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Energy Policies and Food Prices

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Biomass energy has been regarded as an effective instrument in combatting a high oil price. However, the increased production of biomass energy has raised the demand for agricultural products and led to a global grain deficiency and rising grain prices. This paper discusses the influence of energy policies on the agricultural product price using a macro model that contains the energy demand for agricultural products. The results show that: 1) A rise in the subsidy for agricultural products used for biomass energy will have an ambiguous effect on the agricultural product price and exchange rate in the long run. 2) The rise in the subsidy on agricultural

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products used for biomass energy will result in a misadjustment of the exchange rate in the short run. 3) When the elasticity of substitution between agricultural products and bonds is extremely large, the rise in the energy tax on fossil fuels will reduce the agricultural product price in the long run. 4) Given the extremely large elasticity of substitution between agricultural products and bonds, increasing the share of biomass energy in total energy will increase the agricultural product price in the short run and reduce the price in the long run.

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1 Introduction

Having suffered due to the greenhouse effect and climate change in the last decade, many countries are on the one hand looking for alternative energy sources and on the other hand are developing products with low CO_2 emissions during the production and consumption process. Moreover, the increasing oil price associated with a high price index and exhaustible supplies of petroleum has made energy security an important issue. Energy policies on the demand side focus on restraining the consumption of fossil fuels and saving energy, while policies on the supply side are directed toward increasing R&D on independence and alternative energy. Biomass energy is one of the choices that has attracted attention. For instance, the European Union has regulated that the amount of biomass energy should account for 6 percent of total vehicle fuel consumption in 2010, and that this ratio should rise to 10 percent by 2020. As a result, several European countries have been importing large quantities of soy beans and palm oil to produce biomass energy. In addition, the United States in its Energy Independence and Security Act of 2007 has required that the total amount of biofuels to be added to gasoline be increased from 4.7 billion gallons in 2007 to 36 billion gallons by 2022. In other words, biomass energy has generally been regarded as a tool for energy security.

Since the use of fossil fuels leads to the release of CO_2 and pollutes the environment, in order to limit the utilization of fossil fuels one can adopt a policy of endogenizing the pollution cost shouldered by the whole of society so that the burden falls on those who use the fossil fuels. An energy tax is one of several strategies adopted in reducing the pollution resulting from the use of fossil fuels, and is believed to have a "double dividend" effect because it can both balance the intertemporal energy consumption under the resource constraint and make it economically attractive for countries to reduce their greenhouse gas emissions. The green tax revolution in the Nordic countries is a good example. In addition, several OECD countries levy relatively high energy taxes on petroleum, such as an average tax rate of 57.06% on unleaded gasoline #95. Given that most countries are importers of fossil fuels, this paper intends to discuss the impact of an energy import tax on related economic variables.

Moreover, the development of new energy, say, biomass energy, is imperative with the resource constraints imposed on fossil fuels. Biomass energy is one kind of renewable energy that transforms biomass into energy and has agricultural products as important sources of materials. Even though the production and consumption cost tends to be high in the early stage of the product cycle, it can be lowered with technological progress. Therefore, R&D on biomass energy should be aggressively put into operation for the sake of long-run economic development. Many countries have adopted subsidy policies on biomass energy to reduce the reliance on fossil fuels and to respond to the high cost of biomass energy in the early stage of the product cycle. For example, the Republican Party in the United States stated as part of its 2004 party platform that "Republicans will continue to support renewable energy through an extension of the production tax credit for wind and biomass, as well as efforts to expand the use of biodiesel and ethanol, which can reduce America's dependence on foreign oil while increasing revenues to farmers." This was later turned into a proposal for a subsidy policy on ethanol. The Philippines also passed a bill to develop biomass energy and subsidized agricultural products used for biomass energy in 2008 when the increasing rice price induced popular protests. Kenya and Nigeria also plan to refine ethanol using sugar cane and cassava, even though the latter is one of the major grain crops.

In addition to its inexhaustible characteristics, the other main advantage of biomass energy as an alternative source of energy is that it does not discharge CO_2 and thus can help reverse the greenhouse effect. Since the production and consumption costs are relatively high at the moment, the government should implement a subsidy policy for this new form of energy that is equipped with an external advantage in order to achieve the social optimum. Nevertheless, it should increase the demand for related agricultural products globally and raise the prices of energy crops as biomass energy becomes popular. Consequently, the competition for agricultural products between energy and food provision will be aggravated, and how to distribute agricultural products to serve these two different purposes will be closely linked to the agricultural product price. Therefore, the second purpose of this study is to analyze the influence of a biomass energy subsidy on related economic variables.

Although biomass energy has been viewed as an effective instrument that can counter the high oil price and global warming, it remains a controversial issue at present as the increased production of biomass energy raises the demand for agricultural products, which accordingly leads to a global grain deficiency and rising grain prices. In other words, the derivative problems were not adequately taken into consideration when the development of biomass energy was aggressively promoted. For example, there used to be abundant supplies of crops such as wheat, maize and soy beans and prices remained stable over the long term. However, such crops suffered from global supply-demand disequilibrium and rising prices in 2008. While the global food crisis may have arisen due to fluctuations in climate, frequent natural disasters, increasing demand on the part of both China and India and opportunistic behavior, biomass energy has also had a part to play, as stated by the Food and Agricultural Organization (FAO), International Energy Forum (IEF), International Food Policy Research Institute (IFPRI), International Monetary Fund (IMF), World Food Programme (WFP), and the World Bank (WB). For this reason, there are demands to freeze, postpone and review the policy of developing biomass energy, especially grain biomass energy. Whether the increase in grain prices due to the biomass energy subsidy is a long-run phenomenon or only a short-term adjustment constitutes the third purpose of this paper. If the biomass energy subsidy will decrease the grain prices in the long-run, then the government can still hold fast to its subsidy policy with regard to its long-term energy policy.

