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ABSTRACT

A demand model was developed for the following markets for United States potato products: chips; dehydrated-foodservice; dehydrated-retail; fresh; frozen-foodservice; frozen-Japan; and frozen-retail. Factors that were found to affect demand were: population; consumer price index; consumer income; consumer debt; retail potato product price; females in the labor force; homes with microwave ovens; meal expenditures away from home, price of substitute potato products, price of complements (hamburger); and advertising expenditures.

The model was used to forecast the demand for U.S. potatoes at average real prices in 1995. Some of the 1995 estimates for explanatory variables were provided by USDA sources. Other explanatory variables were estimated via econometric techniques. It was estimated that a U.S. potato crop of 420 million cwt could be sold at average prices in 1995. Idaho's share of that crop was estimated at 116 million cwt.

INTRODUCTION

Potato prices are quite sensitive to changes in supply. Small increases in supply can cause large decreases in price. Many potato growers are painfully aware of the low prices caused by large potato crops -- such as the 1985 crop which brought Idaho growers prices well below costs of production.

Growers are also aware of the benefits of relatively small crops, such as the drought-impacted U.S. crops of 1988 and 1989 which brought record high prices in Idaho. Idaho growers, processors and shippers are also aware of the successful Idaho Potato Commission programs that have steadily increased Idaho's market share and supported the prices of Idaho potato products.

During the early 1980's a rule of thumb was that Idaho potato prices would be unprofitable if the crop was larger than 80 million cwt. The 1989 Idaho crop was 100 million cwt and Idaho price records were set because of reduced yields elsewhere. Some Idaho potato businesses have recently expanded operations or are considering expansion. There is concern that too-rapid expansion could depress potato prices to unprofitable levels.

In 1989, members of the Idaho Potato Commission decided that a study of future potato demand was needed. The Commission provided a grant to the University of Idaho to estimate the demand for Idaho potatoes in 1995. This report provides preliminary results of that analysis.

METHODS

Markets

A search for data found that a reliable series of consumer-level price and quantity data for Idaho potato products was not available from either public or private sources. Therefore, it was decided to construct a demand model for the entire U.S. potato market and then analyze Idaho's production share.

The focus of the analysis was on the food segments of the potato market. Food market uses made up 92.6% of the 1988 U.S. potato crop sales. Livestock feed and seed potato sales made up the remaining 7.4%. Since the seed and feed markets are relatively small and stable they were not included in this analysis.

According to the USDA, fresh potatoes made up 36.7% of 1988 potatoes-for-food sales, frozen 37.4%, dehydrated 9.6%, and chips 14.3%. Since these products are the main components of the potatoes-for-food market they were the focus of the demand analysis. Canned, starch and flour potato products make up the remaining 2 percent of the potato food market.

Potato products are consumed both at home (retail) and away from home (foodservice). The USDA does not provide data on quantities of potato products sold in both types of markets. Private firms, however, do sell useful data on some of the potato products. SAMI and Nielsen were the two private firms that provided data for this study.

Retail dehydrated potato sales volume and revenue was obtained from SAMI. Nielsen was the source of retail frozen potato volume and revenue. Subtracting the SAMI and Nielsen retail quantities from USDA per capita consumption gave foodservice quantities for both dehydrated and frozen potatoes. Neither SAMI nor Nielsen collect retail data for fresh potatoes or potato chips.

Although potato exports make up a relatively small part of the total market for U.S. potatoes, frozen potato exports to Japan grew rapidly in the late 1980's. Price and quantity data on frozen potato imports into Japan were obtained from a Japanese government source.

Following the search for quantity and price data, it was decided that the U.S. potato demand model would consist of the following components:

Potato chips
Dehydrated potatoes - foodservice
Dehydrated potatoes - retail
Fresh potatoes
Frozen potatoes - foodservice
Frozen potatoes - Japan
Frozen potatoes - retail

Explanatory Variables

Economic theory suggests that the demand for a product is influenced by price, consumer income, prices of other products, consumer tastes and preferences, and population. These factors will be called the potato demand model's explanatory variables.

