Tomatoes

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A Model of the U.S. Fresh Tomato Industry and the Mexican Influence

by

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I. Introduction[1/]

The tomato (Lycopersicon esculentum) is a member of the nightshade family, and is a native of the United States' southern neighbors in tropical America. The tomato had reportedly taken a circular route to introduction into the United States, first having traveled from Peru to Italy, then from Italy to Northern Europe, and then finally from Europe to the United States in 1781. By 1835 the tomato was widely cultivated for culinary purposes in the U.S. In the late 1960's and in the 1970's, there has been increasing concern by United States producers that the tomato is completing its circular journey by leaving the United States and heading south for the winter (and early spring). The Mexican share of the United States' Market for fresh winter and early spring tomatoes has recently climbed to greater than 50%, compared to 30-35% in the early 1960's. The increase in market share was attained at the expense of Florida producers, who are the only commercially significant domestic suppliers of fresh winter and early spring tomatoes.

Import duties are in effect throughout the year in the United States with the intent to protect domestic producers of tomatoes from excessive foreign competition. The tariff has varied seasonally, the highest rate occuring in March through July 14 (2.1¢/lb.), with a lower rate applying at other times (1.5¢/lb.).[2/] The general consensus is

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[1/]Much of the discussion concerning the role of Mexico in the U.S. Tomato Market was distilled from Fliginger, et. al.; Simmons, et. al; and Goldberg. The origin and historical points of interest concerning the tomato were taken from Ware and McCollum.

[2/]Tariff Schedules of the United States, U.S. Tariff Commission, various issues.

that the tariffs provide considerable protection for U.S. producers, and that elimination of tariffs would cause a substantial reduction in domestic production and a concomitant signficant rise in imports. The Agricultural Act of 1956 provides the authorization for establishing quotas on imports when economic conditions are judged to warrant such restrictions. No quotas have ever been instituted regarding tomato imports.

The purpose of this paper is to quantitatively examine the Mexican influence on the U.S. tomato industry using an econometric simulation model of the industry. The tomato model used is part of a larger U.S.D.A. study to develop quarterly market models for a selected set of fresh salad vegetables. The model is a first generation model that is to be further refined along the lines suggested in the final section of this paper. The specific simulations involve manipulations of the tariff schedules and the use of import quotas to form various scenarios for the 1960-1978 period. The effects of the various scenarios on prices and quantities in the tomato market are examined, and the Mexican influence on the market is assessed in light of the simulation results.

A secondary objective of the study is methodological. The use of mixed estimation with uniformly distributed stochastic prior constraints on parameters was utilized for the first time in this analysis. The utility of the uniform distribution in this context and the interpretation of the mixed estimator are briefly examined.

II. Elements of Industry Structure

In this section, a brief description of some salient characteristics of the U.S. production base, the Mexican supply for export, the supply and demand situation in Canada, and the method of price determination in the tomato industry is presented. Some additional details of direct relevance to model specification are presented in the next section.

U.S. Production Base

Tomato production occurs in the United States during all quarters of the year.[3] Domestic production is most geographically dispersed in the summer, with commercially significant production occurring in over twenty states. The dominant producer in the summer is California, typically supplying 40-50% of the summer tonnage. During the 1970's, generally 40% or more of the total annual domestic production of tomatoes occurred during the summer months.

Domestic production becomes more geographically concentrated in the spring and fall. In the fall, California and Florida are the dominant producers. The two states accounted for virtually all of the fresh fall tomato production during the 1970's, with roughly 50% of the tonnage attributable to each state. Slightly over 20% of total annual domestic tomato production occurred in the fall.

Florida is the dominant domestic producer of fresh tomatoes in the winter and spring. Roughly 60% of the spring production is accounted for by Florida, with South Carolina, California, and Texas accounting for the majority of the remaining production. Slightly less than 25% of total annual domestic tomato production occurred in the spring during the 1970's. Florida is the only commercially significant domestic producer of fresh winter tomatoes.

3/ In referring to quarters of the year, standard U.S.D.A. definitions were used, namely winter = January-March, Spring = April-June, summer = July-September, and fall = October-December.

Annual production has been at or around the 20 million cwt level during the 1970's. Annual production for 1979 was 22.4 million cwt.

Mexican Supply for Export and CAADES

Mexico has been producing winter vegetables for export (primarily tomatoes, bell peppers, cucumbers, and eggplant) since the 1930's. However, it was not until the 1950's that production was developed on a large scale. Rapid expansion of production occurred during the 1950's and 1960's due in large part to heavy investment by the Mexican government in irrigation facilities in the states of Sonora and Sinaloa (the states lie south of Nogales, Arizona, the major point of U.S. entry for Mexcian produce). In addition, the west coast highway was completed and the railway connecting Culiacan, Sinaloa with Nogales was improved. It is perhaps ironic that the development of the vegetables industry on the west coast of Mexico was also significantly fostered by production credit obtained from U.S. sources. Production credit from Mexican sources was limited and available only at rather high interest rates. Mexican growers obtained credit by affiliating with producer-handlers and brokers in the United States, who were repaid at the time the produce was sold.

During the last twenty years, the Mexican producers have reportedly acquired the highest technology in vegetable crop production as evidenced by their increasing usage of fertilizers, insecticides, and modern machinery (Fliginger, et. al., and Simmons, et. al.). The growers have also developed a high degree of sophistication in the marketing of tomatoes, with production, packing, and selling being a closely integrated operation.

Beginning with the winter crop of 1960, the Mexicans have adhered to a planned supply program. A marketing board in association with CAADES (Confederation of Agricultural Associations of the State of Sinaloa) develop goals in terms of acreage and expected production for the entire tomato industry in Mexico. Goals are established after examining production capabilities in Mexico, and the expected supply-demand situations in the United States, Canada, and the domestic markets. Maximum acreages for each producer are specified, with acreage controls enforceable under the penalty of law. The level of exports through Nogales are closely monitored, and the level is restricted whenever the price falls below "acceptable levels" that have been determined and approved by a general assembly of vegetable growers affiliated with CAADES.

The levels of fresh tomato exports to the United States by Mexico has increased dramatically in the last twenty years, from 2.5 million hundredweight in 1960 to over 7 million hundredweight in 1979. The large majority of Mexican exports to the U.S. occur in the winter and spring quarters, accounting for approximately 88% of exports to the U.S. in 1979.

Canada's Role in the Industry

As in the United States, tomatoes are consumed in Canada year round. On the other hand, commerically significant production occurs in Canada only during the summer quarter. (During the 1970's, production has been at an average level of .7 million hundredweight.) Thus, Canadian demand is satisfied by imports from the U.S. and Mexico in winter, spring and fall, and satisfied by domestic production and imports in the summer.

A Canadian tariff on tomato imports is in effect in and around the period of domestic harvest.[4/] The tariff has been 1.5¢ (Canadian) per pound, or 10% advalorum, whichever is greater. There is generally no tariff applied in the winter or spring quarters.

Price Determination

Prices in the fresh tomato industry appear to be determined competitively through the forces of supply and demand (Simmons, et. al.). Vegetable buyers will attempt to purchase a given quality of produce at the lowest delivered price. The buyers are for the most part indifferent regarding the source of supplies for a given quality of tomato. Prices vary in the market place depending on the quantity delivered and the quantity expected to be sold.

The price received by domestic producers is equal to the market price minus transportation and marketing costs. The price received by foreign producers additionally depends on the relevant exchange rates and tariff.

Prices are influenced somewhat by the effect of the Federal marketing order regulating Florida tomato handlers. The order provides grade, size and maturity specifications that limit the handling of tomatoes and can affect supplies available for market. In addition, the aforementioned supply control strategies of the Mexican growers may significantly affect market price in the winter and spring quarters.

III. Model Structure an Estimation

In this section, the specific structure of the simulation model used to analyze the U.S. Tomato Industry is discussed. Estimation

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[4/] The exact dates of application can vary from year to year. Application has generally occurred in the summer and fall quarters.

results for the behavioral equations are presented and discussed. The discussion begins with a general overview of the model structure.

Structural Overview

The U.S.-Canadian market for fresh tomatoes is approximated by a simplified set of six behavioral equations and four identities. Market outcomes are modeled on a quarterly basis for the four quarters of the year, and all time subscripts henceforth refer to quarters unless it is specifically stated otherwise. Behavioral equations are estimated for acres planted, acres harvested, yield, U.S. domestic per capita demand, Canadian domestic per capita demand, and Mexican export supply. Identities are used to define U.S. production, and equilibrium of quantity flows in the U.S.-Canadian market, as well as to convert per capita domestic quantities demanded in the U.S. and Canada to aggregate demands.

It should be noted that the U.S.-Canadian tomato market is considered closed in the sense that supplies produced in the U.S. and Canada, and exports to the U.S.-Canadian market by Mexico are totally consumed within the U.S. and Canada. This is a simplification in two respects. First of all, some exports to the U.S.-Canadian market originate in countries other than Mexico (from the Caribbean). For the purposes of this study, all are considered originating in Mexico as a practical matter, since the Mexican origin accounts for greater than 95% of the exports. Secondly, a minor amount of exports by the U.S. are shipped to Europe. However, 98% of the exports have generally been to Canada, and as a practical matter the minor destinations are ignored in the model.

Figure 1 illustrates the simplified structure and logic of the tomato industry model. Arrows indicate causality, and thus if an arrow is pointed away from a particular variable, that variable is considered predetermined or exogenous in the model. Groups of variables connected by straight lines are considered simultaneously determined. Exogenous variables that act as shifters in behavioral equations are omitted from Figure 1.

U.S. Domestic Production

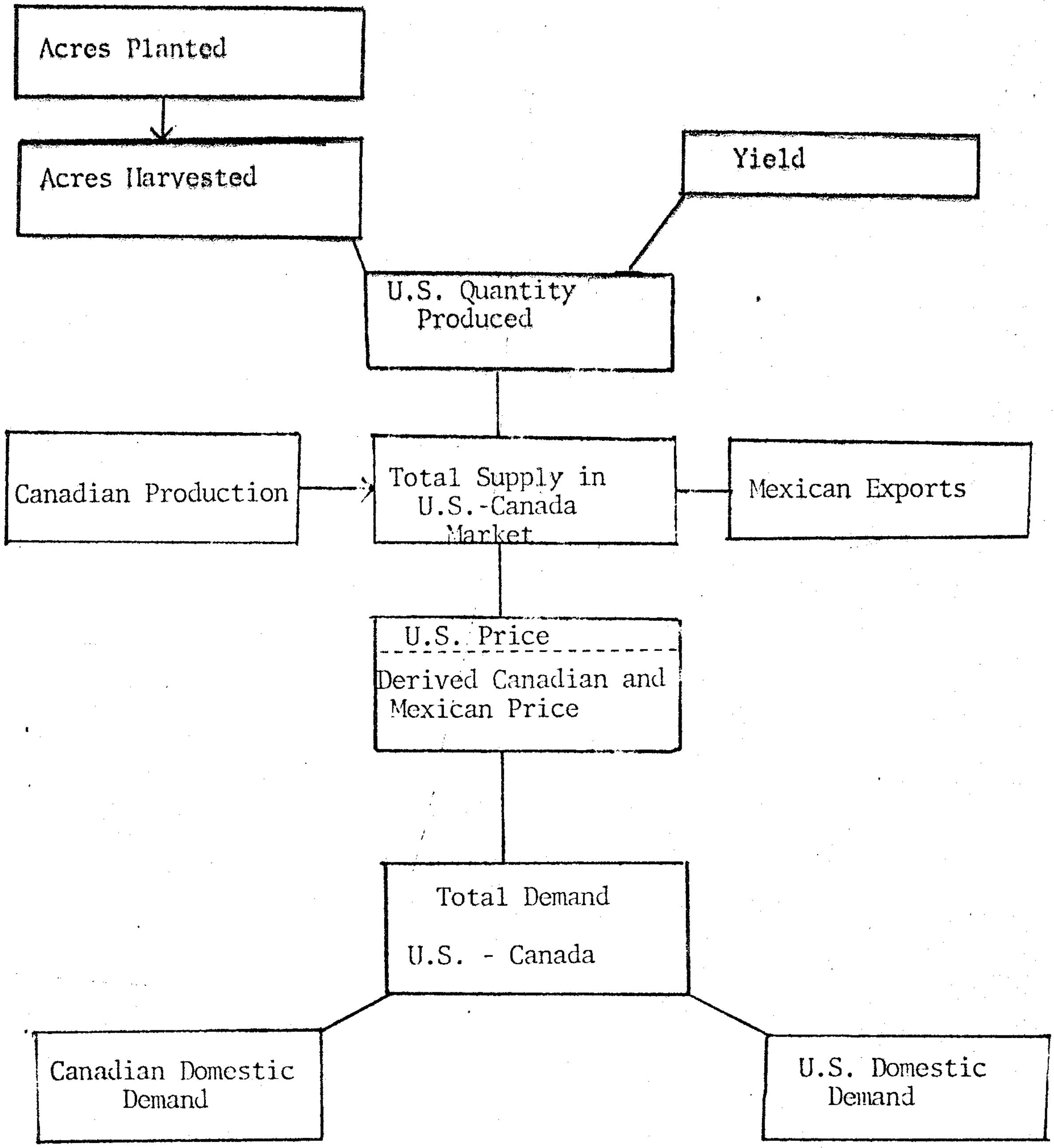
The sub-model of U.S. domestic production consists of three behavioral equations explaining acres planted, acres harvested, and yield, and an identity that defines total production as the product of acres harvested and yield.

Acres Planted

The time that passes between seeding and harvesting of fresh tomatoes is three to four months. Thus, the acreage planted decision must be based on information that is available well in advance of the time when actual production, consumption and tomato prices are known to producers.

It is hypothesized that the most important factors influencing the number of acres planted include the expected price of tomatoes at harvest time, the risk of error associated with the price expectation, expected yields per acre, the risk of error associated with the yield expectations, and the costs of production inputs. In addition time trends in each of the quarters were used in an attempt to capture any secular trends occuring in acreage planted that were not represented by the aforementioned explanatory variables. The acreage planted equation utilized was:

Figure 1. Simplified Structure of the Tomato Industry Model.



NOTE: A straight line indicates simultaneity, an arrow indicates causality with reference to the industry model.

