A Simple Environment-Trade Model of Hog Production in Taiwan

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I. Introduction

As worldwide attentions are increasingly being paid on the international trade and environmental quality, there is more and more requirement of understanding the complexities and the relation of international trade and natural resources. The linkages of environment and trade and the andlysis of their oplicy implications are especially important for a country like Taiwan, which has very limited natural resources but depends largely on internationl trade. In particular,hog industry in Taiwan represents the typical production pattern of high dependency on environment and trade. On the one hand, in production process, farmers are producing output by extracting service from the environment; i.e. dumping sewage into rivers flowing past their farms. On the other hand, agricultural inputs, such as feed cereals, applied in the process of production are mostly purchased from international markets. both environmental and trade policie are affecting the production coust of hog farms.

The environment-trade model should demonstrate the interrelations between domestic agriculture, international trade, and environmental

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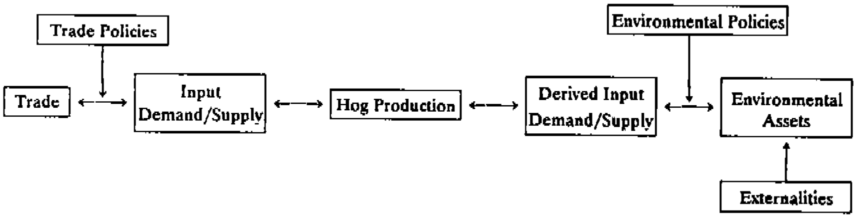
issues. Figure 1[1] demonstrates that the agricultural production process plays the central role in the linkages between environment and trade in agricultural inputs/commodities. In the environment-production-trade linkage, trade policies affect production through the trade-resource interaction, while environmental policies affect production through the production-resource interaction.

Prices of inputs purchased from a barrier-free market reflect the real values, while inputs characterized with common property often bring externalitiex. If the effects of the farmers' production activities generate externalities, the producer will not take these effects into account unless some internalization mechanism is in place. Environmental policies, such as regulations on the use of those inputs, raise the private cost of agricultural production. In contrast to the enviromental regulations, free trade leads to lower market prices of imported inputs and hence decrease the production cost of agricultural output.

In other words, imposition of environmental regulations puts downward pressure on profits which affects international competitiveness of hog production in Taiwan. Under such environmental programs, there are impacts on input demands of hog production. On the contrary, international trade liberalization benefits hog production in the way that the prices of imported inputs, such as feed cereals, are declining. This also encourages farmers to shift agricultural input employed on farms. As there are growing concerns of environmental protection in Taiwan, environmental regulatory climate will be strictly imposed, even if liberalization on international trade stimulates intensification on hog production. Therefore, it is useful to devlop a hybrid model explicitly integrate these two policies.

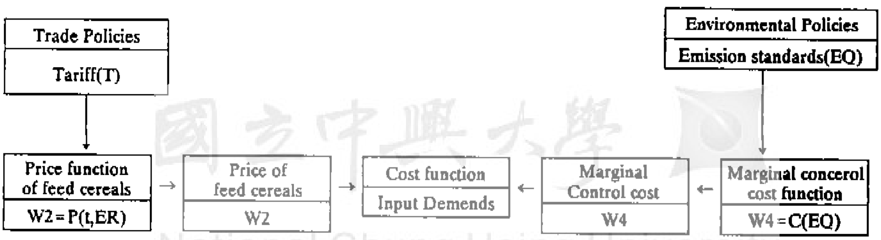
Figure 1. Environment-Trade Linkages of Hog Production



II. Theoretical model

Based on the environment-trade linkages of hog production in Figure 1, a simple hybrid model is structured in Figure 2. As environmental and trade policies are imposed, two sets of adjustment take place simultaneously in hog production. The first set is due to the changing environmental quality standard, which shifts the marginal cost of pollution control on hog production through the marginal control cost function. A similar set of adjustments comes from the changing trade policies, which affects a tradable input such as feed cereals in hog production. As these two sets of adjustment occur, the result is revealed in changing proportions in the input mix, which can be derived from the duality of cost function.

