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The role of subsidy policies in achieving grain self-sufficiency in China: a partial equilibrium approach

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Abstract: Food security is a critically important issue in China and can be enhanced by implementing subsidy policies. This paper employs a partial equilibrium model which takes into account the impact mechanism of subsidy policies to simulate the impact of current subsidy policies on grain supply and demand and on enhancing grain self-sufficiency in China. The simulation results suggest that subsidies can generally promote grain production, reduce consumption, increase imports, reduce exports and increase ending stocks. Subsidies may also result in increases in grain self-sufficiency rate and stock-to-use ratio, but the increases are relatively small, indicating that the subsidies lack efficiency. Given that subsidies constitutes only a very small share of farmers' total income, and that significant scope remains for increasing subsidy levels in China, employing subsidy policies can help to enhance or at least maintain China's grain self-sufficiency at a high level. Various measures should be implemented to improve the inefficiency of the current subsidy system, such as (1) combining different types of subsidies; (2) providing discriminatory subsidies to poor/rich farmers or developing/developed areas; and (3) increasing subsidy rates for wheat and corn.

Keywords: equilibrium model, food security, impact of subsidy, simulation, supply and demand

China is the most populous country in the world and accounts for the largest shares of grains supplied and demanded in the world market. Accordingly, food security has been a central issue of concern both for China and the wider world (Qian et al. 2013b). Given the huge population in China, food security is partly achieved by ensuring "quantity security", which can be achieved by grain self-sufficiency. Although China's grain production has experienced increases for 12 consecutive years since 2004, grain consumption also has seen significant increases, and the growth of grain consumption has been faster than that of grain production. This has resulted in the country's grain self-sufficiency rate undergoing year-on-year decreases. In fact, the aggregate self-sufficiency rate of the three main grains (rice, wheat and corn) dropped from 105.4% in 2008 to 98.9% in 2014, a decrease of 6.5%. According to the projection by the U.S. Department of Agriculture, rice self-sufficiency rate in China may further fall to 96.7% in 2015 (USDA PSD Online 2015). Therefore, the food security issue remains highly relevant in China, and the decreasing trend of grain self-sufficiency has aroused concerns both within and outside of the country. In response to this situation, ensuring the country's grain self-sufficiency level was unusually afforded priority in all government actions at the meeting for national economics in December 2013. In addition, the new guideline of "guaranteeing basic self-sufficiency of cereal grains and absolute grain food security" was proposed in the meeting. Furthermore, the importance of guaranteeing grain self-sufficiency was frequently re-emphasised in official documents. Now, the issue of how to increase or maintain China's grain self-sufficiency at a certain level has become an urgent consideration for both academics and policy makers.

Providing subsidies to farmers is a popular way to mobilise farmers' enthusiasm for production, thus

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promoting rebounds in grain production as well as in levels of grain self-sufficiency. Since 2003, a series of subsidies has been paid to farmers under the guideline of "offering more, taking less and loosening control." The subsidies include high-quality seed subsidies, direct grain subsidies, farm machinery subsidies and comprehensive subsidies. Table 1 demonstrates the rapid increases in total subsidies: an increase from 14.5 billion yuan in 2004 to 160.9 billion yuan in 2013, a more than 11-fold increase.

Such large-scale subsidies and the rapid growth in overall subsidy expenditures may exert significant influence on grain sector. Since the implementation of these subsidy policies, their effects have attracted extensive attention from academics, and so far, many studies have been conducted to assess the effects on agriculture. Wang and Xiao (2006) concluded that the impact of subsidy policies on grain production is not large, but they do play a large role in increasing farmers' income when the positive mathematical programming model is used. Jiang and Wu (2009) analysed a field survey data in Miluo City in Hunan Province and found no significant increase in areas planted with grain when the subsidy policies were implemented. Huang et al. (2011) used a multiple regression analysis based on household panel data to demonstrate that the subsidies do not exert effects on grain production or planted areas. Liu (2010) applied the logit model and multiple regression method to survey data from Jiangxi Province and concluded that the subsidy policies have increased willingness for grain production for farmers whose incomes are mainly derived from grain production and increased the size of areas planted with grain to a certain extent. Based on regression results that used provincial panel data from 2004 to 2007, Chen et al. (2010) indicated that subsidy policies can have a positive influence on grain production through affecting grain planted areas and input capital. Some other studies employed the general equilibrium model to simulate the impacts of the subsidy policies on the agricultural sector (Mu and Koike 2009; Zhou et al. 2009). However, previous studies have not empirically examined the relationship between the subsidy policies and grain self-sufficiency; in addition, no study has evaluated the impacts of subsidy policies on both grain supply and demand sectors. Therefore, this paper attempts to evaluate the impacts of subsidy policies on grain production, consumption, imports, exports and ending stocks and their contributions to enhancing China's grain self-sufficiency. Incorporating the existing studies, this paper evaluates the very detailed impacts of the subsidy policies on the grain sector and empirically links the subsidy policies to national food security in China. This not only fills a gap in the literature but also reports findings with practical and heuristic significance for national food security strategies in China.

THEORETICAL FRAMEWORK

To explore the relationship between subsidy policies and grain self-sufficiency, the mechanisms by which subsidy policies affect the grain sector must first be identified. For example, subsidies may show direct impacts on grain prices and production (planted areas and yields). These impacts are channels linking subsidy policies to maintaining the grain self-sufficiency level, and the mechanisms are bases for model construction.

