THE EFFECT OF ENERGY COST CHANGES ON THE U.S. POTATO INDUSTRY

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INTRODUCTION

Since World War II U.S. Agriculture has seen regional shifts and greater concentration in the production of certain commodities. Technological and infrastructural developments in irrigation, plant varieties, cultivation techniques, transportation, storage, and processing have lowered the barriers of time and space, thus allowing remote regions to compete with and even dominate the traditional production areas. The U.S. potato industry offers an excellent example of this. Processed potatoes have become the dominant food use form and production has shifted westward and become more concentrated both with respect to time and location. In 1947, 44 percent of U.S. potato production was in the seven largest potato states for the fall crop, 35 percent was produced in the nonfall crops, and eight percent was processed. By 1978, 75 percent was produced by the seven leading states for the fall crop, 14 percent in the early nonfall crops, and 59 percent was processed. Because many of these changes involved the adoption of relatively energy intensive techniques, the existence of low and fairly stable energy prices until 1973 aided this change. The increases in energy costs since 1973 raise questions about the long-run stability of recent patterns of production and consumption.

The impacts of energy cost changes on production by regions in the U.S. potato industry is the focus of this study. An econometric model was used to estimate the structural characteristics of the industry. The model was then employed to simulate the impact of energy cost changes on the industry.

INDUSTRY CONSIDERATIONS

The Northwest produces about half of the total U.S. potato crop and 85 percent of all processed potatoes. There are several reasons for this production pattern. First, the Russet Burbank variety, generally recognized as the premier potato for freezing, thrives in Northwest growing conditions. Second, the cost of labor has historically been low in this region. Finally, storage is relatively inexpensive because of the cool climate. Energy considerations are important since processed forms (frozen and dehydrated) require large amounts of energy for processing, but generally less energy for transportation than fresh potatoes.[1] Because energy prices are generally lower in the Northwest than in other regions, the advantages in transportation may well dominate the disadvantage in processing, at least at higher energy costs. The need to irrigate crops throughout most of the Northwest results in higher energy use growing conditions. The net effect of these cost differences can offset planting and product form decisions as well as the regional location of production.

THE MODEL

An econometric model was developed to estimate the structural characteristics of the U.S. potato industry.[2] The existence of lags between actions, such as planting and harvesting or processing and marketing, suggest that the industry can be viewed as recursive. If so, this permits the use of ordinary least squares. Two "seasons" were identified, Fall for September through February and Early for March through August. Five production regions were identified: three Fall regions (Northeast, Northcentral, and Northwest), and two Early regions (Early Western and Early Eastern). Four usage categories were selected: Fresh (tablestock and chips), Frozen, Dehydrated, and Miscellaneous (nonfood uses and waste). Demands were estimated at the national level. In all cases supplies and demands were assumed to equate. The sample period was from Early 1961 to Early 1978. This time frame was selected because the processed forms were much less important prior to 1960. Data were almost exclusively derived from USDA and U.S. Department of Energy sources. The complete model consisted of 50 equations and 24 identities.

Space limitations preclude a detailed discussion of the model or the results. Rather, the discussion will focus on the three decision levels at which energy considerations are most likely to have an impact: the planting decision, the type of processing chosen, and the storage decision. The remaining relationships will only be discussed in passing.

Within each season and region the activities of planting, yield determination, nonfood use allocation, farm level price determination, allocation among product forms, and carryover recursively follow one another. Each region's current supply then enters the national retail price determination relationships. The general specification of each type of relationship is presented in Table 1. Those decisions where energy cost considerations are most likely to have a significant impact are discussed below.

The Planting Equations: Regional acreage planted was estimated as a function of fuel costs, the expected regional farm prices of pota-

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[1] Processing is generally done very near to the growing areas. The energy savings in transportation are due to two factors: the weight reduction resulting primarily from water loss in processing and the fact that no special handling is needed (other than refrigeration). See Greig (1971), pp. 156-8.

[2] For greater detail concerning all aspects of the model, see Beilock.

