9.0 and measured in direct quotes. Increases of real exchange rates, thus, indicate real appreciations. Other country level variables include real GDP and real GDP per capita. They are collected from the World Development Indicators and are denoted by *RGDP* and *RGDPPC*. Aggregating firm-product-destination-year level export values by country and year, we obtain the total annual food export value to each destination market, *EXP*.

Finally, we constrain ourselves to the sub-period of 2002–2006 within the entire sample period to avoid possible structural changes upon China's accession to the WTO. A total of 5,290 firms were present for at least one year during this sub-period.

2.2 Stylized facts

Table I provides a statistical summary of our ASIF data that are merged with the GACC data and country level variables as specified above. As Panel A demonstrates, the average annual growth rates of *RGDP* and *RGDPPC* were, respectively, around 5 and 4 percent across destination markets. The relatively faster growth of *RGDP* than

	Obs.	Mean	SD	P10	P90
Panel A: by country					
EXP_t/EXP_{t-1}	541	2.075	1.882	0.746	3.773
RER_t/RER_{t-1}	541	1.014	0.097	0.906	1.148
$RGDP_t/RGDP_{t-1}$	541	1.053	0.032	1.018	1.093
$RGDPPC_t/RGDPPC_{t-1}$	541	1.039	0.043	1.000	1.080
Panel B: by product-country					
uv_t/uv_{t-1}	14,962	1.141	0.532	0.734	1.561
q_t/q_{t-1}	14,962	2.680	5.021	0.356	5.529
Panel C: by firm-product-country					
uv_t/uv_{t-1}	44,778	1.090	0.326	0.804	1.416
q_t/q_{t-1}	44,778	1.915	2.817	0.299	4.056

Table I.
Statistical summary of
the merged data

that of *RGDPPC* implies a positive contribution of population growth to the real GDP growth on average. The country level total export value *EXP* was more than doubling each year on average, indicating a rapid expansion of food exports. As manifested by Panel B and C, quantity expansions served as the driving force of food export growth, because the average growth rate of export volume *q* was much higher than that of unit value *uv* for both product-country and firm-product-country combinations. A much starker gap between the two growth rates, however, is observed in Panel B. We can thus infer the critical contribution of newly entering firms to quantity expansions of food exports[7].

The simple average of annual growth rates of yuan's bilateral real exchange rates was roughly 1 percent across destination markets. Since the simple average ignores export weights, the positive growth rate could result from depreciations of yuan in countries with limited food imports from China, and thus does not imply that the overall value of yuan was declining. In fact, yuan's performance differed substantially across destination markets and periods. Figure 1 shows historical trajectories of yuan's real exchange rates in the top five destination markets of firms in our sample that together accounted for more
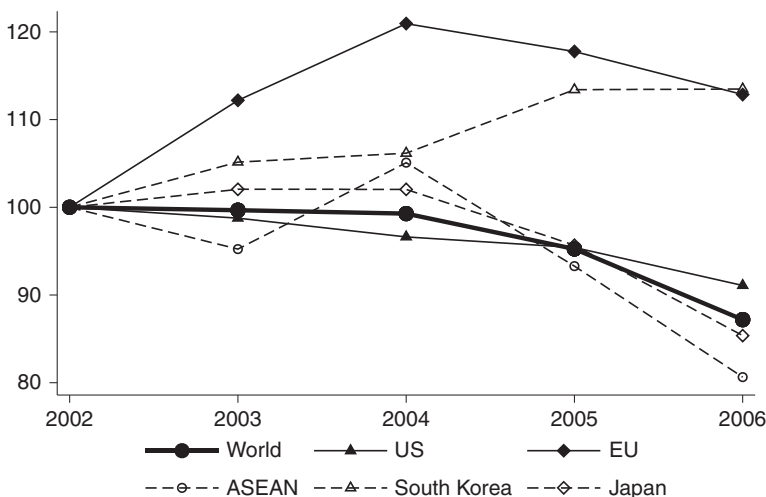
Figure 1.
Real exchange rates of
yuan in various
destination markets
(2002 = 100)

than 85 percent in terms of export value. Bilateral real exchange rates are used for the USA, South Korea and Japan. Using country level export values *EXP* as the weight, real effective exchange rates (REER) are derived for the EU and ASEAN from bilateral real exchange rates with member states[8]. The figure demonstrates that yuan underwent real depreciations between 2002 and 2004 in all these destination markets except the USA. The degree was especially noticeable in the EU thanks to Euro's increasing strength against the USD over that period. Salient real appreciations of yuan in most of these regions, however, are observed in 2005 when China reformed its pegged nominal exchange rate regime. Such trends were reinforced in 2006. In contrast, since the Korean Won experienced a wave of real appreciations between the late 2004 and early 2005, yuan's value continued to decline in Korea, though the rate slowed in 2006 (www.fujitsu.com/jp/group/fri/en/column/message/2012/2012-01-06.html). As indicated by the thick solid line with circular markers, the overall export-weighted REER of yuan remained stable between 2002 and 2004 but rapidly fell afterwards. Thus, the year of 2005 appeared to be a turning point of real exchange rates facing most food exporters.

To intuitively examine the relationship between real exchange rates and food exports, we plot the growth rate of yuan's REER against that of the total export value of all firms in this sample. As Figure 2 demonstrates, although the growth rate of REER remained negative for the period of 2002–2006, it was increasing between 2002 and 2004 when the growth rate of export value kept climbing. In other words, the slowing rate of real appreciations was accompanied by a rapid expansion of food exports. This expansion, however, was abruptly curbed by the acceleration of real appreciations in 2005. The growth rate declined more pronouncedly for the total export value than for REER, which indicates an instantaneous and huge impact of real appreciations on food exports. The large negative response of exports could be a result of additional channels, e.g. liquidity constraints and increased uncertainties (Rahman and Serletis, 2009), which reinforced the effect of the loss of export competitiveness. Despite the further acceleration of real appreciations in 2006, the growth rate of export value slightly picked up, since both exporters and importers might have updated their expectations about the real exchange rates.
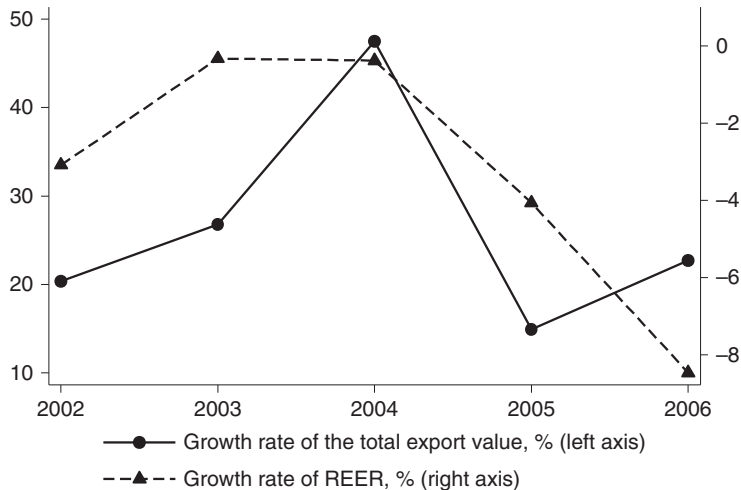
Figure 2.
The growth of total export value vs the growth of REER

Growth rate of the total export value, % (left axis)

Growth rate of REER, % (right axis)

3. Benchmark results

3.1 Country and country-product level estimations

We start with estimations on country- and country-product levels to examine the impacts of real exchange rates on food exports of China. The country level empirical model is specified as follows based on variables defined in Panel A of Table I:

$$\Delta \ln EXP_{ct} = \beta_0 + \beta_1 \Delta \ln RER_{ct} + \beta_2 \Delta \ln RER_{ct} \times y2005$$

$$+ \beta_3 \Delta \ln RGDP_{ct} + \alpha_c + a_t + \varepsilon_{ct}. \tag{1}$$

Subscripts c and t, respectively, denote destination markets and years. Δ is an operator that calculates differences between two consecutive years. Such a first-differencing approach is adopted following Li *et al.* (2015)[9]. Aside from $\Delta \ln RER$, we also introduce the interaction term between $\Delta \ln RER$ and a dummy variable for the year of 2005, $y2005$, to capture the increased responsiveness of food exports to real exchange rates upon the exchange rate reform that is observed in Figure 2. The demand of the destination market is controlled by $\Delta \ln RGDP$. Finally, we also include a constant term β_0, fixed effects of destination markets α_c, and year dummies α_t in this equation. ε_{ct} is the error term as usual[10].

Our empirical results can be found in the first column of Table II. As indicated by the estimated coefficient for $\Delta \ln RER$, the total export value did not significantly respond to real exchange rates in years other than 2005. This is compatible with Figure 2, which reveals that the growth rates of total export value and REER moved in opposite directions after the exchange rate reform in spite of their overall comovement between 2002 and 2004. The coefficient before the interaction term $\Delta \ln RER \times y2005$, in contrast, suggests a significant and substantial negative effect of real appreciations on the total export value. In particular, an appreciation of the real exchange rate, i.e. a decline of RER, by 1 percent would lead to a 1.6 percent decline of the total export value[11]. That is the change in total exports was larger than that in real exchange rates, which is in line with our observation in Figure 2 again.

To further check if the year of 2005 is indeed special, we replace the year dummy $y2005$ in the interaction term $\Delta \ln RER \times y2005$ by dummy variables for other years, i.e. $y2003$, $y2004$ and $y2006$. Our results confirm the special export response to the real exchange rate in 2005. To be specific, the coefficient before the interaction term is either insignificant as in the case when $y2003$ or $y2004$ is used, or becomes significantly negative as in the case when $y2006$ is used. We also adopt a dummy variable for the post-reform period, i.e. the years of 2005 and 2006, to replace the dummy variable for the single year, $y2005$. An insignificant coefficient before the interaction term is found from the estimation, indicating no statistically significant differences regarding the export response to real

Dependent variable	Country level $\Delta \ln EXP$	Country-product level	
		$\Delta \ln q$	$\Delta \ln uv$
$\Delta \ln RER$	0.086 (0.359)	0.488** (0.202)	−0.161** (0.069)
$\Delta \ln RER \times y2005$	1.597** (0.625)	0.995** (0.417)	0.316** (0.143)
$\Delta \ln RGDP$	0.156 (0.716)	1.051 (0.720)	0.995*** (0.247)
Constant	0.480*** (0.060)	0.279*** (0.041)	0.015 (0.014)
Dummy 2004	0.035* (0.017)	0.019** (0.008)	0.012* (0.006)
Dummy 2005	−0.085*** (0.022)	−0.117*** (0.003)	0.061*** (0.018)
Dummy 2006	−0.092*** (0.023)	−0.135*** (0.011)	0.043** (0.019)
Observations	541	14,962	14,962
Adjusted R^2	0.251	0.383	0.341

Notes: Standard errors in parentheses. Country or country-product level fixed effects are also included. The bottom row reports the within R^2. Same applies to following tables. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table II.
Country and country-product level results

exchange rates before and after the exchange rate reform. Such evidence lends support to our specification of the reform as a one-time shock. In fact, although the band of yuan's movement has widened after the reform, the appreciation was much slower than what the market expected and the new regime could allow (Frankel and Wei, 2007). Therefore, the reform primarily acted as a shock to people's prediction of real exchange rates in the old regime, seeing that specific rules of exchange rate management after the reform, in particular the currencies and their associated weights in yuan's reference basket, was not clear when the reform was announced (Frankel and Wei, 2007). A number of theoretical frameworks could explain how such a change in uncertainty would alter the response of exports to real exchange rates (Baron, 1976; Caballero and Corbo, 1989; Hooper and Kohlhagen, 1978). After the reform, however, patterns of real exchange rate movements in the new regime could be learnt to reduce the increased uncertainty upon the shock. The export response might, thus, return to the pre-reform level. To sum up, it makes sense to isolate the effect in 2005 as in our specification in Equation (1), since it tends to capture how a "surprise" (Eichengreen and Tong, 2015) influenced the export response to real exchange rates. For the ease of presentation, estimation results for these alternative specifications are not reported in Table II.

We then move on to investigate the effect of real exchange rates on food exports at the country-product level. Since products are defined at the disaggregated HS six-level, we can infer the unit value of each product, and thus distinguish the price (unit value) uv and quantity q as in Panel B of Table I. Using $\Delta \ln q$ and $\Delta \ln uv$ as the dependent variable, an empirical model can be specified similar to Equation (1). Subscripts ct, however, need to be replaced by jct with j denoting products, and then we will control country-product fixed effects α_{jc} instead of α_c.

According to our estimation results reported in the last two columns of Table II, $\Delta \ln RER$ had a significantly positive effect on $\Delta \ln q$ in years other than 2005. A 1 percent real appreciation would lead to approximately 0.5 percent loss of export quantities. As suggested by the estimated coefficient for $\Delta \ln RER \times y2005$, this effect was substantially enhanced upon the exchange rate reform. Consequently, the same degree of real appreciations would result in an extra 1 percent decline in export quantities. In contrast, as for $\Delta \ln uv$, the coefficient before $\Delta \ln RER$ was significantly negative while that before $\Delta \ln RER \times y2005$ was significantly positive. The negative coefficient indicates that real appreciations increased the unit value in years other than 2005, which could result from decreased weights of lower-price varieties in the country-product export flow (Auer and Chaney, 2009). This effect was reversed in the year of 2005 due to the significantly positive coefficient with a larger magnitude before $\Delta \ln RER \times y2005$. In fact, a 1 percent real appreciation would reduce the unit value by 0.16 percent (0.316–0.161 percent) in 2005, indicating an incomplete but high pass-through rate around 84 percent of the exchange rate shock. To check the validity of isolating the effect in 2005, we also replace the interaction term by the product between $\Delta \ln RER$ and other year dummies. For both quantity and unit value responses, the coefficient before these interaction terms remains insignificant.

3.2 Firm-product-country level estimations
To further examine the conclusions at country and country-product levels, exchange rate effects on agricultural exports will be inspected at the firm-product-country level using an empirical model that resembles Equation (1) again. Since we can also distinguish the unit value and quantity for each firm-product-country export flow, $\Delta \ln q$ and $\Delta \ln uv$ will be used as the dependent variable. Subscripts now, however, shall be replaced by $ijct$, where i denotes firms and j again denotes HS six-digit products. Investigations on particular firm heterogeneities will be left for the next section. Here, we simply control firm-product-country fixed effects α_{ijc}[12].

Extending from the country-product level to the firm-product-country level brings two benefits. First, the control of firm-product-country fixed effects helps to mitigate the confounding effects on estimated coefficients caused by firm heterogeneities. Second, the response of incumbent exporters can be isolated since entrants to any country-product market are naturally excluded when we derived the dependent variables. As revealed by the first two columns of Table III, the effects of real exchange rates on export quantities and unit values at the firm-product-country level are qualitatively similar to those reported in the last two columns of Table II for the country-product level. A 1 percent decrease in *RER* resulted in a 0.56 percent decline of export quantities in years other than 2005. In 2005, this response was enhanced by a further 0.52 percent quantity loss. Comparing with our country-product level estimates, the overall effect of real appreciations on export quantities (0.488 percent + 0.995 percent vs 0.560 percent + 0.522 percent) in 2005 was mitigated, probably because the deterrent effect on potential entrants was excluded in the firm-product-country level estimation. We also find that a 1 percent real appreciations led to a 0.11 percent drop of unit values in 2005. The smaller effect than that in the country-product level result indicates that entrants during the shock adopted lower prices probably due to the intensified price competition. In years other than 2005; however, real exchange rates no longer significantly influenced unit values, which is in contrast to our finding from Table II that real appreciations increased unit values in those years. As discussed above, increases of unit values could be a result of decreased weights of lower-price varieties in a country-product market. The insignificant coefficient we find in Table III implies that such changes were led mainly by entries of firms producing higher-price varieties.

Though entrants are naturally excluded from firm-product-country level estimations, responses to real exchange rates on extensive margins could still take place since firms might leave a country-product market. With a focus on the subsample of firm-product-country combinations that remained throughout the period of 2002–2006, the third and fourth columns of Table III provide an investigation entirely on intensive margins. We find that quantity responses to real exchange rates increase in this subsample for both 2005 and other years, whereas unit value responses completely disappear. This implies that firms experiencing more price cuts and fewer quantity losses might have a larger chance to leave a country-product market. One explanation of such differences is the weight on fixed inputs in the production function. If a firm mainly used fixed inputs, then reducing prices could be a better strategy to cope with real appreciations in the short-run than reducing quantities as most production costs were sunk. In the long-run, the firm could sell off fixed inputs and quit the market.

Dependent variable	All		Without entry or exit		"Single" product	
	$\Delta \ln q$	$\Delta \ln uv$	$\Delta \ln q$	$\Delta \ln uv$	$\Delta \ln q$	$\Delta \ln uv$
$\Delta \ln RER$	0.560*** (0.088)	−0.022 (0.021)	0.720*** (0.116)	0.008 (0.029)	0.040 (0.198)	0.018 (0.047)
$\Delta \ln RER \times y2005$	0.522*** (0.181)	0.113*** (0.043)	1.172*** (0.245)	0.078 (0.062)	0.630* (0.345)	0.184** (0.083)
$\Delta \ln RGDP$	0.757*** (0.242)	0.235*** (0.057)	0.586* (0.305)	0.103 (0.077)	0.550 (0.652)	0.260* (0.150)
Constant	0.058*** (0.011)	0.040*** (0.003)	0.092*** (0.014)	0.044*** (0.003)	−0.020 (0.026)	0.033*** (0.006)
Dummy 2004	0.009* (0.004)	0.005** (0.002)	0.011** (0.005)	0.003* (0.001)	0.010* (0.005)	0.004** (0.002)
Dummy 2005	−0.028** (0.013)	0.008*** (0.001)	−0.024* (0.012)	0.007*** (0.001)	−0.026** (0.012)	0.009** (0.004)
Dummy 2006	−0.031** (0.014)	0.006** (0.003)	−0.025** (0.011)	0.008*** (0.002)	−0.029** (0.014)	0.007** (0.003)
Observations	41,379	41,379	17,205	17,205	11,083	11,083
Adjusted R^2	0.411	0.293	0.466	0.312	0.506	0.319

Notes: Standard errors in parentheses. Firm-product-country level fixed effects are also included. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table III.
Firm-product-country
level
benchmark results

Due to the prevalence of multiproduct exporters, we also wonder if the product scope of a firm would affect the response of its export decisions to each country-product market. For example, while a multiproduct exporter might fortify its international competitiveness in one product at the expense of that in other products by reallocating resources, this strategy would not be available to an exporter of a single product. To exclude the impact of product scopes, we focus on a subsample of firms that exported only one product to each destination during the sample period (Berman *et al.*, 2012)[13]. We find that either in terms of export quantities or unit values, these exporters were more responsive to real exchange rates in 2005 than multiproduct exporters as indicated by the comparison between the first and the last two columns of Table III. In contrast, they did not respond to real exchange rates at all in other years.

3.3 Firm-country level extensive margins

Changes in real exchange rates not only induce continuing exporters to adjust export quantities and unit values, but also lead to entries and exits of firms in destination markets. To investigate such effects on extensive margins, we specify the following empirical model:

$$x_{ict} = \beta_0 + \beta_1 \Delta \ln RER_{ct} + \beta_2 \Delta \ln RER_{ct} \times y2005$$
$$+ \beta_3 \Delta \ln RGDP_{ct} + \beta_4 \Delta \ln TFP_{it} + \alpha_i + \alpha_c + \alpha_t + \varepsilon_{ict}. \tag{2}$$

In this equation, x_{ict} is a dummy variable that indicates whether firm i exported to destination market c in year t and $\Delta \ln TFP_{it}$ is the growth rate of the firm's TFP that is estimated by the OP method. To obtain these TFP estimates, we utilize the ASIF data and follow Olley and Pakes (1996) to estimate the coefficient for labor input in the logged production function using a semi-parametric technique first. We then estimate the firm survival probabilities to address the attrition issue based on a probit model featuring a non-parametric form. We finally take fitted values into the production function to complete the estimation of other coefficients using a non-linear least square method. As before, α_c and α_t are country and year level fixed effects. In contrast, α_i is a vector of time-invariant variables that include the average levels of the firm's employment, wage, productivity and net assets during the sample period[14]. Regressing Equation (2) on subsamples of potential entrants ($x_{ict-1} = 0$) and dropouts ($x_{ict-1} = 1$), we can reveal impacts of real exchange rates on extensive margins.

In Table IV, we estimate Equation (2), using the probit, logit and linear probability models. Regardless of which model we choose, the probability of entering always declined with real appreciations. The response was especially substantial in 2005. In contrast, the probability of exiting is found to increase with real appreciations in 2005. In other years, however, this response was not significant. The effect of TFP growth on the extensive margins was also noticeable. Expectedly, TFP growth induced entries and reduced exits. The demand of destination markets, nevertheless, did not significantly influence the probability of entering or exiting.

4. Robustness checks

4.1 The year of 2005 alone

One concern about our benchmark regression results is that firms might expect changes in real exchange rates, such that real appreciations would be endogenous. The exchange rate regime reform in 2005 could serve as a natural experiment to alleviate this problem. While yuan has been receiving revaluation pressures for a long time, the revaluation plan, not least its specific time, were unknown to the public before the reform (Eichengreen and Tong, 2015)[15]. The jump of yuan's forward rate upon the announcement by the People's Bank of China on July 21, 2005 further lends support to such a view (Eichengreen and Tong, 2015). Since movements of other currencies against the USD are

Dependent variable	Probit		Logit		LPM	
	Enter	Exit	Enter	Exit	Enter	Exit
$\Delta\ln RER$	0.083*** (0.018)	0.125 (0.114)	0.041*** (0.012)	0.208 (0.190)	0.001*** (0.000)	0.041 (0.038)
$\Delta\ln RER \times y2005$	0.284*** (0.089)	−0.407*** (0.130)	0.683*** (0.249)	−0.675*** (0.183)	0.003*** (0.001)	−0.129*** (0.037)
$\Delta\ln RGDP$	0.352 (0.216)	−0.379 (0.583)	0.974 (0.606)	−0.576 (0.968)	0.003 (0.003)	−0.117 (0.194)
$\Delta\ln TFP$	0.044*** (0.010)	−0.036* (0.020)	0.116*** (0.025)	−0.063* (0.037)	0.001*** (0.000)	−0.012* (0.007)
Constant	−2.924*** (0.059)	0.218 (0.153)	−6.195*** (0.179)	0.367 (0.246)	−0.001 (0.001)	−0.417*** (0.053)
Dummy 2004	0.002** (0.001)	0.001* (0.001)	0.001* (0.001)	0.001* (0.000)	0.001** (0.000)	0.000*** (0.000)
Dummy 2005	−0.004*** (0.001)	0.005** (0.002)	−0.003*** (0.000)	0.004*** (0.001)	−0.002** (0.000)	0.002*** (0.000)
Dummy 2006	−0.001** (0.000)	0.004** (0.002)	−0.002*** (0.000)	0.002** (0.001)	−0.001** (0.000)	0.001* (0.001)
Observations	33,504	35,988	33,504	35,988	33,504	35,988
Pseudo/adjusted R^2	0.653	0.562	0.649	0.563	0.592	0.665

Notes: Standard errors in parentheses. Time-invariant firm controls and country level fixed effects are also included. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table IV.
Firm-country level
extensive margins

arguably exogenous, the depeg of yuan also resulted in an overall appreciation in relative sense, as Figure 1 demonstrates. Thus, consistent with Eichengreen and Tong (2015), this event shall be modeled as a simultaneous shock to all exporters, not only those involved in the Sino-US trade. To empirically utilize this shock, we restrain ourselves to the year of 2005 and re-examine the effect of real exchange rates on export quantities, unit values and extensive margins[16].

According to the first two columns of Table V, a 1 percent real appreciation in 2005 would lead export quantities and unit values to decline, respectively, by 0.55 and 0.11 percent among firm-product-country triplets on average. In addition, both export quantities and unit values increase with the destination's real demand. These findings of the 2005 subsample are qualitatively similar to those in the first two columns of Table III, which are estimated from the 2002–2006 sample. Regarding extensive margins, since results of the probit, logit and linear probability models are qualitatively similar, we focus on the probit model for the ease of presentation and report the estimation results in the last two columns of Table V. These results confirm our findings in the first two columns of Table IV. In particular, real appreciations in 2005 reduced the probability of entering while increased that of exiting. The effects of TFP growth were significant and opposite. Real GDP, in contrast, did not exhibit significant impacts. In sum, with a focus on the exogenous event of yuan's exchange rate reform, findings in Table V estimated from the 2005 subsample demonstrate that our benchmark results are robust to the threat of endogeneity.

4.2 Firm heterogeneities

Due to heterogeneities in productivities and ownerships, firms might respond to changes in real exchange rates differently. Berman *et al.* (2012) considered a number of theoretical models that can result in differential pricing-to-market strategies with respect to firm productivity and, thus, reconcile with heterogeneous response to real exchange rate movements. These models yield two predictions: the price elasticity to real exchange rate grows with firm productivity; the quantity elasticity, in contrast, falls with firm productivity. To explore how firm productivities influence responses on intensive and extensive margins, we introduce interaction terms into our benchmark empirical models. Hence, the equation for quantity and unit value responses of continuing exporters becomes:

$$\Delta \ln y_{ijct} = \beta_0 + \beta_1 \Delta \ln RER_{ct} + \beta_2 \Delta \ln RER_{ct} \times \ln A_{it-1}$$

$$+ \beta_3 \Delta \ln RER_{ct} \times y2005 + \beta_4 \Delta \ln RER_{ct} \times y2005 \times \ln A_{it-1}$$

$$+ \beta_5 \Delta \ln RGDP_{ct} + \beta_6 \Delta \ln A_{it} + \beta_7 \ln A_{it-1} + \alpha_{ijc} + \alpha_t + \varepsilon_{ijct}. \tag{3}$$

Dependent variable	Intensive margins		Extensive margins (probit)	
	$\Delta \ln q$	$\Delta \ln uv$	Enter	Exit
$\Delta \ln RER$	0.548** (0.276)	0.110** (0.049)	0.956** (0.402)	−0.944*** (0.293)
$\Delta \ln RGDP$	0.106** (0.006)	0.077*** (0.016)	0.609 (0.433)	−0.601 (0.586)
$\Delta \ln TFP$			0.014** (0.007)	−0.050* (0.029)
Constant	0.120*** (0.035)	0.047*** (0.007)	0.237*** (0.088)	1.058*** (0.065)
Observations	13,059	13,059	8,498	8,518
Pseudo/adjusted R^2	0.356	0.313	0.449	0.425

Table V.
Responses in the year of 2005

Notes: Standard errors in parentheses. Firm-product level fixed effects are controlled for regressions on the intensive margins. Time-invariant firm controls are included for the regressions on the extensive margins. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

In Equation (3), y is the export quantity q or the unit value uv. A is the firm productivity, which we measure using the TFP estimated by the OP method and the labor productivity. We interact $\Delta\ln RER_{ct}$ and $\Delta\ln RER_{ct} \times y2005$ with the log value of firm productivity in the previous year to exclude possible influences of quantity and unit value responses on the current productivity. The productivity growth rate $\Delta\ln A_{it}$ and the log level of lagged productivity $\ln A_{it-1}$ are also included. To explore heterogeneous responses on extensive margins, we consider the following model:

$$x_{ict} = \beta_0 + \beta_1 \Delta\ln RER_{ct} + \beta_2 \Delta\ln RER_{ct} \times \ln A_{it-1} + \beta_3 \Delta\ln RER_{ct} \times y2005$$

$$+ \beta_4 \Delta\ln RER_{ct} \times y2005 \times \ln A_{it-1} + \beta_5 \Delta\ln RGDP_{ct} + \beta_6 \Delta\ln A_{it}$$

$$+ \beta_7 \ln A_{it-1} + \alpha_i + \alpha_c + \alpha_t + \varepsilon_{ict}. \tag{4}$$

In Equation (4), x is a dummy variable that indicates whether firm i exported to destination c in year t as before, and we focus on the probit model again for the ease of presentation.

The first column of Table VI demonstrates that in years other than 2005, real appreciations led to declines in export quantities, but the effect was not heterogeneous across firms with different TFP or labor productivity levels. In the year of 2005, the effect of real exchange rates on export quantities was enhanced, seeing that the same degree of real

Dependent variable	Intensive margins		Extensive margins (probit)	
	$\Delta\ln q$	$\Delta\ln uv$	Enter	Exit
Panel A: TFP				
$\Delta\ln RER$	0.833*** (0.305)	0.103 (0.157)	0.984** (0.459)	−0.590 (0.570)
$\Delta\ln RER \times \ln TFP_{-1}$	−0.117 (0.124)	−0.021 (0.037)	−0.573 (0.479)	0.088 (0.260)
$\Delta\ln RER \times y2005$	0.413* (0.242)	0.563** (0.262)	1.154*** (0.198)	−1.212*** (0.275)
$\Delta\ln RER \times y2005 \times \ln TFP_{-1}$	−0.443** (0.210)	0.134** (0.060)	−0.420** (0.197)	0.406* (0.225)
$\Delta\ln RGDP$	0.054 (0.673)	0.272 (0.210)	0.628** (0.256)	−0.202** (0.072)
$\Delta\ln TFP$	0.054** (0.025)	0.010 (0.008)	0.064** (0.027)	−0.074*** (0.027)
$\ln TFP_{-1}$	−0.312*** (0.034)	0.012 (0.010)	0.040 (0.032)	−0.051 (0.035)
Constant	1.393*** (0.141)	−0.013 (0.044)	−0.139*** (0.026)	−0.110 (0.156)
Dummy 2004	0.007** (0.003)	0.003*** (0.001)	0.001* (0.001)	0.001* (0.000)
Dummy 2005	−0.021*** (0.009)	0.005*** (0.001)	−0.003*** (0.001)	0.005*** (0.002)
Dummy 2006	−0.024** (0.011)	0.006*** (0.002)	−0.002*** (0.001)	0.003** (0.001)
Observations	40,293	40,293	33,426	35,864
Pseudo/adjusted R^2	0.532	0.391	0.683	0.627
Panel B: labor productivities				
$\Delta\ln RER$	0.421*** (0.032)	−0.019 (0.124)	0.537** (0.251)	−0.693 (0.442)
$\Delta\ln RER \times \ln LP_{-1}$	−0.090 (0.104)	−0.001 (0.031)	−0.384 (0.401)	0.030 (0.189)
$\Delta\ln RER \times y2005$	0.517** (0.249)	0.358* (0.213)	0.646*** (0.203)	−0.973** (0.402)
$\Delta\ln RER \times y2005 \times \ln LP_{-1}$	−0.326* (0.180)	0.102*** (0.031)	−0.411*** (0.120)	0.285*** (0.042)
$\Delta\ln RGDP$	−0.059 (0.680)	0.305 (0.212)	0.339* (0.165)	−0.311** (0.109)
$\Delta\ln LP$	0.010** (0.004)	0.001 (0.004)	0.043*** (0.009)	−0.068*** (0.020)
$\ln LP_{-1}$	−0.134*** (0.019)	−0.002 (0.006)	0.098 (0.125)	−0.151 (0.164)
Constant	0.623*** (0.077)	0.046* (0.024)	0.243 (0.632)	0.029 (0.097)
Dummy 2004	0.006** (0.003)	0.004* (0.002)	0.001* (0.000)	0.000*** (0.000)
Dummy 2005	−0.022*** (0.008)	0.004*** (0.000)	−0.003*** (0.001)	0.004*** (0.001)
Dummy 2006	−0.026*** (0.009)	0.005*** (0.001)	−0.003** (0.002)	0.003* (0.001)
Observations	39,671	39,671	32,968	35,226
Pseudo/adjusted R^2	0.530	0.377	0.659	0.643

Notes: Standard errors in parentheses. Firm-product-country level fixed effects are controlled for regressions on the intensive margins. Time-invariant firm controls and country-level fixed effects are included for the regressions on the extensive margins. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table VI.
Heterogeneous responses due to firm productivities

appreciations resulted in deeper declines in export quantities. As significantly negative coefficients before "$\Delta\ln RER \times y2005 \times \ln TFP_{-1}$" and "$\Delta\ln RER \times y2005 \times \ln LP_{-1}$" indicate, the response of export quantities to real exchange rates increased more substantially in 2005 for firms with low productivity levels. In other words, low-productivity firms were more vulnerable in export quantities to unexpected real appreciations during the exchange rate reform. According to the second column of Table VI, real appreciations did not significantly influence unit values in years other than 2005, which is in line with our finding in the second column of Table III. The result applies to firms with different TFP and labor productivity levels. In 2005, in contrast, real appreciations led to declines in unit values, especially for firms with high TFP or labor productivity levels as indicated by significantly positive coefficients for "$\Delta\ln RER \times y2005 \times \ln TFP_{-1}$" and "$\Delta\ln RER \times y2005 \times \ln LP_{-1}$." That is, high-productivity firms priced more to markets and exhibited a lower degree of exchange-rate pass-through consequently.

In terms of extensive margins, the last two columns of Table VI report estimation results based again on the probit model. The probability of entering is found to decline with real appreciations in years other than 2005, while the probability of exiting did not significantly depend on real exchange rates. No heterogeneities with regard to firm productivity levels were discovered for both probabilities. In 2005, in contrast, the sensitivity of the entering probability to real exchange rates increased and the response of the exiting probability became significant. Meanwhile, according to coefficients for "$\Delta\ln RER \times y2005 \times \ln TFP_{-1}$" and "$\Delta\ln RER \times y2005 \times \ln LP_{-1}$," decreases of the entering probability and increases of the exiting probability were especially large for firms with low TFP or labor productivity levels. Low-productivity firms, thus, were more vulnerable to real appreciations during the exchange rate reform on extensive margins too.

Heterogeneous responses to real exchange rates may also be observed across firm ownerships. In particular, as in Guariglia *et al.* (2011), we define a firm to be an SOE if the sum of its state and collective capital accounted for more than 50 percent of its total capital. Other firms are defined as non-SOEs. To reveal heterogeneities across ownerships, we repeat benchmark regressions on intensive and extensive margins as in Tables III and IV for subsamples of SOEs and non-SOEs, respectively, and compare estimated sensitivities.

According to the first two columns of Table VII, SOEs were not responsive to real exchange rates in export quantities while their unit values increased with real appreciations. These results held both in 2005 and other years. For non-SOEs in years other than 2005, export quantities declined with real appreciations, while no significant responses for unit values were revealed. In 2005, in contrast, the quantity responses of non-SOEs were enhanced, and their unit values were significantly reduced by real appreciations. In sum, such comparisons demonstrate that on average, real appreciations almost did not impose negative impacts on SOEs on intensive margins. Nonetheless, negative impacts have been received by non-SOEs, especially in the year of the exchange rate reform.

Regarding extensive margins, the last two columns of Table VII find that for SOEs, the entering probability was not influenced by real exchange rates, while the exiting probability even decreased with real appreciations probably as a result of substantial subsidies (Girma *et al.*, 2009). Such results were not different for 2005 and other years. For non-SOEs, the entering probability decreased while the exiting probability increased with real appreciations in years other than 2005. In 2005, these two responses were both enhanced. Such comparisons indicate that non-SOEs were more vulnerable to real appreciations than SOEs on extensive margins as well.

4.3 Destination heterogeneities
Responses of firm exports to real exchange rates also tend to differ across destination markets. We first investigate heterogeneities that relate to destination income levels.

Dependent variable	Intensive margins		Extensive margins (probit)	
	$\Delta \ln q$	$\Delta \ln uv$	Enter	Exit
Panel A: SOEs				
$\Delta \ln RER$	0.414 (0.310)	−0.119* (0.070)	0.127 (0.179)	0.944** (0.409)
$\Delta \ln RER \times y2005$	0.586 (0.728)	0.118 (0.164)	0.025 (0.445)	−0.825 (1.050)
$\Delta \ln RGDP$	1.927** (0.816)	−0.151 (0.186)	0.091** (0.038)	−0.003 (0.084)
$\Delta \ln TFP$			0.029 (0.727)	−0.530 (2.236)
Constant	0.009 (0.038)	0.042*** (0.009)	−3.159*** (0.313)	−0.257 (0.533)
Dummy 2004	0.003* (0.002)	0.001* (0.000)	0.001* (0.001)	0.000* (0.000)
Dummy 2005	−0.015** (0.006)	0.004*** (0.001)	−0.002** (0.001)	0.001** (0.000)
Dummy 2006	−0.017* (0.008)	0.005** (0.002)	−0.001** (0.000)	0.000* (0.000)
Observations	2,866	2,866	2,142	2,589
Pseudo/adjusted R^2	0.311	0.293	0.462	0.401
Panel B: non-SOEs				
$\Delta \ln RER$	0.571*** (0.092)	−0.011 (0.022)	0.163*** (0.051)	−0.832*** (0.107)
$\Delta \ln RER \times y2005$	0.594*** (0.187)	0.111** (0.044)	0.275*** (0.094)	−0.671*** (0.195)
$\Delta \ln RGDP$	0.640** (0.253)	0.267*** (0.060)	0.040*** (0.011)	−0.034 (0.022)
$\Delta \ln TFP$			0.406* (0.231)	−0.923*** (0.217)
Constant	0.064*** (0.011)	0.040*** (0.003)	−2.939*** (0.062)	0.729*** (0.028)
Dummy 2004	0.004* (0.002)	0.003** (0.002)	0.001** (0.000)	0.001** (0.001)
Dummy 2005	−0.018*** (0.004)	0.003*** (0.000)	−0.004*** (0.001)	0.002** (0.001)
Dummy 2006	−0.019** (0.008)	0.004*** (0.001)	−0.003*** (0.001)	0.002** (0.001)
Observations	38,393	38,393	31,328	32,416
Pseudo/adjusted R^2	0.420	0.323	0.698	0.597

Notes: Standard errors in parentheses. Firm-product-country level fixed effects are controlled for regressions on the intensive margins. Time-invariant firm controls and country-level fixed effects are included for the regressions on the extensive margins. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table VII.
Heterogeneous responses due to firm ownerships

High-income countries usually have more stable nominal exchange rates. According to Devereux and Engel (2001), exporters to these destinations tend to exhibit lower degrees of exchange-rate pass-through. Therefore, we expect them to respond more in unit values and less in export quantities. To allow for heterogeneities on intensive margins, we interact $\Delta \ln RER_{ct}$ and $\Delta \ln RER_{ct} \times y2005$ with the destination income level. The log level of income level is also introduced. To be specific, the empirical model is specified as follows:

$$\Delta \ln y_{ijct} = \beta_0 + \beta_1 \Delta \ln RER_{ct} + \beta_2 \Delta \ln RER_{ct} \times \ln RGDPPC_{ct}$$

$$+ \beta_3 \Delta \ln RER_{ct} \times y2005 + \beta_4 \Delta \ln RER_{ct} \times y2005 \times \ln RGDPPC_{ct}$$

$$+ \beta_5 \Delta \ln RGDP_{ct} + \beta_6 \ln RGDPPC_{ct} + \alpha_{ijc} + \alpha_t + \varepsilon_{ijct}. \quad (5)$$

Again, y is the export quantity q or the unit value uv. $RGDPPC$ is the real income level of the destination market, which we measure by the real GDP per capita. Similarly, we consider the following model with these interaction terms to examine heterogeneities on extensive margins:

$$x_{ict} = \beta_0 + \beta_1 \Delta \ln RER_{ct} + \beta_2 \Delta \ln RER_{ct} \times \ln RGDPPC_{ct}$$

$$+ \beta_3 \Delta \ln RER_{ct} \times y2005 + \beta_4 \Delta \ln RER_{ct} \times y2005 \times RGDPPC_{ct}$$

$$+ \beta_5 \Delta \ln RGDP_{ct} + \beta_6 \ln RGDPPC_{ct} + \alpha_i + \alpha_c + \alpha_t + \varepsilon_{ict}. \quad (6)$$

As before, x is a dummy variable indicating whether firm i exported to destination c in year t, and we will also focus on the probit model again.