Prices were obtained for all of the above potato products except dehydrated and frozen potatoes in the foodservice markets. Average annual prices for restaurant potato products such as frozen french fries were not available from either public or private sources. Interviews with industry executives indicated that restaurant potato product prices tended to be fixed for long periods. Another complication was that the foodservice market includes schools, hospitals, nursing homes, prisons, and military bases where clientele are not directly charged a price for potato products. It was hypothesized that non-price explanatory variables could be used to construct the demand for the foodservice products.

Consumer income can have either a positive or negative impact on the demand for a product. For example, as income increases, consumers are likely to buy more steak but less beans. Other researchers have found a normal, positive relationship between income and processed potatoes but a negative relationship between income and fresh potatoes. The consumer income variable used in this model was disposable (after-tax) income per capita.

Consumer debt was also included as an explanatory variable. This was included to capture the trade-off between durable and non-durable consumption. For example, as consumers take on more debt for mortgages or car loans, they are likely to decrease their purchases of other goods.

Prices of competing products can also influence the demand for potatoes. Consumer surveys have found that rice and pasta are considered by some to be substitute products for potatoes. Although this study found fresh potatoes to be a strong substitute

for some of the processed potato products, rice and pasta were found to be statistically insignificant.

The price of hamburger as a complementary product to frozen potatoes was also included in the model. It seems that a traditional American meal is hamburger and french fries. According to economic theory, an increase in the price of hamburger should cause a decrease in the demand for frozen french fries.

The prices of many other goods and services can influence the demand for potatoes. In order to capture this influence the consumer price index was included in the model by deflating all monetary variables.

Changes in consumer tastes and preferences can also affect the demand for potatoes. Four types of explanatory variables were included in the model to account for changing tastes and preferences: females in the labor force, homes with microwave ovens, restaurant sales, and advertising.

The percentage of females in the labor force was used to capture the changing preference for convenience. It was assumed that increases in the percentage of females in the labor force would increase the demand for convenience foods such as processed potatoes.

The percentage of U.S. homes that have microwave ovens is another variable that is related to convenience. Microwave ovens make fresh baked potatoes more convenient to prepare. The logic was that as the percentage of homes with microwave ovens increases, the demand for fresh potatoes should increase.

A restaurant sales variable was used to capture changing preferences for meals away from home. The thinking was that as consumers choose to purchase more of their meals away from home the demand for frozen potatoes in the foodservice sector should increase.

Advertising is the fourth variable that was included to measure changing tastes and preferences. Corporations and potato commissions buy advertising to do exactly that -- increase preferences for potato products. Data was obtained for four types of advertising expenditures: generic, frozen, dehydrated and potato chips. The generic advertising included expenditures by the Potato Board, the Idaho Potato Commission, the Washington Potato Commission and other state potato associations. Although retail food stores frequently feature fresh potatoes in newspaper ads, a fresh potato advertising data series was not found.

Population was incorporated into the model by dividing all quantities of potato products by population. The consumer income, consumer debt, and restaurant sales variables were also on a per capita basis.

A wide variety of sources was used to obtain data. The UDSA provided per capita consumption quantities for the main categories of potato products. The U.S. Department of Commerce was the source for data on population, consumer price index, consumer income, consumer debt, the hamburger price index, females in the labor force, the percentage of homes with microwave ovens, and restaurant sales. SAMI was the source for retail dehydrated potato prices and quantities. Nielsen was the source for retail frozen potato prices and quantities. Advertising data was purchased from Leading National Advertisers.

Two explanatory variables were used in the model for sales of frozen potato products to Japan -- the import price in yen and the number of Western-style restaurants in Japan. Prices and quantities of imported frozen potatoes were reported by Japan's Bureau of Custom, Ministry of Finance. The Potato Board was the source of the restaurant data.

Estimation Methods

The approach of this study was to predict future demand based on historical relationships. It was assumed that the past relationships between the factors that affect the demand for potato products would continue into 1995. The period of analysis was 1970 through 1988, the last year for which complete data was available. For dehydrated potatoes and potato chips the data was limited to the 1975-88 period.

An econometric technique known as ordinary least squares was used to estimate the model. This technique estimates both the direction and magnitude of influence that the explanatory variables have on the demand for potato products. A separate equation was estimated to depict the demand for each of the seven components of the potato market.

All of the six domestic market equations were estimated in a linear form. The Japanese market was estimated in double-log form. Autocorrelation problems were detected by the Durbin-Watson statistic and corrected by the Cochrane-Orcutt method.

