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U.S. Kiwifruit Industry Model: Annual Supply and Monthly Demand

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ABSTRACT

A dynamic econometric model of the U.S. kiwifruit industry provides a framework for empirical analysis of small-scale commodities, particularly those used by producers for diversification. Production and marketing processes are explained by annual and monthly components, respectively. Results confirm that plantings were speculative and that economic feasibility critically impacts acreage retention as the industry matures. Prices at alternative outlets and fruit quality in storage affect monthly shipments. Flexibilities of monthly f.o.b. prices imply elastic kiwifruit demand, and imports are found to be substitutes. The industry could increase its average annual gross revenue by marketing the crop earlier in the season.

Key Words: *econometrics, demand flexibility, imports, kiwifruit, specialty crop.*

In response to the added market volatility following the 1996 Farm Act, agricultural producers have frequently pursued enterprise diversification as a risk-management strategy (Harwood *et al.*). For many regions of the country, particularly the Southeast, the Northeast, and the Pacific states, specialty crops serve as diversification alternatives. Yet the economic consequences of venturing into these small-scale specialty crops are not well understood. One way to gain this understanding is to develop an economic model of the industry structure of these crops and use the model for prediction and analysis. Since limited data are often a characteristic of the specialty industries, it is important to develop a model based on sound economic theory that takes advantage of the available data. We present such an analysis for the U.S. kiwifruit industry.

Kiwifruit is a specialty crop that consumers recognize worldwide. Originally called *Chinese gooseberry,* the kiwifruit plant was brought from China to New Zealand in the beginning of the 20th century. Following World War II, New Zealanders marketed the fruit as kiwifruit, and its success encouraged the export of vines to other temperate-zone countries. Kiwifruit first entered the U.S. market in 1962, and California producers initiated commercial production during the subsequent decade.

Kiwifruit, a perennial vine crop, requires four years for the initial crop and an additional four years to reach full yield. A high initial investment is necessary on vines, trellises, and

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agricultural land of high quality with a permanent irrigation system. Production and acreage in California boomed in a speculative fashion during the 1970s and the early 1980s. Since the end of the 1980s, global expansion in acreage, production, and trade has lowered the growers' price in every producing region including the U.S. (USDA/FAS). A tray equivalent of kiwifruit (7 pounds), which sold for $13 or more in 1980, is currently marketed for under $3 (1982–84 dollars). Today, there are approximately 6,600 acres of kiwifruit vineyard in the U.S. producing about 35,000 tons per year, compared to a peak of 7,300 acres and 52,000 tons of production in the beginning of the 1990s. These changes occurred despite an increase in U.S. per-capita consumption to one-half pound per person in the mid-1990s (USDA/ERS).

Kiwifruit can be stored for more than six months after harvest but spoils within a year. In a typical season, the California crop is harvested during October and November and is marketed through May. There are several months at the beginning and end of the marketing season when imports from the Southern Hemisphere, primarily New Zealand and Chile (where harvest is during April and May), are marketed concurrently with domestic fruit. The domestic industry has enacted several measures to compete with these imports. The California Kiwifruit Commission (CKC) was established in 1980 to promote U.S. kiwifruit on behalf of California kiwifruit growers. In response to the CKC's lobbying effort, a federal marketing order for kiwifruit was established in 1985 and was extended to imports from all countries in 1990. In 1992, anti-dumping tariffs were imposed on all New Zealand kiwifruit as a result of a dumping charge filed by the CKC.

To date no study of the U.S. kiwifruit industry has captured the factors of supply and demand in a dynamic economic framework to assess the impacts of changes in the industry on growers' return. The objectives of this research are to analyze the determinants of supply, demand, and the price received by U.S. kiwifruit growers using a dynamic model of the industry, and to provide a modeling framework for other specialty crops with limited available data. Specifically, we (1) investigate the effectiveness of the industry's efforts to alleviate competition from imports, (2) identify the factors which affect kiwifruit shipments, (3) estimate the price flexibility of U.S. kiwifruit demand, and (4) suggest how U.S. kiwifruit growers could enhance their returns. To achieve our objectives we conceptualize, estimate, and validate a dynamic industry model. Our results provide a quantitative description of the U.S. kiwifruit industry and a framework that may be applied to analyze production and marketing decisions of other fresh horticultural commodities with seasonal production.

In subsequent sections we discuss the conceptual and empirical specifications of the industry model. The model framework, which is based on farm-level relationships, consists of an annual component depicting the production process and a monthly component representing the marketing process. We then present and interpret estimation results. We perform static and dynamic simulations for the estimated sample period, and use the model to forecast two crop years beyond the sample. Finally, we draw implications from the results regarding how growers could enhance their returns.

Model Development

This study is the first economic analysis of the U.S. kiwifruit industry.[1] The model includes two sectors with different periodicities—the production sector, following the literature on perennial crops, determines the annual production volume, and the marketing/demand sector determines monthly shipments and the price received by growers. In what follows, crop years are defined from October through September.

