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Full Length Research Paper

International trade and productivity of China's soybean commodity: Trade policy simulations by GTAP

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This study explores China's soybean trade and production since soybean is an important commodity in China's consumption market. It uses data envelopment analysis (DEA) to measure the productivity of China's soybean, and then based on the DEA results it applies Global Trade Analysis Project (GTAP) to simulate China's soybean import change concerning both potential productivity change and the pressure of currency upvaluation of RMB (Chinese Yuan). It appears that, with the currency upvaluation of RMB, North American Free Trade Area (NAFTA) would be the biggest beneficiary from China's soybean oil seeds imports even if China's soybean producers could improve their efficiency.

Key words: Soybean, production, productivity, data envelopment analysis (DEA), trade, import, GTAP, efficiency.

INTRODUCTION

Facing stronger global competition, China's crop sector has to consider the possible effects of such competition on agricultural production and trade. Producers of major field crops such as soybeans are directly challenged by cheaper agricultural products in the international market. Although, soybean is an important crop planted in China traditionally, the yield of it is much lower than that of US and other countries in America (Hunter et al., 2000). With the sharply increasing consumption of soybeans in the domestic market, China's soybean production cannot satisfy the domestic demand and it has become one of the largest soybean importers in the world. In addition, since China is the largest grain producer and consumer globally, its food balance is especially significant for the world food security (Huang et al., 1999).

However, there no sufficient observed studies that have analyze China's soybean production and trade. Using a data envelopment analysis (DEA) model, this paper measures technical efficiencies in different provinces of China over 7 years (from 1996 to 2002). And then, based on the measurement of soybean productivity, we simulate China's soybean trade change by Global Trade Analysis Project (GTAP). In this computed general equilibrium (CGE) model, the potential domestic productivity change from DEA results will be considered as one of shocks in import trade. Here, the DEA efficiency scores would provide the measurement of maximum potential improvement capacity of soybean productivity and would be applied in the GTAP to simulate the shock of productivity variation. Another important factor taken into consideration will be the pressure of currency upvaluation of RMB.

Since this paper is original in its application, the authors do not want to develop some new algorithm. The main purpose of this paper is to analyze the status of China's soybean production and trade. Although, China holds a huge market for soybean consumptions, the total yield of soybean in China is relatively low. Therefore, China has to import enormous quantity of soybean products, which would subsequently influence the global soybean market. So, this paper analyzes China's domestic soybean productivity using DEA and China's soybean trade using GTAP. And, finally, it provides some useful policy

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Table 1. The consumption of soybeans in China Unit: Ten thousand tons.

Year	Consumption	Year	Consumption
1978	755.2	1996	1430.9
1980	830	1997	1547.2
1988	1026.2	1998	1992.9
1989	905.1	1999	2304.5
1990	971.3	2000	2617.7
1991	875.6	2001	2760
1992	1015	2002	3028
1993	1433.5	2003	3891.6
1994	1576.1	2004	4413.9
1995	1407.3	2005	5095.7

Data source: FAOSTAT and National Bureau of Statistics of China.

implications and conclusions.

Soybean demand and production in China

China holds a huge market for soybean consumptions. After year 2000, China's domestic soybean market claimed over 15% of the total soybean consumption globally. In addition, China's soybean consumption had increased rapidly from 8.6% of the global soybean consumption in 1992 to 15.74% in 2000. From Table 1, the consumption of soybeans in China was increased slowly from 1978 to 1991, but in next 10 years, the consumption of soybeans in China had been tripled from 8756 thousand tons in 1991 to 26177 thousand tons in 2000. And then in 2005, this figure was up to 50957 thousand tons. The growth in consumption should be a result of increased demand in China for soybeans and soybean meal.

Although, China's farmers improved the yields up to nearly 1.6 ton1.7 tons/hectare at the beginning of 1990's, the planted area of soybean in China has been substantially influenced by the sharp expansion of the urban area and it is obviously lower than the planted acres in the US.