(1) $\ln APTOM_t = \underset{(65.95)}{11.667} + \underset{(1.26)}{2.3458}\,(EPTOM_t/CPDN_{t-1})$

$$+ \underset{(2.29)}{.0017833}\ EYIELD_t - \underset{(-.71)}{.23016}\ PRISK_t$$

$$- \underset{(-.62)}{.11507}\ YRISK_t - \underset{(-8.32)}{.0373}\ TIME_t$$

$$+ \underset{(17.18)}{.016132}\ (DSP_t)\ TIME_t + \underset{(20.30)}{.023912}\ (DSM_t)\ TIME_t$$

$$+ \underset{(13.78)}{.0091826}\ (DFL_t)\ TIME_t$$

$R^2 = .965$ Estimation Method: OLS

Variable Definitions:

a) $APTOM_t$ = acres of tomatoes planted in quarter t.

b) $EPTOM_t$ = expected price of tomatoes prevailing at harvest time t in ¢/lb., defined as

$$EPTOM_t = \sum_{i=1}^{3} W^i\ PTOM_{t-4i},\ \text{with}\ \sum_{i=1}^{3} W^i = 1,\ \text{and}\ PTOM_t$$

is the price of tomatoes in quarter t in ¢/lb. (w = .54369).

c) $CPDN_t$ = proxy for price of production inputs, index of prices paid by farmers for production inputs 1967 average = 100.

d) $PRISK_t$ = risk of error in the price expectation, defined in relative terms as

$$PRISK_t = \left(\sum_{i=1}^{3} W^i (PTOM_{t-4i} - EPTOM_{t-4i})^2\right)^{1/2} / EPTOM_t$$

e) $EYIELD_t$ = expected yield of tomatoes in quarter t, defined as a simple three year moving average of yields for the quarter.

f) $YRISK_t$ = risk of error in the yield expectation, defined in relative terms as $YRISK_t = STDY_t/EYIELD_t$, where $STDY_t$ is a three year moving standard deviation of yields for the quarter.

g) DSP_t = spring dummy variable, = 1 if spring quarter, 0 otherwise.

h) DSM_t = summer dummy variable, = 1 if summer quarter, 0 otherwise.

i) DFL_t = fall dummy variable, = 1 if fall quarter, 0 otherwise.

j) $TIME_t$ = a quarterly time trend defined as = 60 if $t \varepsilon (1, 2, 3, 4)$; = 61 if $t \varepsilon (5, 6, 7, 8)$; ...; = 78 if $t \varepsilon (73, 74, 75, 76)$.

Note that the values in parentheses are the t values. The choice of the semi-logarithmic form of the model was motivated by the belief that the change in the level of aggregate acreage planted in response to changes in the costs of production inputs, price and yield expectations, and risk levels should depend on the level of the aggregate operation in a given quarter (e.g., the summer operation usually involves well over four times the acreage planted in the winter, and it seems unreasonable to presume that a unit change in expected price would increase winter and summer planting by the same number of acres). The specification results in the derivatives of APTOM with respect to EPTOM/CPDN, PRISK, EYIELD, and YRISK being proportional to the level of acreage planted, $APTOM_t$. The price of production inputs proxy, $CPDN_{t-1}$, was specified in lagged form in an attempt to account for the fact that production costs associated with output in t depends primarily on input expenditures in t-1.

As a point of reference, elasticities of acres planted with respect to the expectation and risk variables were calculated at the mean level of the data. The elasticity of APTOM with respect to EPTOM/CPDN was found to be .227, for PRISK it was -.033, for EYIELD it was .258, and for YRISK it was -.011.

Acres Harvested

The level of acres harvested is hypothesized to depend on the actual price prevailing at the time of harvest, the costs of harvesting, and the level of acres planted. In addition, a freeze in Texas in the spring of 1960 and a severe freeze in Florida in the winter of 1977 affected the amount of acreage harvestable.

It is also hypothesized that the short run supply elasticity of tomato production is inelastic with respect to price and with respect to costs of harvesting which implies that the elasticities of acres harvested with respect to price and costs of harvesting are also in the inelastic range (note that the elasticity of quantity supplied is logically the sum of the elasticities with respect to acres harvested and with respect to yield). The acres harvested equation utilized was:

$$(2) \quad \ln AHTOM_t = \underset{(1.86)}{.14652} \ln PTOM_t - \underset{(-2.07)}{.13841} \ln CHARV_t + \underset{(80.35)}{1.0245} \ln APTOM_t - \underset{(-11.20)}{.04446} (FREEZE_t) \ln APTOM_t$$

$$\chi^2_2 = 3.12 \quad \Theta_p = .03 \quad r = .998$$

Estimation Method: 2SLS-Mixed Estimation

Definitions of Variables Not Previously Defined:

a) $AHTOM_t$ = acres harvested of tomatoes in quarter t.

b) $CHARV_t$ = cost of harvesting inputs, proxied by the index of prices paid by farmers for hired farm labor, 1967 average = 100.

c) $FREEZE_t$ = dummy variable for freezes in 1960 spring quarter and 1977 winter quarter which seriously affected volume of harvestable acreage.

Numbers in parentheses are ratios of the estimated coeffient to its estimated standard error. The r refers to simple correlation between the dependent variable and its prediction generated by equation (2). The Θ_p refers to the proportion of the posterior precision of the mixed estimator that is accounted for by the prior information, which in this case consisted of two stochastic constraints on the elasticities of AHTOM with respect to PTOM and CHARV (see Theil on the interpretation of Θ_p). The constraints were that the elasticities of AHTOM with respect PTOM and with respect to CHARV were contained in the intervals [0, 1] and [-1, 0], respectively, with probability .95 in each case. Points in the interval were considered equally likely, and thus a uniform distribution was used in reference to the disturbance terms of the stochastic constraints. Estimated probability values associated with the null hypotheses of compatibility of each stochastic constraint with the sample data resulted in value of .239 and .235, respectively. The rather high probability values lend a fair amount of support to the null hypothesis of compatibility between sample and prior constraints (see the appendix for a more detailed description of the mixed estimator under the uniformly distributed prior stochastic constraint assumption). The χ^2 value associated with Theil's test of compatibility between sample and prior information is presented for reference, although since the prior constraints were not assumed to be normally distributed, the χ^2 distribution for Theil's test statistic does not obtain. The χ^2 test would indicate compatibility of sample and prior information at the standard .05 level.

The double log form of the relationship was chosen basically on its empirical merits. Being in double log form, the short run elasticities of AHTOM with respect to PTOM and CHARV are represented directly by the estimated coefficients .146 and -.138, respectively.

Yield

There are three major factors that ultimately affect the yield forthcoming from acres harvested. The initial decision concerning seeding rates, and cultivation practices including fertilizing, application of herbicides, and pruning and training represent the capital investment in the production unit. The foregoing activities occur for the most part prior to initial harvesting, and thus decisions regarding these practices are based on expectations of market conditions during the harvest period.

A second major factor determining yields is a decision regarding the intensity of the harvest. Tomatoes must be harvested continually as they mature, although as harvesting progresses, yields per harvest eventually decline. The actual price at harvest time and harvesting costs would seem to significantly influence the intensity of the harvest.

Finally, weather has a substantial effect on the potential yield from harvested acreage. The tomato is a warm-season plant. The tomato plant does best in moderately dry areas with temperatures ranging between 65^{0} to 85^{0} F. Plants are frozen at temperatures less than 32^{0} F, and do not grow when temperatures are above 95^{0} F. Foliage diseases are induced by high temperatures coupled with high humidity.

The variables used to explain tomato yields include the expected price of tomatoes, the risk of error in the price expectation, the cost of harvesting the crop (proxied as before by CHARV, the index of prices paid for hired farm labor), and the past level of yield in the quarter.

In addition, winter freezes in Florida significantly reduced yields in 1970 and 1977, and a dummy variable representing these quarters was included. Also, exceptional weather conditions resulted in an extremely large crop in the winter of 1975 (310 cwt per acre). A dummy variable to account for this exceptional phenomenon was also included in the specification. Finally, a spring quarter dummy variable was useful in interaction with the past level of yield (summer and fall dummy variables were also initially utilized, but were found not to be significant).

It was also hypothesized that the short run elasticities of yield with respect to PTOM and CHARV would be inelastic, in keeping with the previous hypothesis that quantity supplied in the short run is inelastic with respect to these variables. The yield equation utilized was:

$$
\begin{aligned}
(3)\quad \ln YIELD_t = {} & \underset{(4.16)}{2.1978} + \underset{(1.93)}{.22575} \ln PTOM_t - \underset{(-3.87)}{.47797} \ln CHARV_t \\
& + \underset{(2.78)}{.41213} \ln EPTOM_t - \underset{(-1.60)}{.053824} \ln PRISK_t \\
& + (\underset{(7.76)}{.69167} - \underset{(-5.10)}{.06739}\, FIAFREZ_t - \underset{(-1.98)}{.014018}\, DSP_t) \ln YIELD_{t-4} \\
& + .40759\, D_{75}\, WINT
\end{aligned}
$$

$X^2 = .984 \qquad \Theta_p = .034 \qquad r = .919$

Estimation Method: 2SLS-Mixed Estimation

<u>Definitions of Variables Not Previously Defined</u>:

a) $YIELD_t$ = yield per acre, in cwt./acre.

b) $FLAFREZ_t$ = Florida Freeze, = 1 in winter quarters of 1970 and 1977, = 0 elsewhere.

c) D_{75WINT} = dummy for exceptionally good weather resulting in heaviest yields on record in winter of 1975, = 1 in winter of 1975, = 0 elsewhere.

As before, values in parentheses are ratios of coefficients to their estimated standard errors, r is the simple correlation between actual and predicted values of the dependent variable, and θ_p is the proportion of the posterior precision of the mixed estimator attributable to the prior information, which consisted of two stochastic constraints on the PTOM and CHARV elasticities. As before, the elasticities were constrained to the intervals [0, 1] and [-1, 0], respectively, with prior probability .95 derived from the uniform distribution. The probability values associated with the hypotheses of inelasticity were .295 and .694, respectively, indicating strong support for the hypothesis (again, see appendix for further details).

Since the yield equation was specified in double logarithmic form, elasticities are equal to estimated coefficients. The short run elasticity of yield with respect to PTOM was .226, with respect to CHARV it was -.478, with respect to EPTOM it was .412, and with respect to PRISK it was -.054.

Quantity Supplied

Aggregate domestic quantity of fresh tomatoes supplied is determined by multiplying acres harvested by yield, and is scaled to be in units of millions of hundredweights, as

(4) $QSTOMUS_t = (AHTOM_t)(YTOM_t)(.000001)$

Definition of Variables Not Previously Defined:

$QSTOMUS_t$ = quantity produced in the U.S., in millions of hundredweights.

The short run elasticities of aggregate quantity supplied with respect to PTOM, CHARV, EPTOM and PRISK are found by summing the elasticities of AHARV and YIELD with respect to the appropriate variable (e.g., $(\partial QSTOMUS/\partial X)(X/QSTOMUS) = (\partial AHARV/\partial X)(X/AHARV) + (\partial YIELD/\partial X)(X/YIELD)$), and were equal to .372, -.618, .412 and -.054, respectively.

Mexican Supply for Export

Ideally it would have been desirable to model the total production of tomatoes in Mexico in a given quarter, and then model quantity allocated to the export market and the domestic market. The data available for Mexico allowed only a simplistic modeling of the amount supplied to the U.S.-Canadian market.

Given the behavior of CAADES in determining Mexican supply for export (see previous discussion of Mexican supply for export and CAADES) it was hypothesized that the quantity of tomatoes exported to the U.S.-Canadian market would depend on the previous export level in the quarter (representing previous excess demand in the U.S.-Canadian Market met by Mexican supplies), the previous level of price received by Mexican growers supplying the U.S.-Canadian market in the quarter, and the price received by Mexican growers at the time of harvest. The first two variables pertain to information relevant for the setting of goals for production. The third variable is relevant for decisions regarding what percentage of supplies available is to be diverted to the export market. Prices were deflated by an index of prices paid to farmers for commodities sold in Mexico City in order to place the price relative to prices of other farm commodities sold by Mexican growers, and thereby proxy the "acceptable price" phenomenon utilized in decisions concerning level of exports (see previous discussion of Mexican supply for export). A dummy variable shift for the summer and fall quarter was found to be useful, which differentiated between the quarters of greatest Mexican comparative advantage (winter-spring) and least advantage (summer-fall). The final equation utilized was:

(5) $$\ln MEXEXP_t = \underset{(4.06)}{1.3066} - \underset{(-3.64)}{1.1752}/PMX_t$$

$$+ \underset{(1.98)}{.58058} \ln PMX_{t-4} + \underset{(5.94)}{.4995} \ln MEXEXP_{t-4}$$

$$-\underset{(-5.11)}{1.2574} DSMFL_t$$

$r = .959$ Estimation Method: 2SLS

Definitions of Variables not Previously Defined:

a) $MEXEXP_t$ = the level of Mexican exports to the U.S.-Candian Market, in million cwt.

b) PMX_t = the relative Mexican price, defined as

$$PMX_t = (PTOM_t - USTARIFF_t)EXCHRATE_{US}^{MEX} \div MXPPIND_t.$$

Where:

$USTARIFF_t$ = the most favored nation U.S. tariff rate on tomatoes in quarter t, in ¢/lb.

$EXCHRATE_{US}^{MEX}$= exchange rate PESOS/U.S. DOLLARS.

$MPPIND_t$ = prices paid to farmers for commodities sold, Mexico city, 1970 = 100. Note, this is an annual index that could not be obtained on a quarterly basis. Each quarter was assigned the appropriate annual value of the index.

c) $DSMFL_t$ = summer-fall dummy variables, = 1 in summer and fall quarters, = 0 elsewhere.

As before, numbers in parentheses are ratios of coefficients to their estimated errors and r is the simple correlation between predicted and actual values of the dependent variable. Note that the functional form is double logarithmic except for the inclusion of the recipricol of the relative Mexican price, and the summer-fall dummy variable. Entering a dummy variable in this way allows a shift in the entire surface implied by (5), and in fact the shift is estimated to be downward in the summer-fall quarters. The use of the reciprical of PMX_t in equation (5) implies the notion of an asymptotic level for the response surface, i.e., as PMX_t increases, the functional form would be consistent with the notion that all of what was planned to be exported to the U.S.-Canadian market is in fact exported (see Johnston, Chapter two, for additional details on this functional form).

The short run elasticity with respect to lagged relative Mexican price was estimated to be .581. The short run elasticity with respect to the current relative Mexican price was estimated to be .981 at the mean level of the data.

Demand in the U.S.-Canadian Market

U.S. Domestic Demand

A rather simplistic view of the domestic demand for fresh tomatoes was taken in specifying the behavioral equation. It was hypothesized that the domestic percapita demand for tomatoes at the farm level was a function of the price of tomatoes, per capita disposable income, and tastes and habits. The prices of all other goods were proxied by the consumer price index, which was used to deflate the price of tomatoes and per capita disposable income. Tastes and habits were represented by including values of per capita consumption lagged one, two, and three years in the equation.