Empirically, the growth of corn-based ethanol production and soybean-based bio-diesel production following the increase in the oil price is confirmed to have had a significant impact on the world's agricultural grain production and its prices, for example, Lunnan (1997), Elobeid *et al*. (2007), Urbanchuk (2007), Yang *et al*.

(2009), Baek and Koo (2010), and Chen *et al*. (2010). In addition to various studies that discuss the influence of a rising oil price on agricultural production and related prices, Ignaciuk and Dellink (2006) use a general equilibrium model to assess the impact of multi-product crops in response to climate policies. They find that the competition between agriculture and biomass for scarce land will result in a decreased production of agricultural goods and will increase the prices of agricultural goods. Nevertheless, there are few studies that theoretically discuss the impact of energy policies on agricultural grain production and its prices, which is the main contribution of this paper.

The remainder of the paper is organized as follows. Section 2 describes the dynamic behavior of an open economy, which contains an agricultural product market, manufacturing product market, money market and foreign exchange rate market, with the demand for energy. Section 3 analyzes the influence of policy on the economy, including the impact of a biomass energy subsidy and the impact of levying a fossil fuel tax, with respect to the short-run dynamic adjustment and long-run equilibrium. Section 4 concludes.

2 The Model

This paper constructs an open macro model containing an agricultural product market, manufacturing product market, money market and foreign exchange rate market. We make the following assumptions: 1. Following Lai *et al*. (2005), Chen *et al*. (2013), and Tai *et al*. (2014), manufacturing products are assumed to be tradable, while agricultural products are not. 2. Capital flows across countries frequently as internationalization becomes an important development goal for most countries. Put simply, the literature usually assumes perfectly free-flowing capital or complete substitutes between domestic manufacturing products (tradable goods) and foreign manufacturing products, which refers to the law of one price (e.g., Dornbusch, 1976; Tai *et al*., 2014). Therefore, manufacturing products produced by the home country are assumed to be completely substitutable with those produced by the foreign country. 3. Fossil fuels demanded by the home country are imported with ad valorem duties. 4. The home country produces biomass energy using agricultural products. 5. Frankel (1986) assumed that people can hold two different kinds of assets, bonds and agricultural products, which are completely substitutable. However, the extent of substitution may influence the effect of policy announcements on the dynamic adjustment route of the economy (Lai *et al*., 2005). Therefore, the two assets are not assumed to be completely substitutable in this study. 6. The home country adopts a floating exchange rate system. 7. People have perfect foresight regarding economic factors.

Based on these assumptions, the model can be expressed as follows:

$$Q_d^c = D^c\left(\frac{P^c}{P^m},\frac{M}{P^m}\right)+G^c+\mathrm{A}^c\left(\frac{\dot{P}^c}{P^c}+k-i\right) +\alpha\Gamma\left(\frac{P^c}{P^m},\frac{(1-s)\alpha P^c+(1-\alpha)P^n}{P^m}\right), \tag{1}$$

where $D_1^c<0,\ D_2^c>0,\ \mathrm{A}_1^c<0,\ \Gamma_1<0$ and $\Gamma_2<0$.

$$Q_s^c = S^c\left(\frac{P^c}{P^m}\right), \text{ where } S_1^c>0. \tag{2}$$

$$\dot{P}^c = j\left(Q_d^c - Q_s^c\right). \tag{3}$$

$$EP^{m*} = P^m. \tag{4}$$

$$L(Y, i)=\frac{M}{P}, \text{ where } L_1>0 \text{ and } L_2<0. \tag{5}$$

$$X\left(\frac{P^c}{P^{m'}}\frac{M}{P^{m'}}\frac{(1-s)\alpha P^c+(1-\alpha)P^n}{P^m}\right)-\frac{(1-\alpha)P^n}{P^m}\Gamma\left(\frac{P^c}{P^{m'}}\frac{(1-s)\alpha P^c+(1-\alpha)P^n}{P^m}\right) +F\left(i-i^*-\frac{\dot{E}}{E}\right)=0, \tag{6}$$

where $\mathrm{X}_1<0,\ \mathrm{X}_2<0, \mathrm{X}_3<0, \Gamma_1<0, \Gamma_2<0$ and $\mathrm{F}_1>0$.

$$P=\beta P^c+\gamma P^m+(1-\beta-\gamma)P^n. \tag{7}$$

$$P^n=(1+\tau)EP^{n*}. \tag{8}$$

The notation is defined as follows: Q_d^c = total demand for agricultural products; P^c = agricultural product price; P^m = manufacturing product price; M = nominal money supply; G^c = governmental purchasing demand for agricultural products; A^c = people's asset demand for agricultural products; $\dot{P}^c$ = time variation of agricultural product price; k = the difference between convenience yield and storage costs;[1] i = domestic nominal interest rate; P^n = domestic price of imported energy; s = rate of price subsidy for using biomass energy; α = share of biomass

[1]See the definition of the convenience yield in Frankel (1986) and Lai *et al*. (1996).

energy in total energy demand; Q_s^c = total supply of agricultural products; E = nominal exchange rate defined as the price of foreign currency in terms of domestic currency; P^{m*} = price of manufacturing product made by foreign country in terms of foreign currency; Y = aggregate output; P = average price level; i^* = nominal foreign interest rate; $\dot{E}$ = time variation of exchange rate; τ = energy import tariff; and P^{n*} = energy price in terms of foreign currency.