Production

Bearing acreage in the current crop year (BA_t) is defined as the bearing acreage in the pre-

[1] According to a recent literature search, there are no other economics studies on kiwifruit (February 2000).

vious year (BA_{t-1}), plus the acreage planted k years ago (N_{t-k}, $k = 5$ for kiwifruit) coming into bearing in the current year, less the acreage removed at the end of the previous year (R_{t-1}) (French; French and Bressler; French and Matthews; French, King and Minami). Since no historical data are available for kiwifruit plantings and removals, the variable of interest is a combined outcome of the two decisions, i.e., the net change in bearing acreage during the previous year ($NET_{t-1} = N_{t-5} - R_{t-1}$).[2] Factors from both planting and removal decisions affect net acreage changes. Growers' planting and removal decisions may be based on expected per-acre profitability of kiwifruit production and of alternative crop production, and on non-farm opportunities such as converting land to residential districts, at the time respective decisions are made (French and Matthews). The institutional changes initiated by the industry against competition with imports—the establishment of the federal marketing order and New Zealand's anti-dumping case—may have encouraged acreage to remain in production. In addition, severe weather would induce removals of vineyards.

It follows that the current number of bearing acreage in crop year t is the sum of the bearing acreage in the previous year and the net acreage change at the end of the previous year.

$$(1)\qquad BA_t = BA_{t-1} + NET_{t-1}.$$

Annual production of kiwifruit (QP) is determined by multiplying the current number of bearing acres by yield, where per-acre yield is considered to be exogenous.

$$(2)\qquad QP_t = BA_t \times YIELD_t.$$

[2] Knapp and Konyar propose a method for estimating planting and removal decisions for perennial crops. Their method requires observations on average yield per age class over time, which are not available for kiwifruit. A state-space model would allow the unobservable planting and removal decision to be distinguished (Kalaitzandonakes and Shonkwiler). Yet it is not feasible for this application because the kiwifruit industry is relatively new and the number of observations is limited.

Marketing/Demand

The marketing process of U.S. kiwifruit, from harvest in October through May, may be conceptualized as a series of monthly allocation decisions across three outlets—domestic shipments, exports, and inventory—where prices are determined by domestic and export inverse demands. Export shipments must meet a stringent size and quality requirement, which cannot be captured by modeling export allocation decisions.[3] Thus, we model the allocation decisions for domestic shipment and inventory changes, and export quantities are determined residually. A small country assumption is used in this model, since U.S. exports account for less than 2 percent and imports for less than 17 percent of annual world trade volume in the mid-1990s (USDA/FAS).[4] This assumes that prices quoted for exports and arriving imports are exogenously determined at the international level. In addition, import quantities are assumed exogenous, because data are insufficient to estimate a behavioral equation. Hence, there are three current endogenous variables in this system of equations: domestic shipments (*QDOM*), change in inventory (*DINV*), and the monthly f.o.b. (free-on-board) price (*FOBDOM*).[5]

For market allocation decisions, the quantity allocated to each outlet is specified as a function of relevant current and expected future prices and total available supply (French

[3] Based on conversations with the industry, marketers prefer to export all fruit that meet the exporting criteria because of higher prices. The majority of handlers do not have access to such quality fruit, and the size and quality of fruit are determined by detailed production practices and other biological factors, which are beyond the scope of the available data.

[4] The percentage share of imports may seem substantial, but the majority of imports arrive at U.S. ports during the spring and summer. Our analysis focuses on the U.S. marketing season (fall and winter), when U.S. imports account for a much smaller percentage of world trade.

[5] The f.o.b. prices for California kiwifruit are published daily by the Federal-State Market News Services (USDA/AMS). These prices differ from the port-of-entry import prices published by the U.S. Department of Commerce.

and King).[6] Shipment decisions to the U.S. market depend on the trade-offs between current and future revenues and between revenues from domestic and export markets. Relevant prices are the current prices in the domestic and export markets and expected future prices in the two markets, assuming that price expectations are formed by economically rational agents. Total available supply is annual production. In addition, the number of months kiwifruit has been in storage enters into the marketing decisions, because the fruit diminishes in quality over time and is ultimately perishable.

The level of inventory at the end of a month is the sum of beginning inventory, incoming harvest, and monthly arriving imports, minus the total quantity of shipments during that month. The change in inventory—specified here as beginning minus ending inventory—is dependent on factors similar to those affecting the domestic shipment. Alternatively, this specification can be regarded as an inverse supply-of-storage equation (Tomek and Robinson). Export shipment is obtained as the sum of the monthly changes in inventory and incoming harvest, minus monthly domestic shipments and any quantity culled at packing and lost during storage and marketing.

The demand relationship for California kiwifruit in the U.S. market determines the price. The real f.o.b. price, the dependent variable of the inverse demand equation, is a function of domestic shipment volume, shipment volume of imported kiwifruit, shipment volume of related fruit, levels of promotional activities, real per-capita income in the U.S., and the marketing margin between primary and derived demand.

The annual f.o.b. price is obtained as an average of monthly prices for domestic and export shipments, weighted by the respective shipment volumes over a crop year. The annual price, in turn, is the major determinant of growers' profit expectations, which determine production levels in subsequent years.