Three stochastic prior constraints were used in estimating the demand equation. It was hypothesized that the elasticity of demand with respect to price and with respect to income would be in the inelastic range. The mean level price elasticity and the mean level income elasticity were constrained to be in the intervals [-1, 0] and [0, 1]; respectively, with .95 probability. The uniform distribution was utilized for the error terms of these stochastic constraints. In addition, Shiller's method was used to impose the hypothesis of smoothing declining weights on successive lags of per capita consumption which was included in the equation to proxy tastes and habits. The rationale and method for deriving the stochastic constraint for imposition of Shiller's method is identical to the one used by Hammig and Mittelhammer, and is not repeated here. It should be noted, however, that in the case at hand, the uniform distribution again was utilized for the disturbance term of the stochastic constraint (and not the normal distribution, as was used by Hammig and Mittelhammer).

The final equation utilized was:

$$
\begin{aligned}
(6)\quad QDTOMUS_t/POPUS_t = {} & \underset{(.89)}{.0022641} - \underset{(-2.03)}{.00049959}\, PTOM_t/CPIUS_t \\
& + \underset{(2.68)}{.0022453}\, INCUS/(CPIUS_t \cdot POPUS_t) + \underset{(4.88)}{.47619}\, QDTOMUS_{t-4}/ \\
& POPUS_{t-4} + \underset{(3.06)}{.27027}\, QDTOMUS_{t-8}/POPUS_{t-8} + \underset{(1.49)}{.14316}\, QDTOMUS_{t-12}/ \\
& POPUS_{t-12}
\end{aligned}
$$

$x^2 = 2.48 \qquad \Theta_p = .08 \qquad r = .958$

Estimation Method: 2SLS-Mixed Estimation

<u>Defintions of Variables Not Previously Defined</u>

a) $QPTOMUS_t$ = aggregate domestic quantity demanded in the U.S., in millions of cwts.

b) $POPUS_t$ = population of the U.S., in millions.

c) $CPIUS_t$ = consumer price index in the U.S., 1967 average = 1.00.

d) $INCUS_t$ = aggregate disposable income in the U.S., in billions of dollars, seasonally adjusted annual rates.

Numbers in parentheses, χ^2, o_p, and r are as they were defined earlier. The probability values associated with the hypotheses of inelasticity with respect to price and income were .301 and .383, respectively, lending significant support to the hypotheses. The hypothesis of smoothly declining weights on the lagged per capita consumption variables imposed by Shiller's method had a probability value of .672, lending strong support to the hypothesis. As a point of reference, Theil's χ^2-test of compatibility would indicate compatibility of sample and prior information at the .05 level.

Price and income elasticities were calculated at the mean level of the data. They were found to be -.181 and .219, respectively. Aggregate domestic quantity demanded was found by multiplying the dependent variable in (6) by $POPUS_t$.

Canadian Demand

The specification of the Canadian per capita demand curve was similar to the demand curve for the U.S. However, only per capita consumption lagged four quarters was included in the equation to represent tastes and habits since quantity lagged eight and twelve quarters did not prove to be useful.

Similar to the demand in the U.S., it was hypothesized that both the price and the income elasticities would be in the inelastic range. Mean level elasticities with respect to price and income were constrained to be in the range [-1, 0] and [0, 1] with probability .95. As before, the disturbance terms of the stochastic constraints were generated from uniform prior distributions.

The final equation utilized was:

$$(7)\quad QDTOMCAN_t/POPCAN_t = \underset{(.42)}{.0012331} - \underset{(-1.58)}{.030006}\, PCAN_t/CPICAN_t$$

$$+ \underset{(1.82)}{.8088}\, INCCAN_t/(CPICAN_t \cdot POPCAN_t)$$

$$+ \underset{(30.49)}{.91765}\, QDTOMCAN_{t-4}/POPCAN_{t-4}$$

$$\chi^2 = 3.32 \qquad \Theta_p = .03 \qquad r = .963$$

Estimation Method: 2SLS-Mixed Estimation.

Definitions of Variables not Previously Defined:

a) $QDTOMCAN_t$ = aggregate Canadian demand for tomatoes, in millions of cwts.

b) $POPCAN_t$ = population of Canada in millions.

c) $PCAN_t$ = Canadian price of tomatoes, defined as

$$PCAN_t = (PTOM_t \cdot EXCHRATE_{US}^{CAN}) - CANTARIFF_t$$

where

$CANTARIFF_t$ = the Canadian Tariff on imports of fresh tomatoes, in ¢/lb. (Canadian)

$EXCHRATE_{US}^{CAN}$ = the Canadian/U.S. exchange rate in \$ Canadian/\$ U.S.

d) $CPICAN_t$ = Canadian consumer price index, with 1971 AUG = 100.

e) $INCCAN_t$ = Quarterly Canadian disposable income, in billions of dollars (Canadian).

Numbers in parentheses, χ^2, Θ_p and r are as previously defined. The probability values associated with the hypotheses of inelasticity with regard to the price and income elasticities were .191 and .260, respectively, indicating a fair amount of support for the hypotheses. As a point of reference, Theil's χ^2 test would imply compatibility of sample and prior information at the .05 level.

Price and income elasticities were calculated at the mean level of the data. They were found to be -.104 and .150, respectively.

Aggregate quantity demanded in Canada was found by multiplying the dependent variable in (7) by POPCAN.

Equilibrium of Quantity Flow

An identity was used to define equilibrium between total quantity supplied and total quantity demanded in the U.S.-Canadian market, as follows;

(8) $QDTOMUS_t + QDTOMCAN_t = QSTOMUS_t + QSTOMCAN_t + MEXEXP_t$

IV. Model Simulation

Goodness of Fit

The set of six behavioral equations and four identities was solved simultaneously using the Gauss-Seidel iterative method for solving sets of nonlinear and linear equations. The model was evaluated in terms of its performance in generating one-step ahead (short-run) predictions and in generating a long run series of predictions during the 1960-1978 historical period. In the former evaluation, actual historical values for all lagged endogenous variables as well as for all exogenous variables are used in obtaining solutions (predictions) for the 1960-1978 period. In the latter evaluation, actual historical values of exogenous variables are used, but only the initial solution (first quarter, 1960) utilizes actual historical values for lagged endogenous variables. All remaining solutions (predictions) use the appropriate solution (prediction) values for lagged endogenous variables generated internally by the model.

Table 1 presents measures of goodness of fit for the short run and long run evaluations. It should be noted that the rather large mean

Table 1. Goodness of Fit Measures in Simulation, 1960-1978.

Short Run Predictive Performance[1/]

	Mean Percent Error	Mean Absolute Percent Error	Y vs. Y-HAT Correlation	Theil U Statistic
APTOM	-.663	8.555	.980	.210
AHTOM	-.958	8.167	.982	.194
YIELD	-.625	6.865	.924	.436
QSTOMUS	-1.137	8.229	.979	.205
MEXEXP	-16.975	40.854	.957	.332
QDTOMUS	-.083	6.377	.967	.308
QDTOMCAN	-.437	9.741	.963	.208
PTOM	-2.618	14.233	.880	1.225

Long Run Predictive Performance[2/]

	Mean Percent Error	Mean Absolute Percent Error	Y vs. Y-HAT Correlation	Theil U Statistic
APTOM	-1.163	9.153	.980	.211
AHTOM	-1.344	8.696	.981	.203
YIELD	-1.607	8.882	.868	.507
QSTOMUS	-2.596	11.201	.961	.287
MEXEXP	-13.890	39.633	.951	.357
QDTOMUS	-1.100	10.015	.899	.445
QDTOMCAN	1.734	8.830	.968	.217
PTOM	-1.363	12.771	.910	1.067

[1/] Solutions obtained by utilizing actual historical data on all lagged endogenous and exogenous variables.

[2/] Solutions obtained by utilizing actual historical data on exogenous variables, and internally generated values for lagged endogenous variables.

absolute precent error in predicting Mexican exports is primarily due to large relative errors in predicting the summer and fall quarters. As a practical matter, the errors in these quarters, though large relative to the actual level of exports, amount to very little in nominal terms. Exports in winter and spring are for the most part in the 1.5 to 4 million cwt. range. In summer and fall, exports are generally much less than .4 million cwt.

It should be noted that for the purposes of simulation under alternative scenarios, the long run predictive performance of the model is most relevant in assessing goodness of fit.

Simulation Under Alternative Tariff Structures

In this section two alternative U.S. Tariff structures are compared with the actual historical situation during the period 1960-1978 (the simulation of the actual historical situation during this period will henceforth be denoted as the baseline solution). In one alternative, the U.S. Tariff is eliminated entirely, with all else being as it was in history. In the other alternative, the U.S. Tariff is doubled as compared to its historical values.

Discussion of all simulations is concentrated in the winter and spring quarters, as this is the period of significant activity by Mexico in the U.S.-Canadian tomato market. Qualitatively speaking, very little changes significantly in the summer and fall quarters when Mexican activity is altered, as one would expect. In order to expedite the discussion, only the effects on U.S. quantity supplied, U.S quantity demanded, U.S. price, and acreage planted are specifically examined.

Acreage Planted

As expected, when the tariff is eliminated, acreage planted in the winter is reduced relative to the baseline as more Mexican imports enter the market. However, the magnitude of the reduction is somewhat less than startling. The reduction in total winter acreage planted over the full 19 year period of simulation is estimated to be 6.9%.

On the other hand, when the U.S. Tariff is doubled and protection of domestic growers from Mexican competition is increased, acreage planted increases. However, the magnitude of the increase is again not large, being 5.1% in aggregate over the 19 year period of simulation.

Corresponding figures for the spring quarter are a 4.5% decline in acreage planted when the tariff is eliminated, and a 3.2% increase in acreage planted when the tariff is doubled.

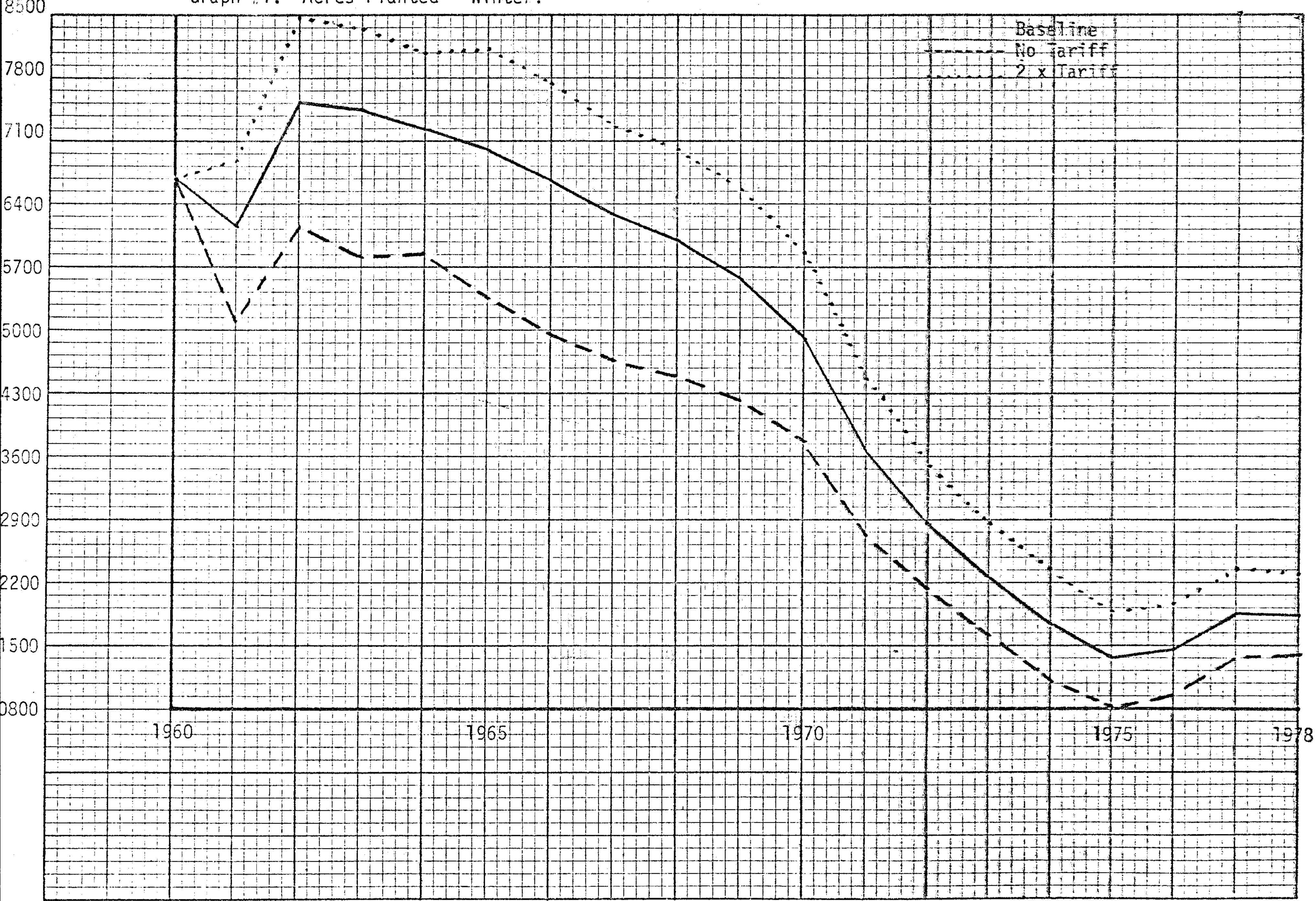
Time paths of the simulated values of acreage planted under the alternative tariff structures are illustrated in graphs 1 and 2.