Equation (1) represents the demand function for agricultural products, which includes consumption demand, governmental purchasing demand, asset demand and energy demand. Consumption demand is decreasing in the relative price of agricultural products and manufacturing products and increasing in real money balances. Governmental purchasing demand is assumed to be an external policy variable. Asset demand is an increasing function of the relative return on agricultural products and bonds, in which the setting is the same as in Frankel (1986) and Lai *et al*. (1996). Energy demand is decreasing in the relative price of agricultural products and manufacturing products and decreasing in the relative price of energy and manufacturing products.[2]

Equation (2) is the supply function for agricultural products, which is increasing in the relative price of agricultural products and manufacturing products. Equation (3) represents the mode for agricultural product price adjustment in that excess demand for agricultural products will raise the price. In the equation j denotes the speed of price adjustment and is assumed to be finite. Equation (4) states the law of one price for manufacturing products. Since manufacturing products produced by the home country are completely substitutable with those produced by the foreign country, the price of foreign manufacturing products in terms of the domestic price will be the same as the price of domestic manufacturing products. Equation (5) is the equilibrium condition for the money market, in which real money demand is increasing in aggregate output and decreasing in the domestic interest rate.

Equation (6) shows that the balance of payments, containing the current account and capital account, should be zero under the floating exchange rate system. The current account is calculated by subtracting imported energy from net commodity exports. Net commodity exports are decreasing in the relative price of

[2]See the details for the setting in Appendix A.

agricultural products and manufacturing products, real money balances, and the relative price of energy and manufacturing products. The capital account is increasing in the relative return on domestic bonds and foreign bonds. Equation (7) defines the average price level, which is a weighted average of the agricultural product price, manufacturing product price and energy price. Equation (8) states that the domestic price of imported energy is equal to the exchange rate-transformed price of foreign energy multiplied by the energy import tariff.

This paper intends to analyze the influence of the fossil fuel import tariff (τ) and biomass energy subsidy (s) on the economy. To simplify the analysis, let $dM = dG^c = dk = dY = dP^{m*} = di* = dP^{n*} = 0$. The differential equations of P^c and E can be expressed as follows:[3]

$$\begin{bmatrix} d\dot{P}^c \\ d\dot{E} \end{bmatrix} = \begin{bmatrix} \Psi_1 & \Psi_2 \\ \Phi_1 & \Phi_2 \end{bmatrix} \begin{bmatrix} dP^c \\ dE \end{bmatrix} + \begin{bmatrix} \Psi_3 d\tau + \Psi_4 ds + \Psi_5 d\alpha \\ \Phi_3 d\tau + \Phi_4 ds + \Phi_5 d\alpha \end{bmatrix}. \tag{9}$$

Let μ_1 and μ_2 be characteristic roots in the economy. Given that P^c is a slowly adjusting variable and E is a jump variable, the condition of saddle-point stability, $\mu_1\mu_2 \equiv \Omega < 0$, must be satisfied to obtain a single solution. Moreover, $\mu_1 < 0 < \mu_2$ is assumed.

In the literature there are different settings in the substitution elasticity, A_1^c, between agricultural products and bonds. Frankel (1986) and Lai *et al*. (1996) assume that both agricultural products and bonds are completely substitutable. i.e., A_1^c is infinitely large; Lai *et al*. (2005) find that the relative size of A_1^c will influence the jump scale of the agricultural product price; Chao *et al*. (2011) do not consider the asset demand for agricultural products, i.e., A_1^c is taken as zero. In addition, the degree of capital movement, F_1, has been assumed to be infinitely large in the foreign exchange rate market in several previous studies, such as Dornbusch (1976), Gray and Turnovsky (1979), Lai *et al*. (2005), and Chao *et al*. (2011). Therefore, this paper follows the literature and formulates the dynamic analysis by assuming complete substitutability between agricultural products and bonds, i.e., an infinitely large A_1^c, and full mobility of capital, i.e., an infinitely large F_1.[4]

[3]See the details for the symbols in Appendix B.

[4]We will obtain $\Psi_1 > 0$, $\Psi_2 > 0$, $\Psi_3 < 0$, $\Psi_4 < 0$, $\Psi_5 < 0$, $\Phi_1 > 0$, $\Phi_2 > 0$, $\Phi_3 < 0$,

In the steady state, $\dot{P}^c = \dot{E} = 0$. Let $\tilde{P}^c$ and $\tilde{E}$ be the steady-state values. The following comparative static analyses can be obtained using Cramer's rule:[5]

$$\frac{\partial \tilde{P}^c}{\partial \tau} = \frac{-\Psi_3\Phi_2 + \Psi_2\Phi_3}{\Omega}, \qquad (10a)$$
$$= \frac{M^2(1-\beta-\gamma)[(1-\beta-\gamma)(1+\tau)(2-\alpha)+\alpha\gamma]}{\Omega(L_2)^2} < 0.$$

$$\frac{\partial \tilde{E}}{\partial \tau} = \frac{-\Psi_1\Phi_3 + \Psi_3\Phi_1}{\Omega} = -\frac{M^2\beta(1-\beta-\gamma)\alpha}{\Omega(L_2)^2} > 0 . \qquad (10b)$$

$$\frac{\partial \tilde{P}^c}{\partial s} = \frac{-\Psi_4\Phi_2 + \Psi_2\Phi_4}{\Omega} \gtrless 0 . \qquad (11a)$$

$$\frac{\partial \tilde{E}}{\partial s} = \frac{-\Psi_1\Phi_4 + \Psi_4\Phi_1}{\Omega} \gtrless 0 . \qquad (11b)$$

Equation (10a) shows that the agricultural product price is decreasing in the long run when the government raises the import tax on fossil fuels, which results from the aggregation of three effects. The first one is the so-called "price effect of agricultural products" whereby an increase in the import tax on fossil fuels raises the domestic price of imported energy and cuts down the demand for energy. Consequently, the energy demanded for agricultural products will decrease and the agricultural product price will decline. The second effect is the so-called "asset effect of agricultural products," which refers to the situation where the agricultural product price is decreasing and the domestic price of imported energy is increasing. This is because a higher domestic price of imported energy will increase the average price level, which will in turn cause the interest rate to rise to maintain the balance in the money market. As a result, there will be a lower rate of return on agricultural products relative to that of bonds, and the agricultural product price will decline due to the reduction in the asset demand for agricultural products. The third effect is the so-called "export effect" for a rise in the import tax on fossil fuels will lead to an

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$\Phi_4 \gtrless 0$ and $\Phi_5 > 0$ under these assumptions. On the contrary, $\Psi_1 < 0$, $\Psi_2 \gtrless 0$, $\Psi_3 < 0$, $\Psi_4 > 0$, $\Psi_5 < 0$, $\Phi_1 > 0$, $\Phi_2 > 0$, $\Phi_3 < 0$, $\Phi_4 \gtrless 0$ and $\Phi_5 > 0$ if A_1^c is close to zero.

