Agricultural sector has been subjected to major governmental interventions throughout the world, and almost all governments make great efforts to support agriculture (Anderson et al. 2013). During the development of economic, protection is generally shifting from the industrial sector to agriculture (Swinnen 1994). Furthermore, agricultural supports offered by the governments are much larger in developed countries than in the developing countries (Anderson et al. 2013). However, arguments about the reasons for the governments to subsidize agriculture are never ending. Generally speaking, there are two major viewpoints about agricultural support. One opinion issues that politicians who support farmers are to obtain more political votes (Swinnen 1994; Graff et al. 2009; Anderson and Swinnen 2010; Anderson et al. 2013), while other people declare that the reasons for governments to subsidize agriculture are that agriculture has an intrinsic weakness because the demand for agricultural products are inelastic but the supply of them are elastic (Zhang 1949; Krueger et al. 1988; Zietz and Valdts 1993). Most of the studies which are based on developed countries followed the political support assumption, while other studies which focused on developing countries sustained a weak agriculture assumption.

People who with the political vote assumption will focus their attention on the distortions of agriculture support. Therefore, numerous studies captured the negative effects of agricultural protection, such as the price distortions and welfare losses. Swinnen (1994) explained agricultural protection with the positive political theory. He argued that it is well known to us that agriculture is generally taxed in developing countries but mostly subsidized in developed countries. The reason for that is the economic development reduces the farmers’ organization costs, leading to such government policies that are increasingly beneficial to agriculture. And he noted that there is a negative correlation

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**Agricultural subsidy with capacity constraints and demand elasticity**

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**Abstract:** Agricultural subsidy has attracted more and more attention. This paper captures the effects of subsidy (including area subsidy and price subsidy) on the total sown areas of crops based on the assumption that subsidy has both stimulating effects and inhibiting effects. Different from the prior studies, this paper considers the impacts of the farmland constraint and demand elasticity and some interesting conclusions are achieved. Firstly, a stimulating effect increases crop sown areas while an inhibiting effect reduces them. Secondly, the output efficiency of farmland as well as the demand elasticity has a major impact on the government subsidy. Besides, the capacity constraint makes thing difference and the government should choose between the areas subsidy and price subsidy under different conditions. Finally, this paper offers an empirical test on the conclusions by adopting the Chinese agricultural statistical data.

**Key words:** allowance, constrained farmland inputs, inhibiting effect, stimulating effect

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Supported by the Guangdong Social Science Foundation (GD13YLJ02), the Fundamental Research Funds for the Central Universities, the GDUPS (2012), the National Natural Science Foundation of PRC (No. 71271100 and No. 71401057), the National Social Science Fund (No. 14AJY020) and the Key Program of the National Natural Science Foundation of China (No. 71333004).
between agricultural protection and agricultural income relative to other income. Anderson et al. (2013) used the Relative Rate of Assistance (RRA) to capture the anti-agricultural bias (positive RRA) or the pro-agricultural bias (negative RRA). Their studies found that high-income countries are more pro-agricultural than the low-income countries and a high RRA results in high welfare losses. Graff et al. (2009) declared that the politicians support agriculture because they can acquire more votes by agricultural subsidy. Another Europe-based study drew by Greenaway and Swinnen (2009) also emphasized the distorting effects of agricultural subsidy.

Agricultural protection is not only confined to industrialized countries, but it also appears in developing countries such as China and Korea in the process of industrialization for the low or decreasing agricultural comparative advantage (Zietz and Valdts 1993). The empirical research of Olper (2001) found that the effects of agricultural protection are different between developed countries and developing countries, which implied that the developing countries should make reforms to protect and enforce property. Many other studies also focused on developing countries for the different effects of agricultural protection (Krueger et al. 1988; Anderson and Will 2009).

China has abolished the agricultural tax, which has been imposed for more than 2000 years, in 2006. Furthermore, the Chinese government adopted rice subsidies in 2004 and cotton subsidy in 2008. Then at the same year as the cotton subsidy has been implemented, the Chinese government drafted and announced its longstanding food security policy. As the largest developing country, China attracts more and more attention for its agricultural reform (Huang et al. 2010; Yu and Jensen 2010; Du et al. 2011; Anderson et al. 2013; Tan et al. 2013). Although agricultural subsidies have distortion effects, the evidence shows that subsidies stimulate the agricultural development, too Rizov et al. (2013) issued that after the decoupling reform was implemented, the subsidies have a positive impact on the farm productivity in several EU countries. Tan et al. (2013) declared that subsidies have a negative effect on the total agricultural factor productivity. However, based on the Chinese national household’s survey data, Huang et al. (2010) indicated that there is no evidence shown that agricultural subsidies distort the producer decisions.

