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HETEROGENEOUS EFFECTS OF CHINA'S SLOPING LAND CONVERSION PROGRAM ON FARM PRODUCTIVITY

Zhen Liu[a,*], Meng Li[b]
[a] *School of Business, Nanjing Normal University, Nanjing, China*
[b] *China Centre for Land Policy Research & College of Public Administration, Nanjing Agricultural University, Nanjing, China*
* Corresponding Author. Tel.:+86 25 8589 1140; fax: +86 25 8589 1140.
E-mail address: zhenliu_cn@yahoo.com (Zhen Liu)

In order to examine the effect of the Sloping Land Conversion Program (SLCP) on the farm productivity of farm households, this study applies a non-parametric Malmquist Productivity Index to estimate the changes in farm productivity and its components among different regions and income groups. The results show that farm productivity increased after the implementation of the SLCP, although heterogeneity is present among different regions and income groups. The regional heterogeneity is mainly from the difference in technological change, whereas technological efficiency contributes to the heterogeneity among income groups.

Key words: Sloping Land Conversion Program; China; Malmquist Productivity Index; Data Envelopment Analysis, Heterogeneity

1. Introduction

Achieving economic growth and environmental protection at the same time seems to be a dilemma that cannot be resolved (Leonard.1989; World Bank 1992). Many countries face the problem that rapid economic growth is accompanied by environmental degradation, especially in the developing countries. In the late 1990s, Payments for Environmental Services (PES) was introduced by many countries to reduce the negative environmental effects of overfarming (Landell-Mills and Porras 2002, Scherr et al.2003). In 1999, the Chinese government launched the Sloping Land Conversion Program (hereafter, SLCP), which introduced a fixed-payment incentive mechanism to compensate rural households for converting farmland to forestland. This program was originally designed to improve environmental conditions, although the alleviation of poverty was subsequently added as side goal (Liu and Lan, 2015). The structure and function of ecosystems is greatly improved by afforestation; however, this may cost huge farm production due to the reduction in farmland, especially grain production. After retiring degraded farmland, grain production is bound to decrease to a certain extent and this has brought the issue of food security to the attention of the Chinese government.

Some previous studies have examined the potential effect of the program on food supply and farm production. Using a multi-objective programming model, Feng et al. (2005) simulated the impact of the SLCP on China's grain supply in the upper reaches of the Yangtze River and the Yellow River. They pointed out that at the national level, the SLCP might not have a major effect on China's grain supply, although a significant impact was found at the local level. Under modified assumptions regarding farmers' production behavior such as their response to price changes, Xu et al. (2006) revealed that the SLCP has an even smaller effect on China's grain production and little influence on prices or food imports. With the application of a household model, Liu and Heningsen (2014) found that implementing the SLCP did not result in a decline in farm production that was in proportion to the reduction in sloping land. All of this suggests that the reduction in grain production caused by implementing the SLCP may be offset through improvements in grain productivity. Yao and Li (2010) analysed farm productivity change, but they did not separate rain production out which is more critical for food security, while they only focused on one special study site – Wuqi in the Loess Plateau Region. Additionally, scholars have studied farm productivity change after the introduction of the SLCP. Yu and Yao (2009) calculate "pure" scale efficiency and "pure" technical efficiency in Wuqi County. The "pure" scale efficiency of farmers involved in the program decreased significantly compared to the dramatic increase in "pure" technical efficiency. Guo and Ruan (2014) conducted a further investigation into efficiency change by using the data from Zhijin County and found that scale efficiency and technical efficiency decreased in the short run, but it tended to increase in the long-term, which shows the farmers adoption to the SLCP. Using the SFA method, Li et al. (2010) find that though the TFP (total factor production) increased for all participants in the SLCP in Wuqi and Huachi County. The increase in TFP for small-scale conversion farmers was mainly due to technical efficiency, while for large-scale conversion farmer, the increase in TFP was due to technical change.