Figure 2. A Simple Environment-Trade Model of Hog Production



The cost function that corresponds to the minimization problem is

$$C(y;w) = \min[w'x: f(x) \geqq y] \tag{1}$$

where C is cost, y is output of hog production, w is the vector of input prices, and x is the input vector. If marginal products of the inputs are non-negative and marginal rates of substitution between input pairs are non-increasing, then this minimum cost function corresponds to the production function exisits and is continuous. It is non-decreasing in the input price vector and is homogeneous of degree one in all input prices. Finally, it is concave in each input price for a given level of output.

The first-order conditions of the cost minimization problem give the following results:

$$MRTS = \frac{mp_i}{mp_j} = \frac{w_i}{w_j} \quad , \text{for } i \neq j \tag{2}$$

where MRTS is the marginal rate of technical substitution and mp_i is the marginal product of input x_i. Applying Shephard's lemma, the input demand function of x_i's can be obtained:

$$\partial C/\partial w_i = x_i \quad i = 1,2, \cdot\cdot\cdot ,n \tag{3}$$

The factor demand equation for each input should be homogeneous of degree zero in all factor prices. The elasticities of own-price and cross-price input demand is defined as:

$$e_{ij} = \%\text{ change in } x_i / \%\text{ change in } w_j = (\partial x_i/\partial w_j) \cdot w_j/x_i \tag{4}$$

The elasticity of substitution is a parameter that indicates the extent to which one input substitutes for another. The elasticity of substitution between two inputs, x_i and x_j , is defined as:

$$\sigma_{ij} = \%\text{ change in } (x_i/x_j) \;/\; \%\text{ change in } (w_i/w_j) \qquad (5)$$

Any elasticity might be written as the derivative of one natural log with respect to another. The definition of elasticity of input demand can be written as:

$$e_{ij} = \partial \ln x_i / \partial \ln w_j \qquad (6)$$

The definition of the elasticity of substitution, upon logarithm-taking, can be generalized as:

$$\sigma_{ij} = [\partial \ln(x_i/x_j)]/[(\partial \ln(w_j/w_j)] \qquad (7)$$

This definition can be evaluated based on constant output, cost, or marginal cost. It can also be evaluated assuming the prices on the remaining inputs other than i and j are held constant. The quantities of inputs other than i and j can also be held constant or allowed to vary as w_i and w_j vary, which generates elasticities of substitution measures.

Standard results from neoclassical duality theory can be applied to compute the elasticities of substitution between pairs of input. Uzawa showed that in a profit maximizing, competitive model, the Allen partial elasticities of substitution between inputs i and j can be derived from the dual (cost function) as:

$$\sigma_{ij} = (\partial^2 C/\partial w_i \partial w_j \cdot C)/(\partial C/\partial w_i \cdot \partial C/e w_j) \qquad (8)$$

Suppose that an international trade policy (TP) is imposed, and this affects the domestic price of input j. The relation can be expressed in percentage as:

$$\varepsilon_{jt} = \% \text{ change in } w_j / \% \text{ change in TP} = (\partial w_j / \partial \text{TP}) \cdot \text{TP}/w_j \quad (9)$$

where wj is the price of input i which is directly affected by trade policies. For example, domestic price of feed cereal changes ε_{vt}% as there is a 1% change in import tariff rate of feed cereals. The changes in the price of feed cereal will induce changes in relative price of inputs. Farmers, facing such variations in relative price of input, will alter the utilization of agricultural resources.

$$\varepsilon_{it} = \frac{\% \text{ change in } x_i}{\% \text{ change in } w_j} \cdot \frac{\% \text{ change in } w_j}{\% \text{ change in TP}} = e_{ij} \cdot \varepsilon_{jt} \quad (10)$$

