May 2007

An Economic Analysis of the Effectiveness of the Pork Checkoff Program

Final Report

Prepared for

National Pork Board
P.O. Box 9114
Des Moines, IA 50325

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Executive Summary

The primary goal of the Pork Checkoff Program is to increase the profitability of hog and pork producers and importers through expansion of the demand for hogs and pork and reductions in production costs. The purpose of this study is to assess how well the Program's goals are being met.

The Pork Checkoff Program is funded by a mandatory assessment collected from hog producers and hog and pork importers, and the revenues are collected and managed by the National Pork Board, a quasigovernmental, nonprofit entity that administers the program. The primary goal of the Pork Checkoff Program is to increase the profitability of hog and pork producers and importers through expansion of the demand for hogs and pork and reductions in production costs. The purpose of this study is to assess how well the Program's goals are being met. Davis et al. (2001) previously conducted a study that focused on the Program's performance from inception of Program activities in 1987 through 1998. Although we use data covering the entire time frame of the Program for estimation purposes, the focus of the current study is on the period from 1999 through 2005.

ES.1 INTRODUCTION

Instituted in 1986, the Pork Checkoff Program aims to help the pork industry more effectively address important issues affecting a wide spectrum of market participants in a joint and organized manner. The Program is funded by a mandatory assessment on the market value of all hogs sold in the United States, as well as an equivalent amount on imported hogs, pork, and pork products (currently 0.4% of market value). Assessments have totaled around $60 million annually in recent years. These funds are invested in programs attempting to increase domestic pork consumption, increase export demand for U.S. pork, conduct research to improve production practices, and conduct outreach to provide producers with knowledge necessary to compete in modern agriculture.

The economic value of the Program to those paying assessments depends not only on whether promotion and research have been effective in increasing sales and/or lowering the cost of hog production, but also on the cost-effectiveness of these activities. It is unlikely that Program promotion and research activities would not have at least some positive impacts on sales and production costs. The key question is whether the costs of the Program are justified by its benefits.

ES.1 STUDY OBJECTIVES

To assess how successfully the Pork Checkoff Program is meeting its economic goals, the National Pork Board directed that this study must address the following key issues:

1. Measure the economic and financial benefit to producers (and, if possible, other pork value chain participants) of pork checkoff-funded programs in terms of net return on investment. Define, as possible, historic benefits achieved.
2. Define and quantify, as possible, the influence that specific pork checkoff-funded programs (demand enhancement, science, and outreach) have had on enhancing pork demand and resulting net return on investment to producers and value chain participants. Isolate the influence of specific pork check-off funded programs net of other macro-economic factors such as shifts in meat demand, changes in consumer incomes, global trade issues, and health and safety concerns, for example.

To examine these issues, we developed and applied econometric and equilibrium displacement models of the markets for U.S. hogs and pork. Using the econometrically estimated parameters within the equilibrium displacement model, we can obtain empirical evidence of the Program's effectiveness in enhancing the demand for—and in the case of agricultural research, the supply of—U.S. hogs and pork. These models can tell us whether the Program has had statistically significant market effects, while controlling for factors that are economically important but outside the sphere of the Program's influence (e.g., income, prices of substitutes, food safety events).

ES.2 DATA AND METHODS

We describe the study approach used by the team of researchers from RTI and North Carolina State University to accomplish these objectives.

ES.2.1 Data

The data used in the econometric modeling come from various sources in the public domain, with the exception of commodity research and promotion expenditures. These data are not publicly available at the appropriate level of detail and were obtained from the appropriate organizations or researchers that have access. We used quarterly data for 1982 through 2005 on prices of hogs and pork, prices of substitute meats, input costs, hog and pork quantities produced and consumed in the United States, income, and trade data obtained from a variety of public data sources, as well as Pork Checkoff research and promotion expenditures provided by the National Pork Board and generic beef promotion expenditures from Dr. Ron Ward at the University of Florida.

Consistent with the previous evaluation conducted by Davis et al. (2001), the various program activities of the National Pork Board were grouped into four categories: retail advertising and promotion aimed at increasing the demand for pork (PDE), postfarm research expenditures expected to directly increase the demand for hogs (HDE), agricultural production research expected to shift hog supply (HSE), and foreign market development expenditures aimed at increasing exports (FMD).

ES.2.2 Econometric Models

The economic questions in this study relate to the degree of influence that the Pork Checkoff Program has on the hog and pork markets and the profitability of producers. To quantify these effects, econometric models were developed that statistically estimate the relationship between economic variables for domestic demand for hogs, supply of pork, domestic supply of hogs, import demand for Canadian hogs, domestic demand for pork, and export demand for U.S. pork. Table ES-1 lists the components and the variables used to estimate the model.

Table ES-1. Econometric Model Components and Variables

Market Component	Dependent Variable	Explanatory Variables[a]
Domestic inverse demand for hogs	Hog price	Hog quantity Retail price of pork Index of marketing costs Capacity constraint (=1 in 1998[4]) Polynomial inverse lag structure on National Pork Board postfarm marketing research expenditures
Pork supply	Pork quantity	Hog quantity Retail price of pork Index of marketing costs Capacity constraint (=1 in 1998[4])
Domestic supply of hogs	Inventory of sows	Inventory of sows at 1 quarter lag Hog price at 5 quarter lag Corn price at 1 quarter lag
	Pounds per market hog	Ratio of hog price to corn price
	Pigs per litter	Severe drought (=1 in 1998) Polynomial inverse lag structure on National Pork Board production research expenditures
Import demand for Canadian hogs	Number of hogs imported from Canada per capita	Number of hogs imported from Canada per capita at 1 quarter lag Canadian hog price at 5 quarter lag Real U.S. per capita personal consumption expenditures Real Canadian per capita disposable income
Domestic demand for pork	Demand system (GAIDS) with per capita retail consumption of beef, pork, and poultry	Prices of beef, pork, and poultry Media food safety indices for beef, pork, and poultry Structural change variable (=1 for 2002–2005) Polynomial inverse lag structures on National Pork Board domestic promotion expenditures and beef promotion
Export demand for U.S. pork	Net trade in pork	Net trade in pork at 1 quarter lag Trade volume weighted gross domestic product of major importers of U.S. pork U.S. retail pork price Polynomial inverse lag structure on National Pork Board foreign market development expenditures

[a]In addition, we include quarterly dummy variables to account for seasonality and a trend variable to account for changes in technology and other changes taking place over time that are not explicitly included in the model.

Estimation of the econometric models summarized in Table ES-1 yields values for parameters that capture the nature (sign) and magnitude of the economic effects of interest. Of particular interest are the parameters capturing the effects of Program expenditures because they are key determinants of Program returns to producers.

ES.2.3 Using Econometric Model Parameters to Simulate Return on Investment

The parameter estimates in the econometric model provide empirical evidence on the size of Program effects on U.S. hog and pork supply and demand. In this phase of the study, we used the econometrically estimated parameters to quantify the return on investment provided by the program. For instance, a program that successfully raises the demand for U.S. hogs and pork will increase the quantity purchased in the market and raise the price above the level that would prevail if there were no demand-enhancing program. These changes in the market will, all else equal, raise the well-being of those domestic producers and importers that obtain a higher price for their product. However, producers and importers must also pay for the Program through an assessment on the hogs or hog equivalents they produce or import. Net returns were estimated using the economic measure of producer surplus, subtracting out the assessment paid by producers. This net return measure was then divided by the cost to estimate the benefit-cost ratio for the program:

Benefit-cost ratio = Net return to producers/Program cost

Thus, a program with a positive net return will have a positive benefit-cost ratio. The larger the ratio, the higher the rate of return producers are receiving on the assessments paid to fund the Program.

