A General Equilibrium Model of Agricultural Trade: An Intertemporal Optimizing Approach with Implications for Tariffication

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ABSTRACT

The paper develops a theoretical model such that the performance of the macroeconomy is consistent with optimizing behavior of rational individuals. It demonstrates that, in principle, it is possible to convert existing trade barriers into tariffs by using the price-gap method. In practice, however, tariff and nontariff barriers are not equivalent; replacing policies that result in a price gap of x percent with a tariff of x percent will generally yield different trade volumes.

U.S. farm exports will initially decline in anticipation of a reduction in foreign trade barriers. Current demand for U.S. agricultural exports is likely to decline as rational agents in the foreign agricultural sector reduce current storage and demand and increase current production in anticipation of a decline in their domestic prices. U.S. export performance will improve once trade restrictions are actually reduced.

A GENERAL EQUILIBRIUM MODEL OF AGRICULTURAL TRADE: AN INTERTEMPORAL OPTIMIZING APPROACH WITH IMPLICATIONS FOR TARIFFICATION

This paper provides a bridge between recent developments in international finance literature and agricultural trade and policy literature. Specific attention is paid to the tariffication proposal for long-term agricultural reform that the United States has submitted to the latest General Agreement on Tariffs and Trade (GATT) Round. Using an intertemporal-optimizing, general equilibrium framework, many presumptions of traditional international finance literature have been overturned. Svenson and Razin (1983) show that there is no particular reason to expect a permanent change in a nation's terms of trade to influence its current account balance. The reasoning has nothing to do with the price responsiveness of agents to relative price changes; rather, in an intertemporal context, the current account balance is viewed as a decision to save or dissave. Permanent relative price changes provide little incentive to intertemporally alter consumption/saving behavior. Mussa (1984) shows that money neutrality implies nominal exchange rate neutrality; it is contradictory to assert that anticipated money supply changes are neutral but that changes in the nominal exchange rate have real effects. Another virtue of macromodels derived from individual optimizing behavior is that they are not subject to the Lucas (1976) critique; the behavioral rules of agents are consistent with the performance of the macroeconomic model. Recent work (Lapan and Enders 1980; Enders and Lapan 1983) shows the importance of basing policy decisions on behavioral rules of individuals rather than on some overall macroeconomic performance goal.

Those familiar with international finance literature will not find any new theoretical insights here. The model developed in this paper is designed to be simple enough to be readily understood while containing the important characteristics of new developments in international finance. The model is one of a small, open economy producing an agricultural and a nonagricultural good in each of two periods. The novelty of the model is that it is readily applicable to agricultural trade and policy issues.

The nation is an importer of agricultural goods and the government uses trade policy to protect its agricultural sector. Production decisions are made to maximize profits. The agricultural good is storable; producers must decide how much of current production to sell and how much to store. The model is general equilibrium in nature; households are the ultimate owners of firms and view all production as income. Each household is forward-looking in that it maximizes lifetime utility subject to an intertemporal lifetime budget constraint. All transactions require using money, so it is possible to consider the co-movements of the nominal exchange rate and real economic variables. Within this framework, it is also possible to analyze the effects of various macroeconomic shocks on the household. Particular emphasis is placed on the role of tariffs and nontariff trade barriers.

This paper considers the optimization problems of households, firms, and storage facilities; solves the general equilibrium model and presents a specific example; considers the effects of internal and external macroeconomic shocks; examines the equivalence of tariffs and quotas and makes some observations concerning the U.S. proposal to "tariff" all nontariff barriers; and concludes with suggestions for further research.

The Basic Model

Consider a small, open economy producing and consuming two goods: an agricultural good (denoted by *a*) and a nonagricultural good (denoted by *n*). For simplicity, it is assumed that:

1. The economy can be portrayed by a representative agent model in which the individual lives for two periods. For ease of exposition, it is assumed that the agent's objective function is such that production/storage decisions can be analyzed separately from consumption decisions.

2. In the initial period of life, the individual must decide how much of each good to consume and how much to save (dissave). Consumption decisions are made under conditions of perfect foresight to maximize a well-defined utility function.

3. As a producer, the agent must decide how much of each good to produce in each period. The agricultural good is storable; in the initial period, producers must also decide how much of good *a* to put into storage.

4. The institutional structure requires that currency be used to purchase commodities—barter is assumed to be inefficient relative to exchanges using money. Domestics and foreigners

wishing to buy domestic goods must use domestic money. Similarly, a domestic wishing to import must first acquire foreign currency.

5. Governments do not take an active role in the economy. Rather, the monetary authority simply supplies domestic currency to the banking system. For the time being, it is assumed that the fiscal authority imposes an import tariff on good a (which may be zero). Agents pay for all duties using domestic currency. In each period, the government rebates the tariff revenue as a lump sum.

Supply

Within each period, production takes place along a concave production possibilities frontier. It is assumed that the output of each good depends only on that period's domestic relative price of the good and a productivity factor:

$$a_i^s = A_i f^a [p_i] , \qquad \frac{\partial f^a}{\partial p_i} < 0; \tag{1}$$

$$n_i^s = N_i f^n [p_i], \qquad \frac{\partial f^n}{\partial p_i} > 0; \textit{ and} \tag{2}$$

$$p_i = \frac{p_{ni}}{p_{ai}} , \tag{3}$$

where a_i^s (n_i^s) is production of good a (good n) in period i; p_i is the domestic relative price of good n in period i; p_{ai} (p_{ni}) is the domestic nominal price of good a (good n) in i; and A_i (N_i) is the multiplicative productivity term acting to shift the supply of good a (good n). Because there are only two time periods ($i = 0, 1$), as a notational convenience the subscript zero can be dropped when it is unambiguous to do so.

Total production valued in terms of domestic relative price of good a is

$$y_i = a_i^s + p_i n_i^s , \tag{4}$$

where y_i is total production valued in terms of the domestic relative price of the agricultural good. Given that production takes place along a concave production possibilities frontier, it follows that:[1]

$$\frac{dy_i}{dp_i} = n_i^s. \tag{5}$$

Storage

Some of the initial period (period zero) output may be stored until period one. In principle, it is possible to store some of almost any commodity; however, it is assumed that only the agricultural good can be stored. Before discussing optimal inventory behavior, it is useful to define real interest rates. Because relative prices may change over time, real borrowing costs can be measured in terms of either good:

$$(1 + r_a) \equiv (1 + i)\left(\frac{p_a}{p_{a1}}\right), \textit{ and}$$

$$(1 + r_n) \equiv (1 + i)\left(\frac{p_n}{p_{n1}}\right), \tag{6}$$

where r_a (r_n) is the real interest rate measured in terms of good a (good n), and i is the domestic nominal interest rate on borrowing (saving).