A similar proposition can be made for the environment policies (EQ). In percentage format, changes in environmental quality can affect the pollution control cost that farmers need to spend.

$$\varepsilon_{ke} = \% \text{ change in } w_k / \% \text{ change in EQ} = (\partial w_k / \partial \text{EQ}) \cdot \text{EQ}/w_k \quad (11)$$

where w_k is the input price of pollution control. Again, changes in input price bring on changes in relative input price ratio, which would induce the changes in input demand.

$$\varepsilon_{xe} = \frac{\% \text{ change in } x_i}{\% \text{ change in } w_k} \cdot \frac{\% \text{ change in } w_k}{\% \text{ change in EQ}} = e_{ik} \cdot \varepsilon_{ke} \quad (12)$$

III. Empirical model

The translog cost function is particularly useful in deriving partial elasticities of substitution in terms of cost function parameters. It is written as a logarithmic Taylor series expansion to the second term of a twice differentiable cost function. The translog cost function has been widely applied in agricultural studies[2].

In corresponding to equation (1), a translog cost function for hog production is specified as :

$$\ln C^{*} = k_0 + a\ln y + \Sigma b_i \ln w_i + \frac{d(\ln y)^2}{2} + \frac{\Sigma \Sigma f_{ij} \ln w_i \ln w_j}{2} + \Sigma g_i \ln y \ln w_i \qquad (13)$$

where C^{*} = minimum total cost

x_i, x_j = inputs;labor(x_1),feed(x_2),piglet(x_3),&effots in pollution control(x_4)

y = hog production

w_i,w_j = unit price of inputs X_i and X_j

Partially differentiating equation (13) with respect to the ith input price gives:

$$\partial \ln C^{*} / \partial \ln w_i = b_i + \Sigma f_{ij} \ln w_j + g_i \ln y \quad \text{fori} = 1,...,4 \qquad (14)$$

Invoking Shephard's lemma:

$$\partial \ln C^{*} / \partial \ln w_i = \frac{\partial C^{*}}{\partial w_i} \cdot \frac{w_i}{C^{*}} = \frac{x_i w_i}{C^{*}} = S_i \qquad (15)$$

where S_i = the cost share for the ith input, i = 1,...,4, and

$$S_i = b_i + \Sigma f_{ij} \ln w_j + g_i \ln y \qquad (16)$$

The homogeneity and symmetry restrictions imposed on the estimation are:

$\Sigma b_i = 1$

$\Sigma g_i = 0$ for i = 1,...,4

$\Sigma f_{ij} = \Sigma f_{ji} = \Sigma \Sigma f_{ij} = 0$

$$f_{ij} = \partial 2 \partial \ln C^{*} / (\partial \ln w_i \partial \ln w_j) = f_{ji} = \partial^2 \ln C^{*} / (\partial \ln w_j \partial \ln w_i) \qquad (17)$$

From the parameter estimates of the cost share equations, the corresponding Allen elasticities of substitution (AES) between input pairs and the related measures can be derived. In the translog model, AES can be written as:

$$\sigma_{ij} = [f_{ij} + S_i S_j]/S_i S_j \tag{18}$$

The AES estimate is readily derived from the parameter estimates of the cost share equation. The usual approach is to insert the mean of the cost shares S_i for each input i into the estimated Allen measure. It has been proved that the price elasticities of demand for inputs can be derived from equation (18) as:

$$e_{ij} = (\partial x_i / \partial w_j) \cdot w_j / x_i = S_i \cdot \sigma_{ij} \tag{19}$$

for all pairs of input i and j.

A large elasticity of substitution indicates that the farmer has a high degree of flexibility in i dealing with input price variation. If there exists a large elasticity of substitution between a pair of factors, farmers would quickly adjust the input mix would be hardly altered even there are large relative shifts in prices. The extent to which a farmer adjusts the input nix to changing relative prices thus indicates the magnitude of the elasticity of substitution between input pairs. In the two factor case, the elasticity of substitution will lie between zero and posotive infinity. However, if there are more than two inputs, some input pairs may be complements with each other, thus leading to negative elasticity of substitution for some of the input pairs.