Therefore, it can be easily discovered that China's soybean output was dropped obviously in 1995. And again, in 1999 it dropped to 14251 thousand tons from 15152 thousand tons in 1998. From 2000 to 2009, China's soybean yield had always waved around 14720 thousand tons without any clear improvement.

It is obvious that the gap between China's soybean demand and domestic output was enlarged. Therefore, the conclusion can be safely drawn that China's domestic soybean production cannot satisfy the growing demand. China has becomes one of the world's largest importers of soybeans.

Recently, although China's government has strengthened its efforts to protect domestic soybean producers, China's domestic soybean producers are expected to be seriously influenced by rising imports and the associated declining price of soybean oil. Therefore, the most important policy purpose of China is to promote its soybean production efficiency. In addition to government policy and financial support in accordance with World Trade Organization rules, the efforts to protect domestic soybean suppliers can also include the technical improvement of soybean production.

In this study, to analyze the efficiency of China's soybean production, DEA method is used, and GTAP is applied to simulate the change trend in soybean import with considering RMB's upvaluation and potential productivity improvement.

Data envelopment analysis (DEA) model and productivity measurement

Data envelopment analysis (DEA)

The conception of the DEA method was developed by Farrell (1957) and Fare et al. (1985, 1994) or others. DEA involves the use of linear programming methods to construct a non-parametric frontier over the observations, so as to be able to calculate efficiencies relative to this frontier. These methods are outlined in Fare et al. (1994). Modern efficiency measurement begins with Farrell (1957) who drew upon the work of Debreu (1951) and Koopmans (1951) to measure firm efficiency which could account for multiple inputs.

Thus, this section begins with Farrell's original ideas which were illustrated in input/input space and hence had an input-reducing focus in Figure 1. These are usually termed input-orientated measures. In fact, the input-orientated DEA can be easily explained as the ability of a firm to minimize its cost with a given set of outputs. The input-orientated DEA can be illustrated by a simple example. There are firms which use two inputs (X1 and X2) to produce a single output (Y).

Normally, the frontier set is constructed from a non-parametric piecewise-linear convex isoquant. In Figure 1, the point Q can be defined as a given firm using

