Regional and National Impacts of Expanded Pacific Northwest Potato Production

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A 46-equation econometric model of the U.S. potato market was developed. The model examines the determination of planted acreage, yield, production, and farm prices in the Pacific Northwest and in five other producing regions which compete with Northwest production. National demand relationships for potatoes used in processing, fresh consumption and livestock feed are also specified. These estimated relationships are used to simulate future scenarios which assume alternative rates of expansion for Northwest potato production. Results suggest that opportunities for considerable expansion of Northwest potato production exist if the secular shift in potato demand continues and increases in acreage are not excessive or expansion does not occur too quickly.

One notable change in Pacific Northwest agriculture during the 1970's was the increase in farmland under irrigation. Preliminary Census of Agriculture figures for Washington show an increase of irrigated cropland of 478,000 acres, or 39% between 1969 and 1978. Growth was particularly rapid between 1974 and 1978.

Further significant expansion is currently under consideration in some areas, and in progress for others. Whittlesey, et al. estimated that there are 2.2 million acres of potentially irrigable land in the Pacific Northwest, though development of much of this land may be economically infeasible at present. However, over 500,000 acres of this total are in the Columbia Basin area where federal development has been authorized.

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Work for this paper was done under Project 0330, College of Agriculture, Washington State University. Scientific paper No. SP 6004

Cropping patterns on irrigated lands tend to emphasize production of high value crops, such as potatoes, in order to cover large initial capital and operating costs. A major expansion of potato production in the Northwest would add significantly to national supply, yet the impact of additional supplies on Pacific Northwest growers, on producers in competing regions, and on consumers are unknown. In particular, Northwest potato producers are uncertain of their ability to market expanding production without depressing local and national potato prices.

Available evidence from past studies of potato demand indicate quantity demanded to be highly price inelastic [Brandow; George and King; Simmons; Zusman]. By itself, this suggests that rapid expansion in total potato production would have substantial depressing effects on potato price. However, the net market impacts depend not only on demand elasticity, but also the actual increase in Pacific Northwest production, the time interval over which production increases occur, shifts in potato demand, and the supply response behavior of producers in competing regions.

This paper reports the results of an investigation of these issues. A 46-equation econometric model of the U.S. potato market was developed. It models national demand for fresh potatoes and potatoes for processing; national and regional potato prices; and acreage, yield and production in the Pacific Northwest and in five other producing regions which compete with Northwest production. These estimated relationships are used to simulate future scenarios which assume alternative rates of expansion for Northwest potato production.

Potato Industry Considerations

Among all vegetable crops, potatoes have consistently ranked highest in terms of acreage, production, and value measures in the U.S. In 1981 there were 1.2 million acres harvested (.5 million hectares) resulting in approximately 330 million cwt of potatoes grown. Since 1955 potato production has expanded over 385 percent, but even more rapid expansion has occurred in Pacific Northwest (PNW) states. Currently, Washington, Idaho, and Oregon provide nearly half of all potatoes produced domestically, are each among the top five states in reported average yield per acre, and supply nearly 87 percent of the potatoes used for processing [Raleigh]. Sustained production growth in the PNW has occurred due to the high yield levels realized, the adoption of improved production technologies, and strong consumer acceptance of the varieties and product forms available from PNW suppliers.

Disappearance data indicate the major utilizations of potatoes can be identified as: (1) fresh consumption; (2) processed products; and (3) livestock feed. Human consumption typically accounts for three-fourths of total disappearance with the remaining one-fourth utilized by livestock feeders, seed stock users, and losses due to shrinkage factors. Fresh and processed forms have experienced persistent but opposite secular trends since mid-century. Per capita fresh consumption currently is one-half of its level in 1950. Conversely, per capita consumption of processed potatoes has increased 11-fold during the same time span. The trend toward higher consumption of processed products likely reflects a shift of consumer preferences in favor of convenience foods. The strength of processing demand has resulted in the per capita consumption for all potatoes increasing nearly 10 percent since 1955.

While positive trends for per capita consumption, production, and price are evident during the last twenty-five years, year-to-year variations in price and production have caused significant income disruptions for farmers and potato handlers. In part, production and price instability have been caused by comparatively free entry and exit in production, the absence of government supporting activities, and the uncertainty concerning harvest prices and total production at planting time.

Model Specification

The model is comprised of three families of equations: (1) regional and national supply relationships consisting of six regional acreage planted equations, six yield equations, and 24 supply related variable definitions; (2) national demand and price relationships consisting of three demand equations and a market clearing identity; and (3) six relationships which link national and regional prices.