U.S. Quantity Supplied

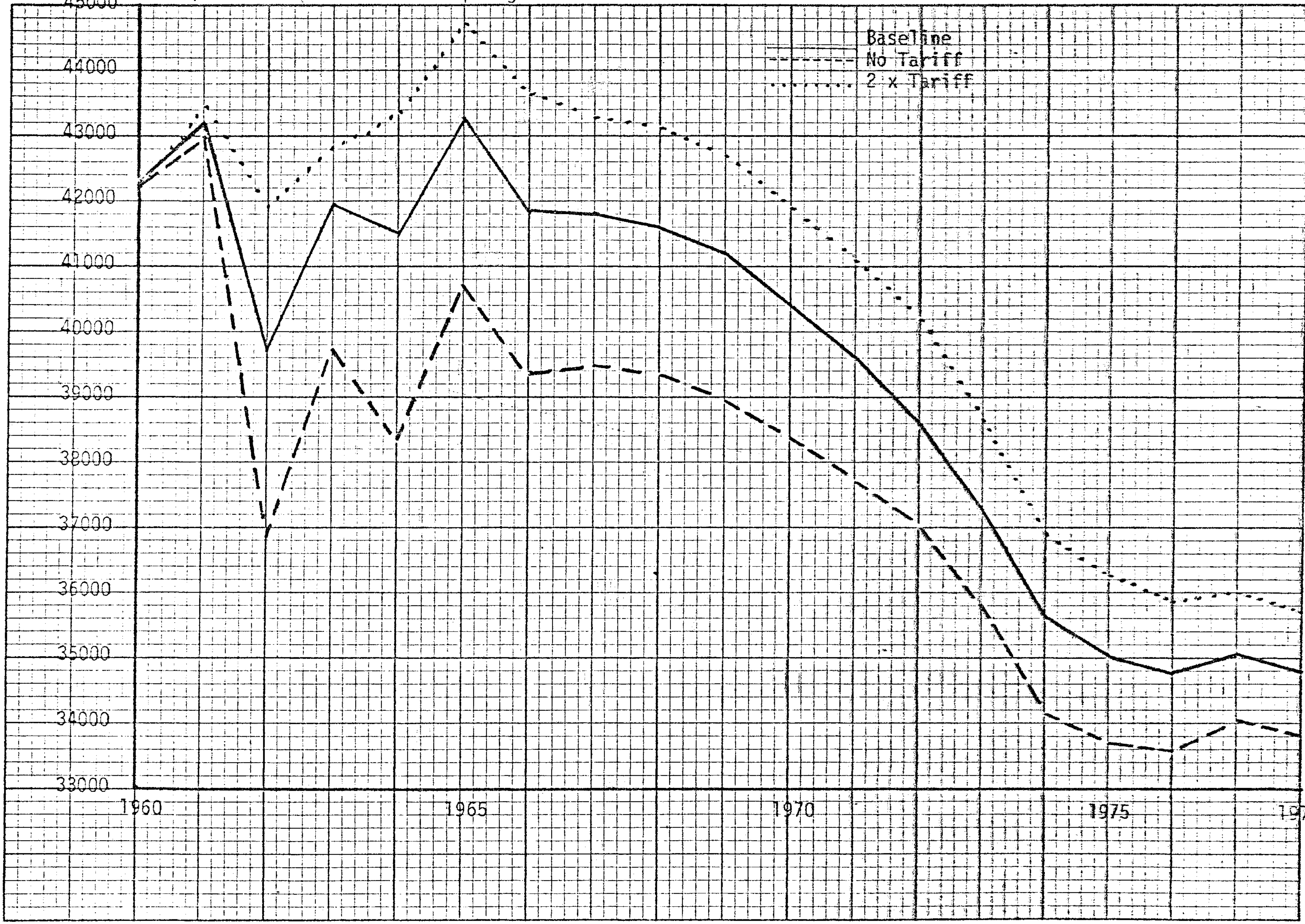
U.S. quantity supplied is significantly affected by changes in the tariff structure both in the winter and in the spring quarters. Elimination of the tariff results in a 23.8% reduction in aggregate quantity supplied in the winter, and a reduction of 17.9% in the spring for the 1960-1978 period. Doubling of the tariff increases winter quantity supplied by 19.6% and increases spring quantity supplied by 14.4%.

Time paths of the simulated values of quantity supplied under the alternative tariff structures are illustrated in graphs 3 and 4.

Graph #1. Acres Planted - Winter.

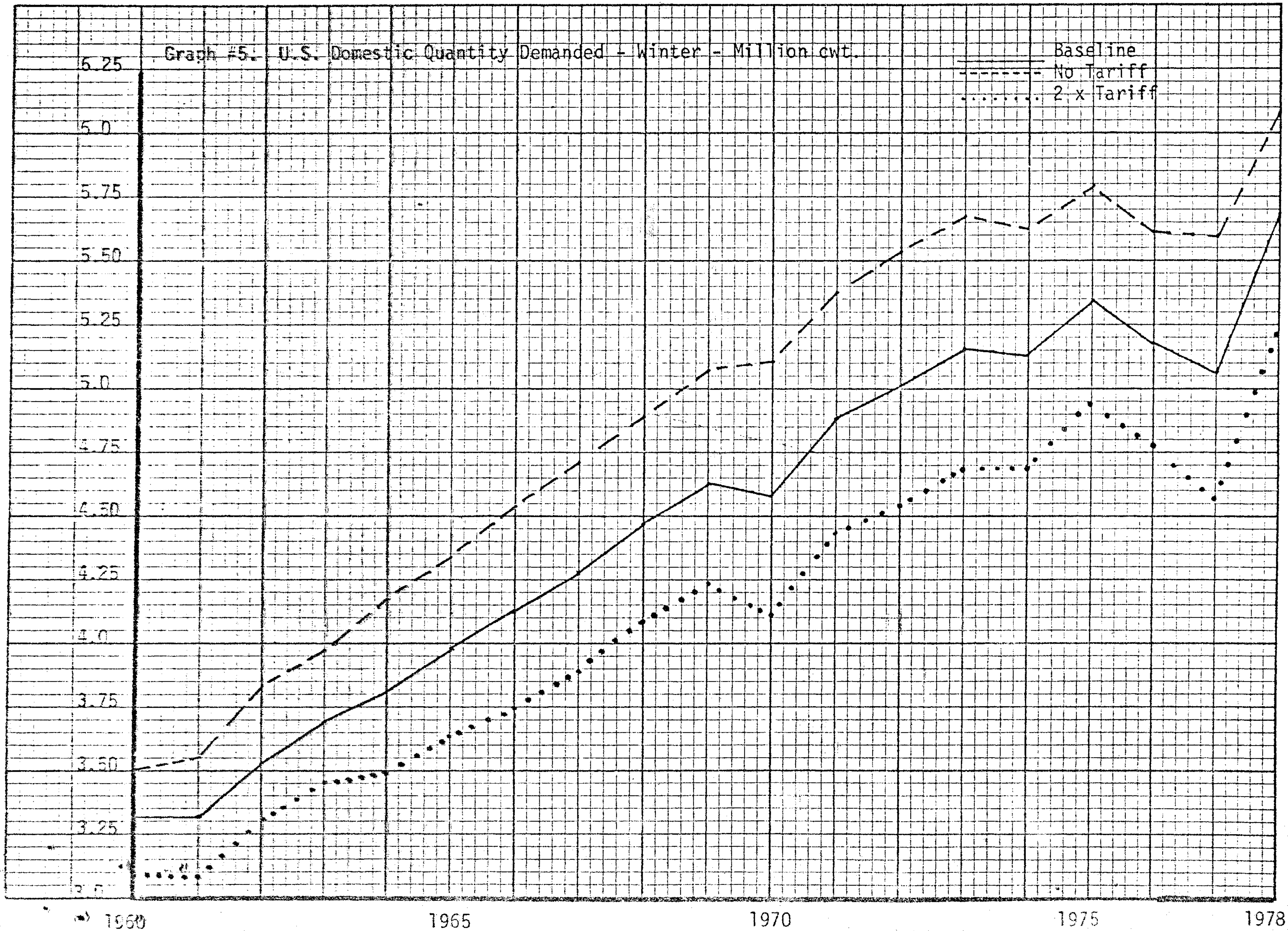


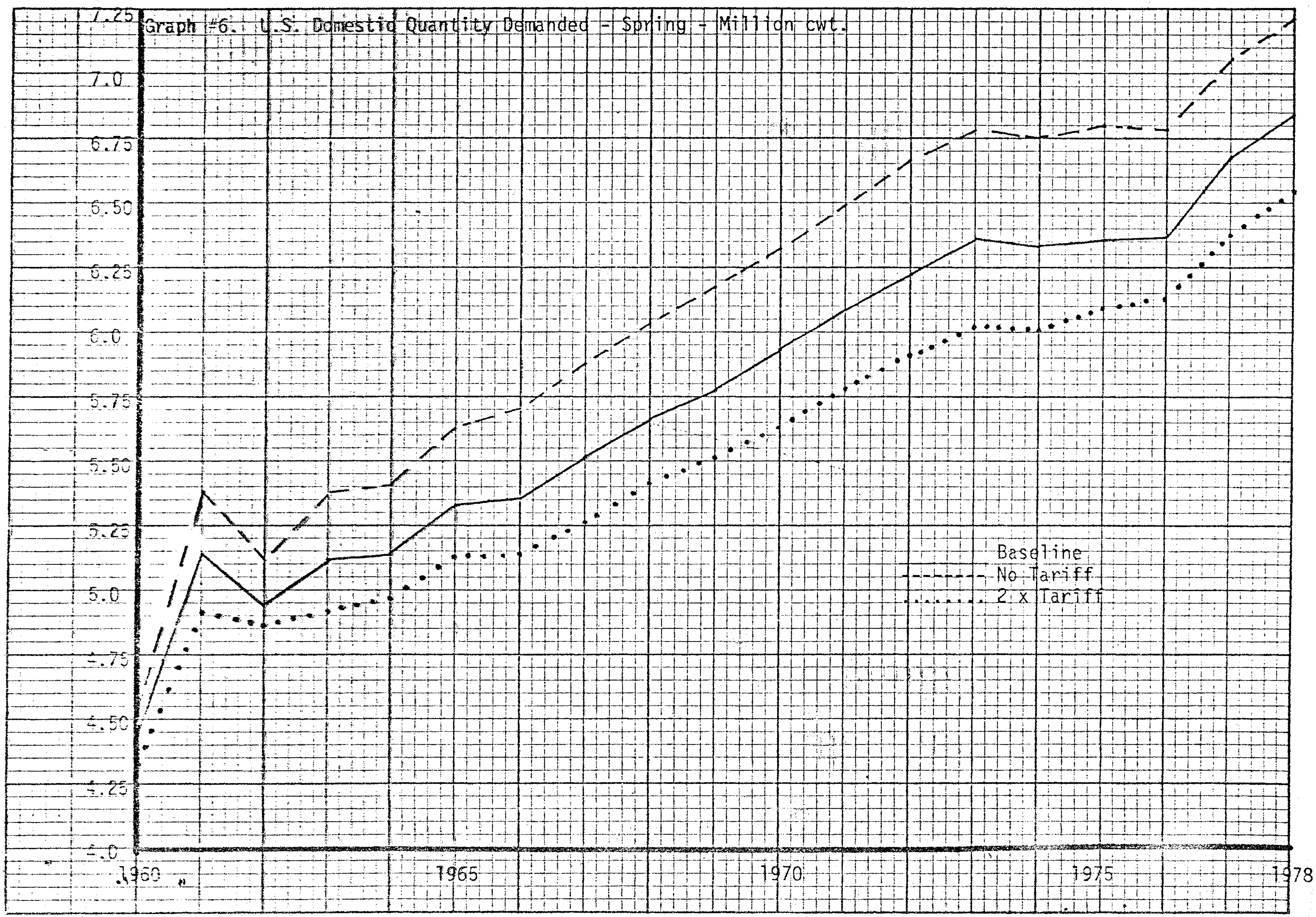
Graph #2. Acres Planted - Spring.



Graph #3. U.S. Quantity Supplied - Winter - Million cwts.
Baseline
No Tariff
2 x Tariff
4.0
3.75
3.50
3.25
3.0
2.75
2.50
2.25
2.0
1.75
1.50
1.25
1.0
1960
1965
1970
1975
1978

Graph #4. U.S. Quantity Supplied - Spring - Million cwts.
Baseline
No Tariff
2 x Tariff
5.5
5.25
5.0
4.75
4.50
4.25
4.0
3.75
3.50
3.25
3.0
2.75
2.50
1960
1965
1970
1975
1978


Graph #5. U.S. Domestic Quantity Demanded - Winter - Million cwt.
Baseline
No Tariff
2 x Tariff
5.25
5.0
5.75
5.50
5.25
5.0
4.75
4.50
4.25
4.0
3.75
3.50
3.25
1960
1965
1970
1975
1978



Graph #6. U.S. Domestic Quantity Demanded - Spring - Million cwt.
7.25
7.0
6.75
6.50
6.25
6.0
5.75
5.50
5.25
5.0
4.75
4.50
4.25
4.0
1960
1965
1970
1975
1978
Baseline
No Tariff
2 x Tariff

U.S. Quantity Demanded

The U.S. quantity demanded of fresh tomatoes is moderately affected by changes in the tariff structure. Elimination of the tariff increases aggregate quantity demanded over the 19 year period by 9.2% in the winter, and by 5.8% in the spring. Doubling the tariff depresses aggregate quantity demanded by 8.4% in the winter and 4.4% in the spring.

Time paths for simulated quantities demanded over the historical period under the various tariff structures are given in graphs 5 and 6.

U.S. Tomato Price

The U.S. tomato price appears to be moderately affected by changes in the tariff structure. Comparing simple averages of prices during the historical period, it was found that the elimination of the tariff reduces average tomato prices by 6.0% and 5.1% in the winter and spring quarters, respectively. A doubling of the tariff increases the average price by 5.6% in the winter quarters, and 4.0% in the spring quarters.

Weighted average real (deflated by CPI) demand prices and supply prices were also calculated for the historical period 1960-1978. The direction and magnitudes of the changes in the weighted average prices parallels the changes in the simple average price. The percentage changes are displayed as part of table 2, to be discussed in the next section.

Graphs 7 and 8 depict the time paths for the simulation values of prices under the alternative tariff structures.

