Policy reforms, rice production and sustainable land use in China: A macro-micro analysis

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Abstract

This paper presents a macro-micro analysis of the impact of policy reforms on agricultural production, input use and soil quality change for a major rice-producing area, namely Jiangxi Province. The paper starts with an overview of major policy reforms implemented in recent decades, from the introduction of the household responsibility system (HRS) at the end of the 1970s to the rural income support policy introduced in 2004. It is followed by a quantitative assessment of the impact of market liberalization policies on the economic environment of farm households in Jiangxi Province. Econometric analyses based on provincial, national and world market data are used to explain changes in agricultural input and output prices in Jiangxi Province over time. Next, the impact of China’s recent income support policy and recent price trends on farm household choices with respect to activity choice (particularly rice and livestock) and input use (fertilizers, pesticides, manure) is assessed for two villages with different degrees of market access in Northeast Jiangxi Province. Two village-level general equilibrium models are used to analyse household decision making and interactions between households within these villages. The parameters are estimated and calibrated from an extensive survey held in these villages in the year 2000. Finally, the impact of land tenure policy on farm management decisions (labour, manure and chemical input use), soil quality (available P and K and total N and C) and rice yields is analysed through an econometric analysis of plot-level data for three villages. Two-stage least squares (2SLS) is used to control for interactions with yields

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and for feedbacks towards input use. The main conclusions drawn from the analysis are:

• The world market price has become the main determinant of the prices of grain in Jiangxi Province and in China since 1994.
• The profitability of fertilizer application in Chinese agriculture has increased considerably during the 1990s, particularly in Jiangxi Province.
• Recent grain price increases seem to aggravate agriculture related environmental problems in Northeast Jiangxi Province.
• The grain price increases since the second half of 2003 have a much larger effect on farm household incomes and production decisions than the direct income subsidy and (to a lesser extent) the abolition of the agricultural tax.
• The recent rural income support policy does not reach its goal of promoting grain production. It reaches the goal of reducing income inequality only within villages, not between villages.
• Consolidating small, fragmented plots into a smaller number of large plots will increase input-use efficiency contributes to soil quality improvement by increasing the availability of the two major yield-limiting factors in rice production in the research area, the available phosphorus and potassium in the soil.

Keywords: Market policy; Rural income policy; Land tenure; Price changes; Input use; Soil quality; Village economy; Household responses

1. Introduction

Economic and institutional reforms implemented in China since the end of 1970s have caused an impressive growth of agricultural production. In several regions, however, this growth was obtained at the expense of the quality of land or other natural resources, and future agricultural growth is seriously threatened. Government policies aimed at controlling resource degradation are largely based on direct regulation and large-scale public projects. With the policy reforms, however, resource use decisions have largely been transferred to households. This raises the question to what extent farm household responses to the ongoing economic and institutional policy reforms contribute to resource degradation, and how policies may be shaped to promote sustainable resource use in Chinese agriculture.

The objective of this paper is to assess the impact of recent policy reforms on agricultural production, input use and soil quality change for a major rice-producing area in China, namely Jiangxi Province. It focuses on how these policies shape the
economic and institutional environment that farmers are facing, and how farmers’
decisions on production activities and input use are affected by changes in their
environment. Three sets of policies will be examined: market liberalization policies,
rural income support policies, and land tenure policies. Three different levels of
analysis will be used for examining the impact of these policies on farm household
behaviour and soil quality. We start with an econometric analysis of province, national
and world market data to assess the impact of market liberalization policies on the
economic environment of farm households in Jiangxi Province. Next, two village-level
models are used to assess the impact of China’s recent income support policy and
recent price trends on farm household incomes, production activity choices and input
use levels. Finally, we use household and plot-level data for three villages in Jiangxi
Province to make an econometric analysis of the impact of the prevailing land tenure
policy on farm management decisions, soil quality and rice yields.

The focus of this paper is on Jiangxi Province. Although it is located in the
Southeast of China, not far away from the country’s centres of economic growth,
Jiangxi is one of China’s poorest provinces. In 2002, its per capita GDP equalled 5,829
RMB (= $705) or 71% of the national per capita GDP (source: NBS, 2003). Its
economy is dominated by agricultural production. In 2002, 76% of its population was
classified as rural. It has 3.0 mln ha of cultivated land, with 1.9 mln ha of effective
irrigated land. Jiangxi is one of China’s main grain producing areas, with rice as the
major crop. Of the total sown area, 52% is planted with rice. Rice yields equalled
5,209 kg per ha in 2002, while fertilizer consumption amounted to 376 kg ha⁻¹ (NBS,
2003). More than 20% of the land in Jiangxi Province is affected by soil erosion,
causing siltation of rivers and reservoirs, ecological environment deterioration and soil
productivity declines (Shi et al., 2000). Soil nutrient depletion is widespread, partly
due to the decreased planting of green manure and the declining use of manure, partly
because of soil erosion (Guo, 1994; Kuiper et al., 2001; Wei, 1999). Because most
farm households are planting (applying) less and less green manure (manure), much
land has declined in soil nutrient contents and experienced worsening soil physical
properties (natural compaction). Soil acidification is also a matter of concern in some
areas of Jiangxi Province. It may be induced by soil erosion, but may also be caused
by improper applications of fertilizers (Fu and Wan, 2000; Wei, 1999).

Each of the three levels of analysis will be discussed in separate sections below.
Before that, however, we start with a brief overview of the reforms in economic policy
in China since the end of the 1970s that will serve as a background for our analyses.
2. Economic Policy Reforms: A brief overview

China’s economic policy reforms began in its rural area at the end of the 1970s. An important element of the agricultural reforms, besides shifting the responsibility for production decisions to the household level, was the price reform for agricultural products as part of the broader market liberalization process in China. The market liberalization in the agricultural sector was a complicated and meandering process. The central government objectives have been quite stable over time, but the priorities have varied as a result of changing socioeconomic conditions (OECD, 2005). Food security, defined as ensuring an adequate supply of food at affordable prices, is a top priority in policy making. Grain self-sufficiency is traditionally seen at the key to achieving food security. Until the early 1990s, policy making not only focused on ensuring adequate food supplies, but also on ensuring that they were available at affordable prices. Since the end of the 1990s, the growing rural-income gap has become an important policy issue. As a result, the policy focus shifted towards raising agricultural incomes in combination with maintaining adequate food supplies (Gale et al., 2005; OECD, 2005). Policies with respect to agricultural marketing since the end of the 1970s can roughly be divided into three main stages (see e.g. Fan and Cohen, 1999; Heerink and Spoor, 2003; Zhu and Zhong, 2001; OECD, 2005).

The first stage was from 1979 to 1984. Reform measures centered on improvements of cost calculation and adjustments of controlled prices. The prices of 18 agricultural product groups, such as grain, oil-bearing crops, and pork, were increased from 1979 onwards to encourage the development of agriculture. A small part of the production, the above-quota production, could be sold at higher but controlled prices.

During the second stage, from 1985 to 1993, the focus shifted to decontrol of prices. The most important agricultural products (such as grain, oil-bearing crops, pork) faced a dual price system, while other products (such as fruit and aquatic products) were sold at market prices. The dual price system, introduced in 1985, consisted of a fixed price for the planned delivery quota and a market price (or negotiated contract price) for surplus production exceeding the quota. To stimulate farmers to increase productivity and sell to the government, contract prices were raised over time. In 1993, procurement quotas were reduced and in some regions fully eliminated. Most agricultural products were sold through the market with a floating price.

The third stage started in 1994. In that year, the government procurement system was re-introduced for grain. Procurement prices, which had been brought closer to the world market prices since 1992, were even raised above world market prices in order to stimulate farmers to shift production from cotton and oil-bearing crops to grain. Export and storage of grain was subsidized. To promote regional food security and
stabilize food prices, the Governor’s grain bag responsibility system was implemented. It made provincial governors and governments responsible for balancing supply and demand of grains and edible oils in their own provinces, for stabilizing grain and edible oil prices, and for achieving 95% grain self-sufficiency within their province (Colby et al., 1997). In 1998, only state-owned grain enterprises were allowed to purchase surplus grain in rural areas; private merchants and private enterprises were prohibited from engaging in grain trade. Since then, government agencies remain the main purchaser of grains while diversifies market channels are available for other agricultural products (OECD, 2005).

The last stage started in 2004. The costly policy of subsidizing grain procurement, storage and exports was replaced by a policy aimed at directly promoting grain production and raising farm incomes and more in line with World Trade Organisation (WTO) regulations. State pricing and state procurement were abolished, except for tobacco. Agricultural taxes were cut, and even fully abolished in a few provinces. They should be eliminated in all provinces in three years time. Since 2004, farmers growing grains receive a direct income subsidy based on the land area cultivated with rice, wheat or maize. In addition, high-quality grain seeds and machinery are subsidized, public investments in rural infrastructure and agricultural research are raised considerably, the budget of the Ministry of Agriculture is increased substantially, land acquisition for urban and industrial use is limited, and off-farm employment opportunities are stimulated.

Most agricultural input markets and prices have also been liberalized since the 1980s, but the reform of the fertilizer market and prices has only been partial (Huang, 1997). Attempts to lift fertilizer price controls at the retail level led to rapid price increases. To deal with this problem, a provincial responsibility system aimed at meeting excess input demand and stabilizing prices was implemented in 1995. In addition, measures were taken to limit private enterprise involvement in domestic fertilizer distribution and to control fertilizer imports. China is the world’s largest producer of fertilizers, but about one quarter of China’s fertilizer requirements is imported. In 1999, state production and procurement plans for fertilizers were abolished and state-set prices were replaced by state-guided prices that are intended to protect fertilizer producers and consumers from excessive price fluctuations (OECD, 2005).

Macroeconomic and foreign trade policies can also have important implications for the economic environment of farm households. Since the start of the economic reforms, China’s foreign trade regime has gradually changed from a highly centralized, plan-based, import-substitution regime to a more decentralized, market-based, export-promotion regime (Heerink and Spoor, 2003; Huang, 2002; OECD,
Due to their strategic importance, however, trade in food grains, textiles, fiber, and chemical fertilizers still remain largely monopolized. China’s average import tariff on agricultural products was reduced from 45% in 1992 to 15% in 2004 (OECD, 2005).