The six supply regions considered are: the Pacific Northwest (PNW) consisting of Washington, Idaho, and Oregon; the Red River Valley (RRV); Maine; the North Central region (NC) consisting of Michigan and Wisconsin; the Central West (CW) consisting of Colorado and California; and all other states of the continental U.S. The specification of the supply response model attempts to acknowledge price uncertainty as an important factor affecting producer decisions. Farmer decision-marking under uncertainty within a free-market environment has been examined by Nerlove (1956, 1958), Carter and Dean, and Just (1974, 1977) among others. In addition, general theoretical considerations concerning decision-making behavior by Markowitz, Tobin, Cagan, and Anderson, et al. suggest that these decisions can be analyzed by examining the mean and variance values obtained from a subjective probability distribution of random variable outcomes.[1] This study utilizes the generalized adaptive expectations framework for incorporating risk suggested by Just (1974, 1977), subject to certain extensions adopted to improve estimator efficiency and to aid in the interpretation of estimator results [Estes; Estes, et al.]. In particular, unobservable expectation-type variables are constructed on the basis that producers form perceptions of both mean and variance of the subjective distribution of future prices through a Nerlovian adaptive adjustment process.[2] Further, it is assumed that the squared difference between true price outcomes and expected prices measures a degree of uncertainty surrounding the price expectation. Regional potato acreage equations ultimately utilized included expected regional potato prices, expected prices of principal substitutes, potato acreage planted in the previous year, and a measure of the uncertainty attached to expected potato prices.[3]

The equations for acreage in the Pacific Northwest, the Red River Valley, and Maine also contain a time trend, though the trend added little potato supply in any region except the Pacific Northwest. The trend variable in the PNW acreage equation is interpreted as primarily representing the effects of growth in the area under irrigation. No specific interpretation is offered for the trend in other regions' acreage equations, but the variable may capture the net effect of secular change in omitted economic variables. In addition, consideration was given to the possibility of a partial adjustment process in potato acreage determination by examining the effect of lagged potato acreage as a variable explaining current acreage.

Although a variety of attempts were made to model yields per planted acre in the six regions, potato yields are best explained by simple functions of time. Regional production is then defined as the product of acreage times yield.

The demand for potatoes is modeled as a derived demand at the farm level. Separate equations are used to model demand for potatoes to be consumed fresh, demand for potatoes to be used for processing, and demand for potatoes to be used as livestock feed.

The fresh and processed demands together represent the demand for human consumption. These demands are modeled on a per capita basis and include deflated U.S. average price received by farmers for potatoes, real per capita income, and the fraction of women in the U.S. labor force as explanatory variables. The proportion of women in the U.S. labor force is used as a proxy measuring consumer preference for convenience in food products. The fresh demand equation also includes an index of hourly wage rates in wholesale and retail trade (IWR), while the demand for processing equation contains the industrial wholesale price index (IWPI). Both indices are used to proxy the cost of marketing services affecting the marketing margin between farm and retail prices for potatoes. The IWR is chosen for the fresh demand

[1]Over successive periods the incorporation of previously perceived errors permits a producer to formulate expectations adaptively. Cagan and Nerlove offer excellent discussions of the expectation arguments.

[2]For a single output, Q, produced with inputs (X_1, X_2, $\ldots$, X_n), and for output and input prices (P, r_1, r_2, $\ldots$, r_n) expected profit is $E[PQ - \Sigma_i^N r_i x_i]$. The expression in brackets defines profit, or what is sometimes termed "gross margin." The randomness of such a quantity may be due to the randomness of output prices, input prices, or the process through which inputs are converted into output. The preferred circumstances would be to make use of expected profit or expected gross margins in empirical analysis. Oftentimes, data limitations preclude this approach and thus price expectation is employed as a reasonable proxy for returns. Price is one of the most important and most variable determinants of profit levels.

[3]The specification originally considered included measures of uncertainty attached to prices of substitute crops. These terms were dropped from final equations because t-values for their coefficients were much smaller than 1.0. See the section on Behavioral Model Results for discussion of the equation strategy used.

equation based on research conducted by the National Commission on Food Marketing indicating labor cost as the most important cost component in the movement of fresh fruit and vegetable products through the market channel. In the processing demand equation, the IWPI is felt to be a more suitable proxy for costs of marketing services, a substantial portion of which are associated with goods and services required in processing plant operations.

Initial specification of the feed demand relationship included livestock population and substitute feed variables in addition to the farm price of potatoes as explanatory variables. No significant statistical relationship could be found except between quantity of feed potatoes and farm prices, and thus feed demand is a simple function of farm price of potatoes.

U.S. average price received by farmers for the crop harvested in any year is determined as the price that equates the sum of fresh demand, demand for processing, feed demand, and miscellaneous minor demands (treated exogenously) with harvested supply.

Six equations are also specified to link regional average prices received by farmers to the national average price received by farmers. In each case, regional price is expressed as a function of national average price and a variable which captures the influence of the particular season in which a region's production is marketed.