We relied on an equilibrium displacement model (EDM) to account for all linkages between market levels as well as endogeneity of prices and quantities. Within this model, we simulated the effects of a 1% increase in overall Program expenditures as well as individual components and combinations of Program components to generate estimates of marginal returns to the Program. Assuming declining marginal returns for promotion and research, these estimates place a lower bound on the point estimate of average historical returns from 1999 through 2005 and provide information on the relative marginal returns available across alternative Program activities.

ES.3 KEY RESULTS

Results of the analysis can be reviewed from two perspectives: econometric estimation of the market model and calculation of Program rate of return.

ES.3.1 Econometric Estimation

General Results

Estimated elasticities of prices, expenditures, input costs, food safety events, and other parameters have the expected signs and reasonable magnitudes in almost all cases.

In general, the estimated econometric model conforms quite well to expectations based on economic theory. Estimated elasticities of prices, expenditures, input costs, food safety events, and other parameters have the expected signs and reasonable magnitudes in almost all cases. In addition, the predictive power of the models is generally very good, indicating that they are well suited for simulating the demand effects of altering program expenditures.

Because the majority of Program expenditures have been devoted to domestic retail promotion, one of the most important components of this study is our retail meat demand system. We modeled domestic demand for pork within a Generalized Almost Ideal Demand System (GAIDS) framework (Bellino, 1990), which contains the major meat species consumed by Americans: beef, pork, and poultry (chicken and turkey). A demand system is chosen over an ad hoc single equation approach because a system approach for closely related goods corresponds well to an underlying consumer preference structure and is fully consistent with consumer demand theory.

As shown in Table ES-2, the Marshallian own-price elasticities of demand are –0.7614 for beef, –0.6413 for pork, and –0.3788 for poultry, all of which fall within typical ranges reported in the literature.[1] These parameters indicate, for example, that the quantity of pork demanded would fall by 0.6413% in response to a 1% increase in the price of pork. The

[1] All cross-price elasticities in the model are negative, implying that these products are all complements. This is at least in part reflective of the GAIDS functional form and the presence of pre-committed quantities, as explained in more detail in Section 5.6.

Table ES-2. Estimated Price, Expenditure, Food Safety, and Generic Advertising Elasticities with Structural Change for Pork Advertising between 1987–1998 and 1999–2005[a]

	Beef q	Pork q	Poultry q
Uncompensated (Marshallian) Price Elasticities[a]			
Beef p	–0.7614	–0.2824	–0.0707
Pork p	–0.1232	–0.6413	–0.1887
Poultry p	–0.1092	–0.2401	–0.3788
Expenditure Elasticities			
Expenditure	0.9938	1.1638	0.6382
Food Safety Elasticities			
Beef safety	–0.0023	–0.0007	0.0057
Pork safety	–0.0047	0.0023	0.0077
Poultry safety	0.0052	–0.0022	–0.0090
Long-Run Generic Advertising Elasticities (1987–1998)			
Generic beef promotion	0.0066	0.0027	–0.0208
Generic pork promotion	–0.0213	0.0181	0.0279
Long-Run Generic Advertising Elasticities (1999–2005)			
Generic beef promotion	0.0025	0.0053	–0.0118
Generic pork promotion	–0.0226	0.0206	0.0218

[a] The price, food safety, and expenditure elasticities are sample averages over 1982(1) through 2005(4).

expenditure elasticities are also within the range of results typically reported in the literature. The estimated own-food safety elasticities of demand are negative for beef and poultry, indicating negative publicity about these two species adversely affects their own demands. The own-food safety elasticity of demand for pork is not statistically significantly different from zero. This is not surprising given that there has been much less negative publicity about pork than both beef and poultry over the last 2 decades. However, negative publicity about beef or poultry food safety has negative effects on pork demand, perhaps reflective of a general increase in concern about meat safety.

The econometric models were rigorously tested to determine the proper time lag structure between the research and promotion expenditures, respectively, and their supply or demand response.

Program Effects

The econometric models were rigorously tested to determine the proper time lag structure between the research and promotion expenditures, respectively, and their supply or demand response. The promotion elasticities presented in

Table ES-2 reflect long-run responses across all lags included in the final models.

To investigate whether the effectiveness of PDE in affecting pork demand has changed since the last program evaluation in 1998, we conducted an additional econometric analysis of the demand system by interacting a dummy variable named "post98" with the coefficients on pork promotion variables. The post98 variable is defined to be equal to one for years after 1998 and zero otherwise. The joint significance of the six interaction terms is tested using the likelihood ratio test, and we find strong statistical evidence that the effectiveness of National Pork Board's promotion effort, as measured by PDE, differs between the previous evaluation period of 1987 through 1998 and 1999 through 2005. As shown in Table ES-2, the estimated own-promotion elasticity for pork has increased from 0.0181 to 0.0206 between 1987 through 1998 and 1999 through 2005. This is within the range of meat promotion elasticities found in the literature and is not a trivial response given the size of the pork market.

Interestingly, these findings suggest that pork promotion has a negative cross-effect on beef consumption, whereas beef promotion is found to have a positive effect on pork consumption (beef promotion elasticity of pork demand is 0.0053 for 1999 through 2005). Beef promotion is found to hurt demand for poultry, on the other hand, while pork promotion has a positive effect on poultry consumption.

Elasticities for other components of the Pork Checkoff Program were estimated to be 0.006 for the elasticity of pigs per litter with respect to production research, 0.012 for the elasticity of hog price with respect to post-farm market research, and 0.3121 for the elasticity of export demand with respect to foreign market development expenditures.

ES.3.2 Benefit-Cost Ratio Calculations

Based on our equilibrium displacement model above, our estimated parameters, and average levels of prices, quantities, Program expenditures, and other variables from 1999 through 2005, a 1% increase in annual domestic promotion expenditures would have resulted in an average farm-level hog price increase of $0.00956/cwt. Increases in postfarm research or foreign market development of 1% would increase farm-level hog prices by \$0.00413/cwt and \$0.00609/cwt, respectively. A 1% increase in production research, on the other hand would reduce farm-level hog price by \$0.0095/cwt. This is because of the increase in hog supply and the estimated inelastic demand for hogs. A 1% increase in all expenditure categories would raise the farm-level hog price by \$0.01026/cwt, increase U.S. hog supply by 478,096 (liveweight) pounds, and benefit U.S. producers \$1,809,166 in producer surplus.

Incorporating the estimated changes in prices and quantities resulting from marginal changes in Pork Checkoff activities and the average levels of prices and quantities over the 1999 through 2005 period, we calculated net changes in producer surplus and computed point estimates for marginal benefit-cost ratios for the Pork Checkoff Program using the methods described above. Table ES-3 presents results of these calculations, accounting for the additional assessment necessary to fund an increase in these activities.

Table ES-3. Simulated Point Estimates of Marginal Benefit-Cost Ratios for Pork Checkoff Expenditures, 1999–2005

National Pork Board Program Expenditure Categories	Marginal Benefit-Cost Ratios
Production research (HSE)	19.5
Postfarm research (HDE)	56.2
Domestic promotion (PDE)	7.1
Foreign market development (FMD)	28.0
Production research and postfarm research combined	24.4
All four expenditure categories combined	13.8

Our results indicated an overall marginal benefit-cost ratio to producers of 13.8, indicating that producers would gain an additional \$13.80 for each additional \$1 of Program expenditures.