Table 1. Changes in subsidy amounts 2003–2013 (billion yuan)

Year	High-quality seed subsidy	Direct grain subsidy	Farm machinery subsidy	Comprehensive subsidy	Total subsidies
2003	0.3	–	–	–	0.3
2004	2.9	11.6	0.1	–	14.5
2005	3.9	13.2	0.3	–	17.4
2006	4.2	14.2	0.6	12.0	31.0
2007	6.7	15.1	2.0	27.6	51.4
2008	12.3	15.1	4.0	71.6	103.0
2009	19.9	15.1	13.0	71.6	119.6
2010	20.4	15.1	15.5	71.6	122.6
2011	22.0	15.1	17.5	83.5	138.1
2012	22.4	15.1	21.5	107.8	166.8
2013	22.6	15.1	21.8	101.4	160.9

Source: China Agricultural Development Report 2004–2014

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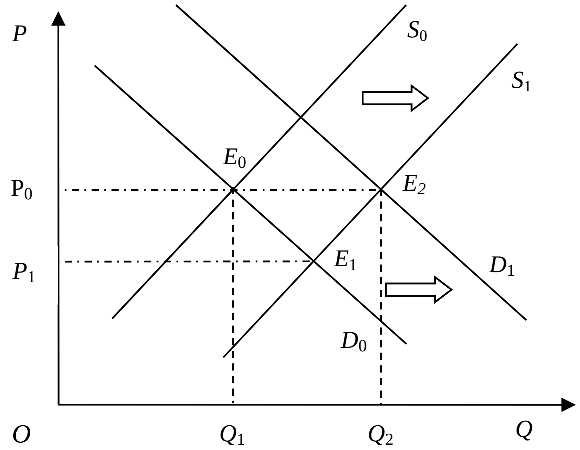

Figure 1. Changes in the grain market with government interventions

In 2004, China implemented a minimum price policy in respect of purchasing grain that set a minimum purchase price in each year for each grain. If the market price of grain were to fall below the minimum price set, then the government would purchase grain at the minimum price until the market prices once again reached the minimum price. This policy intervention offsets the negative impact of subsidy policies on grain price through increased grain supplies, and the mechanism is illustrated in Figure 1. Assuming P_0 is the minimum price set by the government, the grain market realises equilibrium at E_0. As subsidies increase grain production, the grain supply curve will shift from S_0 to S_1, the market will achieve equilibrium at E_1 and the grain market price will drop from P_0 to P_1. However, in practice, the market price does not fall to P_1 due to the existence of the grain minimum purchasing price policy, because as prices drop below the minimum price, the government will enter the market and purchase grain. This intervention behaviour increases grain demand, meaning the demand curve for grain will shift from D_0 to D_1. As a result, grain market prices will remain at or above the minimum price. Therefore, subsidy policies cannot have significantly negative influences on grain market prices through increasing grain supplies; if negative effects do result then these are extremely limited.

Most of the existing subsidies (except for farm machinery subsidies, which account for a small proportion of the total subsidy amount) are paid to farmers directly, and farmers can use them freely. As such, subsidies can increase farmers' incomes and induce farmers to increase the usage of agricultural inputs (Chen et al. 2010; Cui et al. 2014). More specifically, farmers receiving direct subsidies, especially poor farmers who rely on grain production, will have more money to buy sufficient or better basic goods for grain production so as to enhance their grain productivity. Hence, subsidies may initially stimulate input factor demand through increases in farmers' incomes and, in turn, push input factor prices higher. Figure 2 illustrates how subsidies affect factor markets through the income effect. The upper half of the figure shows an income-consumption curve for farmers' use of agricultural input factors. If a farmer's income level increases from level 1 to level 2 through receiving subsidies, then the farmer can purchase more input factors for grain plantation. The quantity of input factor X_1 the farmer purchases rises from Q_1 to Q_2. This means that input factor demand is increased, the factor demand curve in the lower half of Figure 2 shifts from D_1 to D_2 and the factor price rises from P_1 to P_2. Finally, supply and demand in the input markets achieve a new equilibrium at E_2. In addition, grain planted area also can be considered as an input factor; as income increases through government sub-

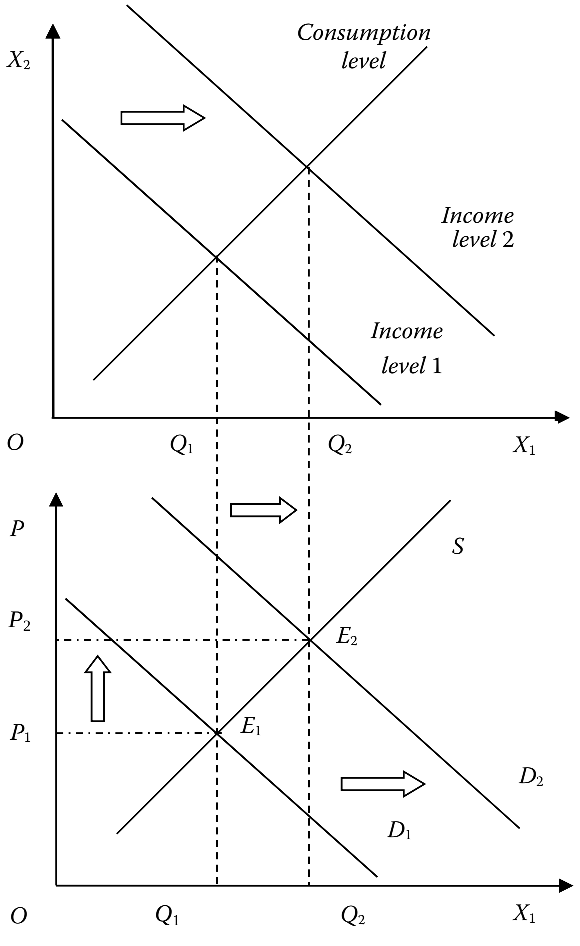

Figure 2. Mechanism by which subsidy policies impact input factor markets

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sidies, farmers can absorb the increased production costs of expanding grain planted areas. This also can result in increased demand for inputs and, accordingly, increases in input factor prices. Finally, grain prices could be pushed up by the increased factor prices caused by the stimulation of the subsidies. In addition, some studies have also suggested that subsidies drive increases in grain prices (Li 2011; Qain et al. 2013a, 2015a, b).