Estimation results are reported in Panel A of Table VIII. According to the first two columns, the response of quantities to real exchange rates was smaller for exports to countries with higher income levels in years other than 2005, as indicated by the significantly negative coefficient before "$\Delta\ln RER \times \ln RGDPPC$." The difference was further widened in 2005, according to the significantly negative coefficient before "$\Delta\ln RER \times y2005 \times \ln RGDPPC$." As for the response of unit values to real exchange rates, while no significant effects of destination income levels have been identified in years other than 2005, we find that real appreciations in 2005 would result in larger declines of unit values for exports to countries with higher income levels according to the significantly positive coefficient before "$\Delta\ln RER \times y2005 \times \ln RGDPPC$." To sum up, these findings about heterogeneous responses on intensive margins are compatible with our expectations.

Dependent variable	Intensive margins		Extensive margins (probit)	
	$\Delta\ln q$	$\Delta\ln uv$	Enter	Exit
Panel A: income levels				
$\Delta\ln RER$	0.468*** (0.137)	0.163 (0.214)	0.088* (0.049)	−0.625** (0.177)
$\Delta\ln RER \times \ln RGDPPC$	−0.068*** (0.014)	0.022 (0.021)	0.007** (0.004)	0.195** (0.083)
$\Delta\ln RER \times y2005$	0.319*** (0.023)	0.195*** (0.046)	0.328*** (0.057)	0.143* (0.072)
$\Delta\ln RER \times y2005 \times \ln RGDPPC$	−0.044* (0.022)	0.008* (0.004)	0.029*** (0.003)	−0.160*** (0.051)
$\Delta\ln RGDP$	0.246*** (0.083)	0.066 (0.068)	0.137 (0.224)	−0.359 (0.597)
$\Delta\ln TFP$			0.042*** (0.010)	−0.036 (0.022)
$\ln RGDPPC$	−0.466*** (0.031)	−0.008*** (0.002)	0.432*** (0.083)	0.207 (0.199)
Constant	0.452*** (0.032)	0.122*** (0.016)	−0.744*** (0.179)	−1.758 (1.903)
Dummy 2004	0.009* (0.004)	0.004** (0.002)	0.002** (0.001)	0.003** (0.001)
Dummy 2005	−0.022*** (0.003)	0.004*** (0.001)	−0.002*** (0.000)	0.004** (0.002)
Dummy 2006	−0.023*** (0.003)	0.007** (0.003)	−0.001** (0.000)	0.005** (0.002)
Observations	41,379	41,379	33,443	35,986
Pseudo/adjusted R^2	0.533	0.488	0.413	0.378
Panel B: Japan/Korea/ASEAN				
$\Delta\ln RER$	0.623*** (0.126)	0.150** (0.061)	0.052*** (0.007)	−0.109 (0.284)
$\Delta\ln RER \times y2005$	0.495** (0.211)	−0.049 (0.083)	0.236*** (0.024)	−0.785** (0.410)
$\Delta\ln RGDP$	0.437 (0.442)	0.707*** (0.279)	1.087 (1.009)	−0.379** (0.175)
$\Delta\ln TFP$			0.047** (0.023)	−0.062* (0.037)
Constant	0.048** (0.019)	−0.012 (0.017)	−2.270*** (0.087)	0.442*** (0.158)
Dummy 2004	0.007* (0.003)	0.005* (0.003)	0.001* (0.000)	0.004* (0.002)
Dummy 2005	−0.023*** (0.006)	0.007*** (0.002)	−0.003*** (0.001)	0.002*** (0.000)
Dummy 2006	−0.022*** (0.009)	0.006*** (0.001)	−0.002*** (0.001)	0.001** (0.000)
Observations	21,653	21,653	8,628	13,490
Pseudo/adjusted R^2	0.497	0.366	0.382	0.417
Panel C: *other destinations*				
$\Delta\ln RER$	0.393*** (0.128)	−0.066** (0.030)	0.023*** (0.005)	0.192 (0.126)
$\Delta\ln RER \times y2005$	0.904** (0.356)	0.174** (0.082)	0.334*** (0.094)	−0.271* (0.144)
$\Delta\ln RGDP$	0.891*** (0.287)	0.017 (0.068)	0.382* (0.221)	−0.115 (0.621)
$\Delta\ln TFP$			0.043*** (0.012)	−0.022** (0.009)
Constant	0.077*** (0.014)	0.055*** (0.003)	−2.926*** (0.060)	0.277* (0.155)
Dummy 2004	0.008** (0.003)	0.004** (0.002)	0.000** (0.000)	0.001* (0.001)
Dummy 2005	−0.029*** (0.003)	0.005** (0.002)	−0.004*** (0.001)	0.003*** (0.001)
Dummy 2006	−0.020** (0.008)	0.007*** (0.000)	−0.003** (0.001)	0.002** (0.001)
Observations	19,726	19,726	24,817	22,496
Pseudo/adjusted R^2	0.487	0.420	0.566	0.364

Table VIII.
Heterogeneous
responses
across destinations

Notes: Standard errors in parentheses. Firm-product-country level fixed effects are controlled for regressions on the intensive margins. Time-invariant firm controls and country-level fixed effects are included for the regressions on the extensive margins. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

As implied by the significantly positive coefficients for "$\Delta \ln RER \times \ln RGDPPC$" and "$\Delta \ln RER \times y2005 \times \ln RGDPPC$" in the last two columns of Panel A, the entering probability responded more substantially to real exchange rates for exports to countries with higher income levels both in 2005 and other years. That is, facing the same degree of real appreciations, the probability to enter a high-income destination declined more than that to enter a low-income destination. In contrast, the exiting probability was less responsive to real exchange rates in countries with higher income levels in years other than 2005. In fact, while real appreciations tended to result in increases of this probability, the degree was smaller for exports to high-income destinations as indicated by the significantly positive coefficient before "$\Delta \ln RER \times \ln RGDPPC$." In 2005, however, such heterogeneities across countries were almost removed according to the significantly negative coefficient before "$\Delta \ln RER \times y2005 \times \ln RGDPPC$."

We then investigate whether responses to real exchange rates were different between exporters to neighboring Asian economies and other destinations. According to our data, food exports to Japan, Korea and ASEAN countries accounted for more than a half of the total export value of China each year, despite that this share was gradually declining. Chinese exporters might have been engaged in more intense competitions in these economies because of similar preferences and endowments. To reveal heterogeneous real exchange rate effects, we perform benchmark regressions for the subsample of exports to China's neighboring Asian economies, which include Japan, Korea and ASEAN countries and the subsample of exports to other destinations.

Comparing the first two columns of Panel B with those of Panel C, we find that in years other than 2005, exports to Japan, Korea and ASEAN countries declined more substantially in quantities with respect to real appreciations relative to exports to other destinations. Meanwhile, the unit values of exports to Japan, Korea and ASEAN countries decreased with real appreciations, while those of exports to other destinations increased with real appreciations, which might imply quality upgrades. In 2005, quantity responses to real exchange rates were enhanced in both groups of destinations, but the degree was smaller for Japan, Korea and ASEAN countries. Overall, export quantities declined more substantially in other destinations than in the neighboring Asian economies with respect to the same degree of real appreciations in 2005 as the sum of coefficients for "$\Delta \ln RER$" and "$\Delta \ln RER \times y2005$" implies. In the meantime, responses of export unit values in other destinations were reversed in 2005 because the magnitude of the positive coefficient for "$\Delta \ln RER \times y2005$" exceeds that of the negative coefficient for "$\Delta \ln RER$." In contrast, responses of export unit values in Japan, Korea and ASEAN countries remained the same in 2005 with those in other years, which can be illustrated by the insignificant coefficient before "$\Delta \ln RER \times y2005$." To sum up, our findings suggest that Chinese food exports to the neighboring Asian economies were more vulnerable to real appreciations relative to those to other destinations in years other than 2005 on intensive margins. In 2005, however, both quantity and unit value vulnerabilities to real appreciations increased more noticeably for exports to other destinations than exports to the neighboring Asian economies.

In the last two columns of Panels B and C, we compare export responses on extensive margins between the two groups of destinations. Relative to other countries, the entering probability declined more substantially in Japan, Korea and ASEAN countries with respect to real appreciations in years other than 2005. In 2005, the exchange rate effect on the entering probability was enhanced in both groups of destinations, but the degree was smaller in the neighboring Asian economies. According to the net effect, the same degree of real appreciations in 2005 led to less, instead of more, substantial declines of the entering probability in the neighboring Asian economies than declines in other countries. The exiting probability, in contrast, did not significantly respond to real exchange rates in both

destination groups in years other than 2005. In 2005, however, the exiting probability increased with real appreciations for both groups, yet the degree for exports to Japan, Korea, and ASEAN countries is more substantial.

4.4 Product heterogeneities

We finally examine whether export responses to real exchange rates differ across product types. It shall be noted that investigations about extensive margins have been grounded on the firm-country level because no product information is available for non-exporters. Accordingly, to reveal product heterogeneities of export responses, we will focus only on intensive margins[17]. Three broad product types, namely "animal and animal products," "vegetable products" and "foodstuffs," are considered here based on the two-digit HS codes. Similar to the study on country heterogeneities, we perform benchmark regressions for these groups of products before comparison. Table IX reports our estimation results.

As coefficients for "$\Delta \ln RER$" and "$\Delta \ln RER \times y2005$" indicate export quantities for vegetable products responded the most to real exchange rates both in 2005 and other years. Smaller responses were found for foodstuffs. Export quantities of animal and animal products, however, were not significantly responsive to real exchange rates in either period. As to unit values, significant responses to real exchange rates have been identified for both animal and animal products as well as vegetable products in 2005, although no significant responses have been found in other years. Unit values of foodstuffs, in contrast, were increasing with real appreciations throughout the sample period without significant differences identified for the year of 2005. Hence, real appreciations exhibited negative impacts on export quantities for foodstuffs, negative impacts on export unit values for animal and animal products, and negative impacts on both export quantities and unit values for vegetable products.

5. Conclusions

Using a panel data of firms in China's food industry that is merged with transaction level export data, exchange rate effects on agricultural exports have been examined in our paper. Negative effects are revealed at multiple levels on both intensive (i.e. export quantities and unit values) and extensive margins (i.e. the entering and exiting probabilities). Such impacts are especially noticeable in 2005 when China suddenly reformed the exchange rate regime. Taking this reform as a natural experiment, the negative exchange rate effects are robust to the endogeneity issue. In addition, low-productivity firms are found more susceptible to real appreciations in 2005 in export quantities and on extensive margins, but less so in unit values. Exchange rate effects did not significantly differ with productivities in other years. Non-SOEs are identified as the main victims of real appreciations. Exporters to low-income destinations are more responsive to exchange rates in export quantities and the probability of exiting, while those to high-income destinations are more responsive in unit values and the probability of entering. Relative to other countries, exporters to China's Asian neighbors are more vulnerable to real appreciations in export quantities, unit values and the probability of entering in years other than 2005, but less so in 2005. The probability to exit from Asian neighbors, however, is larger than that from other destinations in 2005. Finally, exporters of vegetable products received more negative impacts of real appreciations than those of other products.

From a policy perspective, our finding of a more than 80 percent of exchange-rate pass-through even in the year of the exchange rate reform implies a high degree of international price transmission and consequently a close international price comovement of agricultural products. Such results highlight the importance of global cooperation in price management. Real appreciations exert negative effects on firm exports in general, which can further affect workers' employment and income. Policy makers shall pay special attention to

Dependent variable	Animal (products)		Vegetable products		Foodstuffs	
	$\Delta\ln q$	$\Delta\ln uv$	$\Delta\ln q$	$\Delta\ln uv$	$\Delta\ln q$	$\Delta\ln uv$
$\Delta\ln RER$	0.275 (0.231)	−0.078 (0.122)	0.771*** (0.146)	−0.066 (0.057)	0.509*** (0.124)	−0.048* (0.026)
$\Delta\ln RER \times y2005$	−0.515 (0.470)	0.142** (0.060)	0.595** (0.294)	0.166* (0.090)	0.434* (0.261)	0.023 (0.054)
$\Delta\ln RGDP$	0.495* (0.262)	0.189 (0.161)	0.738* (0.439)	−0.126 (0.324)	0.624* (0.326)	0.118* (0.067)
Constant	0.001*** (0.000)	0.048*** (0.007)	0.042** (0.019)	0.063*** (0.012)	0.107*** (0.016)	0.033*** (0.003)
Dummy 2004	0.007* (0.004)	0.004** (0.002)	0.008*** (0.002)	0.003*** (0.001)	0.006** (0.002)	0.005*** (0.001)
Dummy 2005	−0.013** (0.006)	0.003** (0.001)	−0.018*** (0.003)	0.003** (0.001)	−0.015*** (0.002)	0.006*** (0.003)
Dummy 2006	−0.017* (0.008)	0.004* (0.002)	−0.021** (0.009)	0.005*** (0.002)	−0.019*** (0.003)	0.003*** (0.002)
Observations	7,611	7,611	15,254	15,254	18,514	18,514
Adjusted R^2	0.317	0.348	0.563	0.517	0.529	0.491

Notes: Standard errors in parentheses. Firm-product-country level fixed effects are also included. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table IX.
Heterogeneous responses across products

low-productivity and private exporters as well as exporters of vegetable products, since they are particularly vulnerable to exchange rate shocks. Finally, in spite of negative impacts on firm exports, real appreciations can induce desirable structural transformations with low-productivity firms being replaced by high-productivity ones. Combined with facilitative policy tools such as innovation subsidies, real appreciations may instead be taken as a valuable opportunity to improve China's export structure of agricultural products.

Notes

1. The data is compiled by the author using monthly export value statistics reported by the Ministry of Commerce of the People's Republic of China (http://wms.mofcom.gov.cn/article/ztxx/ncpmy).

2. Based on the author's calculation using the UN Comtrade data.

3. Several studies relied on industry or destination level data, including, for example, Abbott *et al.* (1993), Babula *et al.* (1995), Lamb (2000), Baek and Koo (2008) and Pall *et al.* (2013).

4. It is also interesting to examine how real exchange rate changes affect firm decisions to serve both international and domestic markets. However, firm-product level data of domestic sales, which the Annual Survey of Industrial Firms (ASIF) used in this paper does not report, will be required.

5. The food industry includes agro-food processing, food manufacturing and beverage manufacturing industries. To account for changes in CSIC codes in 2003, the GB/T 4754-2002 classification system has been converted to the GB/T 4754-1994 system. According to the GB/T 4754-1994, two-digit CSIC codes for these industries are 13, 14 and 15.

6. Unit values in our paper are at the HS six-digit level, in line with export values and quantities. There are recent attempts to calculate unit values at a more disaggregated level. However, according to Li *et al.* (2015), the GACC data at the HS eight-digit level face coding problems. Moreover, "a firm usually exports just one HS-8 product to a destination country under the same HS-6 category." Berman *et al.* (2012) framed the behavioral basis for how the *f.o.b.* price and export quantities respond to real exchange rates.

7. It must be noted that the sample means reported in Table I are simple averages. For example, the table shows that the average growth rate of RGDP was roughly 5 percent during the sample period across countries. However, taking each country's initial RGDP weight into account, the weighted average growth rate of RGDP was 3.3 percent, which is close to the world's RGDP growth rate of 3.5 percent reported by the World Bank. Similarly, the growth rate of China's total agricultural exports was 28 percent during the sample period, instead of $2.075 - 1 = 1.075$ as directly converted from the table. At the product-country and firm-product-country levels, our statistics are close to those reported by Li *et al.* (2015) in general.

8. EU is defined in this paper as EU-25 to account for the union's enlargement in 2004.

9. Due to the "large N, small T" feature, the non-stationarity of data is not a critical concern in this paper. In addition, panel unit root test results also indicate that key series including lnRER, ln$q$ and lnuv are all stationary (test results available upon request). However, taking first differences is still a safer approach. First, since the time dimension of our data is short which implies that asymptotic properties of unit root tests might fail and yield test results with low powers, first-differencing log variables can deal with potential non-stationarity (Li *et al.*, 2015). Second, the fixed-effects model of first-differenced variables could control unobserved individual trends, which could reflect time-varying unobserved variables to some extent and thus alleviate the concern of missing variables.

10. While we focus on demand-side factors, year dummies and individual fixed effects in our fixed-effects model could reduce the concern of supply-side impacts to some degree.

11. We interpret the coefficient as elasticity following Li *et al.* (2015) for its correspondence with that in the log-log specification before first differencing.

12. As the analysis at country- and country-product levels, we adopt a fixed-effects model following Berman *et al.* (2012) and Li *et al.* (2015). The fixed-effects model allows for arbitrary correlations between unobserved and observed variables. The Hausman test in benchmark case (i.e. the first two columns of Table III) yields statistics at 114.73 and 138.06, both with associated p-values being 0.000, which also favor the use of fixed-effects model over the random-effects model.

13. Resource reallocation between destination markets or between the domestic and foreign markets is a less concern because most market entry costs are fixed.

14. Instead of using firm-country level fixed effects α_{ic}, we respectively control α_c and α_i here to avoid the threat of the incidental parameter problem.

15. According to Li and Zhao (2016), yuan's forward rate largely experienced two short rounds of appreciations before the reform that both ended with a return to the pegged spot rate. Before the announcement of the reform, the forward rate was actually depreciating. In addition, the forward-looking behaviors of exporters, though may exist, are short-living (Li and Zhao, 2016).

16. The reason we solely focus on the year of 2005 is that the exchange rate reform serves as an exogenous shock to the right-hand-side variable, i.e. exchange rate movements, in our empirical model. We note that in 2005, China also substantially reduced import tariffs and quotas which could benefit exporters that use imported goods as intermediate inputs. There is, however, no evidence that the two moves are related, which means that using this year as a shock to yuan's exchange rate shall not be invalidated. Meanwhile, even considering the effect of reduced import tariffs and quotas, the negative export responses to appreciations will not be reversed, since the increased accessibility to imported intermediary inputs tends to promote rather than suppress exports.

17. Because no product information of non-exporters is available, we are only able to investigate the heterogeneous export response to real exchange rates across product types on the intensive margin. Seeing the difficulty to accommodate it with the analysis of firm and destination factors, we examine heterogeneities across firms, destinations and products separately. However, we also considered a framework that simultaneously includes firm- and destination-level factors. In particular, firm TFP and ownership are considered as firm-level factors, and destination income and the dummy for the group of Japan, Korea and ASEAN markets (*JKA*) are considered as market factors. Key results are similar to those of Tables VI and VII. These results are available upon request.

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The impact of weather index insurance on agricultural technology adoption evidence from field economic experiment in china

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Abstract

Purpose – The purpose of this paper is to empirically investigate the impact of weather index insurance on agricultural technology adoption in rural China.

Design/methodology/approach – A field experiment was conducted with 344 rural households/farmers in Heilongjiang and Jiangsu Provinces, China. DID model was used to evaluate farmers' technology adoption with and without index insurance.

Findings – The results show that weather index insurance has a significant effect on the technology adoption of rural households; there is a regional difference in this effect between Heilongjiang and Jiangsu. Weather index insurance promotes technology adoption of rural households in Heilongjiang, while has limited impact on those in Jiangsu. Weather, planting scale and risk preference are also important factors influencing the technology adoption of rural households.

Research limitations/implications – This research is subject to some limitations. First, the experimental parameters are designed according to the actual situation to simulate reality, but the willingness in the experiment does not mean it will be put into action in reality. Second, due to the diversity of China's climate, geography and economic environment, rural households are heterogeneous in rural China. Whether the conclusion can be generalized beyond the study area is naturally questionable. A study with more diverse samples is needed to gain a fuller understanding of index insurance's effects on farmers in China.

Originality/value – This research provides a rigorous empirical analysis on the impact of weather index insurance on farmers' agricultural technology adoption through a carefully designed field experiment.

Keywords Agricultural technology adoption, Field experiment, Weather index-insurance

Paper type Research paper

1. Introduction

For many developing countries, agriculture provides the leading source of employment and contributes large proportion of the national income. Numerous studies have reported that adoption of improved agricultural technologies enhances household well-being in most less developed countries (Bourdillon *et al.*, 2002 in Zimbabwe; Mendola, 2007 in Bangladesh and Kassie *et al.*, 2011 in Uganda).

Because of China's geographic and climatic diversity, extreme weather events occur almost every year. Rural households in China are exposed to the risk of natural disasters. From 2006 to 2015, about 35m hectares of crops were affected by natural disasters each year, accounting for 29 percent of the arable land, with an average annual food loss of nearly 17m tons (China Statistical Yearbook, 2015).

Due to the high cost of or inaccessibility to formal risk management, most of the natural risks remain uninsured in China. Shocks of natural disasters can not only reduce current returns, but

also destroy assets accumulated over years. Small households are liable to adopt safer, but lower-return agricultural technologies, and may keep low consumption because they are always exposed to natural risks (Dercon, 1996; Zimmerman and Carter, 2003; Barnett and Mahul, 2007; Hill, 2008; Carter *et al.*, 2012; Lybbert and McPeak, 2012; Hill *et al.*, 2013). Agricultural technological improvements are crucial to raising agricultural productivity, reducing poverty and solving the problem of food security. Less adoption of new risky agricultural technologies and lack of technological change locked small householders into low productivity and subsistence production, then make them fall into trap of poverty (Barnett *et al.*, 2008; Asfaw *et al.*, 2012). Agricultural insurance has been believed as an effective way of helping small householders diversify production risks. Fadhliani *et al.* (2019) revealed that an increase in the insurance coverage level will lead the farmer to apply more inputs to increase expected yield in Indonesia.

Chinese government promotes multi-peril crop insurance (MPCI) as a way to deal with risks in agricultural sector. The coverage of MPCI is too low and franchise deductibles are too high, and the largest indemnity cannot offset the variable material costs of production, which makes that the insurance product cannot significantly improve farmers' ability to bear risks (Zhao *et al.*, 2016; Ye *et al.*, 2017). Simultaneously, MPCI possesses some well-known structural problems such as moral hazard, adverse selection, blurry boundaries between government and market, disordered market competition and improper management, which makes it extremely expensive. Its operation heavily depends on government subsidies (Hazell, 1992; Miranda and Glauber, 1997; Skees *et al.*1999; Tuo, 2016). Given the high costs of MPCI, a growing number of academic researchers and governments have exhibited interest in the use of weather index insurance to manage the risks faced by poor agricultural producers (Miranda and Vedenov, 2001). Weather index insurance indemnifies the insured based on the observed value that is highly correlated with the losses, but cannot be influenced by the insured (Miranda and Farrin, 2012).Weather index insurance may be the best alternative for achieving Chinese government policy objectives of providing agricultural insurance to as many farmers as possible at reasonable costs.

With the outpouring of index insurance pilot program in Africa, South and Southeast Asia, a number of studies have examined farmer's demand for index insurance and its impact. Theoretical models, framed field experiment and randomized controlled trial have been used to assess the impact of insurance on production decisions. Many researchers have found that improved technologies can increase production, but it is risky and require up-front investment. After index insurance becomes available, farmers can get more credit and invest it in profitable production. Insurance leads to more adoption of innovative agricultural technology (Stein, 2011; Cole *et al.*, 2013; De Nicola and Hill, 2013; Elabed *et al.*, 2013; De Nicola, 2015; Farrin and Miranda, 2015). Jensen *et al.* (2014) claimed that insured households reduce the precautionary savings, and then have more cash to invest in production activities.

But some researchers have stated that the insurance improves household welfare individually, but not for a cumulative household welfare. Insurance has different effects on the households with different wealth. With insurance, low-income households avoid cutting down consumption and families with high income do not sell their productive assets to withstand the shocks (Janzen and Carter, 2013; Karlan *et al.*, 2014). McIntosh *et al.* (2013) advised that index insurance does not boost investments, but help those who have already invest in high agricultural technology spread the risk. Farrin and Murray (2014) argued that the premium of insurance in good years increases farmers' costs and had a negative effect on wealth.

Taken together, the conclusions of existing studies are not consistent and samples are limited to Africa, South and Southeast Asia; no empirical evidence about the impact of index insurance has been investigated in China so far. Further research is needed. The main purpose of this research is to empirically investigate the impact of weather index insurance on farmers' improved agricultural technology adoption. A framed field experiment was conducted with

farmers to detect their technology adoption with and without index insurance in Heilongjiang and Jiangsu Provinces in China. To the best of our knowledge, no prior literature has used field experiment to study weather index insurance and its impact in China. Our experimental design was based on some research that have been successfully implemented in other developing countries (Giné and Yang 2009; Lybbert *et al.*, 2010; Patt *et al.*, 2010; Hill and Viceisza, 2012; Norton *et al.*, 2014; Carter *et al.*, 2014). As field experiment allows farmers to make technology choices in a continuous and dynamic context; this increases the external validity of our findings and the policy implications will be more credible.

The rest of this paper is organized as follows. Section two explains how weather index insurance affects farmers' agricultural technology adoption through theoretical analysis. The third section describes data set and field experiment design. Empirical strategies are presented in section four. Section five introduces the robust test. Section six is the conclusion and discussion.

2. Conceptual framework and hypotheses
Farmers are faced with two technological options when making production decisions: traditional technologies with low risk and low return; innovative technologies with high risk and high return. Natural hazards (e.g. droughts, floods and diseases) are major risks in agricultural production. Households are assumed to maximize their utility function subject to family endowment and natural risks. If the utilities of adopting innovative technologies are larger than that of traditional technologies households will choose the innovative technologies. Unlike other sectors, uncertainty caused by natural risks has a significant effect on decision making in agricultural sector (Ahsan *et al.*, 1982). Most farmers are risk averse and will often be hesitant to adopt innovative technologies with high profitability and high risks, and may choose to maintain existing low productivity technologies with low risks, due to the lack of both *ex ante* and *ex post* risk management strategies such as formal credit and insurance (Mukasa, 2018; Dercon and Christiaensen, 2011; Rosenzweig and Binswanger, 1993). Insurance has two functions: it promotes farmers' *ex ante* adoption of advanced production technology with higher expected return and variance, through reduced credit rationing. It helps rural household smooth consumption when they experience large seasonal fluctuations due to unusual weather events (Ghosh *et al.*, 2000). By allowing farmers shifting risks, insurance enables rural households to undertake risky investment which they would not engage in if there were no insurance, and thus could lead to Pareto-preferred states (Ahsan *et al.*, 1982). In countries where the insurance market is growing rapidly, better designed insurance contracts can mitigate the weather shocks and boost investments in fertilizer, hired labor, irrigation, and pesticides as well, which helps farmers' production choices to achieve a potential Pareto improvement in aggregated social welfare (Ye *et al.*, 2017; Hill *et al.*, 2019). By spreading individual risks, insurance serves as an effective hedge against natural disasters by reducing the variance of output and increasing farmers' risk-taking ability, which then could result in improved allocation of resources in innovative technologies.

In general, by offering the possibility of transferring risks, weather index insurance could improve farmers' ability to withstand risks and enable them to allocate more resources into risky investments such as adopting new technologies. Thus, our hypothesis is:

H1. Weather index insurance will promote farmers' innovative technology adoption.

3. Data collection and experiment design
3.1 study area
The field experiment was conducted in three counties in Heilongjiang Province and two counties in Jiangsu Province in July and August of 2017 (see Table I). Totally, 344 participants were recruited from 32 villages and 1,376 observations were obtained with four-round panel

data. The counties in Heilongjiang Province are all located within the main rice growing areas which suffered a catastrophic flood in 2013. Most households in this region already took up multiple-peril crop insurance to help manage agricultural risks. As a result, it is expected that households from the study region in Heilongjiang Province are more likely to be receptive to weather index insurance. Another important province in the reform and innovation of agricultural insurance is Jiangsu Province which is densely populated with less per capita arable land (0.85 mu[1]). The cultivated land conditions are similar and all in the plains with developed irrigation system. The natural risks are less than that in Heilongjiang Province (see Table VIII). On the contrary, Heilongjiang is vast and sparsely populated and the per capita arable land is 6.27 mu. Some of cultivated land is located in hills and is vulnerable to drought disasters; the other part of cultivated land is located in the plains which is vulnerable to floods due to their proximity to the Songhua River. In order to avoid the difference in cultivated land conditions affects the farmers' response in the experiment, the research team ensure that the samples from villages in the hills equal to those in the plains.

These differences in geographic location, modes of agricultural production and frequency of natural disasters may lead to farmers' different demand for weather index insurance and technology adoption. So these two provinces are selected as study area.

3.2 Sample selection

To ensure subjects could understand the experiment context about agricultural technology adoption and weather index insurance terms, criteria for selecting the subjects were as follows: Subjects should have farming experience and participate in family decision making. They should have received primary or higher educations. We got the villager list from local officials and chose farmers who meet the above criteria to form a sub list, and then randomly recruited subjects from it[2].

3.3 Field experiment design

Field experiment recruits farmers as subjects in the field instead of recruiting students in the lab. Farmers are in the context of agricultural production which they are very familiar with, rather than be introduced of abstract terminologies. It allows researchers to analyze the effects of exogenous treatments on farmers' behaviors (Harrison and List, 2004). The questionnaire survey obtains information by asking farmers some subjective questions. It can only get the static data. The field experiment simulates agricultural production under different weather conditions and lasts for a few rounds. It helps farmers understand insurance terms under different climate in this experiment. Farmers' technology choices are made in a continuous and dynamic context which is close to the real life of famers, and then the results would be more reliable.

3.3.1 Division of the control and treatment group. To test the effect of index insurance on farmers' technology adoption, all subjects were divided into control group and treatment group randomly. With other conditions being equal, treatment group was provided with index insurance and control group without it. Two groups of farmers would choose

Province	County	Number of sample towns	Number of sample villages	Number of sample households
Heilongjiang	Mulan	4	8	75
	Hulan	3	6	71
	Tonghe	2	4	63
Jiangsu	Guanyun	4	8	87
	Jurong	3	6	48

Table I.
The geographical
distribution of
the samples

agricultural technology between traditional technologies with low risk and low return and innovative technologies with high risk and high return. The influence of index insurance could be valued through comparing the data of the two groups.

Experiment was conducted for four rounds with two groups, respectively. Each round represented one planting cycle. To analyze the impact of index insurance on the treatment group, there is no insurance for the first two rounds and with insurance for the next two rounds in this group.

According to preliminary research, it was found that improved seeds, new chemical fertilizers and pesticides are the main technologies affecting rural households' farming income. Among them, seeds had the greatest impact on yields, and then were selected as representative of improved agricultural technologies (Giné and Yang, 2009; Lybbert *et al.*, 2010; Stein, 2011; Ward and Singh, 2015; Freudenreich and Mußhoff, 2018).

3.3.2 External validity. To ensure the external validity of the experimental design, the experimental process need to be controlled, prerequisites need to be introduced and the experimental parameters should be set carefully before the formal experiment.

3.3.2.1 Liquidity constraints. In the experiment, the subjects who suffered bad weather may get net income equal to or less than zero, and have no funds to purchase agricultural production materials next year. To continue agricultural production, they must borrow money from relativities or rural financial institution in real life. The purpose of this research is to test the impact of insurance and other factors were excluded. It is assumed that there are no credit or liquidity constraints.

3.3.2.2 Status quo bias. Status quo bias means that people tend to maintain choices that have been made in the past. To avoid this preference, the farmers draw lots to determine the weather at the end of each round. Different weather leads to changes of income, which made farmers rethink and choose technology, not just repeating his choice of former rounds. After the experiment, if the farmer's choice remains unchanged in four rounds the experimenter would ask him the reason to judge whether his choices were based on status quo bias or serious thinking. In the total samples, about 30 percent of the farmers' choices remained unchanged, which was close to the reality[3].

3.3.2.3 Peer effects. To minimize the effects of subject's peers and social networks on individual's technology adoption, the subjects sat in a class room of local primary school and were separated to ensure that they cannot see each other's choice and talk with each other from the beginning to the end of the experiment. If they have any questions, they were instructed to ask the experimenter for help. Each experimenter was responsible for four subjects in every experiment. They were trained before the experiment to ensure they express all instruction in neutral and unified language. All experiment information and tasks were put into a unified laboratory manual and were expressed in neutral language. The manual was handed out to famers for reference.

3.3.3 Experiment scenario. To simplify the experiment, each farmer is provided with the same initial endowment (10 mu of land and ¥11,200) as startup funds. In the preliminary experiment, we consulted local farmers and technicians about the cost and income of agricultural production. The cost of traditional seeds with traditional fertilizers and pesticides is nearly ¥600 per mu, and then the cost of improved seeds with improved fertilizers and pesticides is about ¥1,100 per mu[4]. The cost here includes all material costs. It is easy to understand for farmers. The income per mu is around ¥1,000 with traditional seeds and almost ¥2,000 with improved seeds. Insurance premium and indemnity of current local agricultural insurance are ¥15 and ¥200 per mu, respectively. The experimental parameters were designed based on these values and ratios.

The living cost is ¥5,000 for every family, and was covered by the earning of last year. When the farmers make the technology decision at the beginning of next year, they do not

need to consider it and have enough money to buy improved seeds (11,200 > 11,000). The subjects were told this assumption before the experiment began.

The weather is simplified as two kinds: bad weather and normal weather. The probability of bad weather is 30 percent (based on the historical weather data of study area). To prevent farmers from being influenced by experimental setting; we label traditional and improved seeds as No. 1 and No. 2, respectively. Table II shows the experiment parameters.

3.3.4 Experiment process. The experiment includes four parts: a game to help farmers understand index insurance, field experiment of technology choice, a game to test farmers' risk preference and a short questionnaire survey.

3.3.4.1 The game of introducing weather index insurance. Most farmers are not familiar with weather index insurance in study area; poor understanding of insurance will influence the experiment efficiency. The challenge we faced in experimental design was interpreting index insurance clearly to the participants. We played a game to help them understand index insurance terms and basis risk before the formal experiment.

First, weather index insurance was introduced to the participants. The weather index insurance is a new product. Its indemnity is calculated according to the contract weather index (such as rainfall or temperature) which is highly correlated with yield. When the crop growth period rainfall/temperature of the nearest weather station is less or higher than the contract index, all insured farmers will receive the same indemnity no matter how much loss they suffered.

Second, the participants simulated production, and then the representative drew lots to determine the crop growth period temperature/rainfall. Afterwards, compare it with the contract index; if it is more or less than the contract index, all the participants got the same indemnity. Third, the participants drew lots to determine personal loss, and then compared it with his indemnity. The difference was the basis risk which is an important factor affecting the performance of weather index insurance (Xiao and Yao, 2018).

Finally, we assessed the participants' understanding through a quiz. If the participants could not answer the questions correctly, we helped them understand it until they gave correct answers before the formal experiment began.

According to local climate, weather index insurance is designed as a rice temperature and rainfall composite index insurance. The insurance clauses took the form of the contract of Guoyuan Insurance Company which is the first company to provide index insurance in China.

3.3.4.2 Technology selection experiment. We introduced experiment task to the subjects and handed out flyers with experimental parameters to them for reference. The subjects selected seeds to simulate production with initial endowment, and then draw lots to determine the weather. The experimenters calculated net income for them at the end of each round and carried it over as start-up capital for the next round. This process lasted four rounds for control group. The first two rounds of treatment group were the same with control group. In the last two rounds, the subjects were provided with weather index insurance and then they made seeds decisions.

3.3.4.3 The game to test farmers' risk preference. Farmers' risk preference influences their production decisions (Dercon and Christiaensen, 2011; Ward and Singh, 2015).

	Cost	Earnings normal weather	Earnings bad weather	Living cost	Insurance premium	Insurance indemnity
Traditional seeds (No. 1)	6,000	13,000	0	5,000	200	3,000
Improved seeds (No. 2)	11,000	21,000	0	5,000	200	3,000
Source: Authors' calculations, based on data collected by the field experiment						

Table II.
The experiment
parameters setting
unit: RMB

Based on the research of Holt *et al.* (2002), Brick and Visser (2015), we played a game to test farmers' risk preference.

The subjects participated in a lottery game with two options. Option A is to obtain a certain amount of money which increased from ¥3 to ¥25. Option B is a gamble which has seven black balls (present ¥0) and three white balls (present ¥50). The probability of drawing black and white balls is 70 and 30 percent, respectively.

The subject was asked to choose from two options to decide which one he is more preferred: to get 3¥ directly, or to participate in the game of drawing. If the subject chose option B, then the next time the amount of money in option A would increase two more ¥ and the subject continued to choose. The game ended when the subject chose option A. The more times Option B is chosen, the higher farmer's risk tolerance is, because there is more uncertainty in Option B than in Option A. The times of choosing option B is farmer's risk preference score which varies from 0 to 12. The higher the score is, and the farmer is more willing to take risks (Table III).

3.3.4.4 A short questionnaire survey. Finally, a questionnaire survey was conducted to collect the information about households' characteristic. Each experiment lasted for 60 min. After the experiment, each participant got ¥80 as compensation which equals two and half hours wages of local labor.

