# INTERNATIONAL TRADE

# WORKSHOP



## ANNOUNCEMENT AND IMPLEMENTATION EFFECTS OF AGRICULTURAL POLICIES: AN EXAMPLE OF TRADE LIBERALIZATION

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Announcement and Implementation Effects of Agricultural Policies:
An Example of Trade Liberalization

by

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## Abstract

This paper demonstrates the policy announcement and implementation effects of direct intervention in agricultural markets. As a corollary, the policy implications of assuming inventories are constant or adjust with a lag are shown.


In the agricultural economics literature to date there has been much theoretical and empirical work on the announcement and implementation effects of macro policies on agricultural markets. Bond (1984), Chambers (1985) and Frankel (1984, 1986) have demonstrated that agricultural markets may be sensitive to the announcement and implementation of macro policies via the interest rate in a closed economy setting. This has been verified by Barnhart (1989) and Frankel and Hardouvelis (1988). Chambers (1984), Chambers and Just (1981) and Batten and Belongia (1986) all consider the effects of macro policies on agricultural markets through the exchange rate in an open economy setting. While macro-policy announcement and implementation effects are important, it would seem that a market would respond more to the announcement and implementation of a direct market intervention than to the announcement and implementation of a macro policy. This paper therefore concentrates on the announcement and implementation effects of a direct market intervention.

There are many examples in which direct intervention in agricultural markets is announced prior to implementation. For example, it is common practice for GATT settlements to be announced and then implemented over several years. Other examples include the U.S. Farm Bill and bilateral trade agreements between countries such as the U.S. and Canada. This paper concentrates on this type of direct policy intervention for two reasons. First, as mentioned, it seems reasonable that direct market intervention policies would have a larger impact on commodity markets than macro policies and therefore, understanding the market's response both before and after the policy is implemented is important for the policy analyst. Second, though in some cases the results are intuitively obvious, there is no place to this author's knowledge where this intuition about agricultural policy announcement and implementation effects has been analyzed theoretically.

This paper will show that an intervention policy announcement will affect the price of a good with a distributed lead and the implementation will affect the price with a distributed lag. As the price of the good changes, changes in the quantity supplied and demanded of the good in question and in related goods will occur.

## Model Development

In order to demonstrate succinctly the announcement and implementation effects of a market intervention policy on the trade and domestic aspects of an agricultural market, a hybrid model is developed by coupling a version of Muth's (1961) model with a differentiated product trade model (Armington 1969, Johnson, et. al. 1979). Though this hybrid model greatly simplifies the complex dynamics of an internationally traded commodity, it is developed for two reasons. First, the model is more efficient than elaborate models in isolating the dynamic effects of a policy announcement and implementation. Second, as a corollary, the model exploits the separate advantages of the popular Muth and differentiated product models. The advantage of the Muth model is that it explicitly captures the dynamics of future policy expectations, but it does not consider the interaction effect of these dynamics across substitute goods. The advantage of the differentiated product model is that it captures the interaction effects across substitutes goods, but it is limited in its dynamic capabilities by either assuming inventories are constant (yielding static results) or assuming inventories are determined solely by predetermined variables (capturing only policy implementation effects). The hybrid model used here however captures all of these effects: static (constant inventories), dynamic (announced and implemented), and interactions across substitute goods. To convey the theme of the paper, some policy change must be chosen to analyze. Because trade liberalization is presently a germane policy consideration, a tariff reduction is considered.

## The Model

As a vivid example consider three countries: Portugal, France and the United States (U.S.). Assume Portugal represents a small country which produces and consumes Portuguese corn, does not export corn, and imports corn from France and the U.S. To further highlight the importance of policy expectations on trade flows, assume -as is true- that Portugal and France are members of a customs union but the U.S. is not and therefore the U.S. faces a barrier to trade with Portugal. Let the trade barrier be a specific tariff ($T_b$) on the imports of corn from the U.S. and the trade liberalization rule be a reduction of that tariff to $T_a$ after period s. Finally, assume Portugal



only holds inventories of Portuguese corn and the corn market is perfectly competitive. The Portuguese corn market can then be characterized by the following linear system.