Equation (6) is the familiar definition of the real interest rate; one plus the real interest rate measured in terms of good a (good n) is equal to one plus the nominal interest rate divided by one plus the rate of price change of good a (good n). If the rate of price increase of good a (good n) exceeds the nominal interest rate, then r_a (r_n) is negative.

The key determinant of the amount of storage is the real interest rate measured in terms of good a. To explain, consider the optimization problem faced by the operator of a storage facility:

$$\max_{\{h\}} \left[\frac{p_{a1}}{(1 + i)}\right] h - p_a h - p_a s(h) \; ; \; s' > 0 \; s'' > 0. \tag{7}$$

In Equation (7), the discounted value of marginal revenue obtained from storing (hoarding) one unit of good a is $p_{a1}/(1 + i)$ and the number of units stored is h. Each unit hoarded must be purchased at the market price p_a. The function $s(h)$ denotes the real costs of running the storage facility valued in terms of good a; $p_a\, s(h)$ is the nominal value of these storage costs.[2]

The first-order condition for an interior solution is

$$\frac{p_{a1}}{p_a}(1 + i) = s'(h),$$

or

$$\frac{1}{(1 + r_a)} = s'(h). \tag{8}$$

Given that the second-order condition is satisfied, the optimal amount of good a stored will be an increasing function of $p_{a1}/[p_a\,(1 + i)] = 1/(1 + r_a)$; using the inverse function rule, it is possible to express the hoarding function as

$$h = h\left[\frac{1}{(1 + r_a)}\right] \textit{ and } h' > 0 \textit{ for } \frac{1}{(1 + r_a)} \geq \frac{1}{(1 + r_{a\_crit})} \tag{9}$$

$$h = 0 \textit{ for } \frac{1}{(1 + r_a)} < \frac{1}{(1 + r_{a\_crit})},$$

where r_{a_crit} is a critical number at which storage is not profitable.

Equation (9) indicates that increases in the discounted value of the intertemporal price of good a (i.e., decreases in the real interest rate measured in terms of good a) will generally increase hoarding. However, this price ratio may be such that profits are negative at the value of h satisfying Equation (7); if r_a exceeds r_{a_crit}, the storage facility will close.[3] A necessary condition for positive hoarding is for r_a to be negative; if $p_{a1}/(1 + i) = p_a$ (so that $r_a = 0$), the return from storage will fall short of the storage costs given by $s(h)$. Mathematically, this condition can be expressed as $r_a h \leq 0$.

The Individual's Optimization Problem

Let the individual receive utility from the consumption of each good in each period of life:

$$u = u\,(a_0, n_0, a_1, n_1), \tag{10}$$

where $a_i(n_i)$ is consumption of good a (good n) in period i, and the function u is a well-behaved utility function.

In the beginning of each period, the individual must go to the financial market to obtain the necessary currencies to purchase goods and pay import fees, and to save, dissave, or repay loans. The amount of domestic currency that the individual demands from the financial market is the sum of purchases of agricultural goods from domestics plus the import fee on agricultural goods plus the purchases of nonagricultural goods from domestics:

$$m = p_a\,[a^s - h] + p_n\,n + tep_a^*\,(a - a^s + h), \tag{11}$$

where m is the number of units of domestic currency demanded by domestics, e is the domestic currency price of foreign exchange, p_a^* is the foreign currency price of a, and t is the ad valorem tariff rate on good a so that tep_a^* is the tariff per unit of a imported. Note that the nation is an importer of the agricultural good so that consumption equals the amount marketed by domestic producers ($a^s - h$) plus imports ($a = a^s + h$).

The individual must pay for imports using the foreign currency; because the foreign price of imports is p_a^*, the demand for the foreign currency is

$$m^f = p_a^*\,(a - a^s + h). \tag{12}$$

The total amount of the two currencies demanded equals expenditures in the period. The individual budget constraint states that expenditures plus saving equals disposable income. Within the general equilibrium framework presented here, the representative agent's disposable income is equal to the market value of sales (production less hoarding) plus the transfer from the proceeds of the tariff revenue:

$$m + e\,m^f = p_a\,[\,a^s - h\,] + p_n n^s - s + \tau, \tag{13}$$

where s is saving and τ is the transfer received from the government.

In the initial period, the agent knows that he/she will receive an income from sales equal to $p_a(a^s - h) + p_n n^s$ and a transfer from the government equal to τ. Given this income, the individual decides how much to save (s) and how much to spend; total spending including the tariff duty is equal to $m + em^f$. At the end of the period, sellers of commodities hold $p_a\,[a^s - h] + p_n\,n^s$ units of domestic currency; the currency is deposited in the banking system. Any deposits in excess of expenditures earn the nominal interest rate i payable at the beginning of the next period.

In the beginning of the next period, then, the agent faces the three constraints:

$$m_1 = p_{a1}\,[a_1^s + h] + p_{n1}\,n_1 + t_1\,e_1\,p_{a1}^*\,(a_1 - a_1^s - h)\ , \tag{14}$$

$$m_1^f = p_{a1}^*\,(a_1 - a_1^s - h),\ and \tag{15}$$

$$m_1 + e_1\,m_1^f = p_{a1}\,[a_1^s + h] + p_{n1}\,n_1^s + (1 + i)\,s + \tau_1\ . \tag{16}$$

In Equation (14), domestic currency is used to purchase the quantities $a_1^s + h$ and n_1 from domestics and to pay the period 1 tariff on imports. Foreign currency is used to purchase the quantity $a_1 - a_1^s - h$ of imports. Equation (16) states that the individual uses his/her gross income from sales and dishoarding plus savings and interest to acquire domestic and foreign currency. Because Equation (16) holds with equality, the individual leaves no estate and pays all debts.

Thus, the individual's optimization problem is to select a, n, a_1, and n_1 to maximize the utility function of Equation (10) subject to the constraints in Equations (11) through (16). For presentation purposes, the problem can be simplified by forming the agent's lifetime budget constraint. First note that commodity arbitrage in the assumed absence of transport costs requires:

$$p_{ni} = e_i\,p_{ni}^*\ ,\ and \tag{17}$$

$$p_{ai} = (1 + t_i)\,e_i\,p_{ai}^*\ . \tag{18}$$

In Equation (18), the full cost of importing good a is the foreign purchase price ($e_i p_{ai}^*$) plus the tariff ($t_i e_i p_{ai}^*$). Combining Equations (11) through (18) yields the individual's lifetime budget constraint:

$$p_a\,(a^s - h - a) + p_n\,(n^s - n) + \tau + \frac{p_{a1}\,(a_1^s + h - a_1) + p_{n1}\,(n_1^s - n_1) + \tau_1}{(1 + i)} = 0. \quad (19)$$

Selecting a, n, a_1, and n_1 subject to the constraint of Equation (19) so as to maximize the utility function of Equation (10) yields the individual's demand functions.