4. Empirical analysis of weather index insurance's influence on technology adoption

4.1 Selection of DID model

Panel-Difference in Difference (Panel-DID) was used to analyze the impact of index insurance. DID assesses the influence of policy or external events by comparing the difference between treatment group and control group. Weather index insurance is an external variable. It will influence the technology choices of the treatment group before and after insurance was provided; moreover, it makes farmers' technical adoption of treatment group differ from control group. DID was used to investigate the impact of risk shock and insurance on farmers' venture capital investment by Hill and Viceisza (2012); following their study, logistic regression (LOGIT), fixed effect model (FE) and random effect model (RE) are used for DID regression to ensure the robustness of the model. The panel-DID model can be established as:

$$Tech_{it} = \beta_0 + \beta_1 T + \beta_2 I_{it} + \beta_3 T \times I_{it} + \beta_4 X_{it} + \varepsilon_{it}. \qquad (1)$$

$Tech_{it}$ represents the agricultural technology choice of the ith farmer in the tth period, T is a dummy variable of group (control group is 0; treatment group is 1). I denotes a dummy

Order	Option A	Option B (draw a ball)
1	¥3	Black ball: ¥0; white ball: ¥50
2	¥5	Black ball: ¥0; white ball: ¥50
3	¥7	Black ball: ¥0; white ball: ¥50
4	¥9	Black ball: ¥0; white ball: ¥50
5	¥11	Black ball: ¥0; white ball: ¥50
6	¥13	Black ball: ¥0; white ball: ¥50
7	¥15	Black ball: ¥0; white ball: ¥50
8	¥17	Black ball: ¥0; white ball: ¥50
9	¥19	Black ball: ¥0; white ball: ¥50
10	¥21	Black ball: ¥0; white ball: ¥50
11	¥23	Black ball: ¥0; white ball: ¥50
12	¥25	Black ball: ¥0; white ball: ¥50

Table III.
Risk preference
test unit: RMB

variable of period (Before providing with weather index insurance, $I = 0$; otherwise $I = 1$). $T \times I$ indicates the net effect of weather index insurance on the agricultural technology adoption. X_{it} are control variables, including individual characteristics of households, family characteristics, risk preferences, etc.

4.2 Dependent variables

We measured farmers' technology adoption through the selection of traditional seeds and improved seeds: when the farmer chooses the traditional seeds, it is 0, otherwise it is 1. Farmers' agricultural technology adoption in four rounds is shown in Table IV.

Table IV shows that the improved seeds adoption rates are different within the group and between groups. Overall, the improved seeds adoption ratios are all more than 70 percent in four rounds of two groups, and higher than those of traditional seeds. Through focus group interviews, we learned that seeds companies often organized new seeds promotional activities. The technicians in technology extension stations provided technical training program sometimes. Farmers in study area are familiar with improved seeds and willing to accept them.

The growth rates of the improved seeds adoption ratio between the two groups are different. In the last two rounds of the treatment group, the ratio of the farmers' choosing improved seeds substantially increases, compared with those of the first two rounds. After index insurance was provided, the ratio of the farmers' choosing improved seeds increases from 70.35 and 73.26 percent in the first and second rounds to 81.98 and 85.47 percent in the third and fourth rounds of the treatment group. In the control group, the experimental context remains unchanged, and the improved seeds adoption is relatively stable. The ratio of farmers' choosing improved seeds increases from 76.74 percent in the first round to 80.81 percent in the fourth round. The change is much smaller than that of the treatment group.

There are differences in the rate of improved seeds adoption between two groups. In the first two rounds, the ratios of improved seeds adoption in the control group are higher than those of the treatment group by 6.39 and 5.81 percent, respectively. After the farmers were provided with insurance, the rates of adopting improved seeds in treatment group are higher than those of the control group by 2.91 and 4.66 percent in the last two rounds. The findings preliminarily indicate that weather index insurance influences farmers' technology selection, but further empirical tests are needed.

4.3 Control variables

Based on the research of Ward and Singh (2015), and Meng, individuals and households characteristics, natural disaster experience and risk preference are included as control variables. The household endowments of rural households have been set as experimental parameters; they are not taken as control variables. Descriptive statistics of the main variables are shown in Table V.

Table V shows that most of the subjects are male (about 84.4 percent), and the mean of education is 7.305 years with only 36.7 percent completed junior high or higher education ($\geqslant 9$ years). The average experience engaging in planting is about 27 years and the average rate of agricultural labor is 85 percent. In other words, most of the samples' income comes from agriculture. The average household farm size is about 80 mu. About 60 percent of the farmers have suffered natural disasters in the past five years, and the loss is nearly 40 percent of normal annual income.

The average risk appetite of the farmers is about 6 (on a scale of 0–12). There is no significant difference in the individual characteristics of the two groups.

According to the meteorological data, the probability of bad weather in the experiment is 30 percent. The weather of the former year will affect the technological choices of the next year; the lag phase of weather is used as a control variable.

Group	Traditional seeds		Improved seeds		Difference	
	Number of samples	Ratio (%)	Number of samples	Ratio (%)	Number of samples	Ratio (%)
The first round						
Control	40	23.26	132	76.74	92	53.48
Treatment	51	29.65	121	70.35	70	40.70
Difference	11	6.39	−11	−6.39	−22	−12.78
The second round						
Control	36	20.93	136	79.07	100	58.14
Treatment	46	26.74	126	73.26	80	46.52
Difference	10	5.81	−10	−5.81	−20	−11.62
The third round						
Control	36	20.93	136	79.07	100	58.14
Treatment	31	18.02	141	81.98	110	63.96
Difference	−5	−2.91	5	2.91	10	5.82
The fourth round						
Control	33	19.19	139	80.81	106	61.62
Treatment	25	14.53	147	85.47	122	70.94
Difference	−8	−4.66	8	4.66	16	9.32

Source: Authors' calculations, based on data collected by the field experiment

Table IV.
Farmers' technical choices and differences in two groups

Variables	Definition	All samples Mean (SD)	Control group Mean (SD)	Min.	Max.	Treatment group Mean (SD)	Min.	Max.
Weather	1st year (disaster = 0, normal = 1)	0.733 (0.443)	0.75 (0.434)	0	1	0.715 (0.453)	0	1
	2nd year	0.631 (0.483)	0.622 (0.486)	0	1	0.639 (0.481)	0	1
	3rd year	0.765 (0.425)	0.825 (0.381)	0	1	0.703 (0.458)	0	1
	4th year	0.639 (0.481)	0.587 (0.494)	0	1	0.692 (0.463)	0	1
Individual characteristics	Province ($H=0, J=1$)	0.385 (0.487)	0.335 (0.473)	0	1	0.435 (0.497)	0	1
	Age (years)	51.302 (10.017)	51.823 (10.139)	26	77	50.782 (9.895)	27	74
	Gender (male = 1, female = 0)	0.844 (0.371)	0.829 (0.377)	0	1	0.859 (0.366)	0	1
	Education (years)	7.305 (2.856)	7.059 (2.851)	0	16	7.553 (2.847)	0	16
Household production characteristics	Years of planting (years)	27.938 (12.449)	28.341 (12.499)	2	55	27.535 (12.423)	2	57
	Rate of agricultural labor (%)	0.854 (0.239)	0.863 (0.231)	0	1	0.845 (0.246)	0.2	1
	Household farm size (mu)	79.897 (120.95)	93.860 (129.38)	1	1,200	65.933 (110.51)	2	1,100
Natural disasters	If suffer natural disasters in the past five years (yes = 1, no = 0)	0.644 (0.479)	0.624 (0.486)	0	1	0.665 (0.473)	0	1
Risk preference	Risk preference (0–12)	6.079 (4.681)	6.658 (4.541)	0	12	5.500 (4.762)	0	12

Notes: H represents Heilongjiang Province; J represents Jiangsu Province; Household farm size is farmers' planting scale in their real life
Source: Authors' calculations, based on data collected by the field economics experiment

Table V.
Descriptive statistics
of the main variables

The previous studies of Dercon and Christiaensen (2011), Ward and Singh (2015) and (Ahsan *et al.*, 1982) found that risk attitude affects farmers' production behavior. To investigate the impact of different risk attitudes on farmers' technology adoption, all subjects were classified into three categories based on the study of Binswanger (1980) and the scores of the test. Farmers with risk scores between 0~4, 5~8 and 9~12 were classified as risk-averse, risk-neutral and risk-preferring farmers, respectively. Risk-averse farmers account for the highest proportion of 42.73 percent. Risk-neutral households account for 18.9 percent, the lowest proportion (see Table VI).

4.4 Model regression results and interpretation
This research focuses on the regression coefficient of $T \times I$, which expresses the net effect of weather index insurance on farmers' agricultural technology adoption. Since agricultural development, natural conditions, and production methods are different in Heilongjiang and Jiangsu Province, DID model is adopted to analyze both pooled and by province samples.

It can be seen from Table VII that the coefficients of $T \times I$ of the pooled sample and the Heilongjiang sample in three models are all significant, but that of the Jiangsu sample is not significant. It means that weather index insurance plays an important role in promoting the adoption of improved seeds after controlling the time-varying effect and the differential effect in Heilongjiang Province, and there are regional differences in the impact of weather index insurance.

In the experiment, farmers' adoption rate of improved seeds increases after the insurance is provided, which verifies the research hypothesis. The result is consistent with previous studies by Hill and Viceisza (2012) and Norton *et al.* (2014), which indicates when farmers are provided with insurance they are more willing to allocate resource endowment in risky investment. Improved seeds would cost more investment, in the absence of risk-sharing strategies, farmers will suffer a higher loss if bad weather occurs, which constrains the farmers' advanced technology adoption; weather index insurance, as a risk management tool designed specifically for natural disasters, can effectively help farmers diversify natural risks and reduce post-disaster losses. Table VII shows after they are provided with index insurance which effectively spread the natural risks, new technologies adoption are much higher than before.

In terms of statistical criteria, three models are all significant; which means that the research results are robust. In view of the variable significance and informativeness of the model results, the logit model can provide a full picture of farmers' advanced technology adoption; we focus on the discussion of it to investigate the major drivers in addition to weather index insurance which influence agricultural technology adoption. In the logit model, the variable of risk preference has significant positive effects on technology adoption both in pooled and by province samples. It indicates that risk-preferring farmers have

| Risk-averse | | | Risk-neutral | | | Risk-preferring | | |
Risk score	Number (person)	Ratio (%)	Risk score	Number (person)	Ratio (%)	Risk score	Number (person)	Ratio (%)
0	50	14.53						
1	56	16.28	5	17	4.94	9	26	7.56
2	14	4.07	6	11	3.20	10	12	3.49
3	9	2.62	7	22	6.40	11	1	0.29
4	18	5.23	8	15	4.36	12	93	27.03
Total	147	42.73		65	18.90		132	38.37

Table VI.
Risk preference distribution

Source: Authors' calculations, based on data collected by the field economics experiment

Table VII. Panel-DID model regression results of by province and pooled samples

Variables	(1) LOGIT JS Coefficient	JS Margin	HLJ Coefficient	HLJ Margin	TOTAL Coefficient	TOTAL Margin	(2) FE JS Coefficient	FE HLJ Coefficient	Total Coefficient	(3) RE JS Coefficient	RE HLJ Coefficient	TOTAL Coefficient
T×I	0.394 (0.283)	0.055 (0.048)	0.827* (0.240)	0.130* (0.038)	0.476** (0.179)	0.071** (0.026)	0.091 (0.037)	0.118*** (0.029)	0.108*** (0.031)	0.062 (0.034)	0.114*** (0.027)	0.086*** (0.027)
Weather (Lag one phase)	0.320 (0.281)	0.046 (0.040)	0.522** (0.229)	0.082** (0.036)	0.415** (0.182)	0.059** (0.025)	0.045 (0.033)	0.034 (0.026)	0.034* (0.022)	0.048 (0.032)	0.044* (0.025)	0.039*** (0.025)
Province					0.301 (0.197)	0.046 (0.034)						0.024 (0.056)
Age	−0.016 (0.022)	−0.002 (0.003)	−0.042** (0.021)	−0.007** (0.003)	−0.026** (0.015)	−0.005** (0.003)				−0.00058 (0.005)	−0.006 (0.005)	−0.005 (0.003)
Gender	1.378*** (0.479)	0.194*** (0.064)	0.261 (0.234)	0.039 (0.035)	0.501** (0.213)	0.069** (0.033)				0.226* (0.125)	0.050 (0.059)	0.059 (0.062)
Education	0.122*** (0.045)	0.017*** (0.006)	−0.0292 (0.0388)	−0.004 (0.006)	0.037 (0.029)	0.007 (0.009)				0.020** (0.009)	−0.005 (0.010)	0.009 (0.011)
Years of planting	−0.005 (0.014)	−0.00065 (0.002)	0.139 (0.174)	0.002 (0.003)	0.007 (0.012)	0.003 (0.005)				−0.001 (0.003)	0.003 (0.004)	0.004 (0.001)
Agricultural labor	0.830** (0.421)	0.117** (0.057)	0.907 (0.645)	0.014 (0.098)	0.576* (0.463)	0.086* (0.051)				0.108 (0.091)	0.024 (0.146)	0.082 (0.074)
Household farm size	0.005 (0.002)	0.00065 (0.0003)	0.002* (0.001)	0.003* (0.002)	0.004*** (0.001)	0.0005*** (0.0003)				0.00022 (0.00026)	0.00020 (0.00021)	0.003 (0.005)
If Suffered Natural disasters	0.723** (0.304)	0.102** (0.042)	0.293 (0.283)	−0.044 (0.043)	0.153 (0.186)	0.031 (0.036)				0.092 (0.058)	−0.049 (0.062)	0.023 (0.045)
Risk Preference	0.074** (0.029)	0.010** (0.004)	0.055*** (0.025)	0.009** (0.004)	0.073*** (0.018)	0.015*** (0.009)				0.011* (0.006)	0.010* (0.006)	0.013** (0.006)
Constant			−0.939 (0.372)		0.064*** (0.813)		0.723*** (0.029)	0.739*** (0.018)	0.726*** (0.021)	0.344*** (0.006)	0.954*** (0.006)	0.665*** (0.173)
F/Wald χ²	45.32		37.35		71.69		2.81	5.76	11.93	32.12	32.65	50.67
Prob > F/χ²	0.000		0.000		0.000		0.039	0.001	0.000	0.002	0.000	0.000

Notes: The values in brackets are standard errors. *, **, ***Significant at the 10, 5 and 1 percent levels, respectively
Source: Authors' calculations, based on data collected by the field economics experiment

preference for advanced technology; they are more concerned about benefits other than risk, and will prefer to new technologies with high risk and high return rather than traditional technologies with low risk and low return. For each additional unit of farmer's risk tolerance, the possibility of adopting new technology is increased by 1.0, 0.9 and 1.5 percent in Jiangsu, Heilongjiang and pooled samples, respectively, which is consistent with the theoretical hypothesis.

The results also show that advanced technology adoptions are driven by changes in weather, household farm size and the age of farmers. In Table VII we see that the coefficient of weather is significant at 5 percent level in both the pooled and Heilongjiang samples, indicating that if the weather of the previous year is normal, more new technologies would be adopted by the farmers, which is consistent with our expectations. The variable of household farm size has a significant positive impact, which denotes that large-scale farmers can achieve more significant scale effects by adopting technology, and thus they are more inclined to adopt new technologies. Age negatively affects the technology adoption significantly, indicating that the older farmers are more reluctant to accept new technology.

Variables of gender and agricultural labor rate have significant positive effects in the pooled and the Jiangsu samples; gender has a significant positive effect on technology adoption at 1 and 5 percent levels, respectively. This is consistent with the previous findings by Li *et al.* (2010) and Zhu *et al.* (2015). The rate of agricultural labor is also the main driver of technology adoption, the more agricultural labor, the more dependent the household income is on agriculture, and improved technologies are more crucial to income increase.

Variables of education and suffering natural disasters have significant positive effects only in the Jiangsu sample, the possible reason is that farmers in Jiangsu Province have longer education experience than those of Heilongjiang Province (see Table VIII), and they can better understand the advanced technology, which results in a significant positive effect of education; Jiangsu sample is less likely to suffer natural disasters than that of Heilongjiang, and their perception of extreme weather event may not be as strong as that of Heilongjiang farmers, then they are more liable to adopt new technology. These variables should be considered when implementing weather index insurance to promote farmers' agricultural technology adoption.

Table VII shows that the same variable has different influences in pooled and by province samples. In order to find the possible reasons, a sample *t*-test is conducted to compare the individual or households characteristics differences between samples of the two provinces. Only the significant variables are listed (see Table VIII).

It can be seen from Table VIII, the rate of agricultural labor and the average household farm size in Heilongjiang Province reaches 94.40 percent and 101.53 mu, which are 1.45 and 2.3 times of those in Jiangsu Province, respectively. That is, farmers in Heilongjiang rely more on agriculture and there would be more human capital and resources invested in agriculture which is the main source of the households income. Relying on agricultural income makes farmers pay more attention to advanced agricultural technology. Natural

| Variables | Heilongjiang province | | | Jiangsu province | | | *t*-test |
	Mean	Min.	Max.	Mean	Min.	Max.	
Education (years)	6.919 (2.724)	0	16	8.954 (3.192)	0	16	−5.98***
The rate of agricultural labor (%)	0.944 (0.170)	0	1	0.655 (0.315)	0	1	18.88***
Household farm size (mu)	101.531 (119.573)	10	1,200	43.981 (113.291)	1	710	9.58***
Disasters in the past five years (yes = 1; no = 0)	0.799 (0.401)	0	1	0.385 (0.487)	0	1	14.90***

Table VIII.
Variables descriptive statistics of by province sample and *t*-test results

Notes: The values in brackets are standard deviations. We selected some scale farmers from each village due to the rapid development of large-scale farmers in Jiangsu Province, and thus the average household farm size is much larger than that of only including small farmers. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

disasters increase the risks of agricultural investment and farmers have limited resources to mitigate risks when they adopt new risky agriculture technology. Large-scale farmers are faced with more risk than their smaller counterparts, arising from the considerable up-front investment. The compensation mechanism of weather index insurance alleviates the risks, and then induces farmers to take risky, yet profitable technology. Once weather index insurance is provided to farmers, it will stimulate them to invest in technology. Then the insurance has a significant impact on Heilongjiang sample which contains more large-scale farmers.

In Heilongjiang sample, 79.90 percent of them have suffered natural disasters in the past five years, which is 2.07 times of farmers in Jiangsu Province. That is to say, for farmers in Heilongjiang Province, adopting new agricultural technologies is more likely to suffer losses due to the higher incidence of natural disasters. Weather index Insurance reduces farmers' exposure to risk, then their perception of the degree of risk would change, which can result in behavioral adaptation such as adoption of risky agricultural technology (Hill *et al.*, 2013). The farmers' average education experience in Heilongjiang Province is 6.9 years, while that in Jiangsu Province is 8.954 years. Different educational experiences lead to diverse acceptance of new technologies and insurance; farmers have different attitudes toward technology choices even if they are covered by insurance simultaneously, which contributes to regional differences in the impact of weather index insurance on technology adoption.

In addition to the above factors, the difference in the impact of weather index insurance on technology adoption between the two provinces may also be caused by some unobserved characteristics such as the development of insurance and credit market. In fact, the insurance and credit markets in Jiangsu Province are more developed than those of Heilongjiang Province[5]. Farmers in Jiangsu Province can more easily gain access to the financial market. Weather index insurance has less marginal utility for them; As a result, the stimulation of weather index insurance in Jiangsu Province is not as significant as that in Heilongjiang Province.

4.5 Placebo testing

The DID model avoids endogenous problems effectively, but the control group and the treatment group must meet the common trend hypothesis. That is, there may be fixed differences between the two groups but their time trends should be consistent. If there is a significant difference in time trends which are caused by non-policy factors between two groups, the results will be bias. Placebo testing was used to test the applicability of the DID model. The pre-insurance samples of the control group and the treatment group are assigned to "pseudo-control group" and "pseudo- treatment group" randomly, and then the DID model was used to estimate two groups. If the coefficient of the interaction item is significant, it means the time trends between groups are different, it is not suitable for the DID model. Otherwise, the estimation results of the DID model are reliable.

Table IX shows the interaction items of the "pseudo-processing group." The period dummy variables are not significant in these three models, indicating that the control group and the treatment group have similar time trends and the DID model is suitable.

5. Robust test

t-test is performed to assess the robustness of the empirical results.

Table X shows that p ($|T| > |t|$) < 0.01, which indicates there is a significant difference in technical adoption between two groups. $Pr(T < t) = 0.0000 < 0.01$, indicating that the average willingness of farmers in treatment group to adopt new technologies is greater than that of the farmers in control group. It indicates the results are robust and further certifies the hypothesis that weather index insurance has a catalytic effect on the adoption of agricultural technology for rural households.

Variables	(1) OLS	(2) FE	(3) RE
$T \times I$	0.041 (0.061)	0.041 (0.035)	0.041 (0.035)
Control variables	Control	Control	Control
F/χ^2	4.73	1.35	16.87
Prob > F/χ^2	0.0000	0.2600	0.1547
$T' \times I$	0.041 (0.061)	0.041 (0.044)	0.041 (0.044)
Control variables	Control	Control	Control
F/χ^2	6.71	14.95	53.49
Prob > F/χ^2	0.0000	0.0000	0.0000

Notes: The values in brackets are standard errors. *,**,***Significant at 10, 5 and 1 percent levels, respectively. $T \times I$ denotes the interaction items of group dummy variable and period dummy variable of "pseudo-control group" and "pseudo-treatment group"; $T' \times I$ indicates the interaction items of the group and the period dummy variable of the sample before providing the insurance
Source: Authors' calculations, based on data collected by the field experiment

Table IX.
Regression results of placebo test

6. Conclusion and discussion

A field experiment was conducted to test the impact of weather index insurance on farmers' improved technology adoption. DID model was used to evaluate the effect. The placebo testing and the *t*-test further confirmed that results are robust to various estimation methods. The findings are as follows.

First, weather index insurance has a positive impact on the adoption of improved seeds – the key inputs influencing the yields. The results show that the rate of improved technology adoption increased after the weather index insurance was provided. The number of households with weather index insurance apply improved seeds is greater than that of farmers without insurance. Second, weather index insurance has a significant positive effect on farmers' technology adoption in Heilongjiang Province, but no significant effect on farmers in Jiangsu Province after control variables are added. Third, household farm size, gender, age, rate of agricultural labor, and weather and risk reference are important factors affecting farmers' technology adoption. Similar results were found by Giné and Yang (2009), Carter *et al.* (2011), Miranda and Gonzalez-Vega (2011) and Hill and Viceisza (2012) in Africa, southeast Asia, etc.

These results have some straightforward implications from a policy perspective: first, sound risk management methods will help farmers reduce the consequences of weather risks and smooth income fluctuations so as to promote adoption of income-raising technologies. Promoting weather index insurance can improve the risk tolerance of farmers and then increase their risky investment with high return. This will improve agricultural productivity, and enhance rural households' well-being in China.

Second, when promoting weather index insurance, regional differences should be considered. Empirical analysis shows that there are regional differences in the role of weather index insurance. It means that weather index insurance should not be unified like traditional agricultural insurance. Adequate regional investigation should be done

Variable	Observations	Mean	SE	SD
Control group (A)	688	0.644	0.018	0.479
Treatment group (B)	688	0.777	0.016	0.416
Diff. = Mean (A)−Mean (B)		−0.134	0.024	
H_0: diff. = 0				$t = -5.526$
H_a: diff. < 0		H_a: diff. = 0		H_a: diff. > 0
$Pr(T < t) = 0.0000$		$Pr(|T| > |t|) = 0.0000$		$Pr(T > t) = 1.0000$

Source: Authors' calculations, based on data collected by the field experiment

Table X.
t-test of weather index insurance's impact on farmers' technology adoption

before initiating an index insurance product pilot project. Providing different risk-sharing measures or suitable insurance contracts for different region may improve the operational efficiency of the insurance product. Weather index insurance should be preferentially promoted in major grain growing areas with a high natural risk where farmers are more willing to accept index insurance, which in turn will affect farmers' technology adoption. It will improve productivity in the agricultural sector and ensure food security in China.

Third, because the household farm size has a significant positive effect on technology adoption, from the perspective of insurance marketing strategy, the insurance companies should target large-scale farmers first which are more dependent on farming income than others. Index insurance can help them spread risk when they adopt advanced technologies. In addition, large-scale farmers are the role models in rural communities and have a peer effect on small farmers. Small-scale farmers will wait and see the response of large-scale farmers and make decisions, and then the recognition of insurance qproducts by large farmers plays a vital role in the implementation of index insurance in rural China.

This research is subject to some limitations. First, the experimental parameters are designed according to the actual situation to simulate reality. But the willingness in the experiment does not mean it will be put into action in reality. Second, due to the diversity of China's climate, geography and economic environment, rural households are heterogeneous in rural China. Whether the conclusion can be generalized beyond the study area is naturally questionable. Third, limited by the experimental design, unobserved characteristic and external environment variables which may cause the difference between the two provinces were not included in the model. This may cause the results unable to give a complete explanation of the index insurance impact difference. A study including more diverse samples and considering more external environmental factors is needed to gain a full understanding of index insurance's effects, and then allows more precise policy recommendations.

Notes

1. Per capita arable land is calculated based on the data from China Statistical Yearbook 2018, it equals to the total cultivated land area of the province divided by the total population of the province.

2. Except for following the sample selection rules of this study (see Section 3.2), we selected some scale farmers (more than 50 mu) from each village in Jiangsu Province for two reasons: First, the average planting scale of another sample area (Heilongjiang Province) is higher than the national average from the official statistics. Second, the Jiangsu Provincial Agriculture Commission has invested a lot of funds and issued many policies to encourage land transfer and farmers to expand farm scale. We selected some scale farmers from each village in Jiangsu Province so that the sample distribution can reflect the reality.

3. This 30 percent is calculated based on experimental data. In the focus group interviews pre and post the experiment, we learned that approximately half of the farmers like to keep using the same variety they are familiar with when choosing seeds in reality. Then we believe that the effect of status quo bias was not significant in our experiment. In other words, farmers' technology choices also have certain status quo bias in their real life.

4. Cost of high-yield hybrid rice seeds is nearly ¥300 per mu, cost of improved compound fertilizer is ¥500 per mu, and cost of improved herbicide and pesticides is ¥150 and ¥150 per mu, respectively.

5. In 2017, agricultural loan of Jiangsu was ¥2,827.12bn (Statistics Bureau of Jiangsu Province, "Continuous Optimization of the Total Financial Fiscal Growth Structure", September 2018), and Heilongjiang, ¥851.83bn (Banking Regular Press Conference held by Li Lan, Deputy Director of the Banking Regulatory Bureau of Heilongjiang Province on March 15th, 2018). The insurance premium income and the total indemnity were ¥269.02bn and ¥91.51bn (Statistics Bureau of

Jiangsu Province, "Continuous Optimization of the Total Financial Fiscal Growth Structure", September 2018), respectively in Jiangsu Province; whereas those in Heilongjiang were ¥93.14bn and ¥240.5bn (Heilongjiang Province Finance Office official website, "2017 Heilongjiang Province insurance premiums more than ¥931bn to pay more than ¥24bn", 21 March 2018) the same period.

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Economic policy uncertainty and grain futures price volatility: evidence from China

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Abstract

Purpose – The purpose of this paper is to investigate the influence of economic policy uncertainty (EPU) on China's grain futures prices. Related literature has discussed several factors contributing to the dramatic boom and bust in China's grain futures prices, but has overlooked the influence of EPU.

Design/methodology/approach – The study employs a newly developed time-varying parameter vector autoregressive model to study and contrast the impact of different types of uncertainty on China's grain futures prices. The directional volatility spillover index is used to measure the impact of EPU on China's grain futures prices and compare the differences among commodities.

Findings – The results show that EPU affects China's grain futures prices significantly. The 2008 global financial crisis had stronger influence on China's grain futures prices than other types of uncertainty. Furthermore, EPU has smaller influence on wheat futures price than on maize and soybean. The Chinese Government interventions may be the reason for this difference.

Originality/value – This study addresses the lack of empirical investigation on the influence of EPU on China's grain futures price volatility.

Keywords Economic policy uncertainty, China's grain futures prices, Directional volatility spillover, Time-varying parameter vector autoregressive model

Paper type Research paper

1. Introduction

The last decade witnessed periods of dramatic booms and busts in China's grain futures prices. Since 2006, China's grain futures prices experienced large fluctuations during 2007–2008, 2010–2011 and 2016–2017 (see Figure 1). The following is a description of the grain futures price spike and crash that happened in 2007–2008. From July 2007 to February 2008, China's grain futures prices experienced a sharp rise, with futures prices of soybean, wheat and corn rising by 48.2, 18.4 and 18.4 percent, respectively. However, over the next ten months, prices slumped, with soybean, wheat and corn futures prices dropping by 40.8, 7.6 and 16.2 percent, respectively. Large and unpredictable price movements lead to uncertainty that increases risks for consumers, producers, traders, governments and investors (Li, Ker and Sam, 2017; Li, Li and Chavas, 2017). Price volatility leads to problems of food scarcity and security for consumers. For producers and traders, large fluctuations in
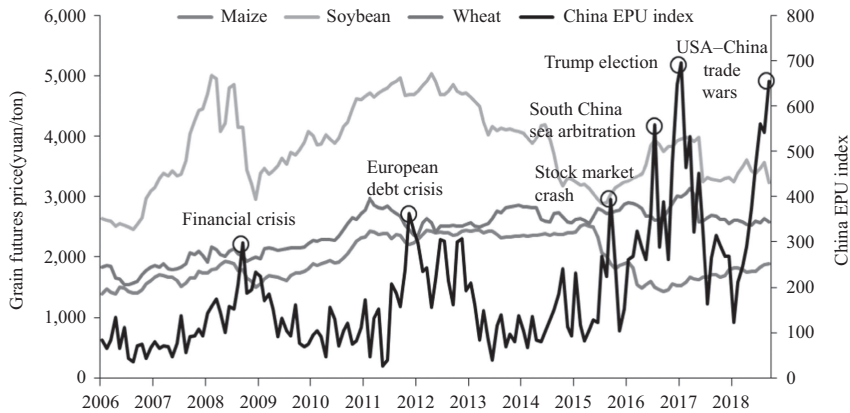
Source: Price data from Wind database; China EPU Index from www.policyuncertainty.com

prices render production and investment decisions uncertain, particularly for commodities with long-term production cycles. Furthermore, volatile prices increase difficulties for regulators and governments in managing markets, as it requires substantial human resources and wealth. Hedging is a basic function of the futures markets and aims at mitigating the adverse effects of price uncertainty. However, when futures prices are exceptionally volatile, managing price risk through futures contracts for investors becomes costlier.

The challenges of large and unpredictable price movements highlight the need for understanding the causes better. Although several studies investigated the reasons for the recent grain price volatility, there is no consensus on the most important cause (Gutierrez, 2013). Some researchers believe that demand (e.g. population and economic growth, shifting dietary patterns and growth in biofuels production) and supply dynamics (e.g. lower production growth rate, higher production costs, and climate change) are the fundamental causes (Mawejje, 2016). However, some authors disagree and argue that commodity price booms can be explained by macroeconomic factors such as money supply (Gilbert, 2010), exchange rates (Myers *et al.*, 2014) and interest rates (Jebabli *et al.*, 2014). Some researchers believe that speculation underpins the boom and bust cycles (Gutierrez, 2013) in agricultural commodities prices, thereby leading to the so-called price bubble (Sanders and Irwin, 2010; Gilbert, 2010; Gutierrez, 2013; Etienne *et al.*, 2015; Li, Ker and Sam, 2017; Li, Li and Chavas, 2017). In addition, several studies confirmed that a strong link between energy prices and food prices is likely to be the dominant influence for agricultural commodities (Baffes and Haniotis, 2010). This link works mainly through input costs, such as fertilizers and insecticides, output costs, such as production processes, processing, and transportation (Tyner, 2010; Serra *et al.*, 2011; Wu and Li, 2013; Dillon and Barrett, 2016).

An important and often overlooked factor is uncertainty. The past decade witnessed several events of uncertainty, which had a profound influence worldwide. They include the financial crisis in 2007–2008, the European debt crisis in 2010–2011, the stock market crash in China in 2015–2016, the South China Sea arbitration in July 2016, the US presidential election in 2016–2017 and the USA–China trade war in 2018. To proxy for movement in these policy-related economic uncertainties, Baker *et al.* (2016) developed a new economic policy uncertainty (EPU) index based on newspaper coverage frequency. The EPU index, as shown in Figure 1, peaked during the above-mentioned periods, when China's grain futures prices experienced strong fluctuations. It is necessary to understand if EPU affects the volatility in China's grain futures prices as it will provide a better perspective on the sharp fluctuations in Chinese grain futures price.

The impacts of uncertainty on economic activity have been empirically investigated in related literature. Reignited by a highly influential paper focusing on the effects of uncertainty on aggregate output and employment by Bloom (2009), a rich strand of literature has confirmed the effects of EPU on economic growth (Karnizova and Li, 2014), unemployment (Baker *et al.*, 2016), investment (Wang *et al.*, 2014) and trade (Tam, 2018). Some studies examine the effects of EPU on commodity prices, especially oil (Kang and Ratti, 2013; Antonakakis *et al.*, 2014; Bekiros *et al.*, 2015; Yin, 2016; Kim *et al.*, 2017; Wang and Sun, 2017; Kang *et al.*, 2017), gold (Fang *et al.*, 2018; Raza *et al.*, 2018) and stocks (Ko and Lee, 2015; Das and Kumar, 2018). The existing literature has conducted in-depth research on the impact of EPU on economic activities, but some aspects still need to be improved. First, few studies empirically investigate the influence of EPU on China's agricultural commodity futures prices. As the largest developing country in the world, China plays an important role in the world agricultural markets. Paying attention to the impact of EPU on China's agricultural commodity futures prices can provide policy implications for other developing countries to stabilize grain prices. Second, existing studies do not consider the time-varying effects in the models proposed. Most existing studies used fixed-parameter models (e.g. vector autoregressive model (VAR), generalized autoregressive conditional heteroskedasticity (GARCH)) to analyze the impact of EPU on commodity prices. However, due to large fluctuations in commodity prices, structural changes in price sequences were unavoidable and the application of fixed-parameter models will lead to estimation bias. Therefore, it is necessary to use the time-varying parameter model to estimate the impact of EPU on China's agricultural commodity futures prices.

This study uses a new time-varying parameter vector autoregressive (TVP-VAR) model and directional volatility spillover index to analyze empirically the influence of EPU on China's grain futures prices during 2006–2018. Developed by Nakajima *et al.* (2011), the TVP-VAR model allows for stochastic time-varying volatilities and shocks in volatility. Using the TVP-VAR model, this study compares the impact of different types of uncertainties on China's grain futures prices. Specifically, it chooses four periods during which China's EPU index is high: the 2008 global financial crisis, 2011 European debt crisis, 2015 China's stock market crash and the 2017 Trump election (see Figure 1). The study also applies the TVP-VAR model to analyze the impact during different lag periods. In the final part of the empirical analysis, it uses the directional volatility spillover indices to measure the impact of EPU on Chin's grain futures prices and compare the differences among commodities.

The results show that EPU has a significant effect on China's grain futures prices. However, the impact of EPU on grain futures prices differs during various lagged periods, and weakens gradually with the increase in lag periods. In addition, the 2008 global financial crisis had a stronger influence on China's grain futures prices than other types of uncertainty. Moreover, EPU has smaller influence on wheat futures prices than on the futures prices of maize and soybean. This can be attributed to the interventions by Chinese Government. To ensure food security, Chinese Government has implemented a series of policies, such as the minimum purchase price (MPP) policy, National Provisional Reserve policy and trade policy. The results of this study are instructive for governments of other developing countries on better regulation of agricultural markets.

Section 2 ofn this paper introduces the methodological approach. Section 3 describes the data, and Section 4 illustrates the empirical results. Section 5 explains the differences, and Section 6 concludes.

2. Methodological approach
Most studies that focus on commodity price volatility are based on multivariate GARCH models. However, GARCH models are unable to uncover volatility dynamics and structural

changes in a unified manner (Jebabli *et al.*, 2014). The multivariate TVP-VAR model is generalized to allow for stochastic time-varying volatilities and shocks in volatility. Evolving from the basic VAR with the introduction of time-varying parameters to capture changes over time, Nakajima *et al.* (2011) first used the TVP-VAR model to study the relationship between economic growth and monetary policy. Unlike the constant parameter VAR model, the TVP-VAR model does not divide the data into sub-samples to confirm changes in the model structure. Thus, the analysis will not lose information about the entire sample and avoid the risk of arbitrary choice of sub-samples. A basic structural VAR model is defined as follows:

$$Ay_t = B_1 y_{t-1} + B_2 y_{t-2} + \cdots + B_s y_{t-s} + \mu_t, \tag{1}$$

where t represents time, s represents the lag period and $t = s + 1, s + 2,..., s + n.y$ is a $k \times 1$ vector of observed variables. A, B_1, B_2,..., B_n are $k \times k$ matrices of coefficients, and μ represents structural shocks. The study assumes that structural shocks are recursively identified, which means that A is lower triangular:

$$A = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ a_{21} & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ a_{k1} & a_{k2} & \cdots & 1 \end{pmatrix}. \tag{2}$$

Model (1) is reduced as follows:

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_s y_{t-s} + A^{-1} \varphi \varepsilon_t, \tag{3}$$

where $\phi_i = A^{-1} B_i$, $i = 1, 2,..., n$, and $\varepsilon_t \sim (0, I_k)$, in which I_k is a unitary matrix. Convert the elements on each line into β, which becomes a $k^2 \times 1$ vector. Next, define $X_t = I_k \otimes (y_{t-1},..., y_{t-s})$, and Model (3) can be rewritten as:

$$y_t = X_t \beta + A^{-1} \varphi \varepsilon_t. \tag{4}$$

All the parameters are time-invariant at present. Next, the time-varying parameters are introduced into the model:

$$y_t = X_t \beta_t + A_t^{-1} \varphi_t \varepsilon_t, \ t = s+1, s+2,..., s+n, \tag{5}$$

where β_t, A_t, φ_t are all time varying. As suggested by Primiceri (2005), we transform the lower-triangular elements A_t into a_t, and $a_t = (a_{21}, a_{31}, a_{32}, a_{41},..., a_{k,k-1})'$, $h_t = (h_{1t}, h_{2t},..., h_{kt})'$, with $h_{kt} = Ln\sigma_{kt}^2$. Assume that the parameters in (5) follow a random walk process, which is $\beta_{t+1} = \beta_t + \mu_{\beta t}$, $\alpha_{t+1} = \alpha_t + \mu_{\alpha t}$, $h_{t+1} = h_t + \mu_{ht}$, and the variance covariance matrix of the model's innovations is as follows:

$$\begin{pmatrix} \varepsilon_t \\ \mu_{\beta t} \\ \mu_{\alpha t} \\ \mu_{ht} \end{pmatrix} \sim N \left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \mu_\beta & 0 & 0 \\ 0 & 0 & \mu_\alpha & 0 \\ 0 & 0 & 0 & \mu_h \end{pmatrix} \right), \tag{6}$$

where $\beta_{s+1} \sim N(\mu_{\beta_0}, \varphi_{\beta_0})$, $\alpha_{s+1} \sim N(\mu_{\alpha_0}, \varphi_{\alpha_0})$, $h_{s+1} \sim N(\mu_{h_0}, \varphi_{h_0})$ and φ_β, φ_α, φ_h are assumed to be diagonal matrices. To reduce the difficulty of the likelihood

function under random volatility conditions, the study estimates the parameters using the Markov Monte Carlo simulation (MCMC) algorithm to simulate the sampling.