Estimation Techniques

Most empirical results are obtained using conventional econometric procedures. The estimation of the acreage equations is somewhat less conventional. Under the specification adopted, planted acreage is related to the mean and variance of the subjective distribution of future potato prices, among other variables. The use of expectation variables, however, forces one to measure variables that are not directly observable. To handle this an attractive procedure suggested by Just (1974, 1977) was adopted and extended. It is based on the notion that producers form perceptions of both mean and variance of the subjective distribution of future potato prices through a Nerlovian adaptive adjustment process.

A basic prototype of the acreage equations can be represented as

$$(1) \quad A_t = \beta_0 + \beta_1 P^e_{t-1} + \beta_2 V^e_{t-1} + \mu_t$$

$$(2) \quad P^e_{t-1} = P^e_{t-2} + \phi\,(P_{t-1} - P^e_{t-2})$$

$$= \phi \sum_{i=0}^{\infty} (1-\phi)^i P_{t-i-1}$$

$$(3) \quad V^e_{t-1} = V^e_{t-2} + \phi\,[(P_{t-1} - P^e_{t-2})^2 - V^e_{t-2}]$$

$$= \phi \sum_{i=0}^{\infty} (1-\phi)^i (P_{t-i-1} - P^e_{t-i-2})^2$$

where μ_t is a vector of i.i.d. normal variates with mean zero and variance σ^2, A_t is acreage in year t, P_t is price received in year t, and P^e_t and V^e_t are the mean and variance, respectively, of the subjective distribution of year t+1 prices as perceived in year t. The acreage equation set is segmentable from the complete model, and thus the acreage equations can be estimated separately from the remaining equations in the model. The particular estimation technique used involves the construction of a consistent estimator of P^e_{t-1} and of V^e_{t-1} coupled with an application of nonlinear least-squares (in this case, equivalent to maximum likelihood) estimation that ultimately results in consistent estimates of all unknown parameters in the equations, including parameters associated with conventional regressors and the coefficient of adjustment, ϕ. The appendix provides a condensed account of the estimation procedure used (for additional details see Estes, and also Just (1974, 1977)).

Yield equations were estimated by ordinary least-squares (OLS) since only one endogenous variable per equation was specified. Under the conceptualization adopted in this study, season average farm price and annual levels of the three components of demand were simultaneously determined once total production and other predetermined variables were given. Therefore, each structural demand equation contained two simultaneously determined variables and two-stage least-squares (2SLS) was used for estimation. The human consumption demand relationships were estimated as linear functions of the explanatory variables, while feed demand was estimated as an exponential function of undeflated farm price. The six equations linking regional prices with national price were estimated by two-stage least-squares since each equation contained two jointly determined endogenous variables. The parameters of the general model were estimated using annual time series observations from 1955 to 1975.

Behavior Model Results

Parameter estimates for the regional acreage equations estimated via nonlinear least-squares methods are presented in Table 1, while Table 2 reports short-run and long-run acreage elasticities. An ad hoc strategy was adopted for choosing the final specification of the equations, whereby a variable was eliminated from the specification if both the conditional and unconditional t-values of its associated parameter estimate were less than 1.0 in absolute value, unless such elimination had a detrimental effect on the *a priori* reasonableness of the remaining parameter estimates. The specification of substitute crops as alternative production possibilities in each region was determined by conversations with researchers in each region, previous studies, and in part by the specification strategy indicated above. Finally, preliminary attempts to estimate the Central West equation under the partial adjustment hypothesis produced a coefficient on lagged acreage that was greater than 1.0. This result was inconsistent with the hypothesis, and we therefore respecified the equation omitting lagged acreage.

All estimated coefficient signs in the acreage set agree with *a priori* expectations. A range of ϕ values was obtained indicating that producer price expectations are formulated differently in the various regions. In four of the six regions (PNW, RRV, NC, OTH), there is a tendency to weight last period's observed price more heavily than last period's expected price in generating current price expectations. Estimated coefficient values on the variance regressor suggest that planting decisions are impacted by risk considerations in some of the regions, although the influence of risk does not appear large and does vary by region. Price risk can be managed through the use of forward pricing agreements with processors (contracting) and this influence may explain why inclusion of a variance term was unsuccessful in the equation for the PNW, a region in which contracting is a common practice.

The results suggest that the Pacific Northwest acreage is expanding at a rate of approximately 12,000 acres annually on the average (ceteris paribus). In the short-run, it is estimated that potato producers show only limited response to expected price in their output decisions. For the Pacific Northwest, Table 2 suggests that a 1 percent increase in expected price produces a .26 percent increase in planted acreage under average conditions, while the rest of the U.S. would increase planted acreage by .62 percent in response to a 1 percent increase in expected price. Estimated acreage responsiveness to price in the long-run is considerably higher, especially in Maine and the Other region. Mean value estimates for the 1955-75 period indicate a 1 percent increase in price produces approximately a 1.03 percent increase in plantings in the U.S. over the long term.