Empirical Model

All equations in the model are assumed to be linear in parameters. In what follows, kiwifruit volume is measured in tray equivalents (1 TE = 7 pounds). All variables in the empirical specification are defined in Table 1, and details of data sources are discussed in Hanawa, Willett, and Tomek. In order to facilitate the discussion, the equation numbers correspond to those in Table 2, where the model is presented as a complete dynamic system.

Production

As discussed above, the net acreage change (*NET*) in Year $t-1$ is the difference between plantings in Year $t-5$ and removals in $t-1$. Thus, NET_t is a function of factors that influence planting and removal decisions in Years $t-4$ and t, respectively, which include the expected profit from kiwifruit and alternative crop production, non-farm opportunities, and institutional changes against competition with imports. As the most important agricultural alternative to kiwifruit production, clingstone peaches are selected.[7]

Expected profitability of crop production depends on revenue per acre and costs of establishment and production, but there are no time-series data for industry-specific costs. As

[6] In practice, individual shipment is specified by fruit size and container-type, for which prices vary accordingly. Conceptually, therefore, there are as many shipment functions as the number of combinations of size and container type. Since such details cannot be modeled easily and are beyond the purpose of this study, the model is developed at an aggregate level, i.e., quantities in various container types are expressed in tray equivalents and summed across all sizes.

[7] Various tree fruits and nuts were considered as an alternative crop to kiwifruit. Peaches are mentioned as a specific crop for which the production environment is comparable to that of kiwifruit in the pomology literature (e.g., Beutel), and the major production areas of clingstone peaches and kiwifruit correspond at the county level. Mr. Mark Houston at the CKC stated that a period of low returns for clingstone peach growers occurred in the early stage of the kiwifruit industry, inducing some acreage conversion from peaches to kiwifruit (1995). Two-year-old clingstone peaches begin to bear fruit and full yield is achieved in four to five years; the orchards are relatively easy to pull out and re-establish.

Table 1. Empirical Variable Definitions[a]

ADPRO(a)	CKC's annual advertising expenditures	(1982–84 $)
APR(m)	April	(April = 1, 0 otherwise)
AVGFOB(a)	Average of monthly f.o.b. prices	(1982–84 $/TE)
BA(a)	Bearing acres	(acres)
CPI(a)	Consumer Price Index for food	(1982–84 = 100)
DEC(m)	December	(December = 1, 0 otherwise)
DINC(m)	U.S. income	(1982–84 $/person)
DINV(m)	Change in inventory	(1,000 TE)
DSPR(m)	Farm-retail price spread	(1982–84 = 100)
DU(a)	Industry's anti-import measures	(1990/91, 1991/92 = 1, 0 otherwise)
EKIWI(a)	Expected kiwifruit revenue-cost ratio	(dimensionless)
EPEACH(a)	Expected peach revenue-cost ratio	(dimensionless)
FEB(m)	February	(February = 1,0 otherwise)
FOB(a)	Annual f.o.b. price	(1982–84 $/TE)
FOBDOM(m)	Monthly f.o.b. price for domestic shipment	(1982–84 $/TE)
FOBDOME(m)	Monthly expected price for domestic shipment	(1982–84 $/TE)
FOBEX(m)	Monthly f.o.b. price for export shipment	(1982–84 $/TE)
FOBRAT(m)	*FOBDOM/FOBDOME*	(dimensionless)
INV(m)	Ending inventory	(1,000 TE)
JAN(m)	January	(January = 1, 0 otherwise)
LQDOM(m)	Logit of $QDOM_t/INV_{t-1}$	(dimensionless)
KIWI(m)	Kiwifruit revenue-cost ratio	(dimensionless)
MAR(m)	March	(March = 1, 0 otherwise)
NET(a)	Net acreage change	(acres)
NOV(m)	November	(November = 1, 0 otherwise)
OCT(m)	October	(October = 1, 0 otherwise)
OCTALL(m)	*OCT* × *QALL*	(October = *QALL*, 0 otherwise)
PPI(a)	Price Paid by Farmers index	(1992 = 100)
QALL(m,a)	*QSHIP* − *QSEPT*	(1,000 TE)
QDOM(m)	Domestic shipment	(1,000 TE)
QEX(m)	Export shipment	(1,000 TE)
QIM(m)	Shipment of imported kiwifruit	(1,000 TE)
QP(a)	U.S. kiwifruit production	(1,000 TE)
QSEPT(a)	September shipment	(1,000 TE)
QSHIP(a)	U.S. utilized production	(1,000 TE)
REV(m)	Monthly revenue per unit of shipment	(1982–84 $/TE)
UNITAD(m)	Monthly advertising expenditures	(1982–84 $/TE)
URB(a)	Population growth rate	(percentage)
YIELD(a)	Yield	(1,000 TE/acre)

[a] (a) and (m) denote annual and monthly variables, respectively.

a proxy for profitability in a given crop year, per-acre gross revenue—the product of the annual f.o.b. (growers') price and total volume of utilized production divided by bearing acreage—is deflated by the Index of Prices Paid by Farmers for items used for production, interest, taxes, and wage rates. Expectations are assumed to be consistent with the principle of economic rationality, i.e., agents are aware of the stochastic process generating the revenue-cost ratio (Feige and Pearce). The kiwifruit ratio (*KIWI*) was found to be a unit root process and the clingstone peach ratio (*PEACH*) an MA(1) process.