Table 1: General Specification[1,2]

Dependent Variable	Independent Variables
Acres Planted[9]	trend term[3] expected farm-level prices of potatoes[4] expected farm-level price of alternative crop[4] proxy for price risk[5] farm labor costs fuel costs
Yields[9]	trend term[3] acres planted weather condition[6]
Miscellaneous[9] (non-food uses loss)	trend term[3] total crop (acres planted * yields) weather conditions[6]
Farm Price[9] Determination	supply-to-expected demand indicator[7] total crop expected retail price[4]
Quantity Supplied to[9] Each Food Use (Frozen, Fresh, and Dehydrated[8])	trend term[3] total available food potatoes expected margin of the form[4] expected margin of an alternative form[4] fuel costs
Carryovers[9]	trend term[3] expected returns to storage[4] total crop
Retail Price[10] Determination in	Per capita consumption Proportion of all women who are the labor force[11] Per capita real disposable income

1. For a more complete explanation of the model as well as a complete tabulation of the results, see Beilock (1981).
2. All prices and costs are deflated as follows:
   by food CPI if retail level (1967=100)
   by Wholesale Prices Index if wholesale level (1967=100)
   by index of prices paid by farmer if farm level (1967=100)
3. Trend terms were included to capture technological and preference changes.
4. Lagged terms were employed for the expectational variables. In cases such as yields, where wide year-to-year fluctuations are common, an average of more than one lagged term was used.
5. The unbiased sample variance of the previous four observations.
6. Average temperature and total rainfall.
7. (Total crop - Miscellaneous)/Lagged Shipments of Potatoes.
8. With the total supply of food use potatoes already estimated, dehydrated was actually estimated as a residual.
9. For each region.
10. National.
11. Included as a proxy to taste-for convenience (processed) forms.

toes and any alternative crops, a proxy for risk,[3] farm labor costs, and a trend term. The estimated parameter for energy cost was never significant at the five percent level and only rarely at the 10 percent level, suggesting that energy costs did not influence planting decisions.

This lack of responsiveness to energy costs may be due to two reasons. First, as energy costs were fairly low and stable until 1973, growers may not have had a long enough period in which to respond because of asset fixity, habit persistence, or both. Alternatively, the lack of response may be caused by the absence of less energy intensive alternatives. In Maine, for example, many growers believe that there is no viable alternative crop. In the Northcentral and Northwestern regions sugar beets are the major alternative crop. However, since the energy requirements for sugar beets are similar to potatoes, changes in energy costs do not appreciably affect planting decisions.

Allocation Between Product Forms: Once the miscellaneous usage has been subtracted from the total regional crop, the remainder must be divided among the three food uses. This is not necessary for the Early production regions since all their food potatoes are used in the fresh market.[4] Because the total quantity of food use potatoes is known, only two final product forms need to be estimated, with the third product form determined by an identity. Dehydrated was chosen as the residual usage since it requires significant amounts of processing, and commands a relatively low price on a fresh weight equivalent basis.

Regional diesel (or #2 fuel oil) prices were chosen to measure energy costs since it is the fuel most widely employed in both processing and transportation. The expected regional farm-retail margins for Fresh and Frozen, the regional crop size for the Fall season or the regional Fresh carryover into the Early season, and a trend term made up the balance of the independent variables. The results for the Fall and the Early seasons are presented in Tables 2(a) and (b), respectively, and are discussed below.

With the exception of the equation for Northcentral Fall Fresh potatoes, the estimated parameters for the trend term are positive for the Frozen equations and negative for the Fresh equations. This reflects the historical movement to processed uses from fresh consumption. As might be expected, the amounts going into Fresh production are strongly and positively related to the total available supplies of food potatoes. The relationship is also positive and significant[5] for frozen in the Fall, but weak or nonexistent in the Early season. The results suggest that expected margins were poorly captured or have little impact in the short run, or both.

For the estimated parameters associated with fuel costs, the anticipated pattern was evident. For the Northeast and Northcentral regions, rising energy costs encourage shifts into Fresh and out of Frozen production, while in the Northwest rising energy costs encourage Frozen production. This is a very reasonable result since Frozen is energy extensive relative to Fresh with respect to transportation despite being energy intensive in processing. One hundred pounds of fresh potatoes make approximately forty-five pounds of frozen french fries. In addition to the weight savings, frozen potatoes require no special handling except refrigeration. For areas relatively close to final markets, such as the Northeastern and Northcentral regions, the additional energy required for processing would tend to outweigh any advantages in transportation as energy costs increase. For the Northwest, which is remote from the large Eastern markets, the transportation advantages of frozen products would tend to dominate. In other words, increased energy costs increase the comparative advantage which the Northwest holds for Frozen. The fact that regional energy costs in the Northwest are generally lower relative to those of the rest of the nation enhances this effect.