In general, the reported short-run acreage elasticities are consistent with results obtained by previous investigators. Direct comparisons are difficult, however, due to differences in seasonal or regional characeristics of models and data sets used, time, or other specifications. Short-run supply elasticities of acreage, by seasonal group, prior to 1950,

TABLE 1. Parameter Estimates for Regional Equations Estimated Via Nonlinear Least Squares Procedure.

Dependent variable	Intercept	Coefficients of independent variables[a]						TIME	ϕ	R^2
		EP^{POT}	EP^{SB}	EP^{HAY}	EP^{VEG}_{US}	VP^{POT}	AP_{t-1}			
AP_{PNW}	−285.4180	52.6556	−4.4235				.4747	7.0026	.684	.947
	(2.220/1.486)	(2.800/1.816)	(2.287/1.489)			c	(1.998/1.327)	(2.038/1.4206)	(n.a.[d]/1.567)	
AP_{RRV}	33.5574	23.6369	−4.5566			−11.1519	.4587	1.8089	.659	.545
	(.670/616)	(1.987/.732)	(2.474/1.296)			(2.148/.788)	(1.787/1.622)	(1.450/1.435)	(n.a./1.661)	
AP_{ME}	64.4280	31.6577		−2.3228		−7.6953	.7599	−.3183	.397	.821
	(2.683/2.507)	(4.604/2.069)		(2.761/1.928)		(4.676/2.115)	(5.067/5.057)	(.9837/.9185)	(n.a./4.567)	
AP_{NC}	36.5110	5.0238		−1.2461		−3.858	.7685		.933	.677
	(1.880/1.744)	(3.231/3.177)		(2.951/2.031)		(1.389/1.388)	(4.512/4.067)	c	(n.a./3510.100)	
Ap_{CW}	235.8630	124.7504	−13.5040		−244.0307	−15.3005	e	c	.108	.947
	(7.927/7.921)	(5.488/2.076)	(3.838/2.010)		(4.276/2.517)	(1.087/1.065)			(n.a./1.85)	
Ap_{OTH}	124.5309	35.2089[b]		−7.1637[b]			.8708	c	1.000	.982
	(3.236)	(7.545)		(6.121)		b	(918.521)		(n.a./n.a.)	

NOTE: Absolute t-values are given in parentheses below each parameter estimate. The first figure is a t-value calculated by using a standard error of the coefficient which is conditional upon ϕ being equal to the value estimate. The next figure is t-value calculation based on the information matrix and is not conditional on ϕ. See Estes, Blakeslee and Mittelhammer for details on calculation of standard errors and t-values. Symbols have the following meanings: EP^{POT}, EP^{SB}, EP^{HAY} and EP^{VEG}_{US} are expected prices of potatoes, sugar beets, hay and vegetables, respectively: VP^{POT} is subjective variance of potato prices; AP_{t-1} is lagged potato acreage; TIME is the year-1900; AP_{PNW}, AP_{RRV}, AP_{ME}, Ap_{NC}, AP_{CW}, and AP_{OTH} are planted potato acreages in the Pacific Northwest, Red River Valley, Maine, the North Central West, and the other states, respectively.

[a]Each independent variable is to be associated with the region of the dependent variable.

[b]Expected price in OTHER region is the most recent period's actual price. Variance is zero and therefore not estimated; coefficients and t-values are then simply those obtained from OLS estimation.

[c]Insignificant coefficients were obtained.

[d]n.a. = not applicable

[e]Preliminary testing produced a coefficient value greater than 1.0. This result seems unreasonable and therefore the lagged acreage variable is excluded in the cw equation.

TABLE 2. Estimated Elasticities of Potato Acreage Planted with Respect to Expected Potato Price, Expected Price of Substitutes, and Variance of Potato Price, by Region.

	Short-run elasticities with respect to:					Long-run elasticities with respect to:
Region[a]	EP^{POT}	EP^{SB}	EP^{HAY}	EP^{VEG}	VP^{POT}	EP^{POT}
PNW	.259	−.169				.493
RRV	.189	−.273			−.045	.349
MAINE	.476		−.460		−.085	1.982
NC	.131		−.266		−.005	.566
CW	2.053	−1.137		−1.485	−.054	2.053[b]
OTHER	.239		−.438			1.850

NOTE: Elasticities calculated at mean levels for 1955-75 data.

[a]Regional abbreviations are as follows: PNW — Pacific Northwest (Washington, Idaho and Oregon); RRV — Red River Valley; NC — North Central (Michigan and Wisconsin); CW — Central West (Colorado and California); OTHER — all other states.

[b]There is no distinction between the long run and short run values in the CW region since the lagged acreage term does not appear in this equation.

ranged from .12 by Hee to .21 by Gray, Sorenson, and Cochrane to .31 by Pubols and Klaman. More recently, Cardwell and Davis estimated the short-run elasticity of acreage response for fall potatoes during 1958-77 to be approximately .14. Estimates made here suggest that Central West acreage elasticities with respect to expected prices of potatoes and substitutes are higher than their counterparts for other regions. This may be because California acreage dominates this region's total, and the presence of numerous high-valued alternatives to potatoes in California is leading to higher elasticity.