Market Clearing

For the small-country case under consideration, the goods market clears when desired imports (exports) equal actual imports (exports) and the arbitrage conditions in (17) and (18) hold. The domestic money market in period i clears when total available stock of nominal money (M_i) is equal to total demand for money. The foreign demand for domestic currency is equal to the domestic currency value of their desired imports:

$$m_i^{*f} = p_{ni}\,(n_i^s - n_i)\ , \quad (20)$$

where m_i^{*f} is the foreign demand for domestic currency and $p_{ni}(n_i^s - n_i)$ is the domestic currency value of domestic exports (foreign imports).

The domestic money market clears when

$$M_i = m_i + m_i^{*f}. \quad (21)$$

Finally, the assumption of perfect capital mobility links the domestic with the foreign credit markets. Letting i^* denote foreign interest rate, interest rate arbitrage requires:[4]

$$1 + i = (1 + i^*)\,\frac{e_1}{e}. \quad (22)$$

In the subsequent analysis, it will be useful to define real foreign interest rate. Using an (*) to denote the foreign-country counterpart of a domestic currency variable, foreign real interest rates measured in terms of goods n and a are

$$(1 + r_n^*) \equiv (1 + i^*)\ (p_n^*/p_{n1}^*), \text{ and}$$

$$(1 + r_a^*) \equiv (1 + i^*)\ (p_a^*/p_{a1}^*). \tag{23}$$

The small-country assumption means that the domestic nation takes p_{ai}^*, p_{ni}^*, and i^* (hence r_a^* and r_n^*) as exogenous.

The General Equilibrium Solution

Given that the small country is a price taker on international commodity and capital markets, solutions for the supply functions of Equations (1) and (2) and hoarding function of Equation (9) are obtained directly:

$$a_i^s = A_i f^a \left[\frac{p_i^*}{(1 + t_i)} \right], \tag{24}$$

$$n_i^s = N_i f^n \left[\frac{p_i^*}{(1 + t_i)} \right], \text{ and} \tag{25}$$

$$h = h \left\{ \frac{(1 + t_1)}{\left[(1 + t)\ (1 + r_a^*)\right]} \right\}, \tag{26}$$

where $p_i^* = p_{ni}^*/p_{ai}^*$ (foreign relative price of good n in period i).

The general equilibrium nature of the model is such that consumers view the output levels indicated by Equations (24) through (26) as their endowments (or income levels).

Using definitions (22) and (23), the agent's optimization problem can be written as

$$\max u\ (a, n, a_1, n_1) + \lambda \left[w - (1 + t)\ a - p^* n - \frac{(1 + t_1)\ a_1}{(1 + r_a^*)} - \frac{p^* n_1}{(1 + r_n^*)} \right] \tag{27}$$

$$w \equiv (1 + \bar{t})\,[a^s - h] + p^*\,(n^s) + \tau + \frac{(1 + t_1)\,(a_1^s + h)}{(1 + r_a^*)} + \frac{p^* n_1^s}{(1 + r_n^*)} + \frac{\tau_1}{e_1 p_{a1}^*\,(1 + r_a^*)}\,,$$

where λ is the Lagrangian multiplier and w is the discounted value of the real income stream.

Solving the optimization problem yields the demand functions:

$$\begin{aligned}
a &= a\left[(1 + t),\, p^*,\, \frac{(1 + t_1)}{(1 + r_a^*)},\, \frac{p^*}{(1 + r_n^*)},\, w\right],\\
n &= n\left[(1 + t),\, p^*,\, \frac{(1 + t_1)}{(1 + r_a^*)},\, \frac{p^*}{(1 + r_n^*)},\, w\right],\\
a_1 &= a_1\left[(1 + t),\, p^*,\, \frac{(1 + t_1)}{(1 + r_a^*)},\, \frac{p^*}{(1 + r_n^*)},\, w\right],\ and\\
n_1 &= n_1\left[(1 + t),\, p^*,\, \frac{(1 + t_1)}{(1 + r_a^*)},\, \frac{p^*}{(1 + r_n^*)},\, w\right],
\end{aligned} \tag{28}$$

where w is defined in Equation (27) and the values of a_i^s, n_i^s, and h are given by Equations (24) through (26).

Assuming all goods are normal means that each good's demand in each period is positively related to w. Assuming gross substitutability implies an increase in own price, holding all other prices and w constant, reduces demand for that good and increases demand for the other three goods.

To fully complete the general equilibrium system, it is necessary to specify the government's budget constraint. Given that government expenditure is zero and that its budget is balanced in every period, transfers received by consumers are necessarily equal to government tariff revenues:

$$\begin{aligned}
\tau &= tep_a^*\,(a - a^s + h),\ and\\
\tau_1 &= t_1 e_1 p^*{}_{a_1}\,(a_1 - a_1^s - h).
\end{aligned} \tag{29}$$

Equations (24), (25), (26), (28), and (29) characterize the complete general equilibrium system.

A Specific Example

Let the individual have a utility function that is log-linear in consumption of each good in each period of life. Specifically, let

$$u + \theta \ln a_0 + (1 - \theta) \ln n_0 + \frac{\theta}{(1 + \rho)} \ln a_1 + \frac{(1 - \theta)}{(1 + \rho)} \ln n_1 , \tag{30}$$

where θ is a share parameter such that $0 < \theta < 1$ and ρ is the subjective rate of time preference such that $\rho > 0$.

Maximizing Equation (30) subject to the budget constraint yields the demand functions:

$$a = \frac{\theta\ (1 + \rho)}{(1 + t)\ (2 + \rho)}\ w, \qquad a_1 = \frac{\theta\ (1 + r_a^*)}{(1 + t_1)\ (2 + \rho)}\ w,$$

$$n = \frac{(1 - \theta)\ (1 + \rho)}{p^*(2 + \rho)}\ w, \textit{ and } \qquad n_1 = \frac{(1 - \theta)\ (1 + r_n^*)}{p^*(2 + \rho)}\ w, \tag{31}$$

where w is defined in Equation (27).

