SUPPLY RESPONSE TO TECHNOLOGICAL CHANGE AND REGULATION: THE CASE OF MECHANICALLY DEBONED POULTRY

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The supply of poultry meat is being augmented by hundreds of millions of pounds annually at little economic cost and no increase in the output of chickens or turkeys. The food-processing innovation responsible for boosting the utilization efficiency of our scarce food protein resources is mechanical deboning, a technique that separates the remaining meat from bones destined to be rendered into inedible products. The potential gains to society from further widespread adoption of this technology could be enormous. Therefore, it is important to have a clear understanding of the factors that affect the market supply response to this technology, as well as the impact of additional regulations governing its use.

The purpose of this paper is to analyze the supply response by poultry processors to this innovation. After a brief description of the technology and its uses, a conceptual supply-response model is developed. Using data previously not available, parameters of the conceptual model are estimated, and relevant supply elasticities are calculated. Finally, the model is used to analyze the possible impact of new regulations affecting the production and use of mechanically deboned poultry (MDP).

MDP SUPPLY RESPONSE

After chickens and turkeys are slaughtered, some are marketed bone-in as whole birds or as cut-up parts. However, a growing proportion of poultry carcasses or parts are further processed into boneless or comminuted (consisting of minute particles) poultry products. While the major portions of poultry meat are removed by hand, some meat tissue remains attached to the bones. It has been common practice to render the bones and any attached tissue into low-value inedible products, such as animal feed, since further hand deboning was not economically feasible.

The Technology and Its Use

The development and adoption of mechanical deboning technology makes this loss of edible poultry meat unnecessary. Poultry product processors can process the hand-trimmed bones and remaining attached poultry tissue (or even whole birds or parts) through deboning machines that separate and remove most of the bone from the attached skeletal muscle tissue. The resulting paste like product is commonly called mechanically deboned poultry.

Production of MDP increased from 196 million pounds in 1976 (Poultry and Egg Institute) to 330 million pounds in 1979 (USDA 1980), about 23 percent a year. By the end of 1979, 137 deboning machines were in use in 95 different federally inspected poultry-processing establishments. The regional distribution of these establishments include 16 in the West, 16 in the Southwest, 26 in the North Central, 15 in the Southeast, and 22 in the Northeast.

MDP is a relatively inexpensive ingredient, selling for 20 to 40 cents a pound, depending on fat and protein content. MDP is frequently included as the primary ingredient in processed poultry products such as poultry frankfurters, luncheon meats, rolls, and loaves. No special labeling is required to identify the ingredient in any poultry product. The utilization of MDP is contingent upon its functional (binding, texturizing, etc.) and organoleptic (taste, smell, appearance, etc.) characteristics, not on public awareness or perceptions of the ingredient. The low-fat, high-protein content of the ingredient makes it ideal for use in poultry meat products that compete against similar types of processed red meat products.

Complete information about the final-product use of MDP is unavailable. However, the frankfurter market is one example where the significance of the availability and use of MDP can be clearly illustrated. Table 1 shows annual sales volumes and average prices for three types of frankfurters sold through retail outlets for at-home consumption during the period from December 1977 to November 1980. Beef franks must contain only beef. Meat franks usually contain a combination of beef and pork, but may contain some MDP. Poultry (chicken and turkey) franks, which contain up to 100 percent MDP, are relatively new products developed to provide poultry processors with new markets for MDP. Approximately 23 percent of the MDP produced in 1979 was marketed as poultry frankfurters through retail outlets. An additional unknown quantity of poultry frankfurters were sold to consumers by the hotel, restaurant, and institutional trade.

Over the 3-year period, total retail sales of frankfurters remained relatively flat, increasing by less than

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Table 1. Comparative Retail Prices and Sales Volumes of Frankfurters by Type, 1978–1980

12 Month Period	Beef Volume 000 lbs	Beef Price $/lb	Meat Volume 000 lbs	Meat Price $/lb	Poultry Volume 000 lbs	Poultry Price $/lb
Dec. 1977–Nov. 1978	343,332	1.45	494,363	1.37	46,208	1.03
Dec. 1978–Nov. 1979	304,185	1.74	500,178	1.57	74,916	1.12
Dec. 1979–Nov. 1980	257,946	1.84	545,294	1.58	90,362	1.11

10 million pounds or about 1 percent. But these figures mask significant changes that were taking place in this market, largely in response to the adoption of the mechanical deboning technology by poultry processors and the significant increase in MDP production that followed. Retail sales of poultry franks increased by 96 percent, while retail sales of beef franks decreased by 25 percent.