Table 2 results also imply that a 1 percent decrease in price risk, as defined by VP^{POT}, would lead to an increase of plantings from .005 percent to .085 percent in various regions. While direct comparisons of risk's impact on potato plantings as investigated by other researchers are not available, these values are consistent with risk elasticity values obtained by Lin in his investigation of wheat (.06), by Ryan in his investigation of Pinto beans (.09), and Traill in his study of onions (.04).

Demand equation results indicate that consumers do not change consumption drastically in response to price changes (Table 3). Under average conditions, demand for fresh potatoes is estimated to decrease .12 percent for each 1 percent increase in price while demand for processing potatoes is estimated to decrease .24 percent for each 1 percent increase in price (Table 4). These estimates are quite consistent with previous studies of Simmons who obtained demand elasticity values ranging from −.13 to −.64 and Zusman who obtained demand elasticity estimates ranging from −.14 to −.71. Thus, demands were found to be relatively price inelastic, suggesting that abrupt changes in production would have major inverse price effects. Table 4 indicates that preferences in favor of convenience foods, as measured by the WLF_{US} variable, provide a substantial added component of demand growth while the income elasticities suggest that potato demand is relatively insensitive to income changes. Consumers of fresh and processed products are estimated to increase their consumption with higher levels of per capita income, but in each case, the estimated growth in consumption would be less than the corresponding percentage growth in per capita income. The rising fraction of women in the labor force contributed negatively to fresh demand and positively to processed

TABLE 3. 2SLS Parameter Estimates and Related Statistics for Potato Demand Equations.

Dependent variables	Independent variables								Dependent var. means
	Constant	$FP_{U.S.}/CPI$	$WLF_{U.S.}$	$Y/N \cdot CPI$	IWR/CPI	$IWPI/CPI$	$S_{y \cdot x}$	S_y	
Q^d_{FR}/N	2.5572	−.0402	−2.445	.0318	−1.0718		.0206	.148	.746
	(10.999)	(3.689)	(2.003)	(.452)	(5.229)				
Q^d_{PD}/N	−1.8351	−.0482	6.8953	.1200		−.1145	.0442	.191	.471
	(3.221)	(1.881)	(2.671)	(.805)		(.374)			
LOG Q^d_{FD}	3.1410	−.3671[a]					.3194	.477	2.250
	(15.747)	(4.769)							

NOTE: Absolute asymptotic t-values are given in parentheses below each parameter estimate.

[a]In the feed equation $FP_{U.S.}$ is not deflated by CPI.

Symbols have the following meanings: Q^d_{FR}, Q^d_{PD} and Q^d_{FD} are potato demands for fresh use, processed products and feed: $FP_{U.S.}$ is U.S. average price received by farmers for potatoes; $WLF_{U.S.}$ is the percentage of the U.S. labor force who are women; Y is U.S. disposal personal income; IWR is the U.S. industrial wage rate; IWPI is the U.S. industrial wholesale price index; N is U.S. population and CPI is the U.S. consumer price index.

demand as expected, and the net effect on aggregate potato demand was positive. Increasing cost of marketing services has a negative effect on potato demand, as expected.[4]

Potato Market Simulations

Parameter estimates obtained from the historical behavioral model provide an information base to assess future potato market situations. Seven future market scenarios were investigated but results for only three simulations will be reported. In an initial simulation, continuation of recent trends in population, per capita real income, women as a proportion of the labor force, potato yields, and shifts of potato acreage response curves was assumed. All prices, except potato prices, were held at the 1972-76 average levels. Solution values for the endogenous variables in the model were obtained using a Gauss-Siedel iterative procedure, and are identified as "baseline" simulation solutions in Table 5 for selected years (1980, 1985, and 1990).

Baseline simulation results show domestic potato acreage increasing approximately 207,000 acres over the 10-year period, and the PNW accounts for 134,000 acres, or almost 65 percent of this total increase. The estimated PNW market share increases from about 44 percent in 1980 to 50 percent in 1990.

Simulated potato prices, however, remain fairly constant as both national demand and supply increase approximately 2.6 percent each year. This suggests that a continuation of recent shifts in demand and supply would not result in great future market disruptions. Demand growth was most pronounced for processed products and it seems likely, and even necessary, that U.S. potato production must expand if national demands are to be met at constant real prices.

[4]Yield per planted acre and price linking equation results are not reported due to space limitations and our wish to limit results to significant findings. Interested readers can consult Estes for these results.

TABLE 4. Estimated Elasticities of Demand with Respect to Farm Price, Income, Convenience, and Marketing Margins, Mean Level of Data 1955-1975.