Using the definition of w and substituting Equations (28) and (29) into (31) yields the general equilibrium demand functions:

$$a = \frac{1}{\Delta}\left[\frac{\theta}{1 + t}\right]\left[\frac{1 + \rho}{2 + \rho}\right]\left[a^s + p^* n^s + \frac{p^* n_1^s}{1 + r_n^*} + \frac{a_1^s - r_a^* h}{1 + r_a^*}\right],$$

$$n = \frac{1}{\Delta}\left[\frac{1 - \theta}{p^*}\right]\left[\frac{1 + \rho}{2 + \rho}\right]\left[a^s + p^* n^s + \frac{p^* n_1^s}{1 + r_n^*} + \frac{a_1^s - r_a^* h}{1 + r_a^*}\right], \tag{32}$$

$$a_1 = \frac{1}{\Delta}\left[\frac{\theta}{1 + t_1}\right]\left[\frac{1 + r_a^*}{2 + \rho}\right]\left[a^s + p^* n^s + \frac{p^* n_1^s}{1 + r_n^*} + \frac{a_1^s - r_a^* h}{1 + r_a^*}\right], \textit{ and}$$

$$n_1 = \frac{1}{\Delta}\left[\frac{1-\theta}{p^*}\right]\left[\frac{1+r_n^*}{2+\rho}\right]\left[a^s + n^s + \frac{p^* n_1^s}{1+r_n^*} + \frac{a_1^s - r_a^* h}{1+r_a^*}\right],$$

$$\textit{where } \Delta = 1 - \left[\frac{\theta}{2+\rho}\right]\left[\frac{t\,(1+\rho)}{1+t} + \frac{t_1}{1+t_1}\right],$$

$$h = h\left[\frac{(1+t_1)}{(1+t)\,(1+r_a^*)}\right],$$

where p^* is the foreign relative price of good n ($p^* = p_n^*/p_a^*$, and a^*, n^*, a_1^*, and n_1^* are defined in (24) and (25).

Effects of Disturbances

One advantage of an intertemporal optimizing model is that performance of the macroeconomy is consistent with behavioral rules of optimizing agents. As such, the model is not subject to the Lucas critique (1976); it is possible to perform comparative static exercises using the general equilibrium solutions obtained in the previous section. A second advantage of this approach is that the savings/consumption function is consistent with the life cycle hypothesis. Thus, the model is capable of analyzing the effects of anticipated future disturbances on current period behavior.

Productivity Changes

A wide variety of productivity shocks can be represented by appropriate changes in A_0, A_1, N_0, and/or N_1. For example, a permanent productivity increase in the agricultural sector can be represented by equal increases in A_0 and A_1; an anticipated future increase by an increase in A_1 alone, and a current drought by a decline in A_1. Sector neutral technological change can be represented by proportional changes in A_i and N_i for $i = 0$ or 1.

A key feature of the model is that productivity shocks are transmitted across sectors and across time through actions of consumers on the demand side. Notice that the discounted value of the real income stream (w) appears in the demand functions of Equation (28); a positive productivity shock in either sector in either period will increase all demands. In a general equilibrium model, outputs are household incomes. Given that there is a diminishing marginal rate of substitution across commodities and across time, an increase in A_0, N_0, A_1, or N_1 will increase the demand for each good in each period. The direct implication is that it is possible to observe changes in current period demand without any change in current period income. Individuals will lend (or borrow) to maintain the intertemporal marginal rate of substitution with market interest rates. It is also worth making the obvious point that permanent shocks (such that $dA = dA_1$ or $dN = dN_1$) have larger consumption effects than do temporary shocks (in which only one period's output changes).

On the supply side, however, productivity shocks are not transmitted across sectors or across time. From examination of the general equilibrium solutions for a_i^s in Equation (24), it is clear that production of good a in period i depends only on $p_i^*/(1 + t_i)$ and A_i. Thus, productivity disturbances in the nonagricultural sector have no supply-side effects on the agricultural sector. In the same way, productivity changes in the agricultural sector have no supply-side effects on agricultural sectors. From Equation (26), it is seen that the amount of hoarding depends only on tariff rates and the foreign real interest rate measured in terms of good a; hoarding is invariant to production of good a in either period.[5]

The effect of a productivity shock on the trade balance depends on whether the shock is temporary or permanent; temporary productivity shocks have a much stronger influence than do permanent shocks. The sector in which the shock occurs is of little consequence for the trade balance. Because the nation exports good n and imports good a, the balance of trade measured in terms of world price of good a is

$$tb = p^* \, (n^s - n) - (a - a^s + h), \textit{ and}$$

$$tb_1 = p_1^* \, (n_1^s - n_1) - (a_1 - a_1^s - h), \qquad (33)$$

where tb_i is balance of trade measured in terms of the agricultural good's world price.

As an aid to understanding the model, substitute (29) and the definitions of real interest rates into the individual's lifetime budget constraint (19) to obtain

$$(a^s - a) + p^*(n^s - n) + \frac{(a_1^s - a_1)}{(1 + r_a^*)} + \frac{p^*(n_1^s - n_1)}{(1 + r_n^*)} - \frac{r_a^*}{1 + r_a^*} h = 0. \tag{34}$$

For the whole economy, the tariff does not involve a direct income effect; the discounted value of the lifetime consumption stream must equal the discounted value of the lifetime income stream. The tariff does distort prices, so it affects consumption and production decisions. Combining Equations (33) and (34) reveals a fundamental property of the model; the discounted value of the trade balance must be zero:

$$tb + \frac{tb_1}{(1 + r_a^*)} = 0 . \tag{35}$$

Equation (34) demonstrates that, over the course of the agent's lifetime, spending cannot exceed income. As a result, Equation (35) shows that the economy cannot experience a perpetual external deficit or surplus. Any excess spending over income in the initial period must be repaid in the subsequent period. Any changes in productivity affect the current value of the trade balance only to the extent that individuals are induced to save or dissave.

Ruling out inferior goods, demand responds positively to a productivity increase in either sector in either period. For the trade balance, the results can be summarized as follows:

1. Initial period productivity increases that are temporary (i.e., only $dA > 0$ or $dN > 0$) have a positive effect on the trade balance. Individuals attempt to "smooth out" the effects of an increase in current income by saving. As a nation, the increase in saving is equivalent to a balance of trade surplus. In the subsequent period, however, agents dissave by generating an external deficit.

2. Period 1 productivity gains (i.e., only $dA_1 > 0$ or $dN_1 > 0$) have a negative effect on the initial period's trade balance. The increased productivity induces individuals to borrow against their future income to finance current consumption. As current expenditures rise relative to current income, the trade balance deteriorates. In period 1, however, individuals repay their loans; the trade balance for this period shows a surplus.