To illustrate the calcvlation of the interacting elasticities, when estimating the marginal control cost function of hog production, double-log functional form is applied. For the same reason, price function of feed cereal is also estimated in a double-log functional form. As for the policy specification, in Taiwan, the major instrument of environmental policies on hog production is emission standard of water pollutants. On the other hand, changes in trade policies are mostly specified on the exchange rate and import/export tariff rates.

$$\ln w_4 = \alpha_0 + \alpha_1 \ln(BOD) + \alpha_2 \ln(SS) \quad (20)$$

$$\ln w_2 = \beta_0 + \beta_1 \ln ER + \beta_2 t + \beta_3 UN + \beta_4 T \quad (21)$$

where w_4 = marginal pollution control cost of hog production = mcc

BOD = biochemical oxygen demand

SS = suspended solid

w_2 = price of feed cereals

ER = NT\$/US\$ exchange rate

t = import tariff of feed cereals

UN = dummy variable of domestic policies related to feed cereals

T = time

Marginal cost of pollution control increases with the amount of emission reduced. Domestic prices of imported inputs, such as feed cereal, decrease as the international trade liberalization policies are imposed.

In corresponding to equation (10) and (12), the followings can be derived. When there are policy changes in trade or environment quality standard, changes in input demand can be derived as:

$$\varepsilon_{it} = \frac{\%\text{ change in } x_i}{\%\text{ change in } w_2} \cdot \frac{\%\text{ change in } w_2}{\%\text{ change in TP}} = e_{i2} \cdot \varepsilon_{2t}$$

$$= \frac{\partial \ln x_i}{\partial \ln w_2} \cdot \frac{\partial \ln w_2}{\partial \ln TP} = e_{i2} \cdot \beta_{2t} \quad (22)$$

and

$$\varepsilon_{ie} = \frac{\%\text{ change in } x_i}{\%\text{ change in mcc}} \cdot \frac{\%\text{ change in mcc}}{\%\text{ change in EQ}} = e_{im} \cdot \varepsilon_{em}$$

$$= \frac{\partial \ln x_i}{\partial \ln w_4} \cdot \frac{\partial \ln w_4}{\partial \ln EQ} = e_{i4} \cdot \alpha_m \qquad (23)$$

where i = 1 when international trade policy refers to exchange rate,

i = 2 when international trade policy refers to tariff rate,

m = 1 when environmental policy refers to emission standard of BOD,

m = 2 when environmental policy refers to emission standard of SS

IV. Empirical Results

The cost function is estimated with 345 farmers' book-keeping data from the Department of Agricultural and Forestry, Taiwan Provincial Government and with survey data on pollution control from 84 hog farms. Inputs are distinguished into the following four categories: labor(x_1), feed(x_2), piglet(x_3), and pollution control(x_4). The corresponding input prices of x_1 to x_4 are denoted as w_1 to w_4. Data of x_1, x_2, and x_3 contain cross-section for the years 1989, 1990, and 1991. Data of international trade are obtained from the Bureur of International Trade, Executive Yuan.

When share equations are fitted to obtain the coefficient estimates, one share equation has to be dropped from the model because only three equations are linearly independent due to homogeneity constraint. Within the cross-section of each time period, the error terms of the three equations are not independent. In spite of the fact that all equations contain the same explanatory variables on the right-hand side, OLS estimators are no longer efficient when symmetric restrictions across equations are imposed. Therefore, the iterative seemingly unrelated regression (ISUR) method is applied, with the symmetry and homogeneity comstraints imposed in the estimation. The estimated parameters of the system and the associated asymptotic t-value are shown in Table 1.