Since the Japanese market was modelled for all imports, the U.S. share of that market was estimated by a Markov model. The Markov model involves the estimation of probabilities that Japanese importers will repeat purchasing U.S. frozen potatoes rather than switch to the Canadian product.

The estimated model was then used to forecast the demand for potato products in 1995. This involved first forecasting the values of the explanatory variables. For some of the variables, government forecasts were used. The other explanatory variables were estimated either by time trends, or where that did not work, by calculating the average for the study period.

RESULTS

Econometric Model

Table 1 shows the results of the econometric analysis of the seven demand components. Each column contains an equation for the potato product listed at the top of the column. For example, the fresh potato equation is the first column of numbers. Each number is the coefficient for the explanatory variable in the left column. A blank space indicates that the explanatory variable is not included in the equation.

The R^2 listed at the bottom of the column for each potato product is a measure of how well the equation fits the data. For example, the R^2 value of .94 for the potato chip equation means that 94% of the variation in the quantity of potato chips purchased is explained by the variables in the equation.

TABLE 1: ESTIMATED EQUATIONS FOR U.S. POTATO DEMAND

	Dependent Variables-Per Capita Quantity Demanded						
Explanatory Variables	Fresh	Frozen Retail	Frozen Foodservice	Dehydrated Retail	Dehydrated Foodservice	Chips	Frozen Japan
Constant	175309 (24.30)	1404 (4.96)	-32891 (13.84)	4738 (6.64)	24175 (12.24)	13261 (1.82)	2.70 (5.49)
Retail Price	-6904 (1.65)	-5289 (6.22)		-1532 (4.66)		-4517 (5.60)	-0.53 (4.29)
Price Fresh		639 (2.62)	3372 (1.39)	3348 (6.27)	5487 (2.11)		
Price Frozen					69886 (8.37)		
Consumer Income	-7383 (3.74)	658 (7.22)	3651 (4.02)	186 (2.89)	-9851 (10.93)	1044 (1.10)	
Consumer Debt				-910 (4.42)	19242 (9.16)	-3248 (2.39)	
Females in Labor Force	-1548 (6.17)	148 (13.50)	183 (1.53)				
Microwave Ovens	316 (10.38)	-35.3 (12.10)	-142 (7.17)	3.74 (2.11)			
Restaurant Sales	117 (1.88)	-16.8 (4.19)	115 (4.06)			36.1 (2.24)	
Price Hamburger		-2.84 (1.34)	-143 (6.60)				
Advertising Generic			1.11 (3.40)	0.039 (1.76)			
Advertising Frozen		0.023 (2.48)				-0.098 (4.66)	
Advertising Dehydrated				0.017 (2.13)	0.248 (3.88)		
Advertising Chips						0.032 (1.47)	
Restaurants Japan							0.91 (12.2)
Auto-Correlation Coefficient	-0.324 (1.10)	-0.491 (1.62)	-0.676 (2.82)		-0.517 (1.55)		
R^2	0.80	0.97	0.97	0.95	0.90	0.94	0.99

Values in parentheses are T-ratios.

The second row of numbers in Table 1 shows that the retail price of the potato products had a negative impact on demand. When the price increases, the quantity demanded decreases. As previously discussed, price was not used as an explanatory variable for the foodservice markets.

The price of fresh potatoes was found to have a positive influence on the demand for dehydrated and frozen potatoes in both the foodservice and retail markets (Table 1, third row). When the price of fresh potatoes increases, the demand for the processed potato products increases. Frozen potato price had the same type of influence on the demand for dehydrated potatoes in the foodservice market.

Disposable per capita income had a positive impact on both frozen potato markets, the retail dehydrated market and the potato chip market. The impact was negative for fresh potatoes and dehydrated potatoes in the foodservice market. During the study period, increases in income led people to increase their purchases of frozen potatoes, chips and dehydrated retail potatoes at the expense of fresh and dehydrated foodservice potatoes.

Consumer debt had a negative influence on retail dehydrated potatoes and potato chips. The effect on dehydrated potatoes in the foodservice market was positive. Both the consumer income and consumer debt variables suggest that the foodservice dehydrated product is viewed as an inferior good -- as people have more money to spend they are less likely to eat instant potatoes away from home.

