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IMPACTS OF THE EXCHANGE RATE CHANGES ON AGRICULTURE: PROFIT FUNCTION APPROACH AND IMPLICATIONS FOR KOREAN HOG INDUSTRY*

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The effects of exchange rate changes on agricultural markets are examined theoretically and empirically. Unlike the conventional approach simply using excess supply and demand, profit function is used in a partial equilibrium setting. This approach has an advantage over the traditional one in that it can examine the exchange rate effects on input markets explicitly and provide strong theoretical underpinnings for the analytical framework in this area. The effects on output and input prices, production, profit and trade are examined by exploring a theoretical framework from profit function. Theoretical analysis shows that the price elasticities with respect to the exchange rate may exceed one in absolute values, which contradicts to most previous works. However, the results of empirical simulation for Korean hog industry show that such perverse case can seldom happen in reality, supporting the previous results. An important implication for Korean hog industry policy from this study is that the import dependency in inputs needs to be reduced to improve producer welfare.

JEL Classification: Q1, F0
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I. INTRODUCTION

The depreciation of won against dollar in 1997 caused the Korean economy to fall into deep recession. The exchange rate rose up to almost twice as high as before the crisis. This external shock reached every sector of national economy, and agriculture was not an exception. In particular, livestock and horticultural industries, of which production inputs are heavily dependent on

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foreign imports, were seriously influenced by the sudden depreciation of domestic currency.

It has not been so long that the exchange rate began to be considered as a key variable in the analysis of agriculture. The main reason seems to be that agriculture in most countries has been insulated from world market by domestic policies so that it is not directly related to the changes in exchange rate.

Since Schuh, in his seminal paper (1974), emphasized the importance of the effects of the exchange rate change in U.S. agriculture, much works have been done concerning the role of exchange rate and other related macroeconomic variables in agricultural sector (Schuh, 1976; Kost, 1976; Chambers and Just, 1979 and 1981; Rausser, et al., 1986; Jabara and Schwartz, 1987). Using single market models, most previous studies demonstrated that the exchange rates have significant effects on agricultural markets. Their analyses focused on the effects on output prices and trade, export in particular. However, Chambers and Just (1979) criticized the single market model because it would be misleading the result of the exchange rate effects in agricultural sector by demonstrating that the results are sensitive to the model specification of excess demand and supply. They claimed that the price elasticity with respect to exchange rate can exceed one using a multi-market model, which is contradictory to the traditional wisdoms supported by previous literature (e.g., Kost, 1976; Feenstra, 1989).

Although Chambers and Just analyzed the exchange rate effect in more general setting and reached somewhat different conclusion, the model they used is basically for the analysis only of output markets, ignoring input markets. This could be misleading the true consequences of the exchange rate change effects on production and profit in agricultural sector. For the net importing countries in agricultural products like Korea, the changes in agricultural production, input prices and demand for that production, and profits can be more important than output price and export which were the central concerns in most previous literature. The results on such variables can be obtained by considering interactions and interdependencies among various related markets including inputs. A study that addressed this problem was done by Carter, Gray and Furtan (1990). They examined the effects of exchange rate on inputs and welfare using simple excess demand and supply model for the large exporting country. However, their analysis is not comprehensive by not explicitly including input variables in the model, and hence not free from the likelihood of misleading the results owing to model specification problem as Chambers and Just posed.

Korean literature on the exchange rate effects in agricultural sector is very rare. A couple of works have been done for Korean agriculture (e.g., Sol and Kwon, 1989; Seo, 1999), of which methodologies and scope are quite different from this study. Sol and Kwon examined the appreciation of Korean won on agricultural imports, capital intensity, and farm management costs using econometrics and input-output matrix analysis. Seo recently estimated the exchange rate pass-through in Korean agricultural markets such as beef, corn, pork, etc., using econometrics technique, in an attempt to examine how the exchange rate movements are reflected in the prices for Korean agricultural products.

The purpose of this paper is to examine the effects of exchange rate movements on agricultural markets in many respects. The analysis in this study centers on the impacts not only on output price but on output supply, input demand and prices, and producer profit all of which are crucial for net food-importing countries such as Korea. Theoretical analysis and empirical application as well are conducted to derive useful implications for Korean hog industry. Unlike traditional approach in partial equilibrium analysis which directly specifies excess demand and supply for a single agricultural market, profit function is used as a basis of the analytical framework because of its advantageous characteristic for the purpose of this study and its strong theoretical underpinning. That is, more exact results consistent with firm's profit maximizing behavior can be obtained when considering both output and input markets simultaneously within a profit function framework.

Ⅱ. EFFECTS OF THE EXCHANGE RATE CHANGE

Consider an industry consisting of many identical firms who produce one output with multiple inputs, all of which are assumed tradable. Firm's objective is assumed to maximize the *ex post* profit with the exchange rate change under perfect competition both in output and input markets. Then the profit function for the maximizing firm with the exogenously determined exchange rate e, expressed as home currency in terms of foreign currency, i.e., won/$, can be described as follows.

$$\pi = \pi(p, w; e) \tag{1}$$

where p is a domestic output price which is scalar, and w is an input price vector of n dimensions, all of which depend on the exchange rate.