Our results indicated an overall marginal benefit-cost ratio to producers of 13.8, indicating that producers would gain an additional \$13.80 for each additional \$1 of Program expenditures. Our point estimates of marginal benefit-cost ratios range from 7.1 for domestic promotion up to 56.2 for postfarm research, with production research and foreign market development in between at 19.5 and 28.0, respectively. The relative magnitudes across the four categories are consistent with other studies of generic promotion and research programs, including the previous study of the Pork Checkoff Program (Davis et al., 2001).

The benefits of postfarm research are estimated to be particularly high, but this is consistent with several previous studies finding this category of expenditure to yield very high returns (e.g., Davis et al. [2001]; Murray et al. [2001]; Alston et al. [1997]). Although these findings must be interpreted with care when applied to specific programs within these broad categories necessary for econometric estimation, the relative magnitudes of benefit-cost ratios across the categories examined suggest potential increases in the net benefits to producers from reallocation of Program funds away from domestic promotion (and possibly production research, although there may be a need for production research to generate products being developed and marketed under the postfarm research category) toward postfarm research and foreign market development. However, the imprecision associated with category-level rate of return estimates precludes definitive conclusions regarding optimal reallocation of expenditures.

ES.3.3 Comparisons to Previous Studies

The point estimates of price, expenditure, and advertising elasticities are generally within the range of those estimated in previous studies. Our domestic promotion elasticity was 0.0206 for 1999 through 2005, which is a bit larger in magnitude than pork advertising elasticities presented in previous published studies other than Piggott (1997), although in the range of generic advertising elasticities presented in the literature for other commodities. Brester and Schroeder (1995), Kinnucan et al. (1997), Boetel and Liu (2003), and Hyde and Foster (2003) all found smaller elasticities for promotion (<0.007) than our estimate, and none found statistically significant effects of pork promotion. Piggott (1997) estimated a statistically significant elasticity of 0.034 for pork promotion. In the previous evaluation of the Pork Checkoff Program conducted by Davis et al. (2000), they estimated a much larger promotion elasticity than any of the published studies, with an elasticity of 0.11. However, Kinnucan and Zheng (2006) cite the Davis et al. (2000) estimates as a case of implausibly high promotion elasticity/own-price elasticity.

Although any economic model, especially one as complex as this one, is an imperfect representation of reality, we attempted to account for some of the most important criticisms of past generic research and promotion evaluations.

Although any economic model, especially one as complex as this one, is an imperfect representation of reality, we attempted to account for some of the most important criticisms of past generic research and promotion evaluations (e.g., as summarized in Kinnucan and Zheng [2006]) in developing our models. Kinnucan and Zheng (2006) raise concerns about the previous Pork Checkoff evaluation relying on a single-equation model rather than a meat demand system, not accounting for income or meat expenditures in their demand model, and incorporating a lag structure that had beef advertising affect pork demand in the same quarter as expenditures but no effects for pork promotion expenditures until 11 quarters after the expenditure (with no effects for the first 10 quarters). In this study, we rely on a meat demand system that deals with the first two points and use a flexible lag structure that we tested extensively to determine the preferred lag structure and which yields lag structures that appear more plausible than used in the previous study. Our demand system also accounts for cross-commodity impacts of beef and pork promotion on beef, pork, and poultry demand.

We generate marginal benefit-cost ratios, which do not provide exactly the same information as the average benefit-cost ratios generated by Davis et al. (2000). However, assuming expenditures are high enough to have reached the point of declining marginal returns our estimates can be considered a lower bound on the point estimate of average return.

We present marginal benefit-cost ratios simulated using an EDM. The EDM allows us to consistently account for all market linkages and endogeneity of prices and quantities. We generate marginal benefit-cost ratios, which do not provide exactly the same information as the average benefit-cost ratios generated by Davis et al. (2000). However, assuming expenditures are high enough to have reached the point of declining marginal returns our estimates can be considered a lower bound on the point estimate of average return. Keeping in mind that our models are specified with very different structures, the qualitative implications of our findings have many similarities to Davis et al. (2000).

Similar to the previous evaluation of the Pork Checkoff Program, we find marketing chain research (HDE) to have the largest estimated return. Davis et al. estimate average benefit-cost ratios of 116.3 and 197.5 in their time-series and structural models, respectively. Our point estimate of marginal benefit-cost ratio, accounting for increasing assessments to fund these activities, is 56.2. The category with the second highest marginal return in our model is foreign market development (FMD), with an estimated ratio of 28.0, which is higher than the 12.5 average return estimated in the previous study's structural model (they did not include FMD in the time-series model). In contrast to the previous study, which estimated the benefit-cost ratio for production research and extension (HSE) to be negative, between -1 and -9.2, we estimated a fairly sizable marginal benefit-cost ratio of 19.5. Finally, for domestic pork promotion (PDE), the category that tends to receive the majority of Pork Checkoff funding, we estimate a benefit-cost ratio of 7.1. The previous evaluation of the program estimated an average ratio between 15.3 and 22.5.

The overall point estimate generated for the marginal return to Pork Checkoff Programs from our study is 13.8, which is within the range of estimates from Davis et al. for overall average return (4.8 to 26.2) and just slightly below the value of 16 that they suggest using as an overall average return to the Pork Checkoff Program for 1986 through 1998.

The overall point estimate generated for the marginal return to Pork Checkoff Programs from our study is 13.8, which is within the range of estimates from Davis et al. for overall average return (4.8 to 26.2) and just slightly below the value of 16 that they suggest using as an overall average return to the Pork Checkoff Program for 1986 through 1998. If the models were directly comparable, this would suggest that overall marginal returns are less than average, which is expected assuming declining returns to research and promotion activities, but that additional expenditures above historical levels would still be quite profitable for the average hog producer. Although the models differ considerably, they yield qualitatively similar conclusions for the effectiveness of the Program.

Although the point estimates suggest very strong returns to producer investment in Pork Checkoff activities, another important consideration in assessing the returns to the Program and individual components is the variability surrounding these estimates. As with any economic model, the "true" values of parameters are unknown and must be estimated. In addition to the point estimate, econometric models also generate measures of precision on that estimate. The following section describes a sensitivity analysis conducted to assess the precision of our point estimates and present more information on the distribution of estimated returns.

ES.3.4 Sensitivity Analysis

The estimates of the rate of return and the associated changes in producer surplus, farm-level hog prices, and hog quantity supplied presented above are based on point estimates of the model parameters. As noted previously, these values should be thought of as estimates rather than exact measurements. Generally, studies that measure the demand and supply responses to advertising and research report point estimates and do not calculate the precision with which these estimates are measured.[2] However, it may be more informative to know how precisely the benefit-cost ratio is measured.[3] Thus, we generate and present distributions around our benefit-cost ratios.

Although the mean returns generally indicate large returns to producers, the confidence intervals reflect that we, as econometricians, can only measure these values with some imprecision.

Table ES-4 presents 90% confidence intervals for the National Pork Board activities presented as point estimates in Table ES-3. We used the Monte Carlo integration technique described in Piggott (2003) to generate empirical distributions for the benefit-cost ratios. We consider, simultaneously, uncertainties in estimating all demand and supply elasticities in generating our distributions. In so doing, the estimated ranges of benefit-cost ratios are wider than if one is to consider uncertainty in one National Pork Board activity at a time while holding all other estimated elasticities fixed at their point estimates.[4] Although the mean returns generally indicate large returns to producers, the confidence intervals reflect the imprecision with which these returns can be measured. This reflects imperfect data, factors that are influencing markets that cannot be captured, and the less than perfect ability of any economic model to capture all the complexities of reality.

Confidence intervals are larger for some categories than others, reflecting differences in data quality, the ability of the expenditure data to accurately represent the Program activity level, and the number of parameters needed for rate of return calculations (because each parameter is associated with a distribution around it), as well as underlying variability in the effects of the categories modeled.