Even though there have been some studies of SLCP socioeconomic effects on food supply and farm production, it is also important to note that there might be differences in development conditions, patterns of household production and crop varieties. Therefore, the SLCP may have heterogeneous effects on farm productivity among different regions and income groups. Using micro-level household survey data, the primary objective of this paper is to investigate the effect of the SLCP on farm productivity. Farm productivity is represented by the Malmquist Productivity index (MPI) of total factor productivity (TFP), which is applied to a sample of 512 households in three counties and calculated using the non-parametric method ¯ Data Envelopment Analysis (DEA). The study finds that TFP in Wuqi County increased significantly from 1998 to 2010, whereas

[1] Afforestation on converted sloping farmland under the program has been suspended since 2007 and the government started some policies including food subsidies, farm material subsidies, seed subsidies and farm machinery purchase subsidy to increase the grain production.

the growth rate of TFP in Dingbian and Huachi County was slow, which suggests that the SLCP had a regionally heterogeneous effect on farm productivity. The heterogeneity in TFP was mainly caused by the varying rate of technological change in the regions. Dividing farm household total income into low, middle and high categories shows that there is also heterogeneity in TFP between different income groups, which indicates that the effect of the SLCP on farm productivity is also related to the economic conditions of participating households. The framework of this paper is organized as follows. The next Section introduces the background of the SLCP in China. Then, we present the method applied in the study to calculate the farm productivity. Before reporting our empirical results, we describe our data source and define the input and output index used in our study. Finally, we summarize the main conclusions from the result and discuss the opportunities for further research.

2. Background of Sloping Land Conversion program

In response to the increasing environmental pressure in the Yellow River and Yangtze River during the late 1990s, the Chinese government initiated several ecological preservation programs. The SLCP, also known as Grain for Green, was the first and most ambitious program based on payments for environmental services program (Bennett 2008).

The primary and main purpose of this program is to reduce soil erosion by reforestation. The program mainly focuses on cultivated land on steep slopes (greater than 15° in the northwest and 25° in the southwest), which is the single criterion for eligibility in the SLCP since such land tends to suffer from serious erosion (Zuo. 2002). The original ecological objective of the SLCP was to convert 14.67 million hectares of farmland to forestland or grassland (4.4 million of which is on land with slopes greater than 25°) and an additional "soft" goal of afforesting a roughly equal area of denuded mountains and wasteland by 2010 (SFA, 2003). Regarding payment, heterogeneity is present with regards to the subsidy criterion due to the observable landowner attributes. Therefore, two different compensation rates exist at the regional level; 1,500 kg grain/ ha /year in the Yellow River Basin, and 2,250 kg grain in the Yangtze River (grain compensation was changed to cash payments in 2004, and the conversion rate of grain to cash is 1 kg grain = 1.4 CNY), reflecting differences in the opportunity costs of sloping land. However, given the tremendous heterogeneity that exists throughout the SLCP program areas within each River Basin, there is still room for better targeting (cost-effectiveness).

In 2007, the Chinese government adjusted the policy in two ways. First, afforestation on converted sloping farmland was suspended under the program in 2007. This was due to a sharp reduction in grain output, which had been falling continuously and reached its lowest point (430.70 million tons) in 2003. This might have had a serious impact on food security. Furthermore, the central government could no longer afford the subsidies given the significant financial pressure already caused. As a result, the government reduced the subsidy by half (1,350 CNY /hectare/year in the Yellow River Basin and 1,875 CNY/ hectare/year in the Yangtze River Basin) for another eight years for participating households who had already finished the first eight year period.

The program has achieved great progress in ecological recovery and poverty alleviation since 1999. From the perspective of ecological protection, the total area of afforestation had reached 29.4 million hectares by the end of 2012, including 9.26 million hectares which had been converted from farmland to forestland. Additionally, the program costs a 438.5 billion CNY in total which covers the grain subsidy, seed funds, maintenance fees, various special funds, of which 203.39 billion is directly paid to households, which benefit 27,532,879 households spread over 25 provinces (Liu and Lan, 2015).

3. Method

Some scholars prefer to measure productivity by a single factor input such as labor or land productivity (Xue et al. 2013, Guo and Ruan 2014). However, in reality, farm households use multiple inputs such as labor, land and capital to produce multiple outputs. Given multiple inputs and outputs, TFP measured by the ratio of the weighted sum of outputs with respect to the weighted sum of inputs is a more accurate index (Coelli et al.1998). The MPI method is the most commonly used method for measuring TFP changes and was first introduced by Caves et al.(1982), although it has been subsequently developed and used in many microeconomic studies (Färe et al., 1992; Färe and Primont, 1994; Färe et al., 1998; Grifell-Tatje and Lovell, 1993; Grifell-Tatjé and Lovell, 1995).