Assuming that law of one price holds and that no transaction costs such as tariff, transportation cost, etc. exist, the relationships between home and foreign prices can be expressed as,

$$p = ep^* \tag{2}$$

$$w = ew^* \tag{3}$$

where p^* and w^* are corresponding world market output price and input price vector, respectively. Without explicit specification of the underlying production function which is assumed concave in variable inputs, the output supply and input demand functions can be obtained directly from the profit function (1) by using the envelope theorem, respectively, as $y(p, w; e) = \partial\pi(p, w; e)/\partial p$ and $X_i(p, w; e) = -\partial\pi(p, w; e)/\partial w_i$, $i=1, \cdots, n$. Also, foreign excess supply function can be similarly specified under the assumption that it is derived from foreign firm's profit maximizing behavior, i.e., profit function. Without loss of generality, the industry demand for the output can be simply expressed as a function of its own price, i.e., $D=D(p; e)$ assuming the identical representative consumer. Input supply is assumed to be dependent on its own factor price, $g_i = g_i(w_i; e)$, $i=1, \cdots, n$, since we want to closely look at the domestic output market. Foreign excess supply of inputs is similarly specified as a function of its own price.

For an open economy excess demands of importing country must equal the excess supplies of the rest of the world (foreign country), assuming that the rest of the world consists of a single aggregated exporter. Then equilibrium conditions both in output and input markets hold as follows.

$$D(p; e) - y(p, w; e) = y^*(p^*, w^*; e) \tag{4}$$

$$X_i(p, w; e) - g_i(w_i; e) = g_i^*(w_i^*; e) \quad i=1, \cdots, n. \tag{5}$$

where $y^*(\cdot)$ is the excess supply of output for foreign country specified as a function of output price and input price vector expressed in terms of foreign currency, and $g_i^*(\cdot)$ is the excess supply of input i for foreign country as a function of its own price in terms of foreign currency. Home import demand functions for output and inputs are separately specified, instead of using explicit excess demand function, so as to look at the effects on domestic production side more closely. Also, it would be more straightforward for empirical analyses by allowing separate estimation of demand and supply.

Effects on Output and Input Prices

Differentiating equation (4) with respect to e using the price- exchange rate relationships (2) and (3), we can derive the elasticities of output price with respect to the exchange rate, $e_p = (dp/de)(e/p)$.[1]

$$e_p = \frac{\theta \sum_{i=1}^{n} r_i e_i - (1-\theta)\left\{r^* - \sum_{i=1}^{n} r_i^*(e_i - 1)\right\}}{\eta - \theta r - (1-\theta) r^*} \tag{6}$$

where θ is the share of domestic production of total consumption, $r(r^*)$ is the domestic output supply (foreign excess supply) elasticity with respect to domestic (foreign) output prices expressed in terms of domestic (foreign) currency. $r_i(r_i^*)$ is domestic output supply (foreign excess supply) cross price elasticity

[1] See Appendix for more details on derivation.

with respect to ith input price, η is domestic demand elasticity for output, and e_i is the elasticity of ith input price with respect to exchange rate.

Since the denominator is always negative, the sign of e_p is determined by numerator. It is noteworthy that e_p is closely related with n input price elasticities e_is. Equation (6) reflects that output and input markets are interactively affected by exchange rate change. To better understand the sign and structure of the equation it is necessary to make it simple. From the property of the profit function specified in (1), we know that following homogeneity conditions must hold.

$$r+\sum_{i=1}^{n} r_i=0, \quad r^*+\sum_{i=1}^{n} r_i^*=0. \tag{7}$$

By imposing homogeneity for domestic markets and assuming that the same condition holds for foreign excess supply function as in (7), equation (6) can then be reduced as:

$$e_p=\frac{\sum_{i=1}^{n}\{\theta r_i+(1-\theta)r_i^*\}e_i}{\eta-\theta r-(1-\theta)r^*}. \tag{6'}$$

Since output price effect is closely related to input price changes in this model as shown in (6'), we can not definitely determine the output price effect resulting from exchange rate change without simultaneously considering input price effects. Nevertheless, we can obtain general ideas about e_p assuming $e_i \geq 0$ for all i, without loss of generality. We know that $e_p \geq 0$ as long as all e_is are positive since r_i and r_i^* are all negative in normal cases, implying that domestic currency depreciation leads to the increase in output price. Given e_is, the e_p becomes smaller as the demand and supply both in domestic and foreign output markets are elastic, while it becomes larger as the output is more responsive to the input price changes in domestic and foreign markets as well. Price effect is also dependent on the degree of import dependency. If the entire output consumed is produced domestically, i.e., $\theta=1$, (6') becomes $e_p=\sum r_i e_i/(\eta-r)$ so that no foreign factors of output markets have effects on domestic output prices due to exchange rate changes, as can be expected. On the other hand, if $\theta=0$, then $e_p=\sum r_i^* e_i/(\eta-r^*)$ so that foreign factors have substantial effects on domestic output market.