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[2] A plausible explanation for not reporting precision of the estimated return on investment is that it was not calculated as part of the evaluation because the cost entailed by this exercise is not negligible. The difficult and cost of conducting this precision analysis increases as the underlying demand and supply econometric models get more sophisticated.

[3] Both of our peer reviewers suggested placing distributions around the estimates as the single most important issue to consider for the final report.

[4] Although evaluating one source of uncertainty at a time renders a tighter confidence interval for the investigated National Pork Board activity, it may result in an overly optimistic estimate of profitability for this activity. For this reason, we decide to take the comprehensive approach by considering all sources of uncertainty simultaneously, although doing so entails greater analytical resources.

Results in Table ES-4 indicate that three of the six combinations of National Pork Board activities analyzed have a positive lower bound on their confidence interval (accounting for additional assessments to fund the additional activity). In other words, we can say, at a 90% confidence level, that these activities would result in a positive marginal return to hog farmers for additional dollars invested.[5] These activities are foreign market development, production research and marketing chain research combined, and a simultaneous increase in all four expenditure categories. Notice that the medians of the simulated return distributions are not exactly the same as the point estimates of returns reported in Table ES-3; they tend to be higher. This is because we have discarded random draws that violate theoretical curvature restrictions or imply demand or supply curves that contradict the fundamental economic theories of demand and supply. That is, demand has to be downward sloping, while supply has to be upward sloping.

Table ES-4. Median Values and 90% Confidence Intervals for the Simulated Marginal Benefit-Cost Ratios Under Various National Pork Board Expenditure Scenarios (1999–2005)[a b]

Effects of a 1% Increase in	Median and 90% Confidence Interval for the Benefit-Cost Ratio with a Simultaneous Tax Increase[c,d]
Production research (HSE)	25.97 (–4.69 123.84)
Marketing chain research (HDE)	70.57 (–47.73 194.90)
Domestic demand promotion (PDE)	10.39 (–11.39 58.68)
Foreign market development (FMD)	32.67 (8.35 82.84)
Production research and marketing chain research	32.53 (0.07 119.92)
All four expenditure categories	20.11 (2.09 64.37)

[a] Producer benefits are measured in 2004 dollars.

[b] A 90% confidence interval indicates a 90% statistical probability that the true estimate falls in this range.

[c] The 90% confidence intervals are in parentheses.

[d] The magnitude of the tax rate increase is calculated so that the 1% increase in research and promotion expenditures is equal to the increase in tax revenue.

[5] Note that the marginal benefit-cost ratio only needs to be greater than zero, not one, for the program to be profitable. This is because when the producer surplus is calculated, the cost of the checkoff assessment to hog producers has been taken into account.

For HSE, HDE and PDE, although these expenditures are profitable on average, the returns are measured imprecisely.

For HSE, HDE, and PDE, although these expenditures are profitable on average, the returns are measured imprecisely. As with any investment activity, there is some uncertainty regarding the magnitude of net benefits. The confidence intervals for these three categories include negative values, indicating that our simulations find that it is possible for these activities to result in negative returns with certain combinations of parameter values. The imprecision partly arises from the variability around the various elasticities implied by the estimated demand and supply parameters. These elasticities are calculated as functions of these econometric parameter estimates.[6] Although most of these parameters are individually precisely estimated and statistically significant, it does not suggest that the elasticities derived from them are necessarily statistically different from zero at conventional levels of significance.

In addition, there is considerable overlap across the distributions estimated for different Program categories. This indicates uncertainty regarding the relative returns to each category. In fact, none of these point estimates of rates of return are statistically significantly different from one another at any standard level of significance. While some categories have larger point estimates than others, it is important for decision makers to consider the distributions of potential returns in addition to the point estimates. Important questions for consideration include the extent to which one point estimate must exceed another to justify reallocation given the uncertainties and the optimal risk-return tradeoffs.

Finally, following Piggott (2003), we report results from the sensitivity analysis in an alternative way. Table ES-5 reports the probabilities that a marginal increase in National Pork Board expenditures on these activities would result in a net welfare gain to hog producers, taking into account the variability in all

[6] For instance, it is possible that a random draw from the parameter distributions results in a case where pork promotion has minimal effect on pork demand, but has a substantial positive cross-effect on poultry that results in reallocation of expenditures away from pork. There are numerous parameters involved in the simulations in order to capture complexities of the market and uncertainty surrounding the true value of each parameter. Thus, random draws from the estimated distribution can result in combinations of parameters where the returns to generic promotion and research would be negative. The probability of these negative outcomes depends on the estimated distributions of all the parameters.

estimated parameters, with the median value our best estimate of what marginal returns would equal on average. For example, there is a 96.9% probability that a 1% increase in all expenditure categories would bring positive net gains to hog farmers based on random draws from our simulation model allowing all elasticities to vary simultaneously. Similarly, FMD (99.5%), HSE and HDE combined (95.1%), and HSE (91.3%) have probabilities greater than 90%. The probabilities for PDE and HDE activities are lower, between 78.3% and 83.9%, highlighting the fact that returns to these individual subcategories are not as precisely estimated.

Table ES-5. Estimated Probabilities that the Net Gains to Hog Producers Are Greater Than Zero Under Various National Pork Board Expenditure (1999–2005) Accounting for Increase in Assessment to Fund Additional Expenditures[a]

1% Increase in	Probability of Positive Benefit-Cost Ratio
Production research (HSE)	0.913
Marketing chain research (HDE)	0.835
Domestic demand promotion (PDE)	0.783
Foreign market development (FMD)	0.995
Production research and marketing chain research	0.951
All four expenditure categories	0.969

[a] The magnitude of the tax rate increase is calculated so that the 1% increase in research and promotion expenditures is equal to the increase in tax revenue.

ES.4 CONCLUSIONS AND IMPLICATIONS

Based on the results of our analyses, we present the following conclusions about the Pork Checkoff Program's success in meeting its goals:

- The Pork Checkoff Program has a significant positive effect on the demand for hogs and pork.
- The returns to producers, on average, substantially outweigh the costs.
- Marginal increases in Program expenditures would increase producer profitability, on average.
- Although all point estimates of marginal returns are positive and generally fairly large, marginal returns cannot be measured precisely for all expenditure categories.

- Confidence intervals may be wider for some categories than others based on factors such as differences in data quality, the ability of the expenditure data to accurately represent the Program activity level, and the number of parameters needed for rate of return calculations, as well as underlying variability in the effects of the categories modeled.
- The confidence intervals for some categories include negative values. As with any investment activity, there is some uncertainty regarding the magnitude and even sign of net benefits. Negative values indicate that certain combinations of model parameters exist that can result in negative returns for these activities. Important considerations are the probability of this outcome and examination of the entire distribution of returns in making decisions.

- Marginal returns for postfarm research, foreign market development, and production research may all be higher than for domestic promotion based on our estimated point estimates and distributions.
- Differences in marginal returns across Program categories imply that there may be benefits from reallocation of Program expenditures towards categories with higher marginal returns, but the imprecision associated with category-level return estimates precludes definitive conclusions regarding optimal reallocation.
  - Although some distributions are more heavily weighted towards larger positive values, the distributions for all of the categories overlap with one another, indicating that the differences in estimated rates of return are not statistically significant.
- When considering reallocation of expenditures, it is important to consider the sizes of the confidence intervals around the rate of return estimates as well as the point estimates.

Overall, the results of the study indicate that the average hog producer experiences net benefits as a result of the Program. It is also important to note that there have been several years of low prices and high production costs for the average hog producer during 1999 through 2005. However, the econometric models presented in this study suggest market conditions for hog farmers would have been significantly worse without the Program.