[5]If A_1^c is close to zero, then $\partial \tilde{P}^c / \partial \tau \gtrless 0$, $\partial \tilde{E} / \partial \tau > 0$, $\partial \tilde{P}^c / \partial s \gtrless 0$ and $\partial \tilde{E} / \partial s \gtrless 0$.

ambiguous change in the agricultural product price. This is because an increase in the import tax on fossil fuels will reduce both imports and exports of fossil fuels, reflecting the rising energy price, and result in an unclear change in the net exports. If net exports decline, the agricultural product price will rise in response to the increasing manufacturing product price since the exchange rate and the manufacturing product price will rise to maintain the equilibrium in the foreign exchange market and the manufacturing product market, respectively, and the higher manufacturing product price will reduce the supply and increase the demand for the agricultural products. The agricultural product price will change in an opposite direction if net exports increase. Overall, the long-run influence of raising the import tax on fossil fuels on the agricultural product price is ambiguous if the three effects are aggregated. Nevertheless, a higher import tax on fossil fuels will increase the agricultural product price in the long run if the higher import tax results in a huge decline of net exports, i.e., there is a relatively large export effect. Moreover, if agricultural products and bonds are assumed the completely substitutable, the asset effect will be larger than the other two effects and Equation (10a) will hold.[6]

Equation (10b) shows that the exchange rate is increasing in the long run when the government raises the import tax on fossil fuels. Since an increase in the import tax on fossil fuels will raise the domestic price of imported energy and reduce the demand for energy, the supply of manufacturing products will decline given that it is an increasing function of the demand for energy.[7] The manufacturing product price will rise holding other things constant, and the law of one price in Equation (4) will imply a rising level of the exchange rate.

Equation (11a) describes the long-run effect of a rising biomass energy subsidy on the agricultural product price as being ambiguous due to the two effects. The first one is the "energy demand effect", which indicates that the increasing biomass energy subsidy will raise the energy demand for agricultural products and accordingly the agricultural product price. The second effect is the so-called "net export effect". That is, the rising biomass energy subsidy will reduce the energy

[6] If agricultural products can not be held as assets, or the elasticity of substitution between agricultural products and bonds is very low, the long-run influence of raising the import tax on fossil fuels on the agricultural product price will depend on the relative sizes of the agricultural product price effect and the export effect.

[7] The supply of manufacturing products is increasing in the energy input, as shown in Appendix A.

price, i.e., $(1-s)\alpha P^{c}+(1-\alpha)P^{n}$, and increase both exports and imports of energy. If net exports increase, the agricultural product price will decline in response to the increasing manufacturing product price since the exchange rate and the manufacturing product price will decline to maintain the equilibrium in the foreign exchange market and the manufacturing product market, respectively, and the lower manufacturing product price will increase the supply of and reduce the demand for the agricultural products. The agricultural product price will change in an opposite direction if net exports decrease. The aggregation effect of the biomass energy subsidy on the agricultural product price will be positive if net exports decrease. Even in the case where net exports increase, the aggregation effect of the biomass energy subsidy on the agricultural product price will still be positive only if the net export effect is smaller than the energy demand effect. In other words, net exports are required to experience a huge rise to record a relatively larger net export effect than the energy demand effect when the government expects to increase the capacity of biomass energy by raising the biomass energy subsidy; as a consequence, the agricultural product price will fall in the long run.

Equation (11b) depicts a rising biomass energy subsidy as having an ambiguous long-run effect on the exchange rate because of the two effects. One effect is “the manufacturing supply effect”, which states that the exchange rate will decrease as a result of the rise in the biomass energy subsidy. That is because a rising biomass energy subsidy will reduce the domestic energy price and increase the demand for energy, which in turn will reduce the manufacturing product price while the supply of manufacturing products increases. The exchange rate is therefore decreasing under the law of one price. The other effect is the “manufacturing demand effect”. The demand for manufacturing products, which is increasing in the relative price of agricultural products and manufacturing products, will increase when a decrease in the domestic energy price increases the energy demand for agricultural products and raises the agricultural product price. Therefore, the domestic price of manufacturing products will increase and accordingly the exchange rate will rise. When the manufacturing supply effect is larger (smaller) than the manufacturing demand effect, the rising biomass energy subsidy will reduce (increase) the exchange rate as a result of the declining (rising) manufacturing product price under the law of one price. Hence, the long-run effect of a rising biomass energy subsidy on the exchange rate is uncertain.

This paper will discuss the short-run dynamic adjustment of the agricultural product price and the exchange rate under the energy policy announcement by the government in the following paragraphs. The general solutions for P^c and E can be derived from Equation (9):

$$P^c = \tilde{P}^c + \mathrm{A}_1 e^{\mu_1 t} + \mathrm{A}_2 e^{\mu_2 t} . \qquad (12)$$

$$E = \tilde{E} + \frac{\mu_1 - \Psi_1}{\Psi_2} \mathrm{A}_1 e^{\mu_1 t} + \frac{\mu_2 - \Psi_1}{\Psi_2} \mathrm{A}_2 e^{\mu_2 t} . \qquad (13)$$

where A_1 and A_2 are undetermined coefficients.