The estimated parameters are obtained to measure the elasticities of substitutions between pairs of inputs during the time periods covered by the data. The pairwise elasticities of factors substitution computed from the model and the data set are shown in Table 2. Estimates of the Allen partial elasticities are shown in Tables 3. All own elasticities of factor demand have the correct signs. Elasticities of substitution and cross-elasticities of demand are positive for substitutes and negative for complements. These relationships are easier to evaluate by looking at the elasticities of substitution in Tables 3 then the cross-elasticities of demand in Tables 2. Substitution seem exist pairwides among inputs, except between piglet and labor inputs.

In Tables 4 and 5 are OLS estimates of the marginal control cost and feed price functions. Coefficients in both equations are of expected signs and are mostly significant, expect that the coefficients of BOD in marginal control cost equation and of UN in the feed price equation are not significant. The magnitude of the estimated coefficients indicate that the marginal control cost increases 0.1035% and 0.0479% when the reduction of BOD and SS increase 1%, respectively. The estimates in the feed price function show that when NT$/US$ exchange rate decrease 1%, feed price paid by hog farmers decreases 1.5303%. When import tariff on feed cereals decrease 1%, there will be a 0.1572% decrease in feed price paid by hog farmers.

According to equations (22) and (23), estimates in Tables 4 and 5 are further combined with the estimates of elasticities in Tables 2 to measure the input demand changes induced by trade and environmental policies. As an example, when import tariff of feed cereals decreases 1%, feed price decreases 0.1572%, which in turn will induce the input demand changes.

Table 1. Estimates of the Translog Cost Function of Hog Production in Taiwan※

Parameter	Estimates	t-values
k0	-2.329	-9.1*
a	0.608	4.4*
b1	0.058	5.7*
b2	0.060	1.8*
b3	0.032	1.8*
b4	0.850	15.6*
d	0.014	0.7
f11	0.012	2.1*
f22	0.097	16.8*
f33	0.053	32.3*
f44	0.101	20.4*
f12	-0.006	-0.6
f13	-0.010	-3.7*
f14	-0.009	-2.3*
f23	-0.045	-11.9*
f24	-0.143	-20.7*
f34	-0.052	-13.1*
g1	-0.006	-1.9*
g2	0.080	7.8*
g3	0.040	7.3*
g4	-0.113	-6.8*

※ Restrictions imposed: fij = fji and fij = 0, for i,j = 1,2,3,4.

* denotes significant at 5% level

Table 2. Elasticities of Input Demand and Cross Demand on Hog Farm in Taiwan

Input Demand	Input Price			
	Labor	Feed	Piglet	Pollution Control
Labor	-0.376 (-2.7*)	0.200 (0.8)	-0.077 (-1.2)	0.2533 (2.9*)
Feed	0.025 (0.8)	-0.092 (-5.4*)	0.027 (2.3.)	0.040 (2.0*)
Piglet	-0.020 (-1.2)	0.059 (2.5*)	-0.506 (-48*)	0.133 (5.4*)
Pollution Control	0.023 (2.9*)	0.030 (2.0*)	0.046 (5.4*)	-0.099 (-9.1*)

t values in parentheses
* denotes significant at 5% level

Table 3. Estimates of Allen Partial Elasticities on Hog Farm in Taiwan

Input Demand	Input Price			
	Labor	Feed	Piglet	Pollution Control
Labor	-8.938 (-2.7*)	0.584 (0.8)	-0.483 (-1.2)	0.555 (2.9*)
Feed		-0.268 (-5.4*)	0.172 (2.5*)	0.087 (2.0*)
Piglet			-3.176 (-48.9*)	0.291 (5.4*)
Pollution Control				-0.218 (-9.1*)

t values in parentheses
* denotes significant at 5% level

Table 4. Estimates of Marginal Control Cost Function on Hog Production in Taiwan

Variables	parameter	Value	t-ratio
Constant	α_0	4.4192	2.7*
ln BOD	α_1	0.1035	0.4
ln SS	α_2	0.0479	4.3*