Part of this dramatic change in the frankfurter market might be associated with a shift in consumers' tastes and preferences. However, most is attributable to the considerable price/cost advantage of poultry franks made with MDP. Over the 3-year period, the average retail price of poultry franks was 30–40 percent lower than the average retail price of beef franks and 25–30 percent lower than the average retail price of meat franks. While the retail price of poultry franks rose by less than 8 percent over the 3-year period, the retail price of beef franks rose by over 27 percent, and the price of meat franks rose by 15 percent. The result was that the poultry frank share of this frankfurter market doubled from 5 percent in 1978 to 10 percent in 1980. According to industry sources, use of hand-deboned poultry-meat trimmings rather than MDP to make poultry frankfurters would eliminate the price advantage of chicken and turkey franks relative to beef and meat franks. Sun's estimate of an own-price elasticity for poultry franks of -1.7 and cross-price elasticities of 1.1 for beef and 0.2 for meat franks reinforce the hypothesis that the relative price advantage of poultry frankfurters with low-cost MDP was a key variable influencing changes in consumer purchases.

Conceptual Model

Studies by Bullock and Ward, McNiel, and Williams analyze the economic impact of the increased supply of edible red meat that could result from mechanical deboning. In each study, the increased supply of red meat is more or less exogenously determined as a result of various assumptions and rules of thumb about the obtainable yield per carcass and the number of carcasses processed under different regulatory conditions. These exogenously determined supply shocks are then applied to models of the table and processed beef and pork markets (McNiel), to beef and pork price equations (Williams), or simply to relevant beef and pork elasticities (Bullock and Ward) to analyze the possible impacts. In none of these studies is the supply response itself modeled or endogenous in the sense that it is estimated from data reflecting the market response of producers. The reason for this is that no reliable historical data on the production of mechanically deboned red meat exists. An important contribution of this study is that it analyzes MDP production data not previously available and endogenously estimates the MDP supply response of poultry processors. Consequently, it adds to our knowledge about the determinants of a key variable, which in previous studies were treated exogenously or in an ad hoc manner.

Only a few processors specialize in the production of MDP. Most of the poultry processors who have adopted the mechanical deboning technology have flexible production capacity, which can be used to produce boneless, comminuted, cut-up, and whole-poultry products. It is assumed that processors allocate their production capacity among competing products to maximize expected profits. Under free market conditions, aggregate production of MDP may be viewed as a function of its own price, the prices of other substitutes in production, variables reflecting the availability of potential poultry inputs for producing MDP, and the rate of adoption of the technology.

A simple aggregate MDP supply-response function may be hypothesized as follows:

$$(1) \quad QMDP = f(PMDP, PSUB, QINPUT, ADOPT)$$

where QMDP represents the quantity of MDP produced, PMDP represents the price of MDP, PSUB represents the price of substitutes in production for the raw material inputs used in making MDP, QINPUT represents the quantity of poultry raw material inputs potentially available for producing MDP or substitutes in production, and ADOPT represents the adoption rate for the technology. For most establishments cutting up and further processing poultry, MDP production is an alternative way of utilizing byproducts generated in their primary-poultry-processing operations. Since few firms specialize in producing MDP from raw materials collected from other firms, the supply of MDP is contingent upon how many of the over 1000 poultry-processing firms adopt the technology, the quantity of potential poultry inputs available to be processed by these firms, and the extent to which available poultry inputs are processed into MDP. If the price of MDP rises relative to the prices of alternative final food and nonfood product uses for MDP ingredients, not only is a larger portion of the potential-byproduct raw materials of firms utilizing deboning machines likely to be processed into MDP, but additional firms are likely to adopt the technology. On the other hand, if the relative prices of alternative final product uses of these raw materials increase, production of MDP is likely to be curtailed. For example, if the wholesale prices of backs and necks, the two poultry parts most commonly mechanically deboned, rise, processors will find it more profitable to market these parts bone-in and let the production of MDP decline.