A great number of studies have been focused on agricultural subsidies. However, few of them take into account those factors which affect the subsidies efficiency, such as the farmland constraints, the product elasticity and the interaction of different products subsidies. Constraints make the difference (Esó et al. 2010; Nie and Chen 2012; Nie 2014), and it is well known that the total farmland is limited. Furthermore, the elasticity of product impacts the demand as well as the subsidies efficiency. For example, Michael and Wolfram (2013)’s empirical research testified the effects of the elasticity of demands and supplies. Besides, the subsidy efficiencies also have something to do with the interrelation between different products. Therefore, different from the original studies, the paper employs all the facts above to study the efficiencies of the primary products subsidies, following the agricultural weakness assumption.

MODEL AND ANALYSIS

Generally, people classify agricultural products into two kinds: food crop (e.g. rice) and cash crop (e.g. cotton) and we will take both of them into account in our model. Classical economics tell us that the elasticity as well as the product substitutability affects the product price (Michael and Wolfram 2013). Denote products to $i$, $(i = A, B)$ and $A$ represents the food crop while $B$ represents the cash crop. Then similar to Nie and Chen (2012) along with Sacco and Schmutzer (2011), this study takes the following consumer utility function.

$$U(q_a, q_b) = a(q_a + q_b) - \frac{1}{2}[e_q q_a^2 + e_q q_b^2] - \gamma q_a q_b$$

(1)

$e_i$ and $\gamma$ are the demand elasticity parameter of crop $i$ and the substitute parameter between different products. The purpose of employing the demand elasticity parameter is to capture the effects of demand elasticity on the government’s subsidy behaviour. Two kinds of cultivators play with the Cournot competition with a low substitutability. Following, we have the inverse demand function easily.

$$p_i = a - e_q q_i - \gamma q_i$$

(2)

Besides, we assume that there are only two kinds of inputs, labour and farmland. The output of labour satisfies the Cobb-Douglas production function and the total outputs equal to unit outputs of the farmland multiply land area (Tan et al. 2013). Furthermore, the market clearing conditions always hold as a general assumption in other researches. The outputs efficiencies of the labour input (or the unit output of...
farmland) to different crops are the same\(^1\). Then the outputs function is given by the following:

\[ q_i = \theta L^a s_i \]  

(3)

\(\alpha\) implies the output elasticity, \(q\) means the technical efficiency and \(\theta L^a\) is the unit output of farmland which depends on the inputs of labour, while \(s_i\) represents the area of crop \(i\), \((i = A, B)\).

We employ a quadratic cost function and \(S\) represents the total farmland constraint or \(s_i + s_B \leq S\). So following this, this paper will analyse the function (4) with the area subsidy and price subsidy. So following this, this paper will offers farmers subsidies including the area subsidy or the total crop outputs, the government always acquire is the only optimal solution. Solving the function (6), we get the equilibrium cultivation areas

\[ s_d = \frac{a\theta L^a - \gamma aL^a + 2e_a a\theta L^a + (1 + 2e_\gamma)\tau_A - \gamma\tau_B}{(1 - \gamma^2 + 2e_\gamma + 2e_\beta + 4e_\epsilon e_\beta) \theta^2 L^{2a}} \]  

(7)

\[ s_B = \frac{a\theta L^a - \gamma aL^a + 2e_a a\theta L^a + (1 + 2e_\gamma)\tau_B - \gamma\tau_A}{(1 - \gamma^2 + 2e_\gamma + 2e_\beta + 4e_\epsilon e_\beta) \theta^2 L^{2a}} \]

**Price subsidy**

If the government supports farmers with the price subsidy, then the income that the farmers obtain per the sold product is higher than the market equilibrium price, which implies that the government allowances distort the equilibrium price. If the subsidy ratio of crop \(i\), \((i = A, B)\) is also \(\tau\), then the price the farmers acquire is \(p_i = a + \tau_i - e_i q_i - \gamma q_i\) and the cultivators’ profits functions are

\[ \pi_i = (a + \tau_i - e_i \theta L^a s_i - \gamma \theta L^a s_i) \theta L^a s_i - \frac{(\theta L^a s_i)^2}{2} \]  