3. Data and descriptive statistics

The study chooses two categories of data: China's EPU index and grain futures prices in China.

Baker *et al.* (2016) developed China's EPU index based on newspaper coverage frequency of policy-related economic uncertainty. Specifically, to measure EPU in China, Baker *et al.* (2016) construct a scaled frequency count of articles about policy-related economic uncertainty in the *South China Morning Post*, which is the leading English newspaper in Hong Kong. According to Baker *et al.* (2016), the EPU index has high accuracy and can describe economic policy-related uncertainty. China's EPU index is downloaded from the website (www.policyuncertainty.com/).The EPU index spiked around the 2008 global financial crisis, 2011 European debt crisis, China's 2015 stock market crash and the 2017 Trump election. To eliminate the influence of seasonal factors, data are adjusted using Census X-12 seasonal adjustment method.

Grain futures prices are extracted from the WIND database and monthly data from January 2006 to September 2018 are employed. The study investigates the futures prices of maize, soybean and wheat, and excludes rice futures prices as they list for a very short time on the market, resulting in insufficient samples. This study also uses the Nanhua agricultural price index to describe the overall impact of economic uncertainty on China's agricultural prices. The Nanhua agricultural price index is compiled by selecting agricultural futures prices that are more representative and have better liquidity on the Dalian Commodity Exchange and the Zhengzhou Commodity Exchange. All of China's grain futures prices are deflated by dividing each value by China's consumer price index. Except for the price index, all futures prices are in Yuan/ton. Table I shows descriptive statistics for the uncertainty index, price index, and futures prices of maize, soybean and wheat. The mean, median, max, min and deviation of soybean futures prices are higher than that of wheat and maize. The kurtosis values are larger than zero, which indicates that all the series are leptokurtic distributions with heavy tails. The descriptive statistics show that the series are characterized by a time-varying variance and volatility.

The study uses the Augmented Dickey Fuller test and the Phillips–Perron test to assess the non-stationarity of variables. All the series were non-stationary at order 0 and stationary at order 1. Therefore, the data used here meet the requirements of the cointegration test.

4. Empirical results

4.1 Model estimation and diagnosis

Before estimating the parameters in the TVP-VAR model using the MCMC algorithm, the following priors are assumed: $(\varphi_\beta)_i^{-2} \sim \gamma$ (40, 0.02), $(\varphi_\alpha)_i^{-2} \sim \gamma$ (4, 0.02) and $(\varphi_h)_i^{-2} \sim \gamma$ (4, 0.02). The study then simulates 50,000 samples and discards the original 5,000 samples. Table II presents the estimation results of the MCMC algorithm, including posterior means,

	Mean	Median	Max.	Min.	SD	Skewness	Kurtosis
EPU index	189.2	152.0	695.1	26.1	134.5	1.5	5.4
Price index	853.4	851.8	1,078.7	663.4	77.5	0.4	3.3
Wheat price (Yuan/ton)	2,431.3	2,557.2	3,134.3	1,538.6	375.4	0.6	2.4
Soybean price (Yuan/ton)	3,817.9	3,857.6	5,034.5	2,457.8	667.2	0.1	2.1
Maize price (Yuan/ton)	1,950.4	1,858.8	2,542.8	1,388.7	356.9	0.2	1.5

Table I.
Descriptive statistics of uncertainty index and prices

standard deviations, 95 percent credible intervals, Geweke convergence diagnostics statistics and inefficiencies. The Geweke statistics received a null hypothesis of convergence to the posterior distribution for the parameters in the TVP-VAR model, at the 5 percent significance level. The inefficiency factors are quite low, indicating that sufficient valid samples can be obtained and the 95% confidence intervals include the estimated posterior mean for each parameter. The result indicates that the MCMC algorithm efficiently produces posterior draws.

4.2 Time-varying impulse response

4.2.1 Impulse response in different time points. Unlike the constant parameter VAR model, the TVP-VAR model is able to simulate impulse response at different time points. Four peak points of the EPU index are selected to stimulate the impact of different uncertainties: September 2008, November 2011, September 2015 and January 2017, representing the global financial crisis, European debt crisis, China's 2015 stock market crash and Trump election, respectively.

Figure 2 shows the impulse response of China's grain futures prices to the aforementioned uncertainties. Figure 2(a) shows that the global financial crisis had a

Parameter	Mean	SD	95% L	95% U	Geweke	Inef.
$(\varphi_\beta)_1$	0.023	0.003	0.018	0.028	0.077	7.83
$(\varphi_\beta)_2$	0.022	0.003	0.018	0.027	0.279	8.40
$(\varphi_\alpha)_1$	0.038	0.029	0.023	0.087	0.912	30.98
$(\varphi_\alpha)_2$	0.039	0.038	0.025	0.082	0.695	21.20
$(\varphi_h)_1$	0.261	0.077	0.138	0.437	0.368	56.13
$(\varphi_h)_2$	0.514	0.118	0.313	0.773	0.163	181.25

Table II.
Estimation results of the MCMC algorithm
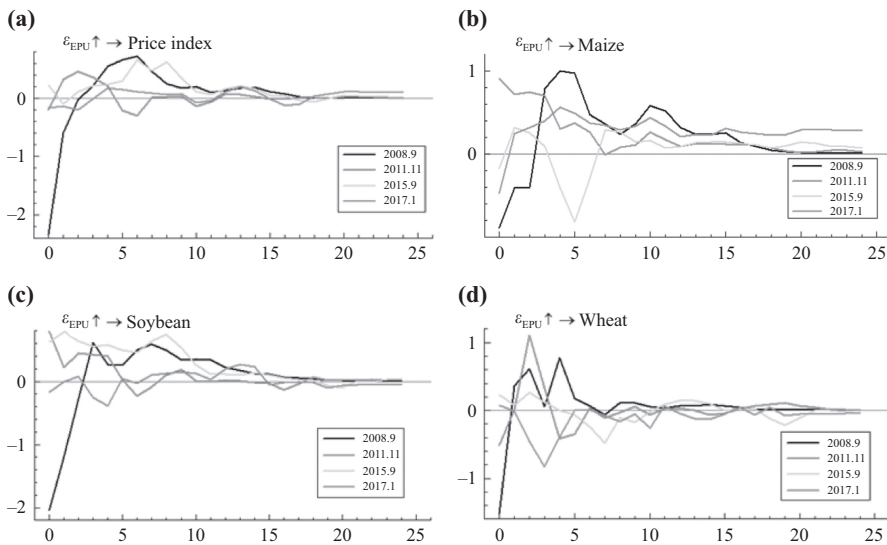
Figure 2.
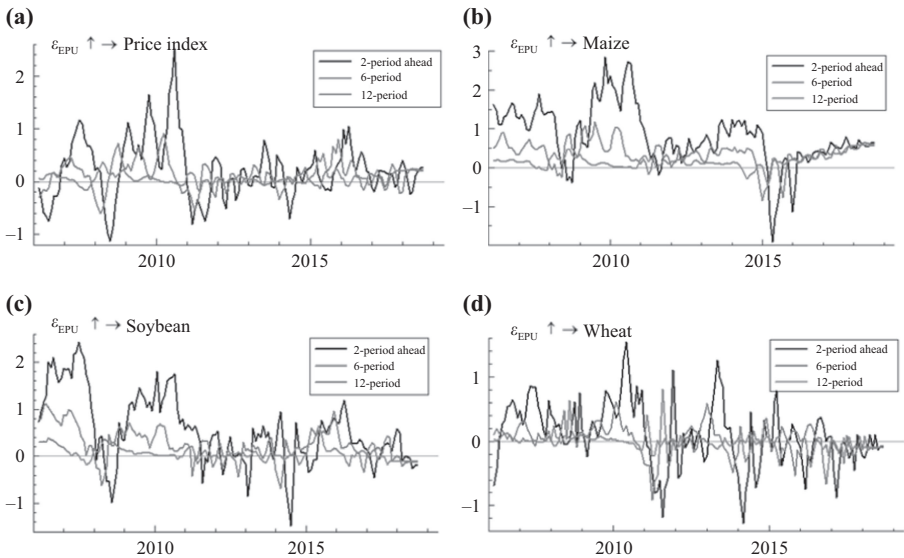Impulse response of Chinese grain prices to different uncertainties

Notes: (a) Impulse response of price index; (b) impulse response of maize price; (c) impulse response of soybean price; (d) impulse response of wheat price

negative impact on futures price index at the beginning; however, this effect turned positive in two months and gradually weakened after ten months. The impact of the European debt crisis was positive in the first four months and turned negative over the next four months; the European debt crisis had a smaller effect than the global financial crisis. Figure 2(b)–(c) shows that when the global financial crisis began in August 2008, EPU had an immediate and significant negative impact on the futures prices of maize and soybean; however, these effects gradually weakened after eight months. The influence of other events such as the European debt crisis, China's stock market crash and Trump election on futures prices of maize and soybean were relatively weak. Figure 2(d) shows that the influence of the global financial crisis and the European debt crisis on futures price of wheat were negative at first, turned positive within a month and fluctuated around zero after six months. The figure also shows that the influence of Trump election on futures price of wheat was positive at first, turned negative within a month and, gradually, weakened after six months.

Overall, Figure 2 shows that the global financial crisis had a strong influence on China's grain futures prices than other types of EPU. During most periods, the black lines in Figure 2, which represent the shocks from the global financial crisis, are higher when in the positive sides and lower when in the negative sides, compared to the lines of other colors. The global financial crisis changed China's macroeconomic environment and disturbed economic development. This affected the expectations and investment decisions of participants in agricultural futures markets. Furthermore, the global financial crisis also affected the regulatory framework of policy makers and the supply and demand dynamics of grain.

4.2.2 Impulse response in different time periods. Figure 3 shows the impulse response of grain futures prices to the EPU index in lagged 2-, 6- and 12-period. Figure 3(a) illustrates the time-varying impulse response of futures price index to the EPU index. Since 2006, the impact of EPU on futures price index has shown obvious cyclical fluctuations. When the lagged six-period is taken as an example, it showed negative impact at the beginning of

Figure 3.
Impulse response of Chinese grain prices to EPU in different lag periods

Notes: (a) Impulse response of price index; (b) impulse response of maize price; (c) impulse response of soybean price; (d) impulse response of wheat price

2006, turning positive in 2007, and negative again in 2008. The response model is similar in the subsequent years. Figure 3(a) shows that the largest negative shock happened in 2008 and the largest positive shock in 2010. Considering the different lag periods, the impact of EPU on the futures price index in China varied in different lagged periods, and the impact weakens gradually with the increase in lag periods. Specifically, the impact of the lagged 2-period is the largest, followed by the lagged 6-period and 12-period. This indicates that the agricultural market can adjust effectively over time to mitigate the impact of EPU shocks and stabilize prices.

Figure 3 shows that the reaction models of futures prices of maize and soybean are similar; however, there is some difference in wheat prices. Figure 3(b) and (c) illustrate the time-varying impulse response of futures prices of maize and soybean to the EPU index. From 2006 to 2011, the impact of EPU on futures prices of maize and soybean fluctuated periodically. After 2011, the impact of EPU on futures prices of maize and soybean was relatively stable at most times, except for the sudden drop in 2014 and 2015. Figure 3(b) shows that the largest negative shock was experienced during 2015–2016 and the largest positive shock in 2010. Figure 3(c) shows that the largest negative shock happened during 2008–2009 and 2014–2015, while the largest positive shock occurred in 2010. Considering the different lag periods, the impact of EPU on futures prices of maize and soybean weakens gradually with the increase in lag periods.

Figure 3(d) illustrates the time-varying impulse response of wheat futures prices to the EPU index. It is seen that the value in the longitudinal axis is smaller than in Figure 3(b) and (c). This value is used in the longitudinal axis to measure the degree of impact. A lower value in the longitudinal axis denotes that the impact of EPU on wheat futures prices is smaller than on the futures prices of maize and soybean. The largest negative shock happened in 2011 and 2014, and the largest positive shock happened in 2010 and 2013. Similarly, considering different lag periods, the impact of EPU on wheat futures prices weakens gradually with the increase in lag periods.

Overall, the impulse responses of China's grain futures prices to EPU in different lag periods show the following characteristics: First, the EPU index has a significant effect on China's grain futures prices. The futures price index, futures prices of maize, soybean, and wheat reacted to the shocks in the EPU index. Second, soybean and maize prices had the strongest response to the EPU index shocks, while the impact on wheat prices is relatively small. Third, the impact of the EPU index on grain futures prices gradually weakens with the expansion of lag periods. The response of grain futures prices in China to the EPU index are more obvious in the lagged 2-period than in the lagged 6-period and 12-period.

4.3 Volatility spillover estimation

To measure volatility spillovers from EPU to grain futures prices in China, the study applies the framework developed by Diebold and Yilmaz (2012) based on a generalized VAR framework, which eliminates the possible dependence on ordering. To ensure the robustness of our results, both static and dynamic directional volatility spillover are calculated. The static directional spillover refers to full sample estimation. With regard to dynamic directional spillover, the study estimates volatility spillover effects using rolling samples of 24, 36 and 48 months, respectively. Table III summarizes the results.

Table III confirms that EPU has volatility spillover effects on China's grain futures prices. The data given in Table III are positive. In Table III, the last row shows that the contribution from EPU to grain futures prices vary from 5.5 (in the static situation) to 24.6 (in the 24-month rolling sample). Existing literatures have already focused on the relationship between uncertainty and financial markets. Pastor and

Veronesi (2012) explained how policy uncertainty affected stock market volatility in a theoretical setting. There are two effects from the announcement of a policy change. First, it will typically increase firms' expected profit, pushing up stock prices driven by cash flow effects. Second, it will increase discount rates because the new policy's impact on profit is more uncertain, which will push down stock prices by the discount rate effect. Therefore, the influence of policy uncertainty on the rise or fall of stock price depends on the sizes of both the cash flow effect and the discount rate effect.

In the futures markets, investors use commodity futures as tools to hedge against risks of uncertain prices and profits. We explain the economic mechanism of the influence of EPU on grain futures prices as follow. First, because prices and returns of commodity futures are inherently risky, the futures prices will contain a risk premium that compensates investors for the extra risks. EPU potentially contain the factors which will increase the uncertainty of futures returns and therefore increase the extent of volatility of grain futures prices. Second, EPU could drive the government to adjust policies, especially the monetary policy, to avoid shocks to financial markets. The main tool of monetary policy which usually influences commodity futures prices is the interest rate. Fama and French (1987) thought that increasing short-term interest rates tended to drive down commodity prices because they raised the costs of storing the commodities. Hence, there is a negative relationship between futures prices and interest rates. Third, EPU affects the anticipation of participants in the agricultural futures markets, urging them to change investment strategies, thereby affecting grain futures prices. The motives of futures market participants are largely speculative. EPU may foster more frequent buying and selling in response to incoming news, causing prices to swing. Fourth, China's futures markets are highly influenced by global futures markets, which are more likely to be shocked by uncertainties. The efficient market hypothesis developed by Fama (1970, 1991) provided a theoretical basis for the linkages among international futures markets. This theory held the view that investors were completely rational. If global economy is integrated and financial markets are completely open, the existence of arbitrageurs will inevitably lead to the convergence of returns in international financial markets. Therefore, the shocks of EPU could be transmitted from the international futures markets to the China's futures market.

EPU has a smaller volatility spillover effect on wheat futures price, compared to futures prices of maize and soybean. In static situations, the volatility spillover index from EPU to wheat futures price is 0.8, smaller than that of maize (3.3) and soybean (0.9). The results are similar in dynamic situations. For instance, when the 24-month rolling sample is considered, the volatility spillover index from EPU to wheat futures price is 4.5, smaller than that of maize (8.2) and soybean (5.6). Therefore, it can be observed that data in the second row from the bottom are smaller than data given in the above two rows, which strongly support the results that EPU has a smaller volatility spillover effect on wheat futures price. The reasons for this phenomenon are given in Section 5.

| | Static directional spillover from EPU | Dynamic directional spillover from EPU | | |
		24-month rolling sample	36-month rolling sample	48-month rolling sample
Price index	0.5	6.3	3.2	2.0
Maize	3.3	8.2	7.0	5.3
Soybean	0.9	5.6	3.3	3.1
Wheat	0.8	4.5	2.1	1.8
Contribution to	5.5	24.6	15.6	12.2

Table III.
Summary of
volatility spillover

5. Role of government intervention

The results of the TVP-VAR model and directional volatility spillover effects show that EPU has smaller influence on wheat futures price, compared to futures prices of maize and soybean. The fundamental reason for this phenomenon is government interventions. Before reforms were launched in 1978, China experienced decades of famine, motivating the government to prioritize food security. The Chinese Government implemented several agricultural policies to improve food security, focusing on staples such as wheat and rice. Other relevant studies support this inference. Using the Global Trade Analysis Project model, Yang *et al.* (2008) concluded that China's policies played an important role in stabilizing domestic wheat prices; for example, the government lowered wheat price by nearly 29.6 percent; however, the policy did not influence domestic soybean price. However, it is not possible to investigate the relationship between government interventions and prices empirically, owing to data deficiency. China's agricultural policies are summarized as follows.

First, the MPP policy that China implemented for rice and wheat, since the marketization of grains in 2004, is discussed. The MPP policy ensures that grain enterprises designated by the Chinese Government buy grain at the MPP when the market prices are lower than the MPP. The basic mechanism of the MPP policy is announcing the MPP in advance to stabilize market expectations and enhance grain supply. Table IV illustrates the MPP of wheat between 2006 and 2017. The MPP policy motivated farmers to grow wheat and this improved yields in China to reach 128,845 thousand tons in 2016, up 20,380 thousand tons from 2006. China's self-sufficiency rate in wheat was over 95 percent. The growth in yield and a high self-sufficiency rate ensured that EPU had little impact on wheat price volatility. In contrast, China's soybean yield in 2016 was 17,294 thousand tons, about 2743 thousand tons less than 2006. Consequently, China's self-sufficiency rate in soybean was under 25 percent (Li, Ker and Sam, 2017; Li, Li and Chavas, 2017), which explains why soybean prices were more affected by EPU.

Second, China has built a central and local reserve system, with wheat accounting for the largest quantity of grain reserves. The National Provisional Reserve system can buy grain from farmers at the MPP when the market prices are lower than the MPP. This helps to regulate food supply and demand and stabilize grain prices. Furthermore, the national provisional reserve system signals the presence of large grain stocks to market participants to combat market speculation and stabilize China's grain prices. As wheat accounts for a large percentage of grain reserves in China, the national provisional reserve policy can effectively reduce the impact of uncertainty on China's wheat price.

Third, international grain trade affects China's grain prices and the government regulates and controls grain import and export in several ways, such as controlling state-owned enterprises' grain trade. Although, at the time of joining the WTO, China promised to reduce the monopoly of state-owned enterprises in grain trade, the proportion continues to remains high. In September 2015, the National Development and Reform Commission formulated and promulgated the "Conditions for the application of the grain import tariff quotas for 2016," which stipulated the proportion of state-owned wheat at 90 percent, corn at 60 percent and rice at 50 percent. For example,

Variety	2006	2007	2008	2009	2010	2011	2012	2013	2014-2017
White wheat	72	72	77	87	90	95	102	112	118
Red wheat	69	69	72	83	86	93	102	112	118
Mix wheat	69	69	72	83	86	93	102	112	118
Source: National Development and Reform Commission (www.sdpc.gov.cn/)									

Table IV.
The minimum
purchase price (MPP)
of wheat in 2006–2017
(Yuan/50 kg)

in mid-2008, when international food prices declined sharply, China did not import large amounts of grain, as per the classical economic theory. In contrast, with government intervention, China imported less than before. As a result, this initiative alleviated the impact of declining global food prices on domestic food prices and ensured stability in China's grain prices. Another example is the customs and export tax rebate. After joining the WTO at the end of 2001, China started to cut tariffs and promised to slash import tariffs on most agricultural products within three years. Simultaneously, China implemented a tariff quota management system for major grains such as wheat, rice and maize. Furthermore, in late 2007, in a bid to reduce grain exports, China cancelled the export tax rebate for wheat, rice, corn and 84 other types of grain and imposed export tariffs in early 2008. Such trade policies on grain import and export ensured food supply in China and reduced the impact of uncertainty on China's grain prices, especially wheat.

6. Summary and conclusions

The past decade has witnessed periods of dramatic booms and busts in grain futures prices. Existing studies often overlook EPU when examining the factors for these dramatic shifts in prices. This study evaluates the influence of EPU on China's grain futures prices during the volatile period from 2006 to 2018. The recently developed TVP-VAR model is used to allow for stochastic time-varying volatilities and shocks in volatility.

First, EPU has significant effects on China's grain futures prices. The results of the TVP-VAR model show that the agricultural futures price index, futures prices of maize, soybean and wheat respond to shocks of the EPU index. However, the impact of EPU on grain futures prices in China differs in different lagged periods, and the impact weakens gradually with the increase in lag periods. The directional volatility spillover indices are all positive, indicating that EPU has volatility spillover effects on China's grain futures prices.

Among the four selected peak points of the EPU index, the 2008 global financial crisis had stronger influence on China's grain futures prices than other types of uncertainties, as apparent from the impulse response of China's grain futures prices to the aforementioned uncertainties. The global financial crisis was a great shock to China's economic system, affecting the expectations of participants in the agricultural futures markets and the decisions of China's policy makers.

The results of the TVP-VAR model and directional volatility spillover indices also show that EPU has smaller influence on wheat futures price, compared to futures prices of maize and soybean. China's interventions possibly explain this phenomenon as the government has implemented several policies, such as the MPP, National Provisional Reserve and trade policy, to ensure food supply in the country. Besides, these policies are both timely and effective. However, administrative interventions in China's grain markets could hamper marketization.

This study enriches the existing literature in the following three aspects. First, it connects China's grain futures price volatility with uncertainties. Though previous studies have highlighted the causes of China's grain futures price volatility, few have focused on the influence of uncertainty. Second, this study enriches the existing literature in the method selection by applying the time-varying parameter model to estimate the impact of EPU on China's grain futures prices. Most existing studies used fixed-parameter models to analyze the impact of EPU on commodity prices, which overlooked the time-varying effects and leaded to estimation bias. Third, this study further confirms that EPU has smaller influence on wheat futures price than on that of maize and soybean by using directional volatility spillover indices, and comprehensively summarizes China's agricultural government interventions, which can provide policy implications for other developing countries in stabilizing grain prices.

This study has two main limitations. First, it examines the impact of EPU on China's grain futures prices from an empirical perspective and not as an economic mechanism using the classic economic theory. This latter approach could shed more light on this issue. Second, due to lack of sufficient data, the agricultural policies are summarized qualitatively to explain why EPU has smaller influence on wheat futures price. These results would be far more convincing if they had empirical support.

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Impact of outward FDI on firms' productivity over the food industry: evidence from China

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Abstract

Purpose – The purpose of this paper is to study the impact of outward foreign direct investment (OFDI) on the productivity of parent firms over the food industry.

Design/methodology/approach – The main data in this paper are derived from the China Industrial Enterprise Database 2005–2013 and a data set of Chinese firms' OFDI information. Then this paper uses propensity score matching to match the treatment and control groups with firm characteristics and combines that with the differences-in-differences method to estimate the real effect of OFDI on total factor productivity.

Findings – The food firm's OFDI significantly improves the parent firm's productivity (known as the OFDI own-firm effect), but this promotion only exists in the short term. The OFDI own-firm effect of food firms differs remarkably as the sub-sectors, regions and ownership of firms vary. The food firm's OFDI in "non-tax havens" and high-income destinations has a significantly stronger effect on the parent firm's productivity. FDI, R&D and exporting can effectively strengthen the OFDI own-firm effect of food firms.

Originality/value – The effect of OFDI on food industry productivity has not been researched yet. This paper aims to fill this gap. This paper further divides the characteristics of food firms into different sub-sectors, regions and ownership types for a comparative analysis, with the aim of conducting a more comprehensive study at the micro-level of firms. In addition, an investigation into which factors influence the degree of the OFDI own-firm effect at the micro-level has not been found in the literature. This paper will draw its own conclusions.

Keywords Productivity, Food industry, Chinese manufacturing, Outward foreign direct investment

Paper type Research paper

1. Introduction

With the deepening of economic globalization and regional economic integration, China's outward foreign direct investment (OFDI) has entered the fast lane in the context of China's "Going out" and "the Belt and Road" Initiatives. The USA, Japan and China, respectively, are the largest investors worldwide and China is responsible for 8.65 percent of the world's OFDI flows (UNCTAD, 2016). China has become a major investor in some developed destinations, especially in cross-border mergers and acquisitions (CM&A). Outward foreign direct investment is abbreviated as OFDI, which is one of the main forms of outward channel of international investment compared with foreign direct investment (FDI). OFDI is defined separately by the International Monetary Fund and the Ministry of Commerce of the People's Republic of China. In this paper, we define OFDI as Chinese firms that invest in

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foreign destinations for operation and management rights of foreign firms with emphasis on capacity-building and adoption of improved production standards. This study only investigates Chinese food firms that have undertaken OFDI. OFDI helps a parent firm stimulate exports (Mucchielli and Soubaya, 2002; Jiang and Jiang, 2014a, b), enhance the quality of export products (Du and Li, 2015; Jing and Li, 2016), promote industrial upgrading (Blomstrom *et al.*, 2000; Li, 2012), ease overcapacity (Wen, 2017) and improve profit margins (Yang and Cao, 2017). OFDI also increases the parent firm's total factor productivity (TFP) because intellectual capital or other nontechnical information through external channels promotes a firm's productivity (Jiang and Jiang, 2014a, b), which is known as the OFDI own-firm effect. This effect may be different among various industries because firms have their own motives, abilities and methods in OFDI (Blonigen, 2005; Chawla and Rohra, 2015).

Chinese food firms have begun to actively explore the overseas markets. For example, the Shuanghui Group spent 7.10bn to acquire the largest US pork producer "Smithfield" in 2013. In 2014, the Yili Group established an oceanic production base in New Zealand. Bright Diary acquired a 76.70 percent stake in an Israeli dairy firm, Troyes, in 2015.

China's main motivations for these FDI are as follows. First, the productivity of the food industry is relatively low in the manufacturing sector (Jin *et al.*, 2017), which influences the efficiency of production processes. Second, the demand for high-quality food is increasing as consumers' income increases. Third, food security incidents have become more frequent, the total degree of trust in the domestic food industry is decreasing (Li and Shi, 2014) and the domestic firms can produce safer food to meet domestic demand by acquiring overseas firms or introducing higher-safety production lines. Technological breakthroughs are required to improve this situation. However, the effect of OFDI on food industry productivity is not in the literature. This paper aims to study this issue. The OFDI in the food industry gradually increased in the background of China's "Going out" and "the Belt and Road" initiatives; this paper put forward suggestions regarding the performance of China's OFDI that may be considered as good practice in innovation promotion within the food industry. In addition, it can help create more specific policies for food firms wanting to engage beneficially in OFDIs. The remainder of the paper is as follows. Section 2 is the literature review and hypotheses. Section 3 describes the data and the calculation of the food firm's TFP. Section 4 presents the model and method of empirical research. Section 5 examines the results of the empirical analysis. Section 6 concludes.

2. Literature review and hypotheses
2.1 Literature review
Two types of research are related to this paper. The first type is the study of the relationship between OFDI and TFP for different destinations. Helpman *et al.* (2004) posited that the most productive firms choose to serve the overseas market through OFDI, the more productive firms choose to export and the lowest productive firms only serve the domestic market. This enterprise heterogeneous trade theory has been verified by a series of empirical studies in different destinations, such as Keller and Yeaple (2004) for the USA, Damijan *et al.* (2008) for Slovenia and Ryuhei and Takashi (2012) for Japan. Many scholars have noticed there may be a mutual causal relationship between OFDI and productivity in developed destinations, that is, OFDI may also increase the parent firm's TFP. The possible theoretical explanation for this phenomenon is that incomplete markets make multinationals gain monopoly advantages and utilize these advantages through OFDI to enhance their technological superiority (Hymer, 1969).

Many scholars have conducted empirical research on the OFDI own-firm effect. Using Swedish manufacturing data, Braconier *et al.* (2001) demonstrated that OFDI can significantly facilitate technology imports. Kimura and Kiyota (2006) used Japanese firm-level vertical panel data to demonstrate that enterprises with OFDI have higher

productivity growth. Imbriani *et al.* (2011) used the 2003–2006 Italian firm-level data to analyze the effect of OFDI and indicated that OFDI would increase the productivity of manufacturing enterprises. Gazaniol and Peltrault (2013) used propensity score matching (PSM) to study the impact of OFDI on the microeconomic performance of French enterprises and demonstrated that part of this business group is more inclined to invest abroad and could significantly improve its business performance through investment.

Does the OFDI own-firm effect still exist in emerging economies and developing destinations? The firms in these destinations cannot improve their productivity by using monopolistic advantages. However, the parent firm may improve their productivity by obtaining advanced technologies and management skills abroad, such as building factories and through CM&A, then utilizing them to improve the product quality and production technology (Desai *et al.*, 2005; Syverson, 2010). Jiang and Jiang (2014a, b) used the 2004–2006 Chinese Industrial Enterprises Database to study the relationship between OFDI and productivity and discovered that OFDI could significantly improve the productivity of enterprises, but the promotion gradually reduces over time. Mao and Xu (2014) used China's 2004–2009 firm-level data to conclude that a significant causal effect exists between OFDI and corporate innovation. Huang and Zhang (2017) used China's firm-level data from 2002–2007 to examine the effect of OFDI based on the heterogeneity of a firm's productivity. They divided firms in terms of absorptive capacity and whether they receive national support and demonstrated the following: enterprises effectively improve productivity if they invest abroad for the first time and the degree of impact varies greatly with the characteristics of the enterprise. Yang *et al.* (2013) used the 1987–2000 data from Taiwan's manufacturing industry to study the effect of OFDI on the technological efficiency of enterprises and demonstrated a positive correlation between the enterprises' OFDI activities and technological progress.

By contrast, some scholars believe that OFDI will not improve the productivity of firms (Hijzen *et al.*, 2007; Bai, 2009) and has a negative effect on them (Dhyne and Guerin, 2014). This may be due to the differences in sample selection, such as Bai (2009) found that the reverse technology spillover effect of China's OFDI was not statistically significant based on the macro data of national statistical yearbooks of 14 destinations. It may also be due to research methods that have resulted in different outcomes despite use of the same Japanese firm-level data as shown by Hijzen *et al.* (2007) and Kimura and Kiyota (2006). Hijzen *et al.* (2007) used a differences-in-differences (DID) model and found that "Going out" had no significant effect on the improvement of firms' productivity. Some scholars even find that OFDI has a negative impact on productivity (Dhyne and Guerin, 2014). So, whether the differences in these conclusions are due to the differences in sample selection or research methods, no consensus exists as to whether OFDI can significantly improve a firm's productivity. Because the literature on the OFDI own-firm effect has been mostly at the macro-level the question then becomes, "Will the OFDI own-firm effect of firms with different micro characteristics be different?" Therefore, this paper further divides the characteristics of food firms into different sub-sectors, regions and ownership types for a comparative analysis, with the aim of conducting a more comprehensive study at the micro-level of firms.

The second type of literature has examined the OFDI own-firm effect in specific industries. Pradhan and Singh (2008) examined the Indian auto industry and demonstrated that enterprises can enhance their productivity when they invest in developed or developing destinations. Shen and Ju (2016) demonstrated that the reverse technology spillover effect of OFDI in China's electronic information industry is significant and increases in the technical level strengthen this effect. Driffield and Love (2003) examined the reverse spillover effect of OFDI in manufacturing in the UK and demonstrated that OFDI does increase the technological level of its manufacturing industry; however, this increase is limited to research and development (R&D) intensive industries. The literature on OFDI in the food industry is insufficient; thus, the impact of OFDI on a firm's productivity is a valuable topic for the food industry.

In addition, an investigation into which factors influence the degree of the OFDI own-firm effect at the micro-level has not been found in the literature. In this paper, we will draw our own conclusions in the final part of the empirical analysis results.

2.2 Hypotheses

As mentioned, China's food firms may conduct OFDI due to efficiency seeking motivation, food quality motivation and food safety motivation, but what is the specific mechanism of the OFDI own-firm effect? This paper generalizes the conduction process into three phases (Figure 1).

The first phase is the acquisition of advanced technology and management experience. Food firms can acquire foreign advanced technology and management experience through four channels: technology transfer, learning and imitation, the flow of talent and sharing platform. The technology transfer refers to the transfer of technological achievements within firms. At present, more and more Chinese firms are engaged in mergers and acquisitions of firms with more advanced technology levels in developed destinations, internalizing the external market, and acquiring patent technologies, supply chain management, R&D teams, etc. Learning and imitation means that foreign subsidiaries of multinational firms could track, learn and imitate the technology research methods and directions of local leading firms. Compared with domestic firms, multinational subsidiaries are more likely to use their convenience to obtain the latest research and marketing methods, management models and cooperation with scientific research institution due to they are closer to local advanced firms and research centers. The flow of talent means that multinational subsidiaries could improve the technical level by introducing local capable technical talents and management talents, in addition, they can also share and exchange technologies and enhance the abilities of technological innovation through cooperation with local firms. Sharing platform means that multinational subsidiary could absorb their advanced technologies by using local resource platforms, R&D facilities, scientific research culture and scientific research achievements.

The second phase is the absorption and transformation of food firms. After acquiring the advanced technology and management experience of foreign subsidiaries, the multinational parent food firm needs a process of absorbing and transforming to internalize it into its own technological advantages, which can be achieved through the personnel and product flows of multinational subsidiaries and parent firms.

The third phase is the stage in which the firm's technology spreads to the food industry. Domestic firms could bring technological upgrading through demonstration effect and competitive effect. The demonstration effect means that multinational corporations will play
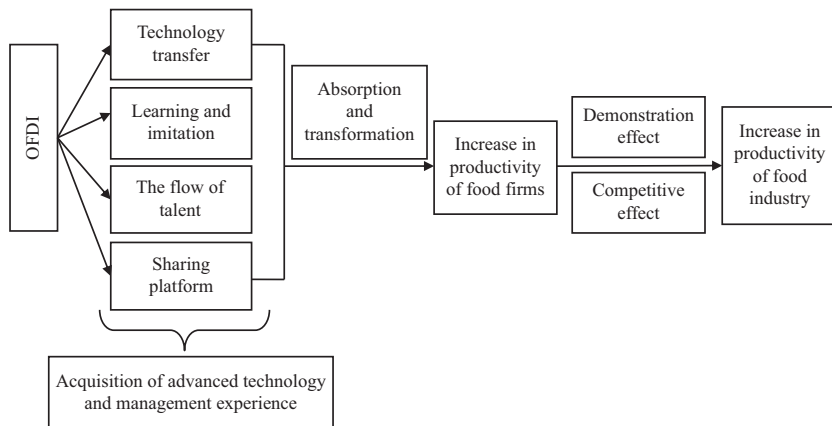

Figure 1.
The mechanism of OFDI's impact on the productivity of the food industry

a demonstration role for other firms within the food industry and encourage domestic non-multinational firms to strengthen the construction of R&D institutions after acquiring advanced technologies of foreign leading firms. The competitive effect refers to that the acquisition of advanced technology by multinational corporations will increase the pressure of firms' competition in the food industry, and then force food firms to enhance their innovation capabilities in order to survive. It is worth noting that such a technological upgrading process can be achieved not only between non-multinational corporations and multinational corporations, but also between different multinational corporations.

Based on the above analysis, we propose the first hypothesis:

H1. OFDI could increase the productivity of China's food industry, and the OFDI own-firm effect has hysteresis due to the time required for the absorption, transformation and diffusion of technologies.

China's food industry consists of three sub-sectors: agricultural food processing industry (AFPI), food manufacturing (FM) and beverage manufacturing (BM), they have different levels of development. There may be differences when the OFDI own-firm effect spreads from firms to the industry. Therefore, food firms affiliated with different sub-sectors may have different effects on productivity through OFDI. The role of FDI in productivity improvement may also be different. Second, the economic level and corporate culture of different regions are also different, so the OFDI own-firm effects of food firms belonging to different regions may also be different, which needs to be verified by subsequent empirical studies. Third, we could divide Chinese firms into state-owned firms and non-state-owned firms according to the type of ownership. OFDI of these two types of food firms may have different effects on productivity due to the operation of non-state-owned firms are freer and more efficient than state-owned firms (Huang and Zhang, 2017), thus, the non-state-owned firms could make better use of reverse technology spillovers from OFDI. Finally, the different destinations of OFDI represent different investment objectives. So, the difference in the destinations of OFDI may have an impact on the OFDI own-firm effect. The manner in which a firm's OFDI can obtain reverse technology spillovers is through investment, CM&A and other activities to obtain advanced technologies and management skills, the parent firms may become the users and creators of technologies and skills, the developed degree of an investment destinations may affect the efficiency of technology and experience absorption, and OFDI in high-income destinations may be more conducive to the promotion of the firm's productivity. Moreover, some firms have "system to escape or speculate" motives to invest abroad, meaning the firm invests in "tax havens," such as Hong Kong, the British Virgin Islands, and the Cayman Islands, to obtain domestic investment preferential policies – their main purpose is not to obtain advanced technologies and management skills. This phenomenon also exists in the food industry, thus, this part of OFDI may have no significant effect on enhancing TFP.

Based on the above analysis, we propose the second hypothesis:

H2. There is a firm heterogeneity in the OFDI own-firm effect. Specifically, the OFDI own-firm effect of food firms in different sub-sectors and regions may be different. Non-state-owned firms could gain greater productivity enhancement through OFDI than state-owned firms. The OFDI in high-income destinations may be more effective than it in low-income destinations, and the OFDI in "tax havens" may not achieve effective productivity gains.