There are two main advantages to using MPI rather than other methods to measure TFP. Firstly, it is not necessary to gather information about factor price and equilibrium assumptions for calculating price and marginal product. Secondly, the index can be exhaustively decomposed into an efficiency change and technical change component (Färe et al.1998). In modern economics, distance functions are related to the MPI method to provide a measure of farm productivity changes without having to specify a behavioral object. Two distance functions are distinguished by orientation, an input distance function which minimizes the proportional contraction of the input vector at the given output vector, while an output distance function characterizes the production technology by maximizing the proportional contraction of the output vector given an input vector. Although, in many cases, there are minor differences by using the two different distance functions (Coelli et al, 1998), we choose the output orientation distance function in this study in view of the long-run stream of the SLCP.

Assume that there are K (K=1, 2, 3¼ k) households in this case, the output distance function at period t is $D_0^p(x^p, y^p)$is defined as:

$$D_0^p(x^p, y^p) = \inf\{\theta(x^p, y^p/\theta) \in L^p, \theta > 0\} \quad (1)$$

Where è is a scalar, x^p and y^p are the input and output vectors at period *p*. L^p is the production possibility set, which represents the vector x with m inputs to produce vector y with n outputs. When y^p is in the production possibility set, the distance value is equal to$(D_0^p(x^p, y^p) = 1)$.

When calculating the output orientated MPI, we use two mixed-period distance functions, which are from period p and technology from an adjacent period p+1,$D_0^{p+1}(x^p, y^p)$ and $D_0^p(x^{p+1}, y^{p+1})$ respectively. Färe et al(1994) first used the geometric mean of two indexes to represent output-based MPI, namely $M_0^p(x^p, y^p, x^{p+1}, y^{p+1})$ and $M_0^{p+1}(x^p, y^p, x^{p+1}, y^{p+1})$.Caves et al(1982) found that) was the ratio of and by comparing respective distances to period p technology, while the definition of replace the period p technology with p+1 technology as a referee.

$$M_0^p(x^p, y^p, x^{p+1}, y^{p+1}) = \frac{D_0^p(x^{p+1}, y^{p+1})}{D_0^p(x^p, y^p)}$$

$$= \frac{D_0^{p+1}(x^{p+1}, y^{p+1})}{D_0^p(x^p, y^p)} \cdot \frac{D_0^p(x^{p+1}, y^{p+1})}{D_0^{p+1}(x^{p+1}, y^{p+1})} \qquad (2)$$

$$M_0^{p+1}(x^p, y^p, x^{p+1}, y^{p+1}) = \frac{D_0^{p+1}(x^{p+1}, y^{p+1})}{D_0^{p+1}(x^p, y^p)}$$

$$= \frac{D_0^{p+1}(x^{p+1}, y^{p+1})}{D_0^p(x^p, y^p)} \cdot \frac{D_0^p(x^p, y^p)}{D_0^{p+1}(x^{p+1}, y^{p+1})} \qquad (3)$$

Where $D_0^{p+1}(x^p, y^p)$ stands for the distance from period p+1 observation to period p technology. This index shows if the value is greater than one, TFP growth is posituve, otherwise there is a reduction in TFP. In most empirical analyses, however, the MPI is defined as follows:

$$MPI(x^p, y^p, x^{p+1}, y^{p+1}) = (??^{??} \times ??^{??+1})^{\frac{1}{2}} = \left(\frac{D_0^p(x^{p+1}, y^{p+1})}{D_0^p(x^p, y^p)} \cdot \frac{D_0^{p+1}(x^{p+1}, y^{p+1})}{D_0^{p+1}(x^p, y^p)}\right)^{\frac{??}{??}} \qquad (4)$$

Two main components explain the economic implications of the MPI: efficiency change and technical change. The fOrmer shows the sign of catch-up, while the latter means the frontier-shift (Färe et al.1994). Rewriting the equation can clearly illustrate the composition of MPI:

$$MPI(x^p, y^p, x^{p+1}, y^{p+1}) = \frac{D_0^{p+1}(x^{p+1}, y^{p+1})}{D_0^p(x^p, y^p)} \cdot \left(\frac{D_0^p(x^{p+1}, y^{p+1})}{D_0^{p+1}(x^{p+1}, y^{p+1})} \cdot \frac{D_0^p(x^p, y^p)}{D_0^{p+1}(x^p, y^p)}\right)^{\frac{??}{??}}$$

where $\frac{D_0^{p+1}(x^{p+1}, y^{p+1})}{D_0^p(x^p, y^p)}$ measures the change in technical efficiency(TE) from period p to p+1, $\frac{D_0^p(x^{p+1}, y^{p+1})}{D_0^{p+1}(x^{p+1}, y^{p+1})} \cdot \frac{D_0^p(x^p, y^p)}{D_0^{p+1}(x^p, y^p)}$

captures the frontier shift in technology between the two periods.