(8)

From the function (8), we have

\[ s_d = \frac{a(1 - \gamma + 2e_\gamma) + (1 + 2e_\beta)\tau_A - \gamma\tau_B}{(1 - \gamma^2 + 2e_\gamma + 2e_\beta + 4e_\epsilon e_\beta) \theta^2 L^{2a}} \]  

(9)

\[ s_B = \frac{a(1 - \gamma + 2e_\gamma) + (1 + 2e_\beta)\tau_B - \gamma\tau_A}{(1 - \gamma^2 + 2e_\gamma + 2e_\beta + 4e_\epsilon e_\beta) \theta^2 L^{2a}} \]

Based on the analyses above, this paper achieves the following propositions:

**Proposition 1** \(\frac{\partial s_d}{\partial \tau_A} > 0, \frac{\partial s_d}{\partial \tau_B} < 0, \frac{\partial \tau_A}{\partial \tau_A} > 0, \frac{\partial \tau_A}{\partial \theta} > 0\)

Proof See in Appendix.

**Remark:** The conclusions of Proposition 1 show that the agricultural subsidy has both the stimulating effects and the inhibiting effects. The stimulating effects increase the farmers’ cultivation areas, while the inhibiting effects decrease the areas. Most of the existing studies ignore the inhibiting effects of the agricultural subsidy. The elasticity parameter as well as the technical efficiency increase the subsidy ratio of the government. Most of agricultural products lack in demand elasticity, so the governments all over the world supply farmers with subsidies to protect the development of agriculture. As the technical efficiency increases, the governments should also give the cultivators more allowances. If not, the paradox

\(^1\)Labor inputs are not a key factor in the study, so we turn the analysis about the output efficiency of labor to the output efficiency of farmland.
that the farmers’ incomes reduce as the output of crops increases will happen time again and again.

**Proposition 2.**

If $0L^\alpha > 1$, it has $s_A - s_B < 0$, if $0L^\alpha < 1$, it has $s_A - s_B > 0$.

Proof See in Appendix.

Remark: Proposition 2 implies that the output efficiency of farmland or $0L^\alpha$ is an important factor which impacts all the total area, the stimulating effects and the inhibiting effects of subsidy. If the output efficiency of farmland is high or $0L^\alpha > 1$, the total cultivation areas, the effects as well as the inhibiting effects of the subsidy are higher at price subsidy case. If the output efficiency of farmland is low or $0L^\alpha < 1$, then the total cultivation areas, the stimulating effects as well as the inhibiting effects of the subsidy are higher at the area subsidy case. The policy implication of Proposition 2 is that the governments should consider the output efficiency of farmland when they make the subsidy decisions.

Many industries are facing the capacity constraints. And agriculture is no exception, for the total areas are limited. So next we will take the tight constraint into consideration.

**Tight constraint or $s_A + s_B = S$**

Again, we will analyse the base model under the area subsidy and price subsidy conditions. Then compare the results of the tight constraint case with the non-tight constraint status. The non-tight constraint means $\lambda > 0$. The same as Nie and Chen (2012), we further assume that $\lambda_A = \lambda_B$ which means the shadow prices of the cultivating lands of different crops are the same. Without losing the general, we denote A to the food crop and B to the cash crop. Furthermore, we assume that the food crop is more important than the cash crop, which means the farmers will plant enough food crops at first if they face the farmland constraint and that the assumption is acceptable.

**Area subsidy**

Substituting $s_A + s_B = S$ or $s_B = S - s_A$ to the function (3), we have

$$\pi_A = [a - e_A \theta L^\alpha s_A - (S - s_A) \theta L^\alpha s_A + \tau_s s_A - \frac{(\theta L^\alpha s_A)^2}{2}]$$

Solving the function (10) we obtain the following equilibrium solutions

$$s_A^{*} = \frac{aL^\alpha - \gamma S\theta^2 L^\alpha + \tau_s}{(1 - 2\gamma + 2e_{\theta}) \theta^2 L^\alpha},$$

$$s_B^{*} = \frac{-aL^\alpha + (1 - \gamma) S\theta^2 L^\alpha + 2Se_{\theta} \theta^2 L^\alpha - \tau_s}{(1 - 2\gamma + 2e_{\theta}) \theta^2 L^\alpha}$$