In addition to objective factors such as sub-sectors and region, the OFDI own-firm effect may also be affected by the firm's own characteristics such as the level of FDI, export status and innovation ability. FDI allows firms to obtain financial advantages in learning that allow them to absorb and apply advanced technologies and management skills better than the other types of firms. Second, firms focused on R&D absorb the advanced technologies,

gain a dominant initiative advantage and apply more efficiently them to the production than other types of firms. Finally, the received advanced technologies can produce the parent firm's own products through OFDI, and the export of these products is one of the communications between the parent and overseas firm. Additional exchanges may promote the parent firm to continue to use the experiences and technologies to enhance TFP.

Based on the above analysis, we propose the third hypothesis:

H3. FDI, R&D and exporting could enhance the OFDI own-firm effect.

This paper then uses the PSM and DID methods to examine the following four questions based on the information from the Chinese Industrial Enterprises Database for the period 2005–2013: does the OFDI own-firm effect exist in the food industry? Could this effect persist? Considering the heterogeneity of firms, do the different types of food firms have different effects? Does the food firm's OFDI in different types of destinations affect the effect? Finally, may some characteristics of food firms affect the OFDI own-firm effect?

3. Data and TFP

3.1 Data sources and processing

The main data in this paper are derived from the China Industrial Enterprise Database (CIED), which is maintained by the China National Bureau of Statistics and includes all state-owned and above-scale (enterprise annual sales above RMB 5 and 20m, respectively, since 2011) non-state-owned enterprises. The subject of this paper is food firms, which corresponds to the following categories in the CIED: AFPI (industry code: 13), FM (industry code: 14) and BM (industry code: 15). We process the data according to Xie *et al.* (2008) and Yang (2015): excluding if industrial output value, total assets, capital stock, product sales or other key variables are missing, zero or negative; excluding if the number of employees in a firm is less than 8; excluding if the firm was established before 1950; and keeping if the paid-in capital of a firm is greater than 0. The CIED does not contain OFDI observations. Thus, this paper will process the information from the CIED and a data set of Chinese firms' OFDI information (CFOFDI) acquired from the Chinese Ministry of Commerce to make matches according to the name of firms and obtain the combined data that comprise firms' OFDI activities. We demonstrate that the observations of OFDI in the combined data before 2004 are very few and begin to increase significantly in 2005. Therefore, the time span of this paper is 2005–2013. The combined data contain 258,182 observations (337 identified as OFDI observations) and 72,981 firms (307 identified as OFDI firms).

3.2 Calculation of TFP

TFP is a key variable in the subsequent analysis of this paper. Studies have used different methods for its estimation, such as the ordinary least squares (OLS) method, the Olley–Pakes (OP) method, the Levinsohn-Petrin method, the fixed effects (FE) method and so on. The OP method could solve the selectivity and simultaneity biases (if we use OLS to estimate TFP) by constructing a survival probability function to estimate the entry and exit of firms and an investment function as the proxy variable of the firm's observable efficiency effect (Olley and Pakes, 1996). Thus, this paper chooses the OP method as its primary method of estimating the TFP of firms for subsequent analysis. We also use the FE model to calculate TFP, to increase the robustness of the results. In this paper, the output elasticities of capital and labor are estimated by the following OP regression model. Next, TFP is calculated according to the Cobb–Douglas production function:

$$\ln Y_{it} = \beta_0 + \beta_1 \ln K_{it} + \beta_2 \ln L_{it} + \beta_3 \text{age}_{it} + \sum_m \delta_m \text{year}_m + \sum_n \theta_n \text{reg}_n + \sum_k \varphi_k \text{ind}_k + \varepsilon_{it},$$

(1)

where $\ln Y_{it}$ is the log of output (total value) from firm i at time t, $\ln K_{it}$ is its capital input measured by total fixed assets and $\ln L_{it}$ is its labor input measured by practitioners. The output value and capital input are based on the industrial producer and fixed asset investment price indexes (base year is 2005) to reduce. The regression uses the OP semiparametric three-step regression method. The state variables are $\ln K_{it}$. The firm's age is age_{it}. The free variables are $\ln L_{it}$, a regional dummy variable (reg_n) and a three-digit code industry dummy variable (ind_k). The control variable is time trend variable ($year_m$). The proxy variable is the investment variable ($\ln I_{it}$). The exit variable is exit according to whether the firm is not included in the combined data, and if the firm is out of the data, exit is 1, otherwise 0. Table I presents the description of the relevant variables.

The results in Table I demonstrate that the TFP estimated by the OP method is less than that of the FE method and the regular pattern that an OFDI firm's TFP is higher than that of non-OFDI firm in the three sub-sectors of the food industry. This phenomenon may be because of the OFDI own-firm effect, but it may also be because the firm had a higher TFP before its OFDI (Helpman *et al.*, 2004) – known as the self-selection effect of the firm. Therefore, determining if OFDI effectively contributes to the improvement of food firms' TFP requires verification by following empirical analysis.

4. Empirical methodology
To verify the aforementioned problems and explore the effect of OFDI on food firms' TFP, this paper constructs a treatment group (OFDI firms) and control group (non-OFDI firms). Considering that the differences between the TFP of OFDI firms and non-OFDI firms are also likely to be caused by other unobservable and non-time-varying factors, this paper first uses the PSM method to match the treatment and control groups with firm characteristics and then combines that with the DID method to estimate the real effect of OFDI on TFP.

4.1 PSM for the sample
According to Heckman *et al.* (1997), we first divided the sample into treatment and control groups. The treatment group consists of OFDI firms, the control group consists of non-OFDI firms. After merging the CIED and CFOFDI, it can be clearly seen which firms have OFDI records, if the firm has OFDI records in the combined data, we set its OFDI value to 1, otherwise 0. And the logit model calculates the probability score of a firm's OFDI. We select the control group for the OFDI firms (the treatment group) based on the proximity of the probability score. This paper selects labor productivity, capital intensity, firm size, export, age, FDI, ownership type and R&D as matching variables, see Jiang and Jiang (2014a, b) and Ye and Zhao (2016). Table II presents the matching variables calculation method.

Table III shows the summary of matching variables. It indicates that the value of each firm characteristic of OFDI firms is significantly different from that of non-OFDI firms

Variable	Agricultural food processing industry		Food manufacturing		Beverage manufacturing	
	OFDI	non-OFDI	OFDI	non-OFDI	OFDI	non-OFDI
$\ln Y_{it}$	12.179	10.847	12.182	10.675	12.255	10.747
$\ln K_{it}$	10.136	8.668	10.388	8.914	10.571	9.206
$\ln I_{it}$	8.964	7.550	9.106	7.744	9.514	8.042
$\ln L_{it}$	5.569	4.657	5.787	4.914	5.878	4.910
TFP_{it} (OP)	6.565	6.093	5.493	4.978	5.596	4.987
TFP_{it} (FE)	9.537	8.697	9.364	8.260	9.052	8.051

Note: The values in the Table are the mathematical mean

Table I.
Descriptive statistics
of combined data

Variable	Variable name	Calculation method
LP	Labor productivity	The log of output labor ratio
KLR	Capital labor ratio	The log of capital labor ratio
SIZE	Firm size	The log of output
EXP	Export	1 if export delivery value is greater than 0, 0 otherwise
AGE	Firm age	The number of years since the creation of the firm
FDI	Foreign direct investment	1 if the firm has FDI, 0 otherwise
OWN	Ownership type	1 if state-owned capital accounts for more than 0.5 paid-up capital, 0 otherwise
RD	Research and development	1 if the firm conducts R&D, 0 otherwise

Note: Output and capital are the real value after the reduction

| | OFDI firms | | Non-OFDI firms | |
Variable	Mean	SD	Mean	SD
LP	6.460	1.200	6.019	1.101
KLR	4.544	1.338	4.076	1.278
SIZE	11.590	1.785	9.877	1.453
EXP	0.543	0.475	0.319	0.466
AGE	11.407	8.171	9.147	7.825
FDI	0.216	0.500	0.415	0.493
OWN	0.021	0.477	0.336	0.473
RD	0.099	0.300	0.039	0.193

before matching. Therefore, we next use PSM to screen out a certain number of non-OFDI firms so that the values of their firm characteristics are close to OFDI firms.

The matching methods of the PSM include radius matching, caliper matching, K-nearest neighbor matching and kernel matching. K-nearest neighbor matching is the most commonly used. We use K-nearest neighbor matching to pair the treatment and control groups. Because the number of OFDI firms in the sample is relatively small, we make the "k" value equal to 4, meaning we match four non-OFDI firms for each OFDI firm with similar firm characteristics. To test the matching effect, Table IV lists the standardized deviation of the matching variables. We can observe that the standardized deviations of all the variables are less than 5 percent, and the t-test results of the variables demonstrate no significant difference between the two groups after matching. According to Rosenbaum and Rubin (1983), the results demonstrate that K-nearest neighbor matching balances the combined data well.

| | Mean | | | |
Variable	Treated	Control	% bias	t-stat.
LP	6.460	6.446	1.2	0.37
KLR	4.544	4.502	3.0	0.91
SIZE	11.590	11.539	3.1	0.92
EXP	0.543	0.558	−3.4	−0.92
AGE	11.407	11.275	1.6	0.50
FDI	0.216	0.210	1.5	0.43
OWN	0.021	0.018	1.9	0.69
RD	0.099	0.097	0.9	0.23

Is the TFP of OFDI firms still higher than non-OFDI firms after controlling the characteristics of firms? First, we use the PSM method for the entire sample. The results (Table V) demonstrate that the TFP of the treatment and control groups is 6.185 and 5.668, respectively, before matching: the difference between the two is 0.517. After K-nearest neighbor matching, the TFP of the control group is 6.101: the difference between the two is reduced to 0.085. However, the *t*-test results demonstrate that the difference in the TFP between the two groups is still significant after matching, that is, the TFP mean of OFDI firms is still higher than that of non-OFDI firms after controlling the firm characteristics. We also use radius and kernel matching to do a robust test. The results demonstrate that the other two matching methods support that the TFP of OFDI firms is significantly higher than non-OFDI firms.

Notably, matching the entire sample does not allow us to locate the non-OFDI firms, the firm characteristics or the TFP closest to the OFDI firms when not yet have the OFDI records because the full sample also contains the observations of the OFDI firms after investing abroad. To meet the common trend assumption acquired by the DID method, this paper matches the treatment and control groups year by year based on the firm characteristics when the OFDI firms have not yet invested abroad (refers to Jiang and Jiang, 2014a, b). Additionally, if the firm has an OFDI record in the first year of its entry into the combined data, we base the firm's characteristics on this year to select the non-OFDI firms that match the OFDI firms. Table VI shows the results of yearly matching. The TFP of the treatment and control groups is very close after yearly matching; the difference is significantly reduced before matching; and the results basically meet the condition that there is no difference between the TFP of OFDI firms before investing abroad and non-OFDI firms.

4.2 DID for the sample after matching

We obtain a new control group in which the firm characteristics are similar to the treatment group after the yearly matching. Next, we add the observations of the treatment group to form new combined data. The new combined data contain 9,120 observations (315 identified as OFDI observations) and 1,444 firms (296 identified as OFDI firms). The ATT results of the whole sample in Table V demonstrate that the TFP of OFDI firms is still higher than non-OFDI firms after matching. Therefore, this paper next uses the DID method to examine whether OFDI can improve the TFP of food firms. The DID model is usually used to examine whether the effect of the policy has significant statistical significance, it has the advantage of avoiding endogeneity compared with the traditional method, that is controlling the possible interaction between the dependent variable and the independent variables. Meanwhile, the DID model as a classical method in empirical research can make causal inference of independent variables influencing dependent variables. But using the DID model requires certain conditions, one of the most important is what is called the "natural experiment," that is the policy impact or the firm's OFDI decision in this paper must

	Variable	Sample	Treated	Controls	Difference	SE	*t*-stat.
K-nearest neighbor matching	TFP	Unmatched	6.185	5.668	0.517	0.026	20.13***
		ATT	6.185	6.101	0.085	0.029	2.90***
Radius matching	TFP	Unmatched	6.185	5.668	0.517	0.026	20.13***
		ATT	6.173	6.084	0.089	0.026	3.42**
Kernel matching	TFP	Unmatched	6.185	5.668	0.517	0.026	20.13***
		ATT	6.185	5.802	0.383	0.026	14.94***

Notes: All the TFP in the Table are estimated by OP method. *,**,***Significant at the 10, 5 and 1 percent levels, respectively

Sample of year	Variable	Sample	Treated	Controls	Difference	SE	t-stat.
2005	TFP	Unmatched	5.744	5.248	0.496	0.082	6.02
		ATT	5.744	5.583	0.161	0.084	1.93
2006	TFP	Unmatched	5.072	5.406	−0.334	0.216	−1.55
		ATT	5.072	4.828	0.244	0.289	0.85
2007	TFP	Unmatched	5.458	5.503	−0.045	0.265	−0.17
		ATT	5.458	5.468	−0.009	0.391	−0.03
2008	TFP	Unmatched	5.573	5.525	0.048	0.302	0.16
		ATT	5.573	5.578	−0.005	0.387	−0.01
2009	TFP	Unmatched	5.871	5.795	0.076	0.370	0.20
		ATT	5.871	5.811	0.060	0.466	0.13
2010	TFP	Unmatched	6.342	5.666	0.676	0.596	1.13
		ATT	6.342	6.209	0.133	0.554	0.24
2011	TFP	Unmatched	5.698	5.931	−0.233	0.199	−1.17
		ATT	5.698	5.888	−0.190	0.276	−0.69
2012	TFP	Unmatched	5.951	6.024	−0.090	0.352	−0.26
		ATT	5.951	5.744	0.207	0.599	0.35
2013	TFP	Unmatched	6.315	5.938	0.377	0.343	1.10
		ATT	6.315	6.318	−0.003	0.344	−0.01

Table VI.
The results of
yearly matching

be exogenous, this is one of the reasons why PSM is used in this paper to control the firm's characteristic and productivity.

The classical DID regression model is as follows:

$$\ln(\text{TFP}_{it}) = \beta_0 + \beta_1 \text{OFDI}_{it} \times \text{TIME}_t + \beta_2 Z_{it} + \beta_3 \text{OFDI}_{it} + \beta_4 \text{TIME}_t + \varepsilon_{it}, \qquad (2)$$

where the interactive term $\text{OFDI}_{it} \times \text{TIME}_t$ is the product of the OFDI dummy variable (takes 1 if the firm belongs to the treatment group, and 0 otherwise) and time dummy variable (takes 1 for the periods in and after the firm undertakes first OFDI, and 0 otherwise). Z_{it} includes the control variables. ε_{it} is the error term. Theoretically, the coefficient of the interaction term β_1 represents the effect of OFDI on the firm's TFP. However, the model is more suitable for the two-stage model. In the data used in this paper, food firms undertake their OFDI in different years, and the period of the same firm's OFDI is not unique; therefore, this paper refers to Beck *et al.* (2010) and estimates the following model:

$$\ln(\text{TFP}_{it}) = \beta_0 + \beta_1 \text{OFDI}_{it} \times \text{TIME}_t + \beta_2 Z_{it} + \beta_3 \text{IND}_{it} + \beta_4 \text{YEAR}_t + \varepsilon_{it}, \qquad (3)$$

where IND_{it} represents the industry FE, and YEAR_t represents the year FE. In this paper, we select KLR, SIZE, EXP, AGE, FDI, OWN and RD as the control variable Z_{it}, according to the literature. The coefficient of $\text{OFDI}_{it} \times \text{TIME}_t$ represents the impact of OFDI on the firm's TFP, meaning that OFDI has a positive effect on TFP if $\beta_1 > 0$, and OFDI has a negative effect on TFP if $\beta_1 < 0$.

5. Empirical results

First, to intuitively perceive the causal relationship between OFDI and the TFP, this paper starts to estimate Equation (3) based on the new combined data. Second, the dynamic trend of the OFDI own-firm effect is investigated by the hysteresis effect test. Third, we examine the effect of OFDI on TFP from the perspective of sub-sectors, sub-regions, the different types of ownership and the different investment destinations. Finally, we introduce microcosmic characteristic variables to investigate the influence of firm characteristics on the OFDI own-firm effect.

5.1 Baseline results

Table VII reports the baseline results. From Column 1, we can see that the coefficient of $OFDI_{it} \times TIME_t$ is significantly positive without controlling any variables, the year or industry FE, indicating that the food firms' OFDI can significantly increase their productivity. Additionally, although the year and industry FE are controlled, the results are still robust, according to Columns 2. Columns 3 and 4 are the regression results after controlling the firm characteristics variables, where Column 4 is the result of the regression of Equation (3), and the coefficient of $OFDI_{it} \times TIME_t$ is still significantly positive with controlling of the firm characteristics variables, year FE and industry FE. These results prove, again, that food firms' OFDI can promote the promotion of TFP. Column 5 reports the result of the TFP calculated by the FE method. The coefficient of $OFDI_{it} \times TIME_t$ is 0.0675, which is significant at a 5 percent significance level. These results indicate that the result reported by Column 4 is robust.

Table VII also reports the values of other variables. The coefficient of the capital labor ratio (KLR) is significantly negative. This result indicates that capital intensity will inhibit the increase in TFP, which may be because of the inefficiency of the re-allocation of food industry resources, and the capital the firms will not have what they require to increase output and TFP, resulting in a waste of capital. This situation inhibits TFP growth. The coefficient of firm size (SIZE) is significant, which indicates that firms with a larger scale have a higher TFP. The coefficient of export (EXP) is also positive, indicating that exports will promote the growth of TFP, which is consistent with most studies. Thus, we can conclude that a food firm's OFDI can significantly enhance its TFP.

5.2 Hysteresis effect

After a firm undertakes OFDI, it may affect more than the TFP in the current period. Generally, firms require some time to learn, absorb, make technological advancements and improve their management skills. Therefore, the impact of OFDI on TFP may have a hysteresis effect. Jiang and Jiang (2014a, b) also confirmed that the OFDI own-firm effect does have a hysteresis effect, by using the Chinese firm-level data. Does the same law apply to food firms? Table VIII shows the results.

Columns 6–8 in Table VIII are the results without controlling for the year and industry FE. We observe that the coefficients of the core interaction term ($OFDI_{it} \times TIME_t$) from the lag one period to three periods are significantly positive, and the OFDI own-firm effect is the

VARIABLES	(1) TFP (OP)	(2) TFP (OP)	(3) TFP (OP)	(4) TFP (OP)	(5) TFP (FE)
$OFDI_{it} \times TIME_t$	0.409***	0.111***	0.213***	0.0871**	0.0675**
KLR			−0.108***	−0.0945***	−0.0486***
SIZE			0.182***	0.159***	0.309***
EXP			0.0279	0.127***	0.128***
AGE			0.0222***	−0.00195	−0.000151
FDI			−0.0350	0.0327	0.0259
OWN			−0.154**	−0.0464	−0.0403
RD			−0.0995***	−0.0116	0.0481*
Constant	5.797***	5.567***	4.039***	4.180***	5.452***
IND_{it}	No	Yes	No	Yes	Yes
$YEAR_t$	No	Yes	No	Yes	Yes
Observations	9,120	9,120	9,120	9,120	9,120
R^2	0.01	0.103	0.08	0.129	0.261

Notes: The dependent variable is $\ln TFP_{it}$. *,**,***Significant at the 10, 5 and 1 percent levels, respectively

Table VII.
Baseline results

	(6) Lag one period	(7) Lag two periods	(8) Lag three periods	(9) Lag one period	(10) Lag two periods	(11) Lag three periods
$\text{OFDI}_{it} \times \text{TIME}_t$	0.188***	0.107**	0.127**	0.0870**	0.0047	0.0376
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes
IND_{it}	No	No	No	Yes	Yes	Yes
YEAR_t	No	No	No	Yes	Yes	Yes
Constant	4.362***	4.474***	4.464***	4.589***	4.837***	5.313***
Observations	7,219	5,986	4,842	7,219	5,986	4,842
R^2	0.080	0.039	0.035	0.082	0.058	0.050
Number of firms	1,348	1,289	1,149	1,348	1,289	1,149

Table VIII.
Results of the
hysteresis effect

Notes: The dependent variable is $\ln\text{TFP}_{it}$ estimated by the OP method. *,**,***Significant at the 10, 5 and 1 percent levels, respectively

strongest in the first period of lag, weakens in the second period and rebounds in the third period. After we control for the year and industry FE (see the results in Columns 9–11), the core interaction term's coefficient of the lag one period is still significantly positive and the highest; however, the coefficients of the second and third periods of lag are no longer significant. The results in Table VII indicate that the OFDI own-firm effect has a hysteresis effect in the food industry and the food firm can also obtain the enhancement after one year of OFDI, but the enhancement will be weakened after two years of OFDI.

This conclusion is significantly different from the findings of Jiang and Jiang (2014a, b). Their research on China's manufacturing shows that the OFDI own-firm effect increases first and then declines and is the strongest in the lag two years. The difference may be because food firms have a relatively short time to learn advanced technologies and gain experience and can continue to effectively increase TFP in the short term; however, its impact on TFP will diminish after full absorption.

In summary, *H1* has been verified.

5.3 Firm heterogeneity effect

To study the impact of OFDI on TFP, this paper classifies food firms according to sub-sectors (two-digital), regions and ownership types. We divide the food industry into three sub-sectors: the AFPI, FM and BM. We divide the regions into the eastern region (ER), northeastern region (NER), central region (CR) and western region (WR), according to the China National Bureau of Statistics. We divide ownership types into state-owned (SO) and non-state-owned (NSO). Table IX presents the results of heterogeneity effect test.

	(12) AFPI	(13) FM	(14) BM	(15) ER	(16) NER	(17) CR	(18) WR	(19) SO	(20) NSO
$\text{OFDI}_{it} \times \text{TIME}_t$	0.068*	0.066	0.229**	0.077**	−0.055	0.340***	0.100	−0.163	0.097***
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
YEAR_t	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	4.12***	3.03***	3.14***	3.83***	4.36***	4.26***	3.26***	3.75***	3.93***
Observations	5,385	2,279	1,456	5,471	966	1,580	1,103	191	8,929
Number of firms	870	414	222	853	159	255	177	67	1,441

Table IX.
The results of
heterogeneity
effect test

Notes: The dependent variable is $\ln\text{TFP}_{it}$, estimated by OP method. *,**,***Significant at the 10, 5 and 1 percent levels, respectively

Columns 12–14 in Table IX report the results of the inspection of the sub-sectors. The coefficients of the core interaction term are both significantly positive in the AFPI (0.068) and BM (0.229). This result indicates that OFDI effectively promotes the TFP of the AFPI and BM firms, and the role of OFDI in promoting BM is greater than that of the AFPI. The coefficient of the core interaction term is not significant in FM, demonstrating that OFDI has no obvious effect on the improvement of TFP in FM. Because of the large differences in productivity levels across regions, the OFDI own-firm effects may have different effects in different regions.

Columns 15–18 report the results of the inspection of the regions. The coefficients of the core interaction term are both significantly positive in Columns 15 (0.077) and 17 (0.340). These results demonstrate that the OFDI own-firm effect exists, obviously, in the ER and CR, and the role in the CR is greater, whereas OFDI cannot significantly improve the TFP of firms in the NER and WR, according to Columns 16 and 18. By calculating the food firm's TFP, we demonstrate that the firm productivity in the CR is the lowest. Thus, the biggest role of OFDI in the CR is probably because of the law of diminishing marginal utility on TFP, that is, the impact of external shocks on productivity is faster and more pronounced in areas with lower productivity.

Columns 19 and 20 report the results of the ownership types inspection. We can observe that the coefficient of the core interaction term is significantly positive in Column 20 and not noticeable in Column 19. This result shows that OFDI cannot significantly improve the TFP of SO firms but can significantly improve the TFP of NSOs.

5.4 Investment destinations

What types of destinations to invest in may be one of the factors that affect the OFDI own-firm effect? Table X shows the inspection results according to the classification of investment destinations.

Table X demonstrates that the core interaction term coefficient of non-tax havens is significantly positive, whereas the core interaction term of tax havens is nonsignificant. These results demonstrate that the food firm's OFDI in non-tax havens can promote the improvement of TFP, and OFDI in tax havens cannot noticeably enhance the firm's TFP. Second, the core interaction term coefficient of high-income destinations is positive, and the core interaction term coefficient is nonsignificant in middle- and low-income destinations.

	(21) Non-tax havens	(22) Tax havens	(23) High-income destinations	(24) Middle- and low-income destinations
$OFDI_{it} \times TIME_t$	0.0795*	0.0977	0.0921**	0.0774
Firm characteristics	Yes	Yes	Yes	Yes
IND_{it}	Yes	Yes	Yes	Yes
$YEAR_t$	Yes	Yes	Yes	Yes
Constant	4.071***	4.400***	4.241***	4.078***
Observations	6,485	2,635	5,866	3,254
R^2	0.137	0.121	0.123	0.143

Notes: The dependent variable is $lnTFP_{it}$, estimated by the OP method. This paper divides the destinations according to the World Bank GNI ranking (2010): high-income destinations have a per capita income that exceeds \$12,276, middle income destinations have a per capita income between \$1,006 and 12,275 and low-income destinations have a per capita income less than \$1,005. Tax havens: several destinations are contained. Based on this new, combined data and tax havens are defined as: Hong Kong (China), the British Virgin Islands and Macao (China). *,**,***Significant at the 10, 5 and 1 percent levels, respectively

Table X.
Results of the investment destinations

These results demonstrate that food firms can achieve effective productivity promotion through investing in high-income destinations. The results in Table X validate the previous hypothesis. So, *H2* has been verified.

5.5 Influence of firm characteristics on the OFDI own-firm effect

Through the aforementioned analysis, we conclude that the food firm's OFDI can significantly improve the TFP. If that is true, then what factors will affect the effect? We will further investigate if the firm characteristics influence the OFDI own-firm effect by constructing the interaction term of OFDI and FDI, RD, capital labor ratio (KLR), export (EXP), firm size (SIZE) and firm age (AGE). The following equation is shown in detail:

$$\ln(\text{TFP}_{it}) = \beta_0 + \beta_1 \text{OFDI}_{it} \times \text{TIME}_t + \beta_2 \text{OFDI}_{it} \times \text{TIME}_t \times M_{it}$$

$$+ \beta_3 Z_{it} + \beta_4 \text{IND}_{it} + \beta_5 \text{YEAR}_t + \varepsilon_{it}, \tag{4}$$

where *M* represents FDI, RD, KLR, EXP, SIZE and AGE, respectively, Table XI reports the results of the joint effect test.

Table XI shows that the coefficients of the interaction term of OFDI and *M* are significantly positive except the results of Columns 30 and 31, it can be seen that when FDI, RD and EXP values are 1, the coefficient values of $\text{OFDI}_{it} \times \text{TIME}_t$ are 0.222, 0.229 and 0.139, respectively, from the results of Columns 26, 27 and 29, they are all significantly higher than 0.111 in Column 25. When FDI, RD and EXP values are 0, the coefficient values of $\text{OFDI}_{it} \times \text{TIME}_t$ are 0.083, 0.105 and 0.077, respectively, and they are all significantly lower than 0.111 in Column 25. The results demonstrate that FDI, R&D and exporting can significantly enhance the OFDI own-firm effect. In Column 28, if the value of KLR is 1, the coefficient value of the interaction term of OFDI and KLR is −0.005, and in fact the value of KLR is between 0 and 1, so in any case the coefficient value of the interaction term of OFDI and KLR is less than that of Column 25, indicating that capital intensity has an inhibitory effect on the OFDI own-firm effect. In Columns 30 and 31, the coefficients of interaction term of OFDI and SIZE, AGE are not significant, it shows that firm size and firm age may not have an outstanding influence on the OFDI own-firm effect. In summary, *H3* has been verified.

	(25) Model 1	(26) Model 2	(27) Model 3	(28) Model 4	(29) Model 5	(30) Model 6	(31) Model 7
$\text{OFDI}_{it} \times \text{TIME}_t$	0.111***	0.0829**	0.105***	−0.0370	0.0766	−0.225	0.157**
$\text{OFDI}_{it} \times \text{TIME}_t \times \text{FDI}$		0.139***					
$\text{OFDI}_{it} \times \text{TIME}_t \times \text{RD}$			0.124*				
$\text{OFDI}_{it} \times \text{TIME}_t \times \text{KLR}$				0.0320*			
$\text{OFDI}_{it} \times \text{TIME}_t \times \text{EXP}$					0.0622*		
$\text{OFDI}_{it} \times \text{TIME}_t \times \text{SIZE}$						0.028	
$\text{OFDI}_{it} \times \text{TIME}_t \times \text{AGE}$							−0.003
IND_{it}	Yes	Yes	Yes	Yes	Yes	Yes	Yes
YEAR_t	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	5.567***	5.567***	5.566***	5.567***	5.567***	5.568***	5.567***
Observations	9,120	9,120	9,120	9,120	9,120	9,120	9,120
R^2	0.103	0.104	0.104	0.104	0.103	0.104	0.103
Number of firms	1,444	1,444	1,444	1,444	1,444	1,444	1,444

Table XI.
Results of the
joint effect

Notes: The dependent variable is $\ln\text{TFP}_{it}$, estimated by the OP method. *,**,***Significant at the 10, 5 and 1 percent levels, respectively

6. Conclusions

Related studies confirm that OFDI has a significant effect on TFP. Does this phenomenon exist in the food industry? What are the characteristics of the OFDI own-firm effect in the food industry? This paper empirically studied the effect of OFDI on TFP by using information from the CIED and the data set of CFOFDI from 2005 to 2013 and draws the following conclusions: first, the OFDI of food firms significantly enhances their own TFP. Therefore, the government should encourage food firms to "Going out" for technological improvement and learn advanced technology and management experience from firms in developed destinations under the conditions permitting. Second, the OFDI own-firm effect has a hysteresis effect on the food industry, and the food firm can obtain strong enhancement in the short term; however, this enhancement will weaken in the long run. Third, the OFDI own-firm effect shows obvious firm heterogeneity. OFDI can significantly improve the TFP of the AFPI and BM at the industry level, and cannot significantly improve the TFP of FM. At the regional level, OFDI can significantly improve the TFP of food firms in the ER and CR but not in the WR and NER. At the ownership level, OFDI can significantly improve the TFP of non-state-owned firms but not state-owned firms. The government should formulate different policies for different sectors and regions to encourage food firms' OFDI and needs to promote the exchange of experiences and lessons among firms, to jointly explore how to strengthen innovation and promote industrial development. The government needs to continue to promote the reform of state-owned firms, encourage fair competition between state-owned and non-state-owned firms, promote the rational use of resources by state-owned firms and inspire their innovation potential. Fourth, the food firm's OFDI in high-income destinations and non-tax havens can have a significant own-firm effect, whereas productivity cannot improve if the firm invests in medium- and low-income destinations and tax havens. The government should improve the legal system, limit domestic food firms' investments for speculative purposes and establish a strict regulatory system to pay close attention to the OFDI of food firms. Fifth, FDI, R&D and exporting can strengthen the OFDI own-firm effect of food firms, whereas the capital intensity will inhibit the effect.

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What are the driving factors of pesticide overuse in vegetable production? Evidence from Chinese farmers

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Abstract

Purpose – Pesticide overuse has caused a series of negative impacts on environment and human health. The purpose of this paper is to examine the farmers' behavior of pesticide overuse and to identify the underlying determinants, based on the survey data from Shandong Province, China.

Design/methodology/approach – A two-stage semiparametric approach and the binary probit model were employed in this study to analyze the marginal pesticide productivity and investigate the determinants of the pesticide overuse.

Findings – Results suggest that the marginal pesticide productivity is negative, indicating a serious overuse of pesticides in the surveyed area. Both market factors and government regulation have impacts on farmers' use of pesticides.

Originality/value – This study estimates marginal pesticide productivity with an innovative methodology, and explores the role of market factors and government regulation in regulating farmers' behavior of pesticide use, especially in a typical vegetable growing area and targeting a specific type of vegetable.

Keywords Market factors, Government regulation, Marginal pesticide productivity, Semiparametric approach

Paper type Research paper

Introduction

The use of pesticides can help increase crop yield to secure sufficient market supply (Widawsky *et al.*, 1998; Rahman, 2015). However, many farmers, lacking information on pesticide spraying and driven by profit, tend to overuse pesticides (i.e. applied beyond the economic optimum) to prevent losses (Stadlinger *et al.*, 2011; Wang *et al.*, 2018), causing a series of negative impacts on environment and human health (Panuwet *et al.*, 2012; Qiao *et al.*, 2012; Sun *et al.*, 2018).

China has been the world's biggest producer and user of pesticides, and the amount of pesticides used in agricultural production has witnessed no abatement in years (Grung *et al.*, 2015; Nie *et al.*, 2018). Central and local governments in China have been working to regulate the use of pesticides and promote food safety in the country. China's Ministry of Agriculture launched the "Zero Increase in Pesticide Use" campaign nationwide in 2015, and started a program to monitor the quality and safety of agricultural products in 2018, hoping to better regulate the use of pesticides. In the 2017 "No. 1 Central Document," stress has been laid on the effort of cracking down on pesticide overuse, and conducting strict spot checks on pesticide residue of agricultural products. The report of the 19th National Congress of the

CPC has stipulated the implementation of food safety strategy to boost the source control of agricultural production and food safety.

To develop efficient policy interventions for pesticide reduction, it is necessary to target the behavior of farmers, who are the handler of pesticides and who are of great relevance to the governmental efforts. The existing studies on pesticide overuse mainly focused on the measurement of pesticide overuse and determinants of pesticide usage. Researchers measure the pesticide overuse by estimating the marginal productivity of pesticides with production functions, and then compare this marginal productivity with the price of pesticides. In most previous literature, pesticides are usually treated either as a direct input of production or as a damage control input (see e.g. Huang *et al.*, 2002; Asfaw *et al.*, 2008; Zhou and Zhang, 2013; Zhu *et al.*, 2014; Wang *et al.*, 2018). In the meantime, many other studies on pesticide overuse explore the factors driving farmers to overuse pesticides. The identified factors include related market profits, government regulation, farmers' awareness, as well as farmers' socio-demographic characteristics (Wang and Gu, 2013; Jiang *et al.*, 2017; Hashemi *et al.*, 2012; Gaber and Abdel-Latif, 2012; Jallow *et al.*, 2017).

The existing studies have substantiated the study of pesticide overuse by establishing the framework for pesticide productivity modeling and estimation, and the examination of various impact factors to explain the behavior of overuse. Such works have laid a sound theoretical foundation for this study, but certain key aspects need to be improved. First, in terms of the pesticide productivity assessment, many of the previous studies have followed the approach suggested by Lichtenberg and Zilberman (1986), which might result in an estimation bias; thus, it is necessary to re-estimate the pesticide productivity with a new approach. Second, regarding the factors causing the overuse of pesticides, the determinants of farmers' practices vary from country to country in previous literature, and even studies of China have different focuses; therefore, it requires further analysis to reveal the impacts of market constraints and governmental regulation, two of the major determinants, on farmers' behavior. Third, in some previous studies, researchers either conducted the survey in untypical areas, or had small sample size, or pooled different types of plants such as leafy vegetables, fruit vegetables and fruits all together when studying farmers' pesticide-handling practices. This might result in biased results; henceforth, relevant studies should be conducted with more sample households from a typical vegetable growing area, and targeting a specific type of vegetable.

To fill these gaps, this study examines the issues of pesticide overuse by evaluating the marginal pesticide productivity with a two-stage semiparametric approach, and then investigates the underlying driving factors of pesticide overuse. This study explores the roles market factors and governmental regulation play in regulating farmers' behaviors of pesticide use in a more systematic manner, thus would provide useful insights to policy-makers on how to effectively reduce the usage amount of pesticides. Due to the humidity and the lack of crop rotation, vegetables grown in greenhouse usually have a short growth cycle and suffer from frequent pest damage (Gao and Ning, 2013). This paper is based on the original data of 546 growers of fruit vegetable (i.e. plant fruits eaten as a vegetable) from Shandong Province, the largest production base of greenhouse vegetables. As the world's biggest producer and user of pesticides (Grung *et al.*, 2015), each year China uses roughly 1.4m tons of pesticides nationwide, accounting for more than 30 percent of the world's pesticide use (Wanglong, 2016). Therefore, our results based on the data from Shandong Province, mean that China could not only promote the safe use of pesticides locally, but also offer valuable suggestion for encouraging environmentally-friendly agriculture nationwide and globally.

This paper is structured as follows. The next section presents the theoretical analysis and the estimation methodology. In the third section we provide some background

information and describe the data. The estimation results and discussion are presented in the fourth section 4. The fifth section concludes, and in the sixth section we discuss the limitations of our study and provide some perspectives to future studies.

Relevant studies

Pesticide overuse has been a focus of many studies, and the existing studies were mainly conducted from the following two strings, namely, the measurement of pesticide overuse and determinants of pesticide usage.

The measurement of pesticide overuse

Studies have discussed the measurement of pesticide overuse. Researchers usually estimate the marginal pesticide productivity with production functions as the measurement of pesticide overuse. In early studies, pesticides were treated the same as labor or capital as direct input, and the productivity assessment was conducted with Cobb–Douglas production function (Headley, 1968; Campbell, 1976); the results suggested the estimated marginal product of pesticides to be greater than the factor price, indicating significant under-use. However, according to Lichtenberg and Zilberman (1986), treating pesticides as a direct input will overestimate the marginal productivity. Hence they defined pesticides as damage control inputs, and accounted for the special nature of damage control inputs using a built-in damage control function in the production function, now a standard approach in applications (see e.g. Huang *et al.*, 2002; Asfaw *et al.*, 2008; Zhou and Zhang, 2013; Zhu *et al.*, 2014; Wang *et al.*, 2018). But Kuosmanen *et al.* (2006) later pointed out that the standard approach fails to account for important interactions between direct and damage control inputs, and the absence of pest pressure information in the damage control function might result in an underestimation of marginal pesticide productivity. In this regard, they introduced the two-stage, semiparametric model to assess the productivity of pesticides, which combines the advantages of both nonparametric and parametric approaches and models the interaction between pest exposure and damage control inputs.