In Year $t-4$, growers choose whether to reallocate peach acreage to kiwifruit production. Given the five-year biological lag in producing kiwifruit, growers make this choice by comparing expected peach profitability in the following year ($t-3$) to expected kiwifruit prof-

Table 2. Empirical U.S. Kiwifruit Industry Model, 1986/87–1994/95[a]

Bearing Acreage

(1) $\boldsymbol{BA_t} = \boldsymbol{BA_{t-1}} + \boldsymbol{NET_{t-1}}$

Production and Utilized Production

(2) $\boldsymbol{QP_t} = \boldsymbol{BA_t} \times YIELD_t$

(3)[b] $$\underset{}{\boldsymbol{QSHIP_t}} = \underset{(226.51)}{-164.104} + \underset{(0.03)^*}{0.873}\ \boldsymbol{QP_t} \qquad R^2 = 0.989 \qquad Adj{\cdot}R^2 = 0.988 \qquad D - W = 1.891^{b}$$

(4) $\boldsymbol{QALL_t} = \boldsymbol{QSHIP_t} - QSEPT_t$

Allocation and Demand

Domestic Shipment

(5) $$\boldsymbol{LQDOM_t} = \underset{(0.69)}{0.313} + \underset{(0.76)^*}{1.591}\ \boldsymbol{FOBRAT_t} - \underset{(0.06)^*}{0.135}\ FOBEX_t - \underset{(0.29)^*}{4.695}\ OCT_t - \underset{(0.29)^*}{3.648}\ NOV_t$$
$$- \underset{(0.29)^*}{3.461}\ DEC_t - \underset{(0.29)^*}{2.934}\ JAN_t - \underset{(0.29)^*}{2.619}\ FEB_t - \underset{(0.30)^*}{1.994}\ MAR_t - \underset{(0.29)^*}{1.110}\ APR_t$$
$$R^2 = 0.890 \qquad Adj{\cdot}R^2 = 0.874 \qquad D - W = 1.875$$

(6) $\boldsymbol{QDOM_t} = \boldsymbol{INV_{t-1}} \times (\exp(\boldsymbol{LQDOM_t})/(1 + \exp(\boldsymbol{LQDOM_t})))$

Change in Inventory

(7) $$\boldsymbol{DINV_t} = \underset{(524.80)}{54.994} - \underset{(99.86)}{172.25}\boldsymbol{REV_t} - \underset{(104.60)}{120.488}FOBDOME_t + \underset{(0.03)^*}{0.090}\ \boldsymbol{QALL_t} - \underset{(0.04)^*}{1.081}\ \boldsymbol{OCTALL_t}$$
$$+ \underset{(420.00)}{643.026}OCT_t + \underset{(164.40)^*}{424.743}\ NOV_t + \underset{(166.30)^*}{517.056}\ DEC_t + \underset{(172.80)^*}{928.841}\ JAN_t + \underset{(169.30)^*}{993.000}\ FEB_t$$
$$+ \underset{(164.80)^*}{1101.963}MAR_t + \underset{(154.10)^*}{432.354}\ APR_t \qquad R^2 = 0.994 \qquad Adj{\cdot}R^2 = 0.993 \qquad D - W = 1.347$$

U.S. Demand

(8) $$\ln(\boldsymbol{FOBDOM_t}) = \underset{(0.18)^*}{1.726} - \underset{(0.0001)^*}{0.00066}\ \boldsymbol{QDOM_t} + \underset{(0.00007)^*}{0.00017}\ \boldsymbol{QDOM_{t-1}} - \underset{(0.00009)^*}{0.00026}\ QIM_t$$
$$+ \underset{(0.49)^*}{1.253}\ UNITAD_t - \underset{(0.0004)}{0.00023}DINC_t - \underset{(0.002)}{0.00351}DSPR_t$$
$$R^2 = 0.822 \qquad Adj{\cdot}R^2 = 0.805 \qquad D - W = 1.475$$

Price Expectation

(9)[c] $$\boldsymbol{FOBDOME_t} = \underset{(0.25)^*}{0.625} + \underset{(0.04)^*}{0.973}\ \boldsymbol{FOBDOM_{t-1}} - \underset{(0.21)^*}{0.489}\ OCT_t - \underset{(0.21)^*}{1.045}\ NOV_t - \underset{(0.21)^*}{0.824}\ DEC_t$$
$$- \underset{(0.21)^*}{0.691}\ JAN_t - \underset{(0.21)^*}{0.519}\ FEB_t - \underset{(0.21)}{0.385}MAR_t - \underset{(0.21)}{0.110}APR_t$$
$$R^2 = 0.926 \qquad Adj{\cdot}R^2 = 0.916 \qquad D - W = 1.921$$

Export

(10) $\boldsymbol{QEX_t} = \boldsymbol{DINV_t} + \boldsymbol{QALL_t} - \boldsymbol{QDOM_t}$