(1) $Q^D_{pt} = a_1P_{ft} + a_2P_{ut} + a_2T_t + a_3P_{pt} + a_4Z_t$ : Demand for Portuguese corn

(2) $Q^S_{pt} = b_1P_{pt}$ : Production Supply of Portuguese corn

(3) $I_{pt} = \rho_0 + \rho_1(P^e_{pt+1} - P_{pt})$ : Portuguese Inventory Speculation

(4) $Q^D_{pt} + I_{pt} = Q^S_{pt} + I_{pt-1}$ : Market Clearing

(5) $M_{ft} = c_1P_{ft} + c_2P_{ut} + c_2T_t + c_3P_{pt} + c_4Z_t$ : Import Demand for French corn

(6) $M_{ut} = d_1P_{ft} + d_2P_{ut} + d_2T_t + d_3P_{pt} + d_4Z_t$ : Import Demand for U.S. corn

(7) $T_t = T_b \quad s > t$ : Policy Rule

$\quad\; = T_a \quad s \le t$

where alphabetic subscripts indicate the country of origin: p = Portugal, f = France, u = U.S.,

and

$T_t$ = per unit tariff on U.S. corn in time t and $T_b$ is the tariff before the implementation date and $T_a$ is the tariff after the implementation date, $T_b > T_a$,

$P_{it}$ = real price of good i = p, f, u, in time t,

$P^e_{pt+1}$ = conditional expectation at time t of $P_p$ at time t + 1,

$Z_t$ = demand shifter in time t,

$a_3$, $c_1$, $d_2 < 0$ and all other coefficients are positive.

Equations (1) - (4) are attributable to Muth (1961). Equations (1), (5) and (6) show the importance of the differentiated products assumption since each demand contains own and cross price terms. Also note the coefficient on the tariff, $T_t$, is the same as the coefficient on $P_{ut}$ in each equation. This reflects the assumption that the trade barrier is a per unit tariff on U.S. corn imports. Equation (3) is the inventory speculation equation and is derived by Muth (1961). Black (1972) shows that this formulation also incorporates futures trading. The constant term $\rho_0$ is designed to represent precautionary holdings and thus stocks are always assumed positive. Equation (4) is the market clearing identity for Portuguese corn since it is assumed there are no exports, corn is differentiated by source and Portugal only holds stocks of Portuguese corn. Notice by equation (4) that under the assumption of constant inventories or no inventories the same static model will result. Equation (7) represents the trade liberalization rule whereby the tariff reduction is announced at period t=0 but the tariff is actually reduced at period **s**. Because of the structure of this model, all left hand side variables along with $P_{pt}$ are endogenous while all other variables are exogenous. The exogeneity of $P_{ft}$ and $P_{ut}$ is due to the small country assumption.

The solution to this model depends on a price expectations solution which is forward looking. Given forward looking behavior is probable for profitable speculative firms, a rational expectations assumption is employed. Since the objective of the model is to isolate the effects of a policy that is announced to be implemented with certainty at time **s**, all exogenous variables except $T_t$ may be assumed constant. This assumption, along with rational expectations, simplifies the model to one of perfect foresight and thus $P^e_{pt+1}$ in equation (3) becomes $P_{pt+1}$. This procedure has been used by many (e.g. Ambler 1989, Fischer 1979 and Wilson 1979).

In order to get the final form price and quantity equations, first use equations (1) through (3) in (4) to obtain:



(8) $$(a_3-b_1-\rho_1)\,P_{pt} = a_1\,P_{ft} - a_2\,P_{ut} - a_2\,T_t - a_4\,Z_t - \rho_1\,P_{pt-1} - \rho_1\,(P_{pt+1} - P_{pt})$$

Notice equation (8) has implemented the perfect foresight characteristic of the model and can be rewritten in a more condensed form using the lag operator and matrix notation as,

(9) $$P_{pt}\,(1 - \theta L + L^2) = -\,[\mathbf{K}\,\mathbf{x}_{t-1} + k_2\,T_{t-1}],$$

where $\theta = (b_1-a_3+2\rho_1)\,\rho_1^{-1}$,

$L$ = the lag operator, $LW_t=W_{t-1}$ $\quad L^{-1}W_t=W_{t+1}$,

$\mathbf{K} = \rho_1^{-1}\,\mathbf{A} = [k_1, k_2, k_3]$

$\mathbf{A} = [a_1, a_2, a_4]$,

$\mathbf{x}_t = [P_{ft}, P_{ut}, Z_t]'$.