The MPI method embraces both mathematical programming and econometric regression. Mathematical programming such as data envelopment analysis (DEA) is a nonparametric approach to determining the production frontier and firm performance while econometric regression is a parametric approach, such as stochastic frontier analysis (SFA) which requires the specification of the functional form of the production function and certain distributional assumptions for a separation of the distance to the frontier function from measurement error. It is better to choose DEA to estimate the best practice production frontier because the frontier function is determined without pre-assumptions. The limitation is that

DEA estimation is sensitive to outliers, but this can be resolved by enlarging the sample size (Yin 2000). Besides, DEA has already been used in other studies (Asmild etal .2004, Coelli and Rao 2005, Lovell 1996). Two assumptions exist; constant returns to scale (CRS), which was proposed by Charnes et al. (1978); and variable returns to scale (VRS) (Banker et al.1984). Numerous studies show that returns to scale in agriculture production tend to be constant (Battese and Coelli 1992, Krugman 1993, Townsend et al.1998). Therefore, in this study, we predict farm productivity with the assumption of CRS.

To make the theoretical method fit the real world problems, it is vital to calculate all the above distance function $D_0^p(x^p,y^p)$, $D_0^p(x^{p+1},y^{p+1})$, $D_0^{p+1}(x^p,y^p)$ and $D_0^{p+1}(x^{p+1},y^{p+1})$ by solving linear programming problems as follows (Färe and Primont 1994,Färe et al.1998):

$$\left[(D_0^p\left(x_j^p,y_j^p\right)\right]^{-1} = \max_{\eta,\lambda}\eta,$$

S,t.

$$-\eta y_j^p + Y^p\lambda \geq 0,$$

$$x_j^p - X^p\lambda \geq 0,$$

$$\lambda \geq 0 \quad (6)$$

$$\left[(D_0^{p+1}\left(x_j^{p+1},y_j^{p+1}\right)\right]^{-1} = \max_{\eta,\lambda}\eta,$$

S,t.

$$-\eta y_j^{p+1} + Y^{p+1}\lambda \geq 0,$$

$$x_j^{p+1} - X^{p+1}\lambda \geq 0,$$

$$\lambda \geq 0, \quad (7)$$

$$\left[(D_0^p\left(x_j^{p+1},y_j^{p+1}\right)\right]^{-1} = \max_{\eta,\lambda}\eta,$$

S,t.

$$-\eta y_j^{p+1} + Y^p\lambda \geq 0,$$

$$x_j^p - X^{p+1}\lambda \geq 0,$$

$$\lambda \geq 0, \quad (8)$$

$$\left[(D_0^{p+1}\left(x_j^p,y_j^p\right)\right]^{-1} = \max_{\eta,\lambda}\eta,$$

S.t.

$$-\eta y_j^p + Y^{p+1}\lambda \geq 0,$$

$$x_j^p - X^{p+1}\lambda \geq 0,$$

$$\lambda \geq 0. \quad (9)$$

Where X represents M´K input matrix, and Y represents N´K output matrix. The column vector xj and yj represent the j-th household's input vectors and output vectors respectively. h is a scalar, the value of h calculates the output distance and shows by how much the output of farm household k can be reached a point on the frontier function. l is a K´1 matrix.