Variables Defined

(11) $\boldsymbol{FOBRAT_t} = \boldsymbol{FOBDOM_t/FOBDOME_t}$

(12) $\boldsymbol{REV_t} = (\boldsymbol{FOBDOM_t} \times \boldsymbol{QDOM_t} + FOBEX_t \times \boldsymbol{QEX_t})/(\boldsymbol{QDOM_t} + \boldsymbol{QEX_t})$

(13) $$\boldsymbol{UNITAD_t} = \frac{ADPRO_t}{8 \times \sum_{t=1}^{12} (\boldsymbol{QDOM_t} \times 1000)}$$

Table 2. (Continued)

Annual Price

(14) $$\boldsymbol{FOB_t} = \underset{(0.21)}{0.136} + \underset{(0.05)^*}{0.861}\, \boldsymbol{AVGFOB_t} \qquad R^2 = 0.979 \qquad \text{Adj}\cdot R^2 = 0.976 \qquad D - W = 2.221$$

(15) $$\boldsymbol{AVGFOB_t} = \sum_{t=1}^{12} \left[(\boldsymbol{FOBDOM_t} \times \boldsymbol{QDOM_t}) \middle/ \sum_{t=1}^{12} \boldsymbol{QDOM_t} \right]$$

Annual Revenue

(16) $$\boldsymbol{KIWI_t} = (\boldsymbol{FOB_t} \times \boldsymbol{QSHIP_t} \times 1000 \times CPI_t)/(\boldsymbol{BA_t} \times PPI_t)$$

(17) $$\boldsymbol{EKIWI_t} = \boldsymbol{KIWI_{t-1}}$$

Net Acreage Change

(18) $$\boldsymbol{NET_t} = \underset{(1171.90)}{-1162.85} - \underset{(0.04)}{0.047}\boldsymbol{EKIWI_{t-4}} - \underset{(0.27)}{0.177}EPEACH_{t-4} + \underset{(0.08)^*}{0.347}\, \boldsymbol{EKIWI_t} - \underset{(187.60)}{30.601}\, URB_t$$
$$+ \underset{(316.20)}{162.366}DU_t \qquad R^2 = 0.766 \qquad \text{Adj}\cdot R^2 = 0.620 \qquad D - W = 2.149$$

[a] See Table 1 for variable definitions. Figures in parentheses are standard errors. Endogenous variables are in bold face. * indicates significance at the 5 percent level.

[b] Estimated by OLS using 15 observations from 1980/81 to 1994/95.

[c] Estimated by OLS using 69 observations from 1986/87 to 1994/95.

itability in Year $t+1$. The expected profitability of peaches $E_{t-4}[PEACH_{t-3}]$ is calculated from the estimated MA(1) equation using OLS residuals, and appears in the model as $EPEACH_{t-4}$. The expectation for kiwifruit, $EKIWI_{t-4} \equiv E_{t-4}[KIWI_{t+1}]$, is the realized value of *KIWI* in Year $t-4$ because it follows a unit root. The expected influences of expected kiwifruit and peach profitabilities on net acreage change are positive and negative, respectively.

At the beginning of Year t, growers must decide whether to maintain their kiwifruit acreage or convert the land to other farm or non-farm uses. In the model, the values of these alternatives are represented by expected peach profitability in Year $t+2$ (peaches require two years to bear fruit) and the rate of population growth in the eight major kiwifruit-producing counties in California, respectively.[8] Thus, the relevant information for growers who are considering a removal decision is expected kiwifruit profitability in Year $t+1$ ($EKIWI_t$), expected peach profitability in $t+2$ ($E_t[PEACH_{t+2}]$), and the current rate of population growth (URB_t). Given the MA(1) process, $E_t[PEACH_{t+2}]$ is a constant that is incorporated in the intercept and is not modeled explicitly. The effects of the regressors $EKIWI_t$ and URB_t on net acreage change are expected to be positive and negative, respectively.

Due to the limited degrees of freedom, a single dummy variable for institutional changes (DU) is specified to equal one in 1990/91 and 1991/92 for the extension of the federal marketing order to imports and the imposition of anti-dumping tariffs, respectively, and zero otherwise.[9] A positive coefficient on the dummy variable implies that growers benefited from these measures against competition from imports. The estimated net acreage change equation is

(18) $$NET_t = f(EKIWI_{t-4}, EPEACH_{t-4}, EKIWI_t, URB_t, DU_t, \epsilon_{N,t}),$$

[8] The eight counties are Tulare, Butte, Kern, Kings, Yuba, Sutter, Fresno, and Stanislaus. Collectively, they account for over 90 percent of U.S. kiwifruit production.

[9] We presume that the impact of the federal marketing order on growers' expectation was larger when the marketing order was extended to all imports in October 1990, than its establishment in 1985. The anti-dumping tariffs went into effect in May 1992.

where all variables on the right-hand side are predetermined and/or exogenous.

Marketing/Demand

Since prices appear to follow a seasonal pattern, the rationally expected price in any month is based on monthly trends and the past month's price (Table 2, Equation 9). Because exporting is not an option for the majority of handlers, the expected export price is not used in the analysis. In order to circumvent the data limitations on harvest loss, cull from initial pack-out, and repack loss over the marketing season, it is assumed that annual shipment volume (*QSHIP*) is a linear function of production volume (Table 2, Equation 3).