Determinants of pesticide usage

A number of studies have documented the determinants of pesticide overuse. Some researchers have proven that farmers tend to overuse pesticides to secure market profit. As Gong *et al.* (2016) pointed out, farmers are generally risk-averse. Farmers in China have very limited access to formal insurance or credit markets to mitigate severe income shocks; thus, they will resort to an intensive use of pesticides as a risk-reducing activity to stabilize the output and market profit. Wang and Gu (2013) and Jiang *et al.* (2017) also showed that protecting market profit is the main purpose of farmers to overuse pesticides. Some studies focused on the impact of government regulation on farmers' use of pesticides. He *et al.* (2005) and Xu *et al.* (2008) indicated that farmers could improve their awareness by attending training and extension programs, and reduce pesticide use. Li *et al.* (2017) suggested that training programs can regulate farmers' use of pesticides, but the effectiveness would be reduced with the increase in the severity of pesticide overuse. Wang *et al.* (2015) and Huang *et al.* (2016), examining the role of different policies on the use of pesticides, revealed in their studies that policy interventions such as training programs, governmental pesticide residue testing and bio-pesticide subsidies can increase farmers' awareness of the safety interval, but cannot regulate pesticide overuse effectively. Jacquet *et al.* (2011) conducted a case study of French farmers and found that the government can help reduce pesticide use by 10–20 percent through education and communication programs, but further reduction would require some incentive policies such as taxation and subsidies or stricter regulation. Skevas *et al.* (2012), in their study of Dutch farmers, suggested that subsidies and taxation

are not effective policies in regulating the use of high-toxic pesticides, but pesticide quotas have a marked effect in reducing the use of such pesticides.

Market and industrial organizations have also been proven to have impacts on farmers' use of pesticide in some studies. Scholars such as Zhu (2004) and Ma and Abdulai (2018) argued that cooperatives could help regulate farmers' use of pesticides. Huang and Qian (2005) revealed that industrial associations and relevant companies are the major force in regulating farmers' behavior and reducing pesticide use.

Moreover, farmers' socio-demographic characteristics such as gender, age and knowledge, as well as different uses of agricultural products, planting scale and main source of income (Hashemi et al., 2012; Gaber and Abdel-Latif, 2012; Wu and Hou, 2012; Jallow et al., 2017; Ma et al., 2017; Wang et al., 2017), would also affect the use of pesticide.

Theoretical model and estimation methodology
The measurement of pesticide overuse and estimation methodology
Economists often evaluate the economic performance of pesticides by measuring a pesticide's marginal products. If the pesticide marginal product is high relative to marginal cost, it indicates that pesticides are under-used, and farmers can get more additional benefit from increasing pesticide use. However, if the value of the pesticide marginal product is low relative to marginal cost, it denotes that pesticides are overused, and farmers can profitably decrease pesticide use while at the same time reducing environmental and health risks (Headley, 1968; Campbell, 1976; Norwood and Marra, 2003).

Pesticide productivity modeling. Early attempts to measure the value of pesticide productivity all used the Cobb–Douglas production function, and have overestimated the marginal product of pesticides. Lichtenberg and Zilberman (1986) presented a critique of the econometric work and proposed an alternative, more intuitive approach to model the role of pesticides in agricultural production. They pointed out that agricultural inputs such as pesticides are different from conventional inputs in that they affect output indirectly by reducing the damage, and that agricultural production subject to pest damage should be modeled by production function F and damage control g with the following separable structure:

$$y = F\left[x^D, g\left(x^P, z\right)\right], \tag{1}$$

where y represents the output, x^D gathers the direct inputs (labor, capital, among others), x^P gathers the damage control inputs (pesticides and other means of pest control) and z denotes the damage agents (such as pest populations).

For reasons of econometric identification, the practice in empirical work is to simplify the damage control function to a proportional one (Shankar and Thirtle, 2005):

$$y = f\left(x^D\right)g\left(x^P, z\right). \tag{2}$$

The usual approach is to assume that $g(x^P, z)$ has a certain parametric functional form, and then estimate the unknown parameters with least squares or maximum likelihood techniques (Fox and Weersink, 1995; Wossink and Rossing, 1998). But Kuosmanen et al. (2006) have discussed in their study that there is no theoretical reason to prefer one functional form to another. Any results of the estimation are often sensitive to the specification of functional form in the sense that different specifications yield contradictory marginal productivities for damage control input. Moreover, the usual approach does not account for the interactions between direct and damage control inputs, and fails to model pest pressure in the estimation of the damage control function, which might result in an

underestimation of the marginal productivity. Therefore, Kuosmanen *et al.* (2006) suggested the semiparametric estimation of the damage control function to avoid strong assumptions about the functional form and model the interaction between pest exposure and damage control inputs as an improved approach. According to them, expression (2) can be reorganized as:

$$g(x^P, z) = y/f(x^D),$$

$$(3)$$

where $y/f(x^D)$ is the reciprocal of Farrell's output-oriented technical efficiency (i.e. the ratio of the maximum output obtainable with the given inputs to the actual output (Farrell, 1957)). θ denotes the technical efficiency (i.e. $f(x^D)/y$), and θ^* is its consistent estimate:

$$1/\theta^* = g(x^P, z) + \varepsilon,$$

$$(4)$$

where ε is the error term. According to Kuosmanen *et al.* (2006), the damage agent variable z are modeled as slope dummies in the specification. This study uses "pest pressure" as the proxy of damage agent variable z. Set $z = 1$ if the pest pressure is low, $z = 2$ if the pest pressure is at a medium level, and $z = 3$ if the pest pressure is high. The information of z can be collapsed into 3 binary dummy variables D_1, D_2 and D_3:

$$D_{jn} = \begin{cases} 1, & z_n = j \\ 0, & \text{otherwise} \end{cases} \quad j = 1, 2, 3.$$

$$(5)$$

These binary variables can be included in a regression model as slope dummies to give the following specification of damage control regression:

$$1/\theta^* = \alpha + D_1\left(\beta_1^L x_1^p + \beta_2^L x_2^p + \cdots + \beta_n^L x_n^p\right) + D_2\left(\beta_1^M x_1^p + \beta_2^M x_2^p + \cdots + \beta_n^M x_n^p\right)$$

$$+ D_3\left(\beta_1^H x_1^p + \beta_2^H x_2^p + \cdots + \beta_n^H x_n^p\right) + \varepsilon.$$

$$(6)$$

As shown in expression (6), the level of pest pressure has impact on the marginal product of the damage control inputs, and β_i^L, β_i^M and β_i^H represent the marginal product of damage control inputs under low, medium and high pest pressure, respectively.

Estimation methodology of pesticide productivity. To avoid strong assumptions about the functional form, Kuosmanen *et al.* (2006) offered a semiparametric approach to estimate the damage control function. Following their approach, the analysis can be divided into two stages.

In the first stage, technical efficiency of the direct inputs is measured relative to the best practice in the sample, and the nonparametric data envelopment analysis (DEA) method is employed in estimation:

$$\max_{\theta, \lambda} \theta,$$

$$\text{s.t. } \theta y_k \leqslant \sum_{i=1}^n \lambda_i y_i, \ x_k^D \geqslant \sum_{i=1}^n \lambda_i x_i^D, \ \lambda_i \geqslant 0,$$

$$(7)$$

where θ is farmer k's technical efficiency, namely the ability to achieve maximum output with given amount of inputs. Variables λ represent weights in the linear combinations of sample farmers. For the ith farmer, the direct input and output data are given by the column

vectors x_i^D and y_i, respectively. The technical efficiency measure θ^* is obtained as the optimal solution to (7).

In the second stage, the average productivity impact of damage control inputs is estimated via parametric regression techniques. Having estimated the dependent variable $1/\theta^*$, the next step is to estimate the damage control function $g(x^P, z)$ from (3). Note that $1/\theta^*$ ranges between 0 and 1, and the truncated linear regression is employed in this regard. The linear specification of the regression function allows us to interpret the coefficients as (average) marginal products of damage control inputs. Moreover, both stages are complemented with bootstrap simulation so as to eliminate the sampling bias and to allow for consistent statistical inference (Simar and Wilson, 2007).

When applying the semi-parameter DEA approach in the estimation, the heterogeneity issue was considered and solved by the following three steps. First, the marginal productivity was estimated for each major vegetable category to deal with the potential heterogeneity from vegetable types; second, our model allows different coefficients across three pest pressure groups, namely, low pest pressure, medium pest pressure and high pest pressure to consider the potential heterogeneity from the different degree of pest pressure; thirdly, the semi-parameter DEA approach employed in this paper can also solve certain heterogeneity issues by avoiding the assumption of particular production function form.

Determinants of pesticide overuse
Theoretical framework of farmers' practice of pesticide use. Based on the estimated pesticide productivity, this paper further analyzes the factors contributing to the overuse of pesticides. The analysis of pesticide use is based on Lewin's equation, which suggests that human behavior is the result of the interaction between the individual and the environment, and is subject to the impact of internal factors (such as one's physiological needs, physiological characteristics, ability and attitude etc.) and the external environment (such as the natural environment and social environment). In this context, farmers' practice of pesticide use is the result of the interaction between farmers' internal factors and the external environment around them.

The practice of pesticide use is influenced by various factors. Based on the existing studies, this paper conducts in-depth analysis on the roles market factors and government regulation play in regulating farmers' pesticide overuse, with farmers' socio-demographic characteristics as control variables. The theoretical framework of this study is shown in Figure 1.
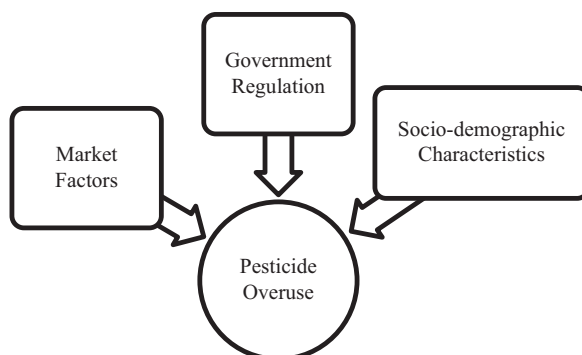
Figure 1.
Theoretical framework
of farmers' practice
of pesticide use

Estimation methodology of determinants of pesticide use. Based on the theoretical framework, this paper conducts empirical analysis with the Binary Probit Regression to estimate the following model:

$$\Pr \left(Y_n = 1 \,|X,Z \right) = \Phi\Big(\alpha+ \sum \beta_{in}X_{in}+ \sum \gamma_{in}Z_{in}\Big), \tag{8}$$

where the dependent variable Y_n is a binary variable based on the self-reported pesticide use information (Alam and Wolff, 2016; Abadi, 2018; Akter *et al.*, 2018). Y_n is set to equal 1 if farmer n reports to use more pesticides than the recommended dose in the instruction, and 0 otherwise. The rationale for doing so is that, such qualitative data exploration can lead respondents to reveal their own internalized perceptions and intuitions about the pesticide use (Abadi, 2018). X_i gathers the explanatory variables, and Z_i is the vector of other control variables. i represents the number of explanatory variable or control variables. β and γ are the coefficients of X and Z, respectively. The description and summary statistics of the variables are reported in Table I.

Data

Study area

This study was conducted in Shouguang City and Qingzhou City, Shandong Province, China. Shouguang City, located between 36°41′ and 37°19′ north latitude and 118°32′ to 119°10′ east longitude, has a total land area of 2,180 km^2 and a population of 1,084,687. It is the largest vegetable production and trading center in China, known as the "home of vegetables."

	Variable	Description	Mean	SD
Farmers' practices	Use of pesticides	Using more pesticide than the instruction (yes = 1, no = 0)	0.34	0.47
Market profit	Yield concern	Concern over yield loss without pesticides (yes = 1, no = 0)	0.62	0.48
	Price concern	Organic vegetables can sell better (yes = 1, no = 0)	0.76	0.43
Market organization	Cooperative	Joining cooperatives (yes = 1, no = 0)	0.22	0.41
	Sales contract	Signing sales contract with companies (yes = 1, no = 0)	0.04	0.19
Government regulation	Pre-sales test	Conducting pre-sales test (yes = 1, no = 0)	0.67	0.47
	Safety control	Having safety control policies in place (yes = 1, no = 0)	0.82	0.38
	Training programs	Training programs on pesticide use (yes = 1, no = 0)	0.59	0.49
	Subsidies	Subsidies for bio-pesticides (yes = 1, no = 0)	0.14	0.34
Control variables	Gender	Gender of the respondent (male = 1, female = 0)	0.82	0.39
	Age	Age of the respondent (years)	47.98	9.10
	Education	Education level of the respondent (primary school and below = 1, middle school = 2, high school = 3, college and above = 4)	2.04	0.61
	Experience	Years of farming experience (years)	18.87	7.78
	Land	Total farm area (mu/household)	4.15	2.97
	Farm income	The share of agricultural income (20% and below = 1, 21%–40% = 2, 41%–60% = 3, 60%–80% = 4, above 80% = 5)	4.57	1.04
	Cucumber	Growing cucumber (yes = 1, no = 0)	0.31	0.46
	Tomato	Growing tomato (yes = 1, no = 0)	0.30	0.46
	Green pepper	Growing green pepper (reference)	0.39	0.49

Table I.
Summary statistics
for the variables

Note: 15 mu = 1 hectare

And Qingzhou City, located between 36°24 and 36°56 north latitude and 118°41′ to 119°46′ east longitude, has a total land area of 1,569 km^2 and a population of 940,400. Vegetable production is also a pillar sector of this city.

Survey design

This study mainly focused on the pesticide-applying practice of farmers growing fruit vegetables (cucumbers, tomatoes, green peppers and eggplants) in greenhouses. The rationale for choosing this particular group of farmers to survey is that, vegetables, with a relatively shorter growth cycle and suffering pest damage more frequently than grains, usually require farmers to use large amount of pesticides in a short period of time to preserve yield, which would easily result in pesticide overuse (Wu *et al.*, 2009). As for fruit vegetables grown in greenhouses, where the pest infestation occurs even more often due to the humidity and the lack of crop rotation, it has become rather common for farmers to overuse pesticides (Gao and Ning, 2013). Therefore, the practice of this group of farmers is very representative.

Moreover, given that different varieties of vegetables vary in their growth cycles, pest infestation, input and output, and require different amount of pesticides, this study also specifically differentiates vegetables by variety in the survey in order to avoid the biased results caused by pooling different vegetables together in the estimation. The sample households mainly include growers of cucumber, tomato, green pepper and eggplant.

The questionnaire used in the field covered the information on household demographics and social-economics, the expenditure and sales related to vegetable production and pesticide-handling practices.

Data collection. The survey data were collected between July and August 2016 through the Rural Eco-environment Project of China Agricultural University. Information was obtained through face-to-face interviews by trained interviewers. The multi-stage random sampling was used to select three towns out of each city, ten villages out of each town and ten households out of each town for the survey. In total, 600 households were interviewed; after eliminating the samples missing important info or vegetables grown in the open field (all the others are in greenhouses), the valid sample size is 571,with an overall response rate of 95 percent. The survey data from the 571 fully completed questionnaires were encoded and entered into Excel spread sheets. The Stata/SE 12.1 software and MaxDEA 7 Ultra software were used in the data analysis.

According to the preliminary statistics of the valid samples, among the 571 households, there were 167 cucumber growers (29.25 percent), 166 tomato growers (29.07 percent) and 213 green pepper growers (37.30 percent); only 25 households (4.38 percent) grew eggplant, which is not representative enough for estimation. Therefore, this study mainly focuses on the practices of cucumber, tomato and green pepper growers (546 households).

Description of the sample

Socio-demographic characteristics. The socio-demographic characteristics of the surveyed farmers are reported in Table I. On average, the survey farmers were around 48 years of age and 81.87 percent of them were men. Most farmers have received secondary education (68.3 percent).

The average number of planting area of the surveyed households was 4.15 mu, and farmers had around 19 years of experience on average. The agricultural income of most farmers accounted for over 60 percent of their total income, indicating agricultural production as the most important source of cash for the villagers.

Use of pesticide. Of interest in this study is the amount of pesticides used in vegetable production. Households were asked whether the amount of pesticides they usually applied

was less than, the same as or more than their instruction. 3.11 percent of the farmers reported applying pesticides less than the amount of instruction; 62.64 percent of them reported to follow the instruction; and 34.25 percent reported overusing pesticides, which might pose risks to the quality of the agricultural products.

Description of relevant explanatory variables. In this article, we try to identify the determinants of pesticide overuse from the perspective of market and government. Based on the existing studies (Jiang *et al.*, 2017; Wang and Gu, 2013), we further divided market factors into market profit and market organization. The statistics of relevant explanatory variables are shown in Table I.

As for market profit, represented by farmers' yield concern and price concern, most surveyed farmers (62.5 percent) reported their concern over yield loss without pesticides, which suggests that preventing the decrease in output can be one of the major motivations of using pesticides. Meanwhile, the majority of the farmers (76.37 percent) reported believing that organic vegetables (not using/using pesticide within regulation limit) can sell better, but there were still over 20 percent of them believing otherwise.

In terms of market organization, represented by farmers' participation in cooperatives, and whether they had sales contracts with companies, only 21.61 percent of the farmers reported joining a cooperative and even fewer had sales contracts with companies (less than 10 percent).

We now turn to government regulation, represented by the pre-sales test of pesticide residue, safety control policies on agricultural products, training programs and subsidies for bio-pesticides. 66.85 percent of the respondents reported receiving pre-sales tests, 82.05 percent reported there were safety control policies in place, and 59.16 percent reported participation in training programs. However, only a small percentage (13.74 percent) reported receiving subsidies for bio-pesticides. Generally speaking, the governmental regulation on farmers' safe use of pesticides needs further improvement.

Results and discussion
The estimation of marginal pesticide productivity
To estimate the marginal pesticide productivity, the input and output variables, and the damage agent have all been employed, as shown in Table II. Output is measured in physical terms as kg of vegetable yield per mu. As direct inputs, this paper employs labor measured in physical terms, production costs, including expenses for seeds, mulching,

| | Cucumber | | Tomato | | Green pepper | |
	Mean	SD	Mean	SD	Mean	SD
Output (y)						
Yield (kg/mu)	7,199.95	4,205.34	6,243.55	6,229.85	4,301.97	2,741.35
Direct inputs (x^D)						
Production costs (RMB/mu)	6,529.94	3,955.73	5,878.77	4,154.66	3,822.41	3,505.74
Labor input (person day/mu)	68.42	53.58	72.76	63.22	46.07	64.41
Damage control inputs (x^P)						
Pesticide use (RMB/mu)	1,033.19	768.23	939.56	674.13	520.41	560.63
Use of sticky trap/pest-killing lamp (yes = 1, no = 0)	0.32	0.47	0.69	0.47	0.21	0.41
Damage agent (z)						
Pest pressure	Ordinal scale indicator (1 = "low", 2 = "medium" and 3 = "high")					

Table II.
Input and output indicators

Notes: 15 mu = 1 hectare. 6.64 RMB ≈ 1 dollar (2016 data)

fertilizer and irrigation, which are used as a proxy for all other direct inputs, reported in RMB per mu. As for damage control inputs, according to previous studies and the field survey, it is learnt that the most common pest control approaches in vegetable production are the physical control (using stick trap or pest-killing lamp) and the biological/chemical control (using pesticides) (Jiao, 2013). Therefore, this paper employs the cost for pesticides (RMB per mu) and the use of sticky trap/pest-killing lamp (scale) as damage control inputs.

Table III reports the distribution of the technical efficiency scores for the surveyed farmers. The results of marginal productivity of the damage control inputs are depicted in Table IV.

As shown in Table IV, the coefficients of pesticides used on all three types of vegetables are significantly negative at all levels of pest pressure, and the increase in the amount of pesticides used will result in a decrease in the yield, indicating a serious overuse of pesticides.

Note that for all three types of vegetables, the marginal productivity of pesticides at low pest pressure is smaller than that at medium pest pressure, which is in consistence with the results of Kuosmanen *et al.* (2006), indicating that farmers were more likely to overuse pesticide when the pest pressure was either low or high, but less likely to overuse pesticide when the pest pressure was at a medium level.

	Cucumber		Tomato		Green pepper	
Efficiency interval	n	%	n	%	n	%
$\theta = 1$	4	2.40	3	1.81	2	0.94
$1 < \theta \leqslant 2$	13	7.78	24	14.46	12	5.63
$2 < \theta \leqslant 3$	28	16.77	26	15.66	19	8.92
$3 < \theta \leqslant 4$	15	8.98	32	19.28	25	11.74
$4 < \theta \leqslant 5$	21	12.57	22	13.25	23	10.80
$5 < \theta \leqslant 6$	20	11.98	11	6.63	27	12.68
$6 < \theta \leqslant 7$	18	10.78	11	6.63	18	8.45
$7 < \theta \leqslant 8$	18	10.78	9	5.42	19	8.92
$8 < \theta \leqslant 9$	8	4.79	11	6.63	6	2.82
$9 < \theta \leqslant 10$	9	5.39	6	3.61	10	4.69
$10 < \theta$	13	7.78	11	6.63	52	24.41

Table III.
The distribution
of the technical
efficiency scores

	Cucumber		Tomato		Green pepper	
	Coef.	SE	Coef.	SE	Coef.	SE
Pesticide low (β_1^L)	−0.103**	0.041	−0.084**	0.042	−0.237***	0.063
Pesticide medium (β_1^M)	−0.100**	0.040	−0.073*	0.041	−0.228***	0.054
Pesticide high (β_1^H)	−0.105**	0.044	−0.081*	0.045	−0.258***	0.050
Trap/lamp low (β_2^L)	0.075	0.108	0.072	0.102	0.071	0.250
Trap/lamp medium (β_2^M)	0.036	0.093	0.107	0.089	0.078	0.202
Trap/lamp high (β_2^H)	−0.113	0.158	0.091	0.151	0.142	0.089
Constant (α)	0.763	0.248	0.617	0.256	1.272	0.269
Number of observations	167		166		213	

Notes: "Pesticide low," "Pesticide medium" and "Pesticide high" represent the marginal pesticide productivity under low, medium and high pest pressure, respectively. *,**,***Significant at 10, 5 and 1 percent levels, respectively

Table IV.
Estimation results
of marginal pesticide
productivity

Determinants of pesticide overuse

The analysis above indicates a serious overuse of pesticides among sample farmers. Previous studies have also pointed out that the overuse of pesticides has become a normalcy among farmers (Zhang *et al.*, 2015; Chen *et al.*, 2016; Jin *et al.*, 2017). According to economic logic, the overuse of pesticides goes against the assumption of farmers as "rational men," as overusing pesticides does not guarantee higher yield (Zhu *et al.*, 2014). But why do farmers tend to be "irrational" and apply pesticides beyond optimum amount? To answer this question, this paper further analyses how the behavior of overusing pesticides can be explained from the perspective of market profit, market organization and governmental regulation, using the Probit regression model.

Given that the explanatory variables might be strongly correlated and compromise the reliability of the estimation results, a correlation test and collinearity diagnostics were conducted prior to the regression analysis. Results of the tests indicate that despite some correlation between the variables, the model has no problem of multicollinearity. Equation (8) was estimated with Probit Regression, and control variables are included in regression II. The estimation results are shown in Table V.

As shown in Table V, in terms of the impact of market profit on farmers' pesticide use, farmers' yield concern and price concern are found to be statistically significant. Farmers' concern over yield loss without pesticides can increase the likelihood of incidence of pesticide overuse by 8.6 percentage points. And farmers' belief of better prices for organic products can reduce the likelihood of incidence of pesticide overuse by 20.2 percentage points. A plausible explanation is that, as pointed out in existing studies, people usually consider the loss twice as valuable as the gain due to loss aversion (Dong, 2006). If there is no such mechanism as "a favorable price for good quality," and farmers believe the loss in profit induced by cutting the use of pesticides outweighs the gain in income, they might resort to pesticide overuse. Therefore, the risk-averse farmers count on overusing pesticides to secure their market profit.

	\multicolumn{4}{c}{I}	\multicolumn{4}{c}{II}				
	Coef.	SE	Marginal effect	SE	Coef.	SE	Marginal effect	SE
Yield concern	0.269*	0.141	0.068*	0.035	0.364**	0.150	0.086**	0.035
Price concern	−0.847***	0.152	−0.214***	0.036	−0.854***	0.157	−0.202***	0.034
Cooperative	−0.520***	0.184	−0.132***	0.046	−0.539***	0.192	−0.127***	0.045
Sales contract	0.39	0.384	0.099	0.097	0.363	0.399	0.086	0.094
Pre-sales test	−0.475***	0.14	−0.12***	0.035	−0.522***	0.148	−0.124***	0.034
Safety control	−1.787***	0.189	−0.452***	0.036	−1.576***	0.193	−0.373***	0.038
Training programs	−0.012	0.141	−0.003	0.036	0.039	0.147	0.009	0.035
Subsidies	0.235	0.191	0.059	0.048	0.287	0.197	0.068	0.046
Gender					−0.742***	0.174	−0.175***	0.040
Age					0.025***	0.009	0.006***	0.002
Education					0.093	0.112	0.022	0.026
Experience					0.009	0.010	0.002	0.002
Land					−0.006	0.027	−0.001	0.006
Farm income					−0.070	0.062	−0.017	0.015
Cucumber					−0.068	0.181	−0.016	0.043
Tomato					−0.045	0.188	−0.011	0.045
Constant	1.890***	0.271	–	–	1.062*	0.618	–	–
Pseudo R^2	\multicolumn{4}{c}{0.296}	\multicolumn{4}{c}{0.342}				
Number of observations	\multicolumn{4}{c}{546}	\multicolumn{4}{c}{546}				

Table V.
Determinants of pesticide overuse

Notes: *,**,***Significant at 10, 5 and 1 percent levels, respectively

As for market organization, farmers' participation in cooperatives has significant impact on farmers' practices. Joining cooperatives can reduce the likelihood of incidence of pesticide overuse by 12.7 percentage points, indicating cooperatives have played an important role in promoting the safe use of pesticides. The coefficient of sales contracts with companies, however, has no statistical significance. The possible reason is that, presently many companies care more about the look of the vegetables to make them more marketable, and the safety of the vegetables as to the amount of pesticides used in production is not the greatest concern; therefore, sales contracts hardly focus on the regulation of pesticide use.

Regarding the impact of government regulation, both pre-sales test and safety control policies on agricultural products are statistically significant, and these two polices can reduce the likelihood of incidence of overusing pesticides by 12.4 percentage points and 37.3 percentage points, respectively, indicating the effectiveness of these two polices in regulating farmers' use of pesticides. The impact of training programs and subsidies for bio-pesticides are insignificant. Our survey has shown that, although 59.16 percent of the respondents have participated in the training programs, 65.94 percent of them complained about the infrequency of such training. In such cases, the current training programs have not been put into full play. And the survey also reveals that only 13.74 percent of the survey farmers have received subsidies for bio-pesticides, and more than half of the recipients reported the limited coverage, lack of supervision and incentive of the subsidy system, which clearly requires further implementation.

Moreover, of all the control variables, gender and age have a significant impact on farmers' use of pesticides. Male farmers are less likely to overuse pesticides, with the marginal effect of 17.5 percentage points. The possible explanation is, male farmers in China are usually better educated and better informed about pesticide-handling skills than their female counterparts, and would consciously avoid overusing pesticides (Wang *et al.*, 2017). Though elder farmers are more likely to overuse pesticides, the marginal effect is rather small (0.6 percentage points). The possible reason is that, elder farmers have the habit of applying pesticides in excessive amounts for years and might be harder to be corrected (Guan *et al.*, 2012).

Conclusions and policy implications

This paper investigates farmers' use of pesticides using original data of fruit vegetable growers from Shandong Province, China. First, we estimated the marginal pesticide productivity as a measurement of pesticide overuse with the two-stage semiparametric approach, and the negative marginal productivity indicated a serious overuse of pesticides among the sample farmers. Second, we studied the determinants of pesticide overuse from the perspective of market profit, market organization and government regulation using the Probit regression model. The results suggest that both market factors and governmental regulation have impacts on farmers' use of pesticides. Regarding the market factors, farmers count on overusing pesticides to secure their market profit; but if organic vegetables can sell better, farmers are willing to reduce the use of pesticides. Cooperatives can help regulate farmers' use of pesticides. As for government regulation, the pre-sales test of pesticide residue, as well as the safety control policies have significant impact on farmers' practice. Farmers' practice is also affected by their gender and age.

The results of this paper have the following policy implications.

First, the mechanism of an agricultural market needs further enhancement to provide market incentives for farmers to reduce pesticide use. The results of this study have shown that farmers who believe organic products have a better price are less likely to overuse pesticides. Nevertheless, the current agricultural market in China has not fully implemented "favorable price for good quality" as the mechanism, resulting in information asymmetry between the buyers and the sellers. Safer products are not endorsed or rewarded enough by

the market, leaving no incentives for farmers to cut the use of pesticides. And farmers, as rational-economic men, can only resort to using large amount of pesticides to secure the yield, and stabilize their profit through yield increase. In order to fundamentally regulate farmers' practices, a better market mechanism should be in place to distinguish the products by quality and pesticide use, and reveal the information through pricing as incentives for safe production.

Second, greater supports are needed to develop organizations such as cooperatives and to better organize agricultural production. Our study has revealed that farmers who have joined the cooperatives are less likely to overuse pesticides. But presently, farmers in China are still under-organized in terms of agricultural production. Therefore, governments should channel greater effort to support the development of cooperatives, promote integrated pest management (IPM), and strengthen the synergy between cooperatives and agro-technology extension systems to provide more information regarding the safe use of pesticides to farmers and regulate their practices.

Finally, stricter enforcement of government regulation is needed to improve safe practices in vegetable production. The findings of this study have suggested that the training programs and subsidies cannot effectively regulate farmers' use of pesticides due to inadequate enforcement. In light of this, improvements in training and communication programs, subsidy polices as well as the pre-sale testing, among other policies, are recommended. Moreover, agricultural insurance can also play a positive role in reducing farmers' reliance on overusing pesticides as a guarantee of steady income.

Given the data availability of the current survey, this study focuses our analysis on how cooperatives, sales contracts, governmental regulations and subsidies influence the pesticide overuse in vegetable production. However, there might be other potential interventions on farmers' behavior that may affect the usage of pesticides, including the training and monitoring of pesticide retailers. Therefore, to provide a more accurate measurement of the pest pressure, future work may want to add other potential impact factors in productivity assessment and behavioral analysis.

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Does network governance based on banks' e-commerce platform facilitate supply chain financing?

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Abstract

Purpose – The purpose of this paper is to provide a framework to illustrate how network governance based on banks' e-commerce platform reduces loan risks and mitigates credit rationing in supply chain financing (SCF).
Design/methodology/approach – The authors conceptualize network governance in terms of authority structure and interorganizational mechanism dimensions, and derive the model of its determinants through arguments drawn from the existing literature. Structural equation modeling is employed to test the theoretical model on data collected from a sample of 271 independent supply chain trading partners in rural China.
Findings – The findings indicate that network governance based on banks' e-commerce platform could integrate the operations and finances in supply chain management to solve the problems of information asymmetry, costly monitoring, insufficient qualified collaterals and mitigate farmers' credit rationing. The collaborative credit-granting mechanism and collaborative debt enforcement mechanism formed by the authority structure and interorganizational mechanisms are the key factors to realize the complete compatibility of incentives. The bank e-commerce platform can provide a foundation for the authority structure and interorganizational mechanisms to enhance the predictability of applicants' transaction and then safeguard the financial exchanges in supply chain.
Practical implications – The research results indicate that it is important to support farmers to establish long-term transaction relationships with leading enterprises through organizational innovation in the development of agricultural industrialization and build a visualization platform for SCF through technological innovation.
Originality/value – This paper contributes to the limited knowledge about network governance mechanisms in SCF by illustrating the model of network governance based on banks' e-commerce platform and its determinants.

Keywords E-commerce platform, Network governance, Credit rationing, Incentive compatibility, Supply chain financing

Paper type Research paper

1. Introduction

In recent years, accompanying the industrialization and specialization of agriculture, a large number of new farmer groups in China have been emerging in the agricultural supply chain. Distinct from the traditional farmers, the agricultural credit demands of these new farmers have changed. These are mainly reflected by: lowered demands on microcredit for agricultural materials such as seeds and fertilizer for traditional agricultural production, and increased demands on large loans for specialized breeding, plantation of typical cash crops, and production

of agricultural and sideline products. Therefore, traditional agricultural loans, mainly microcredit for farmers, cannot satisfy the industrialized development requirements of the agricultural industry. Nevertheless, due to high natural risks in agricultural production, insufficient qualified collaterals in rural areas and other reasons (Li *et al.*, 2013); large loans are seldom granted to these new farmer groups, so their development is faced with financial difficulties.

Meanwhile, the market competition trend gradually shifts from inter-firm competition to inter-supply chain competition, which causes increasingly strong interdependence of upstream and downstream trading partners. Any problem in one link definitely impacts the normal operation of the whole supply chain. Despite the fact that leading agricultural companies, with a high credit rating and strong industrial competitiveness, are normally granted a high credit line by financial institutions, the whole supply chain cannot work normally if upstream and downstream farmers and small- and medium-sized enterprises (SMEs) get few loans from banks. Therefore, the release of farmers' credit constraints in the supply chain through an innovative credit mode is important both for farmers' development and for the group competitiveness of the whole agricultural supply chain and the development of agricultural industrialization.

It is universally acknowledged that incentive compatibility is a necessary and sufficient condition for loan repayment. In traditional research, farmers have always been investigated individually, which presumes that farmers are individually separated and decentralized. Under this assumption, the complete compatibility of internal incentives cannot be fully satisfied, because it is hardly expected that farmers would realize self-constraint by adhering to moral norms. The development of the agricultural supply chain not only brings new challenges to farms' financing, but also creates new opportunities and conditions for solving this problem. This is because farmers' financial difficulties in the agricultural supply chain have become part of the financial issue of the whole supply chain. Solutions to farmers' financial difficulties in supply chain, together with a related approach and conditions, are to be included in and coordinated with the whole supply chain management (SCM) by integrating the operation and finances, involving not only farmers.

Furthermore, with the development of e-commerce, the traditional supply chain organizations are increasingly networked and information flow, capital flow, logistics are integrated in supply chain. It is possible to integrate the process operations and finances through the innovation of network governance and create conditions for solving farms' financial problems in the agricultural supply chain. However, the process operations and finances in supply chain have always been treated as separate problems (Guillen *et al.*, 2007), and there is a paucity of studies on how to satisfy the complete compatibility of internal incentives and solve farms' financial problems in the agricultural supply chain. Although the researchers of SCM are becoming more aware of the potential financial contributions of the network (Ramezani *et al.*, 2014), the existing literature most often focus on financial exchange dyads of lender and borrower rather than on the supply chain network's overall structure or architecture, and it remains unclear whether and how the network mitigates farms' financing difficulties in supply chain.

In this paper, we present a network governance model based on the bank e-commerce platform to illustrate the integration of operations and finances in SCM, and then use data from Chinese rural areas to prove that: in supply chain, the network governance based on the bank e-commerce platform could create a collaborative credit-granting mechanism and collaborative debt enforcement mechanism through organizational innovation to realize the complete compatibility of incentives, reduce agricultural loan risks and then mitigate farmers' credit rationing.

2. Literature review and hypotheses
Along with the growth of global outsourcing business that multinationals seek to minimize costs, the concept of SCM appeared in the early 1990s. Since then, academic research on

SCM has always focused on the flow of goods and information. However, as an integral part of SCM, financial flow management did not get the attention it deserves in the long term. Until the twentieth century, entrepreneurs and scholars have found that the overall cost of financing caused by global outsourcing activities, as well as the effect of the "short side of the barrel" given by financing difficulties of SMEs in supply chain, in fact, partially offset the efficiency advantages of division and cost savings brought by outsourcing. Thus, ways of optimizing the flow of financial resources through efficient financing activities across supply chains have been paid increasing attention (Pfohl and Gomm, 2009). Filling this gap, the concept of supply chain financing (SCF) has begun to evolve. It combines the services and technology solutions that link buyers, suppliers and finance providers to improve the financing cost and availability (Atkinson, 2008). It has received significant scholarly attention and formed a number of research findings from the "finance oriented" perspective and the "supply chain oriented" perspective. However, there are few research findings from the "network governance" perspective and the need for the development of a "general theory of SCF" has not yet been met in the extant literature (Gelsomino *et al.*, 2016).

A network is a set of two or more connected business relationships, in which each exchange relation is between business firms that are conceptualized as collective actors (Anderson *et al.*, 1994), and network governance is a combination of authority structure and interorganizational mechanisms which enable the assurance that the individual behavior of partners follows the rules for collective action (Sauvée, 2002). In supply chain network, due to increased investments between the upstream and the downstream, improved capital specificity, deepened and expanded cooperation, higher interdependence and more stable business relationships, members in supply chain gradually establish semi-tight and even tight cooperative relationships. Furthermore, with the development of e-commerce, all members involved work together. They achieve a high level of cooperation and create a partnership marked by mutual trust and the intensive exchange of information (Jones *et al.*, 1997), which enables banks to use networks governance for coordinating and safeguarding financial exchanges between the supply chain partners. In this paper, we define network governance based on the bank e-commerce platform as a combination of authority structure and interorganizational mechanisms based on electronic technology which may realize the publicity and verification of such data information flow as orders and invoices. This enables the formation of a collaborative credit-granting and collaborative debt enforcement mechanism that aims to mitigate all forms of credit contractual hazards in SCF, and increase credit access for supply chain members.

2.1 Network governance and the collaborative credit-granting mechanism

Due to the pressure of cutting prices and extending the payment period from large companies, SMEs and farmers in the supply chain are often faced with serious financing difficulties. Furthermore, because of information asymmetry, costly monitoring, implementation and the legal system of loan contracts, collaterals and for other reasons, it is difficult for them to obtain affordable financing from traditional channels (Foltz, 2004).

In traditional financing channels, credit-granting is based on a "judgmental" concept using past experiences of the credit officers, which always suffers from frequent incorrect decisions (Witkowska *et al.*, 2001) and can hardly mitigate the credit rationing of SMEs and farmers. In supply chain, through collaboration between enterprises in supply chain, sharing standardized information and setting up objective plans (Shu *et al.*, 2010), the core enterprise has a pivotal role in structuring the network, which facilitates to form an authority structure and interorganizational mechanisms (Sauvée, 2002) between the core enterprise and its partners. Furthermore, when the authority structure and interorganizational mechanisms are applied to SCF, they can provide a collaborative credit-granting mechanism, including structured credit-granting, credit-granting threshold,

tied credit-granting and group credit-granting, to eliminate information asymmetry and then mitigate credit rationing.