3. Permanent productivity changes have an ambiguous effect on the trade balance; if income levels in *both* periods increase, there is no presumption whether individuals will save or dissave. Table 1 presents the effects of changes in A_0, A_1, N_0, and N_1 on current period

Table 1. Consumption effects of productivity shocks

	da	dn	$d\,tb_0 = p^* d(\bar{n}-n) - d(a-\bar{a})$
ds^s	$0 < \frac{1}{\Delta}\left(\frac{\theta}{1+t}\right)\left(\frac{1+\rho}{2+\rho}\right) < 1$	$\frac{1}{\Delta}\,\frac{1}{p^*}\,(1-\theta)\left(\frac{1+\rho}{2+\rho}\right) > 0$	$1 - \frac{1}{\Delta}\left(\frac{1+\rho}{2+\rho}\right)\left[\frac{1+t(1-\theta)}{1+t}\right] > 0$
da^s	$0 < \frac{1}{\Delta}\left(\frac{\theta}{1+t}\right)\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{1}{1+r^*_a}\right) < 1$	$\frac{1}{\Delta}\,\frac{1}{p^*}\,(1-\theta)\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{1}{1+r^*_a}\right) > 0$	$-\frac{1}{\Delta}\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{1}{1+r_a}\right)\left[\frac{1+t(1-\theta)}{1+t}\right] < 0$
$d\bar{a}^s = da^s$	$\frac{1}{\Delta}\left(\frac{\theta}{1+t}\right)\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{2+r^*_a}{1+r^*_a}\right) > 0$	$\frac{1}{\Delta}\,\frac{1}{p^*}\,(1-\theta)\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{2+r^*_a}{1+r^*_a}\right) > 0$	$1 - \frac{1}{\Delta}\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{2+r^*_a}{1+r^*_a}\right)\left[\frac{1+t(1-\theta)}{1+t}\right] = ?$
dn^s	$\frac{1}{\Delta}\left(\frac{\theta}{1+t}\right)\left(\frac{1+\rho}{2+\rho}\right) p^* > 0$	$0 < \frac{1}{\Delta}(1-\theta)\left(\frac{1+\rho}{2+\rho}\right) < 1$	$p^* \{1 - \frac{1}{\Delta}\left(\frac{1+\rho}{2+\rho}\right)\left[\frac{1+t(1-\theta)}{1+t}\right]\} > 0$
dn^s_1	$\frac{1}{\Delta}\left(\frac{\theta}{1+t}\right)\left(\frac{1+\rho}{2+\rho}\right)\frac{p^*}{1+r^*_n} > 0$	$0 < \frac{1}{\Delta}(1-\theta)\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{1}{1+r^*_n}\right) < 1$	$-\frac{p^*}{\Delta}\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{1}{1+r_n}\right) < 0$
$dn^s = dn^s_1$	$\frac{1}{\Delta}\left(\frac{\theta}{1+t}\right)\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{2+r^*_n}{1+r^*_n}\right) p^* > 0$	$\frac{1}{\Delta}(1-\theta)\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{2+r^*_n}{1+r^*_n}\right) < 0$	$p^* \{1 - \frac{1}{\Delta}\left(\frac{1+\rho}{2+\rho}\right)\left(\frac{2+r_a}{1+r_a}\right)\left[\frac{1+t(1-\theta)}{1+t}\right]\} = ?$

where: $\Delta = 1 - \left(\frac{\theta}{2+\rho}\right)\left[\frac{t}{1+t}(1+\rho) + \frac{t_1}{1+t_1}\right]$ and: $da^s_i = f^a\,dA$: j $dn^s_i = f^n dN$:

demands and the trade balance for the specific utility function given by Equation (30). Evaluating at $t = t_1 = 0$, a permanent productivity shock in good a will have no effect on the trade balance if $1 + r_a^* = 1 + \rho$ and a permanent productivity shock to good n will have no effect on the trade balance if $1 + r_n^* = 1 + \rho$. If the subjective rate of time preference is equal to the real interest rate, there is no incentive to intertemporally transfer additional income into the subsequent period when both income levels increase by the same amount. For a nation with a high rate of time preference ($\rho > r_a^*$ or $\rho > r_n^*$), a permanent productivity increase will be associated with an initial period surplus and a deficit in period 1.

The key point is that there is no simple relationship between productivity and trade balance. Permanent productivity changes in either the import or export sectors may generate trade surpluses or deficits. Moreover, current period productivity may be high yet the trade balance may exhibit a deficit if future incomes are expected to be higher than current income. Studies that forecast the direction of the trade balance without decomposing income-level movements into their permanent versus temporary components are bound to be misleading.

External Disturbances

The small, open economy takes p^*, r_a^*, and r_n^* as given; for a given tariff schedule, relative prices can change only through disturbances on international markets. As was the case for productivity shocks, the effects of temporary external shocks are sometimes quite different from those of permanent shocks.

Permanent Changes in the Terms of Trade. Consider first the consequences of a change in p^* for given values of r_a^* and r_n^*. From the definition in Equation (26),

$$p^* = \frac{p_n^*}{p_a^*} . \tag{36}$$

Because the nation imports agricultural goods and exports good n, an increase in p^* represents an improvement in the nation's terms of trade. Given the foreign nominal interest rate (i^*), Equation (23) demonstrates that unchanged values of r_a^* and r_n^* necessitate there be no change in the ratios p_a^*/p_{a1}^* and p_n^*/p_{n1}^*. Thus, an increase in p^* holding r_a^* and r_n^* constant must be interpreted as a permanent improvement in the nation's terms of trade (both p_n^*/p_a^* and p_{n1}^*/p_{a1}^* rise by equal amounts).

The supply functions (24) and (25) show that the output of each good is positively related to own price; thus, a permanent increase in the terms of trade will increase supply of good n and decrease supply of good a in each period. The situation is quite different for hoarding; a permanent change in relative prices will not affect hoarding behavior. To explain, recall that storage is intended to intertemporally arbitrage prices. A permanent change in relative price of the nation's export good does not provide any additional incentive to hoard. On the supply side, then, the overall effect of the permanent improvement in the nation's terms of trade is to increase the quantity of good n and decrease the quantity of good a marketed in each period.

Without imposing additional structure on the model, little can be said about the demand functions other than that own-price effects are negative. For the specific log-linear utility function, however, the effects of a change in relative prices can be calculated directly from Equation (31). The effects of an increase in p^* are listed in the first row of Table 2 where, for simplicity, all total derivatives are evaluated at point $t = t_1 = 0$. As seen in the table, a permanent increase in the relative price of good n reduces demand for nonagricultural goods and increases demand for agricultural goods in each period.