Because domestic shipment in Month i ($QDOM_i$) cannot exceed beginning inventory, it must be modeled as a limited dependent variable (Greene). Thus, the dependent variable in the domestic shipment equation is specified as the proportion of beginning inventory (INV_{t-1}) that is shipped domestically. This proportion is related to current and expected prices through the logistic expression

$$\frac{QDOM_t}{INV_{t-1}} = \frac{\exp(\mathbf{x}_i'\beta)}{1 + \exp(\mathbf{x}_i'\beta)},$$

where the elements of $\mathbf{x}_i$ are the observed regressors in Month i and β is the vector of parameters. The relevant price regressors are current and expected real f.o.b. prices per TE of domestic shipment and the current f.o.b. price for export shipment (*FOBEX*). The ratio between the first two price variables (*FOBRAT*), which reflects relative prices, is included as a single regressor to resolve collinearity among the price variables. The coefficients on these variables measure the change in the log-odds ratio of stored kiwifruit being shipped domestically per unit change in the regressor (Gujarati, p. 555). The expected signs on the coefficients of the ratio and the export price are positive and negative, respectively. Seven monthly zero-one variables are included as proxies for marketers' expectation of quality differences due to storage over the eight-month marketing season (October through May), with May as the base month. In addition, these dummy variables would account for remaining monthly variations in domestic shipments that the other model variables are unable to capture. The estimated domestic shipment equation is

$$(5)\quad LQDOM_t = f(FOBRAT_t, FOBEX_t, OCT_t, NOV_t, DEC_t, JAN_t, FEB_t, MAR_t, APR_t, \epsilon_{D,t}),$$

where

$$LQDOM_t = \ln\left(\frac{QDOM_t/INV_{t-1}}{1 - QDOM_t/INV_{t-1}}\right).$$

The dependent variable in the change in inventory equation (*DINV*) is calculated from domestic and export shipments (*QEX*) and incoming harvest (*OCTALL*) according to the formula $DINV_t = QDOM_i + QEX_t - OCTALL_i$, where $OCTALL_t$ is zero in all months except October. The current domestic and export prices and the expected price for domestic shipment (*FOBDOME*) are the relevant price regressors. The first two prices are averaged, weighted by respective volumes, as a variable representing the per-unit shipment revenue (*REV*). Since *DINV* is the reduction in inventory, the expected signs on current and future revenues are negative and positive, respectively. Total available supply is specified as the total volume to be allocated over the marketing season starting in October 1 (*QALL*).[10] For each observation i in crop year t, the annual value of *QALL* is repeated, and its coefficient is expected to be positive. Similar to the domestic shipment equation, the monthly dummy variables account for marketers' expectations on quality differences associated with the length of time after harvest. Shipment decisions in October are made with uncertainty as the available supply increases throughout the month. These decisions are distinct from decisions in the other months, since those are

[10] The volume-to-be-allocated (*QALL*) is total annual shipment (*QSHIP*) less some kiwifruit that are occasionally harvested early and shipped in September (*QSEPT*) (Table 2, Equation 4).

based on a fixed available supply. The difference between the decisions varies according to the size of the incoming harvest. Hence, an interaction dummy variable between October and total available supply, *OCTALL*, is included to allow for this difference. The empirical change in inventory equation is

$$(7) \quad DINV_t = f(REV_t, FOBDOME_t, QALL_t, OCTALL_t, OCT_t, NOV_t, DEC_t, JAN_t, FEB_t, MAR_t, APR_t, \epsilon_{I,t}).$$

Export shipment (*QEX*) is obtained by the identity

$$(10) \quad QEX_t = DINV_t + OCTALL_t - QDOM_t.$$

In the inverse domestic demand equation, both current and one-month lagged domestic shipments are included to investigate the nature of price adjustment. The expected sign of the coefficient on the current quantity is negative, but that of the lagged quantity depends on the nature of the adjustment process. Imported kiwifruit is held in domestic storage facilities before actual shipment, but the quantity of imported kiwifruit shipped from storage facilities each month is unknown. Thus, the average quantity of current and one- and two-month lagged imports (*QIM*) is specified as a proxy for the shipment of imported kiwifruit during the current month. Since imports are believed to be substitutes during the domestic marketing season, their coefficient is expected to be negative. Because of constraints in degrees of freedom, measures of other fruit are not included. A proxy for the CKC's monthly promotional activities (*UNITAD*) is constructed from annual advertising expenditures spent in the U.S. market per unit of domestic shipment, divided by the number of months in the California marketing year. No lag is included because the construction of the variable eliminates monthly variation, and there are no data regarding New Zealand's promotional activities. Monthly changes in per-capita disposable personal income and the farm-retail price spread for fresh fruit, adjusted for inflation, are included (*DINC, DSPR*). The coefficient on the income variable is expected to be positive; the sign on the spread's coefficient depends on the nature of marketing costs. The estimated domestic demand equation is

$$(8) \quad FOBDOM_t = f(QDOM_t, QDOM_{t-1}, QIM_t, UNITAD_t, DINC_t, DSPR_t, \epsilon_{F,t}).$$