First, there is structured credit-granting. SCF is a "1+N" mode providing financing for supply chain members, aiming to get rid of the group financing difficulties of the upstream and downstream supporting enterprises of the core enterprises in supply chain (He and Tang, 2012). In SCF, the credit-granting and financial exchanges are embedded into the "1+N" authority structure between the core enterprise and its supply chain partners and then the structured credit-granting mechanism is formed. This enables the bank to get more efficient information about borrowers from business partners and then alleviate the credit risk.

Second, there is the credit-granting threshold. In supply chain, the authority structure facilitates the formation of restricting access mechanisms, which safeguard exchanges through status maximization and relational contracting. The status maximization strategy could avoid parties of significantly lower status, and the relational contracting strategy more often leads to work with fewer partners (Jones *et al.*, 1997). So, banks could use restricted access of supply chain to form credit-granting threshold mechanisms, which can reduce the opportunistic behavior and safeguard financial exchanges.

Third, there is group credit-granting. In supply chain, the authority structure can form a joint liabilities mechanism. To ensure the safety of the principle, banks group these borrowers and make them undertake joint liabilities to solve the problem of mortgage and guarantee constraints for the poor and small entrepreneurs, which facilitates the formation of group credit mechanisms in SCF. In the SCF, the group credit mechanisms can provide credit to supply chain members collectively and increase access for small borrowers in supply chain.

Fourth, there is tied credit-granting. One important feature of SCF is the new "credit bound" technology connecting the core enterprise, which introduces core enterprise as risk bearers (Zhong and Zhao, 2015) through the joint liabilities mechanisms between the core enterprise and its supply chain partners. In the SCF, the new "credit bound" technology bundles the risk of a credit applicant with the supply chain partners and forms the tied credit-granting mechanism, which facilitates the alleviation of credit risk and increases access for supply chain members.

According to above analysis, the following hypotheses could be concluded:

H1a. Network governance would be positively correlated with the collaborative credit-granting mechanism.

H1b. The collaborative credit-granting mechanism would be positively correlated with the credit level of borrowers.

H1c. The collaborative credit-granting mechanism would be positively correlated with the credit line of borrowers.

2.2 Network governance and the collaborative debt enforcement mechanism
The general view among economists is that weaker legal enforcement of lender rights increases lending risk. However, stronger enforcement generates general equilibrium effects that may reduce credit access for small borrowers and expand it for wealthy borrowers (Lilienfeld-Toal *et al.*, 2012). In supply chain, network governance can form an authority structure and interorganizational mechanisms to integrate small borrowers and wealthy borrowers in bounded clusters of organizations, which can increase credit access for supply chain members collectively. Furthermore, through collaboration between supply chain partners, the authority structure and interorganizational mechanisms can be used to provide a collaborative debt enforcement mechanism to govern specific contractual

relationships in SCF, including pre-loan screening, peer guarantee, cash flow control and loan re-liquidation. This can fill the gap of contract incompleteness, enforce the contractual promises and then create greater ability to shape the behavior of borrowers (Carpenter and Williams, 2014). So, in SCF, the financial transactions could be affected by the structure of the overall network of relations and could increase access for small borrowers in supply chain.

First, there is pre-loan screening. In SCF, banks could use the peer monitoring mechanisms between the core enterprise and its partners to share standardized information in supply chain. Because of the pivotal role in structuring the network, the core companies or other members in supply may know more about one another than an outside institution such as a bank (Shu *et al.*, 2010). Furthermore, to minimize the joint liabilities they have to take, the core companies or other members may use their good position to monitor the borrower, and reduce opportunistic behaviors and credit risks. So, banks could use the peer monitoring mechanisms to form pre-loan screening, which facilitates the bank to separate the "good borrowers" from the "bad borrowers" and safeguard financial exchanges.

Second, there is peer guarantee. In SCF, guarantees of supply chain partners substitute guarantees of professional institutions. Due to common interest and long-term business relationships, supply chain partners are advantageous concerning information acquisition from farmers or SMEs as their business partners, and willing to provide guarantees for them (Chen, Fu and Zhang, 2016).

Third, there is cash flow control. In order to enhance the likelihood of repayment, it is important to ensure that borrowers exercise prudence in the use of the funds. Peer monitoring is one partial solution (Stiglitz, 1990), because there is a very strong causal relationship between the average monitoring propensity of one's loan group and repayment (Carpenter and Williams, 2014). In SCF, banks can use the peer monitoring mechanisms in supply chain to realize the control of cash flow. For example, farmers' receivables formed by selling agricultural products to leading enterprises are to be first used to repay the loan, and then the remaining part will be transferred to farmers' personal accounts (Chen, Zhu, Zhang and Song, 2016).

Fourth, there is loan re-liquidation. In SCF, core companies or partners have to undertake some joint liabilities for credit risks to form loan re-liquidation mechanisms, which facilitate lending to the low credit (Ghatak and Guinnane, 1999). If a credit applicant has a low credit rating, loan re-liquidation mechanisms could raise the credit rating by introducing his business partner to shoulder joint liabilities (Ghatak and Guinnane, 1999), and the business partner will assist the bank to enhance the likelihood of repayment. Furthermore, if the borrower goes bankrupt, they are required to pay joint liability for the partner.

According to above analysis, we may conclude following hypotheses:

H2a. Network governance would be positively correlated with the collaborative debt enforcement mechanism.

H2b. The collaborative debt enforcement mechanism would be positively correlated with the credit level of borrowers.

H2c. The collaborative debt enforcement mechanism would be negatively correlated with the credit line of borrowers.

2.3 Bank e-commerce platform and predictability of the applicant's transaction

The main reason for credit rationing is information asymmetry, which may cause the lender to be unable or find it too costly to identify bad and good borrowers (Bedane, 2016). Under these uncertainty circumstances, a rise in interest rates may have a negative impact on the demand quality and behavior, which can reduce the banks expected profits and therefore

induce banks to ration credit (Kirschenmann, 2016). In traditional credit modes, due to low transparency and the visibility of transaction information, the credit management and the debt performance mechanism of banks are extremely limited and cannot effectively solve financial exchange problems caused by information asymmetry, costly monitoring, implementation of loan contracts, etc.

As a financing solution based on technology, SCF may realize the publicity and verification of such data information flow as orders and invoices to provide financing for supply chain members (He and Tang, 2012). With the application of the bank e-commerce platform and the technology advances in SCF, transparency and visibility of transaction information can be enhanced. This provides a technological foundation for the interorganizational mechanisms to safeguard the financial exchanges, such as reciprocal investments, joint liabilities (Ghatak and Guinnane, 1999), peer monitoring (Carpenter and Williams, 2014; Stiglitz, 1990), restricted access and collective sanctions (Jones *et al.*, 1997), which could be used to set up the collaborative credit-granting management and collaborative debt performance mechanism by integrating the operations and finances in SCM.

First, as the integrated longitudinal governance structure centering on the authority of core companies is formed, individual behaviors of members in the supply chain are further constrained and governed. Therefore, the exchanges between members are embedded into the network structure, which provides more efficient information about what partners are doing (Uzzi and Gillespie, 2002), and thus has better ability to shape that behavior (Carpenter and Williams, 2014; Granovetter, 1992). That is, the structural embeddedness in supply chain helps to improve the predictability of individual behaviors.

Second, due to opportunistic behaviors and supply chain disruption, the financial institutions are vulnerable to significant risks. However, in the bank e-commerce platform, the external big data set helps to improve the predictability of the business failure of supply chain finance clients, then reduces the risks in SCF (Zhao *et al.*, 2015).

In summary, with the improvement in predictability of the applicant's transactions, it is possible for the lender to identify bad and good borrowers, which is conducive to set up collaborative credit-granting and collaborative debt enforcement mechanism. In this way, the credit risk of bad borrowers can be avoided and the credit line of good borrowers can be raised.

According to above analysis, we may conclude following hypotheses:

H3a. Network governance would be positively correlated with the predictability of the applicant's transaction.

H3d. The predictability of the applicant's transaction would be positively correlated with the collaborative credit-granting mechanism.

H3e. The predictability of the applicant's transaction would be positively correlated with the collaborative debt enforcement mechanism.

H3b. The predictability of the applicant's transaction would be negatively correlated with the credit level of borrowers.

H3c. The predictability of the applicant's transaction would be positively correlated with the credit line of borrowers.

From the above, we can get a theoretical model of farmers' SCF.

As shown in Figure 1, the model includes three parts.

The first part is the network governance mechanism, including reciprocal investments, joint liabilities, restricted access, peer monitoring and collective sanctions.

The second part is the predictability of the applicant's transaction and the credit trading governance mechanism; the credit trading governance mechanism consists of the collaborative

credit-granting mechanism covering the credit-granting threshold, structured credit-granting, tied credit-granting and group credit-granting as well as the collaborative debt enforcement mechanism covering pre-loan screening, peer guarantee, cash flow control and loan re-liquidation.

The third part is the applicant's credit level, including credit rating and credit line; the credit rating covers credit capabilities and credit risks.

3. Methodology

3.1 Sample

From different perspectives, the business patterns of SCF can be divided into different types. In order to ensure the representativeness of the sample, we classify and select the financing mode of supply chain. There are three main types (He and Tang, 2012).

From the perspective of customer, all members in agricultural supply chain have financing demands and can be the banks' customers. In this paper, we are committed to studying the financing difficulties of farmers in supply chain, and all the samples are aimed at SCF for farmers.

From the perspective of risk-borne subject, the business patterns of supply chain finance may be divided into the risk borne by the core enterprises and by the supporting members. In practice, in order to prevent credit risk for providing farmers with financing, banks generally require the core enterprises to provide guarantee for farmers. So, we chose the core enterprise guarantee financing mode in Lanxi County to investigate, accounting for 38 percent of the sample.

From the perspective of the cash flow gap, the cash flow gap of farms in agricultural supply chain often occurs during the period of order and inventory. So, we chose grain order financing mode in Changshan County to investigate, accounting for 30.27 percent of the sample. We chose warehouse receipts financing mode in Shaoxing County to investigate, accounting for 31.73 percent of the sample.

Based on questionnaire interviews with the bureau of grain, the bureau of agriculture and some large grain farmers as well as small-scale sample measurement, the investigation team started the large-scale sample measurement involving large grain farmers in Changshan County, related government workers and loan officers of Changshan Rural Cooperative Bank. During the whole sample measurement procedure, the investigation team finished work related to large grain farmers and government workers in person, and finished some samples of loan officers. The office of Changshan Rural Cooperative Bank assisted by finishing the remaining samples of loan officers. Sample measurement in
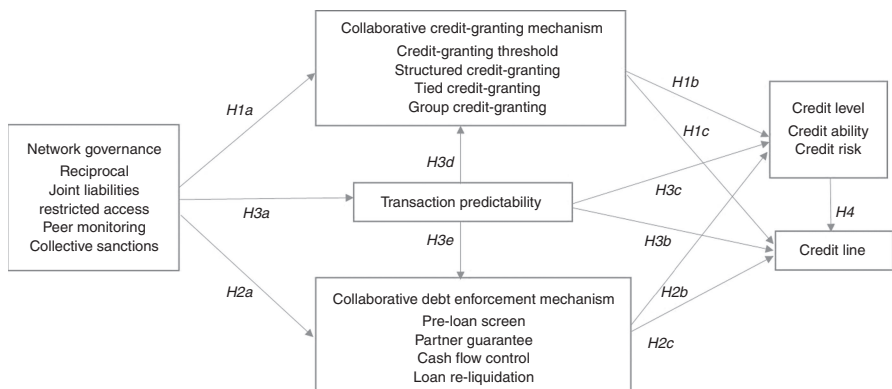

Figure 1.
SCF theoretical model

Changshan County was completed in the first 10-day period of August. In total, 90 questionnaires were distributed and 82 collected questionnaires were valid. The sample of this survey is all about order financing in supply chain.

The investigation team contacted the Rural Credit Guarantee Company under Lanxi Supply and Marketing Cooperatives, leading provincial and municipal companies including Zhejiang Dali Food Co., Ltd, Lanxi Tongying Co., Ltd, Lanxi Huikang Medical Materials Co., Ltd and Lanxi Meijiang White Spirit Co., Ltd. In addition, they got in touch with provincial and municipal demonstrative specialized cooperatives including Lanxi Guankang Fruit & Vegetable Specialized Cooperatives, Changfu Specialized Cooperatives, Mengtang Fruit & Vegetable Cooperatives and Xinghe Pigs Specialized Cooperatives through Lanxi Bureau of Agriculture. The team also contacted Lanxi Rural Cooperative Bank through the Central Sub-branch of Jinhua of PBC. They carried out sample measurement concerning the guarantee-credit-based farmer SCF mode for related government workers, financial/technological service/purchasing and marketing/ management employees from companies, presidents/employees/farmers/growers from specialized cooperatives, as well as credit officers, credit management officers and risk control officers from banks. In respect of all sample measurement in Lanxi, the investigation team finished sample measurement involving Lanxi Bureau of Agriculture, leading companies, specialized cooperatives and large farmers and growers in person, while workers from the department of credit business of Lanxi Sub-branch of PBC and Lanxi Rural Cooperative Bank assisted me in finishing samples involving Lanxi Rural Cooperative Bank. In total, 108 questionnaires were distributed and 103 collected questionnaires were valid in Lanxi. The sample of this survey is all about warehouse receipts financing in supply chain.

The investigation team contacted Evergrowing Bank in Shaoxing, China Citic Bank in Shaoxing, Evergrowing Bank, Industrial Bank, Yuezhou Headquarters of Shaoxing County Rural Cooperative Bank and Lizhu Sub-branch of Shaoxing Rural Cooperative Bank. They conducted field experiments on credit officers, credit management/risk control officers and some middle/senior managers. Evergrowing Bank Shaoxing Sub-branch was newly established and its employees mostly came from other banks in Shaoxing. During the field experiments, the investigation team finished some sample measurement in Evergrowing Bank and Lizhu Sub-branch of Shaoxing Rural Cooperative Bank in person, while other banks finished each sample measurement with the assistance of credit officers from Evergrowing bank. This questionnaire investigation was completed in mid-July. In total, 90 pre-test questionnaires and 90 after-test questionnaires were distributed in Shaoxing, and 86 collected questionnaires were valid. The sample of this survey is all about guarantee financing in supply chain.

Table I shows the sample characteristics. The focus in the sample survey is the credit officer and the farmer, which accounted for 54.6 and 14 percent, respectively. In addition, to get a more comprehensive picture of the network governance and SCF, the sample also involved in a number of other respondents: enterprise and bank administrator accounted for 18 percent, enterprise purchasing, technical and financial staff accounted for 3.4 percent, government official accounted for 3.7 percent, village cadres and other staff accounted for 5.6 percent.

3.2 Measurements
Consistent with Tang (2014), we use 15 items to examine network governance capturing both quasi-integration as a structural dimension and joint action as a process dimension. The former was conceptualized as reciprocal investments and joint liabilities. Joint action was conceptualized as restricted access, peer monitoring and collective sanctions. The Cronbach's α for this construct is 0.8.

Characteristic	%
Region/Type	
Lanxi/Guarantee financing	38.00
Shaoxing/Warehouse receipts financing	31.73
Changshan/Order financing	30.27
Occupation	
Loan officer	54.8
Framer	14
Buyer	0.4
Administrator	18.8
Technician	2.6
Financial staff	0.4
Village cadre	1.5
Government official	3.7
Other	4.1

Table I.
Sample characteristics

Consistent with Chen (2016), we use 18 items to examine collaborative credit-granting and collaborative debt enforcement. The former was conceptualized as credit-granting threshold, structured credit-granting, tied credit-granting and group credit-granting. The Cronbach's α for this construct is 0.73. Collaborative debt enforcement was conceptualized as pre-loan screening, peer guarantee, cash flow control and loan re-liquidation. The Cronbach's α for this construct is 0.74.

Consistent with Zaheer and Venkatraman (1995), we use two items to examine the predictability of the applicant's transaction which was operationalized with two indicators regarding the extent to which the respondent could use the technical platform in supply chain to predict changes in the following factors in relation to supply chain members for the next year.

Consistent with Tang (2014), we use two items to examine the applicant's credit level which was conceptualized with two indicators. The Cronbach's α for this construct is 0.73.

Cronbach's α for all items of SCF was 0.86, suggesting good internal consistency for each factor (Table II).

3.3 Data analysis and discussion
This study conducted data analysis and hypothesis testing using several statistical tools and methods: SPSS v.20. AMOS v.21 was used to test the hypothesis of structural equation modeling (SEM) and confirmatory factor analysis (CFA) was employed to test the goodness of fit test and conduct path analysis.

4. Result analysis
4.1 Descriptive statistics of the variables of interest
Table III summarizes the means and standard deviations, and the correlations between network governance, collaborative credit-granting, collaborative debt enforcement, predictability of the applicant's transaction and credit level.

4.2 Measurement model
CFA was used to test the measurement model's data fit. The measurement model included four latent variables (network governance, collaborative credit-granting, collaborative debt enforcement and credit rating) and 15 observed variables. The measurement model showed good data fit: $\chi^2 = 181.26 (p < 0.001)$, $\chi^2/df = 2.35$; CFI $= 0.910$, IFI $= 0.912$; RMSEA $= 0.071$ (90% CI $= 0.058$–0.084); SRMR $= 0.0583$. All factor loadings for indicators of latent

Factors	Items	Mean	SD	Cronbach's α based on standardized items
Network governance				
Reciprocal	V1–V7	26.9446	5.00525	0.84
Joint liability	V8–V9	8.7306	2.78975	
Restricted access	V10–V11	8.6310	1.54332	
Peer monitoring	V12–V13	8.7269	1.35236	
Collective sanctions	V14–V15	8.5055	1.36862	
Collaborative credit-granting				
Credit threshold	V16–V19	17.0554	2.54745	0.73
Structured credit	V20–V21	8.5646	1.32863	
Tied credit	V22–V23	8.9041	1.34372	
Group credit	V24–V25	8.0332	1.72852	
Collaborative debt enforcement				
Pre-loan screen	V26–V27	8.5203	1.34114	0.74
Cash flow control	V28–V29	8.5793	1.33339	
Peer guarantee	V30–V31	8.3063	1.56771	
Loan re-liquidation	V32–V33	8.0480	1.54005	
Credit level				
Creditability	V34	4.182	0.74387	0.73
Credit risk	V35	2.103	1.04546	
All items	V1–V35	4.132	1.037	0.89

Note: $n = 271$

Table II.
Internal consistency
between the factors
of supply
chain financing

Variables	M	SD	1	2	3	4	5
1. Network governance	4.229	0.0331	–				
2. Collaborative credit-granting	4.254	0.0310	0.358**	–			
3. Collaborative debt enforcement	4.182	0.0323	0.442**	0.548**	–		
4. Predictability	6.386	0.0574	0.317**	0.430**	0.509**	–	
5. Credit level	6.292	0.0531	−0.024	0.092	−0.012	−0.015	–
6. Credit line	7.971	0.3575	−0.011	0.057	0.079	0.122*	0.034

Notes: $n = 271$. *$p < 0.05$; **$p < 0.01$

Table III.
Means, standard
deviations and
correlations between
the variables
of interest

variables were significant ($p < 0.01$), indicating that all latent factors were well represented by their respective indicators.

4.3 Structural equation modeling

The model examined the associations between network governance, collaborative credit-granting, collaborative debt enforcement, predictability of applicant's transaction, credit rating and credit line (see Figure 2). Results showed acceptable data fit, $\chi^2 = 219.58(p < 0.001)$, $\chi^2/df = 2.174$; CFI $= 0.908$, IFI $= 0.911$; RMSEA $= 0.066$ (90% CI $= 0.054$–0.078); SRMR $= 0.062$.

Table IV is a summary of hypothesis testing. Based on Table III and the calculation results, discussions and research works on the verification of the hypothesis are possible.

4.3.1 The collaborative credit-granting mechanism. The research hypothesis argues that the network governance mechanism is an important variable affecting credit trading governance. If network governance is improved, it is favorable to set up collaborative credit-granting mechanism, covering the credit-granting threshold, structured credit-granting, tied credit-granting and group credit-granting. As hypothesized, analysis results show that network governance was significantly positively correlated with collaborative
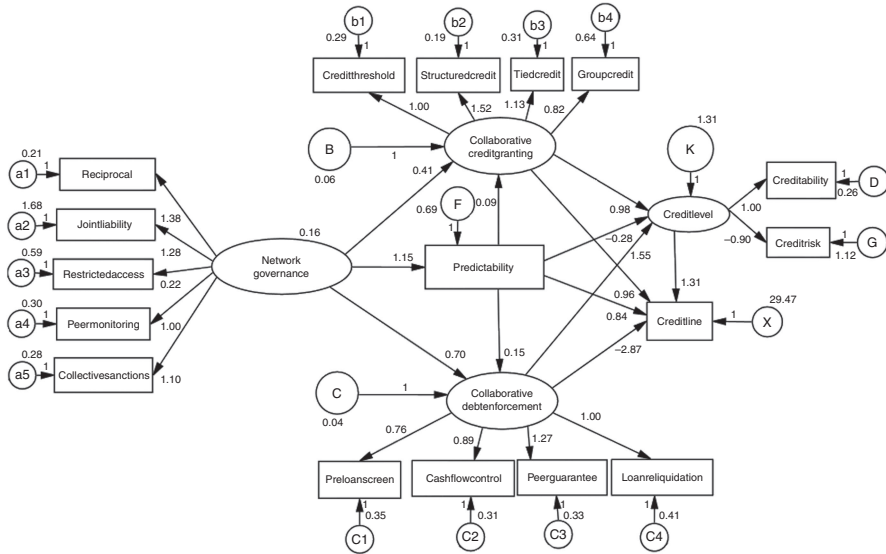
Figure 2.
SCF empirical model

Research hypotheses	Estimate	SE	CR	p	Results
H1					
H1a: collaborative credit-granting ← network governance	0.406	0.095	4.265	***	Accept
H1b: credit level ← collaborative credit-granting	0.982	0.408	2.406	0.016	Accept
H1c: credit line ← collaborative credit-granting	0.957	1.677	0.571	0.568	
H2					
H2a: collaborative debt enforcement ← network governance	0.701	0.128	5.468	***	Accept
H2b: credit level ← collaborative debt enforcement	1.545	0.417	3.706	***	Accept
H2c: credit line ← collaborative debt enforcement	−2.875	1.751	−1.641	0.101	
H3					
H3a: Predictability ← Network governance	1.150	0.192	5.990	***	Accept
H3d: collaborative credit-granting ← predictability	0.087	0.029	3.052	0.002	Accept
H3e: collaborative debt enforcement ← predictability	0.151	0.036	4.242	***	Accept
H3c: credit level ← predictability	−0.277	0.134	−2.064	0.039	Accept
H3b: credit line ← predictability	0.836	0.560	1.494	0.135	
H4: credit risk ← credit level	1.314	0.366	3.588	***	Accept
Note: ***$p < 0.001$					

Table IV.
Summary of
hypothesis
testing (SEM)

credit-granting, which, in turn, was significantly positively correlated with credit level. Therefore, the analysis results directly support *H1a–H1c*. Importantly, analysis results show that credit level fully mediated the collaborative credit-granting effect on credit line. Therefore, the analysis results indirectly support *H1c*.

The existing literature concludes that traditionally credit-granting always suffers from frequent incorrect decisions (Witkowska *et al.*, 2001), and it is difficult for SMEs and farmers to obtain affordable financing from traditional channels (Foltz, 2004). In this research, we found that the authority structure and interorganizational mechanisms in supply chain network are favorable for establishing the collaborative credit-granting mechanism, and therefore raising the credit level and credit line of borrowers.

Additionally, analysis results show that network governance was positively correlated with the credit-granting threshold, structured credit-granting, tied credit-granting and group credit-granting.

The existing literature concludes that the status maximization strategy more often leads to work with fewer partners, and then help to safeguards exchanges (Jones *et al.*, 1997). In this research, we found that the authority structure and interorganizational mechanisms in supply chain network are favorable for establishing a credit-granting threshold mechanism, which can avoid parties of significantly lower credit status and reduce opportunistic behavior in financial exchanges.

The existing literature concludes that firms gain better access to credit when their transactions are embedded in supply chain networks (Ramezani *et al.*, 2014). In this research, we found that the authority structure and interorganizational mechanisms in supply chain network are favorable for establishing a structured credit-granting mechanism, which facilitates banks to get more efficient information about borrowers, shape borrowers' behavior and then increase access for small borrowers.

The existing literature concludes that the new "credit bound" technology connects the core enterprise, and help to control credit risks (Zhong and Zhao, 2015). In this research, we found that the authority structure and interorganizational mechanisms in supply chain network are favorable for establishing tied credit-granting mechanism. Through the tied credit-granting mechanism, bank can introduce business partners as risk bearers to undertake joint responsibilities for repayment and then control credit risks.

The existing literature concludes that SCF is a "1+N" mode aiming to get rid of the financing difficulties for supply chain members (He and Tang, 2012). In this research, we found that the authority structure and interorganizational mechanisms in supply chain network are favorable for establishing a group credit-granting mechanism. Through the group credit-granting mechanism, banks can group the borrowers and make them undertake joint liabilities to solve the problem of mortgage and guarantee constraints for the poor and small entrepreneurs.

Generally speaking, in traditional research, farmers have always been investigated individually, and the complete compatibility of internal incentives cannot be fully satisfied. In this research, we found that through organizational innovation, network governance can integrate the process operations, finances and farmers in SCM and provide a collaborative credit-granting mechanism. This could include a credit-granting threshold, structured credit-granting, tied credit-granting, credit-granting and group credit-granting, in order to realize the complete compatibility of incentives, and then mitigate the farmers' credit rationing.

4.3.2 The collaborative debt enforcement mechanism. This research hypothesis argues that if network governance is improved, it is favorable to enhance the debt performance mechanism, covering pre-loan screening, peer guarantee, cash flow control and loan re-liquidation. As hypothesized, analysis results show that network governance was significantly positively correlated with collaborative debt enforcement, which, in turn, were positively correlated with credit level. Therefore, the analysis results directly support *H2a–H2c*. Importantly, analysis results show that credit level fully mediated the collaborative credit-granting effect on credit line. Therefore, the analysis results indirectly support *H2c*.

There is a paradox in the existing literature that weaker legal enforcement increases lending risk and stronger enforcement may reduce credit access for small borrowers (Lilienfeld-Toal *et al.*, 2012). In this research, we found that the authority structure and interorganizational mechanisms in supply chain network are favorable for establishing the collaborative debt enforcement mechanism, which can control credit risks, improve credit level and then raise the credit line of borrowers.

Additionally, we found that network governance was positively correlated with pre-loan screening, peer guarantee, cash flow control and loan re-liquidation.

The existing literature concludes that joint liabilities promote enforcement of repayment and facilitate lending to the low credit (Ghatak and Guinnane, 1999). We also found that the authority structure and interorganizational mechanisms in supply chain network are favorable for establishing pre-loan screening mechanism by introducing joint liabilities of business partners to undertake the credit risks.

The existing literature concludes that due to common interest and long-term business, supply chain members are willing to provide guarantees for their business partners (Chen *et al.*, 2016). We also found that the authority structure and interorganizational mechanisms in supply chain network are favorable for establishing a peer guarantee mechanism. That is, guarantees by supply chain partners in SCF will substitute guarantees by professional guarantee institutions.

The existing literature concludes that there is a very strong causal relationship between the monitoring propensity and repayment (Carpenter and Williams, 2014). We also found that the authority structure and interorganizational mechanisms in supply chain network are favorable for establishing cash flow control and loan re-liquidation mechanism. That is, banks always use peer monitoring to realize the control of the cash flow and loan re-liquidation in SCF.

Generally speaking, the farmers, process operations and finances in supply chain have always been investigated individually in traditional research, so the complete compatibility of internal incentives cannot be fully satisfied. In this research, we found that through organizational innovation, the network governance can integrate the process operations, finances and farmers in SCM and provide a collaborative credit-granting mechanism, such as pre-loan screening, peer guarantee, cash flow control and loan re-liquidation, to promote enforcement of repayment, and then mitigate the farmers' credit rationing.

4.3.3 The predictability of applicant's transaction. The research hypothesis argues that the network governance mechanism is an important variable affecting the predictability of the applicant's transaction. If the network governance is improved, it is favorable to improve the predictability of the applicant's transaction. As hypothesized, analysis results show that network governance was significantly positively correlated with the predictability of the applicant's transaction, which, in turn, were positively correlated with collaborative credit-granting, collaborative debt performance and credit line. Importantly, analysis results show that the predictability of the applicant's transaction fully mediated the network governance effect on collaborative credit-granting, collaborative debt performance and credit level. Therefore, the analysis results support *H3a–H3c*. Additionally, credit level fully mediated the predictability of the applicant's transaction on credit line. Therefore, the analysis results indirectly support *H3c*.

In the traditional credit mode, the low transparency and visibility of transaction information can reduce the banks expected profits and then induce the rationing of credit (Kirschenmann, 2016). In this research, we found that the authority structure and interorganizational mechanisms based on the technology platform and external big data set are favorable for the establishing collaborative credit-granting mechanism and the collaborative debt enforcement mechanism, therefore helping to raise the credit line and avoid the credit risk of bad borrowers.

5. Conclusions

To illustrate mechanisms of incentive compatibility in SCF, the paper conceptualizes network governance as a specific form of organizational innovation in terms of authority structure and interorganizational mechanisms dimensions based on the bank e-commerce platform. Then a network governance model is developed to illustrate the integration of farms, operations and finances in SCM. SEM is employed to test the model on data collected

from a sample of 271 independent supply chain trading partners in rural China. The conclusions were obtained as follows:

(1) Network governance can mitigate farmers' financing difficulties in agricultural supply chain through organizational innovation in SCF. It means that when farmers are faced with financial difficulties in the development of agricultural supply chain, network governance can solve the problems of information asymmetry, costly monitoring, insufficient qualified collaterals and mitigate farmers' credit rationing through the integration of operations and finances in SCM.

(2) The collaborative credit-granting mechanism and collaborative debt enforcement mechanism formed by the authority structure and interorganizational mechanisms in SCF are the key factors to realize the complete compatibility of incentives and mitigate farmers' credit rationing in supply chain. Compared to using credit officers past experience in traditional credit-granting, the collaborative credit-granting mechanism in SCF can use structured credit-granting, credit-granting threshold, tied credit-granting and group credit-granting to solve the problems of asymmetric information, lower credit status, mortgage and guarantee constraints effectively. Furthermore, the collaborative debt enforcement mechanism can use pre-loan screening, peer guarantee, cash flow control and loan re-liquidation to manage the paradoxe of credit access and credit risk, and then mitigate farmers' credit rationing.

(3) The predictability of applicants' transaction is an important factor to realize the complete compatibility of incentives and mitigate farmers' credit rationing in supply chain. SCF is a financing solution based on technology, the technology advances in SCF can enhance the transparency and visibility of transaction information. This can provide a technological foundation for the interorganizational mechanisms to safeguard financial exchanges.

The limitation of this study is that it used a cross-sectional design; therefore, it was not able to test possible causal relationships between the examined variables. Future research should therefore use a longitudinal design to test such possible relationships.

The findings have the following theoretical and practical implications. First, the mechanisms for SCF to realize the complete compatibility of incentives are based on the supply chain network governance. So, it is important to improve network governance by promoting agricultural industrialization, supporting households to attend the agricultural industry organizations and establish long-term transaction relationships with leading enterprises through organizational innovation. Second, the predictability of the applicant's transaction plays an important role for SCF to realize the complete compatibility of incentives. So, it is important to build a visualization platform for SCF through the operation pattern and technological innovation.

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The impact paths of social capital and the effects of microfinance
Evidence from rural households in China?

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Abstract

Purpose – The purpose of this paper is to investigate the impact paths of the social capital and the effects of microfinance in rural China, and address effective methods to enhance the effects of microfinance for rural China.

Design/methodology/approach – Using a structural equation model with survey data from 350 rural households in China, this paper analyzes empirically whether greater level of social sanctions and social relations caused more tangible effects of microfinance, and whether tangible effects of microfinance are associated with social capital formation of households.

Findings – The results indicate that social capital promotes the effects of microfinance and the process of providing microfinance service is also the process of building social capital. Moreover, social sanctions diminish the effects of microfinance while social relations boost them and enhance the effects of microfinance that can encourage social capital formation. Results also show that a reverse causal relationship exists between social sanctions and social relations.

Research limitations/implications – The empirical results imply that actively utilizing and creating social capital is vital to improve the effects of microfinance, and microfinance institutions (MFIs) should concentrate more on harmonious social relations and deliberately build social capital.

Practical implications – These findings imply that actively utilizing and creating social capital is vital to improve the effects of microfinance, and the MFIs should concentrate more on harmonious social relations and deliberately build social capital to enhance the effects of microfinance while prudently use social sanctions.

Social implications – Enhancing the effects of microfinance, while prudently using social sanctions, increases households income.

Originality/value – This paper originates to investigate the links between the social capital and the effects of microfinance in a mutual way, and the results urge more attentions on the harmonious social relations which have been ignored to enhance the effects of microfinance.

Keywords Microfinance, Social capital, Chinese rural area, Social relation

Paper type Research paper

1. Introduction

Social capital is defined as features of social organization, such as trusts, norms and networks that can improve behavioral and social efficiency by facilitating coordinated actions (Putnam, 1993). The concept of social capital has gained popularity within the field of microfinance since Montgomery (1991) first used it in his study. Many of the successful microfinance programs seem to rely upon social capital (Goodman, 2017; Hadi and Kamal, 2015; Sohail and Jayant, 2013; Ito, 2003; Bastelaer, 1999; Besley and Coate, 1997). Mahjabeen (2008) even notes that only when social capital acts as collateral can microfinance reach the poor. Some studies also argue that social capital can be built through microfinance (Singh, 2003). Dowla (2006) examines the Grameen Bank in Bangladesh and suggests that

creating and culturing social capital has been conducive to the explosive growth of microfinance in Bangladesh and elsewhere.

Prior literature building on agency theory suggests that social sanctions improve the effects of microfinance (Dufhuesa, 2013; Hermes and Lensink, 2007). However, according to stewardship theory, the assumption of self-interest and opportunism in agency theory is improper, and stewards would be more readily engaged in cooperative, altruistic and spontaneous unrewarded citizenship behaviors when they identify with their organizations. Microfinance clients also engage in cooperative behavior when they identify with their groups; therefore, harmonious social relations satisfying the incentive compatibility constraint will produce better outcomes for microfinance programs (Griffin and Husted, 2015; Sohail and Jayant, 2013; Bastelaer, 1999). Building on stewardship theory, we argue that social sanctions diminish the effects of microfinance, whereas social relations boost these effects.

Moreover, although the early literature has generally ignored the social capital-building aspects of microfinance, several recent papers have confirmed that microfinance can help to create and build social capital (Griffin and Husted, 2015; Feigenberg and Field, 2010; Dowla, 2006; Singh, 2003). This study investigates the impact path of the effects of microfinance on social capital formation with game theory and network theory. These two theories suggest that repeated interactions among individuals help to build and maintain social capital (Karlan and Valdivia, 2007; Coleman, 1999; Kreps, 1982).

Microfinance has long been an important tool for rural development and poverty alleviation in China. Early in 1955, China has established a policy of "Loans to Poor Households." In 2004, the first document from the central government of China placed an emphasis on "Actively Creating and Developing Microcredit," and microfinance has become the major instrument in alleviating China's poverty. However, it is believed that the effects of microfinance on rural China are far from being achieved (Xiong, 2014). Ma (2009) and Wang *et al.* (2015) analyze the issue from a social capital perspective. However, their studies do not address the impact paths of social capital and the effects of microfinance and do not address how to fully harness these impacts to improve the effects of microfinance. In this paper, we thoroughly examine the impact paths of the social capital and the effects of microfinance.

Ningxia provides a particularly opportune setting for this study for the following reasons. First, Ningxia is located near the upper Yellow River in Western China. It is one of the poorest regions in the country. Second, leading domestic microfinance institutions (MFIs) such as the Ningxia Hui Min Microfinance Company, Ningxia Zhang Zhen Capital and Logistics Adjustment Company and Yellow River Rural Commercial Bank are all located in Ningxia. Finally, the main operating model of microfinance in Ningxia is similar to the best-known Grameen Bank in Bangladesh, suggesting that lessons from the Ningxia experience may be applicable to other regions of the world.

This study makes three contributions to the microfinance literature. First, whereas prior studies have only investigated one direction of the impact path between the social capital and the effects of microfinance, this study seeks to investigate two directions of impact paths: one is the impact path of social capital on the effects of microfinance and the other is the inverse impact path. Second, many previous papers state that social sanctions have a positive impact on the effects of microfinance but ignore the impact of social relations on the effects of microfinance. In contrast, we find that social sanctions have a negative impact on the effects of microfinance, whereas social relations have a positive impact. Moreover, this study discovers a reverse causal relationship between social sanctions and social relations. That is, intensifying social sanctions worsen social relations, whereas harmonizing social relations reduce the pressure of social sanctions.

The rest of the paper is organized as follow. Section 2 explores different theories that explain the impact paths between social capital and the effects of microfinance. Section 3 describes the data set and variables. Section 4 presents the empirical framework and discusses the empirical results. Section 5 reports the robustness test. Finally, Section 6 concludes the paper.

2. Theory and hypothesis development

Based on agency theory, previous studies suggest that social sanctions increase the effects of microfinance (Besley and Coate, 1997; Wenner, 1995; Karlan and Valdivia, 2007). Other studies, relying on stewardship theory, suggest that harmonious social relations are vital for prompting the effects of microfinance (Armendariz and Morduch, 2004; McKenna, 2002). Invoking game theory and network theory, yet other papers suggest that the MFIs can build social capital by borrowers (Coleman, 1999; Bhatt and Tang, 2001; Dowlas, 2006). All these strands of literature have investigated from a single perspective between social capital and the effects of microfinance. This paper intends to examine the impact paths of social capital and the effects of microfinance in a unified analytical framework. Figure 1 presents a diagram of our conceptual model. It displays the impact paths of social capital and the effects of microfinance, which in turn strengthen the formation of social capital. We interpret these impact paths in detail in the rest of this section.

In addition, most studies on social capital and microfinance take into account group lending, while Margrethe and Nielsen (2012) find that social capital plays a role in individual lending in Peru. Moreover, the main credit models in rural China, such as credit village construction plus MFIs and credit villages plus households, are closely similar to the group lending. Thus, this study applies to both individual and group lending model.