The procedure used for solving (9) is outlined in the mathematical appendix 1.

Focusing on the effects of the announcement and implementation of the new tariff rate on all endogenous variables, assume that $\mathbf{x}_{t+j} = \mathbf{X}$ for all $j \in (-\infty, \infty)$. This simply states that all of the exogenous variables ($P_{ft}$, $P_{ut}$, $Z_t$), except the tariff, are constant for all t. Employing this assumption along with the policy rule (7), the solution to (9) is:

(10)
$$P_{pt} = \frac{\mathbf{AX} + a_2T_b}{(b_1-a_3)} - \frac{a_2\Delta T\,\lambda_1^{s-t}}{\rho_1(\lambda_1-\lambda_2)(1-\lambda_1)} \qquad \text{for all } s \geq t$$

$$P_{pt} = \frac{\mathbf{AX} + a_2T_a}{(b_1-a_3)} + \frac{a_2\Delta T\,\lambda_1^{t-s+1}}{\rho_1(\lambda_1-\lambda_2)(1-\lambda_1)} \qquad \text{for all } s \leq t$$

where $\Delta T = (T_a - T_b) < 0$, $\lambda_1$ and $\lambda_2$ are the roots of the difference equation (9), and

$\rho_1(\lambda_1-\lambda_2)(1-\lambda_1) < 0.$

Equations (10) are represented in Figure 1, along with the static model results. $P_{pb}$ represents the first term in the first equation in (10) which is the static price of Portuguese corn before the policy is implemented. $P_{po}$ represents the dynamic price value evaluated at t=0. The difference in $P_{pb}$ and $P_{po}$ is the negative announcement adjustment term in the first equation of (10). $P_{pa}$ is the static price value after the tariff is reduced and is the first term in the second equation in (10). Figure 2 shows inventory sales or depletions over time and is derived from the inventory equations in the mathematical appendix 2.

Figures 1 and 2 are intimately related and are the catalyst for the remainder of the model, thus some discussion is warranted. Recall that the term $\rho_0$ in Figure 2 represents precautionary inventory demand of Portuguese corn for all periods. At any given time the speculator's decision is how much of this precautionary inventory demand to sell and keep. For any time period t Figure 2 then represents the quantity of precautionary inventories sold and kept. The quantity sold is represented by the difference between the ray $\rho_0$CE and the arcs $\rho_0$D and DE. The amount of precautionary inventory demand that is kept is the difference between the arcs $\rho_0$D, DE and the horizontal axis. Notice that for the announcement period $t \leq s$, sales (depletions) increase at an increasing rate and reach a maximum (minimum) at C - D (D - zero). For the post implementation period $t \geq s$, sales (depletions) decrease at an decreasing rate until the original precautionary inventory demand level is reached. Because sales (depletions) take this form, then the price of Portuguese corn falls concavely during the announcement period $(t \leq s)$ and falls convexly during the post-implementation period $(t \geq s)$, as is shown in Figure 1. Therefore, as is commonly known, inventories act to smooth out price changes in this type of model and, by definition, the static model misses this whole adjustment process.

There are some interesting policy implications associated with Figure 1 and represented by equation (10). First, note as the implementation date (s) goes into the future then the dynamic



price of $P_{po} \rightarrow P_{pb}$. This means that a policy announced to occur far in the future will have a smaller impact on the price the day of the announcement than if the policy were announced at a later date. To see this, let s - k be the period when the tariff reduction date is announced. Until point s - k price is expected to be $P_{pb}$, but when the tariff reduction is announced at s-k the price will drop immediately to point A on the dynamic price path and then decline as though the policy implementation date were announced at period k=0. If the policy is not announced until s=k, then the price will drop to B: the largest amount possible in the announcement period $t \leq s$. The price will not drop to $P_{pa}$ under this scenario but approaches its new longrun equilibrium value $(P_{pa})$ asymptotically due to the price smoothing properties of inventories.

The overall message of equations (10) and Figure 1 is that policy announcements can be used to exploit the price smoothing properties of inventories so that large price deviations may be avoided. To minimize the price deviations due to policy announcements, it is best for the policy maker to announce the policy implementation date well in advance.