In fact, during the policy introduction period of 2003–2012, agricultural input factors demonstrated significant growth, with an increase in annual usage for pesticide, fertiliser and diesel of 32.4%, 33.9% and 36.3%[1], respectively. As a result, from 2003 to 2012, the prices of fertiliser and oil increased by 93.5 and 95.5%; production costs for rice, wheat and corn increased by 115.4%, 66.6% and 92.4%, respectively (Qian et al. 2015a). Consequently, it is possible to conclude that subsidies may positively impact grain prices by raising input prices (production costs).

As a summary: (1) For grain prices, the extensive government intervention in the grain markets take the form of the government purchasing the extra supply in the market; thus, the subsidies can hardly have notably negative impacts on grain prices through increasing the grain supply. While subsidies have resulted in significant increases in grain input prices, subsidies may nevertheless exert positive rather than negative impacts on grain market prices as a whole. Understanding this impact mechanism will help us to build a correct model and, further, to capture more precisely the impacts of subsidies on grain sectors. (2) For grain production, the subsidies induce farmers to expand their planted areas and to use sufficient or better inputs to increase their grain yields through the income effect. Hence, the subsidies may have positive impacts on grain planted areas and yields.

In the equilibrium model, a subsidy variable will be included in the equations for grain prices, planted areas and yields, and is expected to take a positive sign in these equations.

MODEL SPECIFICATION

The partial equilibrium model has been widely applied to research on grain market prospects or the impact of policy on grain supply and demand (Song and Carter 1996; Lee and Kennedy 2007; Rosegrant et al. 2010; Wailes and Chavez 2010). Based on the mechanism through which subsidies influence grain markets, a partial equilibrium model is built to assess the impacts of the subsidy policies on the grain sector. Generally, the model includes five sectors: production sector, consumption sector, trade sector, price linkage and market clearance.

Production sector

Grain production is determined by grain planted area and yield, and the area and yield equations are specified as an extended Nerlovian model which includes a subsidy variable to capture the impacts of the subsidy policies on the grain supply response (Nerlove 1956; French and Mathews 1971; Froster and Mwanaumo 1995; Mushtaq and Dawson 2002; Jeffrey et al. 2009). Although the Chinese government provides subsidies for different purposes, these subsidies work via the same mechanism. Hence, we combine subsidies to construct a single subsidy variable as a proxy for the scale of all subsidies, and incorporate it into the extended area and yield response models. If subsidies induce farmers to expand grain planted areas or use more inputs to increase their grain yields, overall grain planted areas or yields should rise accordingly with the incentive provided by these subsidies; thus, the subsidy variable is expected to take a positive sign in the models. Note that grain planted area is included in the yield models as an independent variable: Farmers tend to plant on good-quality land and abandon inferior land, so even as they expand their planted areas to the inferior land, grain yields as a whole will fall. Thus, land area may show a negative impact on grain yield.

Generally, grain planted area is modelled as a function of last year's planted area, last year's grain producer prices, total subsidy amount, prices of competitive crops and a time trend variable reflecting the shift in supply curve due to factors such as technological change, climate change and so on. Grain yield is specified as a function of one-year lagged yield, one-year lagged producer prices, total subsidy amount, grain planted area, prices of main inputs and a time trend variable. Production is equal

[1]The data are calculated by the authors based on the raw data from the China Agricultural Development Report and the China Statistical Yearbook.

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to the product of the planted area multiplied by yield. The production sector is modelled as

$$lnA_{it} = f(lnA_{it-1}, lnP_{it-1}, lnS_t, lnPC_{it}, T)$$

$$lnY_{it} = f(lnY_{it-1}, lnP_{it-1}, lnS_t, lnA_{it}, lnPI_t, T)$$

$$QP_{it} = A_{it} \times Y_{it}$$

where *A* and *Y* indicate grain yield and planted area, respectively; *P* indicates grain producer prices; *S* represents the total amount of subsidies; *PC* represents the prices of competitive crops, *PI* are the prices of main inputs, *T* is a time trend variable; *QP* represents grain production; *i* indicates rice, wheat and corn; and *t* is the year.

Consumption sector

The total grain use is divided into two categories in terms of grain consumption structures: (1) feed consumption, and (2) food and other consumption, which is comprised of food, industrial and other uses. A double-log model is employed to estimate the impact of grain prices and income levels on grain consumption, with consumption for food and feed for each grain estimated separately. In recent years, the increase in total rice consumption was mainly due to an increase in food consumption; on the other hand, increases in total wheat and corn consumption resulted from feed consumption, which in turn were attributed to high meat prices (Qian et al. 2013a). Therefore, meat prices are also incorporated into the model to explain variations in grain consumption. Generally, grain consumption for food and feed uses are modelled as a function of grain consumer prices, per capita income level, meat prices and prices of substitutes. Total grain consumption is determined by per capita consumption for food and other uses, feed and by China's population. The consumption sector is modelled as

$$lnQfood_{it} = f(lnCP_{it}, lnIN_t, lnPM_t, lnPS_{it})$$

$$lnQfeedd_{it} = f(lnCP_{it}, lnIN_t, lnPM_t, lnPS_{it})$$

$$QC_{it} = (Qfood_{it}+, Qfeed_{it}) \times POP_t$$

where *Qfood* indicates grain per capita consumption for food and other uses; *Qfeed* indicates grain per capita consumption for feed; *IN* indicates per capita GDP in China; *PM* represents meat prices, which take the form of an index; *PS* represents prices for substitutes; *POP* denotes China's population; *i* denotes rice, wheat and corn; and *t* is the year.