The loci of P^c and E can be obtained from Equation (9) by setting $\dot{P}^c = 0$ and $\dot{E} = 0$. The slopes of the loci $\dot{P}^c = 0$ and $\dot{E} = 0$ are $\partial P^c / \partial E \big|_{\dot{P}^c = 0} = -\Psi_2 / \Psi_1 < 0$ and $\partial P^c / \partial E \big|_{\dot{E} = 0} = -\Phi_2 / \Phi_1 < 0$, respectively. Both slopes are negative and the locus $\dot{P}^c = 0$ is steeper than the locus $\dot{E} = 0$.[8]

From Equations (12) and (13) we can obtain the only trajectory satisfying the condition $A_2 = 0$, which is the stable arm and is expressed as SS in the phase diagram. Similarly, the unstable arm expressed as UU in the phase diagram can be obtained under the condition $A_1 = 0$. The slopes are $\partial P^c / \partial E \big|_{SS} = \Psi_2 / (\mu_1 - \Psi_1) = (\mu_1 - \Phi_2)/\Phi_1 < 0$ and $\partial P^c / \partial E \big|_{UU} = \Psi_2 / (\mu_2 - \Psi_1) > 0$ for the lines SS and UU, respectively. The saddle path SS is always downward sloping, while the slope of the divergent branch UU is always positive.[9] In addition, the locus $\dot{P}^c = 0$ is the steepest and the locus $\dot{E} = 0$ is the flattest.[10]

In addition to the dynamic adjustment trajectories of lines SS and UU, the phase diagram in Figure 1 also depicts four different divergent adjustment trajectories, which are denoted as (i), (ii), (iii) and (iv). The same characteristics equipped with the four different divergent adjustment trajectories are asymptotes proceeding from the slope of line SS and diverging along the slope of

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8 $\left.\frac{\partial P^c}{\partial E}\right|_{\dot{P}^c = 0} - \left.\frac{\partial P^c}{\partial E}\right|_{\dot{E} = 0} = -\frac{\Psi_2}{\Psi_1} - (-\frac{\Phi_2}{\Phi_1}) = \frac{\mu_1 \mu_2}{\Psi_1 \Phi_1} < 0$.

9 $\left.\frac{\partial P^c}{\partial E}\right|_{SS} \cdot \left.\frac{\partial P^c}{\partial E}\right|_{UU} = -\frac{\Psi_2}{\Phi_1} < 0$.

10 $\left.\frac{\partial P^c}{\partial E}\right|_{\dot{E} = 0} - \left.\frac{\partial P^c}{\partial E}\right|_{SS} = -\frac{\Phi_2}{\Phi_1} - \frac{\mu_1 - \Phi_2}{\Phi_1} = \frac{-\mu_1}{\Phi_1} > 0$.

line UU .

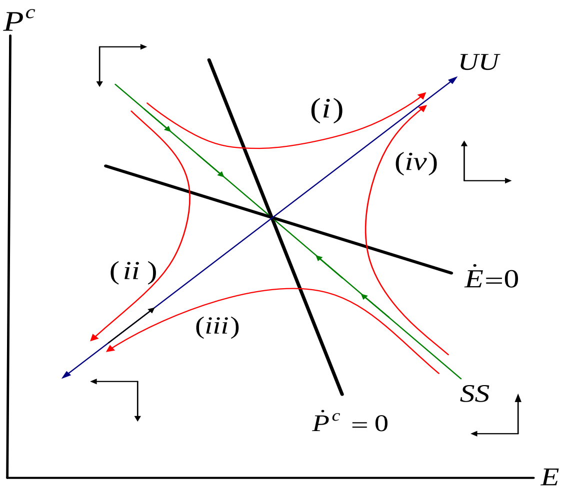

Figure 1: Phase Diagram

3 Dynamic Adjustment in the Economy

This section will analyze the dynamic adjustment in the economy under the expected rise in the import tax on fossil fuels and under the expected rise in the subsidy on biomass energy. Moreover, let 0^- and 0^+ denote the instant before and instant after the policy announcement, respectively, and T^- and T^+ denote the instant before and instant after the policy implementation, respectively.

3.1 An Increase in the Import Tax on Fossil Fuels (τ)

The following three results can be obtained from Equation (9): $\partial P^c/\partial\tau|_{\dot{P}^c=0}=-\Psi_3/\Psi_1>0$; $\partial P^c/\partial\tau|_{\dot{E}=0}=-\Phi_3/\Phi_1>0$; and $\partial P^c/\partial\tau|_{\dot{P}^c=0}-\partial P^c/\partial\tau|_{\dot{E}=0}=M^2\beta(1-\beta-\gamma)\alpha/\Psi_1\Phi_1(L_2)^2>0$. It is implied that the loci $\dot{P}^c=0$ and $\dot{E}=0$ will both shift upwards with an increase in the import tax on fossil fuels, and the locus $\dot{P}^c=0$ will have a larger shifting scale than the locus $\dot{E}=0$.

Assume that the initial equilibrium is at Q_{0^-} , the interaction of the locus

$\dot{E}=0(\tau_0)$ and the locus $\dot{P}^c=0(\tau_0)$ in Figure 2. The corresponding exchange rate and agricultural product price are E_{0^-} and $P^c_{0^-}$, respectively. When the government announces it is raising the fossil fuel import tax from time point T^+ at time point 0^+, the locus $\dot{E}=0(\tau_0)$ and the locus $\dot{P}^c=0(\tau_0)$ will shift upwards to the locus $\dot{E}=0(\tau_1)$ and the locus $\dot{P}^c=0(\tau_1)$, respectively, and interact at Q_1. The new long-run equilibrium is associated with a higher exchange rate E_1 and a lower agricultural product price P^c_1, compared with the previous levels.