## Quantity Paths

Since the price of Portuguese corn adjusts over time this implies that all endogenous quantities will also adjust over time. The final form quantity equations for $x_{t+j} = X$ can be obtained by substituting appropriately (10) into equations (1) through (6) and these are given in the mathematical appendix 2. Since the path of inventories over time has already been discussed and the path of production supply over time is proportional to that of price (i.e. $b_1 > 0$), then attention is turned towards the demand quantities: $Q^D_{pt}$, $M_{ft}$ and $M_{ut}$. These are shown in Figures 3, 4 and 5, respectively. The importance of accounting for the announcement effects are more obvious in Figures 3 and 5 and therefore discussion is limited to these quantities, with the quantity of French corn following similar logic. The key to understanding these diagrams is to note each demand equation includes cross price terms and the tariff rate.

Figure 3 shows the static quantity level of Portuguese corn before the policy is implemented

($Q_{pb}$) and after it is implemented ($Q_{pa}$). The dynamic quantity level at t=0 is $Q_{p1}$. As was stated, the announcement of the policy implementation date prior to implementation causes the Portuguese corn price to decrease. This in turn causes a movement downward along the demand curve for Portuguese corn and the quantity demanded for Portuguese corn reaches a maximum at $Q_{p2}$. When the policy is implemented (t=s), there is a reduction in the tariff rate on U.S. corn and since U.S. corn is a substitute for Portuguese corn, then the demand curve for Portuguese corn shifts to the left at t=s causing the quantity demanded of Portuguese corn to decrease to $Q_{po}$. But since the Portuguese corn price continues to decrease after the policy has been implemented (t>s), the quantity demanded of Portuguese corn begins to increase asymptotically towards $Q_{pa}$ during t>s.

The economic logic for the quantity path of U.S. corn imports (Figure 5) is similar. The static quantity demanded of U.S. corn before the policy is implemented is $M_{ub}$. The dynamic quantity level at t=0 is $M_{u1}$. As the price of Portuguese corn decreases due to the announcement effect, the import demand curve for U.S. corn shifts to the left and quantity demanded of U.S. corn decreases until it reaches $M_{uo}$. The U.S. price ($P_{ut} + T_b$) is constant during this time. At t=s, the tariff reduction occurs and the price of U.S. corn decreases to ($P_{ut} + T_a$) which causes a movement down along the demand curve for U.S. corn and therefore the quantity demanded of U.S. corn increases to $M_{u2}$. As the price of Portuguese corn continues to decrease during the post-implementation period (t>s) then the demand curve for U.S. corn continues to shift to the left until the lower steady state quantity demanded level $M_{ua}$ is reached.

Two points should be clear from these figures. First, relying on the predictions based on a model without inventories (the static theory) leads to counterintuitive results in the short run if inventories are important. This is especially true with regard to the quantities demanded of Portuguese and U.S. corn. In both of these cases, the model with inventories shows directional changes in the quantity variables that are at odds with the final directional change of the static model in the pre and post-implementation stages. Thus assuming inventories are constant over time (the static model) will yield directional change short run results that are incorrect if inventories are in fact not constant.



Second, the timing of the announcement will also influence the quantities since it affects the price path. That is, if the price path possess a substantial discrete jump due to a policy announced at period say **s - k**, then this will result in the quantity variables possessing discrete jumps from their static values to their announcement quantity paths at period **s - k**, ceteris paribus. For this reason it is tempting to conclude that the policy maker will not only minimize price deviations at the time the policy is implemented but will also minimize quantity deviations at this time by announcing the policy implementation date well in advance. While tempting, this conclusion is only partially correct.

The correct part of this conclusion would apply to production of Portuguese corn and imports of French corn (Figure 4), since each of these follow paths similar to that of the Portuguese price. So in order to minimize the deviation in Portuguese corn production and the deviation in imports of French corn it is best to announce the implementation date in advance. Now consider again Figures 3 and 5. For all **k < s** it is true that a policy announcement well in advance of its implementation date would cause a smaller quantity deviation when compared with a policy announcement at period **k** + 1, but this temporary gain is misleading when the entire adjustment path is considered. To see this look at Figure 3. Notice the distance between the initial steady state value $Q_{pb}$ and the implementation value $Q_{po}$ is smaller than the distance between the dynamic quantity value $Q_{p2}$ and the implementation value $Q_{po}$. Similar results hold for Figure 5. This implies that in order to minimize the deviation in the Portuguese corn consumption and imports of U.S. corn over their entire path, it is better not to announce the policy prior to its implementation!