Historically, export incentives were reduced by the overvaluation of China’s currency, the RMB. Since the 1980s, the degree and extent of this distortion decreased as a result of exchange rate adjustments. Between 1980 and 1996 the exchange rate changed from 1.50 RMB per US$ to 8.62 RMB per US$ (while the domestic consumer price index increased by almost 400% during the same period), and remained at a level of around 8.30 RMB per US$ since then. Public control of foreign exchange has been relaxed, and by December 1996 the RMB became convertible on the current account. The system of managed floating is used since 1994 to maintain the exchange rate at its current level (Huang, 2002).

3. Impact of economic policy reforms on the economic environment of farm households

In this section, we use regression analysis to examine the impact of the policy reforms on prices of grain and fertilizer in Jiangxi Province since 1980. This is done in two steps. First, the impact of world market prices on national prices is examined. Dummy variables are used to examine differences between the different stages of the economic reforms. The results indicate the extent to which world market prices affected national prices during different reform periods, taking into account the adjustments that were made to the exchange rate. In the second step, the relation between national prices and regional prices within Jiangxi Province is examined. Different reform periods are again distinguished through the use of dummy variables. The results show the extent to which grain and fertilizer prices in Jiangxi Province were determined by national policies or by internal supply and demand factors and policies within Jiangxi Province during different periods.

Time-series data from 1981 to 2000 on grain and fertilizer prices in Jiangxi Province and in China as a whole, and data on relevant explanatory variables for the same period have been collected from statistical yearbooks, such as China Statistical Yearbook, China Price Yearbook, Jiangxi Statistical Yearbook, etc. Data on world market prices and the official exchange rate over the same period are obtained from IMF, International Financial Statistics (online version). The Durbin-Watson test is used to test for serial correlation. If the test result is positive, a first-order autoregression term AR(1) is added to the regression equation.

No separate information on rice prices is available. In Jiangxi Province, however,
the area sown with rice constitutes 87.4% of the area sown with grain (including soybeans) (NBS, 2003). Fig. 1 shows the changes over time of the retail grain price index in Jiangxi province and in China. The two series have been corrected for inflation by the consumer price indices for Jiangxi Province and China, respectively. The figure shows that both prices remained roughly constant during the 1980s, increased rapidly between 1991 and 1996, and then declined slightly until 2000. Between 1991 and 1996, the grain price in Jiangxi Province increased more rapidly than the grain price for China as a whole.

To examine the impact of economic policy on the real grain price in Jiangxi, first the impact of the world market price on the grain price for China is examined. The following model is used for that purpose:

\[ PGRAINC = c_0 + c_1 \text{PRICEW} + c_2 \text{DUM2} \times \text{PRICEW} + c_3 \text{DUM3} \times \text{PRICEW} + u \]  

(1)

where:
- \( PGRAINC \): Real market price of grain in China (1981 = 100)
- \( \text{PRICEW} \): Real world market price of rice (Thai white rice) in RMB (1981 prices; official exchange rate) per metric ton.
- \( \text{DUM2} \): Dummy variable reflecting second stage of grain market reform (= 1 for 1985 - 1993)
- \( \text{DUM3} \): Dummy variable reflecting third stage of grain market reform (= 1 for 1994 - 2000)
- \( u \): Error term with standard properties
- \( c_0 \): Constant
- \( c_1, c_2, c_3 \): Unknown coefficients.

Since rice constitutes the largest share of grain produced in China, the world market price for rice is used as the explanatory variable. It is multiplied by dummy variables reflecting the second and third stages of the grain market reform, respectively, to estimate whether the impact of the world market price differs between the three stages. All three coefficients are expected to be positive, with the strongest impact of the world market price expected for the last period.

The regression results are reported in the column titled ‘full equation’ in Table 1. The column titled ‘final equation’ reports the results when only the significant variable(s) and the constant are included in the regression equation. As expected, the world market price of rice has a significant positive impact on the domestic grain price for the period 1994–2000. Before 1994, however, the world market price did not have a significant impact on the domestic price. Because data on the domestic grain price is
given as an index number, it is unfortunately not possible to examine whether or not the domestic price exceeded the world market price during the three periods.

Fig. 1. Real grain prices (1981=100), Jiangxi Province and China.

Table 1. Regression results for grain price, China.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Expected impact</th>
<th>Full equation</th>
<th>Final equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td></td>
<td>96.8*** (7.92)</td>
<td>97.7*** (43.7)</td>
</tr>
<tr>
<td>PRICEW</td>
<td>+</td>
<td>0.001 (0.04)</td>
<td></td>
</tr>
<tr>
<td>DUM2*PRICEW</td>
<td>+</td>
<td>0.001 (0.11)</td>
<td></td>
</tr>
<tr>
<td>DUM3*PRICEW</td>
<td>+</td>
<td>0.077*** (9.03)</td>
<td>0.077*** (13.3)</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>Adj. R²</td>
<td></td>
<td>0.89</td>
<td>0.90</td>
</tr>
<tr>
<td>F</td>
<td></td>
<td>52.6</td>
<td>177</td>
</tr>
<tr>
<td>No of observations</td>
<td></td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td></td>
<td>2.05</td>
<td>2.04</td>
</tr>
</tbody>
</table>

Notes: t-statistics are between brackets.
* = Significant at 10% testing level.
** = Significant at 5% testing level.
*** = Significant at 1% testing level.
Next, we examine the impact of the national grain price in China on the price in Jiangxi Province. The following model is used for that purpose:

\[ \text{PGRAINJ} = c_0 + c_1 \text{DUM2} + c_2 \text{DUM3} + c_3 \text{PGRAINC} + c_4 \text{DUM2} \times \text{TPGRAINJ} + c_5 \text{DUM2} \times \text{YPCJ} + c_6 \text{DUM3} \times \text{TPGRAINJ} + c_7 \text{DUM3} \times \text{YPCJ} + u \]  

(2)

where:

- \( \text{PGRAINJ} \): Real market price of grain in Jiangxi Province (1981 = 100)
- \( \text{PGRAINC} \): Real national market price of grain in China (1981 = 100)
- \( \text{DUM2} \): Dummy variable reflecting second stage of grain market reform (= 1 for 1985–1993)
- \( \text{DUM3} \): Dummy variable reflecting third stage of grain market reform (= 1 for 1994–2000)
- \( \text{TPGRAINJ} \): Total production of grain in Jiangxi Province (in 10,000 tons)
- \( \text{YPCJ} \): Real GDP per capita in Jiangxi Province (1981 = 100)
- \( u \): Error term with standard properties
- \( c_0 \): Constant
- \( c_1, \ldots, c_7 \): Unknown coefficients.

The real grain price in Jiangxi is explained from the national grain price and a number of local demand and supply factors. Total grain production (the major supply factor) is expected to have a price-depressing effect, while per capita income (the major demand factor) is expected to boost grain prices. Again, these two variables are multiplied by dummy variables reflecting the second and third reform period, respectively, to estimate whether the impact of demand and supply factors differed between these two reform periods. The regression results are shown in Table 2.

As expected, the national price is a major determinant of the grain price in Jiangxi Province (see also Fig. 1). Domestic supply and demand factors in Jiangxi Province, however, also played an important role during the second stage of the grain market reform. Apparently, these domestic factors were responsible for the above-average increase in the real market price of grain in Jiangxi Province during the period 1985-94 that is evident from Fig. 1. During the third period of grain market reform, supply and demand factors within Jiangxi Province no longer significantly affected the real prices.

The policy reforms affected fertilizer prices as well. As mentioned in Section 2, a provincial responsibility system aimed at meeting excess demand for chemical fertilizers and stabilizing prices was implemented in 1995. In addition, measures were taken to limit private enterprise involvement in domestic fertilizer distribution and to control fertilizer imports. Price controls have gradually been relaxed since 1999. The evolution of real fertilizer prices since 1981 is shown in Fig. 2. Prices fluctuated until
Table 2. Regression results for grain price, Jiangxi Province.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Expected impact</th>
<th>Full equation</th>
<th>Final equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>6.25 (0.50)</td>
<td>9.38 (1.01)</td>
<td></td>
</tr>
<tr>
<td>DUM2</td>
<td>66.6* (1.79)</td>
<td>71.1* (2.13)</td>
<td></td>
</tr>
<tr>
<td>DUM3</td>
<td>28.4 (1.04)</td>
<td>34.5*** (6.71)</td>
<td></td>
</tr>
<tr>
<td>PGRAINC</td>
<td>+ 0.91*** (7.08)</td>
<td>0.89*** (9.33)</td>
<td></td>
</tr>
<tr>
<td>DUM2*TPGRAINJ</td>
<td>-0.05** (−2.07)</td>
<td>−0.06** (−2.49)</td>
<td></td>
</tr>
<tr>
<td>DUM2*YPCJ</td>
<td>+ 0.02*** (4.69)</td>
<td>0.02*** (5.65)</td>
<td></td>
</tr>
<tr>
<td>DUM3*TPGRAINJ</td>
<td>0.00 (0.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DUM3*YPCJ</td>
<td>0.00 (0.50)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R²  0.99  0.99
Adj. R²  0.99  0.99
F  315  503
No of observations  20  20
Durbin-Watson  2.10  2.06

Notes: t-statistics are between brackets.
* = Significant at 10% testing level.
** = Significant at 5% testing level.
*** = Significant at 1% testing level.

Fig. 2. Real prices of fertilizer (1981=100), Jiangxi Province and China.
1994 in Jiangxi and in China, with fertilizer prices in Jiangxi at a relatively higher level between 1987 and 1993 as compared to the rest of China. From 1994 to 1995, fertilizer prices showed a sudden increase; since 1995, prices have declined continuously both in Jiangxi and in China as a whole.