4. Data

4.1 Data source

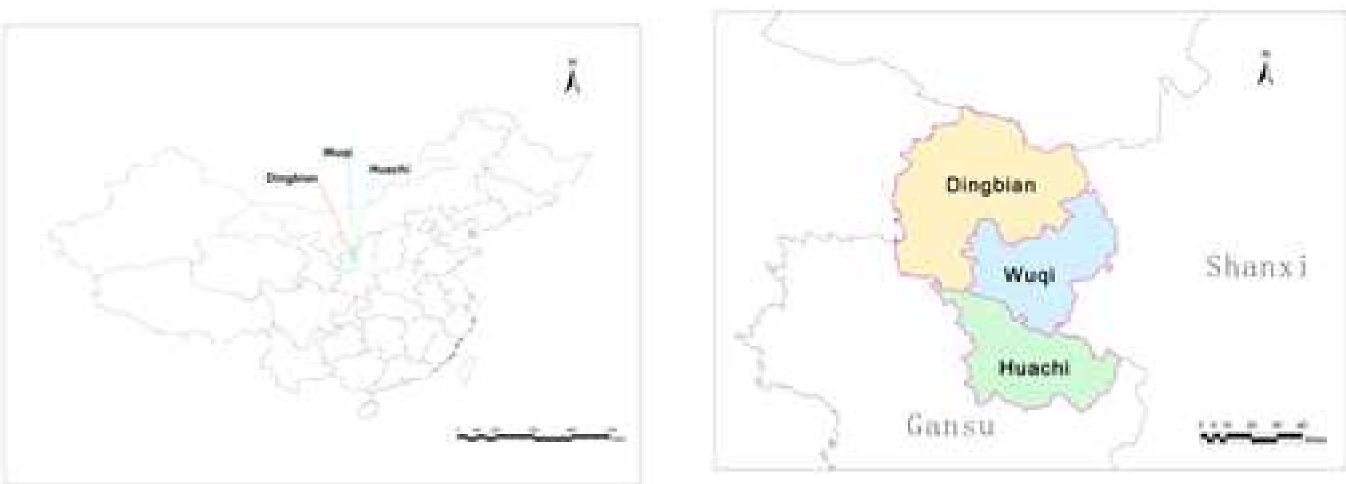
The data used in this study were collected from three different counties: Wuqi, and Dingbian County from Shaanxi Province, and Huachi County in Gansu Province (see Figure1). All of them are typical areas of the Loess Plateau region, which has many hills and gullies with yellow soil. In this arid region, agriculture is largely rain-fed. Due to the lack of precipitation, however, crop yields have been historically low. In order to increase farm production, farmers convert forestland to farmland, which causes land degradation and soil erosion. Therefore, exploring the treatment effect of the SLCP in this region is of great interest and is expected to lead to a better understanding of the effectiveness of the program.

Our data for this study were collected from a household survey conducted with a stratified sampling which was suggested by (Deaton, 1997) to enhance the precision of sampling estimates. The survey was conducted in 2007 and 2010,and data was gathered in 1998,2006 and 2009. The data in 1998 was recall data from just before the SLCP was initiated. To guarantee the quality of the study, several measures were taken before the formal research such as a pre-test, group discussions, enumerator training, etc. A total of 1,536 observations were made consisting of 546 households in Wuqi County, 468 in Dingbian County and 552 in Huachi County.

4.2 Definition of variables used for productivity analysis

The following table shows the variables statistic information used for measuring farm productivity. Based on previous studies (Chavas et al. 2005, Yao and Li. 2010) and our data availability, we use two kinds of variables; input and output. As we only

Figure 1 Location of the study sites



calculate farm productivity changes, one output (farm output) and three inputs (cultivated land, labor for farming, farm investment) are considered. All these variables warrant a brief explanation as follows:

Farm output: farm output includes the value of self-consumed and marketable products such as crop production and timber stock products. Furthermore, the subsidy from participating SLCP is also included because it is also related to agricultural management.

Farmland input: we chose the farmland that produces an income from crops rather than the total farmland as it is a more accurate reflection of the farmer's real input from his farmland. Of course, the sloping land before converting into forest is also included.

Farming labor: the labor expended by the household on mainly crop production. We exclude the labor force engaged in other farm activities, which are less relevant to this study. Furthermore, we only consider labor aged 16 to 65 years.

Production cost: the sum of expenditures on fertilizers, manure, crop coversheets, seeds and mechanical tillage.

The market prices vary depending on the time and location, which causes a problem when counting household-level price data (Gibson and Rozelle 2005). However, according to the "law of one price", all farm households face the same prices within a specific year and within a specific region, so the differences in price only reflect quality differences (Deaton 1998, Deaton 1990). Therefore, by dividing the values of these goods with corresponding province-level price index, we can calculate quality-adjusted quantity indices for the inputs and outputs. All the products are aggregated using 1995 constant prices.