Elasticity of:	With respect to: $FP_{U.S.}/CPI$	$WLF_{U.S.}$	$Y/N \cdot CPI$	IWR/CPI	IWPI/CPI
Q^d_{FR}/N	−.124	−1.056	.111	−1.361	
Q^d_{PD}/N	−.235	4.715	.666		−.250
LOG Q^d_{FD}	−.891				

NOTE: In the feed elasticity calculation, $FP_{U.S.}$ is not deflated by CPI.

Recent rapid growth in irrigated areas makes it relevant to examine the consequences for the national potato market of even more rapid expansion in the PNW's potato acreage of the type that might be associated with accelerated irrigation development through 1990. In these scenarios, it was assumed that year to year secular shifts

TABLE 5. Simulated U.S. Potato Market Outcomes with the PNW Acreage Response Function Shifting 25 and 50 Percent More Rapidly than Historically, and Comparisons.

Variable	Simulation Year	Baseline Values	25% PNW Acreage Acceleration Results	Difference	50% PNW Acreage Acceleration Results	Difference
PNW Supply (mil. cwt)	1980	166.25	168.96	2.71	171.67	5.42
	1985	201.31	208.96	7.65	216.60	15.29
	1990	240.77	254.19	13.42	267.61	26.84
Other Regions' Supply (mil. cwt)	1980	205.64	203.91	−1.73	202.19	−3.45
	1985	224.34	218.40	−5.94	212.47	−11.87
	1990	242.07	231.09	−10.98	220.13	−21.94
U.S. Supply (mil. cwt)	1980	371.89	372.87	0.98	373.86	1.97
	1985	425.65	427.36	1.71	429.07	3.42
	1990	482.84	485.28	2.44	487.74	4.90
Fresh Demand (mil. cwt)	1980	118.13	118.52	0.39	118.91	0.78
	1985	119.61	120.32	0.71	121.03	1.42
	1990	120.41	121.47	1.06	122.52	2.11
Processing Demand (mil. cwt)	1980	201.38	201.86	0.47	202.32	0.93
	1985	249.88	250.73	0.85	251.57	1.69
	1990	302.37	303.63	1.26	304.90	2.53
Feed Demand (mil. cwt)	1980	4.87	4.99	0.12	5.11	0.24
	1985	4.99	5.20	0.21	5.43	0.44
	1990	4.86	5.16	0.30	5.49	0.63
U.S. Average Potato Price ($/cwt)	1980	4.24	4.18	−0.06	4.11	−0.13
	1985	4.18	4.06	−0.12	3.95	−0.23
	1990	4.25	4.08	−0.17	3.93	−0.33

TABLE 5 (Continued)

Variable	Simulation Year	Baseline Values	25% PNW Acreage Acceleration Results	Difference	50% PNW Acreage Acceleration Results	Difference
PNW Potato Price ($/cwt)	1980	3.42	3.37	−0.05	3.32	−0.10
	1985	3.37	3.28	−0.09	3.19	−0.18
	1990	3.43	3.30	−0.13	3.17	−0.26
Other Regions' Potato Price ($/cwt)	1980	4.90	4.85	−0.05	4.78	−0.12
	1985	4.91	4.81	−0.10	4.72	−0.19
	1990	5.07	4.94	−0.13	4.85	−0.22
PNW Acreage (1,000 A)	1980	544.30	555.65	11.35	567.01	22.71
	1985	609.50	635.02	25.52	660.56	51.06
	1990	678.16	718.06	39.90	757.98	79.82
Other Regions' Potato Acreage (1,000 A)	1980	942.91	932.19	−10.72	921.46	−21.45
	1985	978.09	949.47	−28.62	920.85	−57.24
	1990	1,015.85	967.63	−48.22	919.44	−96.41
U.S. Potato Acreage (1,000 A)	1980	1,487.21	1,487.84	0.63	1,488.47	1.26
	1985	1,587.60	1,584.49	−3.11	1,581.41	−6.19
	1990	1,694.01	1,685.69	−8.32	1,677.42	−16.59

in the PNW acreage response schedule occur at rates 25 percent and 50 percent greater than the rate of change in the baseline solutions. To implement this, the PNW acreage schedule was modified by multiplying the coefficient of time by 1.25 (or 1.5) and then adjusting the intercept so that the locus of the schedule was the same in 1975 after modification as it was in the baseline simulation. Results for the entire system were then simulated using the modified PNW acreage schedule and calculated solutions for each year in 1975-90. These two above-average acreage growth rates were selected as representing both feasible and realistic amounts of land to come into production in the PNW as water becomes available. Although simulation results of both above-average acreage growth are presented in Table 5, discussion will focus on the 50 percent growth simulation results since the model is basically linear.