World market prices on chemical fertilizers are available for urea, superphosphate, and potassium. Imports of urea dominated fertilizer imports in China until the mid-1990s, constituting 30–55% of total imports. Since 1997, however, urea imports have been negligible. The share of phosphate and potash fertilizers rapidly increased to 70–80% in 1997–2000 (source: FAO, FAOSTAT).

The model specification used for estimating the impact of world market prices on the national fertilizer price in China is as follows:

\[
PFERTC = c_0 + c_1 \text{PUREAW} + c_2 \text{PPHW} + c_3 \text{PKW} + c_4 \text{DUMF*PUREAW} + c_5 \text{DUMF*PPHW} + c_6 \text{DUMF*PKW} + u
\]  

(3)

where:

- \(PFERTC\): Real market price of chemical fertilizers in China (1981 = 100)
- \(PUREAW\): Real world market price of urea in RMB (1981 prices; official exchange rate) per metric ton.
- \(PPHW\): Real world market price of superphosphate in RMB (1981 prices; official exchange rate) per metric ton.
- \(PKW\): Real world market price of potassium in RMB (1981 prices; official exchange rate) per metric ton.
- \(DUMF\): Dummy variable reflecting the reform of the fertilizer market (= 1 for 1995–2000)
- \(u\): Error term with standard properties
- \(c_0\): Constant
- \(c_1, \ldots, c_6\): Unknown coefficients.

Two different periods are distinguished, the period of gradual reform of input markets, and the period since 1995 when the provincial responsibility system dominated the fertilizer market. The regression results for the impact of the three world market prices on the domestic price for these two periods are shown in Table 3.

The world market price of urea had a significant impact on the price of chemical fertilizers in China throughout the 1980s and 1990s. Since the mid-1990s, the world market price of superphosphate plays a role as well. No significant impact is found, however, for the world market price of potassium. The explanation for this finding is the high correlation (0.99) between \(\text{DUMF*PPHW}\) and \(\text{DUMF*PKW}\) which makes it impossible to estimate their separate effects on the domestic fertilizer price in China.
Table 3. Regression results for chemical fertilizer, China.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Expected impact</th>
<th>Full equation</th>
<th>Final equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>100*** (15.2)</td>
<td>96.7*** (8.25)</td>
<td></td>
</tr>
<tr>
<td>PUREAW +</td>
<td>0.05*** (3.18)</td>
<td>0.03*** (3.10)</td>
<td></td>
</tr>
<tr>
<td>PPHW +</td>
<td>−0.01 (−0.39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PKW +</td>
<td>−0.07 (−3.49)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DUMF*PUREAW</td>
<td>0.04* (1.77)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DUMF*PPHW</td>
<td>0.10** (2.57)</td>
<td>0.04*** (4.42)</td>
<td></td>
</tr>
<tr>
<td>DUMF*PKW</td>
<td>−0.18*** (−3.25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AR(1)</td>
<td>1.13*** (11.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.87</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>Adj. R²</td>
<td>0.80</td>
<td>0.76</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>14.0</td>
<td>20.5</td>
<td></td>
</tr>
<tr>
<td>No of observations</td>
<td>20</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>2.02</td>
<td>2.30</td>
<td></td>
</tr>
</tbody>
</table>

Notes: t-statistics are between brackets.
* = Significant at 10% testing level, ** = Significant at 5% testing level, *** = Significant at 1% testing level.

As a next step, we investigate the impact of the national fertilizer price on the price of fertilizer in Jiangxi. The following model is used for that purpose:

\[
PFERTJ = c_0 + c_1 DUMF + c_2 PFERTC + c_3 TPGRAINJ(-1) + c_4 TPFERTJ(-1) + \\
c_5 \text{DUMF*TPGRAINJ(-1)} + c_6 \text{DUMF*TPFERTJ(-1)} + u
\]  \hspace{1cm} (4)

where:

PFERTJ: Real market price of chemical fertilizer in Jiangxi Province (1981 = 100)

PFERTC: Real national market price of chemical fertilizer in China (1981 = 100)

DUMF: Dummy variable reflecting the reform of the fertilizer market (= 1 for 1995–2000)

TPGRAINJ(-1): Total production of grain in Jiangxi Province in preceding year (in 10,000 tons)

TPFERTJ(-1): Total production of pure fertilizers in Jiangxi Province in preceding year (in 10,000 tons)

u: Error term with standard properties

\(c_0\): Constant

\(c_1, \ldots, c_6\): Unknown coefficients.
Table 4. Regression results for chemical fertilizer, Jiangxi Province.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Expected impact</th>
<th>Full equation</th>
<th>Final equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>−462 (−0.01)</td>
<td>−21.2 (−1.610)</td>
<td></td>
</tr>
<tr>
<td>DUMF</td>
<td>71.4 (1.22)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PFERTC</td>
<td>+ 0.66*** (3.42)</td>
<td>1.00*** (8.17)</td>
<td></td>
</tr>
<tr>
<td>TPGRAINJ(-1)</td>
<td>+ 0.005 (0.34)</td>
<td>0.017** (2.03)</td>
<td></td>
</tr>
<tr>
<td>TPFEERTJ(-1)</td>
<td>− 0.76* (1.86)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DUMF*TPGRAINJ(-1)</td>
<td>−0.013 (−0.53)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DUMF*TPFERTJ(-1)</td>
<td>−1.36 (−1.47)</td>
<td>−0.21*** (−4.35)</td>
<td></td>
</tr>
<tr>
<td>AR(1)</td>
<td>1.00** (2.81)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.94</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td>Adj. R²</td>
<td>0.91</td>
<td>0.86</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>24.4</td>
<td>39.4</td>
<td></td>
</tr>
<tr>
<td>No of observations</td>
<td>18</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>1.92</td>
<td>1.62</td>
<td></td>
</tr>
</tbody>
</table>

Notes: t-statistics are between brackets.

* = Significant at 10% testing level, ** = Significant at 5% testing level, *** = Significant at 1% testing level.

Chemical fertilizer is used in Jiangxi mainly for producing rice. Total grain production in Jiangxi Province is therefore included in the equation as the main demand variable. To avoid causality problems, local demand and supply of fertilizer are lagged one year. Two periods are again distinguished with respect to fertilizer market reform, to examine whether the responsiveness of the fertilizer price to demand has changed since the implementation of the provincial responsibility system in 1995. The results are shown in Table 4.

The regression results, summarized in Table 4, indicate that local demand factors do play a role in determining the market price of chemical fertilizer in Jiangxi Province. Before the policy reform in 1995, local demand had a significant impact on the fertilizer price. Due to the high correlation (0.975) between DUMF*TPGRAINJ(-1) and DUMF*TPFERTJ(-1), however, it is not possible to determine whether local demand factors or supply factors (or both) caused the rapid decline in fertilizer prices at the end of the 1990s.

Fig. 3 shows the changes in the ratio of the fertilizer price to the grain price in Jiangxi Province and in China over the whole 1981–2000 period. Both ratios have declined significantly during the period 1990–94, and showed minor changes during the other years. Hence, the profitability of fertilizer application has increased
considerably since the beginning of the 1990s. The decline in Jiangxi Province was even larger than the decline in China as a whole, indicating that farmers in Jiangxi Province have profited relatively more from these price developments. At the end of the 1990s, the value of the price ratio was less than one half its value at the end of the 1980s. As can be seen from Figs 1 and 2, the major cause of this trend was the rapidly rising grain price in Jiangxi Province during the period 1990–94.

4. Household responses to economic policies

Changes in the economic environment of farm households can have a considerable impact on activity choice and the intensity of input use, and hence on the sustainability of land use. These household responses may depend to some extent on the degree to which a household and the village in which a household resides are integrated into the market. In this section, we use a village computable general equilibrium (CGE) model to assess household responses in a village in Northeast Jiangxi Province to recent price changes and to the new income support policy that was implemented in China in 2004 (see Section 2). The village is one of three villages where Nanjing Agricultural University (China) and Wageningen University (The Netherlands) organized an extensive household survey in the year 2000.

The selected villages are located in a soil degradation prone area in Jiangxi
Province. The main degradation problem in this area, according to local researchers and officials, is natural compaction of the soil due to the reduced used of organic and green manure. Soil erosion occurs in the dryland areas. A stratified sample, based on differences in market access, economic development level and geography, was used for choosing the villages (see Kuiper et al., 2001). Fig. 4 shows the location of the three villages. The selected villages are assumed to be representative of a much larger land degradation-prone area in Jiangxi and neighbouring provinces. A total of 339 households (23% of the population) were interviewed in these three villages.

Basic information on the three selected villages is presented in Table 5. Per capita income in the year 2000 was lowest in Shangzhu, the remote village: 1,042 RMB (= $126). Rice yields were also much lower in this village, about 80-85% of the yields in the other two villages. Fertilizer use in rice exceeds 1,000 kg per planted ha in Banqiao, the village with the highest rice yields. It is more than twice the fertilizer use per ha in Shangzhu. One-season rice dominates rice production in Shangzhu village,
Table 5. Characteristics of selected villages.