It is crucial to note there is no presumption that improving the terms of trade will improve the trade balance. It is true that reducing demand for good n coupled with increasing supply results in an overall increase in the export supply function. However, increased demand for the agricultural good coupled with a supply reduction results in increased import demand. In each period, exports and imports increase. Rewriting Equation (33):

$$tb = a^s + p^* n^s - (a + h + n). \tag{37}$$

The trade balance is the difference between total domestic production $(a^s + p^* n^s)$ and total domestic expenditures including hoarding $(a + h + n)$. The intuitive explanation of the ambiguous effect of a permanent change in p^* on the trade balance is that there is no particular incentive for agents to intertemporally reallocate expenditures in response to a permanent change in relative prices. Formally differentiating Equation (37) with respect to the terms of trade:

Table 2. Effects of relative price changes

	da	dn	da_1	dn_1
dp^*	$\theta\left(\frac{1+\rho}{2+\rho}\right)\left(n^s + \frac{n_1^s}{1+r_n^*}\right) > 0$	$-(1-\theta)\left(\frac{1+\rho}{2+\rho}\right)\left[a^s \ \frac{a_1^s - r_{ah}^*}{1+r_a^*}\right]\left[\frac{1}{p^*}\right]^2 < 0$	$\theta\left(\frac{1+r_a^*}{2+p}\right)\left(n^s + \frac{n_1^s}{1+r_n^*}\right) > 0$	$-(1-\theta)\left(\frac{1+r_n^*}{p^{*2}}\right)\left(a^s + \frac{a_s^1 - r_a^*}{1+r_a^*}\right) < 0$
dr_n^*	$-\theta\left(\frac{1+\rho}{2+\rho}\right)\frac{p^*\,n_1^s}{(1+r_n^*)^2} < 0$	$-\left(\frac{1-\theta}{p^*}\right)\left(\frac{1+\rho}{2+\rho}\right)\frac{p^*n_1^s}{(1+r_n^*)^2} < 0$	$-\theta\left(\frac{1+r_a^*}{2+\rho}\right)\frac{p^*n_1^s}{(1+r_n)^2} < 0$	$\left(\frac{1-\theta}{2+\rho}\right)\left[a^s + \frac{a_1^s - r_a^*}{1+r_a^*} + p^*n^s\right] > 0$
dr_a^*	$\theta\left(\frac{1+\rho}{2+\rho}\right)w' < 0$	$\left(\frac{1-\theta}{p^*}\right)\left(\frac{1+n}{2+\rho}\right)w' < 0$	$\frac{\theta}{2+\rho}\left[a^{s-h} + p^*n^s + \frac{p^*n_1^s}{1+r_n^*} + \frac{r_a^*}{1+r_a^*}\epsilon_h\right] = ?$	$\left(\frac{1-\theta}{p^*}\right)\left(\frac{1+r_n^*}{2+n}\right)w' < 0$

where: $$w' = d\left[a^s + p^*n^s + \frac{p^*n_1^s}{1+r_n^*} + \frac{a_1^s - r_a^*h}{1+r_a^*}\right]/d(r^*_a) = -\frac{a_1^s}{(1+r_a^*)^2} + \frac{r_a^*h}{(1+r_a^*)^2} - \left(\frac{h - r_a^*\,(1+r_a^*)^{-2}h^1}{1+r_a^*}\right)$$

$$= \frac{-a_1^s}{(1+r_a^*)^2} + \frac{r_a^*h'}{(1+r_a^*)^3} - \frac{h}{(1+r_a^*)}\left[1 - \frac{r_a^*}{1+r_a^*}\right] < 0$$

Since $h = 0$ if $r_a^* > 0$ and $h > 0$ only if $r_a^* < 0$.

and: ϵ_h = elasticity of h with respect to $(1/1 + r_a^*)$.

$$\frac{d(tb)}{dp^*} = (n^s - n) - p^* \frac{dn}{dp^*} - \frac{da}{dp^*}$$
$$= (n^s - n) + n\,\epsilon_n - \left(\frac{a}{p^*}\right)\epsilon_a\,, \tag{38}$$

where $\epsilon_n = -(p/n)(dn/dp) > 0$, $\epsilon_a = -(1/pa)\,[da/d(1/p)] > 0$, and so that ϵ_x is total price elasticity of demand for good x. For simplicity, Equation (38) is evaluated at $t = t_1 = 0$; thus, in deriving (38) it is possible to set $p = p^*$ and to use Equation (5) directly.

In general, the sign of Equation (38) is ambiguous. For a nation exporting good n, $n^s - n$ is positive; the increase in p^* increases the value of exports for unchanged levels of production and demand. The expression $(n\,\epsilon_n)$ is also positive; the greater the elasticity of demand for n, the greater the substitution out of the current period demand for good n and the greater the improvement in the trade balance. However, $-(a/p^*)\epsilon_a$ is negative; the greater this elasticity of demand, the greater the substitution into the current period demand for the imported good.[6]

For the specific utility function, substitute the entries from Table 2 into Equation (38) to obtain

$$\frac{d(tb)}{dp^*} = n^s - \frac{1+\rho}{2+\rho}\,n^s + \frac{n_1^s}{1+r_n^*}\,. \tag{39}$$

To interpret, the sign of the trade balance depends on the production pattern (n^s versus n_1^s), rate of time preference (ρ), and real interest rate. Because the nation exports good n, improving trade causes a real income gain in each period; the agent must choose how to allocate this gain across time. A large value of n_1^s relative to n^s implies that the preponderance of the real income gain is associated with future production; the agent will tend to increase present consumption relative to present income. A large value of ρ relative to r_n^* implies a preference for current period consumption; the agent will choose to allocate a large proportion of a given increase in real income to present expenditure.

Interest Rate Changes. It is useful to separate a change in relative commodity prices from a change in the cost of borrowing. Given foreign prices (i.e., p_a^*, p_n^*, p_{a1}^*, and p_{n1}^*), a pure increase in the cost of borrowing is represented by equiproportionate increases in $1 + i^*$, $1 + r_a^*$, and $1 + r_n^*$. On the supply side, production levels remain unaltered. However, the increase in r_a^* makes hoarding less attractive; for all real interest rates below the critical rate, an increase in r_a^* reduces hoarding. Assuming that commodities are gross substitutes in consumers' budgets, an increase in real interest rates induces a substitution away from present consumption and toward future consumption. In this circumstance, the trade balance improves because production is unaltered, current sales of good a increase (due to the hoarding decline), and current period expenditures on goods a and n decline.