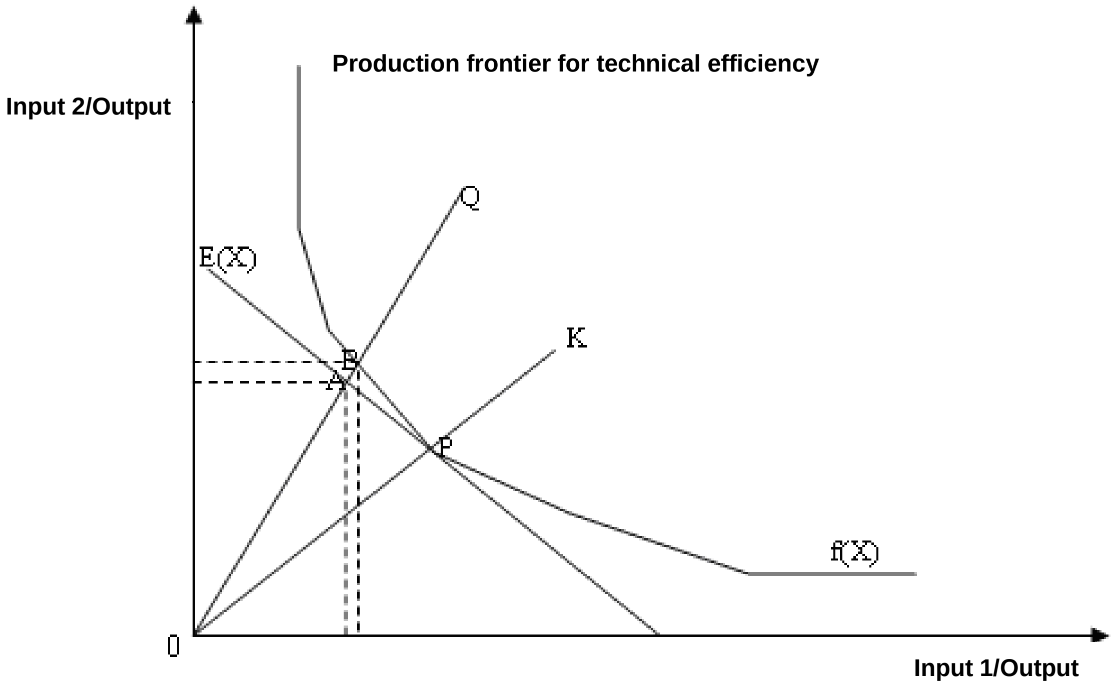

Figure 1. Input-orientated DEA.

quantities of inputs to produce a unit of output. The function f(x) in Figure 1 illustrates the various combinations of inputs required to efficiently produce a given level of output. Thus the technical efficiency of the firm producing at Q can be measured by QB which is the amount by which all inputs could be proportionally reduced to produce the same level of output. Technical efficiency (TE) can be expressed in percentage terms by the ratio OB/OQ which is equal to 1 minus QB/OQ. Technical efficiency measured in this way will take values in the interval between zero and one, indicating the degree of technical inefficiency of the firm. Where TE takes a value of one the firm is operating with full efficiency.

Now, we discuss output-orientated DEA which is the focus of this paper. The assumption of constant returns to scale (CRS) or variable returns to scale (VRS) is debated in this model form. The constant returns to scale assumption allow one to represent the technology using a unit isoquant.

It can be easily expressed as $f_c(x)$ in Figure 2. However, the CRS assumption is only appropriate when all units or firms are operating at an optimal scale. Banker et al. (1984) proposed an extension of the CRS DEA model to a VRS DEA model (variable returns to scale) which can account for a unit not operating at optimal scale. The CRS DEA can be easily modified to VRS by adding the convexity constraint. The VRS DEA frontier can be expressed as f(x) in Figure 2. The point A represents a unit or firm whose maximum possible output for VRS DEA is at point B. Thus, the VRS technical efficiency of A can be defined to be the ratio OA/OB. The scale efficiency can be calculated by CRS TE/VRS TE. The point E is a unit where the CRS frontier and VRS frontier overlap, indicating that CRS TE is equal to VRS TE and therefore scale efficiency is 1.

In the real application, we can use an output-orientated CRS/VRS efficiency model to estimate the technical efficiency of China's soybean production. According to Fare (1994), the CRS model can be expressed as:

$$\frac{1}{E_i} = \text{Max } \phi_i$$

$$st$$

$$\sum_{j=1}^{J} \lambda_j \ y_{qj} - \phi_i y_{qi} \geq 0, q = 1,\ldots,Q$$

$$x_{pi} - \sum_{j=1}^{J} \lambda_j \ x_{pj} \geq 0, p = 1,\ldots,P$$

$$\lambda_j \geq 0, j = 1,\ldots,J \tag{1}$$

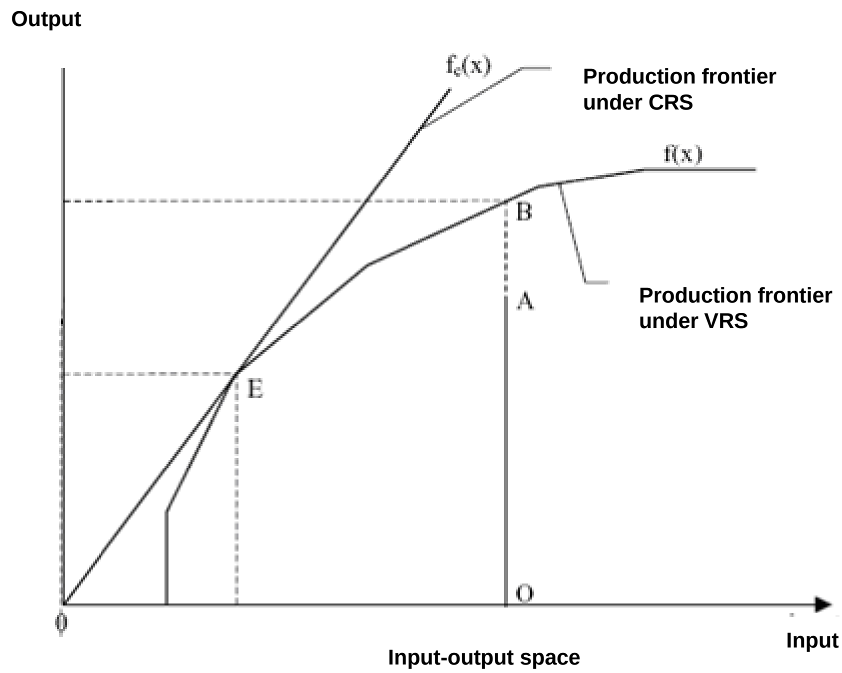

Figure 1. Ouput-orientated DEA.

where x is the input, y is the output and i is the number of the DMU. 1/Φ defines a TE score which varies between zero and one. Index Q represents type of output and index P represents type of input. λj (j=1,..,J) are non-negative constants. Under the assumption of constant returns to scale, the above CRS model can provide technical efficiency of each DMUi point by solving the above linear program according to the definition. The reciprocal of the function (1) is the Shephard output distance function (Shephard, 1970; Fare et al., 1994; Zhang, 2008).

$$\frac{1}{E_i} = \text{Max } \phi_i$$

$$st$$

$$\sum_{j=1}^{J} \lambda_j \; y_{qj} - \phi_i y_{qi} \geq 0, q = 1,\ldots,Q$$

$$x_{pi} - \sum_{j=1}^{J} \lambda_j \; x_{pj} \geq 0, p = 1,\ldots,P$$

$$\sum_{j=1}^{J} \lambda_j = 1$$

$$\lambda_j \geq 0, j = 1,\ldots,J$$

Based on the CRS model, the VRS model can be easily made by imposing the convexity constraint.

One output (soybeans) and four inputs (seed quantity, labor, the cost of machine and fertilizer quantity) were used in the DEA model. All output and input variables used for this study are expressed on a per mu (667m^2) basis.

We solve the linear programs of DEA model using the computer program, Deap version 2.1 developed by Coelli (1996), and we will use multi-stage method to calculate slacks instead of one-stage method.

Data envelopment analysis (DEA) model application and its results

The data set used in the productivity analysis is panel data set, which is based on provincial level observations. One output (soybeans) and four inputs (seed quantity, labor, the cost of machine and fertilizer quantity) are used in the panel data. In China, since all the farms are operated on the basis of labor-intensive, except for the current inputs included in the paper, all other inputs are neglectable. In addition, nearly all the soybean farmers in China only produce soybean products. It is very rare to find a multi-output soybean farm in China. The data set is cited from the survey led by National Development and Reform Commission of China. All data in this data set are based on the planted area of 1 mu which is about 667m^2. Data for the empirical analysis came primarily from the survey of soybean farms in 14 Provinces in China. In fact, the real number of surveyed farms was more than 5000.

From calculated results, it can be found that apart from some fully technically efficient provinces in the model, the estimated technical efficiencies range from 36.8 to 98.5%, with a mean technical efficiency level of 83.2%. This indicates that on average, the overall soybean production in China has the potential to be increased by 16.8%. This estimated result will be used in the trade simulation by GTAP. The estimated results of TE change suggest that only in 1999 to 2000 and 2001 to 2002 technical efficiencies were increasing.

Trade policy simulation with Global Trade Analysis Project (GTAP)

Application of Global Trade Analysis Project (GTAP) model

To analyze the impact of soybean production on trade in current complex trade environment and thus provide clear policy implications, this paper apply the GTAP for seeking to conduct policy and quantitative analyses of international trade issues in a global wide framework. GTAP developed by Purdue University in 1992, has become a fully documented, publicly available, global database and computable general equilibrium (CGE) model that can be easily used to simulate changes in policies and their impacts on specific countries, regions and the world markets. CGE model is now widely used in analyzing international trade (Jian et al., 2006). Its database is derived from government and non-government organization. This paper uses GTAP as a simulation tool in its analyses.