<table>
<thead>
<tr>
<th></th>
<th>Banqiao</th>
<th>Shangzhu</th>
<th>Gangyan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>220</td>
<td>472</td>
<td>930</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Good</td>
<td>Remote</td>
<td>Good</td>
</tr>
<tr>
<td>Upland/total land</td>
<td>60-70%</td>
<td>97%</td>
<td>Plain</td>
</tr>
<tr>
<td>Crops</td>
<td>Rice</td>
<td>Rice</td>
<td>Rice</td>
</tr>
<tr>
<td></td>
<td>Peanuts</td>
<td>Bamboo</td>
<td>Vegetables</td>
</tr>
<tr>
<td></td>
<td>Fruit</td>
<td>Bamboo shoots</td>
<td>Sugarcane</td>
</tr>
<tr>
<td>Irrigated land per household (mu)</td>
<td>5.53</td>
<td>5.06</td>
<td>6.06</td>
</tr>
<tr>
<td>Irrigated land / farmland</td>
<td>73%</td>
<td>86%</td>
<td>97%</td>
</tr>
<tr>
<td>One-season area / Total rice area</td>
<td>3.4%</td>
<td>71.6%</td>
<td>18.5%</td>
</tr>
<tr>
<td>Rice yield (kg/ha)</td>
<td>5,099</td>
<td>3,950</td>
<td>4,629</td>
</tr>
<tr>
<td>Fertilizer use in rice (kg/ha)</td>
<td>1,081</td>
<td>481</td>
<td>759</td>
</tr>
<tr>
<td>Income per capita (yuan)</td>
<td>1,720</td>
<td>1,042</td>
<td>1,854</td>
</tr>
<tr>
<td>Off-farm income share (%)</td>
<td>31.6</td>
<td>40.7</td>
<td>45.4</td>
</tr>
<tr>
<td>Tax payments per household (yuan)</td>
<td>446</td>
<td>227</td>
<td>492</td>
</tr>
<tr>
<td>Tax / household income (%)</td>
<td>5.8</td>
<td>5.0</td>
<td>5.9</td>
</tr>
</tbody>
</table>

whereas the other two villages grow mainly two-season rice. Off-farm incomes are an important share of household incomes, ranging from 32% to 45% in the three villages. Agricultural tax (and village and township fees) payments make up 5%–6% of total household incomes.

To analyse the impact of recent price changes and farm income support policy, simulations are made with a village-level CGE-model which allows for simultaneous decision making on production, consumption and labour supply by farm households. The model integrates standard features in household modelling into a village-level general equilibrium model. Four household groups are distinguished, based on the available resources for earning agricultural income and/or off-farm income. The basic structure of the model is shown in Fig. 5. Three commodity groups are distinguished:
• Tradables: Are traded outside the village; their prices are exogenous to the village.
• Village nontradables: Are traded only within the village; their prices depend on demand and supply within the village.
• Household nontradables: Are not traded; their (shadow) prices depend on demand and supply of the household.

The model is applied to two villages: The village located in a plain, and also happens to be the largest of the three villages (Gangyan) and the village located in mountainous land (Shangzhu). Irrigated land, agricultural labour and traction services are village nontradables, while non-irrigated land, manure and crop residues are household non-tradables. In Shangzhu, fuel wood, and forest land are also household nontradables. All the other commodities are tradables.

Data from the year 2000 household survey held in these two villages is used for determining the tradability of commodities, classifying households, estimating the elasticities used in the model and for calibrating the two models. Household classification is based on the availability of resources for earning agricultural income (draught power: oxen, tractor) and the availability of resources for earning off-farm income (Gangyan: availability of contacts outside the province; Shangzhu: number of educated household members).

![Fig. 5. Basic structure of the village CGE-model.](image-url)
Table 6. Description of scenarios used in village model simulations.

<table>
<thead>
<tr>
<th></th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price changes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000-2004</td>
<td>Rice: +36.6%</td>
<td>Rice: +36.6%</td>
<td>Rice: +36.6%</td>
</tr>
<tr>
<td></td>
<td>Pork: −2.8%</td>
<td>Pork: −2.8%</td>
<td>Pork: −2.8%</td>
</tr>
<tr>
<td></td>
<td>Fertilizer: +13%</td>
<td>Fertilizer: +13%</td>
<td>Fertilizer: +13%</td>
</tr>
<tr>
<td></td>
<td>CPI: +4.9%</td>
<td>CPI: +4.9%</td>
<td>CPI: +4.9%</td>
</tr>
<tr>
<td><strong>Income support</strong></td>
<td>10 yuan per mu</td>
<td>Full abolishment of</td>
<td></td>
</tr>
<tr>
<td><strong>policy</strong></td>
<td>planted with rice</td>
<td>agricultural tax and fees</td>
<td></td>
</tr>
</tbody>
</table>

Three scenarios are run with the model. They are described in Table 6. The first scenario assesses the impact of price changes in the period 2000 till August 2004. Considerable price changes took place over that period in Jiangxi Province (and the rest of China). Rice prices initially declined somewhat, but increased rapidly since the autumn of 2003, resulting in a price increase of more than 35% over the entire period. Fertilizer prices also increased, but only by about 13%. This scenario simulates the impact of these price changes on household incomes, production levels and input use. The second and third scenario add the two main components of the rural income support policy, direct subsidies to grain farmers and agricultural tax cuts, to the price changes simulated in scenario 1. Farmers in Jiangxi Province received a subsidy of 10 yuan per mu for each plot of rice planted with early rice, late rice or one-season rice (Gale et al., 2005: Table 2). The impact of this direct income support policy is simulated in scenario 2. The other main component of the rural income support policy is the cut in agricultural taxes. Between 2001 and 2003, the agricultural tax, special product tax and a myriad of local taxes and fees were consolidated into a single standardized agricultural tax that is based on the normal production value of the land (Tuan et al., 2004; Gale et al., 2005).

The results for household income changes in the two villages are shown in Table 7. In both villages, the household groups that possess resources for off-farm employment but do not have agricultural resources gained substantially less than the other household groups. Since these are the richest groups in both villages, income inequality was reduced substantially by the price changes that occurred since 2000.

Table 8 shows the changes in production activities resulting from the price changes. In Gangyan, all four income groups expand their production of two-season rice at the expense of growing one-season rice, raising pigs and (to a lesser extent) other crops. Due to the intensification of rice cultivation, the demand for traction services goes up and as a result its price (because traction services is a village nontradable). This explains why the two household groups possessing oxen and tractors gain relatively...
Table 7. Income results for scenario 1 (price changes).

<table>
<thead>
<tr>
<th>Village</th>
<th>Household group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gangyan</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Link outside province:</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Income 2000 (yuan)</td>
<td>6,204</td>
<td>7,273</td>
<td>9,098</td>
<td>8,997</td>
</tr>
<tr>
<td></td>
<td>Increase Aug. 2004</td>
<td>27.0%</td>
<td>33.4%</td>
<td>11.8%</td>
<td>24.0%</td>
</tr>
<tr>
<td>Shangzhu</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Educated members</td>
<td>None</td>
<td>≥ 1</td>
<td>1 or 2</td>
<td>≥ 3</td>
</tr>
<tr>
<td></td>
<td>Income 2000 (yuan)</td>
<td>2,861</td>
<td>6,409</td>
<td>5,114</td>
<td>4,969</td>
</tr>
<tr>
<td></td>
<td>Increase Aug. 2004</td>
<td>21.1%</td>
<td>7.0%</td>
<td>24.6%</td>
<td>17.6%</td>
</tr>
</tbody>
</table>

Table 8. Production results for scenario 1 (price changes).

<table>
<thead>
<tr>
<th>Village</th>
<th>Household group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gangyan</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Link outside province:</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>One-season rice</td>
<td>−54</td>
<td>−72</td>
<td>−61</td>
<td>−73</td>
</tr>
<tr>
<td></td>
<td>Two-season rice</td>
<td>23</td>
<td>39</td>
<td>34</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>Other crops</td>
<td>−7</td>
<td>−9</td>
<td>−11</td>
<td>−11</td>
</tr>
<tr>
<td></td>
<td>Pigs</td>
<td>−51</td>
<td>−79</td>
<td>−46</td>
<td>−55</td>
</tr>
<tr>
<td></td>
<td>Traction services</td>
<td>18</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shangzhu</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Educated members</td>
<td>None</td>
<td>≥ 1</td>
<td>1 or 2</td>
<td>≥ 3</td>
</tr>
<tr>
<td></td>
<td>One-season rice</td>
<td>58</td>
<td>132</td>
<td>95</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>Two-season rice</td>
<td>4</td>
<td>−59</td>
<td>−53</td>
<td>−45</td>
</tr>
<tr>
<td></td>
<td>Other crops</td>
<td>−3</td>
<td>−4</td>
<td>−2</td>
<td>−22</td>
</tr>
<tr>
<td></td>
<td>Perennials</td>
<td>−69</td>
<td>−16</td>
<td>−83</td>
<td>−50</td>
</tr>
<tr>
<td></td>
<td>Pigs, chicken, dugs</td>
<td>−15</td>
<td>−48</td>
<td>−43</td>
<td>−43</td>
</tr>
<tr>
<td></td>
<td>Traction services</td>
<td>6</td>
<td>198</td>
<td>−5</td>
<td></td>
</tr>
</tbody>
</table>

Note: Data in table are percentage changes with respect to the base scenario.

more than the two other household groups. In Shangzhu, on the other hand, rice production is strongly dominated by one-season rice, and expanding two-season rice is apparently no option. The rapid price increase for rice therefore causes a very significant expansion of one-season rice cultivation at the expense of perennials and pigs (and small livestock). Traction services also expand in this village, but only for household group 3. That explains why the income increase is highest for this household group.
### Table 9. Input use results for scenario 1 (price changes).

<table>
<thead>
<tr>
<th>Village</th>
<th>Household group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gangyan</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Link outside province:</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Manure</td>
<td>−51</td>
<td>−22</td>
<td>−46</td>
<td>−27</td>
</tr>
<tr>
<td></td>
<td>Fertilizer</td>
<td>27</td>
<td>41</td>
<td>29</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Pesticides</td>
<td>26</td>
<td>33</td>
<td>22</td>
<td>31</td>
</tr>
<tr>
<td>Shangzhu</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Educated members</td>
<td>None</td>
<td>≥ 1</td>
<td>1 or 2</td>
<td>≥ 3</td>
</tr>
<tr>
<td></td>
<td>Manure</td>
<td>21</td>
<td>58</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Fertilizer</td>
<td>64</td>
<td>169</td>
<td>82</td>
<td>86</td>
</tr>
<tr>
<td></td>
<td>Pesticides</td>
<td>43</td>
<td>149</td>
<td>79</td>
<td>73</td>
</tr>
</tbody>
</table>

Note: Data in table are percentage changes with respect to the base scenario.