Trade sector

The trade sector includes grain imports and exports. Currently, China's domestic grain prices are higher than international grain prices, so domestic prices may show a larger influence on grain imports and exports. Therefore, domestic grain prices are considered in the trade equations. The grain trade is also related to increasing domestic grain consumption in China, grain international prices and the exchange rate. These variables are also incorporated into the trade models. Generally, the trade sector is modelled as a function of domestic grain consumer prices, domestic grain consumption, international grain prices and the exchange rate of the Chinese yuan to the U.S. dollar. The trade sector is expressed as

$$lnQI_{it} = f(lnCP_{it}, lnIP_{it}, lnQC_{it}, lnER_t)$$

$$lnQE_{it} = f(lnCP_{it}, lnIP_{it}, lnQC_{it}, lnER_t)$$

where *QI* and *QE* are grain imports and exports, respectively; *CP* is grain consumer prices; *IP* denotes international grain prices; *QC* denotes domestic grain consumption; *ER* denotes the exchange rate of the Chinese yuan to the U.S. dollar; *i* denotes rice, wheat and corn; and t is the year.

Price linkage

As analysed in section Theoretical framework, the subsidies may contribute to increases in grain prices; thus, they are included in the grain producer price equation and are expected to take a positive sign. In addition, grain production costs are also an important factor in determining grain producer prices, and they are also incorporated into the equation for grain producer prices. The grain consumer prices are linked to the grain producer and international prices. The functions can be written as

$$lnP_{it} = f(lnCO_{it}, lnS_t)$$

$$lnCP_{it} = f(lnP_{it}, lnIP_{it})$$

where *P* is grain producer prices; *CO* is grain production costs; *S* is total subsidy amount; *CP* is grain consumer prices; *IP* is international grain prices; *i* denotes rice, wheat and corn; and *t* is the year.

Market clearance

Grain ending stocks are a residual to close the model; they are a residual of total grain supply (production,

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imports and beginning stocks) and the net of total demand (total domestic consumption and exports). The consumption and export sectors are moved to the right side, after which the clearance function can be expressed as

$$QP_{it} + QI_{it} + QS_{it-1} = QC_{it} + QE_{it} + QS_{it}$$

where QP is grain production; QI is grain imports; QC is total grain consumption; QE is grain exports; QS is grain stocks; i denotes rice, wheat and corn; and t is the year.

DATA

Considering the consistency in the quality of the statistics and because only a relatively short data period is available in China, the annual time series data at the national level used for model estimation were generally from 1990 and 2013. Data on grain food consumption and ending stocks were taken from the United States Department of Agriculture (USDA); grain imports, exports, consumer prices, meat prices and subsidy amounts were collected from the China Agricultural Development Report; grain producer prices were obtained from the National Cost and Return of Agricultural Products in China; grain planted area, yield, production and Chinese population data came from the China Statistical Yearbook; per capita GDP served as an income variable and was also taken from the China Statistical Yearbook. Data on prices, income, production costs and subsidy amount are deflated by the consumer price index with 1990 as a base year. Subsidy, grain production costs, meat prices, international grain prices, income, population and the exchange rate were exogenous variables, and other variables were determined by the models.

MODEL ESTIMATION

All parameters are estimated using the annual data. There are lagged dependent variables in model; this may result in endogeneity problems, which can be eliminated by using instrument variables. Nevertheless, in practice, it is very difficult to identify an appropriate instrument, and the estimates keep varying when different instruments are selected. Note that even when the endogeneity problem is not serious, the ordinary least squares (OLS) is still an ideal method for estimation. The estimated results using OLS do not differ much from those obtained using the instrument method, indicating that estimation using OLS does not suffer from the endogeneity problem. Therefore, OLS was still employed for estimation. For some models, we used the weighted least squares (WLS) method to improve the estimates. The individual equations were estimated separately. The specific model structures were finally confirmed in terms of the estimation results.

Because the prices of competitive crops are insignificant in the area response models, the time trend variable is insignificant in the corn area model and all yield models, the planted area variable is insignificant in the rice yield model and the corn yield model and input prices are insignificant in the yield models. Therefore, these were omitted from the models. For rice and corn food consumption, consumer prices

Table 2. Estimated results for rice models

Production:

$lnA = 2.738 + 0.748 lnA_{t-1} + 0.069 lnP_{t-1} + 0.004 lnS - 0.003T$
$(0.57)^a$ $(0.05)^a$ $(0.11)^a$ $(0.00)^a$ $(0.00)^a$

Adj. $R^2 = 0.96$ Q(1) = 0.46 Method = OLS Obs.=23

$lnY = 0.333 + 0.806 lnY_{t-1} + 0.036 lnP_{t-1} + 0.001 lnS$
$(0.051)^a$ $(0.033)^a$ $(0.006)^a$ $(0.001)^c$

Adj. $R^2 = 0.98$ Q(1) = 0.47 Method = OLS Obs.=23

Consumption:

$lnFOD = 4.713 - 0.362 lnCP - 0.102 lnIN + 0.334 lnPM + 0.230 lnPW$
$(0.059)^a$ $(0.127)^b$ $(0.026)^a$ $(0.070)^a$ (0.150)

Adj. $R^2 = 0.97$ Q(1) = 0.27 Method = WLS Obs.=19

$lnFED = 1.699 + 0.302 lnIN - 0.866 lnPM + 0.020 lnPC$
$(0.042)^a$ $(0.006)^a$ $(0.020)^a$ $(0.012)^c$

Adj. $R^2 = 0.99$ Q(1) = 0.13 Method = WLS Obs.=19

Trade:

$lnIM = -62.314 + 5.206 lnCP - 1.771 lnIP + 6.091 lnCS$
$(26.319)^b$ $(0.703)^a$ $(0.417)^a$ $(2.233)^b$

Adj. $R^2 = 0.80$ Q(1) = 0.28 Method = OLS Obs.=19

$lnEX = 33.201 - 5.471 lnCP + 1.176 lnIP - 2.513 lnCS$
(15.085)b $(0.352)^a$ $(0.176)^a$ $(1.287)^c$