The e_p and e_is are interdependent each other. The larger the e_is, the greater the e_p, implying that the impact of the exchange rate change on output is greater as more inputs are imported from abroad. The above equation indicates that the more sensitive to the exchange rate change the input markets, the greater the output price rise. However, it would be rare that the exchange rate change is fully passed through into all domestic input prices. Rather, incomplete pass-through will be normal even though full pass-through is observed for some input markets. Furthermore, not all inputs used for production are imported.

It is of interest to note that, in some cases, depreciation of domestic currency may result in the fall in output price. This perverse phenomenon can occur when the second term in the numerator of equation (6) is very large, and hence the sign of numerator becomes positive. An empirical evidence for this was witnessed in Korean agriculture after the financial crisis in 1997. Cattle price substantially fell despite the dramatic price rise in feed products due to a sudden hike in exchange rate of won against U.S. dollar.[2]

Since e_p and e_is are simultaneously determined in the system, the exact effects of the exchange rate change can be obtained by further looking at input markets. Now, differentiating the input market equilibrium condition (5) with respect to e using the price-exchange rate relationships, we can derive the elasticities of input prices with respect to the exchange rate, $e_i = (dw_i/de)(e/w_i)$.[3]

$$e_i = \frac{-\left\{x_{ip}e_p + \sum_{j\neq i}^{n} x_{ij}e_j + (1-k_i)s_{ii}^*\right\}}{x_{ii} - k_i s_{ii} - (1-k_i)s_{ii}^*}, \quad i,j = 1, \cdots, n. \tag{8}$$

where x_{ip} and x_{ij} are domestic ith factor demand elasticities with respect to output price and input prices, respectively. $s_{ii}(s_{ii}^*)$ is the ith factor supply (foreign excess supply) elasticity with respect to its own price. k_i is the share of domestic input supply of total input demand for ith factor.

Since the denominator of equation (8) is always negative its sign is determined solely by the numerator. However, it seems not easy to determine the sign of e_i because of the term x_{ij} which is either positive or negative, depending on the relationship between the inputs. In other words, the second term of the numerator is crucial to determine the sign of e_i, which depends on the substitution effects among input demands. Given that e_p is positive and each

[2] Cattle price substantially fell due to the depreciation while the prices of feed, most domestic use of which are imported, rose considerably (See the table below).

	Cattle Price		Feed Price		Cattle Price		Feed Price
	Male	Female			Male	Female	
	(1000won/500kg)		(won/kg)		(1000won/500kg)		(won/kg)
1997 Ave.	2,426	2,159	219.3	1998 Ave.	2,007	1,887	261.0
10	2,441	2,122	218.7	1-3	2,151	1,966	292.8
11	2,406	2,159	217.5	4-6	2,066	1,863	278.9
12	2,276	2,058	245.6	7-9	1,749	1,718	248.1

Source: *Monthly Review*, National Livestock Cooperatives Federations, 1997-1999.

[3] See Appendix for more details on derivation.

x_{ij} is not negative e_is will be positive. Nevertheless, it is not conclusive to judge by simply looking at equation (8) because they are interrelated within input markets and with output market, and hence with equation (6).

Homogeneity analogous to (7), resulting from profit function property, requires following condition in input markets.

$$x_{ip} + \sum_{j=1}^{n} x_{ij} = 0, \quad i = 1, \cdots, n. \tag{9}$$

To what extent will prices change due to exchange rate change? Many factors are complicatedly associated with the answer to this question as shown above. Most previous works show that price elasticity with respect to exchange rate lies between 0 and 1, that is, the percentage change of price is less than that of exchange rate change (Feenstra, 1989; Kost, 1976). However, Chambers and Just argue that this is only true in a simple model like single output model. They demonstrate that this may not true in a more general model using excess demand and supply equations that depend on all prices and income in demand and all prices in supply. Their results show that there is no *a priori* belief that price elasticity is necessarily less than one in absolute value. Although they did not incorporate input markets which are very important in producers decision the results seem to be consistent with this study. Equation (6), (6') and (8) show that there exists some possibility that e_p and e_is in absolute values can be greater than unity, although not high in reality. This implies that output and input prices can change more than exchange rates change, in percentage terms, theoretically.[4] However, the precise magnitude by which the variables can change is determined by solving the simultaneous equations system.

Now we are ready to further examine the effects of the exchange rate changes on the domestic markets. We have $n+1$ equations system with $n+1$ unknowns, which is to be simultaneously solved for the output and input price elasticities. First, we obtain the equilibrium values of e_p^* and all e_i^*s by solving the equations system (6') and (8) simultaneously, given that all parameters are estimated. However, it is too complex to solve this simultaneous equation system analytically. Instead we use computer program to solve for e_p^* and e_i^*s after estimating all parameters needed in empirical markets.