A positive sign in the Northwest Fall Fresh equation may indicate shifts out of Dehydrated and into both Frozen and Fresh as energy prices increase. Since dehydration requires especially large amounts of energy, as energy prices increase some shifting out of this form would not be surprising. The Northwest is probably the only region where this effect could be seen. As the ability to transfer potatoes out of Dehydrated production is obviously limited, at high enough energy prices (and consequently low enough levels of Dehydrated production) a negative parametric shift in the coefficient associated with the energy cost variable in the Northwest Fall Fresh equation would be anticipated.

CARRYOVERS

As with the planting equations, energy costs do not appear to affect carryover decisions. This may be due to a relative unimportance of energy costs in storage decisions. In addition, it is not theoretically clear whether the impact of energy costs on storage decisions would be positive, negative, or neutral. Although rising energy costs would discourage storage as the costs of storage have increased (since energy is an input), if continued energy cost increases are anticipated, storage of a unit of the existing product is a relatively cheap way to produce a unit of the future product.

SIMULATIONS

Simulations were performed to investigate the effects of different rates of increase in

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[3] The unbiased sample variance of the four previous years.

[4] Early potatoes are generally not grown in sufficient amounts to justify on-site processing. In addition, they do not store well and they usually command premiums in the fresh market.

[5] Parameter estimates with t-ratios having an absolute value of 2 or more were considered to be significant.

Table 2(a) Total Fall Regional Supply Estimates Via Ordinary Least Squares.

Dependent Variable	Intercept	Trend	Regional Crop	Expected Margin	Expected Margin Alternative[1]	Fuel Costs[2]	F Ratio (Prob>F)	R^2	Durbin Watson
FRH_{NEF}[3]	2662000. (4.68)	-1343. (-4.68)	.2190 (1.80)	-5662000. (-.85)	3749000. (1.66)	11670. (2.69)	33.79 (.0001)	.94	2.20
FRH_{NCF}[3]	-450600. (-1.24)	239.4 (1.29)	.1875 (1.59)	-8116000. (-1.28)	3271000. (1.60)	6099. (1.76)	12.56 (.0005)	.86	2.61
FRH_{NWF}[3]	900900. (1.21)	-448.2 (-1.18)	.3504 (7.35)	-13570000. (-2.14)	2056000. (.09)	8339. (2.55)	141.53 (.0001)	.99	2.66
FRZ_{NEF}[3]	-1042000. (-7.75)	528.2 (7.78)	.1532 (5.29)	15340. (.03)	535400. (.34)	-4570. (-4.46)	18.48 (.0001)	.90	2.62
FRZ_{NCF}[3]	-299400. (-2.76)	152.0 (2.72)	.0830 (2.35)	229100. (.37)	612000. (.32)	-1369. (-1.32)	12.61 (.0005)	.86	2.34
FRZ_{NWF}[3]	-3493000. (6.34)	1777. (6.30)	.1078 (3.05)	2139000. (1.27)	-6419000. (-1.37)	7835. (3.23)	350.15 (.0001)	.99	1.84

NOTE: Independent variables are associated with the region of the dependent variable. t-statistics for the estimated parameters are in parentheses.

[1] FRZ if FRH equation, FRH if FRZ.

[2] DSL/#2 fuel oil.

[3] NEF, NCF, NWF denote the Northeast, Northcentral, and Northwestern Fall producing regions, respectively.

Table 2(b). Total Early Regional Supply Estimates Via Ordinary Least Squares.

Dependent Variable	Intercept	Trend	Regional Carryin	Expected Margin[1]	Expected Margin Alternative[1]	Fuel Costs[2]	F Ratio (Prob>F)	R^2	Durbin Watson
FRH_{NEF}[3]	373000. (2.97)	-192400. (-2.99)	1.016 (7.00)	-446300. (-.23)	76400. (.10)	3299. (2.07)	198.40 (.0001)	.99	1.77
FRH_{NCF}[3]	274500. (3.49)	-141500. (-3.51)	1.071 (28.71)	57590. (.05)	-414500. (-1.00)	908.3 (1.28)	172.73 (.0001)	.99	2.07
FRH_{NWF}[3]	3789000. (6.74)	-1932000. (-6.73)	.9981 (14.45)	447.0 (.00)	-1933000. (-.90)	-6473. (-2.19)	76.20 (.0001)	.97	2.20
FRZ_{NEF}[3]	-257200. (-3.50)	132500. (3.07)	-.0041 (-.10)	108600. (.21)	-106000. (-.08)	-1926. (-1.81)	3.79 (.0305)	.63	1.70
FRZ_{NCF}[3]	-193600. (-3.78)	99620. (3.80)	-.03971 (-1.63)	342300. (1.26)	-300300. (-.38)	-448.7 (-.97)	11.47 (.0005)	.84	2.05
FRZ_{NWF}[3]	-2578000. (-7.46)	1314000. (7.44)	.04503 (1.06)	1013000. (.77)	-1389000. (-.41)	4813. (2.65)	234.98 (.0001)	.99	2.06

NOTE: Independent variables are associated with the region of the dependent variable. t-statistics for the estimated parameters are in parentheses.