1 Introduction

The Pork Checkoff Program is funded by a mandatory assessment collected from hog producers and hog and pork importers. The revenues are collected and managed by the National Pork Board, a quasigovernmental, nonprofit entity that administers the program. The primary goal of the Program is to increase the profitability of hog and pork producers and importers by expanding the demand for hogs and pork and reducing production costs. Demand expansion can occur through advertising and promotion programs aimed at developing consumer preferences for pork relative to substitute products. In addition, new product and marketing chain research can expand the demand for pork by creating new market niches and reducing processing costs. Farm-level agricultural research can reduce the cost of production by developing more efficient production methods.

The economic value of the Program to producers and importers depends not only on whether promotion and research have been effective in increasing sales and/or lowering the cost of hog production, but also on the cost-effectiveness of these activities.

The economic value of the Program to producers and importers depends not only on whether promotion and research have been effective in increasing sales and/or lowering the cost of hog production, but also on the cost-effectiveness of these activities. It is likely that Program promotion and research activities would have at least some positive impacts on sales and production costs. The key question is whether the costs of the Program are justified by its benefits. To address this question, a team of economists from RTI International and North Carolina State University (NCSU) conducted an economic analysis of the Pork Checkoff Program. This report describes the methods used to conduct the economic analysis and its findings.

1.1 BACKGROUND

Instituted in 1986, the Pork Checkoff Program aims to expand the demand for U.S. pork and pork products and develop scientific responses to production issues and consumer perceptions, while aiding producers in adjusting to market changes and increasing the profitability of hog and pork production.

As in other food industries, the hog and pork production sectors have experienced and continue to experience rapid changes. The pork industry introduced many new consumer-friendly products and experienced increased domestic and export sales in recent years. However, the industry also faces numerous external and internal issues. Within the industry, for example, issues revolve around consumer perceptions of issues such as animal welfare, food safety, and environmental conditions (Muth et al., 2005). The Pork Checkoff Program aims to expand the demand for pork and pork products and develop scientific responses to production issues and consumer perceptions, while aiding producers in adjusting to all of these changes and increasing the profitability of hog and pork production.

Instituted in 1986, the Program aims to help the industry more effectively address important issues affecting a wide spectrum of market participants in a joint and organized manner. The Program is funded by a mandatory assessment of 0.4%[1] of the market value of all hogs sold in the United States, as well as an equivalent amount on imported hogs, pork, and pork products. Assessments have totaled around $60 million annually in recent years. These funds are invested in programs to increase domestic pork consumption, increase export demand for U.S. pork, conduct research to support responsible production practices, and conduct outreach to provide producers with knowledge necessary to compete in modern agriculture.

Although producers are presumably interested in instituting checkoff programs because they anticipate receiving positive net benefits, stakeholders funding the checkoff program retain the right to vote the programs out of existence. In the late 1980s, producers began challenging some checkoff programs, arguing that they were not adequately responsive to producers' needs. Programs for pecans, limes, and fresh cut flowers and greens were voted out of existence in 1993, 1995, and 1997, respectively. In addition, a number of recent court cases have challenged the legality of mandatory checkoffs to fund generic promotion, both national programs (e.g., beef, pork, dairy,

[1] Assessments began November 1, 1986, at a rate of 0.25% of market value. However, that rate was increased to 0.35% effective December 1, 1991 (56 FR 51635), and to 0.45% effective September 3, 1995 (60 FR 29963), and was decreased to 0.40% effective September 30, 2002 (67 FR 58320).

cotton) and state programs (e.g., California table grapes, Washington apples, Florida citrus). The Secretary of Agriculture called for the termination of the Pork Checkoff Program following a referendum of pork producers in February 2000, but a temporary restraining order prevented termination, and a settlement agreement was reached in February 2001 that allowed the Program to continue. On May 23, 2005, the U.S. Supreme Court upheld the constitutionality of the beef checkoff promotion program against a First Amendment challenge on the basis that the program constituted government speech. However, the Court left open the possibility that the beef and other checkoff programs could be successfully challenged if it can be shown that their promotion attributes the advertising message to the producers. In that case, the promotional activities would not be considered protected government speech and the producers would have standing to bring a case (McEowen, 2005).

Producers need to have accurate estimates of the net returns provided by program expenditures to make well-informed decisions concerning their support for the checkoff programs in which they participate.

Producers need to have accurate estimates of the net returns provided by program expenditures to make well-informed decisions concerning their support for the checkoff programs in which they participate. It is important for funders to have confidence that estimated returns are continuing over time, clearly explained, and robust to different methods and researchers conducting the studies. Several previous studies have examined the effects of advertising on pork demand and the returns to producers (e.g., Brester and Schroeder [1995]; Piggott, Piggott, and Wright [1995]; Piggott et al. [1996]; Kinnucan et al. [1997]; Davis et al. [2001]; Hyde and Foster [2003]; Hoover, Hayenga, and Johnson [2004]); however, an evaluation is needed that focuses specifically on the effectiveness of the Pork Checkoff Program since the previous evaluation, the distribution of gains, and the relative effectiveness of different program areas.

1.2 STUDY OBJECTIVES

The primary goals of the Pork Checkoff Program include increasing domestic and export demand for pork, establishing science-based standards for the industry, and improving producers' competitiveness and profitability. The purpose of this study is to assess how well the goals of the program are being met. Specifically, the National Pork Board directed that the study must address the following key issues:

To address the key issues of the study; we developed and applied econometric and equilibrium displacement models of the markets for U.S. hogs and pork. These models can tell us whether the Program has had statistically significant market effects.

1. Measure the economic and financial benefit to producers (and, if possible, other pork value chain participants) of pork checkoff-funded programs in terms of net return on investment. Define, as possible, historic benefits achieved.
2. Define and quantify, as possible, the influence that specific pork checkoff-funded programs (demand enhancement, science, and outreach) have had on enhancing pork demand and resulting net return on investment to producers and value chain participants. Isolate the influence of specific pork check-off funded programs net of other macro-economic factors such as shifts in meat demand, changes in consumer incomes, global trade issues, and health and safety concerns, for example.

To examine these issues, we developed and applied econometric and equilibrium displacement models of the markets for U.S. hogs and pork. Using the econometrically estimated parameters within the equilibrium displacement model, we can obtain empirical evidence of the Program's effectiveness in enhancing the demand for—and in the case of agricultural research, the supply of—U.S. hogs and pork. These models can tell us whether the Program has had statistically significant market effects, while controlling for factors that are economically important but outside the sphere of the Program's influence (e.g., income, prices of substitutes).

1.3 REPORT ORGANIZATION

The remainder of the report is organized as follows. Section 2 presents an overview of the Pork Checkoff Program, including the basis for its funding, the size of its budget, and the allocation of program funds across 11 broad categories tracked by the National Pork Board.

Section 3 provides a brief industry profile for hog and pork production. The profile includes an overview of industry structure, historical economic trends, and structural changes taking place over time.

Section 4 describes the conceptual model and analytical methodology used to develop the econometric models and the equilibrium displacement model used to simulate historical returns to the Pork Checkoff Program.

Section 5 presents the results from econometric estimation of the hog and pork market models. The discussion focuses on the statistical and economic significance of the key policy variables of interest (e.g., effects of Pork Checkoff expenditures on hog and pork supply and demand). The section also describes the results of tests performed to gauge the robustness of the model to changes in specification.

The results of using the equilibrium displacement model to simulate rates of return for the Pork Checkoff Program are presented and discussed in Section 6. Results are presented in aggregate as well as for four major subcategories of program expenditures (domestic advertising and promotion, foreign market development, new product and marketing chain research, and farm-level research and extension).