Comments

Table 2 provides a summary of the aforementioned changes induced by changes in Mexican supply behavior due to variations in the tariff structure. The largest percentage changes under the alternative tariff structures occur in U.S. quantity supplied, which tends to support

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Comments

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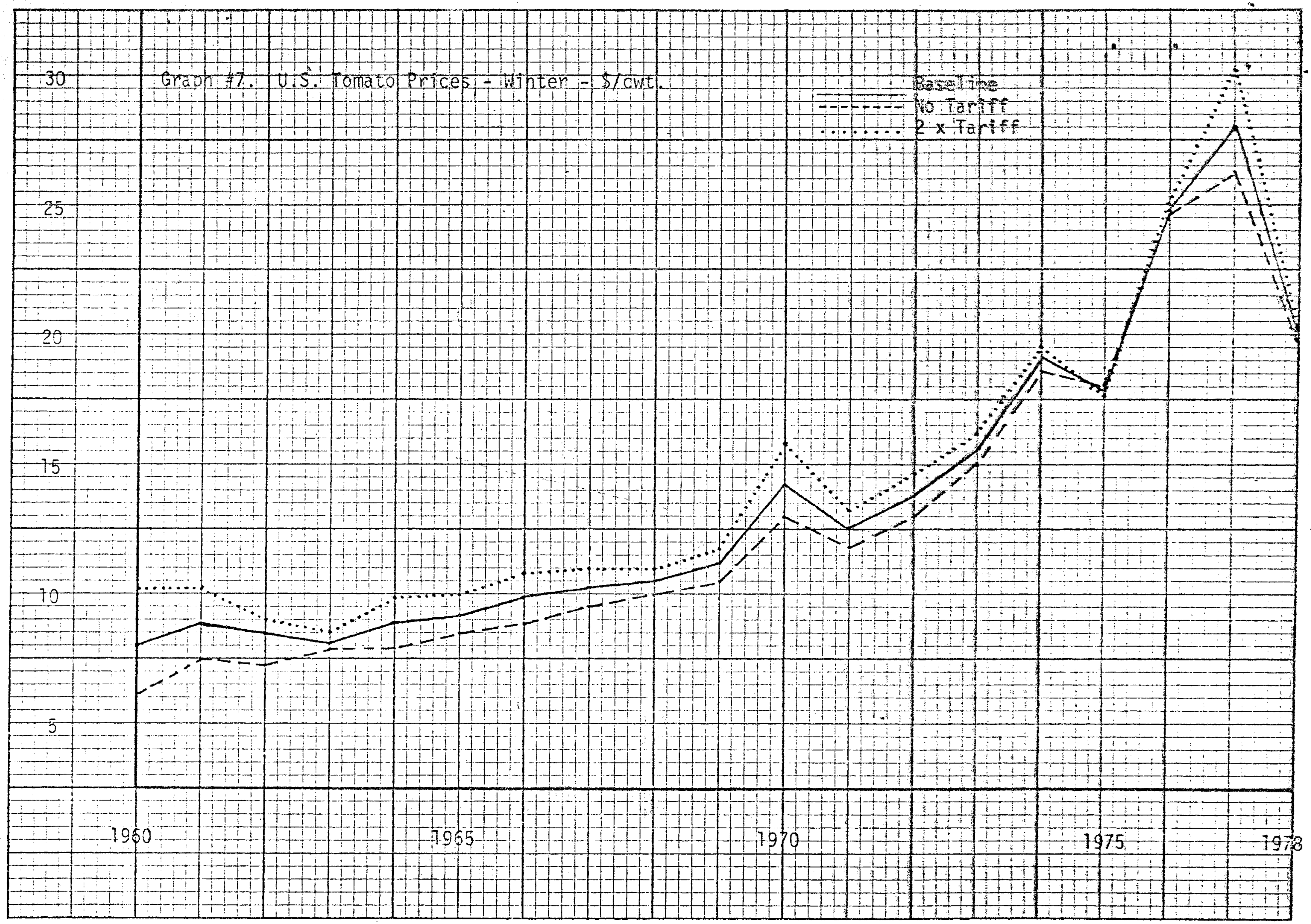
Table 2. Summary of Aggregate Changes from Baseline for Selected Simulated Variables, 1960-1978 Period.

	Tariff Eliminated		Tariff Doubled	
	Winter	Spring	Winter	Spring
Acres Planted	6.9%↓	4.5%↓	5.1%↑	3.2%↑
U.S. Quantity Supplied	23.8%↓	17.9%↓	19.6%↑	14.4%↑
U.S. Quantity Demanded	9.2%↑	5.8%↑	8.4%↓	4.4%↓
AVG U.S. Tomato Price [a/]	6.0%↓	5.1%↓	5.6%↑	4.0%↑
Wt. AVG Real Demand Price[b/]	6.2%↓	5.7%↓	5.7%↑	4.2%↑
Wt. AVG Real Supply Price[c/]	5.9%↓	4.8%↓	6.0%↑	5.1%↑

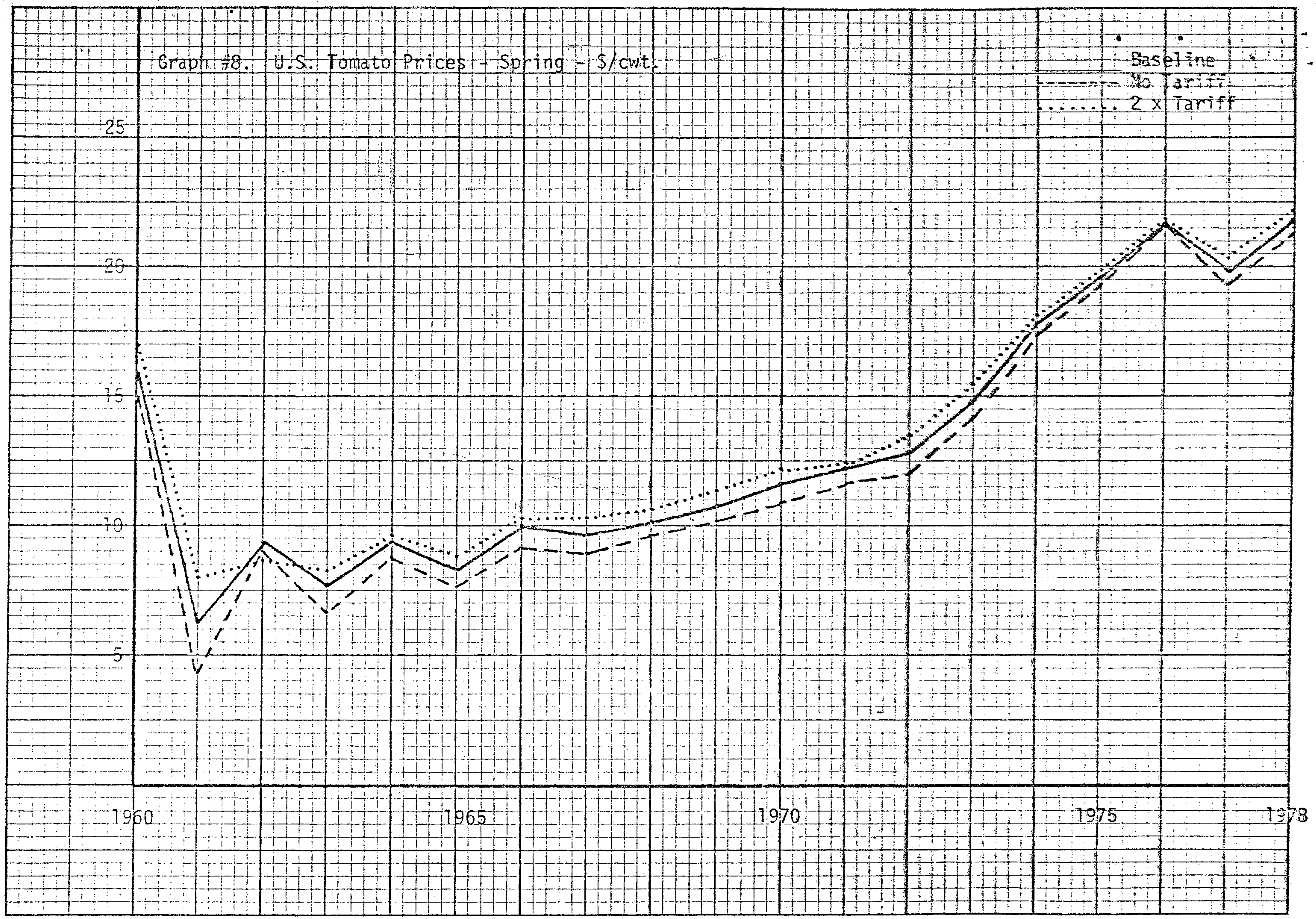
[a/]The average U.S. Tomato price is a simple average of 19 quarters.

[b/]U.S. Quantity demanded-weighted average of price deflated by consumer price index for appropriate quarters in 1960-1978.

[c/]U.S. Quantity supplied-weighted average of price deflated by consumer price index for appropriate quarters in 1960-1978.



Graph #7. U.S. Tomato Prices - Winter - $/cwt.
Baseline
No Tariff
2 x Tariff
30
25
20
15
10
5
1960
1965
1970
1975
1978


Graph #8. U.S. Tomato Prices - Spring - $/cwt.
Baseline
No Tariff
2 x Tariff
25
20
15
10
5
1960
1965
1970
1975
1978

somewhat the contention by domestic growers that Mexican competition is substantial in the winter and spring quarters, and that the tariff provides considerable protection for the domestic producers. There is a moderate price to be paid by domestic consumers for protection of domestic production. Elimination of the tariff would increase Mexican imports resulting in a moderate decline in prices (as judged by the simple and weighted average of prices over the period) and a moderate increase in aggregate quantity consumed. Thus there is a noteworthy penalty to consumers in terms of prices paid and quantity consumed for maintaining the tariff structure.

Ultimately, the advisability of maintaining the tariff structure depends on values placed on the protection of the domestic industry and the welfare of the consumer, an argument which will not be examined in this paper. It is sufficient to note that judging by simulations under alternative tariff structures, Mexican competition is formidable, but manipulatable.

Simulation Under Quota

In this section two alternative restrictions on quantity of fresh tomatoes imported are examined. In one alternative, imports to the U.S. are restricted to 10% of domestic U.S. production, and the tariff is eliminated. In the other alternative, all imports to U.S. and Canada are barred. The latter simulation represents a situation where Mexico is effectively removed from the U.S.-Canadian tomato market. As before, discussion is concentrated in the winter and spring quarters, and only the effects on U.S. quantity supplied, U.S. quantity demanded, U.S. price, and acreage planted are specifically examined.

The directions of changes in the variables indiced by the two induced import restrictions are generally identical, and differ only in magnitude. As one would expect, eliminating all imports produces more violent changes in the variables than does imposing the U.S. 10% of production quota. Any specific comments on the time paths of change are concentrated on the polar case of the complete ban on imports.

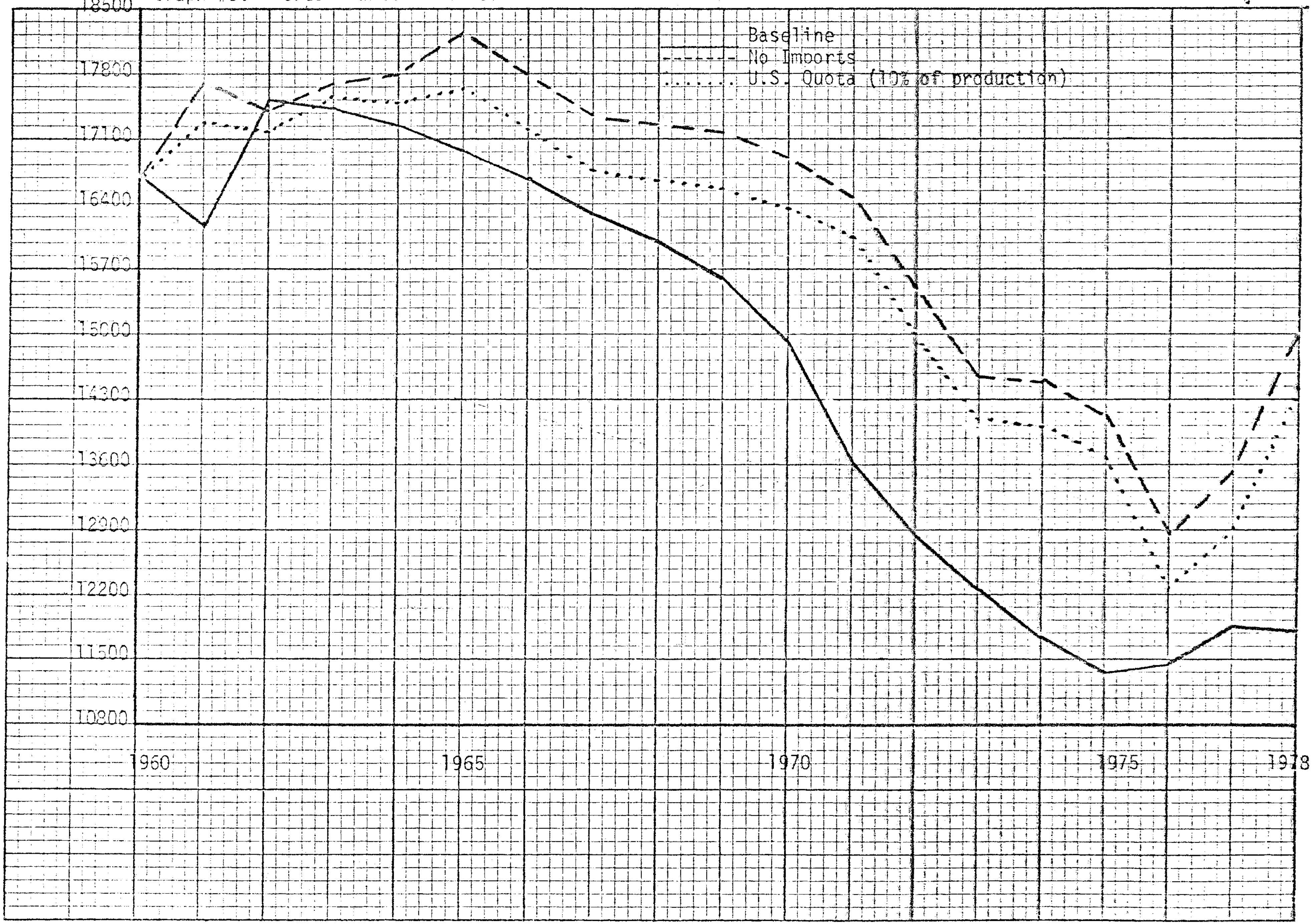
Acres Planted

Import restrictions have only a small effect on acres planted in the spring, increasing aggregate acres for 1960-1978 by 2.8% when all imports are barred, and having virtually no effect (increase of .002%) under the 10% quota. The effect on acreage is significantly greater in the winter quarter, where aggregate acreage is increased 10.8% and 7.7% for the import ban and 10% quota, respectively.