Temporary Price Changes. Temporary changes in commodity prices can be viewed as a combination of a real interest rate change and a change in the terms of trade. For example, a temporary increase in the relative price of good n (i.e., an increase in p^* without any change in p_1^*) does not involve a change in $(1 + i^*)$ or $(1 + r_a^*)$, but r_n^* changes so $p^*/(1 + r_n^*)$ remains constant. An increase in the period 1 price of good a (p_{a1}^*) can be represented by a reduction in p_1^* and $(1 + r_a^*)$ for constant values of p^*, $(1 + i^*)$, and $(1 + r_n^*)$. Current period production of good n increases at the expense of good a, hoarding remains unchanged, and—if commodities are gross substitutes—demand for good n declines and demand for good a increases. The second and third rows of Table 2 give the effects of pure changes in interest rates on commodity demands for the specific log-linear utility function.

Money and Exchange Rate Neutrality

An important feature of the model is that it exhibits exchange rate/money neutrality. Notice that behavior of the real variables in the system could be determined without referring to nominal exchange rate or to money supply. On the other hand, prices and exchange rate are determined by movements in the system's real variables.

To solve for nominal variables, substitute domestic demand for domestic money [Equation (11)] and foreign demand for domestic money (20) into the money market clearing condition (21). In the initial period, money market equilibrium entails

$$M = p_a\,(a^{s} - h) + p_n n^{s} + tep_a^{*}\,(a - a^{s} + h) + p_n\,(n^{s} - n)$$
$$= ep_a^{*}\,[\,a^{s} - h + p^{*}n^{s} + ta\,]\,, \tag{40}$$

where a is determined as in Equation (28). For the case of the specific log-linear utility function,

$$M = ep_a^{*}\left[\,a^{s} - h + p^{*}n^{s} + \frac{t}{1+t}\,\frac{1+\rho}{2+\rho}\,\frac{1}{\Delta}\left(a^{s} + p^{*}n^{s} + \frac{p^{*}n_1^{s}}{1+r_n^{*}} + \frac{a_1^{s} - r_a^{*}\,h}{1+r_a^{*}}\right)\right] \tag{41}$$

Given that a^s, h, p^*n^s, and a are not affected by a money supply change, the nominal exchange rate is directly proportional to domestic money supply and indirectly proportional to p_a^*, p_{a1}^*, p_n^*, and p_{n1}^* (if these four prices all rise by the proportion $\bar{\omega}$, p^*, r_a^*, and r_n^* remain unaltered while the exchange rate falls in the proportion $\bar{\omega}^{0.5}$). Additionally, the exchange rate depends on current and future values of real variables in the system. An increase in current output of either good will appreciate domestic currency as increased transactions increase demand for domestic currency. The hoarding function is negatively related to r_a^*; an increase in r_a^* will increase sales of a in period zero; the value of the domestic currency will be increasing in r_a^*. Also, as long as $t \neq 0$, demand for domestic money depends on tariff revenue from imports; increases in future output levels act to increase current demand for good a and so act to appreciate domestic currency.

The key point is that the exchange rate is completely endogenous; co-movements between nominal exchange rate and other variables in the system cannot be attributed to the exchange rate itself. Moreover, there is no simple relationship between the exchange rate and other endogenous variables in the system. For example, positive productivity shocks to a_1^s or n_1^s will worsen the trade balance in the initial period and appreciate the domestic currency. In no sense can it be said that the trade balance decline is attributable to movements in the nominal exchange rate. Although future productivity shocks are associated with currency appreciation and a trade balance deficit, an increase in current productivity will be associated with currency appreciation (de/da^s and $de/dn^s < 0$) and a trade surplus.

The Equivalence Between Tariffs and Quotas

The intertemporal framework developed here has important implications for the U.S. tariffication proposal. Although there are many varieties of nontariff trade barriers, it is convenient to model all such barriers as quotas. It is assumed that the government issues import licenses; each license allows the holder to import one unit of the agricultural good. Let q_i denote the quantity of licenses issued during time period i.[7] As long as the government captures the quota revenue, collects the revenue in domestic currency, and rebates the proceeds to the public in a lump sum, there is a vector of quotas $[q_o, q_1]$ equivalent to any arbitrary tariff vector $[t_0, t_1]$.

To show this equivalence, assume that in each period the government sells q_i import licenses at the competitively determined price p_{qi}. Each license enables the holder to purchase good a at world price $e_i p_{ai}^*$ and to resell the good at domestic price p_{ai}. Competition ensures that the domestic price of good a differs from the world price by the exact price of the import license:

$$p_{ai} = p_{qi} + e_i \, p_{ai}^* \, , \tag{42}$$

or

$$\frac{p_{ai}}{e_i \, p_{ai}^*} = 1 + g_i \, , \tag{43}$$

where g_i is defined as $p_{qi}/e_i p_{ai}^*$.

The expression g_i is a measure of the price gap between the domestic and foreign price introduced by the quota. If $g_0 = t_0$ and $g_1 = t_1$, it is straightforward to show that the quota regime and the tariff regime will be identical in all respects.

Because the quota affects only the price of good a, the domestic relative price of good n in period i ($p_i \equiv p_{ni}/p_{ai}$) is

$$p_i = \frac{p_i^*}{(1 + g_i)} \, . \tag{44}$$

The supply of each good is obtained by substituting (44) into (1) and (2):

$$a_i^s = A_i f^a \left[\frac{p_i^*}{(1 + g_i)} \right], \textit{ and} \tag{45}$$

$$n_i^s = N_i f^n \left[\frac{p_i^*}{(1 + g_i)} \right]. \tag{46}$$

Given the equality between t_i and g_i, supplies of each good will be equal in each period.

From the definitions of the real interest rate [Equation (6)], the interest rate parity condition, and the definitions of real foreign interest rates [Equation (23)], it is easily verified that domestic real interest rates are tied to foreign real rates by the relationship

$$1 + r_a = \frac{(1 + r_a^*)\,(1 + g)}{(1 + g_1)}, \textit{ and}$$

$$1 + r_n = 1 + r_n^* . \tag{47}$$

Substituting Equation (47) into the hoarding function yields

$$h = h \left[\frac{(1 + g_1)}{(1 + r_a^*)\,(1 + g)} \right]. \tag{48}$$

Comparing (23) and (26) with the above equations shows that, if $g = t$ and $g_1 = t_1$, the values of real interest rates and hoarding in the tariff regime will be equal to those in the prevailing quota regime.