5. Heterogeneous Effect on Farm productivity

In previous studies, it was found that the Grain for Green program led to an increase in farm productivity in specific regions, although they do not indicate whether the program increases farm productivity in the whole Loess Plateau region or which types

Table 1. Descriptive statistic of input and output variables in farm production, averaged in year 1998, 2006 and 2009

Variable		Unit	Wuqi		Dingbian		Huachi	
			Mean	S.D.	Mean	S.D.	Mean	S.D.
Output	Farm output	CNY	2357.3	3334.4	9556.7	17879.8	3439.5	4036.7
Inputs	Farmland	Mu	11.6	6.7	43.6	35.0	18.3	13.5
	Farming labor	Number	2.3	1.3	2.4	1.1	2.0	1.0
	Production cost	CNY	1504.6	3155.1	4860.1	10851.3	2406.4	4937.6

Note: 15 Mu = 1 hectare, and 1 US dollar=8.349 CNY in 1995. Standard Deviation are reported in parentheses below the Mean of each variables.

of farm household benefit more from this policy intervention. It is of great interest for policy makers to know why these changes occur. Therefore, the aim of this study is to determine whether the SLCP has heterogeneous effects on farm productivity among different regions and income groups. We firstly calculate the farm productivity and its components based on non-parametric technology (DEA) combined with the MPI method as we mentioned above.

5.1 Regional Heterogeneous Effect

The results in table 2 illustrate how farm productivity and its components changed from 1998 to 2006 and from 2006 to 2009 by regions. We find that among the three counties, the farm TFP in Wuqi County increased by 65.6% during the period 1998-2006, which is more than in Dingbian or Huachi County where farm production TFP increased by 24.7% and 6.7% respectively.

The results show that after the SLCP, all three counties experienced an improvement in farm productivity; however the rate of growth in the TFP is distinct among the three counties. To further understand the effect of the program on farm household productivity, it is necessary to examine the decomposition of TFP change, which is also interesting. The growth in the TFP is derived from both technological change (TC) and technical efficiency (TE). As we can see from table 2, the growth in the TFP in Wuqi is affected by both TC (22.1%) and TE (35.7%), while in the other two counties, only TC (14.6% and 24.7%) contributes to the farm productivity changes.

During the period 2006-2009, the growth rate of the TFP in Wuqi was still the highest (33.2%) of the sample regions, while the TFP in the other two only increased slightly (5.3% in Dingbian County and 7.8% Huachi County). On the other hand, TC increased continuously, which contributed to the continuous growth in the TFP. Compared with the other two counties, Huachi experienced the lowest TE growth rate, whereas the TC growth rate experienced a significant increase (42.7%) which was three times more than in the first period.

The results in this section show that the SLCP led to an increase in farm productivity, which suggests that economic growth and ecological recovery may be achieved at the same time. As we may conclude from Table 2, the growth in the TFP came mostly from the improvement in technical efficiency, especially during 2006-2009 when the TE decreased dramatically. At the same time as the reduction in farmland, the growth in the TFP implies that the use of farm inputs (e.g. fertilizer, improved seeds, and cover sheets) may become more intensive. Furthermore, livestock production might be promoted even though the outputs of crops were hit hard.

We also find that the SLCP had a heterogeneous effect on farm productivity in different regions; the TFP growth in Wuqi was consistently greater than in the other counties. Based on the interviews during our field work, cropping patterns in Wuqi changed from extensive to intensive, households increased production investments, and the land use structure was optimized during this period. Besides, the local government played an important role in the implementation of the SLCP.

Table 2. Farm productivity and its components in different counties in period 1998-2006 and 2006-2009

		2006-2009		
year	counties	TC	TE	TFP
1998-2006	Wuqi	1.357	1.221	1.656
	Huachi	1.146	0.931	1.067
	Dingbian	1.247	1.000	1.247
2006-2009	Wuqi	1.454	0.878	1.332
	Huachi	1.427	0.797	1.078
	Dingbian	1.190	0.828	1.053

5.2 Heterogeneous Effect in Liquidity

To gauge the relationship between the affluence of households and their farm productivity change, we divide the entire sample into three sub-groups (Low-income, Medium-income and High-income) according to the households' average monetary income in the year 1998, which is prior to program implementation.

The monetary income is dened as disposable cash income, which includes annual income from not only farm production, but also off-farm employment, since Haggblade et al., (1989) argued that access to off-farm income can help stimulate farm investments and improve agricultural productivity through relaxing the credit constraint (e.g. remittance received from part-time family labor). However, the income excludes the consumption of own produce and irregular receipts.

As we can see from the table, during the period 1998-2006, the TFP in of the Low-income group decreased (30.7%), but with regards to the Medium-income group and High-income group the TFP increased by 39.0% and 32.4% respectively. The reduction in the TFP for the Low-income group was significantly reduced by the decrease in the TE, while the TC increased 111.8% which was much more than that of the other two groups (55.1% and 61.7%). For the Medium-income group and High-income group, the growth in the TFP was due to the increase in TC. From 2006 to 2009, only the High-income group experienced an increase in the TFP, while the other two groups did not show much difference (-5.7% and -2.8%).