During the period between 0^+ and T^-, the dynamic adjustment in the economy will be around Q_{0^-} since the fossil fuel import tax has not yet increased. Moreover, the agricultural product price will not jump at the time point 0^+ under the slowly adjusting feature. Therefore, only the trajectory (iv) satisfies this limitation. In other words, the economy will jump from Q_{0^-} rightwards to Q_{0^+} in Figure 2 at the instant when the government announces the policy. Accordingly, the exchange rate will jump from E_{0^-} to E_{0^+}, giving rise to the undershooting phenomenon. During the period between 0^+ and T^-, the economy will move from Q_{0^+} to Q_T along the trajectory (iv). After the time point T^+, the economy will move from Q_T to the new long-run equilibrium Q_1 along the locus $SS(\tau_1)$ because Q_T lies in the stable arm $SS(\tau_1)$.

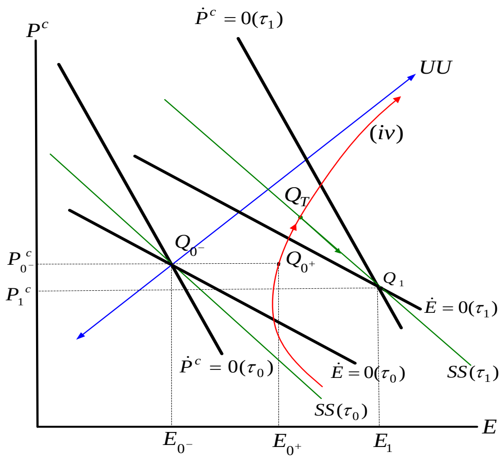

Figure 2: The Dynamic Adjustment under an Increase in the Import Tax on Fossil Fuels

3.2 An Increase in the Subsidy for Biomass Energy (s)

The following two results can be obtained from Equation (9): $\partial P^c/\partial s|_{\dot{P}^c=0} = -\Psi_4/\Psi_1 > 0$ and $\partial P^c/\partial s|_{\dot{E}=0} = -\Phi_4/\Phi_1 \gtrless 0$ if $\Phi_4 \lessgtr 0$. It is implied that the locus $\dot{P}_0^c = 0(s_0)$ will shift upwards and the locus $\dot{E} = 0$ may either shift upwards or downwards with an increase in the subsidy for biomass fuels. As discussed in Section 2, the long-run effect of the biomass energy subsidy on the agricultural product price is indefinite, depending on “the net export effect”; and the long-run effect of the biomass energy subsidy on the exchange rate is also uncertain, depending on the relative size of “the manufacturing supply effect” and “the manufacturing demand effect”. If net exports decrease, i.e., a positive net export effect, or increase on a tiny scale, i.e., a relatively smaller negative net export effect, an increase in the biomass energy subsidy will increase the agricultural product price in the long run. However, if a rise in the biomass energy subsidy increases the net exports to a large extent and the net negative export effect exceeds the energy demand effect, an increase in the biomass energy subsidy will lower the agricultural product price in the long run. Given that there are different dynamic adjustments with an increase in the biomass energy subsidy, the following discussions will focus on two special cases.

Case 1. The Positive or Relatively Smaller Negative Net Export Effect

Equation (11a) implies that an increase in the biomass energy subsidy will result in either a trade gain or a trade deficit. However, the long-run agricultural product price will rise if the extent of the trade gain is not large enough. To investigate the dynamic adjustment, suppose that the economy is located at the interaction of the loci $\dot{P}_0^c = 0(s_0)$ and $\dot{E} = 0(s_0)$, i.e., Q_{0^-}, in Figure 3-1. The corresponding agricultural product price and exchange rate are P_0^c and E_0, respectively. If the government announces an intention to raise the subsidy rate from s_0 to s_1 at the time point T, the loci $\dot{P}_0^c = 0(s_0)$ and $\dot{E} = 0(s_0)$ will shift upwards to the loci $\dot{P}_0^c = 0(s_1)$ and $\dot{E} = 0(s_1)$, respectively, after the time point T. The new equilibrium will lie on the upper left-hand side of the previous equilibrium, where the agricultural product price will increase and the exchange rate will decrease.

At the instant of the policy announcement, the economy will jump rightwards from Q_{0^-} to Q_{0^+}; during the period between 0^+ and T^-, the economy will move from Q_{0^+} to Q_T along the trajectory (iv); after the time point T^+, the economy will move to the new equilibrium Q_1 along the locus $SS(s_1)$ as the subsidy rate has been raised to s_1. To sum up, the agricultural product price will keep on rising from the time of the policy announcement, while the exchange rate will rise before the policy's implementation and decline after the policy's implementation. Nevertheless, the jump scale of the economic variables at the instant of the policy announcement will depend on the time difference between the policy's announcement and its implementation. In addition, the exchange rate may jump and adjust in the wrong direction in the short-run.

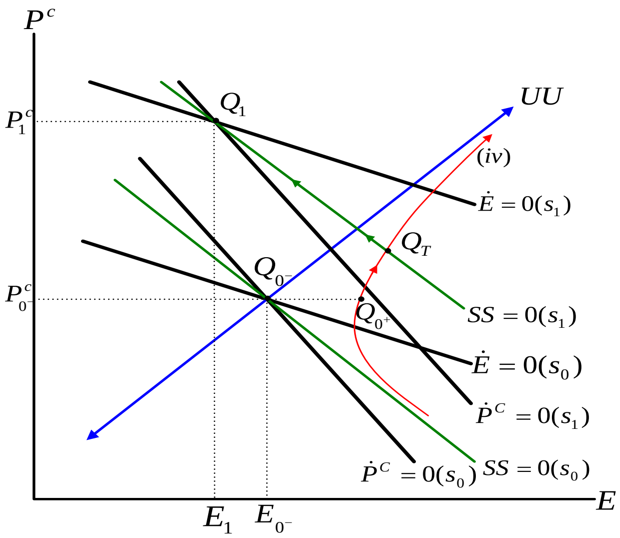

Figure 3-1: The Dynamic Adjustment under an Increase in the Biomass Energy Subsidy - The Positive or Relatively Small Positive Net Export Effect