Since the adoption rate is unlikely to be an exogenously determined variable, a second equation

(2) ADOPT = f(PMDP, PSUB, TREND)

is needed to complete the supply-response model. The adoption rate is hypothesized to be directly related to PMDP, inversely related to PSUB, and directly related to a TREND variable. The trend variable is included to capture the demonstration effect that occurs over time as awareness of the technology spreads, as its efficiency is improved, as regional, national, and foreign markets develop, and as firms become convinced of the stability of relevant regulations and learn to minimize the attendant compliance costs.

Data, Time Frame, and Structure of the Empirical Model

Data on the production of MDP are not collected regularly by the USDA and are not readily available from industry sources. Monthly data on the aggregate U.S. production of MDP in 1978 and 1979 were obtained by a special USDA survey of the 1,065 federally inspected poultry further-processing establishments operating in 1980. Due to the time limitations of this data series, the analysis must be constrained to the short-run time frame.

Monthly price data for MDP was constructed from weekly quotes in the *Urner Barry's Price-Current* reports. A price index for the major substitutes in production was constructed from the monthly prices for chicken backs and necks and turkey necks (*Poultry Market Statistics*). The quantity of ready-to-cook poultry produced in federally inspected plants was used as a measure of the availability of potential poultry raw materials for producing MDP (*Poultry and Egg Outlook and Situation*). Data on the adoption rate of the technology, measured by the percent of establishments operating deboning machines in each period, was also obtained from the special USDA survey. Variation in the absolute number of firms operating deboning machines each period ranged in a nonmonotonic, though generally increasing, pattern from a low of 65 firms to a high of 95 firms as some of those initially adopting the technology either abandoned it or went out of business while other firms subsequently made the adoption.

The TREND variable was assumed to be linear due to the relatively short-run time frame of the study. While a sigmoid relationship between the percent of firms adopting a technology and time is often found in technology-assessment studies, these studies generally span a much longer time frame. For a relatively short time frame, a linear TREND variable should provide a reasonable approximation, even if the long-run trend is nonlinear. There is also reason to believe that during the period analyzed, the demonstration effect referred to above (tending to accelerate the rate of adoption by poultry processors) may have been moderated by the regulatory uncertainty generated by the controversy, negative publicity, and court battles over mechanically deboned red meat regulations and the subsequent near abandonment of the technology by red meat processors.

The appropriate prices for supply analysis are the prices expected by producers at the time production decisions are being made (Gardner, p. 81). Futures prices or lagged prices are often used as proxies for expected prices in supply-response analysis (Gardner; Nerlove). Since MDP futures prices are not available, one-period-lagged prices were used. This procedure also avoids the problems created by the simultaneous determination of supply and demand (Gardner).

Empirical Results

As emphasized by Morzuch et al. (p. 30), processors are concerned with relative prices in allocating production capacity among alternative uses. Consequently, the price variable was entered as the lagged ratio of PMDP to PSUB to estimate the parameters of equations (1) and (2). This formulation was also chosen for its usefulness in modeling the impact of changes in the regulations affecting MDP.

Since the two-equation system is recursive, the parameters were estimated using both ordinary least squares (OLS) and two-stage least squares (2SLS) regression. All coefficients are of the theoretically expected sign (Table 2). The quantity of MDP supplied is directly related to its relative price, the quantity of poultry inputs potentially available for producing MDP, and the rate of adoption of the mechanical deboning technology. The rate of adoption is directly related to both the relative-price and the time-trend variable. All coefficients are significant at the 0.10 level or lower. The Durbin-Watson (DW) statistics indicate no problems with serial correlation, and the condition values