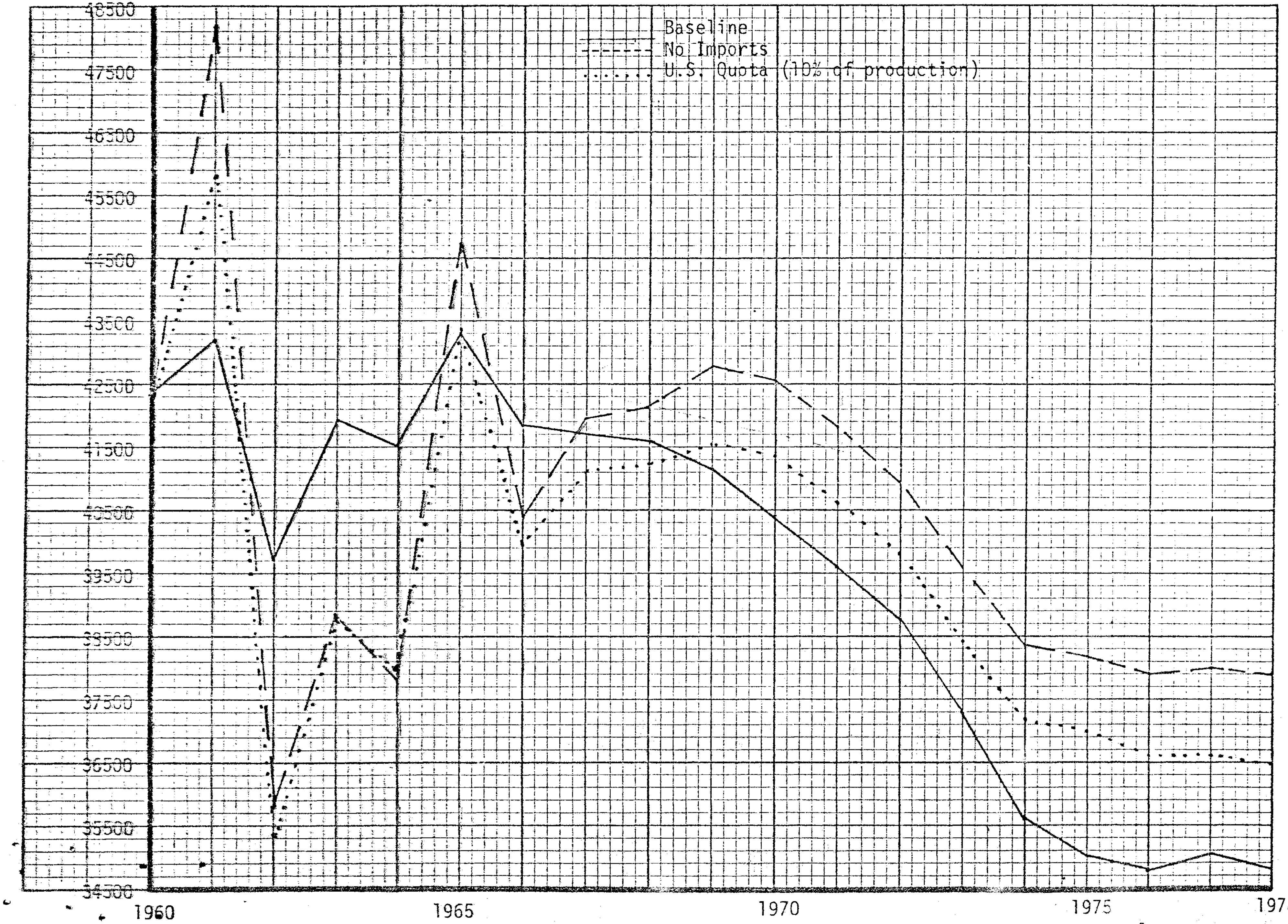
Time paths for the simulated variables are illustrated in graphs 9 and 10. Notice that complete elimination of the Mexican supply source results in more violent disruptions in acres planted over time when there are exogenous shocks to the system as compared to the baseline solutions. This is especially evident in graph 10 for the sping quarter, where in the first year (1960), a freeze caused a significant loss of domestic production, which under the import ban, causes extremely high prices that induce rather violent cyclical variations in acres planted (and in prices) in subsequent years.

Quantity Supplied

Domestic quantity supplied is substantively affected by restictions on imports. In the winter quarters, aggregate quantity supplied during 1960-1978 is increased by 47.0% and 33.2% under the ban and 10% quota, Graph #9. Acres Planted - Winter.



Graph #10. Acres Planted - Spring.



respectively. The corresponding figures for the spring quarters are 6.7% and 22.0%, respectively.

The time paths for the simulated variables are illustrated in graphs 11 and 12. The winter graph 11 illustrates that in the absense of Mexican imports, disruptions in quantities supplied during the 1970 to 1978 period induced by the freezes in 1970 and 1977, and the exceptionally good harvest of 1975 are accentuated. A similar pattern emerges following the spring freeze in 1960. It is also useful to notice that the import ban induces a steady expansion of quantity supplied in the spring quarters from 1968 forward, a time when historically the Mexican penetration into the U.S.-Canadian market was substantially increased.

U.S. Quantity Demanded

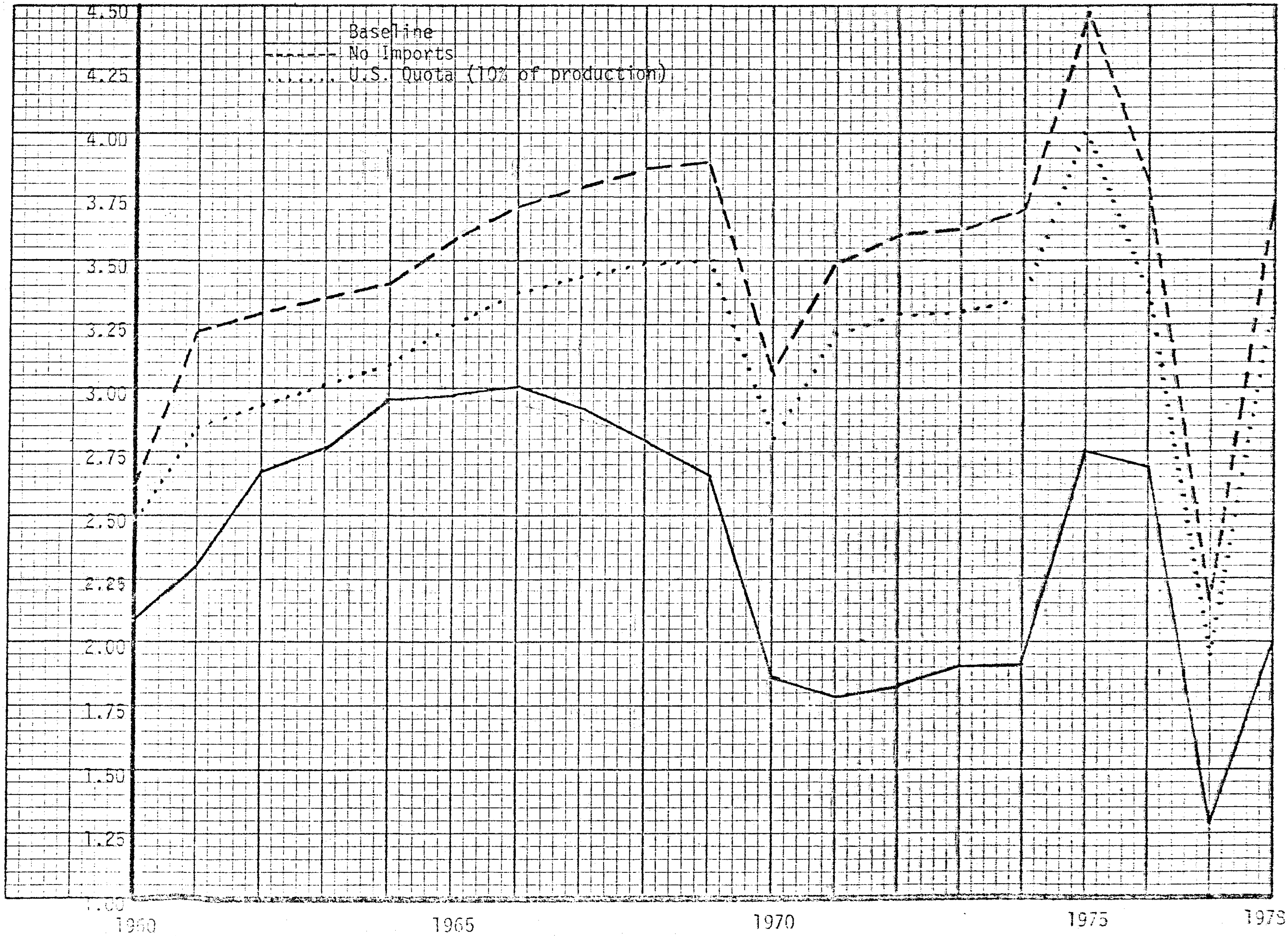
Aggregate consumption of fresh tomatoes is sharply reduced over the 1950-1978 period when import restrictions are applied. In the winter quarter consumption was rediced by 29.6% and 22.5% for the complete ban and 10% quota, respectively. In the spring quarter consumption was reduced by 15.2% and 9.1%, respectively.

The time paths of the simulated variables are illustrated in graphs 13 and 14. Similar to the patterns in supply, freezes in 1970 and 1977, and the exceptional harvest of 1975 cause violent swings in quantity consumed in the winter quarters. A similar discription for the spring quarter is induced by the spring freeze in 1960.

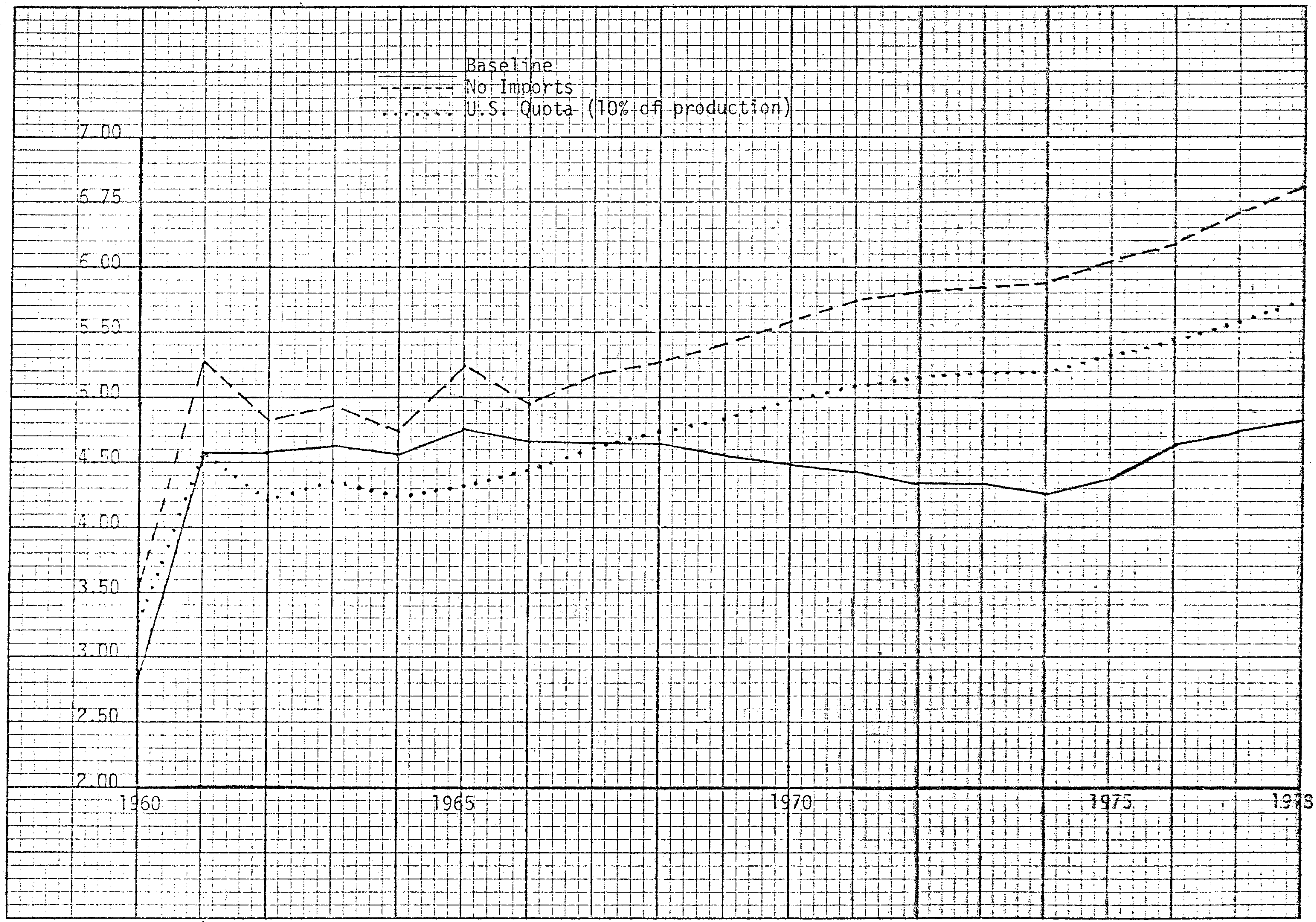
U.S. Prices

Restrictions on imports cause substantial changes in U.S. fresh cause tomato prices. In the winter quarter, the simple average of U.S. prices during the 1960-1978 period is increased by 29.8% and 25.1% for the total ban and the 10% quota, respectively. In the spring quarters, prices are

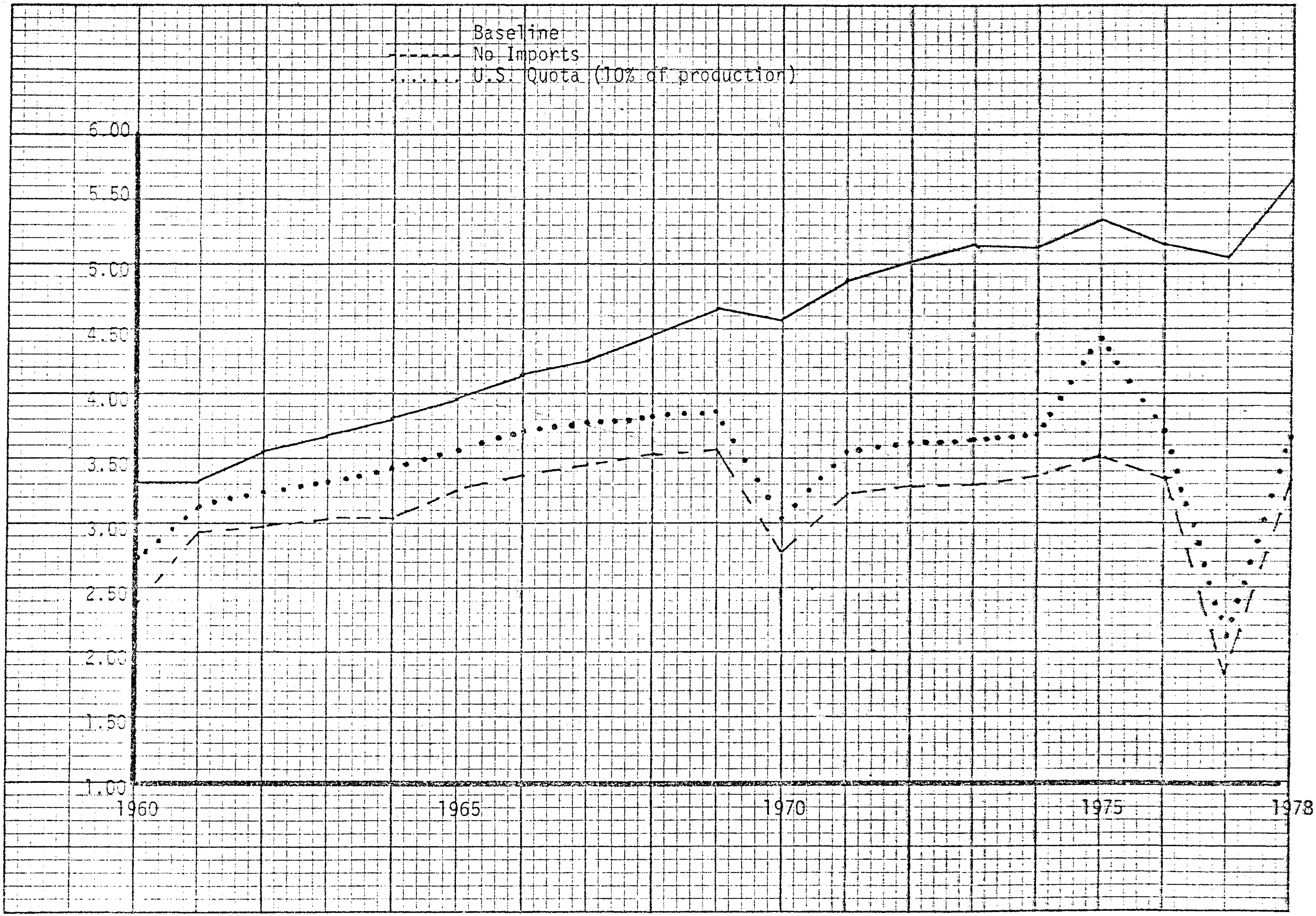
Graph #11. U.S.Quantity Supplied - Winter - Million cwt.