Case 2. The Relatively Large Negative Export Effect

If the rise in the biomass energy subsidy enlarges the scale of the trade gain, which in turn will result in the net negative export effect exceeding the energy demand effect, there will be a decline in the long-run equilibrium price of agricultural products. The dynamic adjustment in the economy can be illustrated in Figure 3-2. Suppose the locus $\dot{P}_0^c = 0(s_0)$ will shift upwards to the locus $\dot{P}_0^c = 0(s_1)$ and the locus $\dot{E} = 0(s_0)$ will shift downwards to $\dot{E} = 0(s_1)$ due to an increase in the subsidy rate. The new equilibrium will be at Q_1, and the corresponding agricultural product price and exchange rate will be P_1^c and E_1, respectively. In other words, the rising biomass energy subsidy will result in a lower agricultural product price and a higher exchange rate compared with the previous levels.

At the instant of the policy announcement, the economy will jump rightwards from Q_{0^-} to Q_{0^+}; during the period between 0^+ and T^-, the economy will move from Q_{0^+} to Q_T along the trajectory (iv); after the time point T^+, the economy will move to the new equilibrium Q_1 along the locus $SS(s_1)$ as the subsidy rate has been raised to s_1. To sum up, the exchange rate will keep on rising from the time of the policy announcement, while the agricultural product price will rise before the policy's implementation and decline after the policy's implementation. Moreover, the exchange rate will be characterized by undershooting in the short-run. These results are contrary to those in Case 1.

Since the rising biomass energy subsidy will raise the agricultural product price in the short-run but lower the price in the long-run for the case where the net negative export effect exceeds the energy demand effect, the subsidy policy currently adopted in several countries should not be postponed or revoked when the agricultural product price is rising, given that it is imperative that alternative sources of energy be sought.

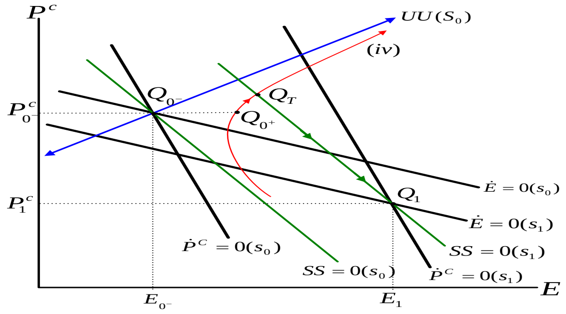

Figure 3-2: The Dynamic Adjustment under an Increase in the Biomass Energy Subsidy – The Relatively Large Negative Net Export Effect

4 Conclusion

Having a clean and reliable supply of energy and ensuring environmental sustainability are priorities in many countries. R&D on biomass energy is particularly believed to be an effective instrument in countering high oil prices and global warming, given the resource constraint imposed by fossil fuels and the associated pollution. Nevertheless, the production of biomass energy increases the energy demanded for agricultural products and consequently leads to a global food deficiency and an increasing grain price, which makes the use of biomass energy a controversial issue.

This paper builds a macro model containing the energy demand for agricultural products and discusses the influence of energy policy on agricultural product prices. The results show that:

1) An increase in the import tax on fossil fuels will have a negative impact on the long-run prices of agricultural products and the exchange rate if the model's setting follows Frankel (1986) and Lai *et al*. (1996), i.e., the elasticity of substitution between agricultural products and bonds is infinitely large, while the impact is ambiguous if the model's setting follows Lai *et al*. (2005) and Chao *et al*. (2011), i.e., the elasticity of substitution between agricultural products and bonds is relatively low or there is no asset demand for agricultural products. The impact in the latter case depends on the relative sizes of the agricultural product price effect and the export effect.
2) When the elasticity of substitution between agricultural products and bonds is small and the export effect is larger than the agricultural product price effect, an increase in the import tax on fossil fuels will increase the long-run agricultural product price.
3) An increase in the subsidy rate for agricultural products used for biomass energy will have an uncertain effect on the agricultural product price and exchange rate in the long run. If the higher subsidy on biomass energy increases net exports on a large scale, the long-run agricultural product price will decline, even though the short-run price will increase.
4) If the government announces a decision to raise the subsidy rate applied to agricultural products used for biomass energy, the exchange rate may jump and

adjust in the wrong direction in the short run.

Appendix A

Let Γ be the total domestic demand for energy, including domestic biomass energy and imported foreign energy. Assume that the domestic biomass energy and imported foreign energy share α and $(1-\alpha)$ percent of the total demand for energy, respectively, where the value of α is between 0 and 1.

The demand for energy can be derived as a function of the relative price of energy and manufacturing products and the relative price of agricultural products and manufacturing products from the following micro-foundation model. Suppose that manufacturing firms have the following profit maximization problem:

$$\begin{aligned}\max_{\Gamma}\ \pi^m &= P^m \cdot Q^m(\Gamma) - (1-s)P^c \cdot \alpha \cdot \Gamma - P^n \cdot (1-\alpha) \cdot \Gamma - P^c \cdot Q^c, \\ &= P^m \cdot Q^m(\Gamma) - [(1-s)\alpha P^c + (1-\alpha)P^n] \cdot \Gamma - P^c \cdot Q^c.\end{aligned} \tag{A.1}$$

where $Q^m(\Gamma)$ is the manufacturing production function, and $P^c \cdot Q^c$ is the opportunity cost for firms to produce manufacturing products.