2 The Pork Checkoff Program

An important step in evaluating any program is to build a description of the program that conveys its mission, objectives, and activities. This information serves as background and informs model development and analysis of the Program.

An important step in evaluating any program is to build a description of the program that conveys its mission, objectives, and activities. This section presents an overview of the Pork Checkoff Program, with a focus on the efforts of the National Pork Board to execute the program authorized by Congress and funded by producers and importers. We begin with a brief history of the program, including the enabling legislation and present organization. The second section presents details of the funding and spending history, including the breakdown into the various areas of effort. The third section describes current National Pork Board activities. This information serves as a background and informs model development and analysis of the Program.

2.1 BACKGROUND AND HISTORY

The earliest predecessor of the Pork Checkoff Program was a voluntary program instituted by the National LiveStock and Meat Board (NLSMB) in 1922 for cattle, hogs, and sheep. The checkoff rate was $0.05 per railroad car of livestock (75 hogs). Some packing companies participated in the voluntary checkoff, matching the producers' $0.05 donation. By 1961, the voluntary checkoff rate had risen to $0.01 per head (Davis et al., 2001). However, by then a group of producers had joined together to address the needs of the pork industry specifically. In 1965 this group evolved into the National Pork Producers Council (NPPC). In 1966, about 90 pork producers from 11 states met in Moline, Illinois, to establish a voluntary checkoff program specific to pork. This group, also known as the "Moline 90," joined forces with the NPPC to begin a pilot voluntary Pork

> The earliest predecessor of the Pork Checkoff Program originated in 1922 as a voluntary program. The program transitioned to a mandatory program in 1985 under the Pork Act. The Pork Act created the National Pork Board with the authority to collect and use checkoff funds for the benefit of pork producers of all sizes.

Checkoff Program in 1967. One year later the program was a nationwide voluntary program. The initial rate was $0.05 per head, but rose to $0.20 per head by 1980 (National Pork Board, 2005a).

Although the voluntary program was successful, pork importers and producers of 40% to 45% of all domestically produced hogs acted as "free riders" (i.e., enjoying the benefits of the program without paying checkoff funds). To address the free rider problem and to keep pork competitive with other meats, the program transitioned from voluntary to mandatory. This transition was made under the Pork Promotion, Research, and Consumer Information Order, which was authorized by the Pork Promotion, Research, and Consumer Information Act of 1985 as part of the 1985 Farm Bill. This legislation is commonly known as the Pork Act. The Pork Act created the National Pork Board with the authority to collect and use checkoff funds for the benefit of pork producers of all sizes. Government oversight is performed by the U.S. Department of Agriculture's (USDA's) Agricultural Marketing Service (AMS), which supervises all national checkoff programs.

Beginning November 1, 1986, producers were mandated to pay 0.25% of the gross value of sales from U.S.-produced market hogs, feeder pigs, and breeding stock. Imported hogs and pork producers were also assessed at the same rate. The rate increased in 1991 and 1995 to 0.35% and 0.45%, respectively, but decreased in 2002 to 0.40% of the gross value of sales. These rate changes were allowed under the Pork Act's limitations of a 0.5% maximum rate and annual increases of not more than 0.1%.

The Pork Act required a referendum of pork producers and importers after the program had been in effect for 24 months; 77.5% of voters favored the program. Another referendum was held in 2000 as the result of a large petition seeking to terminate the program, and indeed, 53% voted to end the program. Although the Secretary of Agriculture directed AMS to terminate the program, the U.S. District Court for Western Michigan issued a temporary order prohibiting USDA from doing so. USDA and the NPPC reached a settlement in 2001 allowing the checkoff program to continue but separating the National Pork Board from the NPPC (USDA/AMS, no date). The decision to continue or terminate the program has been debated

Over the years, the decision to continue or terminate the Pork Checkoff Program has been debated through various court proceedings and a series of appeals.

through various court proceedings and a series of appeals. In October 2002, a federal court judge in Michigan ruled that the Pork Checkoff Program is unconstitutional, violating the First Amendment rights of some producers. In 2003, the U.S. Court of Appeals for the Sixth Circuit upheld that decision. However, a precedent was set in 2005 when the U.S. Supreme Court ruled in favor of the beef checkoff program. Their position was that commodity checkoff programs are forms of government speech, and farmers must pay the assessment as they would any government tax. The pork case, on hold at the U.S. Supreme Court, was then returned to the Sixth Circuit Court of Appeals in Cincinnati so that it can reconsider its earlier decision based on the beef ruling (National Pork Board, 2005b). The case is currently waiting to be heard again by the Sixth Circuit Court of Appeals.

2.2 PROGRAM EXPENDITURES

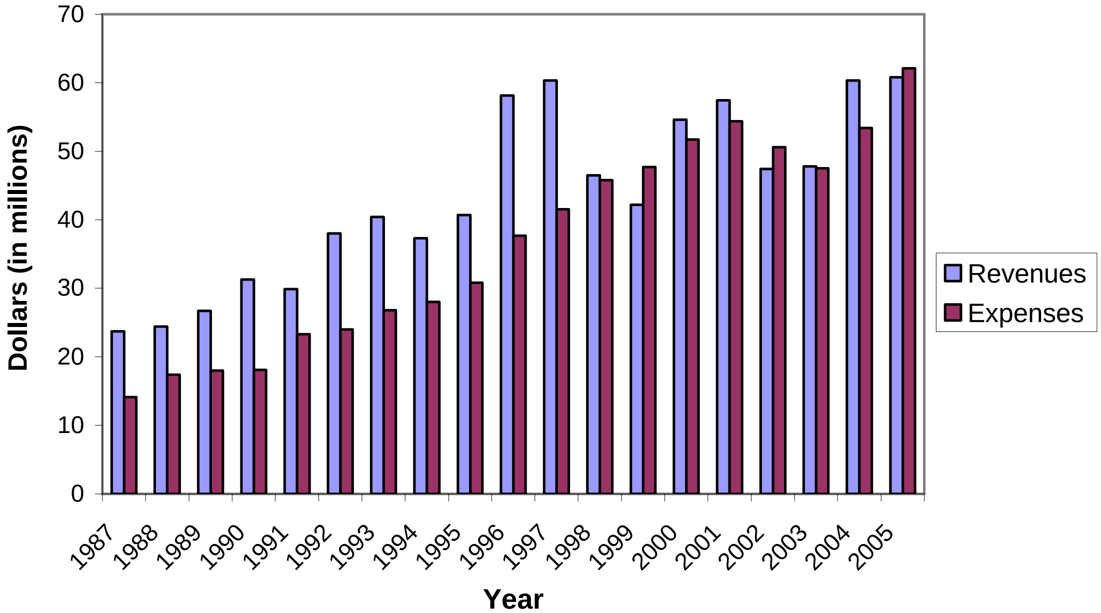
The National Pork Board operates on a January 1 to December 31 fiscal year. The Order is administered by the National Pork Producers Delegate Body, which has 104 members. There are at least two producers authorized from each of 44 states and one importer. The Secretary of Agriculture appoints Delegate Body members from pork producers who have been nominated through special elections or other USDA-approved selection processes in each state, while importer representatives are selected from individuals nominated by eligible organizations.

Each year the 15 members of the National Pork Board meet to determine the critical issues facing the pork industry that the checkoff program can address. Producer-led committees and National Pork Board staff then design programs and budgets to meet these objectives (National Pork Board, 2006).

The Delegate Body recommends the assessment rate, determines what percentage of total assessments will be allocated to state associations, and selects hog producers and importers for appointment by the Secretary to the 15-member National Pork Board. The Board's headquarters is located in Des Moines, Iowa. Each year the 15 members of the National Pork Board meet to determine the critical issues facing the pork industry that the checkoff program can address. Producer-led committees and National Pork Board staff then design programs and budgets to meet these objectives (National Pork Board, 2006).