**Price subsidy**

Replacing the area subsidy with price subsidy, we acquire the alternative expression of (10) as follows

$$\pi_A = [a + \tau_s - e_A \theta L^\alpha s_A - \gamma \theta L^\alpha (S - s_A) \theta L^\alpha s_A - \frac{(\theta L^\alpha s_A)^2}{2}]$$

Then we have

$$s_A^{*} = \frac{a - \gamma S\theta L^\alpha + \tau_s}{(1 - 2\gamma + 2e_{\theta}) \theta L^\alpha},$$

$$s_B^{*} = \frac{-a + (1 + 2e_{\theta}) S\theta L^\alpha + \gamma S\theta L^\alpha - \tau_s}{(1 - 2\gamma + 2e_{\theta}) \theta L^\alpha}$$

Now, we achieve other two propositions of this study.

**Proposition 3.** The conclusions of Proposition 1 and Proposition 2 are holed under the farmland constraint. Proof See in Appendix.

Remark: Proposition 3 illustrates that no matter whether the farmland constraint is tight or not, we can get the same conclusions that the stimulating effects increase the cultivating areas while the inhibiting effect decrease them and the output efficiency of farmland is a major factor in the process of the subsidy policy implementation. In other words, our conclusions are robust.

**Proposition 4.** If $0L^\alpha > 1$, then $s_A^{*} - s_B^{*} < s_A^{*} - s_B^{*}$; If $0L^\alpha < 1$, then $s_A^{*} - s_B^{*} > s_A^{*} - s_B^{*}$.

But $$\frac{dL^\alpha (s_A^{*} - s_B^{*}) - (s_A^{*} - s_B^{*})}{\delta s_A} > 0$$ always holds.

Proof See in Appendix.

Remark: Once again, the conclusions of Proposition 4 show that the output efficiency of farmland has critical impacts on the results of the agricultural subsidy. The cultivating areas difference between crops is lager under the price subsidy than under the area subsidy if the output efficiency of farmland is high.
and vice versa, while the subsidy of the advantage crop always enlarges the gap of the cultivating areas difference between different crops under a different subsidy status.

**Proposition 5.**

\[ \sum_{a \neq b} \left| s^{*} - s^{*'} \right| > \sum_{a \neq b} \left| s^{*} - s^{*'} \right| \]

\[ \sum_{a \neq b} \frac{\partial s^{*}}{\partial \tau_{a}} - \sum_{a \neq b} \frac{\partial s^{*'}}{\partial \tau_{a}} < 0, \]

\[ \sum_{a \neq b} \frac{\partial s^{*}}{\partial \tau_{a}} > \sum_{a \neq b} \frac{\partial s^{*'}}{\partial \tau_{a}} \]

\[ \sum_{a \neq b} \frac{\partial s^{*}}{\partial \tau_{a}} + \sum_{a \neq b} \frac{\partial s^{*'}}{\partial \tau_{a}} < 0. \]

Proof See in Appendix.

**Remark:** Proposition 2 and Proposition 3 illustrate that the relationships of the cultivating areas, the stimulating effects and the inhibiting effects between different subsidy cases are ambiguous, because they depend on the output efficiency of farmland (\( \theta L^{a} \)). However, the Proposition 5 shows that the gaps of the cultivating areas, as well as the gaps of the stimulating effects and inhibiting effects, among different subsidy conditions are larger at the tight constraint state than the non-tight constraint status, which means the farmland constraint enlarges the effects difference of different subsidy policies. And those differences have nothing to do with the output efficiency of farmland.

**Welfare analysis**

Another significant issue is the welfare of different cases, so we compare the welfare differences between the area subsidy and price subsidy both at the non-tight constraint condition and the tight constraint condition. As we all know, the total social welfare (SW) includes the consumer surplus (CS) and the producer surplus (PS), or \( SW = CS + PS \). Denoting the total social welfare, consumer surplus and the producer surplus at the area subsidy case to \( SW, CS \) and \( PS \), while at the price subsidy case to \( SW', CS' \) and \( PS' \) under the non-tight constraint condition. Based on the analyses above, we have the following conclusions:

**Proposition 6.** \( CS > CS', PS > PS' \) and \( SW > SW' \) if \( \theta L^{a} < 1 \); \( CS < CS', PS < PS' \) and \( SW < SW' \) if \( \theta L^{a} > 1 \). Proof See in the Appendix.