The optimal demand function of the energy and supply function for manufacturing products can be derived as:

$$\Gamma^* = \Gamma\left(P^m\ ,\ (1-s)\alpha P^c + (1-\alpha)P^n\ ,\ P^c \right). \tag{A.2}$$

$$Q^* = Q^m\left(\Gamma\left(P^m\ ,\ (1-s)\alpha P^c + (1-\alpha)P^n\ ,\ P^c \right)\right). \tag{A.3}$$

Equation (A1) implies that the demand for energy (Γ) is homogeneous of degree zero in P^m, $[(1-s)\alpha P^c + (1-\alpha)P^n]$ and P^c. That is,

$$\Gamma^* = \Gamma\left(\lambda P^m\ ,\ \lambda((1-s)\alpha P^c + (1-\alpha)P^n)\ ,\ \lambda P^c \right). \tag{A.4}$$

$$Q^* = Q^m\left(\Gamma\left(\lambda P^m\ ,\ \lambda((1-s)\alpha P^c + (1-\alpha)P^n)\ ,\ \lambda P^c \right)\right). \tag{A.5}$$

Let $\lambda = 1/P^m$, and Equation (A4) can be expressed as:

$$\begin{aligned}\Gamma^* &= \Gamma\left(\frac{P^m}{P^m} = 1,\ \frac{(1-s)\alpha P^c + (1-\alpha)P^n}{P^m},\ \frac{P^c}{P^m} \right), \\ &= \Gamma\left(\frac{P^c}{P^m},\ \frac{(1-s)\alpha P^c + (1-\alpha)P^n}{P^m} \right).\end{aligned} \tag{A.6}$$

$$Q^* = Q^m\left(\Gamma\left(\frac{P^m}{P^m}=1, \frac{(1-s)\alpha P^c+(1-\alpha)P^n}{P^m}, \frac{P^c}{P^m}\right)\right),$$
$$= Q^m\left(\Gamma\left(\frac{P^c}{P^m}, \frac{(1-s)\alpha P^c+(1-\alpha)P^n}{P^m}\right)\right). \tag{A.7}$$

Therefore, the demand function for energy can be expressed as follows:

$$\Gamma\left(P^c/P^m, [(1-s)\alpha P^c+(1-\alpha)P^n]/P^m\right).$$

Appendix B

$$\begin{bmatrix} d\dot{P}^c \\ d\dot{E} \end{bmatrix} = \begin{bmatrix} \Psi_1 & \Psi_2 \\ \Phi_1 & \Phi_2 \end{bmatrix}\begin{bmatrix} dP^c \\ dE \end{bmatrix} + \begin{bmatrix} \Psi_3 d\tau + \Psi_4 ds + \Psi_5 d\alpha \\ \Phi_3 d\tau + \Phi_4 ds + \Phi_5 d\alpha \end{bmatrix}. \tag{B.1}$$

where:

$$\Psi_1 = \frac{\partial \dot{P}^c}{\partial P^c} = \frac{j}{(1-jA_1^c)}[D_1^c + \alpha\Gamma_1 - S_1^c + \alpha\Gamma_2(1-s)\alpha + \frac{A_1^c M\beta}{L_2}] > 0.$$

$$\Psi_2 = \frac{\partial \dot{P}^c}{\partial E}$$
$$= -\frac{j}{(1-jA_1^c)}[D_1^c + \alpha\Gamma_1 - S_1^c + \alpha\Gamma_2(1-\alpha s) + D_2^c M$$
$$-\frac{A_1^c M[\gamma-(1-\beta-\gamma)(1+\tau)]}{L_2} - \alpha\Gamma_2(1-\alpha)(1+\tau)] > 0.$$

$$\Psi_3 = \frac{\partial \dot{P}^c}{\partial \tau} = -\frac{j}{(1-jA_1^c)}[\frac{A_1^c M(1-\beta-\gamma)}{L_2} - \alpha\Gamma_2(1-\alpha)] < 0.$$

$$\Psi_4 = \frac{\partial \dot{P}^c}{\partial s} = -\frac{j}{(1-jA_1^c)}\alpha\Gamma_2\alpha < 0.$$

$$\Psi_5 = \frac{\partial \dot{P}^c}{\partial \alpha} = -\frac{j}{(1-jA_1^c)}(\alpha s\Gamma_2 - \Gamma) < 0.$$

$$\Phi_1 = \frac{\partial \dot{E}}{\partial P^c}$$
$$= \frac{1}{F_1}\{X_1 + X_3(1-s)\alpha - (1-\alpha)\Gamma_1 - (1-\alpha)\Gamma_2(1-s)\alpha - F_1\frac{M\beta}{L_2}\} > 0.$$

$$\Phi_2 = \frac{\partial \dot{E}}{\partial E}$$

$$= -\frac{1}{F_1}\{X_1 + X_2 M + X_3[(1-s)\alpha + (1-\alpha)] - (1-\alpha)\Gamma - (1-\alpha)\Gamma_1$$

$$-(1-\alpha)\Gamma_2([(1-s)\alpha + (1-\alpha)])$$

$$+F_1\frac{M\gamma}{L_2} - (1-\alpha)\{X_3 - (1-\alpha)\Gamma_2 - \Gamma\}(1+\tau)$$

$$+F_1\frac{M\{(1-\beta-\gamma)(1+\tau)\}}{L_2} > 0.$$

$$\Phi_3 < 0 .$$

$$\Phi_4 = \frac{\partial \dot{E}}{\partial s} = -\frac{1}{F_1}\{X_3\alpha - \alpha(1-\alpha)\Gamma_2\} \gtrless 0 .$$

$$\Phi_5 = \frac{\partial \dot{E}}{\partial \alpha} = -\frac{1}{F_1}[\Gamma + s(1-\alpha)\Gamma_2] > 0 .$$

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