### Table 10. Income and production results for scenario 2 (price changes & direct income payment).

<table>
<thead>
<tr>
<th>Village</th>
<th>Household group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gangyan</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Link outside province:</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Household income</td>
<td>2.1</td>
<td>2.1</td>
<td>1.0</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>One-season rice</td>
<td>2.0</td>
<td>2.2</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Two-season rice</td>
<td>−0.3</td>
<td>−0.2</td>
<td>−0.1</td>
<td>−0.2</td>
</tr>
<tr>
<td></td>
<td>Other crops</td>
<td>0.3</td>
<td>0.2</td>
<td>−0.3</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Pigs</td>
<td>1.9</td>
<td>2.4</td>
<td>−0.3</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Traction services</td>
<td>0.0</td>
<td>0.0</td>
<td>&lt; 0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Shangzhu</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Educated members</td>
<td>None</td>
<td>≥ 1</td>
<td>1 or 2</td>
<td>≥ 3</td>
</tr>
<tr>
<td></td>
<td>Household income</td>
<td>1.6</td>
<td>0.7</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>One-season rice</td>
<td>−0.5</td>
<td>−0.1</td>
<td>−0.6</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Two-season rice</td>
<td>0.3</td>
<td>−1.6</td>
<td>1.3</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Other crops</td>
<td>0.9</td>
<td>0.6</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Perennials</td>
<td>−3.8</td>
<td>−0.1</td>
<td>1.0</td>
<td>−1.3</td>
</tr>
<tr>
<td></td>
<td>Pigs, chicken, dugs</td>
<td>1.3</td>
<td>−1.0</td>
<td>1.1</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Traction services</td>
<td>0.1</td>
<td>0.1</td>
<td>&lt; 0.0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Note: Data in table are percentage changes with respect to scenario 1 (price changes only).
The results for input use are shown in Table 9. The intensification of rice cultivation in Gangyan also means that substantially more fertilizers and pesticides are used by all household groups, while the use of manure is drastically reduced. In Shangzhu, the large increase in one-season rice cultivation causes an even larger increase in fertilizer and pesticides use than in Gangyan. And, in contrast to Gangyan, the amount of manure used also increases slightly for all household groups. The model results therefore indicate that the rapid price increase since the second half of 2003 has caused a large increase in the use of chemical inputs and a more unbalanced use of inputs in both villages.

Scenario 2 simulates the combined impact of the direct income subsidy to grain farmers and the same price changes as in scenario 1. The results are compared with the outcomes of scenario 1. Table 10 shows the impact on income and production activities. The policy has only a modest impact on incomes. The average income increase in Gangyan is 1.6% and in Shangzhu it is 1.3%. Again the richest household groups gain least from it, so the income support policy reduces inequality in both villages indeed. Farm households in Gangyan respond to the income increase by raising more pigs (except for the richest group) and switching from two-season rice to one-season rice. Pigs raising is intensive in the use of external inputs. The income increase means that farmers have more cash available, which they can use for buying such inputs. Moreover with the increase in wealth, households attach more value to leisure and therefore resort to a less intensive way of rice cultivation. Households in Shangzhu also increase pigs production (accept for the richest group), but their response is smaller and they do not seem to resort to less intensive rice cultivation. The lower average income level in Shangzhu is probably a major factor in the difference in these responses.

The third scenario simulates the combined effect of the full tax abolition and the price changes (Table 11). Results are again compared with those of the first scenario. The results are very similar to those of scenario 2, but the magnitude is much larger. The average income increase in Gangyan is 10.7% and in Shangzhu it is 5.0%. So, although income inequality within villages declines, the inequality between villages increases. Due to the better market access in Gangyan, farm households in that village can realize much larger shifts in production activities than farmers in Shangzhu and therefore realize much larger additional income gains.

Finally, the consequences of these changes in production patterns for input use are shown in Table 12. The changes in input use under scenario 2 are very small, and therefore are not discussed here. Also the changes in input use under scenario 3 are much smaller than under scenario 1. Household groups 1 and 2 in Gangyan village use substantially more manure. All the other changes in input use are relatively small. The
abolition of taxes and the income support policy therefore do not seem to have much
effect on environmental quality in these two villages.

Table 11. Income and production results for scenario 3 (price changes and tax abolition).

<table>
<thead>
<tr>
<th>Village</th>
<th>Household group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gangyan</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Link outside province:</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Household income</td>
<td>16.5</td>
<td>14.8</td>
<td>7.4</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>One-season rice</td>
<td>15.3</td>
<td>15.6</td>
<td>7.3</td>
<td>11.9</td>
</tr>
<tr>
<td></td>
<td>Two-season rice</td>
<td>−2.3</td>
<td>−1.8</td>
<td>−0.9</td>
<td>−1.2</td>
</tr>
<tr>
<td></td>
<td>Other crops</td>
<td>2.6</td>
<td>1.1</td>
<td>−2.4</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>Pigs</td>
<td>14.9</td>
<td>17.4</td>
<td>−2.2</td>
<td>29.0</td>
</tr>
<tr>
<td></td>
<td>Traction services</td>
<td>−0.7</td>
<td></td>
<td></td>
<td>−1.0</td>
</tr>
<tr>
<td>Shangzhu</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Educated members</td>
<td>None</td>
<td>≥ 1</td>
<td>1 or 2</td>
<td>≥ 3</td>
</tr>
<tr>
<td></td>
<td>Household income</td>
<td>6.8</td>
<td>4.2</td>
<td>3.9</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>One-season rice</td>
<td>−1.7</td>
<td>0.4</td>
<td>−0.5</td>
<td>−0.4</td>
</tr>
<tr>
<td></td>
<td>Two-season rice</td>
<td>1.3</td>
<td>−8.6</td>
<td>16.8</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>Other crops</td>
<td>4.3</td>
<td>3.5</td>
<td>0.4</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Perennials</td>
<td>−16.8</td>
<td>−0.8</td>
<td>3.8</td>
<td>−6.7</td>
</tr>
<tr>
<td></td>
<td>Pigs, chicken, dugs</td>
<td>5.5</td>
<td>−6.4</td>
<td>6.5</td>
<td>5.4</td>
</tr>
<tr>
<td></td>
<td>Traction services</td>
<td>4.6</td>
<td>1.9</td>
<td></td>
<td>4.2</td>
</tr>
</tbody>
</table>

Note: Data in table are percentage changes with respect to scenario 1 (price changes only).

Table 12. Input use results for scenario 3 (price changes and tax abolition).

<table>
<thead>
<tr>
<th>Village</th>
<th>Household group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gangyan</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Link outside province:</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Manure</td>
<td>14.9</td>
<td>1.3</td>
<td>−2.2</td>
<td>8.7</td>
</tr>
<tr>
<td></td>
<td>Fertilizer</td>
<td>0.7</td>
<td>−0.6</td>
<td>−0.6</td>
<td>−0.2</td>
</tr>
<tr>
<td></td>
<td>Pesticides</td>
<td>0.9</td>
<td>0.1</td>
<td>−0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Shangzhu</td>
<td>Owns draught power:</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Educated members</td>
<td>None</td>
<td>≥ 1</td>
<td>1 or 2</td>
<td>≥ 3</td>
</tr>
<tr>
<td></td>
<td>Manure</td>
<td>−0.3</td>
<td>0.1</td>
<td>1.7</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Fertilizer</td>
<td>−0.8</td>
<td>0.5</td>
<td>4.3</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Pesticides</td>
<td>0.3</td>
<td>0.5</td>
<td>2.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Note: Data in table are percentage changes with respect to scenario 1 (price changes only).
5. Institutional environment, farm management and soil quality

Policy reforms in China have also had a great impact on the institutional environment of farm households. In this section, we will examine two major institutional factors, the high degree of land fragmentation and the development of land rental markets. Land fragmentation in China is caused to a large extent by the egalitarian principles used in distributing and reallocating land use rights to households. Land within each village is classified into different classes, with each household receiving land from each class. Moreover, land is basically assigned on the basis of household size, with large households receiving substantially more (and slightly bigger) plots than small households. As a result, farm holdings in China have an average size of only 0.53 ha, dispersed over 6.06 plots (Tan et al., 2005). Administrative reallocations are frequently used to adjust for demographic changes occurring within villages. In recent years, however, land rental markets have emerged and were legally sanctioned to enable farm households to adjust the size of the land they intend to cultivate and to correct mismatching of land and labour (Feng et al., 2004). These land rental markets tend to contribute more to equity and efficiency than administrative reallocations do (Deininger and Jin, 2002).

In this section, we examine the impact of land fragmentation and land renting on farm management decisions, soil quality and crop yield, taking into account their interrelations. The analytical framework that we use is presented in Fig. 6. Farm management refers to decisions on activity choice, use of chemical inputs, labour, animal traction, machinery, and so on. Farm management affects the yield of a crop either through soil management (nutrients, water) or through crop husbandry (weeding, crop protection, harvesting, and so on).

![Fig. 6. Interactions between institutions, farm management, soil quality and yield.](image-url)
Soil has both inherent and dynamic qualities. Inherent soil quality is a function of soil parent material and prevailing climatic conditions. Dynamic soil quality is affected by soil management. For example, chemical fertilizer use directly affects the macro-nutrient contents in the soil; manure application and crop residue incorporation may increase soil organic matter content. Soil tillage can improve soil air and water conditions, increase soil depth, and accelerate the decomposition of soil organic matter. Investment decisions can also have profound implications for soil quality. For instance, land-attached investments (like irrigation and drainage facilities) can improve soil physical characteristics and sustain soil quality in the long-run. Differences in crop yield due to farm management (like fertilizer application) or non-farm management causes (such as unfavourable weather conditions or pests) can have different impacts on soil quality. On the one hand, higher yields will remove more nutrients from the soil; on the other hand, higher yields often mean more crop residues that, when left on the land, form into soil organic matter and thus improve soil quality.