**Remark:** The conclusions of Proposition 6 indicate that the relationships of the consumer surplus, producer surplus as well as the total social welfare between different subsidy cases depend on the output efficiency of farmland (\( \theta L^{a} \)). If the output efficiency of farmland is efficient or \( \theta L^{a} > 1 \), then the price subsidy results in high welfares. However, if the output efficiency of farmland is inefficient or \( \theta L^{a} < 1 \), then the government should carry out the area subsidy. The policy implication of Proposition 6 illustrates that the politician should take the output efficiency of farmland into consideration if they make choice between the area subsidy and price subsidy. However, unfortunately the relationships of the consumer surplus, the producer surplus and the total social welfare under different subsidy cases are ambiguous if the farmland constraint is tight. The reason for it is that the sown areas increase of one kind of crops will reduce the sown areas of the other, so the total social welfare is ambiguous.

**EMPIRICAL ANALYSIS: EVIDENCE FROM CHINA**

China is the biggest developing country which has more than 1.3 billion people, but only 1.827 billion cultivated lands. In other word, it has to cultivate 20% people with less than 8% farmland of the world. Furthermore, one negative effect of the process of industrialization is that our farmlands are becoming less and less. That is why the food security and food safety are so serious in China. So in order to heighten the output efficiency of agriculture and to enhance the total food supplies, on the one hand, the Chinese government abolishes the agricultural tax and on the other hand, it has begun to subsidize farmers since the beginning of 21 century. Rice is the most important product of the food crops while...
cotton is one of the major cash crops. Following, we will employ the Chinese statistical data of rice and cotton to test the Propositions about the results of subsidy of China.

The results of Figure 1 show that the total sown area of rice decreases for most of the years before 2004, while it increases in all the years after 2004. One significant reason is that the Chinese government started to subsidise rice farmers at 2004. However, the thing that confuses us is that although the Chinese government also supplies the cotton farmers with the allowance since 2008, the same change of the total sown areas has not happen for cotton, or the total sown areas of cotton are not increasing.

The same phenomenon happens again for the total outputs of rice and cotton (Figure 2). From Figure 2, we know that the total outputs of rice increase year by year since 2004 but to the contrary, the total outputs of cotton even decrease after 2008. Why did this happen? It is possible that the reasons for that are the output efficiency increase or the demands for cotton decrease.

So in the following, we will employ the output efficiency and the demands data of China. Figure 3 tells us that the yields per area unit of rice and cotton were not changing significantly since 1997, which means that the farmland output efficiency of rice as well as cotton was almost the same from 1997 to 2011. Combining Figures 1, 2 and 3, we get the conclusions that the major reason for the increase (decrease) of rice (cotton) is the increase (decrease) of the cultivating areas.

It is possible that the reasons for the decrease of the total outputs and sown areas of cotton are that the Chinese people reduced their demand for cotton. However, Figure 4 illustrates that the net imports of cotton are increasing as the total outputs of cotton decrease. So we can exclude the demand decrease out of the reasons for the reducing of the total outputs and sown areas of cotton.

The total cultivable areas of China are near 1.83 billion and they are decreasing year by year because of the urbanization and industrialization of China, which means that the Chinese agricultural products are produced under the inputs constraint. The inputs constraint combined with the dual-effects of subsidies leads to the results of increasing the production of rice and decreasing that of cotton.

Figure 2. Total outputs (Unit: ten thousand tons)
Notes: The left ordinate represents rice and the right ordinate represents cotton

Figure 3. Yields per unit of area (unit: kilogram/hectare)

Figure 4. Net imports (Unit: million tons)
Note: Because the data of imports of rice before the year of 1996 are missing, the net imports data of rice begin at 1996.
DISCUSSION AND CONCLUSIONS

Employing two major kinds of crops, the food crop and the cash crop, this paper captures the agricultural subsidy with the farmland constraint and the demand elasticity. Taking the area subsidy and price subsidy into consideration, this study analyses the base model both at the non-tight farmland constraint and the tight constraint status. Then we adopted the Chinese rice (food crop) and cotton (cash crop) statistical data to carry out the empirical research.