The National Pork Board's primary source of revenue is monies collected from producers and importers as a percentage of their gross sales of hogs and pork products. Other revenue sources include program income and earned interest. Maximum revenues were seen in 2001, with $65.7 million in revenue (see Figure 2-1). Revenues were greater than expenses in 11 out of 18 years (1990, 1992, 1993, 1995, 1996, 1997, 2000, 2001, 2003, 2004, and 2005).

Figure 2-1. National Pork Board Revenues and Expenditures, 1988–2005



The National Pork Board allocates its checkoff fund expenditures into 11 broad categories. Since 1987, two-thirds of the National Pork Board's budget was spent on domestic and foreign promotion, which includes activities such as advertising, foreign market development, and marketing to specific groups.

The National Pork Board allocates its checkoff fund expenditures into 11 broad categories:

- advertising
- merchandising
- consumer research
- food service marketing
- pork information bureau
- foreign market development
- new products research and development
- market chain research
- production research
- producer education
- overhead

Activities performed within these categories are designed to increase the demand for hogs and pork and to lower production costs for hog producers. Table 2-1 lists the definitions of these activities, and Figure 2-2 provides the average proportion spent on each category from 1987 through 2005.

Since 1987, two-thirds of the National Pork Board's budget was spent on domestic and foreign promotion, which includes activities such as advertising, foreign market development, and marketing to specific groups such as retailers and food service operators.

Generic advertising dollars have steadily risen over time, from $7.4 million in 1987 to $17.6 million in 2005. However, this is considerably less than branded advertising, which has ranged from a low of $23.6 million in 2000 to a high of $68.1 million in 1998.

In addition to generic advertising done by the National Pork Board, some pork companies advertise their specific brand of pork (i.e., brand advertising). Depending on the advertising message and substitutability between brands, brand advertising may increase the total demand for pork (Ward, 2006). Figure 2-3 compares the dollars spent by the National Pork Board on generic advertising to branded advertising from 1987 through 2005. Generic advertising dollars have steadily risen over time, from $7.4 million in 1987 to $17.6 million in 2005. However, this is considerably less than branded advertising, which has ranged from a low of $23.6 million in 2000 to a high of $68.1 million in 1998. The average expenditures for generic and branded advertising are $11.8 million and $45.3 million, respectively.

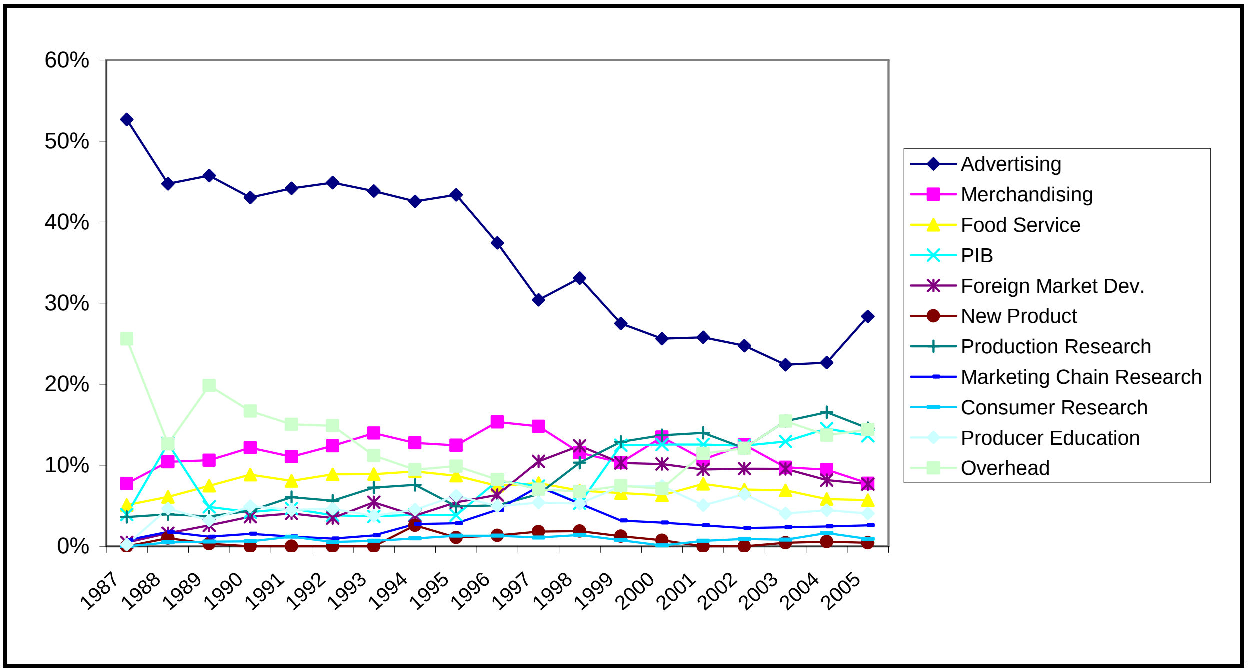
Figures 2-4 through 2-13 show expenditures, both in dollar and percentage terms, over the 19-year period from 1987 to 2005. In dollar terms, the overall budget grew, but there are substantial changes in the distribution of funds across expenditure categories over time. One of the most obvious trends is within the advertising category (see Figures 2-4 and 2-5). Total dollars spent on advertising increased from $7.4 million in 1987 to $17.6 million in 2005. Yet the percentage of the total budget spent on advertising dropped from 53% to 28% in those same years. Similarly, total dollars spent on Merchandising and Food Service Marketing quadrupled, but the percentage of the total budget spent on these remained relatively stable. The Pork Information Bureau category has become more prominent over time, starting with expenditures near $500,000 and growing to over $8 million in 2005 (increasing from 4% to 14% of the total budget).

Table 2-1. Definitions of National Pork Board Expenditures
These definitions were developed in consultation with the NPPC for the 2001 evaluation of the Pork Checkoff Program.

Target Market and Activity	Definition
Pork Demand Expenditure	
Advertising	Development, production, and delivery of domestic advertising
Merchandising	Promotions and materials aimed at retail pork outlets
Consumer Research	Research to discover and clarify consumer tastes, preferences, habits, and needs
Food Service Marketing	Promotions to commercial and noncommercial food service establishments and distribution systems
Pork Information Bureau	Consumer-targeted public relations and programs to provide factual information about pork to consumers
Foreign Market Development Expenditures	Activities targeted at increasing the demand for U.S. pork in foreign markets
Postfarm Research Expenditure	
New Products Research and Development	Research into the development and design of new products in pork-related products
Market Chain Research	Research aimed at increasing the efficiency of the pork processing and marketing system, including quality and safety
Farm Research and Education Expenditure	
Production Research	Research aimed at increasing efficiency and/or reducing costs in hog production
Producer Education	Programs intended to raise the level of expertise and understanding of hog producers
Overhead	Administrative expenses associated with operating the National Pork Board