The impact of females in the labor force was positive for both the retail and foodservice frozen potato equations and negative for the fresh equation. As more women are employed outside the home they are likely to substitute frozen potatoes for fresh potatoes for the sake of convenience.

Microwave ovens had the opposite impact of females in the labor force for both fresh and frozen potatoes. People who own microwaves are likely to substitute fresh potatoes for frozen potatoes. This was true during the study period because consumers may not have been aware of, or satisfied with, the frozen potato microwave products. Product development and advertising could change that in the future.

The restaurant sales variable was positive for fresh potatoes, potato chips, and frozen potatoes in the foodservice market. The increasing number of restaurants that feature baked potato bars appears to have had a positive influence on the demand for fresh potatoes away from home. The restaurant sales variable had a negative impact on the retail market for frozen potatoes. Apparently when consumers increase their purchases of frozen potato products in restaurants, they reduce their purchases for consumption at home.

The hamburger price index was found to have a negative impact on the demand for frozen potatoes in both the retail and foodservice markets. When the price of hamburger increases, the demand for both hamburger and frozen potato products decreases. If hamburger prices decline, increased demand for frozen potatoes can be expected.

Generic advertising was found to have a positive impact on the demand for both frozen and dehydrated potatoes. It likely also influences the demand for other potato products but since the results were found to be statistically insignificant, generic advertising was excluded from the other equations.

Frozen potato advertising had a positive influence on the demand for frozen potatoes in the retail market but no statistically significant impact on the frozen foodservice market. Frozen advertising had a negative impact on the demand for potato chips. This indicates that increased advertising for the frozen product causes some people to substitute frozen potatoes for potato chips.

Advertising for dehydrated potatoes had a positive impact on the demand for dehydrated potatoes in both the retail and foodservice markets. Potato chip advertising had a positive impact on the demand for potato chips. Fresh potato advertising data was not available.

The number of Western style restaurants in Japan had a positive impact on the demand for frozen potatoes imported. According to Potato Board data, the number of fast food and family restaurants in Japan increased from 1,617 in 1980 to 4,788 in 1988.

Explanatory Variable Forecast

Actual values of the explanatory variables were used to estimate the potato demand model. In order to complete the 1995 forecast, the values of the explanatory variables had to be estimated. For the potato product prices, the average 1970-88 deflated value was used as the 1995 estimate. This was done to provide an estimate of the size of the U.S. and Idaho potato crops that could be sold at average prices.

Forecasts for some of the explanatory variables were provided by U.S. government sources. Estimates of population and females in the labor force were in the U.S. Department of Commerce Statistical Abstract of the United States. In the National Food Review, the USDA provided estimates of consumer income and the consumer price index. Restaurant sales were projected by using the USDA's trend estimates published in U.S. Food Demand. Estimates of growth in the number of Western-style restaurants in Japan were found in The Japanese Food Service Market, a publication prepared for the U.S. Agricultural Trade Office in Tokyo.

Consumer debt, frozen advertising, potato chip advertising, and the hamburger price index were estimated by extrapolating from simple linear trends. The microwave oven variable was estimated by a logistic function of time. Since efforts to model generic and dehydrated potato advertising based on time were unsuccessful, the 1995 values were assumed to the deflated average of the 1970-88 period.

1995 Forecast

The 1995 demand forecast, based on average deflated potato product prices, is in Table 2. Also in Table 2 are the actual quantities for the 1975-88 period. The figures include the demand for chips, dehydrated, fresh and frozen potatoes but not canned, starch, seed or feed. The forecasted quantity for 1995 is 18 percent above 1988.

The market for frozen potato exports to Japan was estimated to be 6.8 million cwt on a raw product basis, which is a 76 percent increase over 1988. This projection was made based on the assumption that import prices and currency exchange rates would be the same as the 1986-87 average.