The theoretical and empirical study show that the agricultural subsidy has positive (stimulating) effects on increasing the total sown areas of the allowed crop itself, but it also has negative (inhibiting) effects on reducing the total cultivating areas of others. Those conclusions imply that the studies about subsidies should take different crops into consideration at the same time. If not (it means considering one kind of crop such as rice or cotton singly), the study will overestimate or underestimate the effects of the subsidy or even get absurd conclusions. Furthermore, this study illustrates that the output efficiency of farmland as well as the demand elasticity have a significant impact on the subsidy and the relationships of welfare among different subsidy cases depending on the output efficiency of the farmland. Therefore, the governments should take those factors into account when they make the area subsidy or price subsidy decisions.

This study also offers a reasonable explanation to the phenomenon that the total sown areas of cotton are decreasing after the cotton subsidy. Because the food crops are more important than the cash crops, then if agriculture faces the farmland constraint, the people will meet their need for the food cultivation first. The result of that is that the total sown areas of the cash crops are not necessarily increasing even when the governments subsidise farmers with allowances. And the government should take notice of the interaction between different crops subsidies. Agricultural subsidy is important for the agriculture development, especially for the developing country such as China, so more researches should be taken to help the government to formulate an efficient subsidy policy.

APPENDIX

Proof of proposition 1

From (7), we have the following conclusions by the comparative static analysis,

\[ \frac{\partial s_{A}}{\partial \tau_{A}} = \frac{1 + 2e_{j}}{(1 - \gamma^{2} + 2e_{A} + 2e_{B} + 4e_{A}e_{B})\theta^{2}L^{2}} > 0 \]  

\[ \frac{\partial s_{B}}{\partial \tau_{A}} = \frac{\gamma}{(1 - \gamma^{2} + 2e_{A} + 2e_{B} + 4e_{A}e_{B})\theta^{2}L^{2}} < 0 \]

Then we get the following conclusions by the comparative static analysis, we achieve

\[ \frac{\partial s_{A}}{\partial \tau_{E}} = \frac{2a\theta L^{n}(1 - \gamma) + 2ae_{B}\theta L^{n} + (1 + 2e_{B})\tau_{B} - \gamma \tau_{B}}{1 - \gamma^{2} + 2e_{A} + 2e_{B} + 4e_{A}e_{B}} > 0 \]  

\[ \frac{\partial s_{A}}{\partial \tau_{E}} = \frac{a(1 - \gamma)\theta L^{n} + 2ae_{B}\theta L^{n} + (2 + 2e_{B})\tau_{B} - 2\gamma \tau_{B}}{(1 + 2e_{B})\theta} > 0 \]

and

\[ \frac{\partial s_{A}}{\partial \theta} = \frac{2ae_{B}\theta L^{n} + (2 + 2e_{B})\tau_{B} - 2\gamma \tau_{B}}{(1 + 2e_{B})} > 0 \]

For the same reasons, from (9) we have the following results,

\[ \frac{\partial s_{B}}{\partial \tau_{A}} = \frac{1 + 2e_{B}}{(1 - \gamma^{2} + 2e_{A} + 2e_{B} + 4e_{A}e_{B})\theta L^{2}} > 0 \]  

\[ \frac{\partial s_{B}}{\partial \tau_{B}} = \frac{\gamma}{(1 - \gamma^{2} + 2e_{A} + 2e_{B} + 4e_{A}e_{B})\theta L^{2}} < 0 \]

and
\begin{equation}
\frac{\partial s_A}{\partial e_A} = \frac{(1 - \gamma + 2e_A)\tau_A - \gamma e_A}{(1 - \gamma^2 + 2e_A + 2e_A^2 + 4e_A^2)\theta^2 L^2} > 0
\end{equation}

(4a)

\begin{equation}
\frac{\partial s_A}{\partial e_A} = \frac{(1 - \gamma + 2e_A)\tau_A - \gamma e_A}{(1 - \gamma^2 + 2e_A + 2e_A^2 + 4e_A^2)\theta^2 L^2} > 0
\end{equation}

(4b)

The conclusions are therefore achieved and the proof is complete.