Effects on Profit and Production

How profit changes due to exchange rate change can be examined by deriving, from the profit function (1), the profit elasticity with respect to exchange rate (π_e) as follows.

[4] For instance, from (6'), (7), (8), and (9), we know that $|e_p|$ can be greater than one for extremely low η when $|e_i| > 1$ for all i, which can happen if $\sum_{j=1}^{n} x_{ij}(e_j - e_p) > k_i s_{ii}$ from (8).

$$\pi_e = e_p^* + \frac{C}{\pi}\left(e_p^* - \sum_{i=1}^{n} c_i e_i^*\right) \tag{10}$$

where C is total cost, c_i is the share of ith factor cost, that is, $c_i = w_i X_i / C$, and hence $\sum_{i=1}^{n} c_i = 1$. Here only the positive profits will be considered to obtain more reasonable results ($\pi > 0$). Equation (10) shows that profit response to exchange rate change is critically dependent on the magnitudes of e_p^* and e_i^*s, and the cost structure of the industry. That is, whether producer profit will increase or not from exchange rate change depends on price elasticities and factor cost ratios. If $e_p^* = e_i^*$ for all i, then profit changes exactly the same as the rate at which prices change, i.e., $\pi_e = e_p^*$ because the second term vanishes. This is obvious as is implied by linear homogeneity of profit function. With currency depreciation, the profit is not expected to rise as much as output price increase unless output price elasticity exceeds the sum of the products of factor cost ratio and input price elasticity. However, if all factor prices change more than output price does, profit may reduce as a result of depreciation. If the value of $\sum c_i e_i^*$ is very large, producers may lose even though domestic price rises with currency depreciation. This could happen when the heavily import-dependent inputs account for large part of total costs. The term $\sum c_i e_i^*$ is critically influenced by the equilibrium values of input price elasticities, which in turn depend on various factors, particularly on import dependency of inputs $(1 - k_i)$ as shown in equation (8). This implies that if production inputs are heavily dependent on foreign imports, producer profit may decrease although output price rises from depreciation of domestic currency.

The change in production is similarly examined by deriving following production elasticity with respect to exchange rate (y_e).

$$y_e = r e_p^* + \sum_{i=1}^{n} r_i e_i^* = \sum_{i=1}^{n} r_i (e_i^* - e_p^*). \tag{11}$$

Production may increase or decrease with depreciation since r_i is non-positive, depending on e_i^* and e_p^*. If input prices increase very much so that the absolute value of the second term is greater than first term, domestic production will reduce despite output price increase. If $e_p^* = e_i^*$ for all i, then $y_e = 0$ so that production remains unchanged with exchange rate change. This seems to be an obvious result since the supply function is homogeneous of degree zero in prices. Nevertheless, in this case, profit increases at the same rate as e_p^* as equation (10) indicates. Suppose that e_i^* is constant for all factors, i.e., $e_i^* = \overline{e_i}$, then by imposing homogeneity restriction of (7), we obtain $y_e = r(e_p^* - \overline{e_i})$. This implies that output price elasticity with respect to exchange rate needs to be greater than input price elasticity, on average, in order for the production to be expanded with depreciation.

Effects on Trade

Based on the analytical results discussed above, we can further examine the effects of exchange rate change on trade related problems such as imports of output and inputs. Import elasticity of output with respect to exchange rate (M_e) can be expressed as:[5]

$$M_e = \frac{1}{1-\theta}\,\eta\, e_p^* - \frac{\theta}{1-\theta}\, y_e. \tag{12}$$

As shown above, M_e appears to be normally negative unless both e_p^* and y_e are negative, implying that output imports reduce when domestic currency is depreciated. Suppose $e_p^* = e_i^* > 0$ for all i with the depreciation. Then (12) becomes $M_e = 1/(1-\theta)\,\eta\, e_p^* < 0$ by using equation (11). Imports of output will always reduce even though domestic supply does not change as shown in (11). The more elastic the demand and the larger the output price response to exchange rate change, the greater reduce the imports of output. Reduction in imports in this case stems from the fall in demand which is specified as a function solely of its own price. There exists some possibility that imports of output increase with depreciation, that is, if e_p^* and y_e are both negative, or the second term with $y_e < 0$ is greater than the first term, then M_e can be positive. M_e depends on the size of θ at *status quo* before the exchange rate changes. That is, the larger the output dependence on import in equilibrium, the smaller the import elasticity *ceteris paribus*. Since r_i is non-positive if e_i^*s are sufficiently greater than e_p^*, then output supply declines, and hence imports of output may increase despite price rise. This is because the reduction in supply will exceed the reduction in demand.