Adj. $R^2 = 0.96$ Q(1) = 0.98 Method = WLS Obs.=19

Price linkage:

$lnP = 1.558 + 0.665 lnCO + 0.048 lnS$
$(0.333)^a$ $(0.096)^a$ $(0.015)^b$

Adj. $R^2 = 0.95$ Q(1) = 0.40 Method = OLS Obs.=11

$lnCP = 1.021 + 0.766 lnP + 0.086 lnIP$
$(0.172)^a$ $(0.084)^a$ (0.064)

Adj. $R^2 = 0.97$ Q(1) = 0.73 Method = OLS Obs.=19

Values in parentheses are standard error; Q(1) indicates probability of first-order Q-statistics; a, b, and c indicates 1%, 5%, and 10% significance level, respectively

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for the main substitute wheat were incorporated into the models. For the wheat food consumption model, corn consumer prices were included to reflect the substitution of wheat for corn. As most corn is used for feed purposes, corn consumer prices were included in the feed per capita consumption model for rice and wheat. In the corn feed consumption equation, wheat consumer prices were incorporated to reflect the substitution of wheat for corn. In the rice feed consumption model, rice consumer prices have a very low significance probability and with an unexpected sign, so these prices were omitted from the model. Similarly, the exchange rate variable is omitted from the rice import and export functions. In the wheat yield model, we use AR (1) to account for autocorrelation in residuals. In the wheat import and export functions, we use the ratio of the domestic prices to the international prices as an explanatory variable to modify the models.

Tables 2, 3 and 4 report the estimated results. All coefficients take their expected signs, and most variables are statistically significant at the 1% or 5% levels. Most R-squared values are high, indicating that the models fit the data well. The probability for first-order Q-statistics (Q(1)) is given for each equation to instead of Durbin Watson statistics since the lagged dependent variable appears as an independent variable in some equations. From the results, parameters on the subsidy variable are highly significant and take a positive sign as expected in the area and yield response models for all grain crops, suggesting that subsidies promote grain planted areas and yields. The elasticities of planted areas

Table 3. Estimated results for wheat models

Production:

$lnA = 2.085 + 0.836lnA_{t-1} + 0.134lnP_{t-1} + 0.010lnS - 0.007T$
(0.466)[a] (0.043)[a] (0.019)[a] (0.002)[a] (0.001)[a]

Adj. R^2 = 0.99 Q(1) = 0.74 Method = OLS Obs.=23

$lnY = 2.843 + 0.666lnY_{t-1} + 0.125lnP_{t-1} + 0.006lnS - 0.208lnA$ +
(0.472)[a] (0.041)[a] (0.024)[a] (0.001)[a] (0.039)[a]
+ [ar(1) = –0.447]
(0.224)[b]

Adj. R^2 = 0.99 Q(1) = 0.20 Method = OLS Obs.=22

Consumption:

$lnFOD = 4.812 - 0.042lnCP - 0.125lnIN + 0.085lnPM + 0.074lnPC$
(0.029)[a] (0.024)[c] (0.004)[a] (0.024)[a] (0.028)[b]

Adj. R^2 = 0.99 Q(1) = 0.70 Method = WLS Obs.=23

$lnFED = -0.022 - 1.452lnCP + 0.598lnIN + 1.569lnPC$
(0.382) (0.316)[a] (0.036)[a] (0.414)[a]

Adj. R^2 = 0.96 Q(1) = 0.26 Method = WLS Obs.=24

Trade:

$lnIM = -48.022 + 3.700lnCP/IP + 8.461lnCS - 2.586lnER$
(19.336)[b] (0.444)[a] (1.651)[a] (0.531)[a]

Adj. R^2 = 0.92 Q(1) = 0.51 Method = WLS Obs.=24

$lnEX = 57.131 - 2.115lnCP/IP - 7.204lnCS + 2.688lnER$
(42.095) (0.677)[a] (3.134)[b] (1.592)[c]

Adj. R^2 = 0.39 Q(1) = 0.57 Method = OLS Obs.=21

Price linkage:

$lnP = 2.092 + 0.470lnCO + 0.070lnS$
(0.245)[a] (0.066)[a] (0.009)[a]

Adj. R^2 = 0.96 Q(1) = 0.93 Method = OLS Obs.=11

$lnCP = 0.323 + 0.733lnP + 0.161lnIP$
(0.220) (0.055)[a] (0.063)[b]

Adj. R^2 = 0.96 Q(1) = 0.10 Method = OLS Obs.=24

Explanation see Table 2

Table 4. Estimated results for corn models

Production:

$lnA = 3.179 + 0.703lnA_{t-1} + 0.108lnP_{t-1} + 0.005lnS + 0.004T$
(0.651)[a] (0.065)[a] (0.019)[a] (0.002)[b] (0.001)[b]

Adj. R^2 = 0.99 Q(1) = 0.49 Method = OLS Obs.=23

$lnY = 0.891 + 0.538lnY_{t-1} + 0.054\ln P_{t-1} + 0.008\ln S$
(0.250)[a] (0.124)[a] (0.030)[c] (0.002)[a]

Adj. R^2 = 0.95 Q(1) = 0.43 Method = OLS Obs.=24

Consumption:

$lnFOD = 2.596 - 0.093lnCP + 0.268lnIN + 0.322lnPM + 0.251lnPW$
(0.179)[a] (0.100) (0.028)[a] (0.117)[b] (0.107)[b]

Adj. R^2 = 0.99 Q(1) = 0.25 Method = WLS Obs.=24

$lnFED = 1.957 - 0.155lnCP + 0.303lnIN - 0.321lnPM + 0.273lnPW$
(0.109)[a] (0.042)[a] (0.012)[a] (0.062)[a] (0.018)[a]

Adj. R^2 = 0.99 Q(1) = 0.81 Method = WLS Obs.=24

Trade:

$lnIM = 53.700 + 19.595lnCP - 6.110lnIP + 1.146lnCS - 5.207lnER$
(18.013)[a] (0.633)[a] (0.658)[a] (0.609)[c] (1.834)[b]

Adj. R^2 = 0.98 Q(1) = 0.74 Method = WLS Obs.=24

$lnEX = 4.461 - 9.128lnCP + 0.885lnIP - 1.421lnCS + 0.618lnER$
(5.146) (0.658)[a] (0.3133)[b] (0.314)[a] (0.365)[c]

Adj. R^2 = 0.99 Q(1) = 0.32 Method = WLS Obs.=24

Price linkage:

$lnP = 1.288 + 0.713lnCO + 0.048lnS$
(0.331)[a] (0.098)[a] (0.015)[b]

Adj. R^2 = 0.93 Q(1) = 0.69 Method = OLS Obs.=11

$lnCP = 0.461 + 0.715lnP + 0.164lnIP$
(0.184)[b] (0.046)[a] (0.056)[a]

Adj. R^2 = 0.96 Q(1) = 0.83 Method = OLS Obs.=24

Explanation see Table 2

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Table 5. Grain supply and demand and self-sufficiency for baseline solution (1000 tons)

Grain	Year	Prod.	Cons.	Imports	Exports	E. Stocks	Self-sufficiency rate (%)	Stocks-to-use ratio (%)
Rice	2012	142 094	143 998	2 369	279	42 001	98.68	29.17
	2013	143 399	146 298	2 271	478	40 895	98.02	27.95
Wheat	2012	120 123	125 007	3 703	286	65 847	96.09	52.67
	2013	122 983	121 498	5 534	278	72 588	100.22	59.74
Corn	2012	205 581	199 998	5 208	257	61 233	102.79	30.62
	2013	213 084	212 006	3 266	78	65 499	100.51	30.89

Source: Model solution

with respect to subsidies for rice, wheat and corn are estimated to be 0.004, 0.010, and 0.005, respectively; the elasticities are 0.001, 0.006 and 0.008 for yields of rice, wheat and corn, respectively. In the equations of grain producer prices, the subsidy variable is significant at the 5% level with a coefficient of 0.048 for rice and corn together, and is significant at the 1% level with a coefficient of 0.070 for wheat; the signs of the subsidy variable for each grain are all positive. These results strongly suggest that the subsidies have contributed to increases in grain prices and provide convincing evidence to support the analyses in Theoretical framework. For grain trade equations, the domestic grain prices are all highly significant, and the sign of domestic prices is positive in the import equation and negative in the export equation. This indicates that, as domestic grain prices increase, grain consumers will switch to purchasing grains from international markets, which have lower prices, and grain exporters will transfer their grains for domestic use to gain more profits. The coefficients of domestic prices in corn trade equations are large, indicating that domestic corn prices exert tight control on corn imports and exports.

The above findings from the estimation results are reported here for the first time. In addition, the parameters of the model are all estimated using the Chinese data, and thus may reflect the current macroeconomic and policy situation in China. Therefore, the equilibrium model can precisely capture the effects of the subsidy policies on grain sectors.

SIMULATION ANALYSIS

Baseline solution and definition of policy shocks for simulations

The econometric parameters derived from the previous estimation (see Tables 2, 3 and 4 for details) and the policy scenarios were incorporated into the equilibrium framework. In order to ensure the accuracy of the simulation and to capture the precise effect of subsidy policies, we used add factors to adjust the solution results for the baseline and to match the actual values. The results for the baseline solution are reported in Table 5.

To assess the impacts of the subsidy policies on grain supply and demand and grain self-sufficiency, three simulation scenarios were defined to compare with the baseline solution. The total subsidy amounts are assumed to be increased by 10%, 50% and 100% over the actual amount only in 2012 for Scenarios 1, 2 and 3, respectively. This definition can also capture the dynamic impacts on grain markets in the following year, 2013. The strategies to simulate percentage changes in total subsidy amount are shown in Table 6.

Simulation results

The three scenarios were simulated using the equilibrium models for rice, wheat and corn, respectively. The main focus of the simulations was to determine the impacts of subsidies on grain supply and demand and, further, to capture changes in measurements

Table 6. Policy shock scenarios for subsidies in 2012 (billion yuan)

Year	Actual subsidy(baseline)	Scenario 1 10% increase	Scenario 2 50% Increase	Scenario 3 100% Increase
2012	166.80	183.48	250.20	333.60

Changes are assumed to be added to the actual subsidy amounts in 2012

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for grain self-sufficiency, the self-sufficiency rate, which is defined as the ratio of grain production to consumption and the stocks-to-use ratio, which is defined as the ratio of grain ending stocks to consumption. The detailed simulation results for rice, wheat and corn are shown in Tables 7–9, respectively. Changes in grain self-sufficiency rate and stocks-to-use ratio for each scenario are reported in Tables 10–11, respectively.

Changes in grain supply and demand

The subsidy policies have dynamic effects on grain production. They not only promote grain production in the current year by promoting grain planted areas and yields but also stimulate the following year's production by affecting grain prices. In addition, the impact in the following year is relatively larger than that in the current year. Empirically, a 10% increase in the total amount of subsidies could result in a 0.05% increase in rice production in the current year and a 0.08% increase in the following year; for wheat production, the respective increments are 0.13% and 0.24%, and for corn production, the respective increases are 0.12% and 0.15%. The subsidies can negatively impact the current year's grain consumption by influencing grain prices, and a 10% increase in the subsidy amount can reduce consumption of rice, wheat and corn by 0.12%, 0.16% and 0.05%, respectively. The subsidies can have an impact on grain imports and exports through the channels of grain domestic prices and demand. In this regard, a 10% increase in subsidy amount can increase imports of rice, wheat and corn by 1.12%, 0.47% and 6.62%,

Table 7. Simulation results for rice supply and demand (%, 1000 tons)