**Proof of proposition 2**

Subtracting (7) by (9), it is easy to know that

\begin{equation}
s_A - s_A = \frac{(1 - 0L^a)(1 + 2e_A)\tau_A - \gamma e_A}{(1 - \gamma^2 + 2e_A + 2e_A^2 + 4e_A^2)\theta^2 L^2} \big|_{u_c^*} < 0, \big|_{u_c^*} > 0
\end{equation}

(5a)

(1a) minus (3a) results in

\begin{equation}
\frac{\partial s_A}{\partial e_A} - \frac{\partial s_A}{\partial e_A} = \frac{(1 - 0L^a)(1 + 2e_A)}{(1 - \gamma^2 + 2e_A + 2e_A^2 + 4e_A^2)\theta^2 L^2} \big|_{u_c^*} < 0, \big|_{u_c^*} > 0
\end{equation}

(5b)

And subtracting (1b) by (3b), we have

\begin{equation}
\frac{\partial s_A}{\partial e_A} - \frac{\partial s_A}{\partial e_A} = \frac{\gamma(1 - 0L^a)}{(1 - \gamma^2 + 2e_A + 2e_A^2 + 4e_A^2)\theta^2 L^2} \big|_{u_c^*} < 0, \big|_{u_c^*} > 0
\end{equation}

(5c)

The conclusions are therefore achieved and the proof is complete.

**Proof of proposition 3**

Combining (11) and (13) and using the static analysis and comparative statistics, we have

\begin{equation}
\frac{\partial s_B}{\partial e_A} = \frac{1}{(1 - 2\gamma + 2e_A)\theta^2 L^2} > 0
\end{equation}

(6a)

\begin{equation}
\frac{\partial s_B}{\partial e_A} = -\frac{1}{(1 - 2\gamma + 2e_A)\theta^2 L^2} < 0
\end{equation}

(6b)

\begin{equation}
\frac{\partial s_A}{\partial e_A} = \frac{2[0L^a(\alpha - \gamma SL^a) + \tau_A]}{1 - 2\gamma + 2e_A} > 0
\end{equation}

(6c)

\begin{equation}
\frac{\partial e_A}{\partial e_A} = \frac{aL^a + 2e_A}{\theta^2 L^2} > 0
\end{equation}

(6d)

as well as

\begin{equation}
\frac{\partial s_A}{\partial \tau_A} = \frac{1}{(1 - 2\gamma + 2e_A)\theta^2 L^2} > 0
\end{equation}

(7a)

\begin{equation}
\frac{\partial s_B}{\partial \tau_A} = -\frac{1}{(1 - 2\gamma + 2e_A)\theta^2 L^2} < 0
\end{equation}

(7b)

and
\[
\frac{\partial \tau}{\partial e_A} = \frac{\partial s_A}{\partial e_A} = \frac{2(a - \gamma S_0 L^n) + \tau_A}{1 - 2\gamma + 2e_A} > 0
\] (7c)

\[
\frac{\partial \tau}{\partial \theta_A} = \frac{\partial s_A}{\partial \theta_A} = \frac{a + \tau_A}{\theta_A} > 0
\] (7d)

Then similar to the proof of Proposition 2, we have

\[
s_A^c - s_A^c = \frac{(1 - \theta L^n)\tau_A}{(1 - 2\gamma + 2e_A)\theta^2 L^{2n}} |_{\theta^* < 1} < 0, |_{\theta^* > 1} > 0
\] (8a)

\[
\frac{\partial s_A}{\partial \tau_A} - \frac{\partial s_A^*}{\partial \tau_A} = \frac{1 - \theta L^n}{(1 - 2\gamma + 2e_A)\theta^2 L^{2n}} |_{\theta^* < 1} < 0, |_{\theta^* > 1} > 0
\] (8b)

and

\[
\frac{\partial s_A}{\partial \tau_B} - \frac{\partial s_A^*}{\partial \tau_B} = \frac{1 - \theta L^n}{(1 - 2\gamma + 2e_A)\theta^2 L^{2n}} |_{\theta^* < 1} < 0, |_{\theta^* > 1} > 0
\] (8c)

The conclusions are therefore achieved and the proof is complete.