From a biophysical point of view, crop yield is determined by the available energy from the sun, the quantity of water that is available from the soil, the content of nutrients in the soil, the extent to which these nutrients can be taken up by the plants, the incidence of yield-reducing factors such as pests and diseases, and labour input for farm management. Whether, and to what extent, essential nutrients are available to plants not only depends on the nutrient concentration in the soil, but also on soil chemical characteristics (e.g. soil pH) and soil physical characteristics (soil depth and structure, for example). Deep soils allow more extensive rooting than shallow soils, and provide more nutrients if the nutrient concentrations are the same for both. Labour input is not a direct factor in biomass formation. However, labour input in weeding, fertilizer application, plant protection, harvesting, and so on, indirectly contributes to higher yields through crop husbandry.

The relationships shown in the figure are empirically estimated using data collected in the three villages described in Section 4. Out of the 339 households in the original survey, 47 households were randomly selected for plot-level data collection with respect to their rice plots. They were interviewed in January 2003 on the agricultural season 2002. The resulting number of plots in the data set is 154; 29 plots in Banqiao, 50 in Shangzhu, and 75 in Gangyan. Table 13 gives the descriptive statistics of the collected data and the definitions of the variables that are used in the analysis.

The equations that are used for estimating the factors explaining farm management decisions are:

\[
FM_i = \alpha_{0i} + \alpha_{1i}DH + \alpha_{2i}PA + \alpha_{3i}PD + \alpha_{4i}PD^2 + \alpha_{5i}PN + \alpha_{6i}RY + \alpha_{7i}AG + \alpha_{8i}AG^2
+ \alpha_{9i}DE + \alpha_{10i}DV1 + \alpha_{11i}DV2 + \nu_{1i}
\] (5a-5f)
with

\[ F_{M_i} = LB, HB, NP, PP, KP, \text{ and DM, respectively} \]

where,

\[ \alpha_0, \ldots, \alpha_{11} \]

are unknown coefficients;

\[ \nu_{1i} \]

is a disturbance term with standard properties.

Table 13. Descriptive statistics and definitions of the variables used in the analysis.

<table>
<thead>
<tr>
<th>Endogenous variables</th>
<th>Number of observations</th>
<th>Unit</th>
<th>Mean</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Farm management activities</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor used (LB)</td>
<td>154</td>
<td>man days/mu</td>
<td>56.8</td>
<td>249</td>
<td>10.0</td>
<td>31.7</td>
</tr>
<tr>
<td>Herbicides used (HB)</td>
<td>154</td>
<td>yuan/mu</td>
<td>2.34</td>
<td>10.0</td>
<td>0.33</td>
<td>1.51</td>
</tr>
<tr>
<td>Pure nitrogen (NP)</td>
<td>154</td>
<td>jin</td>
<td>24.0</td>
<td>86.4</td>
<td>2.25</td>
<td>14.4</td>
</tr>
<tr>
<td>Pure phosphorus (PP)</td>
<td>154</td>
<td>jin</td>
<td>11.5</td>
<td>73.0</td>
<td>0.00</td>
<td>9.70</td>
</tr>
<tr>
<td>Pure potassium (KP)</td>
<td>154</td>
<td>jin</td>
<td>14.8</td>
<td>100</td>
<td>0.00</td>
<td>12.6</td>
</tr>
<tr>
<td>Manure use dummy (DM)</td>
<td>154</td>
<td>0 or 1</td>
<td>0.38</td>
<td>1.00</td>
<td>0.00</td>
<td>0.49</td>
</tr>
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<td><strong>Dynamic soil quality</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil organic matter (SO)</td>
<td>154</td>
<td>%</td>
<td>3.80</td>
<td>6.21</td>
<td>1.27</td>
<td>1.02</td>
</tr>
<tr>
<td>Total nitrogen (NT)</td>
<td>154</td>
<td>%</td>
<td>0.26</td>
<td>0.48</td>
<td>0.10</td>
<td>0.07</td>
</tr>
<tr>
<td>Available phosphorus (PA)</td>
<td>154</td>
<td>g/kg</td>
<td>13.4</td>
<td>63.6</td>
<td>1.36</td>
<td>11.2</td>
</tr>
<tr>
<td>Available potassium (KA)</td>
<td>154</td>
<td>mg/kg</td>
<td>94.4</td>
<td>385</td>
<td>19.8</td>
<td>54.6</td>
</tr>
<tr>
<td><strong>Crop yield</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice yield (RY)</td>
<td>154</td>
<td>jin/mu</td>
<td>930</td>
<td>1725</td>
<td>250</td>
<td>353</td>
</tr>
<tr>
<td><strong>Exogenous variables</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Institutional factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hired in land dummy (DH)</td>
<td>154</td>
<td>0 or 1</td>
<td>0.25</td>
<td>1.00</td>
<td>0.00</td>
<td>0.44</td>
</tr>
<tr>
<td>Plot area (PA)</td>
<td>154</td>
<td>mu</td>
<td>1.85</td>
<td>9.00</td>
<td>0.20</td>
<td>1.35</td>
</tr>
<tr>
<td>Plot distance (PD)</td>
<td>154</td>
<td>minutes</td>
<td>14.3</td>
<td>60.0</td>
<td>1.00</td>
<td>12.1</td>
</tr>
<tr>
<td>Number of plots in a farm (PN)</td>
<td>154</td>
<td>plots</td>
<td>8.94</td>
<td>16.0</td>
<td>3.00</td>
<td>3.43</td>
</tr>
<tr>
<td><strong>Soil characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay content (CL)</td>
<td>154</td>
<td>%</td>
<td>14.2</td>
<td>27.6</td>
<td>4.77</td>
<td>4.76</td>
</tr>
<tr>
<td>Topsoil depth (TD)</td>
<td>154</td>
<td>cm</td>
<td>17.1</td>
<td>35.0</td>
<td>9.0</td>
<td>4.45</td>
</tr>
<tr>
<td>pH value (PH)</td>
<td>154</td>
<td>pH units</td>
<td>5.15</td>
<td>5.90</td>
<td>4.60</td>
<td>0.22</td>
</tr>
<tr>
<td><strong>Farm household characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age of household head (AG)</td>
<td>154</td>
<td>years</td>
<td>46.6</td>
<td>75.0</td>
<td>30.0</td>
<td>11.7</td>
</tr>
<tr>
<td>Education dummy (DE)</td>
<td>154</td>
<td>0 or 1</td>
<td>0.81</td>
<td>1</td>
<td>0</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Village characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shangzhu dummy (DV1)</td>
<td>154</td>
<td>0 or 1</td>
<td>0.32</td>
<td>1.00</td>
<td>0.00</td>
<td>0.47</td>
</tr>
<tr>
<td>Gangyan dummy (DV2)</td>
<td>154</td>
<td>0 or 1</td>
<td>0.49</td>
<td>1.00</td>
<td>0.00</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Source: Calculated from the plot survey data.
In this specification, farm management decisions depend on institutional factors (plot tenure status, land fragmentation), rice yield, household characteristics (age and education of the household head) and village characteristics (measured by village dummies). Quadratic terms are added for plot distance (PD) and for age of the household head (AG) to account for potential nonlinearities in the impact of these variables.

Rented land is less secure to farmers than contracted land. More secure land tenure can stimulate selection of efficient cropping patterns and increase the willingness to invest in agriculture (Feder et al., 1988; Li et al., 1998; Yao, 1998). It can offer incentives for investments attached to land (e.g. perennial crops, physical anti-erosion measures), non-attached investment (i.e. farm implements), and use of material inputs (i.e. improved seed, fertilizers) and labor. Empirical studies assessing the implications of land tenure for fixed investment, material input use and labour use, however, provide rather mixed results (Ruben et al., 2001).

Land fragmentation affects farm management directly and indirectly. It directly causes an increase in travel time, leaving less labour available for cropping activities. It may also cause difficulties in management. For example, small and scattered plots need more supervision due to crop theft risk and damage by wild animals. It discourages the use of machines and other new technologies, and may affect household decisions on the use of improved seed, chemical fertilizers, and pesticides. Farm households often tend to cultivate scattered plots relatively extensively. Land fragmentation may also contribute to the neglect of farming facilities, because it is more difficult for farmers to timely irrigate and drain the fields. Construction and maintenance of farming facilities involve high costs for individual farms, especially when the plots are scattered.

Yields obtained from a plot may influence farm management decisions. For instance, farmers may use more labour and fertilizers on plots with higher productivity. Or they may use fewer inputs, and use their labour and other inputs for improving the productivity of low-yielding plots.

Household characteristics may affect farmers’ capacities of decision-making. More educated farmers are often more efficient in managing fields. Likewise, older, more experienced farmers are more likely to better manage the soil. Other important exogenous variables affecting farm management decisions are agro-climatic factors and soil types. These factors tend to be relatively constant within villages or small regions, but may vary greatly between regions.

The dynamic component of soil quality depends on the quantity of nutrients and manure applied in rice production, the yield obtained, and soil chemical processes. For soil organic matter (SO), the following equation will be used:
\[ \text{SO} = \beta_0 + \beta_1 \text{DM} + \beta_2 \text{RY} + \beta_3 \text{CL} + \beta_4 \text{DV1} + \beta_5 \text{DV2} + \nu_2 \]  

(6a)

where,

\( \beta_0, \ldots, \beta_5 \) are unknown coefficients;

\( \nu_2 \) is a disturbance term with standard properties.

Soil organic matter contents in this specification depends on the application of manure (DM), the net biomass removed by harvesting rice (RY), the soil clay content (CL; clay soils can retain more soil organic matter by reducing its decomposition) and on village-specific factors (represented by dummy variables DV1 and DV2). We do not have information on crop residues left in the field, so the yield variable (RY) reflects the net effect of biomass removed through harvesting and biomass left on the land through crop residues.

The equation for total nitrogen is as follows:

\[ \text{NT} = \gamma_0 + \gamma_1 \text{NP} + \gamma_2 \text{DM} + \gamma_3 \text{SO} + \gamma_4 \text{RY} + \gamma_5 \text{DV1} + \gamma_6 \text{DV2} + \nu_3 \]  

(6b)

where,

\( \gamma_0, \ldots, \gamma_6 \) are unknown coefficients;

\( \nu_3 \) is a disturbance term with standard properties.