This result indicates that the SLCP contributed to farm TFP growth of the High-income group more than that for the other two groups. Especially for the Low-income group, the low technical efficiency suggests that they should consider no longer focusing on the farm production , but shift to non-farm work by relaxing the liquidity constraint (Uchida et al. 2009). The Medium-income group took effective measures at the initial state, but the measures did not last long, which may have been caused by the reduction in the payment in the period of the second contract. These findings shed light on policy making and indicate that more attention should be paid to Low-income farm households. Besides, measures should be taken to improve the TE of farm production.

6. Conclusion and discussion

This study has presented an economic analysis of farm productivity heterogeneity in different regions and income groups affected by the implementation of the SLCP. Using the non-parametric Malmquist index

Table 3. Farm productivity and its components in different income-groups in 1998-2006 and 2006-2009

Period	Groups	TC	TE	TFP
1998-2006	Low-income	2.118	0.395	0.693
	Med-income	1.551	0.978	1.390
	High-income	1.617	0.874	1.324
2006-2009	Low-income	1.399	0.709	0.943
	Med-income	1.448	0.699	0.972
	High-income	1.246	1.076	1.528

method, we calculated the farm productivity of households in Wuqi, Huachi and Dingbian counties in the Loess Plateau region.

The results clearly show that the SLCP increased farm productivity in all three counties with technical efficiency contributing most regarding TFP growth. Moreover, the SLCP does indeed have heterogeneous effects on the TFP changes among different regions, which corresponds to our hypothesis. This suggests that the TFP changes may also be related to the extra support, for instance, the improvement in farming infrastructure and financial policy regarding farming credit. The heterogeneous effect on farm productivity is also found among different income groups. Implementing the SLCP has caused a decline in the farm productivity of the Low-income group, but it has contributed to an increase in the farm productivity of the High-income group. The substantial growth in the TFP for the High-income group is mostly derived from the improvement in technical efficiency. This result demonstrates that the high-income households have more interest in optimizing farm production by increasing farm investments and balancing farming between crop and animal production. In sum, we find that, on average, the SLCP has a positive effect on farm productivity; however, heterogeneous effect should be taken into account when a new round of this program or a similar program is launched in the future. Besides, in order to achieve long-run success, policymakers may need to provide increased technology training for farm households.

Reference

Asmild M, Paradi JC, Aggarwall V, Schaffnit C (2004) Combining DEA Window Analysis with the Malmquist Index Approach in a Study of the Canadian Banking Industry. Journal of Productivity Analysis 21(1):67-89.

Banker RD, Charnes A, Cooper WW (1984) Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. Management Science 30:1078-1092.

Battese GE,Coelli TJ(1992) Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India. Journal of Productivity Analysis3:153-169.

Bennett MT (2008) China's sloping land conversion program: Institutional innovation or business as usual? Ecol Econ65:699-711.

Caves DW, Chrestensen LR,Diewert WE(1982) The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity. Econometrica 50:1393-1414.

Chavas J, Petrie R, Roth M (2005) Farm Household Production Efficiency: Evidence from the Gambia, American Journal of Agricultural Economics 87(1)160-179.

Charnes A, Cooper WW., Rhodes E (1978) Measuring the efficiency of decision making units. Eur J Oper Res 2:429-444.

Coelli TJ,Rao DSP(2005) Total factor productivity growth in agriculture :a Malmquist index analysis of 93countries,1980-2000.Agricultural Economics 32:115-134.

Coelli TJ,Rao DSP,O'Donnell CJ,Battese GE(1998) An introduction to efficiency and productivity analysis. London: Kluwer Academic Publisher.

Deaton A (1990) Price elasticities from survey data: Extensions and Indonesian results. J Econ 44:281-309.

Deaton A (1998) Quality, Quantity, and Spatial Variation of Price. The American Economic Review 78(3):418-430.

Deaton A (1997) The Analysis of Household Surveys: A Microeconomic Approach to Development Policy. Baltimore and London: The Johns Hopkins University Press.

Färe R, Grosskopf S, Lindgren B,Roos P(1992) Productivity changes in Swedish pharamacies 1980-1989: A non-parametric Malmquist approach. Journal of Productivity Analysis 3:85-101.

Färe R, Grosskopf S, Lindgren B,Roos P(1994) Productivity Developments in Swedish Hospitals: A Malmquist Output Index Approach. Data Envelopment Analysis: Theory, Methodology, and Applications a!: 253-272.