Scenario	Year	Prod.	Cons.	Imports	Exports	E.Stocks
1 (10%)	2012	0.05 (64.2)	−0.12 (−170.7)	1.12 (26.6)	−1.62 (−4.5)	0.63 (266.0)
	2013	0.08 (118.9)	– (–)	– (–)	– (–)	0.94 (384.9)
2 (50%)	2012	0.19 (273.3)	−0.50 (−724.5)	4.87 (115.3)	−6.72 (−18.8)	2.69 (1131.8)
	2013	0.35 (506.2)	– (–)	– (–)	– (–)	4.01 (1638.0)
3 (100%)	2012	0.33 (467.6)	−0.86 (−1236.1)	8.47 (200.5)	−11.20 (−31.3)	4.61 (1935.4)
	2013	0.60 (866.5)	– (–)	– (–)	– (–)	6.85 (2801.9)

Values in parentheses are quantitative changes with a unit of thousand tons; In scenario 1, 2 and 3, the subsidy amounts were increased by 10%, 50% and 100% in 2012, respectively.

Source: Authors' simulations

Table 8. Simulation results for wheat supply and demand (%, 1000 tons)

Scenario	Year	Prod.	Cons.	Imports	Exports	E. Stocks
1 (10%)	2012	0.13 (153.7)	−0.16 (−196.3)	0.47 (17.5)	0.10 (0.29)	0.56 (367.2)
	2013	0.24 (293.3)	– (–)	– (–)	– (–)	0.91 (660.5)
2 (50%)	2012	0.55 (655.3)	−0.66 (−826.6)	2.07 (76.8)	0.4 (1.1)	2.37 (1557.5)
	2013	1.02 (1252.5)	– (–)	– (–)	– (–)	3.87 (2810.0)
3 (100%)	2012	0.93 (1122.5)	−1.12 (−1399.7)	3.64 (134.8)	0.62 (1.78)	4.03 (2655.2)
	2013	1.75 (2149.0)	– (–)	– (–)	– (–)	6.62 (4804.2)

Explanation see Table 7

Source: Authors' simulations

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Table 9. Simulation results for corn supply and demand (%, 1000 tons)

Scenario	Year	Prod.	Cons.	Imports	Exports	E. Stocks
1 (10%)	2012	0.12 (249.6)	−0.05 (−90.7)	6.62 (344.6)	−2.90 (−7.5)	1.13 (692.4)
	2013	0.15 (314.3)	– (–)	– (–)	– (–)	1.54 (1006.7)
2 (50%)	2012	0.52 (1063.9)	−0.19 (−385.7)	31.30 (1631.9)	−11.80 (−30.3)	5.08 (3111.8)
	2013	0.63 (1340.4)	– (–)	– (–)	– (–)	6.80 (4452.2)
3 (100%)	2012	0.89 (1822.2)	−0.33 (−658.9)	59.40 (3091.3)	−19.30 (−49.5)	9.20 (5622.0)
	2013	1.08 (2296.6)	– (–)	– (–)	– (–)	12.10 (7918.6)

Explanation see Table 7

Source: Authors' simulations

respectively; further, it can reduce exports by 1.62% and 2.90% for rice and corn, respectively, and increase wheat exports by 0.10%. Finally, subsidy policies can have positive and dynamic impacts on grain ending stocks; they can increase grain ending stocks not only in the current year but also in the following year. The impact on the following year is actually larger than that on the current year. In this regard, a 10% increase in the amount of subsidies can result in a 0.63% increase in rice ending stocks in the current year and a 0.94% increase in the following year; for wheat, the respective increases are 0.56% and 0.91%, and for corn the respective increases are 1.13% and 1.54%. The detailed changes in Scenarios 2 and 3 for each grain see Tables 7–9.

Changes in the level of grain self-sufficiency

The grain self-sufficiency level is generally determined by the self-sufficiency rate and the stocks-to-use ratio. Therefore, changes in grain self-sufficiency rates and grain stocks-to-use ratios caused by subsidies are calculated according to the simulation results, with the results listed in Tables 10 and 11. For Scenario 1, in which subsidies are assumed to increase by 10%, the rice self-sufficiency rate rises from 98.68% to 98.84% in 2012 and from 98.02% to 98.10% in 2013, net increases of 0.16 and 0.08 percentage points over the baselines in 2012 and 2013, respectively; for wheat, the respective rises are 0.27 and 0.24 percentage points, and for corn, the rises are 0.17 and 0.15 percentage points, respectively. For Scenario 2, in which a 50% subsidy increase is assumed in 2012, the net percentage point increases in the self-sufficiency rate for rice are 0.69 in 2012 and 0.35 in 2013 over the baselines; for wheat, these rises are 1.17 and 1.03, respectively, and for corn, the respective increases are 0.73 and 0.63. For Scenario 3, in which subsidies are assumed to increase by 100% in 2012, the rice self-sufficiency rate increases by 1.18 percentage points in 2012 and 0.59 percentage points in 2013; for wheat, the respective increases are

Table 10. Changes in grain self-sufficiency rate to baseline (percentage points)

Scenario	Year	Rice	Wheat	Corn
1 (10%)	2012	0.16	0.27	0.17
	2013	0.08	0.24	0.15
2 (50%)	2012	0.69	1.17	0.73
	2013	0.35	1.03	0.63
3 (100%)	2012	1.18	2.00	1.25
	2013	0.59	1.77	1.08

In scenario 1, 2 and 3, subsidies were assumed to increase by 10%, 50% and 100% in 2012, respectively.

Source: Simulation results

Table 11. Changes in grain stocks-to-use ratio to baseline (percentage points)

Scenario	Year	Rice	Wheat	Corn
1 (10%)	2012	0.22	0.38	0.36
	2013	0.26	0.54	0.47
2 (50%)	2012	0.94	1.60	1.62
	2013	1.12	2.31	2.10
3 (100%)	2012	1.61	2.74	2.92
	2013	1.92	3.95	3.74

Explanation see Table 10

Source: Simulation results

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2.00 and 1.77, and for corn, the respective increases are 1.25 and 1.08 (see Table 10).