The application of nitrogen fertilizer (NP) and manure (DM) can increase the nitrogen content in the soil. Soils with a high soil organic matter content (SO) tend to have lower nitrogen losses from leaching and volatilization. Harvesting of crops (RY) removes nitrogen from the field and hence reduces the nitrogen stock. Finally, village-specific factors (DV1, DV2) such as differences in soil types may also play a role.

For available phosphorus, the following equation will be estimated:

\[ \text{PA} = \delta_0 + \delta_1 \text{PP} + \delta_2 \text{DM} + \delta_3 \text{RY} + \delta_4 \text{PH} + \delta_5 \text{CL} + \delta_6 \text{DV1} + \delta_7 \text{DV2} + \nu_4 \]  

(6c)

where,

\( \delta_0, \ldots, \delta_7 \) are unknown coefficients;

\( \nu_4 \) is a disturbance term with standard properties.

Phosphorus fertilizer (PP) and manure (DM) can supplement the available phosphorus in the soil, while crop harvesting (RY) removes available phosphorus. Soil pH (PH) also affects the form and availability of soil phosphorus. Phosphorus availability is lower both in soils with low pH (formation of insoluble Al-phosphates).
and in soils with high pH (formation of insoluble Ca-phosphates). Soils with a high clay content (CL) may adsorb P and reduce the P available for plant growth. Again, village-specific factors (DV1, DV2) such as soil types may play a role as well.

The same equation, with phosphorus application replaced by potassium application (KP), is used for explaining available potassium:

\[
KA = \varepsilon_0 + \varepsilon_1KP + \varepsilon_2DM + \varepsilon_3RY + \varepsilon_4PH + \varepsilon_5CL + \varepsilon_6DV1 + \varepsilon_7DV2 + \nu_5
\]  
(6d)

where,

\( \varepsilon_0, \ldots, \varepsilon_7 \) are unknown coefficients

\( \nu_5 \) is a disturbance term with standard properties.

Soil pH is expected to have a negative impact. An increase in acidity (lower value of PH) will increase the concentration of aluminum in the soil solution. This in its turn could make more potassium available for crop growth. The expected impact of clay content (CL) is opposite to its impact on available phosphorus. Potassium is relatively mobile and vulnerable to leaching. A clayey soil may reduce the loss, and therefore increase the availability of potassium for plant growth.

Finally, a Cobb-Douglas production function is used for estimating the rice yield equation:

\[
\ln(RY) = \zeta_0 + \zeta_1\ln(LB) + \zeta_2\ln(HB) + \zeta_3\ln(PA) + \zeta_4\ln(SO) + \zeta_5\ln(NT) + \zeta_6\ln(PA) \\
+ \zeta_7\ln(KA) + \zeta_8\ln(TD) + \zeta_9\ln(PH) + \zeta_{10}\text{DV1} + \zeta_{11}\text{DV2} + \nu_6
\]

(7)

where,

\( \zeta_0, \ldots, \zeta_{11} \) are unknown coefficients;

\( \nu_6 \) is a disturbance term with standard properties.

In this specification rice yield depends on the labour used in growing rice (LB), the herbicides applied (HB), the area of the plot (PA), soil organic matter content (SO), as a proxy for the availability of water, the macro-nutrients available for plant growth (SO, NT, PA, and KA), the depth of the topsoil (TD) and the soil pH-value (PH). Soil type, agro-climatic factors and other village-specific factors are captured in the village dummies (DV1 and DV2). All factors except plot area are expected to have a positive impact on rice yield. The variables in this production function are expressed on a per mu basis. Plot area is therefore added to the equation to estimate whether there are decreasing \( (\zeta_3 < 0) \), constant \( (\zeta_3 = 0) \), or increasing \( (\zeta_3 > 0) \) returns to scale in crop husbandry.
Equations (5a-5f), (6a-6d) and (7) together make up the model. It consists of 11 equations, explaining 11 endogenous variables. All equations are identified, except the yield equation. We explain below how the identification problem for the yield equation is solved. Two-stage least squares (2SLS) is used to estimate the model. Results for the (second-order) Ramsey-test, the Jarque-Bera normality test and the F-test show that a double-logarithmic specification performs better than a linear specification for all equations except for manure and soil organic matter. Each equation is estimated by 2SLS, except the manure equation. Because the dependent variable is a dummy variable, a probit model is applied to estimate equation (5f), with rice yield, the only endogenous explanatory variable in that equation, replaced by its estimate obtained from the first stage of 2SLS. Tables 14-17 report the results. Insignificant explanatory variables and variables with coefficients that have wrong signs are left out of the equations.

The results for the six farm management variables are reported in Table 14. The use of labour, herbicides, manure, and nitrogen does not differ significantly between hired-in plots and contracted plots. This supports the findings of Li et al. (1998). However, controlling for the yield level, hired-in plots are found to receive significant higher quantities of phosphorus and potassium fertilizer use. A possible explanation, consistent with our observations during the field work, is that farmers who rent a plot to another farmer do not apply P and K during the last one or two years before they start to rent out. This normally does not affect yields in the short run. Farmers who rent the land apply extra P and K as compensation.

Of the land fragmentation indicators, plot size is found to have a negative impact on labour input, herbicides use and nitrogen application. Larger plots are easier to manage and therefore have higher input use efficiency. A one percent increase in plot size reduces the inputs of labour, herbicides, and nitrogen per mu by 0.10, 0.21 and 0.12%, respectively. The use of manure, phosphorus and potassium is independent of plot size. Plot distance plays a role in labour use and in manure and nitrogen application. Far-away plots receive less manure but more nitrogen. The labour use data collected in our survey include the time travelled to the plots. This probably explains why plot distance has a positive impact on labour use on nearby plots and a negative impact on far-away plots, with a turning point at a travel times of around 8 minutes. The number of plots on a farm affects only herbicides and phosphorus use. Farms with a large number of plots are more easily invaded by weeds from neighbouring non-cultivated land, necessitating a higher use of herbicides. Application of phosphorus is a relatively long-term investment. A higher probability of land reallocation for farmers with a large number of plots may explain the reluctance of such farmers to invest in soil quality through phosphorus application.
Table 14. Regression results for farm management, 2SLS.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Labour</th>
<th>Herbicides</th>
<th>Manure</th>
<th>Nitrogen</th>
<th>Phosphorus</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hired in plot dummy</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.31**</td>
<td>0.34**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(2.17)</td>
<td>(2.00)</td>
</tr>
<tr>
<td>Plot area</td>
<td>-0.10*</td>
<td>-0.21***</td>
<td>-0.12*</td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(-1.82)</td>
<td>(-3.86)</td>
<td>(-1.85)</td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Plot distance</td>
<td>0.49***</td>
<td>-0.03***</td>
<td>-</td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(2.76)</td>
<td>(-2.57)</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Plot distance squared</td>
<td>-0.12***</td>
<td>-</td>
<td>0.15***</td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(-3.17)</td>
<td>(2.45)</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Number of plots</td>
<td>-</td>
<td>0.23**</td>
<td>-</td>
<td>-0.37***</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.02)</td>
<td></td>
<td>(-2.49)</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Yield</td>
<td>0.68**</td>
<td>0.88****</td>
<td>1.68***</td>
<td>0.97***</td>
<td>1.21***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.16)</td>
<td>(4.93)</td>
<td>(7.02)</td>
<td>(2.63)</td>
<td>(2.70)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-</td>
<td>9.81**</td>
<td>0.16**</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(1.98)</td>
<td>(1.92)</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Age squared</td>
<td>-</td>
<td>-1.27*</td>
<td>-0.001**</td>
<td>-</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.97)</td>
<td>(-2.06)</td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Education dummy</td>
<td>-</td>
<td>-</td>
<td>-0.29***</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(-2.55)</td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Shangzhu dummy</td>
<td>0.68***</td>
<td>-</td>
<td>1.48***</td>
<td>-0.71***</td>
<td>-0.44*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.85)</td>
<td>(3.98)</td>
<td></td>
<td>(-3.02)</td>
<td>(-1.74)</td>
<td></td>
</tr>
<tr>
<td>Gangyan dummy</td>
<td>-</td>
<td>-0.19**</td>
<td>1.15***</td>
<td>-0.64***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-2.04)</td>
<td>(3.12)</td>
<td>(4.12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-2.13)</td>
<td></td>
<td></td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

R² 0.39 0.36 0.43 0.40 0.35
Adj. R² 0.37 0.33 0.41 0.38 0.33
McFadden R² 0.14

Notes: t-statistics are between brackets.
Double-log specifications for all equations except manure; manure equation is estimated by a two-stage probit model.
* = Significant at 10% testing level.
** = Significant at 5% testing level.
*** = Significant at 1% testing level.
Table 15. Regression results for soil stock variables, 2SLS.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Dependent variable</th>
<th>Soil organic matter</th>
<th>Soil total nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure nitrogen use per mu</td>
<td>n.a.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Manure use dummy</td>
<td>1.42*** (4.51)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Yield</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Soil organic matter</td>
<td>n.a.</td>
<td>0.65*** (12.4)</td>
<td>-</td>
</tr>
<tr>
<td>Clay content</td>
<td>-</td>
<td>n.a.</td>
<td>-</td>
</tr>
<tr>
<td>Shangzhu dummy</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gangyan dummy</td>
<td>0.28 (1.70)</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

R² 0.01 0.74
Adj. R² −0.00 0.74

Notes: t-statistics are between brackets; n.a. means not applicable

Double-log specifications for soil total nitrogen.

*  = Significant at 10% testing level.
** = Significant at 5% testing level.
*** = Significant at 1% testing level.

Yield is found to have a positive impact on all farm management variables except manure use. So, controlling for the technical relationship between input use and rice yield (as estimated by the production function), plots with higher yields receive significantly higher quantities of inputs. The estimated elasticities range from 0.68 for labour to 1.68 for nitrogen use.