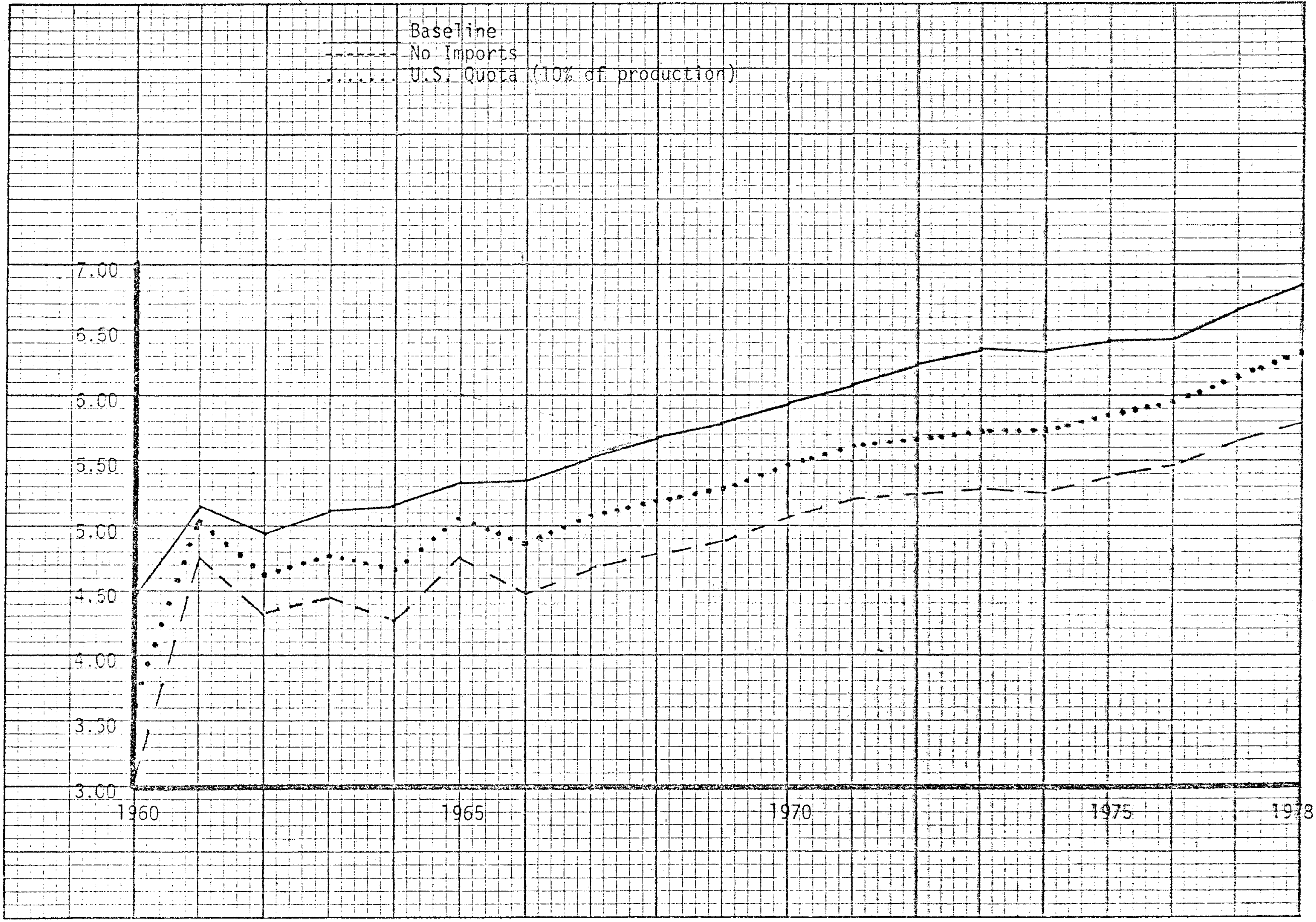
Graph #12. U.S. Quantity Supplied - Spring - Million cwts.



Graph #13. U.S. Quantity Demanded - Winter - Million cwts.



Graph #14. U.S. Quantity Demanded - Spring - Million cwts.



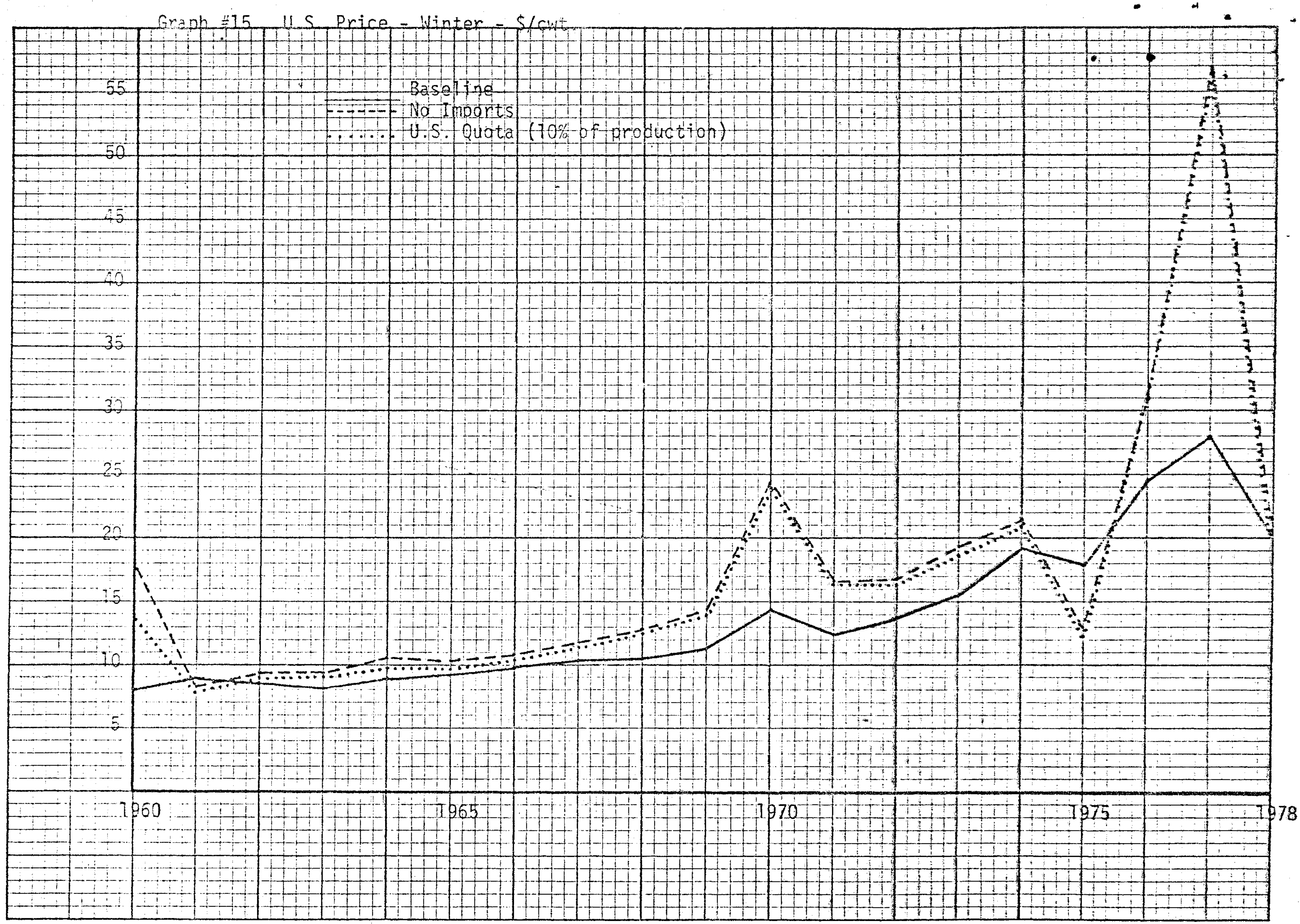
increased 14.1% and 7.2%, respectively. Similar patterns are evident in the quantity demanded and quantity supplied weighted average real prices for 1960-1978 period. These latter averages are displayed in Table 3.

The time path for simulated prices are illustrated in graphs 15 and 16. It is seen that the absence of Mexican imports cause a substantial amplification in price savings induced by the 1970 and 1977 freeze swings and 1975 exceptional harvest in the winter quarters, and by the 1960 freeze in the spring quarter.

Comments

The absence of Mexican exports to the U.S.-Canadian market results in greater instability in prices and domestic consumption, and results in substantially higher prices paid for fresh tomatoes in the winter and spring quarters (as judged by simple and weighted average real prices) than when Mexican supply is available. Thus, from the standpoint of the tomato consumer, the participation of Mexico in the winter-spring tomato market provides the benefit of more stable prices coupled with the opportunity for more stable consumption patterns in the quarters.

On the other hand, participation of Mexican growers in the U.S.-Canadian tomato market significantly reduces the ability of the market to compensate producers with higher prices when domestic quantity supplied is uncontrollably restricted. In addition, potential expansion of the productive capability of the domestic tomato industry appears to have been substantially muted by the participation of Mexican growers in the market.


Graph #15 U.S. Price - Winter - $/cwt
Baseline
No Imports
U.S. Quota (10% of production)
55
50
45
40
35
30
25
20
15
10
5
1960
1965
1970
1975
1978

Graph #16. U.S. Price - Spring - $/cwt.

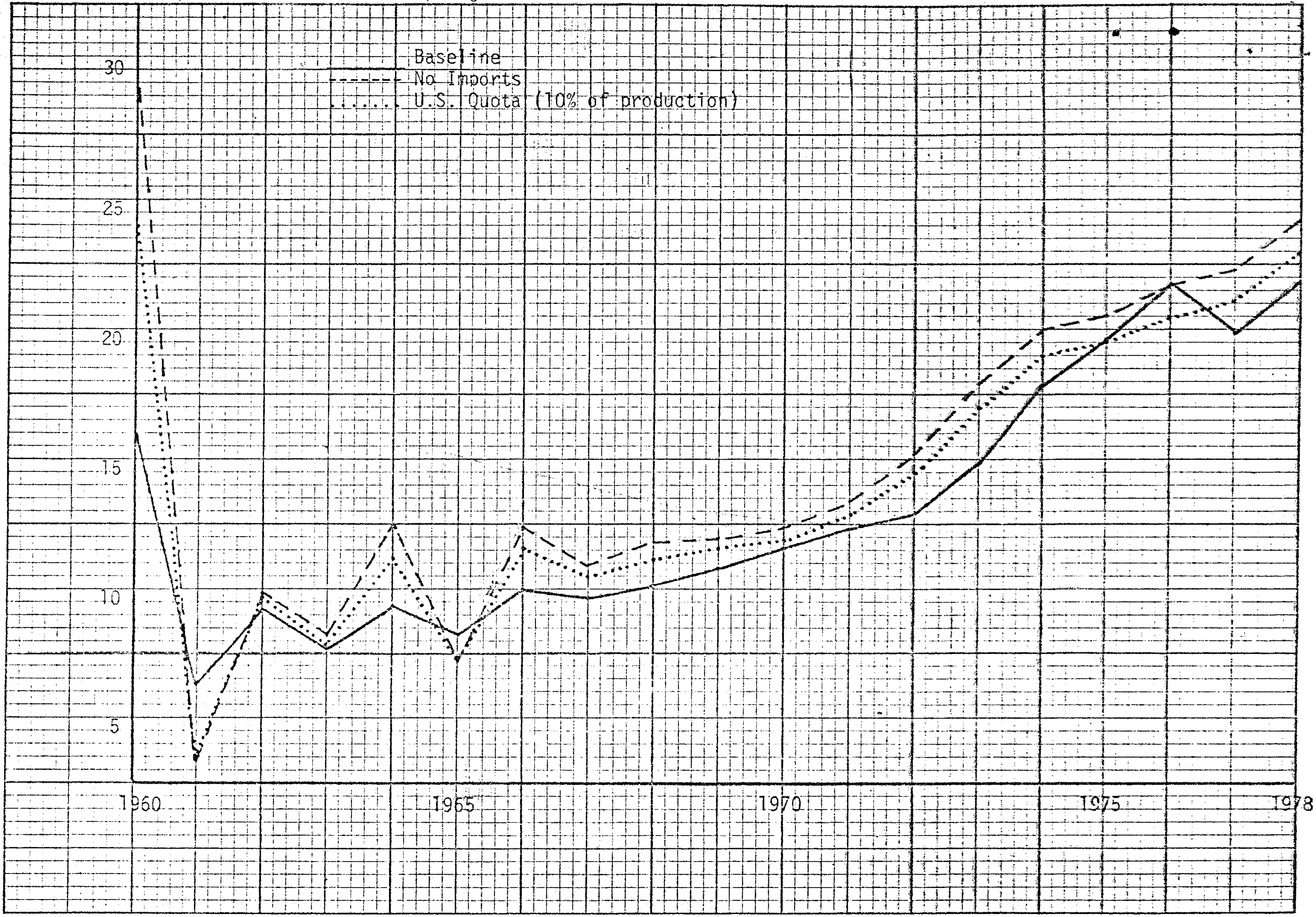


Table 3. Summary of Aggregate Changes from Baseline for Selected Simulated Variables, 1960-1978 Period, Import Restrictions.