Here, we only consider the imports of soybean in China, for the exports of it is negligible in China. Because more than 90% of China's imported oil seeds are soybean, we will use the simulated change of imported oil seeds directly to proxy the change of imported soybean. For example in 2006, the total imported oil seeds was 24350 thousand tons, but among them 23500 thousand tons are soybean.

There are two factors which we regard as shock factors on import trade. One is productivity change, and the other is currency upvaluation of RMB. It is obvious from the result of DEA productivity analyses that under the present technology level the potential increase for China's soybean production is about 16.8% on average. In other words, under current technologies, the maximum possible improvement in China's soybean production is about 16.8%. However, from the Malmquist analyses, China's soybean production has no increasing trend; instead, it decreases in some years. The largest decrease in VRS technical efficiency came from 1998 to 1999 in which efficiency was reduced by about 7%. In this paper, we apply the above DEA results in international trade analyses of China's soybean by GTAP.

While a currency upvaluation shock cannot be directly modeled in GTAP, it can be proxied by simulating impacts of import tax. The upvaluation of the China's RMB currency can be represented by a reduced tariff on China's imports (Grennes, 1984; Houck, 1986). Such shocks are available in GTAP and their intensity can be determined by the percentage change in China's currency relative to the US' dollar and tax rate. Currently, the import tax rate for soybean in China is about 3%. Thus, if the exchange rate of RMB relative to US dollar is increased by 3% for up valuation, the import tax rate should be reduced by 100% to proxy the upvaluation change. If the exchange rate of RMB relative to US dollar is increased by 1.5% for upvaluation, the import tax rate should be set to be reduced by 50%.

We aggregated the regional and commodity aggregation for this study as follows: the 87 regions of GTAP are combined into 4 aggregates; China, NAFTA; EU and rest of the world (ROW). The 57 GTAP commodities were aggregated into four groups: soybean oilseeds, other food, services and activities and manufactures. After incorporating the import tariff change to the aggregated regions and commodities, simulation results show changes in import quantities for China. These changes reflect the policy shocks that are simulated within the model. Due to the objectives of this study, the analysis is concentrated on the simulated results from different production change and exchange rate change in GTAP.

Simulated results from Global Trade Analysis Project (GTAP)

The following tables are percentage changes in imported quantities of soybean oilseeds in China according to different simulations. Simulation results in Table 2 show percentage changes in imports of soybean oilseeds in China with the assumption of no efficiency change. The results indicate that China would import more quantity of soybean oilseeds from the world soybean market after the currency upvaluation took place. The China's imports of soybean oilseed would be increased by 77.84% if the RMB's exchange rate is increased by 3% and there is no improvement in China's domestic soybean production. Even if the RMB's exchange rate is only increased by 0.3%, there would be an increase of 7.78% in China's soybean imports.

Table 3 depicts the simulated percentage changes of soybean oilseeds imports with the assumption of 16.8% production increase indicating the soybean production in China would be implemented at full efficiency. The above assumption combined with 0.3% upvaluation would yield a 10.33% decrease in soybean imports. However, if the exchange rate of RMB is increased by 0.75%, even with the full efficiency domestic production under current technology, China's soybean imports would be increased by 1.35%. This indicates that the effect of upvaluation can

Table 2. Simulated results from GTAP {Assuming no efficiency (production) change}.

Importer	Exchange rate change (%)	Imported quantity change (%)
China	0.3	7.78
	0.75	19.46
	1.5	38.92
	3	77.84

Table 3. Simulated results from GTAP {Assuming 16.8% efficiency (production) increase}.