Färe R, Grosskopf S,Roos P (1998)Malmquist Productivity Indexes: A Survey of Theory and Practice. Index Numbers: Essays in Honour of Sten Malmquist: 127-190.
Färe R, Primont D (1994) Multi-output production and duality: theory and applications, Springer.

Feng Z, Yang Y, Zhang Y, Zhang P, Li Y (2005) Grain-for-green policy and its impacts on grain supply in West China. Land Use Policy 22:301-312.

Gribson J, Rozelle S(2005) Prices and Unit Values in Poverty Measurement and Tax Reform Analuysis. World Bank Economic Review 19(1):69-97.

Grifell-Tatjé E, Lovell CAK(1993) Anew decomposition of the Malmquist productivity index, Department of Economics, University of North Carolina.

Grifell-Tatjé E, Lovell CAK(1995) A note on the Malmquist productivity index. Economics Letters47:169-175.

Guo Xiaonian, Ruan Ping (2014) Evaluation and Convergence Analysis of Agricultural Production Efficiency in the Western Reforestation Area in China: Based on Zhijin County in Guizhou Province. Finance Science 1:114-124 (in Chinese).

Haggblade S, Hazell P, Brown J (1989) Farm-nonfarm linkage in rural sub-Saharan Africa. World Dev17:1173-1201.

Krugman P (1993) On the number and location of cities. Eur Econ Rev37:293-298.

Landell-Mills N,Porras I(2002) Silver Bullet or Fools' Gold? A Global Review of Markets for Forest Environmental Services and their Impact on the Poor, Russell Press.

Leonard, H.J. (1989) Environment and the poor: Development strategies for a common agenda. New Brunswick, NJ: Transcation Books.

Li Hua, Yao Shunbo, Guo Yajun (2011) An Empirical Analysis of Different Conversion land Scale's Impact on Agricultural TFP: Based on household survey data in the Loess Plateau. Chinese Rural Economy 10:35-43 (in Chinese).

Liu Z, Henningsen A (2014) Estimating the Effects of Sloping Land Conversion Program on the Agricultural Household Behaviors, Working paper, University of Copenhagen.

Lovell CAK (1996) Applying efficiency measurement techniques to the measurement of productivity change. Journal of Productivity Analysis 7:329-340.

Scherr S, White A, Khare A (2003) Current Status and Future Potential of Markets for Ecosystem services of Tropical Forests: An Overview. Paper Prepared for the International Tropical Timber Organization.

SFA (2003) China Forestry Development Report, China Forestry Publishing House.

Townsend RF, Kirsten J, Vink N (1998) Farm size, productivity and retuns to scale in agriculture revisited: a case study of wine producers in South Africa. Agricultural Economics 19:175-180

Uchida E., Rozelle, S.. & Xu,J (2009). Conversion payments, liquidity constraints, and off-farm labor: Impact of the grain-for-green program on rural household in china. American Journal of Agricultural Economics.91 (1).70-86.

World Bank (1992) World development report 1992: development and the environment. New York: Oxford University Press.

Xu JT, Yin RS, Li Z, Liu C (2006) China's ecological rehabilitation: unprecedented efforts, dramatic impacts and requisite policies. Ecological Economics 57:595-607.

Xue Caixia,Yao Shunbo, Yu Jinna (2013) The technology efficiency analysis of the Participations of the Sloping Land Conversion Program based on latent category Stochastic Frontier Model – an example from Ya'an City, Sichuan. Chinese Rural Economy 5:12-23.

Yao SB, Li H (2010) Agricultural Productivity Changes induced by the Sloping Land Conversion Program: An Analysis of Wuqi County in the Loess Plateau Region. Environmental Management 4:541-550.

Yin RS (2000) Alternative Measurements of Productive Efficiency in the Global Bleached Softwood Pulp Sector. Forest Science 46(4):558-569.

Yu JN, Yao SB (2009) the Sloping Land Conversion Program's impact on productivity: take Wuqi county as an example. Issues of Forestry Economics 29:434-437 (in Chinese).

Zhen Liu, Jing Lan (2015)The Sloping Land Conversion Program in China: Effect on the Livelihood Diversification of Rural Households. World Development 70:147-161.

Zuo T (2002) Implementation of the SLCP. In J. Xu, E. Katsigtis, & T.A. White (Eds), Implementing the natural forest protection program and the sloping land conversion program: Lessions and policy implications. CCICED-WCFGTF, Beijing: China Forestry Publishing House.