The elasticity of imports of ith factor with respect to exchange rate (M_e^i) is derived as:

$$M_e^i = \frac{1}{1-k_i}\sum_{j=1}^{n} x_{ij}(e_j^* - e_p^*) - \frac{k_i}{1-k_i}\, s_{ii} e_i^*, \quad i = 1, \cdots, n. \tag{13}$$

As the sign of the second term in the right hand side can be easily determined, the substitution effects among inputs (x_{ij}) and the sizes of e_i^* and e_p^* in the first term become crucial to determine the effects of exchange rate

[5] Details of the derivation for equations (12) and (13) are omitted to avoid mathematical tediousness. They are available from the author on request.

change on the imports of inputs. If factor i is complement for all other inputs so that $x_{ij}<0$ and $e_j^*>e_p^*$ for all j, then depreciation will always result in the reduction in imports of input. On the other hand, if factor i is substitute for all other factors $(x_{ij}>0)$ whether the imports of input will increase or decrease depends on the sizes of e_i^*, e_p^*, and s_{ii}. In normal case, however, imports of input in question will decrease because the positive effect of first term is expected to be less than negative effect of second term when small difference between e_i^* and e_p^* exists. If $e_i^*=e_p^*$ for all factors, then $M_e^i=-k_i/(1-k_i)s_{ii}e_i^*$ which is non-positive regardless of x_{ij} and smaller or larger than $e_i^*(e_p^*)$. Suppose that 50 percent of ith factor is domestically supplied at *status quo* and its domestic supply elasticity is unitary. Then import of ith factor will reduce by exactly the same rate as the depreciation rate in this case. The larger the portion of import at *status quo*, the smaller the percentage reduction in import with currency depreciation given supply elasticity.

Ⅲ. AN EMPIRICAL EXAMPLE FOR KOREAN HOG INDUSTRY

Theoretical analyses discussed so far will be applied to the Korean agricultural market. Hog industry is singled out for the empirical example, which is believed to have been significantly influenced by the depreciation in 1997 because of its heavy dependency on foreign import for input use.

Parameter Estimation

Many parameters need to be estimated in order to examine the effects of exchange rate change as was discussed earlier. To maintain consistency with the theoretical framework developed in previous section we start with the profit function as in equation (1) for this purpose. Then the output supply and input demand functions are first estimated. Hog industry is assumed to have three inputs for production, i.e., piglet, feed and labor, those of which costs account for more than 90 percent of total production costs. The Generalized Leontief profit function is specified for parameter estimation as follows because of its flexibility of local second-order approximation to any profit function (See Lopez and Varian for similar Generalized Leontief-type function).

$$\pi(p, w)=b_{oo}p+2\sum_{i=1}^{3}b_{oi}(p\cdot w_i)^{1/2}+\sum_{i=1}^{3}\sum_{j=1}^{3}b_{ij}(w_i\cdot w_j)^{1/2} \tag{14}$$

where $b_{oi}=b_{io}$ and $b_{ij}=b_{ji}$ for all i, j. The output supply and factor demand functions are derived by simply differentiating (14) with respect to own prices.

$$y=b_{oo}+\sum_{i=1}^{3}b_{oi}\left(\frac{w_i}{p}\right)^{1/2} \tag{15}$$

$$-X_i = b_{io}\left(\frac{p}{w_i}\right)^{1/2} + \sum_{j=1}^{3} b_{ij}\left(\frac{w_j}{w_i}\right)^{1/2}, \qquad i=1,2,3. \tag{16}$$

Then from above equations the parameters r, r_i, x_{ii}, $x_{ij}(x_{ip})$ evaluated at the means can be calculated, respectively, as follows.

$$r = -\frac{1}{2}\left(1 - \frac{b_{oo}}{y}\right), \quad r_i = \frac{1}{2y} b_{oi}\left(\frac{w_i}{p}\right)^{1/2} \qquad i=1,2,3.$$

$$x_{ii} = -\frac{1}{2}\left(1 + \frac{b_{ii}}{X_i}\right), \quad x_{ij} = -\frac{1}{2X_i} b_{ij}\left(\frac{w_j}{w_i}\right)^{1/2} \qquad i=1,2,3.$$

We can check from above that the homogeneity requirements implied by (7) and (9) are automatically satisfied. The empirical data from five provinces for five years (1993-1997) are used. The seemingly unrelated regression technique is used to estimate the parameters imposing the restriction $b_{ij} = b_{ji}$. The estimated results of relevant elasticities are presented in Table 1.

Simulation

For hog industry, output is domestically produced while the feed is heavily dependent on foreign imports. In 1998, for example, only 24 percent of total feed used for Korean livestock industry was domestically produced, and hence 0.24 will be used for $k_2 (k_2 = 0.24)$. Other inputs, piglets used for hog production and labor, are all regarded as domestically produced so that $k_1 = k_3 = 1$ are assumed in this section. The empirical experimentation in this study will be conducted for the effects on output and input prices, production, and profit.