Table 2. Estimated MDP Supply Response Model

Equation	OLS and 2SLS Regression Coefficients[a] (with standard errors)[b]						
	$(PMDP/PSUB)_{t-1}$	$QINPUT_t$	$ADOPT_t$	TREND	R^2	DW	COND(X)
(1) $QMDP_t$							
OLS	26.90 (10.43) **	5.45 (2.49) **	46.71 (6.77) ***		.87	2.26	39.59
2SLS	26.69 (10.44) **	5.20 (2.54) *	47.99 (7.19) ***		.87	2.30	41.91
(2) $ADOPT_t$	.36 (.11) ***			.71 (.05) ***	.92	1.80	14.44

a) Intercept terms: equation (1) OLS—18,705.60 (3,761.16) *** 2SLS - 19,236.60 (3,894.87) ***

equation (2) 504.83 (19.54) ***

b) *** - significant at .01 level.
** - significant at .05 level.
* - significant at .10 level.
Statements of significance are only approximate for 2SLS.

c) Units of measurement: QMDP - pounds per month, PMDM/PSUB - ratio X 100, QINPUT - pounds per month ÷ 10 ; ADOPT - percent firms X 100, TREND - months X 10.

(COND(X)) indicate that multicollinearity is not a serious problem.

If the errors of the two equations are mutually independent, direct regressions would be preferred in estimating equation (1). Under these conditions, both OLS and 2SLS yield unbiased estimates, but OLS estimators will be more efficient. However, if the errors of the two equations are correlated, the coefficients, from direct regressions will be biased while 2SLS still yields unbiased estimators (Malinvaud). Since there was reason to suspect correlation in the errors of the two equations, the 2SLS coefficients were used in computing the elasticities reported in Table 3.

Preliminary investigations considered QINPUT as a determinant of the adoption rate, but the hypothesis that its coefficient was equal to zero could not be rejected, so this variable was not included in equation (2). An alternative formulation of the model with the price variables entered separately, as in equations (1) and (2), found the coefficients of PMDP and PSUB to have the expected positive (own-price) and negative (cross-price) signs, respectively, with both significant at the .05 level. Distributed lag relationships on the relative price variable were also examined for equations (1) and (2), but none proved as satisfactory as the more simplistic formulation reported in Table 2.

REGULATORY POLICY ANALYSIS

Mechanical deboning is not unique to the poultry-processing industry. The technique was first developed for the Japanese seafood industry over 20 years ago and was later adapted for use on poultry and red meat bones. In the United States, the supply response to the technology by the red meat and poultry industries has been quite different. In 1979, almost 330 million pounds of MDP were produced, compared to less than 3 million pounds of mechanically deboned red meat (MDM). Nearly 10 percent of the federally inspected poultry-processing establishments had adopted the technology, compared to an insignificant number of red meat processors.

Table 3. MDP Supply Response Model Elasticities

Elasticity Measures	Elasticity Value[a]
Elasticity of $QMDP_t$ with respect to:	
$(PMDP/PSUB)_{t-1}$	.20
$QINPUT_t$	.25
$ADOPT_t$	1.51
Elasticity of $ADOPT_t$ with respect to:	
$(PMDP/PSUB)_{t-1}$	.09

a) Calculated at scaled sample means of $QMDP_t = 22{,}203$, $(PMDP/PSUB)_{t-1} = 166$, $QINPUT_t = 1{,}084$, $ADOPT_t = 7 \times 10^2$, $TREND = 125$

Some of the disparity between production of MDM and MDP may be due to differences in the physical characteristics of red meat and poultry carcasses, which affect the extent to which bones can be utilized, as well as yields (Fields). However, USDA calculations taking into account the potential supply of useable inputs as well as their expected yields estimated the potential supply of MDP to be about twice the amount actually produced in 1979. The potential supply of MDM in that year was estimated to exceed 100 times the amount actually produced.