By 1990, PNW planted area is estimated to be approximately 758,000 acres, nearly 80,000 acres more than in the baseline solution for that date. Over the same time span, the five competing regions would plant 96,000 fewer acres of potatoes in comparison to 1990 baseline solution values. Additional PNW acreage results in an approximately 26.8 million cwt increase in production for the Northwest while the concomitant reduction in the competing regions' production results in a 21.9 million cwt decline in their aggregate potato production. As a result, the market share for Northwest potato growers increases to nearly 55 percent by 1990. The estimate of increased U.S. potato production associated with a lower level of U.S. potato area under the accelerated irrigation development assumption is due to Northwest potato yields being notably higher than yields in competing regions. Thus, though the decrease in acreage in competing regions exceeds the increase in potato acreage in the Northwest, total U.S. production remains above the baseline solution value. The redistribution of production shares among the regions, however, would be accompanied by a \$.26 per cwt decline in Northwest farm price, a \$.22 decline in other regions average farm price and a \$.33 per cwt decrease in U.S. average farm price for potatoes over the projection period.

Table 5 suggests that the small increment of additional U.S. production would be distributed about equally between processing and fresh uses with a small amount being used for feed.

Perhaps the most surprising results from the simulations with accelerated shifts of the PNW planted acreage schedule are the rather modest price effects. These were generated under circumstances where PNW potato supply is increased significantly from a base where the region already accounted for a major share of national supply, and where price elasticity of national demand is estimated to be small. A key factor in bringing about these results is the comparatively higher long-run price elasticity of potato supply in the competing regions. Of equal importance is that potato products in various forms can be shipped economically between regions so that price effects originating in one region are readily transmitted to others. The combination of easy price transmission and relatively elastic supply in competing regions means that negative price impacts originating from one region's expanded supplies produce supply retrenchment in competing regions. Under such conditions, market penetration can occur with minimal price impacts on the suppliers who expand production, and with most of the impact being in the form of displacements of existing production in competing regions.

Summary and Conclusions

A behavioral model describing forces operating in the U.S. potato market for the 1955-75 period was estimated. Potato supply was shown to be generally price inelastic in the short run. The statistical importance of price risk as an explanatory force in the planting decision was evident in four of the six regions examined. Demands were found to be price elastic suggesting that abrupt changes in total production would have major inverse price effects. Estimated coefficients also suggested a relatively rapid rate of demand expansion, especially for processed potato products.

A baseline simulation provided a set of reference values which indicated the acreage, production, and price levels for potatoes, that would prevail in 1990 if recent historical trends were to continue. If market penetration by Northwest producers is accelerated by a more rapid rightward shift in the region's potato acreage response function, it appears that the price effects would be quite modest. Most of the effects take the form of displacements of production in competing areas. Opportunities for a considerable expansion of production in the PNW pursuant to irrigation development appear to exist if, as seems likely, the secular shift in potato demand continues. This is most likely to occur if changes in age distribution and make-up of the work force continue to favor demand for convenience foods. However, even moderately excessive increase in PNW acreage tend to have discernable adverse price effects. Thus, additional market penetration by Northwest producers could occur, but only within prescribed limits and at gradual rates over time.

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Appendix

The basic acreage model, generalized to include risk considerations, is given as (1), (2), and (3) in the text. The infinite sums appearing in the definitions of P^e_{t-1} and V^e_{t-1} can be usefully partitioned into: (1) terms for that period of time from an initial observation point (t_b) onward; and (2) terms for all time periods prior to t_b. Using this partitioning, equation (1) can be written as (A1),

$$\text{(A1)}\quad A_t = \beta_0 + \beta_1 [\phi \sum_{i=0}^{t-t_b-1} (1-\phi)^i P_{t-i-1} + (1-\phi)^{t-t_b} P^e_{t_b-1}] + \beta_2 [\phi \sum_{i=0}^{t-t_b-1} (1-\phi)^i (P_{t-i-1} - P^e_{t-i-2})^2 + (1-\phi)^{t-t_b} V^e_{t_b-1}] + \mu_t$$

or using an obvious change of notation, as equation (A2).

$$\text{(A2)}\quad A_t = \beta_0 + \beta_1 X_{1t}(\phi, P^e_{t_b-1}, P_{t-1}, P_{t-2}, \ldots, P_{t_b}) + \beta_2 X_{2t}(\phi, P^e_{t_b-1}, V^e_{t_b-1}, P_{t-1}, P_{t-2}, \ldots, P_{t_b}) + \mu_t$$

The main data set used for estimation consists of the T observations for the time interval (t_b, t_f) where t_b is the initial observation and t_f is the final observation.

It is apparent that if ϕ, $P^e_{t_b-1}$ and $V^e_{t_b-1}$ were known, then the functions $X_{1t}(.)$ and $X_{2t}(.)$ could be evaluated for each t, and β_0, β_1, and β_2 could be estimated by standard multiple regression techniques. The resulting estimates can be described as either conditional least squares estimates or conditional maximum likelihood estimates. Of immediate concern is the estimation of the unknown quantities $P^e_{t_b-1}$ and $V^e_{t_b-1}$.