What do these results mean for the policy maker? These results mean that the policy maker faces a tradeoff when considering the optimal time to announce the policy implementation date. This tradeoff is between price deviations and some quantity deviations. If the policy maker in this model is committed to announcing the implementation date in advance, he can minimize the price deviation of Portuguese corn, the quantity deviation in Portuguese corn production and the quantity deviation in imports of French corn by announcing the policy implementation date as soon as possible. However, by committing to announce the implementation date in advance he forfeits the opportunity to minimize the quantity deviations in Portuguese corn consumption and imports of U.S. corn. On the other hand, if the policy maker does not announce the policy until the day it is implemented, he will minimize the quantity deviations in Portuguese corn consumption and imports of U.S. corn but will forfeit the ability to minimize the price deviation of Portuguese corn, the quantity deviation in Portuguese corn production and the quantity deviation in imports of French corn. In net, the optimal rule is clear: announce soon to minimize price and production deviations, do not announce at all to minimize consumption deviations.

## Summary and Generalizations

This paper has demonstrated in a partial equilibrium framework that policy announcement and implementation effects in agricultural markets will occur due to direct policy intervention in addition to the macro policy channels that have been studied to date in the agricultural economics literature. This result was generated by integrating Muth's (1961) model with a differentiated product trade model and using a trade liberalizing rule as the policy intervention. This hybrid model generated two results: First, it showed that if a trade liberalizing policy were announced at $t=0$ to occur at period $s>0$, then all variables, prices and quantities, would change both before and after $s$. This result was driven by a speculative inventory equation based on a rational expectations solution which is forward looking. By including forward looking inventory behavior, the model demonstrated that some variables move counter to the direction of the static results before and after the policy is implemented but asymptotically converge to the static results. Showing these results are important for the policy analyst who may reach the wrong short run conclusions by assuming inventories are unimportant (i.e. the dynamics dampen quickly, Samuelson p. 331) when in fact they could be.

Second, the model demonstrated that, in net, with only one policy instrument the policy maker cannot minimize both price and quantity changes with the announcement date of a policy implementation date. It was shown, again in net, that an early announcement of the policy implementation date minimized price and production deviations and no announcement minimizes consumption deviations.



As with any model, it is necessary to make assumptions that simplify reality and therefore subject the model to criticism. While there are many dimensions in which the model used here could be expanded (e.g. more commodities or more countries), there are three that immediately seem worthy of comment. The small country assumption proved useful in that feedback effects into the price of French or U.S. corn were zero. Relaxing this assumption seems desirable for demonstrating how the effects studied here are transmitted internationally (i.e. to France or the U.S.) but the qualitative effects in the policy implementing country (Portugal) seem unaffected under normal multimarket stability conditions, except for a possible dampening of the effects found here. The other assumption which may seem overly restrictive is that each country holds only inventories of its own commodity. A more general theory which considers forward looking speculators in all corn markets in Portugal would have to distinguish then between domestic demand for foreign corn and import demand for foreign corn. While it would be true that domestic demand for foreign corn would increase prior to the policy being implemented as Portugal speculators released foreign corn stocks onto the market, it would also be true that forward looking importers would realize that foreign corn would be cheaper after implementation and therefore postpone some immediate consumption as is shown here. Finally, the model contains no uncertainty and in reality expectations are formed about announcement dates as information leaks onto the market. Though this would make the model more realistic it would also make the model more complicated and the benefits of this additional realism are not immediately obvious.

Thus while other more elaborate models may capture more intricate dynamics, the model developed here seems an appropriate starting point for more detailed analysis of announcement and implementation effects of agricultural policies.