TABLE 2

U.S. Potato Sales: Chips, Dehydrated, Fresh and Frozen

Year	Quantity * (Million cwt)
1975	255
1976	264
1977	264
1978	258
1979	267
1980	258
1981	256
1982	265
1983	273
1984	280
1985	286
1986	296
1987	296
1988	309
1995 Forecast	**365**

* Raw product weight

The next step in the study was to determine the size of the U.S. potato crop needed to meet the total quantity demanded in 1995. The following equation was estimated by ordinary least squares:

$$SALES = -6860 + \underset{(1.8)}{30.2}*(QP) + \underset{(3.2)}{58.2}*(QP_{t-1}) + \underset{(11.5)}{3.5}*(YEAR)$$

$$- \underset{(-1.8)}{9.5}*(DV78) - \underset{(-1.1)}{6.1}*(DV85) \qquad R^2 = .94$$

where:
SALES is the quantity of potatoes sold in the seven market outlets;
QP is the quantity of potatoes produced in the U.S.;
QP_{t-1} is the quantity of potatoes produced in the U.S. the previous year;
DV78 is a dummy variable accounting for the 1978 government diversion program; and
DV85 is a dummy variable accounting for the frost damaged crop of 1985.

T-values are in parentheses below the coefficients.

Both QP variables were needed because the model was built on a calender year basis and stored potatoes from the previous fall crop are sold in the following calender year. The YEAR variable's positive coefficient suggests that improved handling, storage and processing technology allows an increasingly larger share of production to reach the

consumer. The two dummy variables account for two unusual potato years when the market was disrupted by government intervention and excessive field frost.

Next, Idaho's share of U.S. production was estimated by the following equation:

$$\text{IDAHO} = -942.4 + .17^{*}(\text{QP}) + .49^{*}(\text{YEAR}) + 11.19^{*}(\text{DV78}) + 8.89^{*}(\text{DV8889})$$
$$(5.6) \qquad (2.9) \qquad (4.0) \qquad (3.8)$$
$$R^2 = .94$$

where:
IDAHO is the quantity of potatoes produced in Idaho;
QP is the quantity of potatoes produced in the U.S.;
DV78 is a dummy variable accounting for the 1978 government russet potato diversion program; and
DV8889 is a dummy variable accounting for the expansion of Idaho's processing and fresh pack facilities during the late 1980's.

Table 3 shows the potato production demanded forecast for 1995 along with actual production during the study period. The 1995 forecast is not an estimate of what production will be. It is an estimate of the size of the potato crops in Idaho and the U.S. that could be sold at average prices. Larger crops would be sold at lower prices and smaller crops would command higher prices.

Idaho's share of the 1995 crop is estimated at 27.6 percent. The average Idaho share for the 1975-89 period is 25 percent. The 1988 and 1989 Idaho share was higher than average because of the drought reduced potato yields outside the Pacific Northwest.

SUMMARY AND CONCLUSIONS

A potato demand econometric model was estimated in order to forecast the demand for potatoes in 1995. The forecast was that a U.S. crop of 420 million cwt and an Idaho crop of 116 million cwt could be sold at average prices.

Athough the forecast is favorable for continued growth of the Idaho potato industry, expansion-minded growers, shippers, and processors should be cautious. A 116 million cwt crop in 1995 is a 13% growth spread over 6 years. This represents a potential growth rate of slightly more than 2% per year.

Like most economic forecasts, the 1995 potato demand forecast is subject to error. The forecast may be proven inaccurate for a number of reasons. Unreliable data, uncertainty about the influence of certain variables, variables that were overlooked or for which data was not available, errors in the forecasting of explanatory variables, and statistical bias in the method of estimation can all cause projections to be inaccurate. Although subject to normal economic forecast error, the authors followed accepted econometric methods and are confident that the forecast is reasonable.

TABLE 3

Potato Production Demanded, U.S. and Idaho

Year	U.S. Production (Million cwt)	Idaho Production (Million cwt)	Idaho Share (Percent)
1975	322.3	78.5	24.3
1976	357.7	88.5	24.7
1977	354.6	88.2	24.9
1978	365.3	100.3	27.5
1979	342.5	84.9	24.8
1980	302.9	79.9	26.4
1981	338.6	84.5	25.0
1982	355.1	91.8	25.9
1983	333.9	86.0	25.8
1984	362.6	86.6	23.9
1985	407.1	102.5	25.2
1986	361.5	90.2	25.0
1987	389.3	99.7	25.6
1988	356.4	102.6	28.8
1989	367.3	102.5	27.9
1995 Forecast	**420.0**	**116.0**	**27.6**