Dynamic Model and Estimation Results

In the production sector, the net acreage equation (18) was estimated by OLS assuming independence of the random error term, using 14 annual observations from 1980/81 to 1993/94, inclusive. The results may be subject to small sample bias. In the marketing/demand sector, the monthly allocation and demand equations (5,7,8,10) comprise a system of simultaneous equations and were estimated by 3SLS. Due to the nonlinearities in the system, the dependent variable in the demand equation (8) was specified in logarithms. The data file for this estimation included monthly observations for crop years 1986/87 through 1994/95; observations for the 1995/96 and 1996/97 crop years were reserved for forecasting. Price variables were missing during the off-season (typically June through September of each year), yielding 69 usable observations. Observed values were used for all lagged variables. The results are presented in Table 2 as equations of a complete dynamic system.[11]

Production

The results for equation (18) confirm the speculative nature of early investment in kiwifruit production; neither the expected profitability

[11] Cointegration tests were performed on all equations. Using the Dickey-Fuller test, we reject the null hypothesis of no cointegration for the domestic shipment (5), change in inventory (7), and domestic demand (8) equations, but not for the net acreage change equation (18). However, the sample size is small and the lack of power of the Dickey-Fuller test is well known (e.g., Myers). According to the Park test, we cannot reject the null hypothesis of the existence of cointegration for all equations.

from kiwifruit nor peach production at the time of planting had a significant impact on net acreage change. On the other hand, removal decisions critically depend on expected profitability from kiwifruit. A unit increase in the revenue-cost ratio retained 0.35 acres of bearing acreage *ceteris paribus*. The elasticity at the sample mean indicates a 6.9-percent increase in the net acreage change due to a one-percent increase in the expected revenue-cost ratio at the time removal decisions are made. Urbanization impacted net acreage in the expected direction but was statistically insignificant. Though the industry identified the importance of urbanization pressure, the best available proxy may not have captured its full impact. The coefficient on the dummy variable, which is intended to identify the industry's measures against import competition, was positive but statistically insignificant.

Marketing/Demand

In the domestic shipment equation (5), both economic trade-offs and physical characteristics of the commodity appear to be important. Taking the antilog of the coefficients, a *ceteris paribus* unit increase in the ratio of current to expected domestic prices increases by nearly four times the share of inventory that is shipped to the domestic market. If the current export price rises by a dollar, the share of stored kiwifruit shipped to the domestic market declines by 12.6 percent. The elasticities evaluated at the sample means suggest that domestic shipment would increase by 0.27 percent and decrease by 0.48 percent due to a one-percent increase in the current-expected price ratio and export price, respectively. These relatively low elasticities support our observations that marketers seem to move their inventory by seasonality, and that specialized requirements of size and quality for export shipments limit the allocation to exports in response to prices.

The biological and physical nature of kiwifruit handling and storage appears to be more important in determining the change in inventory than economic incentives (Equation 7). The coefficients on current and expected future revenues per shipment have expected signs but low statistical significance. The results further support the notion that the industry markets fruit primarily according to seasonality. Throughout the sample period shipments are concentrated in the middle of the season, and prices are correspondingly lower in those months. Prices do not recover until the end of the season and never attain the price level that prevailed at the beginning. This apparent anomaly is further addressed in the discussion of industry implications below. Crop size has a significant impact on the overall change in inventory, but its magnitude is small. The estimated elasticity is 0.65 at the sample mean. The coefficients on the monthly dummy variables indicate that the net impacts of January, February, and March shipments on inventory changes are nearly twice as large as the net impact of the remaining months' shipments.

The results for the inverse demand equation (8) imply that in the current month, a *ceteris paribus* 1,000 TE increase in the volume of domestic shipment leads to a 0.6-percent decline in monthly f.o.b. price. Evaluated at the mean of the sample, the flexibility is −0.55, implying elastic demand. Since kiwifruit has potentially many substitutes and complements, the reciprocal of flexibility, −1.81, is the lower limit of the actual elasticity. The coefficient on one-month lagged shipment implies that there is habitual consumption and that price adjustment with respect to quantity takes longer than a month. The long-run price flexibility is −0.79, the reciprocal of which is −1.27. Imports are found to be substitutes as expected; 1,000 TE more imports decrease the f.o.b. price by 0.26 percent. Flexibility with respect to imports is −0.07, which is much smaller in magnitude than own-quantity flexibility. The industry's concern about imports threatening the domestic market may not be justified, since the distinct U.S. price responses to imported and domestic kiwifruit suggest that consumers view them as different commodities. Regarding domestic advertising, a dollar per TE of advertising has increased the f.o.b. price by a factor of 1.25, which is economically significant; the price flexibility with respect to advertising expenditures is 0.21 at the sample mean. The coefficients on the income and spread variables are negative but statistically insignificant.