R2 = 0.76
* denotes significant at 5% level

Table 5. Estimates of Feed Price Function in Taiwan

Variables	parameter	Value	t-ratio
Constant	β_0	-7.2377	-3.0*
ln ER	β_1	1.5303	2.8*
t(%)	β_2	0.1572	2.5*
UN	β_3	0.6394	1.4
T	β_4	-0.1092	-5.7*

R2 = 0.83
* denotes significant at 5% level

The effects of trade liberalization policies on the input demand are reported in Table 6 As shown, trade liberalization policy such as a 1% decreases in import tariff on feed cereals will induce change of -0.0314%, 0.014%, -0.0093%, and -0.004% on input demands in labor, feed, piglet, and pollution control, respectively. This implies that when trade liberalization policies are imposed, input sturctures in hog farm respond inelastically. A similar set of adjustments for a change in environmental policies affecting the input demand is easy to trace. Suppose the emission standard of BOD increases 1%, use of labor in hog farms will increase 0.0262%,

Together, the input demand elasticities of trade and of environmental policies determine the total effect of the simultaneous changes in both policies. By examining the signs of the elasticities in Table 6, there are opposite effects of trade policies and environmental policies on inputs of cereals and pollution control in hog production. Meanwhile, trade and environmental policies cause the same direction of effects on input adjustment of labor and piglet inputs.

Table 6. Elasticities of Input Demand on Trade/Environemntal Policies

Policies	Input Demand			
	Labor	Feed	Piglet	Pollution Control
Tariff[1]	-0.0314	0.0144	-0.0093	-0.0047
ER[2]	-0.3061	0.1405	-0.0904	-0.0456
BOD[3]	0.0262	0.0041	0.0137	-0.0103
SS[4]	0.0121	0.0019	0.0064	-0.0048

1. Import tariff on feed cereals
2. NT$/US$ exchange rate
3. Emission standard of BOD
4. Emission standard of SS

V. Conclusions

This paper establishes a simple model connecting the hog production, trade policies, and environmental policies. The key issue is that agricultural production process plays the central role in the linkages between environment and trade in agricultural inputs. In the environment-production-trade linkage, trade policies affect production through the trade- production interaction, while environmental policies affect production through the production-resource interaction. Specifically, in Taiwan, the major instrument of environmental policies applied on hog production is the emission standard of water pollutants. Trade policies are specified on the exchange rate and import/export tariff rates. The results imply that, when both policies are carried out simultaneously, stricter levels of emission standards on sewage water offset some of the impacts of trade liberalization on hog production in Taiwan.

Footnotes

1. Adopted and simplified from J. M. Antle & R.E. Howitt, (1988).

2. Aoun(1983) was concerned with the potential changes in elasticities of substitutions i between agricultural inputs over time, particularly energy and farm machinery. Fuss, et.al.(1978) referred to technological change which impacts the partial elasticites of substitution between input pairs as substitution augmenting technological change. Ray (1982) and Binswanger (1974) used the translog cost function to derive estimates of derived input demand and elasticities of substitution for the U.S. agricultural sector.

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台灣毛豬生產之環境與貿易混合模型

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摘要

本文目的主要在建立環境與貿易之關聯模式。本文建立之混合模型係以毛豬生產爲關聯中心，分爲生產及環境與生產及貿易兩大部份。其中環境政策係透過生產與環境關聯影響看豬生產結構，而貿易政策弓則透過生產與貿易關聯影響毛豬生產結構。環境政策工具係以本國規範毛豬廢水污染主要指標－放流水標準爲主；貿易政策工具則是以匯率及進出口關稅爲主。研究結果顯示，貿易自由化與環境政策趨嚴雙管齊下時，較嚴之放流水標準對毛豬生產之影響爲將抵銷掉貿易自由化對毛豬生產之影響效果。

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