Figure 1
Price of Portuguese Corn

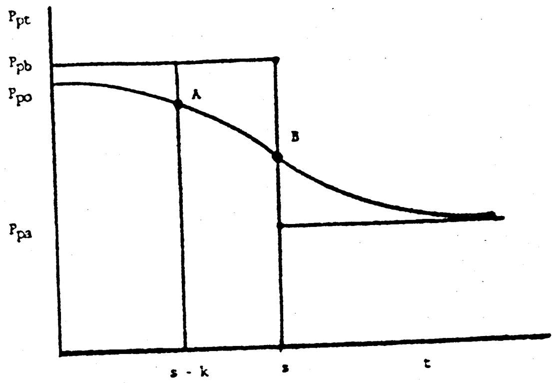
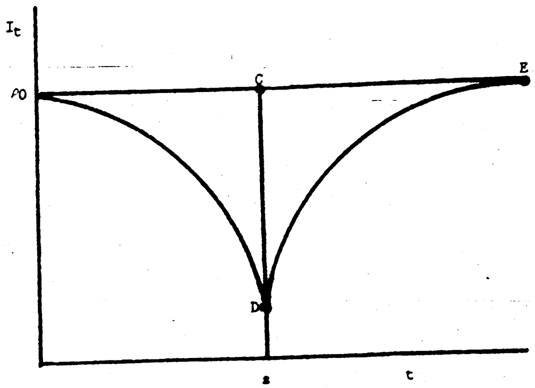



Figure 2.

Inventories of Portuguese Corn




Demand for Portuguese Corn

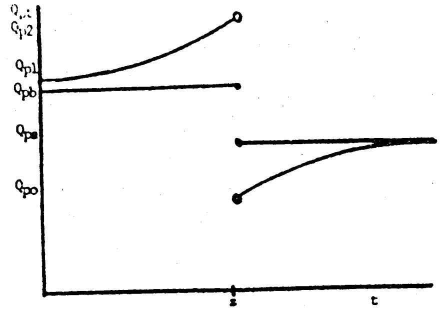



Figure 4.
Import Demand for French Corn

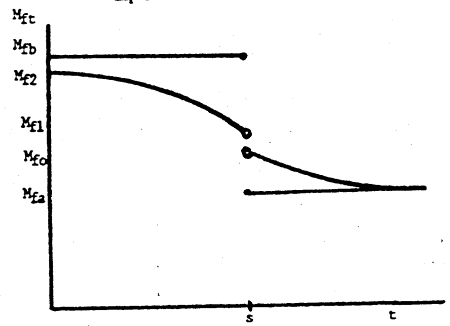
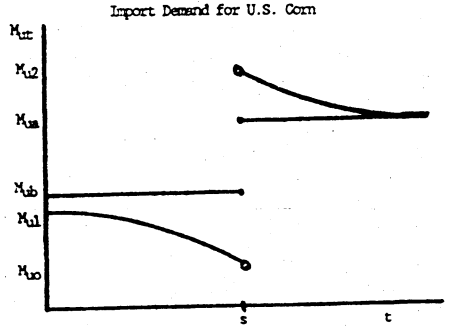



Figure 5.

Import Demand for U.S. Corn



## MATHEMATICAL APPENDIX 1:

Following Sargent Chpt.IX, pages 178 and 184, equation (9) may be solved by noting,

(a) $(1 - \theta L + L^2) = (1 - \lambda_1 L)(1 - \lambda_2 L)$

implies $\lambda_1 + \lambda_2 = \theta$

$\lambda_1 \lambda_2 = 1.$

Thus the roots, $\lambda_1$ and $\lambda_2$, are reciprocal pairs which in this case states one root is inside the unit circle and the other root outside. Assume $\lambda_1 \epsilon (0,1)$ and note

$$(1 - \lambda_2 L)^{-1} = -(1 - \lambda_2^{-1} L^{-1})^{-1} \lambda_2^{-1} L^{-1}$$

Using the fact that $\lambda_2^{-1} = \lambda_1$ from (a) implies,

(b) $(1 - \lambda_2 L)^{-1} = -(1 - \lambda_1 L^{-1})^{-1} \lambda_1 L^{-1}.$

Also note

$$\frac{1}{(1-\lambda_1 L)(1-\lambda_2 L)} = \frac{1}{(\lambda_1 - \lambda_2)} \left[ \frac{\lambda_1}{1-\lambda_1 L} - \frac{\lambda_2}{1-\lambda_2 L} \right]$$

and again using (a) and (b) gives,

(c)
$$\frac{1}{(1-\lambda_1 L)(1-\lambda_2 L)} = \frac{1}{(\lambda_1 - \lambda_2)} \left[ \frac{\lambda_1}{1-\lambda_1 L} + \frac{L^{-1}}{1-\lambda_1 L^{-1}} \right]$$

$$= \frac{1}{(\lambda_1 - \lambda_2)} \left[ \lambda_1 \sum_{j=0}^{\infty} \lambda_1^j L^j + L^{-1} \sum_{j=0}^{\infty} \lambda_1^j L^{-j} \right]$$

Using this result (c) in (9), $x_t = X$ and some algebra gives equation (10).