	10% of U.S. Production Quota		No Imports to U.S-Canada	
	Winter	Spring	Winter	Spring
Acres Planted	7.7%↑	0.0%↑	10.8%↑	2.8%↑
U.S. Quantity Supplied	33.2%↑	6.7%↑	47.0%↑	22.0%↑
U.S. Quantity Demanded	22.5%↓	9.1%↓	29.6%↓	15.2%↓
Avg. U.S. Tomto Price[1/]	25.1%↑	7.2%↑	29.8%↑	14.1%↑
Wt. Avg. Real Demand Price[2/]	17.0%↑	7.6%↑	21.1%↑	12.3%↑
Wt. Avg. Real Supply Price[3/]	18.6%↑	9.4%↑	26.2%↑	14.5%↑

[1/]The average U.S. Tomato price is a simple average 19 quarters.

[2/]U.S. Quantity demanded-weighted average of price deflated by consumer price index for appropriate quarters in 1960-1978.

[3/]U.S. Quantity supplied-weighted average of price deflated by consumer price index for appropriate quarters in 1960-1978.

V. Concluding Remarks

The main objective of this paper was to provide a quantitative perspective on the importance of Mexico in influencing prices and quantities in the U.S. fresh tomato industry. It was found that the Mexican influence, especially on prices, domestic quantities supplied and domestic quantities demanded, and especially in the winter quarter, was substantial. It was also found that the degree of competition was sensitive to the tariff rate, and that the current tariff provides substantial protection of domestic growers- consistent with conjectures.

The Mexican supply has acted as a buffer against violent fluctuations in prices and quantities in times when the domestic crop was severely restricted due to weather conditions. The buffer effect also prevented the market from stabalizing revenue to domestic producers in times of short supply.

Attitudes towards Mexican competition in the U.S. fresh tomato industry must ultimately be r? famed with benefits to consumers and costs to producers in mind. The simulation model indicates that policy instruments are available which can significantly affect the degree of Mexican competition, as well as the distribution of the benefits and costs of that competition to consumers and producers, respectively.

There are a number of areas for future work that have the potential to improve the model and its results. Canadian supply should be modeled endogenously, and the data enabling this to occur are being assembled. Improved data on the Mexican situation would enable a more detailed modeling of the Mexican supply and diversion to the U.S.-Canadian market, but there is presently difficulty in securing the needed information.

Differentiation of the relationships by quarters in terms of slope shifting (perhaps seperate equation estimation) and by regions may improve the modeling of domestic supply response. Finally, expansion of the model to include substitutes on the supply side could prove to be useful.

Appendix: Mixed Estimation Using Uniformly Distributed Prior Stochastic Constraints

Mixed estimation is a method for deriving an estimate of the unknown parameter vector β in the linear model

(A.1) $\quad y = x\beta + u$

that is subject to the stochastic constraints

(A.2) $\quad r = R\beta + V$

(see Theil for details concerning the basic mixed estimator). The constraints (A.2) are often generated by the researcher in a subjective manner, representing a distillation of commodity specialist opinion, introspection, and the results of past studies.

To the authors' knowledge, all the empirical applications of the technique have assumed normality of the disturbance term V, as well as normality of u. Unfortunately, for certain applications, the use of the normality assumption may imply more prior information about the linear combinations $R\beta$ than the researcher is comfortably willing to admit. For example, if a researcher is willing to bet 19:1 that a given coefficient $\beta \varepsilon [0, 1]$, he might represent this prior information as

(A.3) $\quad .5 = \beta_1 + V$

with

(A.4) $\quad V \sim N\ (0,\ .065077)$

This then implies a 95% confidence interval in the usual sense utilizing the pivotal quantity

(A.5) $$\frac{.5 - \beta_1}{(.2551)} \sim N(0, 1),$$

defining the probability statement

(A.6) $$\Pr[-1.96 \leq \frac{.5 - \beta_1}{(.2551)} \leq 1.96] = .95,$$

and pivoting to obtain

(A.7) $$\Pr[0 \leq \beta_1 \leq 1] = .95.$$

However, following this example, the assumption of normality also implies, among other things, that the researcher is willing to bet approximately 2:1 that $\beta \epsilon [.25, .75]$, something he may be uncomfortable about doing. The point is, another distribution - the uniform distribution, may be more useful in that it assigns equal probability to all equal-length subintervals in the domain of definition of the uniform density. Thus, for example, a researcher can adequately incorporate information such as the prior notion that an income elasticity is in the inelastic range [0, 1], without incorporating any additional information concerning differing probabilities of various equal-length subintervals in the [0, 1] range.

Unfortunately, once the assumption that V is normally distributed is removed, the mixed estimator is no longer normally distributed, and the convenient and familiar normal theory useful for hypothesis testing and confidence interval construction is no longer applicable. The distribution of the mixed estimator must be derived anew, and hypothesis tests and confidence intervals determined accordingly.

We now discuss the distribution of the mixed estimator when the stochastic constraints are associated with independent uniform distributions. We concentrate initially on the relevant theory for cases in which OLS can be applied to the general linear model. Extensions to 2SLS are straightforward resulting in the same final conclusions.

The standard formula for the mixed estimator is

$$\hat{\beta} = (\sigma^{-2}X'X + R'\Psi^{-1}R)^{-1}(\sigma^{-2}X'y + R'\Psi^{-1}r) \tag{A.8}$$

which in view of (A.1) and (A.2) can be rewritten as

$$\hat{\beta} = \beta + Au + BV \tag{A.9}$$

where it is assumed that

$Euu' = \sigma^2 I$, $Eu = 0$,

$EVV' = \Psi$, $EV = 0$,

and $EuV' = 0$.

Thus from (A.9) it is seen that $\hat{\beta}$ is a linear combination of entries in the normally distributed vector u and the uniformly distributed vector V. The distribution of this linear combination can be derived in principle, but the distribution involves integrals that do not exist in closed form. Numerical integration of the expressions becomes infeasible for even a moderate number of entries in the V vector (details are available from the authors).

However, there are useful results that can be derived concerning probability statements wrt. specific entries in the $\hat{\beta}$ vector, and wrt to univariate tests of capatibility between sample information and prior constraint. These topics are examined in turn.

Probability Values Associated with Standard t tests as Upper Bounds

In this section, we prove that the probability value associated with the conventional asymptotic t-test of significance asymptotically forms an upper bound to the true probability value associated with the null hypothesis $\hat{\beta}_i = 0$ when $\hat{\beta}_i$ is the mixed estimator combining normally distributed sample information and uniformly distributed prior information. Thus, if a coefficient is signficant at the α-level of type I error using the conventional t-test, it is significant at the $k < \alpha$ level of type I error in actuality (asymptotically).

We actually prove the result for the simplest case where j, the number of prior constraints, is one. The extension to the case $j > 1$ is an obvious extension of the proof for $j = 1$.

Proof:

Examine a linear combination of the entries in the random vector $(\hat{\beta} - \beta)$.

$$\text{(A.10)} \qquad Ci'(\hat{\beta} - \beta) = Ci'Au + Ci'BV = U_* + V_*$$

and let Ci be a (K x 1) column vector of zeros except for a 1 in the i^{th} position, and thus u* is a normally distributed scalar random variable with mean zero and variance $\sigma^2 a_{i.}' a_{i.}$ where $a_{i.}$ is the i^{th} row of A. The variable V_* is a uniformly distributed random variate, since $Ci'B = B_i$, the i^{th} entry in the B vector, and a scalar times a uniformly distributed random variate is itself distributed uniformly. Examine the ratio

$$\text{(A.11)} \qquad R_u = \frac{Ci'(\hat{\beta} - \beta)}{(Ci'\Lambda^{-1}Ci)^{1/2}},$$

where R_u denotes the fact that V_* is distributed uniformly, and the probability statement

$$\text{(A.12)} \qquad Pr[-K \leq \frac{Ci'(\hat{\beta} - \beta)}{(Ci'\Lambda^{-1}Ci)^{1/2}} \leq K]$$

$$= \Pr\,[-K \le \tilde{u}_* + \tilde{V}_* \le K]$$

$$= \Pr\,[-K-\tilde{u}_* \le \tilde{V}_* \le K-\tilde{u}_*]$$

$$= E_{\tilde{u}_*}[\Pr\,(-K-\tilde{u}_* \le \tilde{V}_* \le K-\tilde{u}_* \mid \tilde{u}_*)]$$

$$= E_{\tilde{u}_*}[\Phi_u(K - \tilde{u}_*) - \Phi_u(-K - \tilde{u}_*)]$$

where $E_{\tilde{u}_*}$ denotes the expectation taken with respect to the normal distribution of $\tilde{u}_*$, $\Phi_u(\cdot)$ refers to the cumulative distribution function of the uniformly distributed random variable $\tilde{V}_*$, and $\tilde{u}_*$ and $\tilde{V}_*$ are proportional to u_* and V_*. It is clear that

(A.13) $$E_{\tilde{u}_*}\Phi_u(K - \tilde{u}_*) = \int_{-\infty}^{\infty} \frac{1}{2\pi\sigma_{\tilde{u}_*}} e^{-1/2 \frac{\tilde{u}_*^2}{\sigma_{\tilde{u}_*}^2}} \int_{-\infty}^{K - \tilde{u}_*} \frac{1}{b-a} I_{(a,b)}(\tilde{V}_*)\,d\tilde{V}_*\,d\tilde{u}_*$$

where $I_{(a,b)}(\tilde{V}_*)$ is the indicator function (see Mood, Graybill, & Boes).

Compare the value of $E_{\tilde{u}_*}\Phi_u(K-\tilde{u}_*)$ to

(A.14) $$E_{\tilde{u}_*}\,\Phi_n(K-\tilde{u}_*) = \int_{-\infty}^{\infty} \frac{1}{2\pi\;\sigma_{\tilde{u}_*}} e^{-1/2 \frac{\tilde{u}_*^2}{\sigma_{\tilde{u}_*}^2}} \int_{-\infty}^{K-\tilde{u}_*} \frac{1}{2\pi(\frac{b-a}{\sqrt{12}})} e^{-1/2 \frac{\tilde{V}_*^2}{(\frac{(b-a)^2}{12})}} d\tilde{V}_*\,d\tilde{u}_*$$

where $\Phi_n(\cdot)$ denotes the cumulative normal distribution with $Ev=0$ and $EV^2 = (b-a)^2/12$. It is obvious that

(A.15) $$\int_{o}^{\delta} \frac{1}{b-a}\, I_{(a,b)}(\tilde{V}_*)\, d\tilde{V}_* \ge \int_{o}^{\delta} \frac{1}{2\pi(\frac{b-a}{\sqrt{12}})} e^{-1/2 \frac{\tilde{V}_*^2}{(b-a)^2/12}} d\tilde{V}_*$$

for any $\delta > o$, and since $\Phi_n(o) = \Phi_u(o) = .5$, and since the maximum value of $N(0, \sigma_{\tilde{u}_*}^2)$ occurs at zero (which is associated with $K-\tilde{u}_* = K > 0$), it follows that

(A.16) $E_{\tilde{u}_*} \Phi_u(K-\tilde{u}_*) > E_{\tilde{u}_*} \Phi_n(K-\tilde{u}_*)$.

An analogous argument shows that

(A.17) $E_{\tilde{u}_*} \Phi_u(-K-\tilde{u}_*) < E_{\tilde{u}_*} \Phi_n(-K-\tilde{u}_*)$

whence it follows immediately that

(A.18) $Pr[-K \leq R_u \leq K] > Pr[-K \leq R_n \leq K]$

where R_n is the ratio in (A.11), but assuming a normal distribution for V.

Standard asymptotically valid t-ratios, $\hat{R}_n$, are formed by substituting a consistent estimate, $\hat{\Lambda}$, for Λ in the denominator of the ratio. Thus, (A.18) becomes an asymptotically valid bound, implying the following relationship between probability values under the null hypothesis $\beta = \beta_o$:

(A.19) $Pr[|R_u| \geq K] < Pr[|R_n| \geq K]$.

Univariate Compatibility Tests

A test of compatibility between a uniformly distributed stochastic constraint and sample information can be based on the standard probability value concept. The point estimate of $R\beta$ generated by least squares applied to sample information is simply Rb, and is distributed normally, with mean $R\beta$ and variance $\sigma^2 R(x'x)^{-1}R'$, where it is assumed here that R is a row vector of constrants and u is normally distributed. The prior point estimate of $R\beta$ is r, and is distributed uniformly, and under the null hypothesis has expectation $R\beta$. Define the difference between the sample and prior point estimate of $R\beta$ as

$$(A.20)\quad d = r - Rb = R\beta + V - R\beta - R(x'x)^{-1}x'u$$
$$= V - R(x'x)^{-1}x'u$$
$$= V - u_*$$

under the null hypothesis of compatibility (i.e., $Er = ERb = R\beta$), where $u_* \sim N(0, \sigma^2 R(x'x)^{-1}R')$, and V is uniformly distributed with mean zero. The two-sided probability value associated with having observed a value of $d = \xi$ under the null hypothesis is

$$(A.21)\quad \Pr[|d| \geq \xi] = 1 - \Pr[-\xi \leq d \leq \xi]$$
$$= 1 - \Pr[-\xi \leq V - u_* \leq \xi]$$
$$= 1 - \Pr[-\xi + V \leq u_* \leq \xi + V]$$

The probability value can then be calculated via a rather straightforward numerical integration of

$$(A.22)\quad 1 - \int_a^b \frac{1}{b-a}\, I_{(a,b)}(V) \int_{-\xi+V}^{\xi+V} \frac{1}{2\pi\sigma_{u_*}}\, e^{-1/2\left(\frac{u_*^2}{\sigma_{u_*}^2}\right)}\, du_* dV$$

Since $\sigma_{u_*}^2 = \sigma^2 R(x'x)^{-1}R'$ is generally unknown because σ^2 is unknown, consistent estimates of the probability values must be obtained by subsituting a consistent estimate of $\sigma_{u_*}^2$ in (A.22). The test is then performed with reference to a critical level of the probability value, traditionally .05.

Selected References

Fliginger, C. John, et. al. "Supplying U.S. Markets with Fresh Winter Produce: Capabilities of U.S. and Mexican Production Areas." U.S.D.A. Agr. Econ. Rpt. No. 154, March, 1969.

Goldberg, R.A. Agribusiness Management for Developing Countries -- Latin America. Boston, Mass: Ballinger Publishing Co., 1974.

Johnston, J. Econometric Methods. New York: McGraw-Hill, Inc., 1972.

Mood, A.M., F.A. Graybill, and D.C. Boes. Introduction to the Theory of Statistics. New York: McGraw-Hill, Inc. 1974.

Simmons, Richard L., et. al. "Mexican Competition for the U.S. Fresh Winter Vegetable Market." U.S.D.A. Agr. Econ. Rpt. No. 348, August, 1976.

Theil, H. Principles of Econometrics. New York: John Wiley and Sons, Inc., 1971.

Ware, George W. and J.P. McCollum. Producing Vegetable Crops. Danville, Illinois: Interstate Printers and Publishers, Inc., 1968.