Importer	Exchange rate change (%)	Imported quantity change (%)
China	0.3	-10.33
	0.75	1.35
	1.5	20.81
	3	59.73

16.8% is estimated as maximum possible production increase under current technology on average in China.

Table 4. Simulated results from GTAP {Assuming 7% efficiency (production) decrease}.

Importer	Exchange rate change (%)	Imported quantity change (%)
China	0.3	15.33
	0.75	27.01
	1.5	46.47
	3	85.39

Table 5. Simulated results for NAFTA from GTAP

Exporter	Exchange rate change (%)	Importers		
		Imported quantity change from NAFTA (%)		
		E.U.	Row	China
NAFTA	0.3	-0.04	-0.16	8.07
	0.75	-0.1	-0.39	20.17
	1.5	-0.2	-0.78	40.34
	3	-0.4	-1.56	80.69

easily overcome the effect of efficiency improvement in domestic production. In other words, China's soybean production system needs innovative technology progress, if it wants to have a better performance in soybean trade balance. Table 4 gives the results of soybean oilseeds import change assuming 7% efficiency decrease in domestic production. As discussed in the DEA analyses, China's real soybean production did not show any large increase in efficiency although it has the potential to be increased by 16.8%. Thus, we also should simulate the effects of efficiency decrease on China's soybean trade. It is clear that under this assumption, only 0.3% upvaluation of RMB would make soybean imports increased by 15.33%. With the assumption of 3% increase in RMB's, exchange rate would yield 85.39% increase in soybean imports in China.

Here, we are also interested in the regional trade change. In Table 5, the regional imported quantity changes of soybean oilseeds from NAFTA are also provided with the assumption of no efficiency change, compared with the enormously increased export quantity from NAFTA to China, the export decrease from NAFTA to EU and other countries is negligible. With the assumption of no efficiency change in China's domestic production, if the exchange rate of RMB relative to US dollar is increased by 3%, the export quantity from US to China would be increased by 80.69% which is higher than China's average import increase (77.84%) under the same assumption. This indicates that, with the upvaluation of RMB, NAFTA would be the biggest beneficiary from China's soybean oilseeds trade.

DISCUSSION AND POLICY IMPLICATIONS

The DEA result is robust and useful for policy implications, even though the current study includes only 14 provinces in the application. It can be safely concluded that the productivity of soybean farms is quite low in China. In other words, in China, there exists some potential to increase soybean production through improvements in efficiency. As a result of limited domestic production level and increasing demand for soybean consumption, the China's government has recognized the need to use profit stimulation instead of government regulation. However, even though China's domestic soybean production could be operated at full efficiency, its competition capacity is still far lower than other countries such as US. The only solution to enormously improve China's domestic soybean productivity and competition ability is probably depending on innovative technology progress, such as the application of genetically modified seeds, although current policy of China's government does not allow planting genetically-modified (GM) soybeans widely.

From the results of GTAP, even though currency upvaluation can be of benefit to soybean proceeding industries depending on imported soybean oilseeds, decreasing import prices of products bring overall increase in China's soybean imports which will harm agricultural trade balance and domestic economy of China. The real data suggests China's increased soybean oilseeds imports and the GTAP simulations suggest that these increases in imports may be even larger in the long-run. In addition, with the currency upvaluation of China, the main exporters in NAFTA would be the biggest beneficiaries from China's soybean oilseeds trade.

Conclusion

The paper has explored the soybean production and international trade of China. It investigates the technical efficiency of China's soybean production, and also provides an overview of soybean production system and demand in China. The result of DEA model shows that technical efficiency of China's soybean production is not high, and in some provinces it is extremely low. Thus, the increasing of TE in China's soybean plant system can improve the profit of China's soybean production activity. Therefore, essential approaches to improve China's overall soybean production are necessary, depending on the improvement of farm efficiency and the introduction of high-yield varieties of soybean such as GM soybeans.

In addition, because of the low productivity and the pressure of RMB's upvaluation, it is clear from GTAP simulations that China will continue to increase soybean imports including GM soybeans to satisfy the domestic demand in the long term.

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