**Proof of proposition 4**

Subtracting the equilibrium sown areas of crop A by B both at the non-tight case and the tight case, we have

\[
s_A^c - s_B^c = \frac{2\alpha 0 L^n - S_0^2 L^{2n} - 2e_s A_0^2 L^{2n} + 2\tau_A}{\theta^2 L^{2n} (1 - 2\gamma + 2e_A)}
\] (9a)

and

\[
s_A^c - s_B^c = \frac{2\alpha - S_0 L^n - 2e_s S_0 L^n + 2\tau_A}{\theta L^n (1 - 2\gamma + 2e_A)}
\] (9b)

Then we have the following conclusions,

\[
\left(s_A^c - s_B^c\right) - \left(s_A^c - s_B^c\right) = \frac{2(0L^n - 1)\tau_A}{\theta^2 L^{2n} (1 - 2\gamma + 2e_A)} |_{\theta^* < 1} < 0, |_{\theta^* > 1} > 0
\] (10a)

\[
\left(s_A^c - s_B^c\right) - \left(s_A^c - s_B^c\right) = \frac{2(0L^n - 1)}{\theta^2 L^{2n} (1 - 2\gamma + 2e_A)} > 0
\] (10b)

The conclusions are therefore achieved and the proof is complete.

**Proof of proposition 5**

From (7), (9), (11) and (13), we get

\[
\left|s_A - s_A\right| - \left|s_B^c - s_B^c\right| = \left|s_A - s_B^c\right| - \left|s_B^c - s_B^c\right| = \frac{\gamma(0L^n - 1)(2 - \gamma + 4e_A)\tau_A + (1 - 2\gamma + 2e_A)\tau_A}{(1 - 2\gamma + 2e_A)(1 - \gamma^2 + 2e_A + 2e_A + 4e_A e_A)\theta^2 L^{2n}} < 0
\] (11a)

and by the comparative static analysis, we obtain the following relationships,

\[
\left|\frac{\partial s_A}{\partial \tau_A} - \frac{\partial s_A^c}{\partial \tau_A} \right| - \left|\frac{\partial s_B^c}{\partial \tau_A} - \frac{\partial s_B^c}{\partial \tau_A} \right| = \frac{\gamma(0L^n - 1)(2 - \gamma + 4e_A)}{(1 - 2\gamma + 2e_A)(1 - \gamma^2 + 2e_A + 2e_A + 4e_A e_A)\theta^2 L^{2n}} < 0
\] (11b)

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The conclusions are therefore achieved and the proof is complete.

**Proof of proposition 6** \((i, j = A, B)\)

From (1), we know that \(\frac{\partial U(q_i, q_j)}{\partial q_i} = p_i > 0\) and \(\frac{\partial U(q_i, q_j)}{\partial q_j} = p_j > 0\), \((i, j = A, B)\). If \(s_i > s_i^*\), then \(q_i = e_0L^a s_i > q_i^* = e_0L^a s_i^*\) and \(U(q_i, q_j) > U(q_i^*, q_j^*)\); If \(s_i < s_i^*\), then \(q_i = e_0L^a s_i < q_i^* = e_0L^a s_i^*\) and \(U(q_i, q_j) < U(q_i^*, q_j^*)\). So from Proposition 2, we have \(CS > CS^*\) if \(qL^a < 1\) while \(CS < CS^*\) if \(qL^a > 1\).

Denoting the total profits of producers at the non-tight constraint and the tight constraint cases are \(\Pi^1\) and \(\Pi^2\), from (10) and (12) we have

\[
\Pi^1 - \Pi^2 = \frac{(1 - 2e^*_a)(1 + 2e_a)(1 + 2e_a)\tau_a - 2\alpha(1 - \gamma + 2e_a)\alpha L^a + (1 + 2e_a)(1 + 0L^a)\tau_a - (1 + 0L^a)\gamma \tau_a}{(1 - \gamma + 2e_a)}
\]

Then, it gets \(\Pi^1 - \Pi^2\) \(\big|_{0L^a < 1} < 0\), \(\big|_{0L^a > 1} > 0\) or \(CS - CS^*\) \(\big|_{0L^a < 1} < 0\), \(\big|_{0L^a > 1} > 0\). So it is easy to obtain \(SW - SW^*\) \(\big|_{0L^a < 1} < 0\), \(\big|_{0L^a > 1} > 0\) for \(SW = CS + PS\).

The conclusions are therefore achieved and the proof is complete.

**Table 1. Main statistical data about rice and cotton in China (1978–2011)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sown areas</th>
<th>Total yields</th>
<th>Yields per unit area</th>
<th>Imports</th>
<th>Exports</th>
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<td></td>
<td>rice cotton</td>
<td>rice cotton</td>
<td>rice cotton</td>
<td>rice cotton</td>
<td>rice cotton</td>
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<tr>
<td></td>
<td>thousand ha</td>
<td>ten thousand tons</td>
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Received: 22th April 2014
Accepted: 16th June 2014

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