The computer simulation results are presented in table 2, under the assumption of $\theta = 1$ considering that all hogs are domestically produced. These results are obtained from the equations system (6′) and (8), and then (10) and (11), using the estimated parameters in table 1. The effects of exchange rate change on output and input prices, domestic production and producer profit by varying demand elasticity are given in terms of elasticities. Three different cases for demand elasticity are compared, ranging from extremely low case to relatively elastic case; that is, $\eta = -0.1, -0.5, -1$. The subscripts 1, 2, and 3 indicate three production inputs, i.e., piglet, feed, and labor in order. The value 0.5 is used for s_{11}, s_{22}, s_{33}, and s^*_{22} under the assumption that the factor supply markets in hog industry are inelastic as is the case in other agricultural sectors. The results with other parameter sets for $s_{ii}(s^*_{ii})$ are not reported here since no significant differences have been found within inelastic ranges.

First, consider the case $k_2 = 0.24$. With intermediate demand elasticity ($\eta = -0.5$), domestic hog price increases by one percent ($e^*_p = 0.106$), feed and

[Table 1] Estimated Elasticities for Various Parameters

	Price of			
	Output	Piglet	Feed	Labor
Output	2.10	-1.10	-0.94	-0.20
	(1.17)	(0.81)	(0.66)	(1.19)
Piglet	3.44	-1.71	-1.16	-0.67
	(1.59)	(1.08)	(0.79)	(1.37)
Feed	1.94	-0.78	-2.73	1.46
	(1.19)	(0.30)	(1.66)	(0.43)
Labor	0.91	-0.97	3.17	-3.27
	(5.02)	(3.06)	(6.71)	(1.40)

Numbers in parentheses are standard errors.

[Table 2] The Effects of Exchange Rate Change on Output and Input Prices, Production and Profit.

	$-\eta$	k_2				
		0.0	0.1	0.24	0.5	1.0
e_p^*	0.1	0.291	0.262	0.221	0.145	0.0
	0.5	0.140	0.126	0.106	0.070	0.0
	1.0	-0.043	-0.039	-0.033	-0.021	0.0
e_1^*	0.1	-0.049	-0.044	-0.037	-0.024	0.0
	0.5	-0.237	-0.214	-0.180	-0.119	0.0
	1.0	0.017	0.016	0.013	0.009	0.0
e_2^*	0.1	0.611	0.550	0.464	0.305	0.0
	0.5	0.547	0.492	0.416	0.274	0.0
	1.0	0.071	0.064	0.054	0.036	0.0
e_3^*	0.1	0.596	0.537	0.453	0.298	0.0
	0.5	0.555	0.499	0.422	0.277	0.0
	1.0	-0.032	-0.029	-0.024	-0.016	0.0
y_e	0.1	0.012	0.010	0.009	0.006	0.0
	0.5	-0.050	-0.045	-0.038	-0.025	0.0
	1.0	-0.175	-0.158	-0.133	-0.088	0.0
π_e	0.1	0.041	0.037	0.031	0.021	0.0
	0.5	-0.302	-0.272	-0.230	-0.151	0.0
	1.0	-0.330	-0.297	-0.251	-0.165	0.0

Note: $s_{11}=s_{22}=s_{33}=s_{22}^*=$ 0.5 are assumed in the above simulation.

labor costs substantially increase by more than 4 percent ($e_2^*=0.416$, $e_3^*=0.22$) when Korean won is depreciated by ten percent. It is interesting to note that piglet price falls due to currency depreciation. The table shows that a ten percent depreciation of won will cause the piglet price to reduce by approximately two percent ($e_1^*=-0.18$) whereas other input prices significantly rise. Why does the price for input fall with depreciation? The currency depreciation usually has direct influence on the imported goods such as feed in this study. However, piglets that are used for hog production are not imported from abroad. Also, table 1 shows that piglet is not substitute for either feed or labor as is indicated by negative signs although they are not statistically significant. This result is supported by the actual data after the foreign currency crisis in 1997 as shown in table 3. Table 3, which is graphically reproduced in Figure 1 for better understanding, shows that piglet prices have had a tendency to fall while hog and feed prices have substantially risen since November 1997.

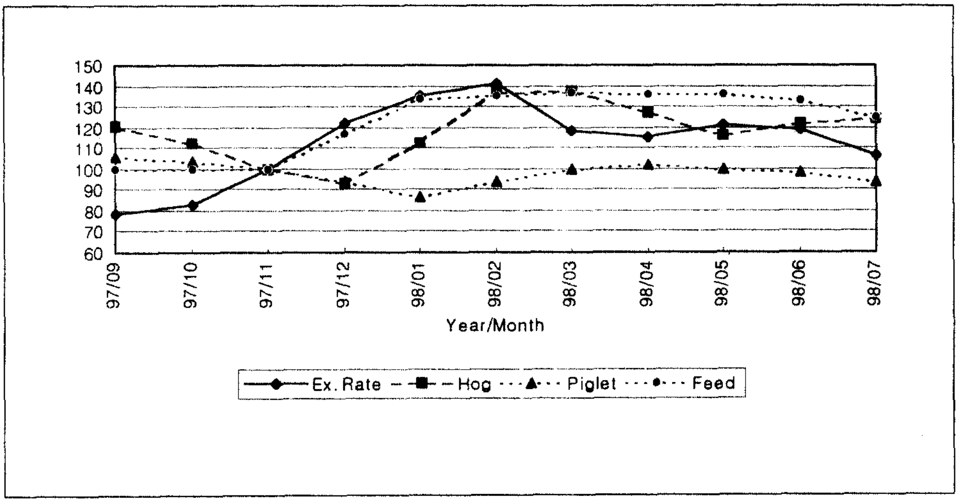
The table confirms empirically that the absolute values of output and input price elasticities with respect to exchange rate are not likely to exceed one as long as the relevant parameters move within a reasonable range. We examined in previous section that price elasticities with respect to exchange rate can exceed one in theory. However, Table 3 shows that in reality such an extreme case is not likely to occur in hog market. The absolute values of e_p and e_is are all less than 0.7 in the table. Therefore, we would say from an empirical point of view that the traditional wisdom that the percentage change in prices