Having established the equivalence of the two supply-side regimes, it is easy to show that, if $g = t$ and $g_1 = t_1$, the consumer's intertemporal budget constraint is also invariant to the choice of tariffs versus quotas. Because quota revenue is collected in domestic currency, the individual's demand for domestic currency in each period is

$$m = p_a [a^s - h] + p_n n + gep_a^* (a - a^s + h), \text{ and} \tag{49}$$

$$m_1 = p_{a1} [a_1^s + h] + p_{n1} n_1 + g_1 e_1 p_{a1}^* (a_1 - a_1^S - h) . \tag{50}$$

Replace Equations (11) and (14)—the individual's demands for domestic currency under that tariff regime—with (49) and (50) and use Equations (12), (13), (15), and (16) to solve for the intertemporal budget constraint. The result is identical to (19). Because the tariff and quota revenues are equal, the solution to the consumer's optimization problem is identical to that of Equation (29).

The point is that the government can use its two instruments $[q, q_1]$ to achieve price gaps $[g, g_1]$. Thus, for any given tariff schedule $[t, t_1]$, the government can select $[q, q_1]$ to perfectly mimic the tariff regime. Moreover, the values for q and q_1 are equal to the import quantity prevailing under the tariff regime. Clearly, the equivalence works in both directions; a quota regime can be converted into an equivalent tariff regime by selecting tariff rates so that $t = g$ and $t_1 = g_1$.

It is incorrect, however, to assert that the tariff t_0 is equivalent to the price gap g_0 and that the tariff t_1 is equivalent to the price gap g_1. Rather, the tariff vector $[t, t_1]$ is equivalent to the price-gap vector $[g_0, g_1]$. To replace a quota regime with an equivalent tariff regime, it is not sufficient to select a tariff rate t_0 equal to the price gap g_0. Behavior in the initial period, for example, depends on the tariff rate (or price gap) in both periods. Replacing quotas (and other nontariff barriers) with equivalent tariffs must be conducted in an intertemporal context so $t_0 = g_0$ and $t_1 = g_1$. This seemingly innocuous observation is important to the U.S. tariffication proposal:

Selecting an import tariff that is equal to the price gap prevailing under the quota regime (i.e., the difference between the domestic price of the import good and the world price) is inappropriate unless future tariff rates are also specified. The time path (t, t_1) is equivalent to the time path (q_0, q_1); there is not a mapping between t and q_0 unless t_1 and q_1 are specified.

As an illustration, suppose that the price gap under a quota regime happens to be x percent in periods zero and one. Equivalent tariffication necessitates a tariff schedule so that $t = t_1 = x$ percent;

selecting $t = x$ percent and any other value for t_1 will not yield equivalence for either good in either period. Notice that in Equations (28) and (32), both t and t_1 appear in reduced form demand equations for goods a and n and in the hoarding function. Unless $t = t_1 = x$ percent, the net supply of good a ($a^s - h$) and the demands for goods a and n in period zero (even though $t = x$ percent) will not be equivalent to those prevailing under the quota regime.

Also suppose that under tariffication t is set at x percent and that the signatories to GATT agree to cut t_1 to something less than x percent. As seen from Equation (28), the demand for good a in period zero is an increasing function of t_1; the future cut in tariff rates induces individuals to reduce current purchases of a. More important, the future price decline induces a reduction in hoarding as the return from holding inventories of good a declines. The overall effect of reducing t_1 is an excess supply of good a in period zero. Thus, the value of t that maintains the equivalent volume of imports as prevailed under the quota is something less than x percent given that $t_1 < x$ percent.

Conclusion

In the context of a simple intertemporal optimizing model, it was shown how productivity shocks and external terms of trade shocks affect the domestic economy. The model was designed to be useful for policy analysis. It was shown that there is an equivalence between tariffs and quotas; however, policymakers must consider this equivalence within an intertemporal context. At the Uruguay Round of the GATT, the United States has advocated replacing all nontariff barriers with equivalent tariffs. The second stage of the proposal is to negotiate tariff reductions. This paper shows that it is inappropriate to use a two-stage procedure because current and future protection levels are necessarily linked.

The model has some other obvious applications and extensions. The small-country assumption could be relaxed by introducing a downward-sloping foreign demand function for the domestic export. Also, the model can easily be extended to consider a multiperiod world. Introducing uncertainty would provide a more realistic description of actual economies and would provide an interesting vehicle for considering the world's debt problem. In the model presented here, all debt obligations were undertaken with perfect foresight. Most interesting would be to add an element of price stickiness in the nonagricultural sector. Within this framework, it would be possible to analyze the effects of real and nominal shocks on the macroeconomy in general and on the agricultural sector in particular.

ENDNOTES

1. Combine Equations (1) through (4) to obtain $y_i = A_i f^a[p_i] + N_i f^n[p_i]$. Because production occurs where the domestic relative price of good n equals the slope of the production possibilities frontier, $p_i = d\, a_i^s / d\, n_i^s$. Equation (5) follows directly.

2. Expressed in real terms, the optimization problem is

$$\max_{\{h\}} \left[\frac{p_{a1}}{p_a} (1 + i) \right] h - h - s(h); \qquad s' > 0 \; s'' > 0.$$

3. Profits are given by $p_{a1}\, h/(1 + i) - p_a\, h - p_a\, s(h)$. At the value of h that satisfies the first-order condition (h^*), the storage facility will close if profits are negative. Thus, the critical value of r_a is defined so that $1/(1 + r_a) = 1 + s(h^*)/h^*$. Because $s > 0$, it follows that a necessary condition for storage is $r_a < 0$.

4. A dollar invested domestically yields $(1 + i)$ dollars in the subsequent period. The alternative is to purchase $1/e$ units of foreign exchange and invest abroad at the rate i^*; in the subsequent period, the $(1 + i^*)/e$ units of foreign exchange can be exchanged for $(1 + i^*)e_1/e$ units of domestic currency. The absence of risk and any arbitrage costs necessitates that these returns be equal.

5. This result is in direct contrast to that of a quota regime in which domestic markets determine domestic relative prices; the quota regime makes the domestic market more integrated because internal shocks are transmitted across sectors but insulates the economy from foreign shocks. Also, in the large-country case (in which domestic production influences world prices), domestication in either sector influences world prices and output of all sectors.

6. There is no simple relationship between ϵ_n and ϵ_a because individuals may increase or decrease total current period expenditure levels in response to a change in p^*. Moreover, as

opposed to the Marshall-Lerner condition, simultaneously increasing the elasticities of demand for imports and exports has an ambiguous effect on the trade balance.

7. Using this notation, increasing q_i increases the quantity of imports allowed into the nation; raising q_i is a relaxation of trade restrictions.

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