2.1 Social sanctions

Social sanctions are pressures that exerted on borrowers when they do not follow the rules (Hadi and Kamal, 2015). Peer screening, monitoring and enforcement in the form of potential social sanctions are conventionally considered the key explanations of the success of a microfinance program (Dufhuesa, 2013). Social sanctions can improve the positive effects of microfinance by imposing penalties and inspiring stronger group solidarity and more diligent work ethics or by creating sentiments of altruism or reciprocity within social groups (Besley and Coate, 1997; Wydick, 1999; Karlan and Valdivia, 2007; Hadi and Kamal, 2015). Giné and Karlan (2014) argue that social sanctions motivate borrowers to screen other borrowers so that only trustworthy individuals with good projects are allowed in the program, thereby ensuring that funds are invested well and that effort is exerted. The threat of potential social sanctions is also perceived to be a strong motivating force in ensuring punctual repayment (Hermes and Lensink, 2007). The high loan repayment rate, in turn, allows poor groups to continuously obtain loans and persistently operate their loans to increase income (Griffin and Husted, 2015). Baland et al. (2017) confirm that social sanctions rather than bank sanctions can increase the income of borrowers who suffer a medium poverty level.

Social sanctions can also be exerted in the form of potential community sanctions intended to persuade other community members to follow the norms (Griffin and Husted, 2015). Sohail and Jayant (2013) support the observation that social capital at the community level is a
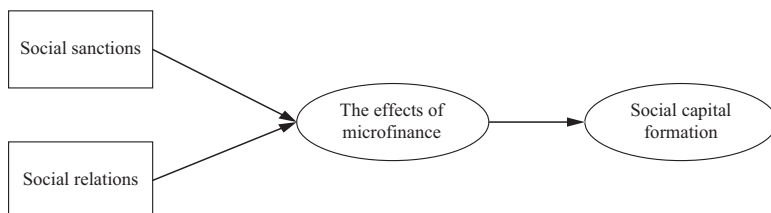

Figure 1.
Conceptual model

key factor affecting a household's access to microfinance. Goodman (2017) concludes that existing borrowing practices and norms govern how people obtain and use microfinance. The relationship between the borrower and the MFI is the same as the patron–client relationship. Thus, following the agency theory, we hypothesize the following:

H1. The greater the level of social sanctions the more tangible the effects of microfinance.

2.2 Social relations

Much of the previous literature has overlooked the positive effects associated with the role that harmonious social relations play in microfinance programs. In fact, harmonious social relations can correct personal preferences and render personal behavior altruistic, thereby curbing moral hazard and promoting collective action. Generally, harmonious social relations can help members benefit from group participation, such as accessing to contents of group meetings, sharing of information, as well as social interaction with other group members (Hadi and Kamal, 2015; Armendariz and Morduch, 2004; McKenna, 2002). Yunus (2012) has even argued that the original goal of group lending is for members to mutually learn and help each other but is not for inflicting social sanctions. McKenna (2002) studies three MFIs in Bangladesh and shows that the sharing of experiences between more productive members and less productive members can help the latter improve their productivity, increase their income and repay punctually. Mokhtar (2009) find that those who participate in group activities are more likely to profit from a loan project. Recently, Quidt and Ghatak (2016) show that individual lending may increase borrowers' income over joint liability, so long as borrowers have sufficient social connections and social interactions (such as attending group meetings) to establish mutual insurance.

Group members can also leverage their resources and relations beyond the group to other members of the community. Griffin and Husted (2015) analyze how harmonious social relations with the group and with wider communities affect the effects of microfinance. Goodman (2017) also demonstrates that exchange relationships with local community members such as family, friends and neighbors that are governed by a moral economy constituted the livelihood strategies of Kumaoni[1] and shaped people's use of microfinance. Harmonious social relations are the core aspects of stewardship theory. Thus, following the stewardship theory, we hypothesize the following:

H2. The greater the level of harmonious social relations, the more tangible the effects of microfinance.

2.3 Study the impact of the effects of microfinance on social capital formation

Coleman (1999) and Bhatt and Tang (2001) suggest that microfinance can consciously create social capital by establishing credit discipline and by regulating the relationships among peer members. Ismawan (2002) argues that economic intermediation can strengthen existing social capital. He states that microfinance helps create social capital to enhance information sharing, collective decision making and sustainable development. The study undertaken by Dowla (2006) in a Bangladesh village also sheds light on the impacts of the effects of microfinance on social capital. Dowla's study finds that trust, norms and networks can all be built through microfinance. Feigenberg and Field (2010) argue that social capital can be cultivated through group pressure and monitoring. They confirm through a quasi-experiment that group meetings and installments help borrowers establish rules and trust through repeated interactions. Shoji *et al.* (2012) find that households facing credit constraints reduce investments in social capital and that temporal declines in investment persistently reduce general trust, trust in villagers and trust in business partners.

Few previous studies have focused on the impact paths of social capital and the effects of microfinance. Till recently, some studies have explored the impact paths using a theoretical analysis and case studies. Hadi and Kamal (2015) state that MFI can effectively allocate loans to lenders while taking social capital as collateral, thereby helping lenders improve their economic and social capital. Panda (2016) analyzes the role of trust in 15 self-help organizations (SHGs) in India. He finds that trust contributes to the formation and operation of the loan group, while SHGs create trust in the process of providing financial service as well. Goodman (2017) shows that microfinance in Kumaon of India must fit with the local lives that are based on exchange relationships within family, friends and neighbors, which in turn facilitates the lending of money to borrowers and the subsequent building of new relationships. Thus, following game theory and network theory, we hypothesize the following:

H3. Tangible effects of microfinance are associated with social capital formation in households.

H4. The greater the level of social relations, the more tangible of social sanctions.

3. Data descriptions and variable definitions

3.1 Data descriptions

We obtain data from several different districts in Ningxia, which help us to test the hypotheses in the pre-testing of the survey and in the final data collection. Three counties in Ningxia are selected – Wuzhong, Ningwu and Yinchuan. The survey is based on stratified random sampling method ordered by city–country–township–village–household. A county and three villages were randomly selected. We interviewed local households that had borrowed through MFIs with the help of a local guide. The data covers 32 villages and 385 households in rural Ningxia[2]. The survey contains detailed information on the households' financial assets, loan demand situations, financial services in the village and household demographics. The final sample size for the empirical analysis consists of 350 households scattered across 32 villages.

The sample population consists of 69 percent males and 31 percent females. The participants' ages range from 18 to 62, with an average age of 42. In total, 96 percent of inhabitants have lived in local areas for more than five years, and 75 percent of the inhabitants have acquired no more than a junior high school education. In total, 68 percent of households have an annual average disposable income between 10,000 and 30,000 yuan per household, and the average loan balance is 35,000 yuan. In total, 59 percent of the total lending is individual lending, and the rest is group lending.

According to the first part of questionnaire analysis, 90 percent of the respondents in 30 villages surveyed are Hui people, and about 60 percent of the respondents in Hanqiao Village and Nanshan Village are Hui people. The individual disposable income of the villages surveyed is between 3,000 and 7,000 yuan, except for Hanqiao Village and Dahe Town in which the individual disposable income is relatively high due to land compensation fees. The village committees in 19 villages admit that local households have a strong preference for loans. The village committees in 28 villages acknowledged that borrowers would repay the loans punctually if they could, whereas village committees in Hanqu Village, Nanliang Village, Zhaoqu Village and Futian Village did not provide a similar confirmation, who admitted that some households in their villages have defaulted even they could afford.

3.2 Variable definitions

Definitions of each variable contained within this study are summered in Table I. All of the questionnaire items measured with a seven-point Likert scale[3].

Social sanctions. Mehmet (2014) found that individual reputation is an element of informal social sanctions. Hill and Sarangi (2011) found a significant association of group

Latent variables	Observed variables	Questionnaire items
Social sanctions	Personal reputation	Members who do not repay loans punctually will suffer from a damaged reputation
	Group sanctions	Members who do not repay loans punctually will be criticized by their group
	Community sanctions	Members who do not repay loans punctually will be criticized by other households of their village
Social relations	Participate	Actively participating in the community
	Social networks	Familiarity with group members
	Trusts	The number of people who trust you
	Norms	Repayment of loans on time as long as they have the ability to pay
The effects of microfinance	Household income	Household income is increased
	Information sharing	Useful information obtained from other households
Social capital formation	Trust formation	Increased trust in other households
	Norms formation	Increased repayment rates
Control variables	Gender	Interviewer's gender
	Age	Interviewer's age
	Education	Interviewer's education level
	Income	Household's income of last year
	Loan pattern	Individual lending or group lending
	Main source of income	Farming, retail, manual work or other
	Family member	Number of family members

Table I.
Variable definitions

pressure and village pressure when a default would affect other members or villages to acquire loans in the future. According to these above thesis, personal reputation, group sanctions and community sanctions are used to measure social sanctions in current study. The questionnaire item contains three questions about social sanctions, namely whether borrowers who fail to repay loans lose reputation, whether they are subject to criticism by the loan group members and whether they are subject to criticism by village households.

Social relations. According to Akram and Routray (2013), social capital is an essential element for the success of microfinance programs. Trusts, networks and norms are resources that can be adopted in a group lending approach. Karlan and Valdivia (2007) has emphasized that those who have actively participated in the community and have shared cultures and beliefs are more likely to have more savings by generating higher repayment rates. Karlan and Valdivia (2007) found that strong social networks lead to better access to finance, which helps to realize business opportunities. Armendariz and Morduch (2004) found that norms may help the borrower with lower literacy to gain more knowledge and improve his or her business skills. Four dimensions for social relations are based on prior questionnaire items, which are used both in Jia *et al.*'s (2016) survey and in Griffin's (2012) study of capital formation. The questionnaire item asks whether participants in the community are active and familiar with other households, whether participants always trust other village households and whether group member pay their loans punctually as long as they are able. The dimensions of social relations include the following: participation in the community, familiarity of participants, trust among participants and the norms to repay loans on time.

The effects of microfinance. Mokhtar (2009) highlighted the fact that micro-recipients who are involved in business-oriented activities are more capable of repaying loans and may enjoy the gains from the business profit. Griffin (2012) assumed that female borrowers who engage in group lending are more motivated to increase their human capital by putting more effort into learning and gaining knowledge in business management. Following Armendariz and Morduch's (2004) survey, effects of microfinance

are determined by two questionnaire items, which are whether the borrower increases his or her household income and whether the borrower obtains the information that he or she needs. The observe variable of the effects of microfinance are the increase in income per household and the usefulness of information obtained from other households. The questionnaire item contains two questions, namely whether households increase their income over past year and whether they share useful information with others.

Social capital formation. According to Maclean (2010), the developmental results from a combination of microfinance and social capital involve trust, norms and networks that allow people to coordinate their actions and achieve their aims. Similarly, Aggarwal (2015) suggests that forming trust through intentionality entails assuming that people value relationships on the basis of mutual and comparable interdependence and group affiliation. For MFI, establishing trust through intentionality entails creating motivation and intention of borrowers to pay back their loans. According to Rotzer (2007), incentives provided by social capital are harnessed to encourage micro-recipients to repay the loans. This study uses two observe variables to assess social capital formation.

Control variables. The following household economic and social characteristics are included as control variables: gender, age, assets, education, loan pattern, and business and product type.

3.3 Data analysis

Factor analysis is a statistical approach that verifies the pertinence of variables. This paper uses the principal component factor and the maximum variance of orthogonal rotation method to conduct the variable factor analysis. The analysis states that the orthogonal factor loads are greater than 0.5, which indicates that there exists a correlation in variables. Only control variable that had significant correlations with items for the main constructs in Figure 1 is included in Table I.

Additionally, it uses Cronbach's coefficient, the KMO test and the Bartlett sphericity test to conduct reliability and validity test on the data. The results are shown in Table II. Cronbach's α is 0.74, which demonstrates that the data are reliable. The KMO value is 0.71. The approximate χ^2 value of the Bartlett sphericity test is 829. The test probability demonstrates that the data pass the test. All of the above results indicate that variables and

Variables	Standardized loading	Cronbach's	Mean	SD
Social sanctions		0.76	4.84	0.11
Personal reputation	0.61		4.67	1.36
Group sanctions	0.74		5.22	1.11
Community sanctions	0.69		4.57	0.98
Social relations		0.74	5.06	0.07
Participation	0.76		5.15	1.36
Social networks	0.73		4.67	1.54
Trusts	0.67		5.55	1.48
Norms	0.66		4.88	1.38
Effects of microfinance		0.77	5.62	0.10
Household income	0.78		5.84	1.20
Information sharing	0.68		5.40	1.40
Social capital formation		0.73	5.56	0.07
Trusts formation	0.63		5.00	1.39
Norms formation	0.72	1.28	5.14	0.52
Control variable				
Education	0.78		4.73	2.22

Note: Data from author's survey

Table II.
Data statistics and factor analysis

models have high degrees of fitness. The correlation coefficient matrix of the variables indicates significant difference. The data suggest the ability to construct a structural equation model (SEM) and conduct a confirmatory factor analysis.

The results in Table II demonstrate that group sanctions and community sanctions can reflect the main features of social sanctions[4], and participation, social networks, trust and norms can reflect the main features of social relations. Therefore, we take social sanctions and social relations as the latent variables and household income and information sharing as the endogenous observation variables. At the same time, we also treat trust formation and norm formation as the endogenous observation variables of capital formation.

4. Empirical results

4.1 Structural equation model

The SEM is a multivariate statistical analysis that estimates and tests the causal relationship model. This model incorporates multiple methods, such as factor analysis, path analysis and multiple linear regression analysis. In this paper, social capital is difficult to measure. The subjective measurement errors are also hard to avoid. Hence, to ensure the objectivity of the research results, this paper selects the path analysis method of the SEM to implement, analyze and assess the impact paths of social capital and the financial effects of microfinance. The SEM includes two sections. The first section is the measurement model, which is used to depict the impact path of the observational variables and the latent variables. The relevant expressions are shown in Equations (1) and (2). The second section is the structural model, which reflects the impact path of the latent variables. The relevant expression is shown in Equation (3):

$$Y = \Lambda_x \eta + \varepsilon, \tag{1}$$

$$X = \Lambda_x \mu + \delta, \tag{2}$$

$$\eta = B_\eta + T\eta + \zeta. \tag{3}$$

In Equation (1), Y is a $p \times 1$ order vector constituted by the p endogenous observation variables; η is an $m \times 1$ order vector constituted by the m endogenous latent variables. In Equation (2), X is a $q \times 1$ order vector constituted by the q exogenous observation variables; μ is an $n \times 1$ order vector constituted by the n exogenous latent variables. In Equation (3), B and T are the path coefficients. Table III provides a detailed explanation of the equation.

As Table III shows, household income and information sharing, as well as norms formation and trusts formation, are the endogenous observation variables. Group sanctions and community sanctions are the exogenous observation variables of social sanctions. Participation, networks, trusts and norms are the exogenous observation variables of social relations. Social sanctions and social relations are the exogenous latent variables. The effects of microfinance and social capital formation are the endogenous observation variables. The effects of microfinance are also an intermediate variable. In addition, in Equations (1) and (2), Λ_x is the factor-loading matrix of Y and X in η and μ. B is the path coefficient of the effects of microfinance and social capital formation. T is the path coefficient of social sanctions, social relations and the effects of microfinance. δ, ε and ζ are residuals.

### 4.2 Modified model and measurement model

Based on the above analysis, we modified the SEM of the null hypothesis and obtained the measurement model (Figure 2).

The fitting indexes, NFI and CFI, of the measurement model are greater than the inspection standard of 0.8, indicating that the measurement model is well fitted. It is worth

Variables	Items
Vector of endogenous observation variables (Y)	Household income
	Information sharing
	Norms formation
	Trusts formation
Vector of exogenous observation variables (X)	Group sanctions
	Community sanctions
	Participation
	Social networks
	Trusts
	Norms
Vector of exogenous latent variables (μ)	Social sanctions
	Social relations
Vector of endogenous latent variables (η)	Effects of microfinance
	Social capital formation
Λ_x	Factor loading matrix of Y and X
B, T	Path coefficient
$\Delta, \varepsilon, \zeta$	Residual

Table III.
Structure equation
model explanation

Figure 2.
Measurement model
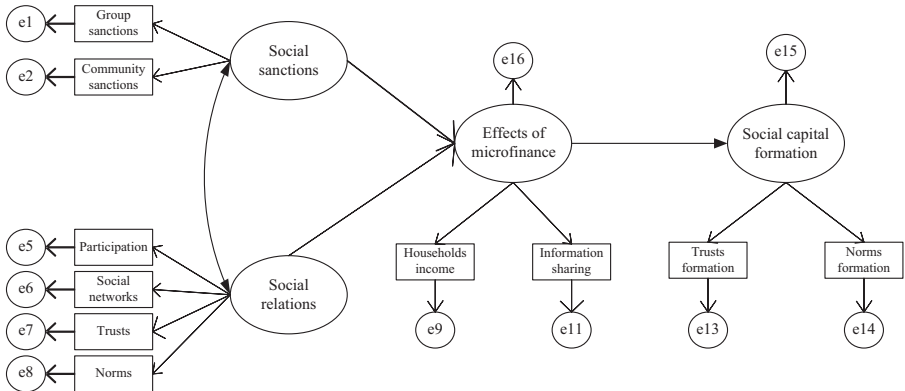
noting that according to the confirmatory factor analysis, the negative load factor of social sanctions and social relations is 0.85, which indicates that a correlation exists between social sanctions and social relations and that a path analysis can be conducted. The CFA is a test of the fit and triteness of the various latent variables in the model to further verify the impact path of the observed and the latent variables. Table IV displays the results of the measurement model. We use the oblimin rotation methods, which allow some correlation among factors, to explore the factor analysis. The data reveal that the four latent variables all load on their separate factors and that the load factors are greater than 0.65, indicating that the latent variables have good consistency because the standardized loading is between 0.66 and 0.87. Discriminant validity may be established by comparing the AVE scores to the squared correlation between the different constructs. The AVE values for the four latent variables indicate that the model has good discriminate validity (AVE between 0.51 and 0.63, all items above 0.5). All the CRs are greater than the test standard of 1.96, and the p values are significant. The statistics indicates the reliability and measurability of the model's observational variable selection. In addition, the model has excellent goodness of fit

Construct	Item	Standardized loading	Measure error	CR	AVE	CR
Social sanctions				0.83	0.61	–
	Group sanctions	0.79	0.37			1.99*
	Community sanctions	0.69	0.37			1.97*
Social relations				0.87	0.63	–
	Participation	0.72	0.59			1.98*
	Social networks	0.65	0.35			2.97**
	Trusts	0.81	0.19			7.28***
	Norms	0.87	0.24			–
Effects of microfinance				0.66	0.51	–
	Household income	0.72	0.28			8.58***
	Information sharing	0.66	0.47			–
Social capital formation				0.73	0.57	–
	Trusts formation	0.70	0.31			–
	Norms formation	0.75	0.47			4.6***

Notes: *,**,***Significant at 10, 5 and 1 percent levels

Table IV.
Measurement model –
construct validity of
the final model

(χ^2/df = 1.24; GFI = 0.92; RMSEA = 0.04 NFI = 0.90; RFI = 0.81; CFI = 0.95), where all construct model statistics are acceptable (AVEs > 0.50; CR > 0.79; construct correlation = 0.212) (Table IV and Figure 2).

4.3 The impact path analysis of the measurement model
The impact path analysis reflects the causal relationship of potential variables and examines whether the effects of each potential variable are significant. The fitness test of the measurement model shows that except for the RFI, the value falls in the general reference standard range and the remaining index values all fall in the best reference standard range (χ^2/df = 1.24; GFI = 0.92; RMSEA = 0.04; NFI = 0.90; CFI = 0.95), which indicates that the measurement model fits the data, and the model has reached the fitting state. The results of the path analysis of the measurement model are shown in Table V and Figure 3.

According to Tables IV and V, we can get following conclusions.

Intensifying social sanctions will diminish the effects of microfinance. The path coefficient of the social sanctions and the effects of microfinance is −0.23, which means effects of microfinance decrease by 0.23 percent for a one unit increase in social sanctions, holding all other variables constant. Moreover, harmonizing social relations will enhance the effects of microfinance. The path coefficient of social relations and the effects of microfinance is 0.48. The results show that when social relations change by 1 percent, the effects of microfinance change by 0.48 percent. Additionally, the path coefficient of effects of microfinance and social capital formation is 0.75. This shows that these variables have significant positive correlations. If the effects of microfinance change by one unit, the social capital formation changes by 0.75 percent. Furthermore, social sanctions and social relations are negatively related in a significance level of 5 percent. The path coefficient is −0.11, which means that when social sanctions change by one unit, social relations change inversely by 0.11 percent.

Path	Path coefficient	Z	Measure error	p
H1: social sanctions → the effects of microfinance	−0.23	−2.96	0.14	***
H2: social relations → the effects of microfinance	0.48	3.08	0.39	***
H3: the effects of microfinance → social capital formation	0.75	4.85	0.11	***
H4: social sanctions ↔ social relations	−0.11	−1.84	0.07	**

Notes: **,***Significant at 5 and 1 percent levels

Table V.
Structure model path
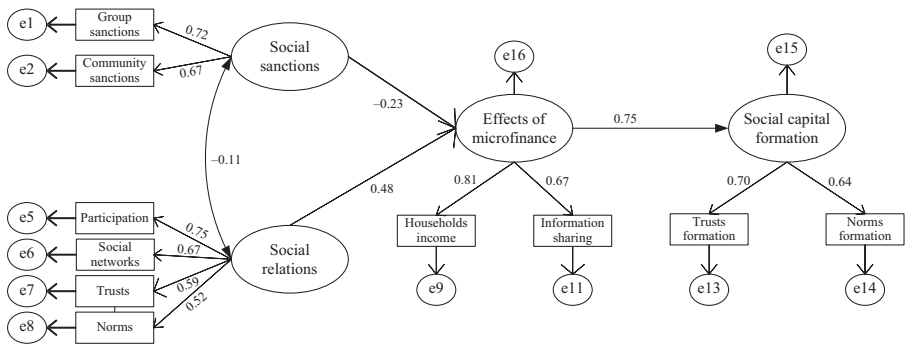
Figure 3.
The impact paths of
social capital and the
effects of microfinance

This shows that intensifying social sanctions will deteriorate social relations and finally diminish the effects of microfinance. On the other hand, when social relations change by one unit, social sanctions also change inversely by 0.11 percent. According to the above results, *H1* should be rejected, whereas *H2* and *H3* should be accepted.

5. Robustness test

We compare the measurement model with the alternative models including the model of reverse causality for the four factors. In Model 1, the endogenous latent variables are social sanctions and social relations; the exogenesis latent variables are the effects of microfinance and social capital formation. In Model 2, the endogenous latent variable is the effects of microfinance; the exogenesis latent variables are social sanctions, social relations and social capital formation. In Model 3, the endogenous latent variable is social capital formation; the exogenesis latent variables are social sanctions, social relations and the effects of microfinance. The robustness test results are shown in Table V. For example, an argument could be made that lower repayment rates lead to higher social sanctions, thus explaining the significant negative sign on the path of social sanctions and the effects of microfinance. The data show that the Δdf of Models 1 and 3 is 3 and that the Δdf of Models 2 and 3 is 2, both of which are less than the comparison criterion of 5, which indicates that these two alternative models can be compared with the original model. At the same time, the SRMR values of Models 1 and 2 are 0.27 and 0.15, respectively, which are greater than the comparison criterion of 0.08. The SRMR value of Model 3 is 0.057, which is less than the comparison criterion of 0.08. These indicate that Models 1 and 2 cannot be effectively estimated, whereas Model 3 can be effectively estimated. Furthermore, the S-BX2 of Models 1 and 3 is 8.1, which is significant at the 1 percent level. The S-BX2 value of Models 2 and 3 is 1.71, which is significant at the 5 percent level (Table VI). This indicates that the significance of the four variables does not change. The results of the robustness test suggest that Model 3 is robust.

Model	(S-BX^2)	(df)	(RMSEA)	(SRMR)	Model comparison	(Δdf)	(ΔS-BX^2)
Model 1	76.08	41	0.069	0.27	Model 1 vs Model 3	3	8.1***
Model 2	67.99*	36	0.07	0.15	Model 2 vs Model 3	2	1.71**
Model 3	69.71	38	0.07	0.047			

Notes: *,**,***Significant at 10, 5 and 1 percent levels

Table VI.
Comparison of
the structural
equation model

6. Conclusions and implications

The most important foothold of financial poverty alleviation is how to enhance the effects of microfinance in rural China. Using the SEM and survey data from 350 households in rural China, this paper investigates the impact paths of social capital and the effects of microfinance. The results are as following. First, social sanctions are negatively related to the effects of microfinance, whereas social relations are positively related to these effects. Moreover, because the social relations have more impacts than the social sanctions, the total impacts of social capital on the effects of microfinance are still positive. Second, the process of providing products and service is also a process of creating social capital for the poor, and the bigger the effects of microfinance the more the social capital is created. Third, a reverse interactive causality exists between social sanctions and social relations. Enhancing the intensity of social sanctions worsens social relations, whereas harmonious social relations lower the pressures of social sanctions. Finally, this study finds that an increase in household income and higher knowledge spillover effects have a significant positive impact on the effects of microfinance, where the household income has a greater relative influence.

The relationships between social sanctions and the effects of microfinance found in this study are consistent with those of Griffin and Husted (2015) but are contrary to those of Hermes and Lensink (2007) and Dufhuesa (2013), who believe that social sanctions help to improve the effects of microfinance. The reasons may be because poverty groups in rural China have little financial knowledge of credit consciousness and may not even understand the concept of "joint responsibility." Therefore, implementing group sanctions can lead to tension among clients, loan officers and MFIs[5]. MFIs usually dispense social sanctions by releasing a list of defaulting borrowers, which are excluded from financial services. However, in the process of transitioning to a market economy, labor mobility in rural areas is increasing, and the traditional social capital in China is gradually collapsing. In this case, strict social sanctions do not exert a positive effect and might even hinder the poor from borrowing from MFI, thereby destroying the relationships among poor people.

Taken together, this study suggests that since social capita are positive association with the effects of microfinance and vice versa, actively utilizing and creating social capital is vital to improve the effects of microfinance. MFIs should concentrate more on harmonious social relations within the process of loan origination, audit, supervision and repayment. By doing so, MFIs can rely on the local old patriarch and capable individuals – in addition to the village committee – who are familiar with the village's status quo and have the ability to influence borrowers and help to ensure regular repayment. At the same time, financial knowledge should be broadly provided to help poverty groups understand financial policies and cultivate their awareness of self-reliance and rules via television broadcasts as well as digital and other media channels. On the other hand, MFIs should prudently impose social sanctions. By employing microcredit insurance, financial guarantees and risk-sharing funds, the impacts of default on the financial performance of MFI would be mitigated, thereby reducing their dependence on social sanctions.

Improving social capital in poor areas can prompt both the effects of microfinance and the development of these areas. However, the creation of social capital is not an automatic outcome and can only be achieved by a deliberate implementation of specific policies, such as capacity building programs and the development of decision-making abilities (Basargekar, 2010). Therefore, MFI should set out to foster social capital for poor groups by organizing different activities through village committees that give poor groups the opportunity to establish certain social connections and build harmonious social relations. Meanwhile, the government should provide institutional guarantee for the formation of social capital. For example, the government can promote credit level of households, offer necessary funds and policies support to encourage the formation of economic social organizations, grant subsidies for non-financial services and conducted by MFIs to invest in the formation of social capital.

Notes

1. Kumauni is located in Pithoragarh of India.

2. The survey villages included 10 villages in Lingwu City, followed by Chongmu Town in Zhangmuqiao Village (18) and Chongxing Town in Hanqu Village (10), Chongxing Town and Jiajiatan Village (19); Chongxing Town Zhongbei Village (10) Chongxing Town Chongliang Village (19) Jinyintan Town Yangma Lake (20) Shangqiao Town Shangqiao Village Committee (20) Wudipo Village (10) in Bantian Town, Nanliang Village (10) in Bantian Town, and Zao Gangzi Village (10) in Baigang Town; 3 villages in Qingtongxia City, followed by Zhao Qu Village in Xiakou Town (20), Dingxiang Nanyang Village (20), Hongshe Fort Township, six villages (19); Wuzhong City, 10 villages, Dahe Xiang Village (20), Dahe Xiang Longquan Village (10), Hongsipu Futian Village (10), Hongsibao Nanchuan Township Kangzhuang Village (14), Shangqiao Xinmin Center Village (10) and Guojiaqiao Yangjiafu Village (15), Nanchuan Village, Tongxin County (19).

3. 1 to 7 means from totally disagree to fully agree.

4. We use the extraction methods of equal prior instant communalities to test the latent variable. The results reveal that personal reputation loads are less than 0.5 and therefore does not pass the factor-loading test for the structural equation model. Hence, personal reputation is eliminated in the modified model.

5. Most interviewed households believe that microfinance is a government program of poverty alleviation. Therefore, they should repay the loan if their income has increased. Otherwise, they would not repay. Moreover, the vast majority of the interviewees think that they should not repay for other members of the joint liability group.

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Chinese farmer income's fluctuant trajectory in the 1970s

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Abstract

Purpose – The purpose of this paper is to examine the farmers' income and to analyze the factors affecting the farmers' income as well as rural life during the People's Commune period.

Design/methodology/approach – The study's data are drawn from unique account books of production team and a great deal of rural archives from the aspects of commune, production brigade and production team during the People's Commune period.

Findings – The fate of the people's commune is closely related to the income of its members. This study tries to explore the answers to "what determines members' income" and "what influences their income," which include the impact of the materialization on farmers' income, the gender structure of the household labor force, the life cycle of the family and the population and so on. The main reason for farmers' income differentiation is the difference in the demographic structure of the farmers, while the social system and traditional culture strengthen the role of this factor.

Originality/value – The biggest feature of the study is that it deeply explored the unique account books of production team from a micro-view, and studied the issue of People's Commune from the level of farmers using the methods of historical textual research and mathematical analysis. This study is a supplement of the research on the family level which has long been lacked in the academic community.

Keywords Chinese farmer income, People's Commune

Paper type General review

People's commune was a type of large rural organization introduced in China in 1958, which had been engaged exclusively in agricultural activities, and became multipurpose organizations for the direction of local government and the management of all economic and social activity. Each commune was organized into progressively larger units: production teams, production brigades, and the commune itself. In 1983, the promulgation of "Notice on Separating Government from People's Commune and Establishing Township Government of the Central Committee of the Communist Party of China and the State Council" marked the disintegration of the People's Commune System officially. People's Commune is a symbol of the times. Even today, we can still see its remaining shadow from land system and the household registration system. Therefore, it is inappropriate to ignore People's Commune system when it comes to rural situation of China. Actually, the discussion of People's Commune has been lasting during the past thirty years or so, and there even exists some controversies.

In the perception of the younger generation, the impression of People's Commune is as simple as "equalitarianism," "big-pot" and "free for dinner." "Equalitarianism" seems to be the synonym of that era which means there is no much difference in income among farmers, or almost the same. In fact, it's not true. Not only the income differences among regions are obvious, but the gap between the rich and the poor in the same production team is also obvious.

After the period of the People's Commune, in 1978, 18 villagers in Xiaogang Village in Anhui Province risked their life to press the red handprint on land responsibility contract, which opened the prologue of Chinese reform and opening up. The village land was thus contracted separately and the farmer's income was distributed according to his work. The reason behind the action was that they were too poor, they ate resold grain every year. Their work-points at that time only worth a few cents, and it was hard for them to get cash all the

year round. In September of 1980, the notification of "Notice on Several Issues Concerning Further Strengthening and Improving the Responsibility System for Agricultural Production" pointed out that people in production teams which located in remote mountainous areas and relied on the resold grain, loans, and relief, had lost confidence in the collective economy. Therefore, if they required to work on households by contract, the government should support them. Consequently, the system of distribution according to work and work on households by contract was allowed, and it should be kept stable in a long period. The notice shows the looseness of the central government regulation on separating the fields land to individual households, especially in poor areas.

From the background, it can be seen that the fate of the people's commune was closely related to the income of its members. In 1970s, what determines members' income? What influences their income? These questions seem critical, so it is of practical reference to study the farmers' income in the period of People's Commune and at the same time, the analysis of the factors affecting the farmers' income also has important theoretical value.

In the book *China's Peasant Household Income in the 1970s* (Social Sciences Academic Press, 2018), written by Yingwei Huang, gives specific analyses of the farmers' income status, the influencing factors of farmers' income, and rural life during the People's Commune period, as well as the efficiency of the People's Commune by the chance. What makes the study special is that it deeply explores the unique account books of production team from a micro-view, which provide a solid research foundation for the study. Meanwhile, the book deals with the issue of People's Commune from the level of farmers using the methods of historical textual research and mathematical analysis.

In order to probe into the subject, the author collected and compiled a great deal of rural archives from the aspects of commune, production brigade and production team, without which nothing original could be conceived. The raw archives of household account book contain rich original information of a production team, such as politics, economics, culture and women militia groups of the Communist Party of China, etc., which fully shows the characteristics of "large in size and collective in nature" of the People's Commune. Besides, the industry, commerce, soldier, agriculture, forestry, husbandry and fishery are also included in it. More importantly, the divided household accounts make it possible to analyze the income differences among farmers, labor input strategy, family age and demographic structure during the People's Commune period. The research on the family level is a supplement for current academic community. Another important data based the book is oral history interview and field research. The author and his teammates interviewed hundreds of People's Commune members. Most background information, especially the specific matters related to production and distribution all came from them.

Based on that large amount of data, the research team established a micro-database of People's Commune, namely "China Rural People's Commune Micro-Database (CRPCMD2015)," which is divided into three levels of communes, production brigades, and production teams (including households). The information of hundreds of production teams and tens of thousands of farmers that has been completed, and the database capacity is increasing. Through the application of econometric history measurement methods and economics theory, the author actually pushed a small step forward in the study of contemporary rural China.

Back to the book's arguments, the author attempts to build the knowledge of the income distribution system of People's Commune and its many changes in 1970s, under the synthesized measurement methods and amounts of data. As the book points out, after The Amended Draft of The Work Regulations of Rural People's Communes ("Agriculture 60 Articles") promulgated in 1962, the distribution system based on the work-point system occupied the main position. The work-point system was both the measurement of labor and the standard of distribution, characterized by enforcing double standards on working hours

and population, but most of the time, the proportion allocated according to the number of people was greater than the proportion allocated according to the working hours. If there were no debts and special population needed to be taken care of, regardless of the population allocation, ultimately, the members had to "buy" the distribution with the work-points. Therefore, if the mechanism were sound, the work system could be regarded as distribution according to work to a certain extent.

The author demonstrates that the distribution of farmers came after taxes and retention, multiple distributions and only one or two settlements per year resulted in a special phenomenon of "overspending" in the work-point system. It was the characteristic of the distribution system that first distribute according to the head and then according to the labor points, thus the demographic factor became particularly important, moreover, assessing base work-point and allocating farm work was accompanied by the political movements. In this context, the author tries to make investigations to explore the distribution system.

First, the author thinks it is important to take the factor of family life cycle into account. According to the age of the first child in the family, the family life cycle is divided into four stages. When the family is in a mature period with a strong labor force and a small labor support ratio, the family income is higher. On the contrary, when the family is at a higher population burden, its income is lower during the growth period. At the same time, the male population is divided into five life cycle stages according to the age, while the female population is divided into six stages. The statistics shows that the family income is strongly correlated with the life cycle. Based on that analysis, the book concludes that the life cycle of the family and the population is one of the main reasons for the income differentiation among farmers, and the institutional (work-point system) and cultural (marriage, etc.) factors also affect farmers' income along with the life cycle.

Second, the book comes to the gender structure of the household labor force, which is another factor influencing income disparity. Under the influence of the work point system and traditional culture, the gender division of household labor results from comprehensive consideration of work contributions and social benefits, which thus affects the income of them. The study found that the contribution of women to the total household work point made up 45.7 percent. There was no much difference between the contributions of women and men in grain amount which distributed by population, and the marginal impacts were 491.6 and 497.3 respectively. However, the difference of the contributions in grain income of work score was apparent, men were 26.4 percent higher than women, while women were 8.5 percent higher than men in self-retained grain income. Compared with grain income, women's contribution in cash income was far less than that of men, and men's contribution in cash income was 34.6 percent higher than women. Women put more labor into compulsory work with no remuneration. Farmers would consider how to allocate the labor based on the premise of utility maximization, resulting in different gender division of labor that affected the household income.

Third, the difference among production teams is investigated. The analysis above mainly focuses on the difference within the production team. Once extended range to compare, the difference among the production teams could be found, which made a greater impact on the diversity of household income compared with the effect within the team. By using hierarchical model, the author found that the production team could explain 37 percent of reasons for the differences among farmers' income, which means that the difference caused by production team added up to more than one-third. Even if the government strived to eliminate the income discrepancy during the People's Commune period, the inherent difference among production teams could not be changed in the short term, so that the ideal of income equalization was difficult to achieve.

Fourth, the book inspects the changes in income, which is conducive to narrow the gap and help to increase the income of the low-earners. The research on income mobility found

that in the long run, income mobility is bigger than that in short term, which means that the income difference becomes smaller in the long run. And both the Gini indicator and the income conversion matrix indicates that income liquidity are "pro-poor," which means that income mobility is more beneficial for low-income people. From the perspective of social inequality, income mobility has reduced social inequality among farmers. More importantly, changes in income liquidity are mainly affected by family demographic factors, including the population dependency ratio, family size, etc. The larger the population dependency ratio is, the harder income level moves upward.

The book's final objective is the impact of the materialization on farmers' income. Although farmers' income was settled by the end of the year, it would be cashed gradually during the year, which was the characteristic of agricultural production. There was a tendency that most of the remuneration was in kind rather than cash which restricted the consumption behavior of farmers, promoting farmers' anti-behavior. In the distribution of grain, the so called "big final accounts" and "small final accounts" appeared at the same time, and the cadres of production team and commune reached a tacit agreement with the farmers, so the farmers' strategies became an informal system and existed for a long time.

On the basis of these investigations, the book gives us a conclusion of the main reasons for farmers' income differentiation, namely, the difference in the demographic structure of the farmers, while the social system and traditional culture strengthen the role of this factor. On one hand it is conducive to social stability, because there is no alternative for the production team members to change their income situation except waiting for the changes of family structure, so all they can do is to be content with the status quo. This may be the reason why the People's Commune system can last for a long time. On the other hand, it may be the main inducement of social change. When the income change of members remains stagnant because of demographic changes, such reality affects the enthusiasm of the members in their work. As a result, there arise some negative phenomena such as dawdle along and loaf on the job. So far, the author demonstrates when this accumulates to a certain extent, social reform will follow, which is undoubtedly cause the disintegration of the People's Communes system.

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