The large disparity between the ratio of actual production to potential production for MDP and MDM has led most researchers to attribute the difference in supply responses to differences in the federal regulatory environment [CFR]. The markets for MDP were developed in an environment virtually free of regulations governing ingredient standards, use limitations, and labeling requirements.[1] But the potential producers of MDM were confronted with a more constraining regulatory environment with provisions that they believed created a negative image of MDM and products that might contain it.[2]

The possible effects of federal regulations on the supply of MDM have been analyzed elsewhere (Bullock and Ward; McNiel; Williams). The contrasting relatively free market in which the MDP supply response to the deboning technology evolved has been virtually ignored by policy researchers. The MDP supply-response model developed here facilitates our ability to assess the implications of a recent report to Congress [GAO] recommending that institutional disparities in the marketplace between the two ingredients be removed by extending the recently promulgated MDM regulations to MDP (USGSA).

While a more rigorous impact analysis must await specific regulatory proposals, a general approach for that analysis can be suggested. If nutrient standards should reduce either the type or amount of potential poultry inputs that may be used for producing MDP, the amount of MDP marketed will be reduced. Depending upon the extent to which blending is allowed, imposition of maximum fat and minimum protein standards, or restrictions on the use of MDP from fowl may eliminate some potential raw material sources for adopting firms. Since actual production of MDP is presently less than potential production, however, regulations that restrict the supply of potential inputs for producing MDP will not result in a proportional re-

[1] The only ingredient standard for MDP is a 1 percent maximum on-bone content (9 CFR 381.117 [d]). MDP may be used in any product in which poultry or poultry meat is allowed, including some processed red meat products such as bologna, knockworst, and frankfurters (9 CFR 319.180). MDP may comprise up to 100 percent of the poultry portion of a meat or poultry food product, and no special labeling is required. Products are simply labled by kind (chicken or turkey) if meat, skin, and fat are present in natural proportions, or as (kind) meat if no fatty tissue or skin are included (9 CFR 381.117).

[2] During the period analyzed, regulations governing MDM as an ingredient included standards for bone content and particular size, calcium, fat, protein quantity and quality (9 CFR 319.5). Use of MDM was limited to no more than 20 percent of the meat portion of any final meat food product (9 CFR 319.6 [b]). MDM could not be used at all in products such as ground beef and hamburger (9 CFR 319.6 [c]). The name on the label of a final product containing MDM had to be qualified by the phrases, "With Mechanically Processed (Species) Product," "Contains Up to ____% Powdered Bone," and the ingredients statement had to list MP(S)P in order of predominance by weight (9 CFR 317.2 [j] [13]).

duction in the amount of MDP marketed. The amount of the reduction can be estimated using the elasticities reported in Table 3. Holding relative prices and the adoption rate constant, a 1 percent decrease in the availability of potentially usable poultry inputs is associated with a 0.25 percent decrease in production of MDP.

A second category of possible new regulations affecting compliance costs may have an even more important effect on the supply of MDP. Examples include regulations governing the type, number, and frequency of laboratory tests required to demonstrate compliance with ingredient standards, or regulations governing quality-control programs, and record-keeping, reporting, and labeling requirements. These types of regulations may be viewed as decreasing the ratio of PMDP to PSUB. To the extent that the additional compliance costs are fixed, their impact on larger firms is likely to be slight, but smaller firms may be significantly affected. While more specific analysis must await concrete regulatory proposals, the elasticities in Table 3 suggest that a 1 percent decline in the relative price of MDP, holding constant the availability of inputs and the adoption rate, is directly associated with a 0.2 percent decline in MDP production. Regulations of this type also affect the rate of adoption, which in turn affects MDP production. Using the relative price elasticity in the second equation of the supply-response model, a 1 percent decrease in the relative price of MDP is also associated with a 0.09 percent decline in the adoption rate. Returning to the first equation in the model, a 0.09 percent decline in the adoption rate is in turn associated with a 0.135 percent (0.09 X 1.5) decline in MDP production, *ceterus paribus*. The combined direct and indirect effects of a 1 percent decrease in the relative price of MDP outweigh the effect of a 1 percent decrease in the availability of potentially usable poultry inputs.

SUMMARY AND CONCLUSIONS

The preceding analysis has demonstrated the importance of the relative price of MDP, the availability of poultry inputs, and the rate of adoption of the mechanical deboning technology in determining poultry processors' MDP supply response. The supply-response model developed should be useful in analyzing the consequences of specific MDP regulatory proposals affecting these supply response variables.

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