Table 15 presents the regression results for the soil organic matter and soil total nitrogen equations. As expected, manure use has a very significant positive impact on soil organic matter (SOM). On plots where manure is applied, the SOM content is on average 1.42/3.80 = 37% higher. The rice yield obtained from a plot and the clay content do not have significant effects. For yield, the net effect of biomass removed through harvesting and biomass left on the land through crop residues is apparently close to zero. Total soil nitrogen is strongly affected by the soil organic matter content. The main reason is that that the larger part of total soil nitrogen is in organic form in soil organic matter. Moreover, higher SOM contents prevent nitrogen losses through leaching and volatilization. A one percent higher soil organic matter content increases total soil nitrogen by 0.65%. Total soil nitrogen content is neither significantly influenced by nitrogen fertilizer use nor by manure application. Total soil nitrogen formation is a relatively slow process. Apparently the differences between plots in
Table 16. Regression results for available soil nutrients, 2SLS.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Dependent variable</th>
<th>Soil available phosphorus</th>
<th>Soil available potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus use per mu</td>
<td>0.41*</td>
<td>(1.60)</td>
<td>n.a.</td>
</tr>
<tr>
<td>Potassium use per mu</td>
<td>n.a.</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Manure use dummy</td>
<td>0.54**</td>
<td>(1.68)</td>
<td>0.43***</td>
</tr>
<tr>
<td>Yield</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Soil pH</td>
<td>-</td>
<td>−1.98**</td>
<td>(−2.19)</td>
</tr>
<tr>
<td>Soil clay content</td>
<td>−0.31*</td>
<td>(−1.79)</td>
<td>0.48***</td>
</tr>
<tr>
<td>Shangzhu dummy</td>
<td>0.87**</td>
<td>(2.10)</td>
<td>-</td>
</tr>
<tr>
<td>Gangyan dummy</td>
<td>0.91***</td>
<td>(3.23)</td>
<td>−0.40***</td>
</tr>
</tbody>
</table>

R²                      0.08
Adj. R²                 0.04

Notes: t-statistics are between brackets; n.a. means not applicable.
Double-log specifications for both equations.

*  = Significant at 10% testing level.
** = Significant at 5% testing level.
*** = Significant at 1% testing level.

Nitrogen and manure application during one agricultural season that we observe in our sample are insufficient to explain such a process. Manure use, however, has an indirect impact on soil nitrogen formation in our model through its contribution to SOM formation. Yield is again found to have an insignificant impact, as was the case for SOM content.

Regression results for soil available phosphorus and potassium are shown in Table 16. Phosphorus fertilizer use is found to have a significant impact on soil available phosphorus. A one percent increase in phosphorus fertilizer application increases the available phosphorus in the soil by 0.41% on average. Potassium fertilizer, however, does not have a significant impact on soil available potassium content. The inadequacy of our one-season data set for explaining long-term processes may again explain the latter result.

Manure use has a significant positive impact on both available phosphorus and available potassium in the soil. On plots with manure application, the content of soil available phosphorus is 54% (7.2 g kg⁻¹) higher and the content of soil available potassium is 43% (40.6 mg kg⁻¹) higher on average than on plots without manure application. Rice yield does not have significant effects on soil available phosphorus.
Table 17. Regression results for rice yield, 2SLS.

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Rice yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour use per mu</td>
<td>0.27*** (2.64)</td>
</tr>
<tr>
<td>Herbicides use per mu</td>
<td>0.34*** (3.25)</td>
</tr>
<tr>
<td>Plot area</td>
<td>0.07* (1.63)</td>
</tr>
<tr>
<td>Soil organic matter</td>
<td>-</td>
</tr>
<tr>
<td>Soil total nitrogen</td>
<td>-</td>
</tr>
<tr>
<td>Soil available phosphorus</td>
<td>0.13** (2.17)</td>
</tr>
<tr>
<td>Soil available potassium</td>
<td>0.16** (1.74)</td>
</tr>
<tr>
<td>Top soil depth</td>
<td>-</td>
</tr>
<tr>
<td>Soil pH</td>
<td>-</td>
</tr>
<tr>
<td>Shangzhu dummy</td>
<td>-0.52*** (−6.03)</td>
</tr>
<tr>
<td>Gangyan dummy</td>
<td>-</td>
</tr>
</tbody>
</table>

R² 0.46
Adj. R² 0.45

Notes: t-statistics are between brackets

Double-log specification.

* = Significant at 10% testing level.
** = Significant at 5% testing level.
*** = Significant at 1% testing level.

and potassium contents. None of the soil quality variables therefore seems to be affected by differences between plots in rice yields.

The results in Tables 14-16 indicate that several explanatory variables have insignificant effects on soil management decisions and on soil quality. After dropping these insignificant variables from the model as presented in (5a-5f), (6a-6d), and (7), the rice yield equation can be identified. Table 17 presents the regressions results for the yield equation. Labour use is found to have a significant positive impact on yield. In other words, marginal labour productivity is not equal to zero. This means that there is no labour surplus, and that labour cannot be withdrawn from agriculture without reducing agricultural production (as many studies on China assume) in our research area. The other farm management variable, herbicide use, also has a significant positive effect on rice yield. Plot area has a small but significant impact on rice yield. Hence, there is some evidence of increasing returns to scale in rice crop husbandry. Among the soil quality indicators, only available phosphorus and potassium have a significant effect on rice yield. This suggests that available phosphorus and available
potassium are the yield-limiting factors in rice production in the research area. Variations among the plots in nitrogen and SOM apparently do not matter, either because they are available in sufficient quantities or, in the case of nitrogen, because it is in an unavailable form. Top soil depth and pH-value do not affect rice yield either. The average topsoil depth of 17 cm in our research area is more than enough for the extension of rice roots. Rice does not have strict requirements for pH value. The range of 4.6 to 5.9 for the soil pH value in our research area is somewhat low, but when flooded, this value will tend to be close to 7.0.

6. Conclusion

In this paper we examine the impact of policy reforms on agricultural production, input use and soil quality change for a major rice-producing area in China, Jiangxi Province. Three sets of policies are examined: market liberalization policies, rural income support policies, and land tenure policies. With respect to market liberalization policies, we find that domestic supply and demand factors had a significant impact on grain prices and fertilizer prices in Jiangxi Province during the period 1985-93. Since 1994, the role of domestic supply and demand factors has diminished substantially (for fertilizer prices) or fully disappeared (for grain prices) as a result of the opening up of China’s agricultural sector to the world market and domestic policies to promote regional food security through controlled production of grain and price stabilization. The world market price has become the main determinant of the prices of grain in Jiangxi Province and in China since 1994.

The profitability of fertilizer application in Chinese agriculture has increased considerably during the 1990s, particularly in Jiangxi Province. At the end of the 1990s, the value of the fertilizer-grain price ratio in Jiangxi Province was about 40% of its value at the end of the 1980s (in China: 60%). Rising grain prices during the 1990s are responsible for these trends. Since the second half of 2003, grain prices have again grown rapidly. The results of two village models that we present in this paper show that farmers in the village with good market access respond to such price increases by increasing two-season rice production at the expense of one-season rice, other crops and pigs raising. In the remote village, on the other hand, one-season rice growing is expanded at the expense of perennials and pigs. In both villages, households owning traction services (oxen, tractors) gain relatively more due to the increased activities in rice production. The increase in rice production causes a more than proportional increase in the use of chemical inputs, particularly in the remote village. Manure use, on the other hand, increases only slightly in the remote village and declines substantially in the village with good market access. The recent grain
price increases therefore seem to aggravate agriculture related environmental problems in the region.

Since the beginning of 2004, the Chinese government has adopted a new rural income support policy that is more in line with WTO regulations. Its major purpose is to address the growing income inequality in China, while at the same time promoting grain production and food self-sufficiency. The two major measures taken in this respect are a direct income support to grain farmers and the abolition of agricultural taxes and fees paid by rural households. The results of the two village models in this paper show that the tax abolition has a much larger impact on incomes and production than the direct income support. Both measures tend to reduce income inequalities within villages, because the richest household groups (who are more involved in off-farm employment) benefit less. Income inequalities between villages, however, tend to widen, because households in villages with good market access have more opportunities to adjust their production structure than households in remote villages have. The income support policy does not reach its goal of promoting grain production. The increased incomes allow farm households to buy more inputs that can be used in livestock production. Moreover, because leisure is valued higher with increasing incomes, farmers tend to switch to less intensive rice production. As a result, the production and selling of grain outside the village declines. The consequences of changes agricultural production patterns caused by the income support policy for input use seem to be minimal.

With respect to land tenure policy, we examine how land fragmentation and renting activities affect farm management decisions, soil quality and rice yields in three villages in Northeast Jiangxi Province. The high degree of land fragmentation in China, that is caused by the current system of land distribution, has mixed effects on farm management decisions. We find that:

- on far-away plots, labour and manure use is lower but application of nitrogen fertilizers is higher,
- on large plots, use of labour, herbicides, and nitrogen fertilizers per unit area is lower, and economies of scale in crop husbandry can be realized, and
- on farms with a large number of plots, the use of herbicides per unit area is higher and the use of phosphorus fertilizers per unit area is lower.

Consolidating small, fragmented plots into a smaller number of large plots will therefore increase input-use efficiency. If these plots are located closer to the homestead, more labour and manure are likely to be used. Our results show that increased manure use contributes to soil quality improvement and increases the availability of the two major yield-limiting factors in rice production in the research area, the available phosphorus and potassium in the soil.
As regards the renting of land, our results indicate that the tenure status of a plot does not affect crop husbandry decisions on labour and herbicide use. Chemical fertilizers (phosphorus and potassium), however, are used in larger quantities on rented plots. Probably farmers do this to compensate for the lack of application of such fertilizers in previous seasons by farmers renting out the land. This implies that farmers are more concerned with short-term yields than with the built-up of long-term soil productivity on rented plots. In order to sustain long-term soil productivity, land policies should therefore stimulate that such soil investments are reflected in the prices for hiring land.

References


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