The procedure used to estimate $P^e_{t_b-1}$ is that suggested by Just (1977). Under the model specification adopted, the true value of $P^e_{t_b-1}$ is given as

$$\text{(A3)}\quad P^e_{t_b-1}(\phi) = \phi \sum_{i=0}^{\infty} (1-\phi)^i P_{t_b-i-1}$$

With ϕ given, a set of observations on prices prior to t_b (say, back to $t_a<t_b$) can be used to estimate $P^e_{t_b-1}$ consistently as

$$\text{(A4)}\quad P^e_{t_b-1}(\phi) = K(\phi)\, \phi \sum_{i=0}^{t_b-t_a-1} (1-\phi)^i P_{t_b-i-1}$$

where $K(\phi)$ is defined as:

$$\text{(A5)}\quad K(\phi) = [\phi \sum_{i=0}^{t_b-t_a-1} (1-\phi)^i]^{-1}.$$

To establish consistency, it is sufficient to observe that as the number of additional observations increases without bound, $P^e_{t_b-1}(\phi)$ converges to $P^e_{t_b-1}$. Then, as Just has argued, $P^e_{t_b-1}(\phi)$ is a consistent estimator of $P^e_{t_b-1}$ even when a consistent estimator of ϕ is substituted for the actual value of ϕ in (A5) so long as $t_f - t_a$ increases without bound in such a way that both $t_f - t_b$ and $t_b - t_a$ increase without bounds. Under maximum likelihood, $t_f - t_b \rightarrow \infty$ insures a consistent estimate of ϕ, while $t_b - t_a \rightarrow \infty$ insures that $P^e_{t_b-1}(\phi)$ converges to $P^e_{t_b-1}$.

The procedure used to estimate $V^e_{t_b-1}$ represents an extension of the procedure used to estimate $P^e_{t_b-1}$. First, if ϕ, $P^e_{t_b-1}$, and actual prices for periods prior to t_b were known, then from equation (A3), prior values of $P^e_{t_b-2}$, $P^e_{t_b-3}$, . . . , could be calculated recursively as

$$\text{(A6)}\quad P^e_{t_b-i-1} = (P^e_{t_b-i} - \phi P_{t_b-i})/(1-\phi) \qquad i = 1,2,3,\ldots$$

If a consistent estimate of $P^e_{t_b-1}$ is available (such as that in (A4)), together with a consistent estimate of ϕ, then $P^e_{t_b-2}$, $P^e_{t_b-3}$, etc., may be estimated consistently by equation (A6). For convenience call these estimates $P^e_{t_b-2}(\phi)$, $P^e_{t_b-3}(\phi)$, etc.

Next, note that the true value of $V^e_{t_b-1}$ is given as

$$(A7) \quad V^e_{t_b-1} = \phi \sum_{i=0}^{\infty} (1-\phi)^i (P_{t_b-i-1} - P^e_{t_b-i-2})^2$$

Though its value is not known, it can be estimated by a procedure analagous to the one used to estimate $P^e_{t_b-1}$. This is shown in equation (A8),

$$(A8) \quad V^e_{t_b-1}(\phi) = K(\phi)\, \phi \sum_{i=0}^{t_b-t_a-1} (1-\phi)^i (P_{t_b-i-1} - P^e_{t_b-i-2}(\phi))^2$$

Instead of using a finite number of observations on prices prior to t_b, prior observations are used on the squared deviations between actual prior prices and consistently estimated prior expected prices. The definition of $K(\phi)$ is the same as that used previously, and the estimates of prior expected prices are calculated as in equation (A6). The demonstration of consistency for the estimate of $V^e_{t_b-1}$ rests on the same arguments used to show consistency in the estimates for $P^e_{t_b-1}$.

Consistent estimates of ϕ, β_0, β_1 and β_2 in (A1) and (A2) are found by nonlinear least squares or maximum likelihood. After expressing estimates of $P^e_{t_b-1}$ and $V^e_{t_b-1}$ as functions of ϕ using (A4), (A5), (A6) and (A8), the parameter set consists on only ϕ, β_0, β_1 and β_2. Estimation is then pursued via the concentrated likelihood function method. A general discussion of nonlinear least squares procedures can be found in Theil (undated). The concentrated likelihood method is explained in Koopmans and Hood. Specific procedures used in this model are described in Estes, Blakeslee, and Mittelhammer.

A significant advantage of this procedure over those in Just (1977) is the elimination of one nonessential trend dominated regressor $((1-\phi)^{t-t_b} V^e_{t_b-1})$ in a manner which preserves the integrity of the model. This removes what can be a considerably multicollinearity problem. In addition, it permits more precise estimation of standard errors.