## MATHEMATICAL APPENDIX 2:

FINAL FORM QUANTITY EQUATIONS:

Supply of Portuguese corn:

$$Q^S_{pt} = \frac{b_1(AX + a_2 T_b)}{(b_1 - a_3)} - \frac{b_1 a_2 \Delta T \ \lambda_1^{s-t}}{\rho_1(\lambda_1 - \lambda_2)(1-\lambda_1)} \qquad \text{for all } s \geq t$$

$$Q^S_{pt} = \frac{b_1(AX + a_2 T_a)}{(b_1 - a_3)} + \frac{b_1 a_2 \Delta T \ \lambda_1^{t-s+1}}{\rho_1(\lambda_1 - \lambda_2)(1-\lambda_1)} \qquad \text{for all } s \leq t$$

Demand for Portuguese corn:

$$Q^D_{pt} = \frac{b_1(AX + a_2 T_b)}{(b_1 - a_3)} - \frac{a_3 a_2 \Delta T \ \lambda_1^{s-t}}{\rho_1(\lambda_1 - \lambda_2)(1-\lambda_1)} \qquad \text{for all } s > t$$

$$Q^D_{pt} = \frac{b_1(AX + a_2 T_a)}{(b_1 - a_3)} + \frac{a_3 a_2 \Delta T \ \lambda_1^{t-s+1}}{\rho_1(\lambda_1 - \lambda_2)(1-\lambda_1)} \qquad \text{for all } s \leq t$$

Import Demand for French corn:

$$M_{ft} = \frac{[(b_1 - a_3)C + c_3 A] \ X + [(b_1 - a_3)c_2 - c_3 a_2] T_b}{(b_1 - a_3)}$$

$$- \frac{c_3 a_2 \Delta T \ \lambda_1^{s-t}}{\rho_1(\lambda_1 - \lambda_2)(1-\lambda_1)} \qquad \text{for all } s > t$$

$$M_{ft} = \frac{[(b_1-a_3)C + c_3A]\,\mathbf{X} + [(b_1-a_3)c_2 - c_3a_2]T_a}{(b_1 - a_3)}$$

$$+ \frac{c_3a_2\Delta T\ \lambda_1^{t-s+1}}{\rho_1(\lambda_1-\lambda_2)(1-\lambda_1)} \qquad \text{for all } s \leq t$$

where $C = [c_1, c_2, c_4]$.

Import Demand for U.S. corn:

$$M_{ut} = \frac{[(b_1-a_3)D + d_3A]\,\mathbf{X} + [(b_1-a_3)d_2 - d_3a_2]T_b}{(b_1 - a_3)}$$

$$- \frac{d_3a_2\Delta T\ \lambda_1^{s-t}}{\rho_1(\lambda_1-\lambda_2)(1-\lambda_1)} \qquad \text{for all } s > t$$

$$M_{ut} = \frac{[(b_1-a_3)D + d_3A]\,\mathbf{X} + [(b_1-a_3)d_2 - d_3a_2]T_a}{(b_1 - a_3)}$$

$$+ \frac{d_3a_2\Delta T\ \lambda_1^{t-s+1}}{\rho_1(\lambda_1-\lambda_2)(1-\lambda_1)} \qquad \text{for all } s \leq t$$

where $D = [d_1, d_2, d_4]$.



Inventories of Portuguese corn:

$$I_{pt} = \rho_0 + \frac{a_2\Delta T\lambda_1^{s-t}(1-\lambda_2)}{(\lambda_1-\lambda_2)(1-\lambda_1)} \qquad \text{for all } s > t$$

$$I_{pt} = \rho_0 + \frac{a_2\Delta T\lambda_1^{t-s+1}(\lambda_1-1)}{(\lambda_1-\lambda_2)(1-\lambda_1)} \qquad \text{for all } s < t + 1$$