The dynamic industry model in a crop year begins by obtaining current bearing acreage using lagged values of bearing acreage and net acreage change (Equation 1). Next, production and total shipment volumes are calculated (Equations 2, 3), and the latter is adjusted for September shipments (Equation 4). Domestic shipment, changes in inventory, domestic f.o.b. price, expected price, export shipment, the ratio between the current and expected prices, per-shipment revenue, and unit advertising expenditures are simultaneously determined within the system of monthly equations (Equations 5–13). The average of monthly price predictions, weighted by predicted levels of corresponding domestic shipments, is adjusted to attain the annual f.o.b. price (Equations 14, 15).[12] This price enters into the net-acreage equation as the expected revenue-cost ratio (Equations 16–18). Bearing acreage and quantity of production in the succeeding year are determined in sequence.

Validation

Static and dynamic simulations were performed to validate the model over the sample period (Pindyck and Rubinfeld), and representative goodness-of-fit statistics were determined for the annual and monthly key variables. Overall, the statistics support the appropriateness of the model as a dynamic system.

In addition, the model was used to forecast two crop years (1995/96 and 1996/97) beyond the sample period using dynamic simulation. Since monthly prices were not available, export prices were computed as the average of the last three years in the sample—a period in which the yearly downward trend in real prices seems to have stabilized. Given the actual net acreage change in 1994/95, the model simulates bearing acreage, annual production, and monthly shipment for 1995/96. Based on the season average of simulated f.o.b. prices and net acreage change predicted at the end of 1995/96, the bearing acreage, annual production, and monthly shipment for 1996/97 are determined. Finally, the 1996/97 net acreage change is projected from the simulated season-average price.

The model replicates the seasonal pattern for domestic and export shipments and inventory changes for both years, and correctly predicts the downward trend in the annual f.o.b. price and net acreage change. The model's forecasting ability of major endogenous variables, measured by root mean square percentage error, is comparable to the in-sample dynamic simulation.[13] The only prediction with a large error is that for monthly export shipment, which is determined residually.

Conclusions and Implications for Industry Returns

The U.S. kiwifruit industry model was conceptualized and estimated incorporating distinct features of the industry. Specifically, the production process was explained by an annual component and the marketing process was depicted by a monthly component. The model was validated by means of in-sample simulation and forecasting beyond the sample. The analysis confirmed the speculative nature of early kiwifruit plantings in the U.S. and that as the industry has matured, economic feasibility is critical in retaining acreage in production. The effectiveness of industry efforts to alleviate competition from imports, such as anti-dumping charges against New Zealand, was measured by the amount of bearing acre-

[12] The adjustment is necessary due to the difference between the annual f.o.b. prices reported by the CKC and monthly observations based on the daily quotes by the Market News Service (USDA/AMS). The adjustment equation (14) is the estimated relationship between the two data series over the sample period, where monthly prices are averaged according to equation (15). Export prices are excluded from the calculation of annual average price to minimize the discrepancy.

[13] Root mean square percentage errors for *FOB*, *NET*, *DINV*, *QDOM*, and *QEX* were 17.3, 69.1, 67.7, 27.5, and 141.7, respectively.

age retained in production, but was not statistically important. Monthly shipment of kiwifruit was specified as a function of prices at alternative outlets and the quality of the fruit in storage, and both factors were found to be significant. The short-run and long-run flexibilities of monthly f.o.b. price were estimated to be -0.55 and -0.79, respectively, implying elastic U.S. demand for kiwifruit. The results suggested that the industry-wide advertising effort has successfully raised the prices received by growers *ceteris paribus*.

The main implication of this study is how kiwifruit growers could enhance their returns. In theory, arbitrage between markets in time leads to an equilibrium where future and present prices differ by storage costs. All else equal, we would expect a larger quantity marketed at the beginning of a season and a steady reduction throughout the season. But the U.S. kiwifruit industry does not follow this pattern. Using a simplified model, it is seen that the theoretically predicted marketing pattern ships the crop earlier in the season and generates average annual gross revenue of $27.6 million, compared to an observed average of $24.6 million during 1986/87 through 1994/95 (Hanawa, Willett, and Tomek).

Several explanations are possible for the seemingly irrational marketing pattern. One possibility is that a principal-agent problem exists. If the incentives for handlers do not align with those for the growers, growers may need to find a means of monitoring marketing decisions. A second explanation is that marketing decisions have been based on mistaken expectations about seasonal price changes. Perhaps marketers have expected seasonal price increases to cover storage costs, but this has not in fact happened. If this is so, our analysis might be used to improve estimates of seasonal price changes. A third possibility is that our analysis has not taken into account some unknown factor that influences the economics of storing and marketing kiwifruit. The presented model may serve as a basis for developing frameworks for further investigation of this seemingly uneconomic marketing pattern.

As is common in empirical econometric work, the quality of results is influenced by the quantity and quality of available data. This study of kiwifruit is limited by the proxy measures used for producers' expectations, the quality of data on advertising, imports, and exports, and potential structural changes that could not be manifested in the short sample period. Despite these limitations, the model predicts well, and these predictions could be further improved as more and better data become available. In particular, future studies could refine the analysis of advertising and incorporate the demand for U.S. exports by individual countries.

This effort provides a framework for empirical analysis of other horticultural commodities, especially those that are new or may be used as a means of speculative diversification. In particular, the research provides a model where limited data can be used to analyze an industry with annual production and a monthly marketing effort.

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