[Table 3] Indexes of the exchange rate and factor prices for hog production.

Year/Month	97/9	10	11	12	98/1	2	3	4	5	6	7
Ex.Rate	78.6	82.9	100.0	121.6	135.2	140.9	118.5	115.0	121.2	119.0	106.2
Hog	120.5	112.3	100.0	93.2	112.3	137.0	137.7	127.4	116.4	121.9	124.0
Piglet	105.7	103.8	100.0	94.3	86.8	94.3	100.0	101.9	100.0	98.1	94.3
Feed	100.1	100.0	100.0	117.1	133.6	135.4	136.4	135.9	135.9	132.9	124.6

Sources: Converted into index numbers from the data in *Monthly Review*, National Livestock Cooperatives Federation, January, 1998 and January, 1999.

[Figure 1] Exchange rate and factor price indexes



cannot exceed the percentage change in exchange rate is still valid for Korean hog industry.

The results also show that depreciation leads to the decline in hog production, although not significantly, and hog producers' profits. A ten percent depreciation will reduce hog production by 0.4 percent ($y_e = -0.038$) and producer profit by 2.3 percent ($\pi_e = -0.23$), respectively. This result implies that producer welfare is likely to be seriously hurt in hog industry with depreciation although it does not have significant impacts on production. This is due mainly to the significant rise in feed price. The effects of exchange rate change are sensitive to the demand elasticity. The less elastic is the demand, the greater the output price increase than the input price increase so that the signs of the output and profit elasticities might reverse. This implies that if the demand for hog is extremely inelastic, domestic production and profit in hog industry can be increased even under the depreciation of won. In general, however, depreciation will hurt hog industry by reducing production and profit, most part of which reduction is due to the rise of feed cost that accounts for more than 50 percent of total production costs. Profits depends largely on the extent and the direction in which output price, piglet and feed costs change.

The effects of exchange rate change are also dependent on the degree of import dependency of inputs used. If feed were totally imported, i.e., $k_2 = 0$, hog price would increase by 1.4 percent, and feed price and wage would increase by 5.5 percent whereas piglet price would fall by 2.4 percent with a 10 percent depreciation. As a result, hog production and producer profit would fall by 0.5 and 3 percent, respectively. The larger the import dependency of inputs used, the more serious the impacts of the exchange rate change. If $k_2 = 1$, no effects are observed at all as is expected since this case is exactly the same as autarky in this paper.

V. CONCLUSIONS

This study examined the effects of exchange rate change on domestic agricultural markets. Analytical focuses were placed on how the exchange rate changes affect output and input prices, production, and profit. This can be especially important for the net agricultural importing countries like Korea under the exchange rate fluctuations. For this purpose, a theoretical framework to analyze the exchange rate effects was developed and then an empirical example for Korean hog industry was provided.

Unlike traditional approach, profit function was used as a starting point to analyze the effects of exchange rate movements in a partial equilibrium setting. This approach has some advantages over the traditional one which simply uses excess demand and supply in a single agricultural market. First of all, the impacts of inputs as well as output markets can be easily examined with this framework. The interactions between output and many input markets can be captured using profit function so that more exact and comprehensive effects resulting from exchange rate changes are obtained. Also, it provides strong theoretical underpinning for the analytical framework and hence for the empirical results because of its underling assumption of producer's profit maximizing behavior.

Many interesting results have been obtained from the analyses in this study. Theoretical analyses demonstrate that the percentage changes in output and input prices can be larger than percentage change in exchange rate. In other words, the price elasticities with respect to exchange rate both in output and input markets can exceed one in absolute values. This is consistent with Chambers and Just while contradicting to most previous literature which were criticized by them for the model specification problems. Another interesting result this study demonstrates is that output and input prices can decline even when domestic currency is depreciated.

The results of an empirical application to the Korean hog industry show that input prices are more responsive to the exchange rate; that is, input prices are more significantly affected by exchange rate change than output price within a reasonable range of parameter values. Feed which is heavily dependent on foreign imports is most significantly influenced as was expected. Interestingly enough, the price for piglet of which cost accounts for over 30 percent of total production costs decreases with depreciation. Furthermore, the result shows that it is almost impossible to expect that the percentage changes in output and input prices can exceed the percentage change in exchange rate, although possible in theory. The empirical results also show that depreciation tends to reduce producer profit significantly while production falls slightly. This is believed to stem from the large increase in input prices.