[1] FRZ if FRH equation, FRH if FRZ.

[2] DSL/#2 fuel oil.

[3] NEF, NCF, NWF denote the Northeast, Northcentral, and Northwestern Fall producing regions, respectively.

energy costs on the U.S. potato industry. Exogenous variables were projected by extrapolating the results of regressing each against a trend term and a trend term squared.[6] Energy costs were assumed to increase by 2, 5 and 10 percent per annum. The simulations were for the period 1979 to 1990.

Reflecting the insignificance found in the energy cost-planting decisions and energy cost-carryover relationships, no substantial differences were noted between the simulations in total regional production levels or carryover behavior. Undoubtedly, at some level of energy cost the competitive positions of the high energy use areas of the Northwest and Northcentral regions will be adversely affected. Therefore, the projections for these areas may be overstated, and the remaining regions understated. In addition, since two of the Fall regions are high energy users for cultivation, and since energy inputs are required in storage, it would seem likely that higher levels of energy costs would favor the Early production regions. This effect, if it exists, was not evident in the simulation.

The major impacts of altering energy costs were on the mix of potato food products which each Fall production region produced, and in the national mix of potato food products. Table 3 presents the absolute amounts and percentages of national and Fall region production of food potatoes which are allocated to each use for selected years.

For the Northeast and, to a lesser extent, the Northcentral regions, it is evident that higher energy costs discourage processing. The 1985 projections indicate that the Northeast would devote 51.4 percent of its total food production to Fresh if a two percent annual increase in energy costs is assumed. This percentage increases to 67.9 and 98.2 for five and ten percent per annum increases in energy costs, respectively. Similarly, by 1985, the Northcentral region's percentage of Fresh is 70.5, 75.3, and 85.4 for the two, five and ten percent energy cost increase scenarios, respectively.

The Northwest picture is somewhat clouded by two related, but somewhat counterbalancing, effects. First, increased energy costs discourage the processing of Dehydrated, which requires relatively large amounts of energy in processing. As can be seen in Table 3, higher energy costs invariably result in lower Dehydrated projections. Second, increased energy costs discourage Fresh in the Early season, but encourage it, as well as Frozen, in the Fall. This is mainly the result of the reallocation of some of the supplies made available by the reduced dehydrated production in the Fall. Continuation of this reallocation depends on the size of the remaining Dehydrated use. As evidence of this, if the ten percent scenario is carried to 1993, Fresh production peaks, as Dehydrated output stabilizes at a low level. Frozen production is strongly and positively associated with higher energy costs. The difference in Frozen production between the two and ten percent scenarios is over fourteen million cwt. in 1985 and thirty-one million cwt. in 1990.

For the nation, increased energy costs are associated with greater supplies of Fresh and Frozen at the expense of Dehydrated. Production of Fresh shifts eastward. The Northeast accounts for 14 percent of Fresh in the two percent scenario for 1985, versus 19 and 22 percent for the five and ten percent scenarios, respectively. In absolute terms Fresh production in the Northeast, in 1985, for the ten percent scenario is nearly double that for the two percent scenario. Processing shifts westward. In 1978, the Northwest produced 85.6 percent of all processed potatoes (not including chips) versus 83.7 percent in the two percent scenario, 87.2 percent in the five percent scenario, and 95.0 percent in the ten percent scenario of 1985.

CONCLUSIONS AND IMPLICATIONS

This study has investigated the effects of rising energy costs with respect to production regions and product forms in the U.S. potato industry. No significant planting decision- energy cost relationships were found. Habit persistence, asset fixity, and a lack of lower energy use alternatives are possible causes of this result. No energy cost-carry-over link was discovered. This may be due to a relatively insignificant role of energy in storage or by a cancellation process from the incentive to avoid the energy costs of storage and the counterbalancing incentive to avoid the energy costs of future production by the storing of current product.