For grain stocks-to-use ratios, the simulation results are as follows: In Scenario 1, in which the subsidies are assumed to increase by 10% over the actual subsidy amount in 2012, the rice stocks-to-use ratio rises by 0.22 percentage points in 2012 and 0.26 percentage points in 2013 over the respective baseline ratios; for wheat, the respective rises are 0.38 and 0.54, and for corn, these rises are 0.36 and 0.47, respectively. For Scenario 2, a 50% increase in the amount of subsidies may lead to rice stocks-to-use ratio increases of 0.94 percentage points in 2012 and 1.12 percentage points in 2013 over the respective baselines; for wheat, these increases are 1.60 and 2.31, respectively, and for corn, the respective increases are 1.62 and 2.10. For Scenario 3, in which subsidies are supposed to increase by 100% in 2012, the rice stocks-to-use ratio increases by 1.61 percentage points in 2012 and 1.92 percentage points in 2013 over the corresponding baselines; for wheat, these increases are 2.74 and 3.95, respectively, and for corn, the respective increases are 2.92 and 3.74 (see Table 11).

Overall, the simulation results indicate the following:

(1) Subsidy policies show positive impacts on grain self-sufficiency rates and grain stocks-to-use ratios; a 10% increase in the total subsidy amount may lead to approximately a 0.1–0.3 percentage point increase in grain self-sufficiency rates and a 0.2–0.6 percentage point increase in grain stocks-to-use ratios. This implies that China's grain self-sufficiency situation could be improved through the use of subsidy polices, although the improvements are small relative to the large increases in subsidy amounts. These small increases in grain self-sufficiency levels suggest that subsidy policies in China lack efficiency. The impacts of subsidies on grain stocks are relatively larger than those on self-sufficiency rates. As the Chinese government employs subsidy policies to maintain the grain self-sufficiency level by increasing grain productivity, increases in grain stocks-to-use ratios would occur more rapidly than that in self-sufficiency rates, indicating stronger pressure on grain ending stocks due to the subsidy policies.

(2) Rice sector is more insensitive to the subsidy policies because the increases in rice self-sufficiency rates and stocks-to-use ratios are smaller than that of wheat and corn. Rice's apparent insensitivity may be linked to the fact that rice is the most important staple food for the Chinese people. As a result, rice production and consumption are rigid, leaving a very limited scope for exogenous factors to impact the rice sector. In other word, wheat and corn are relatively sensitive to the subsidies, so the efficiency of the subsidy policy can be enhanced by raising subsidy rates for wheat and corn.

CONCLUSION

The payment of subsidies is a common policy to promote grain productivity. Previous research has examined the impacts of subsidy policies on grain production from a wide range of perspectives and using a broad spectrum of methodologies. This study evaluated the impacts of the current subsidy policies from a new perspective by focusing not only on the supply sector, but also on the demand sector. Moreover, by employing the partial equilibrium model and the simulation analysis we empirically linked subsidy policies to the level of grain self-sufficiency and examined the contributions of the subsidies toward enhancing grain self-sufficiency in China.

The simulation results suggest that the subsidy policies show positive impacts on grain production in the current year by influencing grain planted areas and yields, and in the following year by influencing grain prices; moreover, the subsidies exert negative effects on grain consumption and increase imports but reduce exports (for wheat exports, the impact is positive but relatively small) through channels of grain consumption and domestic grain prices. Finally, the subsidies can boost the ending stocks of all grains in both the current and the following year. Overall, the grain self-sufficiency situation can be improved by using subsidy policies, although the improvements are relatively small. Given the sharp increases in subsidy amounts since 2003, the impact of subsidies on enhancing grain self-sufficiency was significant. Currently, the subsidies still account for a very small share of a farm's total income, approximately 3%, and far behind the proportion in some developed countries, which reaches over 40%. Therefore, there remains significant scope for increasing subsidy amounts in China, and employing subsidy policies can continue to maintain China's grain self-sufficiency at a high level.

The small increases in grain self-sufficiency rates imply that the subsidy policies lack efficiency. To improve this inefficient situation, some scholars (Hou 2013; Zhang 2013) have suggested that subsidies be tailored to the size of farmers' actual planted areas.

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Although payments in terms of actual planted areas may work more efficiently, the present reality of the large numbers of farmers and the small scale of most farms in China means that this payment method would, in fact, be impractical since it would likely result in huge executive costs. Therefore, the current payments in terms of contracted land areas are still an appropriate method for implementing subsidy policies. In addition, the payment method is capable of promoting grain production to a certain extent. Most importantly, a large number of farmers do in fact benefit substantially from these direct subsidies.

In practice, the current subsidies function as transfer payments and belong to income subsidies, meaning that their influence on grain production may be exerted through the income effect and poor farmers may react sensitively to subsidy incentives. Therefore, providing discriminatory subsidies to poor and rich farmers or to developed and developing areas and increasing subsidy rates for poor farmers or developing areas may make the subsidy policies work more efficiently. Although the subsidies are for different purposes, these subsidies all influence the behaviour of farmers through the income effect and can be used for any purpose without any restrictions. Thus, to enhance the effectiveness of the subsidy policies and to make the policies easy to enforce, it is necessary to combine these subsidies. Since wheat and corn are relatively sensitive to subsidy policies, increasing subsidy rates for wheat and corn can be helpful in ensuring basic self-sufficiency in cereal grains. Note that the subsidy policies may have a larger impact on grain ending stocks. Given that China's grain ending stocks are already large, continuing to employ subsidy policies may place considerable pressures on grain ending stocks and result in high storage costs. Therefore, measures to encourage the use of stocks for consumption should be developed to alleviate this potential problem.

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