An important implication of this study for agricultural policy is that it is necessary to reduce the import dependency in inputs such as feed in order to minimize producer welfare impact (loss) from exchange rate movements (depreciation).

Appendix

A.1 Derivation of Equation (6)

Differentiating the equilibrium condition (4) with respect to exchange rate,

$$\frac{\partial D}{\partial p}\frac{dp}{de}-\left(\frac{\partial y}{\partial p}\frac{dp}{de}+\sum_{i=1}^{n}\frac{\partial y}{\partial w_i}\frac{dw_i}{de}\right)=\frac{\partial y^*}{\partial p^*}\frac{dp^*}{de}+\sum_{i=1}^{n}\frac{\partial y^*}{\partial w_i^*}\frac{dw_i^*}{de}.$$

Rearranging this by using $dp^*/de=1/e(dp/de-p^*)$ and $dw_i^*/de=1/e(dw_i/de-w_i^*)$ yields

$$\left(\frac{\partial D}{\partial p}-\frac{\partial y}{\partial p}-\frac{1}{e}\frac{\partial y^*}{\partial p^*}\right)\frac{dp}{de}=\sum_{i=1}^{n}\frac{\partial y}{\partial w_i}\frac{dw_i}{de}$$
$$-\frac{1}{e}\left\{\frac{\partial y^*}{\partial p^*}p^*-\sum_{i=1}^{n}\left(\frac{\partial y^*}{\partial w_i^*}\frac{dw_i}{de}-\frac{\partial y^*}{\partial w_i^*}w_i^*\right)\right\}$$

Multiplying both sides by e/p, and performing some mathematical manipulation, we have

$$(\eta D-ry-r^*y^*)e_p=y\sum_{i=1}^{n}r_ie_i-y^*\left\{r^*-\sum_{i=1}^{n}r_i^*(e_i-1)\right\}$$

where $r=(\partial y/\partial p)(p/y)$, $r^*=(\partial y^*/\partial p^*)(p^*/y^*)$, $r_i=(\partial y/\partial w_i)(w_i/y)$, $r_i^*=(\partial y^*/\partial w_i^*)(w_i^*/y^*)$, $\eta=(\partial D/\partial p)(p/D)$. Since $D=y+y^*$ at equilibrium, dividing both sides by D, we have

$$\{\eta-\theta r-(1-\theta)r^*\}e_p=\theta\sum_{i=1}^{n}r_ie_i-(1-\theta)\left\{r^*-\sum_{i=1}^{n}r_i^*(e_i-1)\right\}$$

where $\theta=y/D$, which then results in equation (6).

A.2 Derivation of Equation (8)

Differentiating the equilibrium condition (5) with respect to exchange rate e,

$$\frac{\partial X_i}{\partial p}\frac{dp}{de}+\sum_{j=1}^{n}\frac{\partial X_i}{\partial w_i}\frac{dw_i}{de}-\frac{\partial g_i}{\partial w_i}\frac{dw_i}{de}=\frac{\partial g_i^*}{\partial w_i^*}\frac{dw_i^*}{de}.$$

Rearranging this by using $dw_i^*/de=1/e(dw_i/de-w_i^*)$ yields

$$\left(\frac{\partial X_i}{\partial w_i}-\frac{\partial g_i}{\partial w_i}-\frac{1}{e}\frac{\partial g_i^*}{\partial w_i^*}\right)\frac{dw_i}{de}=-\frac{\partial X_i}{\partial p}\frac{dp}{de}$$
$$-\sum_{j\neq i}\frac{\partial X_i}{\partial w_j}\frac{dw_j}{de}-\frac{1}{e}\frac{\partial g_i^*}{\partial w_i^*}w_i^*$$

Multiplying both sides by e, and with some mathematical manipulation, we have

$$(x_{ii}X_i - s_{ii}g_i - s_{ii}^* g_i^*)e_i = -\left(x_{ip}e_p X_i + X_i \sum_{j \neq i}^{n} x_{ij}e_j + s_{ii}^* g_i^*\right)$$

where $x_{ip} = (\partial X_i/\partial p)(p/X_i)$, $x_{ij} = (\partial X_i/\partial w_j)(w_j/X_i)$, $s_{ii} = (\partial g_i/\partial w_i)(w_i/g_i)$, $s_{ii}^* = (\partial g_i^*/\partial w_i^*)(w_i^*/g_i^*)$. Since $X_i = g_i + g_i^*$ at equilibrium, dividing both sides by X_i, we have

$$\{x_{ii} - k_i s_{ii} - (1-k_i)s_{ii}^*\}e_i = -\left\{x_{ip}e_p + \sum_{j \neq i}^{n} x_{ij}e_j + (1-k_i)s_{ii}^*\right\}$$

where $k_i = g_i/X_i$, which then results in equation (8).

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