By far the most important effect of increased energy costs was on the regional mix of product forms. In simulations, higher energy costs were associated with substantial reductions in the output of processed potatoes, and consequently, increased Fresh production in the Northeast and, to a lesser extent, in the Northcentral regions. In the Northwest, higher energy costs resulted in reductions in Dehydrated output. This was reasonable, considering the large amount of energy which this form requires. Frozen output was encouraged, as was Fresh to a lesser extent. The mildly positive energy cost-Fresh production relationship was largely a result of the reallocation of some potatoes previously used for Dehydrated. At low enough levels of Dehydrated production Northwest Fresh production peaked and declined in favor of Frozen. For the nation as a whole, increased energy costs were associated with increased Fresh and Frozen and decreased Dehydrated production.

The polarization of processed production to the Northwest and Fresh production to the Northcentral and Northeast when energy costs were increased was a result of producers seeking less energy intensive bundles of goods. The relative cost of producing bundles of goods for a given market depends upon the distance from the production point to the market (i.e., distance in terms of time, space and form), and the prices and amounts of inputs required for each goods bundle to span these distances. In the Northeast and

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6 The sole exception was population, where the U.S. Bureau of the Census projection was employed, which assumes a 2.1 fertility rate.

Table 3: Simulation Results

Annual Percentage Increase In Energy Crop	Year	Region[1]	Fresh: Percent of Regional Total	Fresh: Amount[2]	Frozen: Percent of Regional Total	Frozen: Amount[2]	Dehydrated: Percent of Regional Total	Dehydrated: Amount[2]
N.A.	1978 (Actual)	NEF	74.74	23.4	18.77	6.6	6.49	2.3
		NCF	77.41	39.7	14.74	7.6	7.85	4.0
		NWF	28.43	43.0	53.15	80.4	18.43	27.7
		Nation[4]	54.12	149.2	34.31	94.6	11.16	31.9
2	1985	NEF	51.41	16.8	24.45	8.0	24.03	7.9
"		NCF	70.52	38.5	16.80	9.2	12.68	6.9
"		NWF	24.82	54.3	51.35	112.3	23.83	52.1
"		Nation[4]	38.61	123.5	40.47	129.5	20.92	66.9
"	1990	NEF	43.09	12.7	30.18	8.9	26.74	7.9
"		NCF	70.43	39.4	17.45	9.8	12.12	6.8
"		NWF	25.77	71.0	50.74	139.8	23.49	64.7
"		Nation[4]	35.62	131.5	42.9	158.4	21.49	79.3
5	1985	NEF	67.94	22.2	17.42	5.7	14.64	4.8
"		NCF	75.29	41.0	15.54	8.5	9.11	5.0
"		NWF	25.21	55.1	53.72	117.5	21.07	46.1
"		Nation[4]	38.98	119.8	42.85	131.7	18.17	55.9
"	1990	NEF	75.31	22.1	15.52	4.6	9.18	2.7
"		NCF	79.79	44.8	15.11	8.5	5.09	2.9
"		NWF	26.33	72.5	53.96	148.6	19.7	54.3
"		Nation[4]	40.0	147.7	43.79	161.6	16.2	59.8
10	1985	NEF	98.25	32.2	1.73	.6	0	0
"		NCF	85.35	46.3	13.09	7.1	1.55	0.8
"		NWF	26.05	57.1	57.76	126.5	16.18	35.4
"		Nation[4]	46.51	148.2	32.10	134.1	11.38	36.4
10	1990	NEF	100.0	29.4	0	0	0	0
"		NCF	95.48	53.3	4.22	2.4	.3	.2
"		NWF	27.40	75.5	62.21	171.4	10.39	28.6
:		Nation[4]	45.05	166.1	47.14	173.8	7.81	28.8

1. NEF = Northeast, NCF = Northcentral, NWF = Northwest, Nation includes Early regions, and is assumed to equal consumption.
2. In 1,000.000 Cwt. Fresh Weight Equivalents.
3. Actual amounts.
4. Discrepancies between the National figures for Fresh and the totals for the Fall regions are due to the Early regions.

Northcentral the energy costs of processing tend to dominate the short-to-medium haul transportation costs of delivering Fresh. For the Northwest, the reverse would appear to be the case, at least for Frozen.

For the Northeast potato industry the above conclusions portend both good and bad. On the negative side, rising energy costs alone cannot be counted upon to arrest the absolute and relative decline in potato production which the region has experienced over the last several decades. Increasing energy costs actually appear to reduce prospects for establishing major processing centers in the East. On the positive side, the working of the patterns of comparative advantages associated with rising energy costs does tend to make Northeastern fresh potatoes more competitive.

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