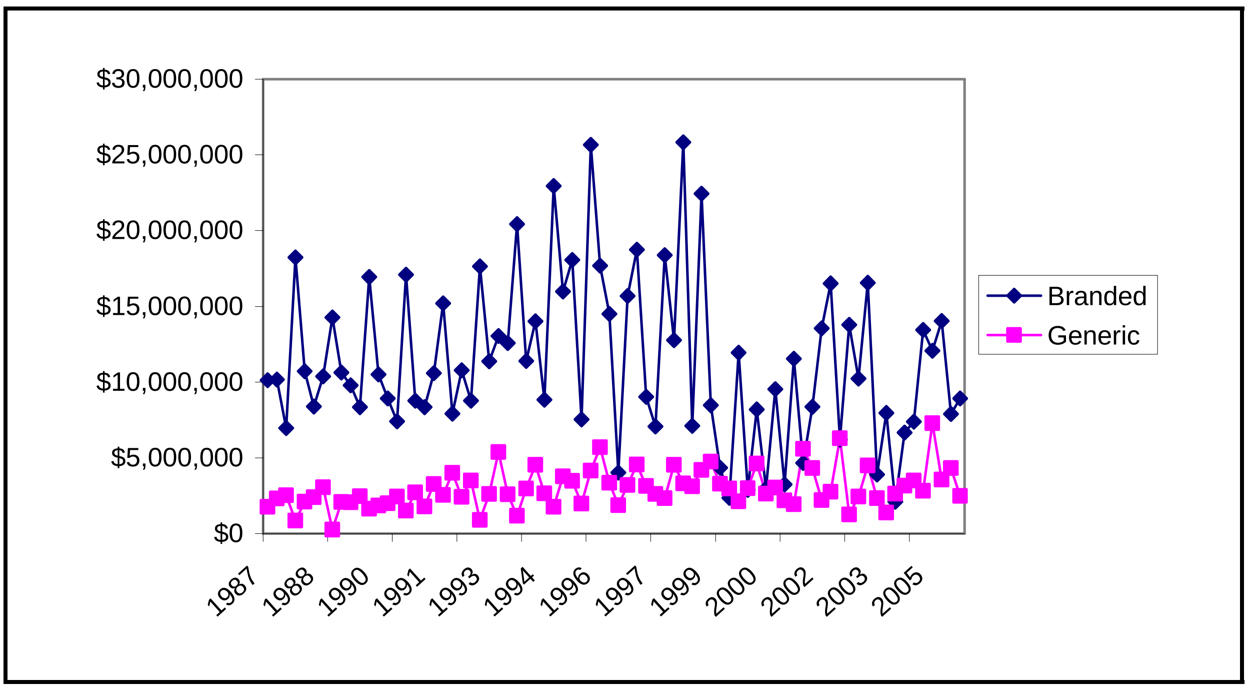
Source: Davis, G.C., O. Capps, Jr., D.A. Bessler, J.H. Leigh, J.P. Nichols, and E. Goddard. 2001. “An Economic Evaluation of the Pork Checkoff Program.” Department Technical Report 01-1. College Station, TX: Texas A&M University.

Figure 2-2. National Pork Board Average Distribution of Checkoff Funds, 1987–2005



Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

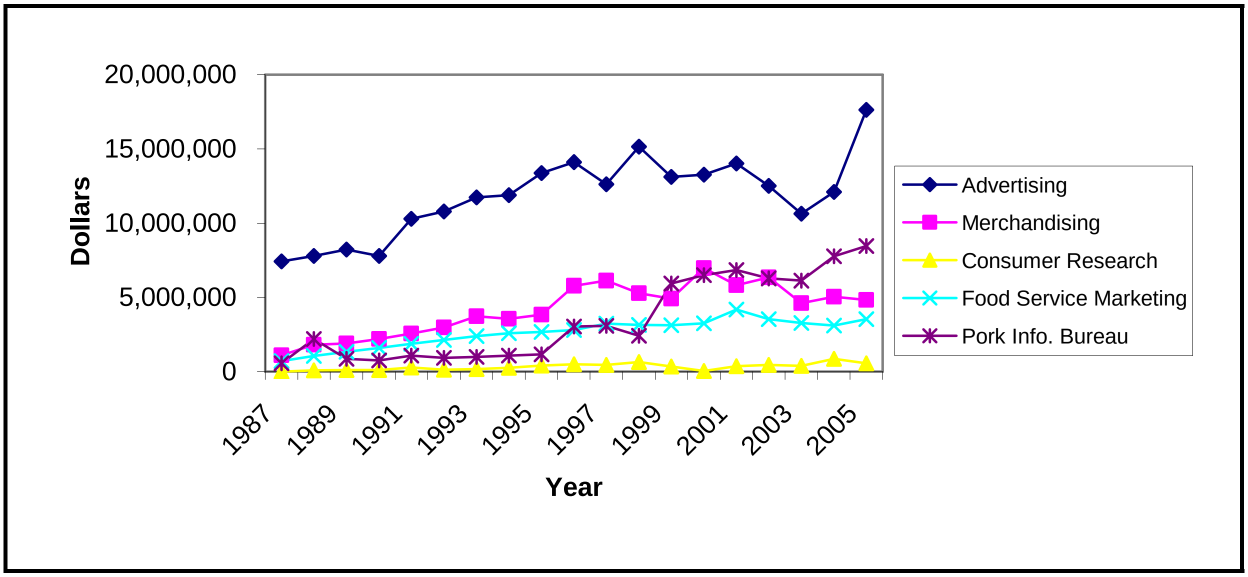
Figure 2-3. Dollars Spent on Branded and Generic Pork Advertising, 1987–2005



Source for generic: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

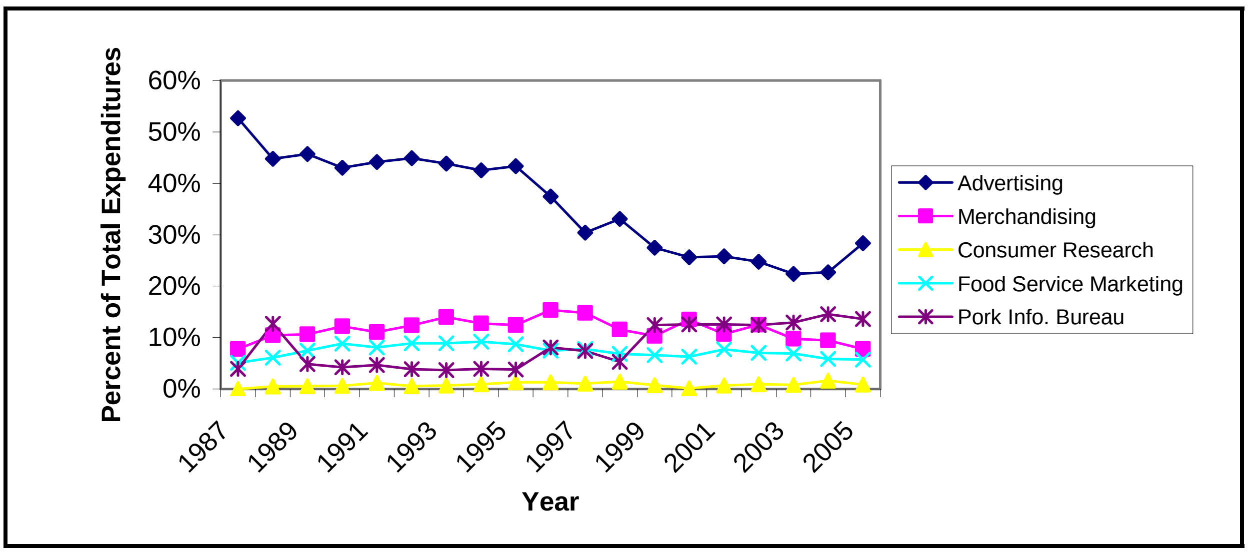
Sources for branded: Brester, Gary, Montana State University, personal communication (email) with Chen Zhen on October 6, 2006 for 1982–1998 and Leading National Advertisers, Inc. *Ad $ Summary*. New York: Leading National Advertisers, Inc. various issues for 1999–2005.

Figure 2-4. Pork Demand Expenditures, 1987–2005



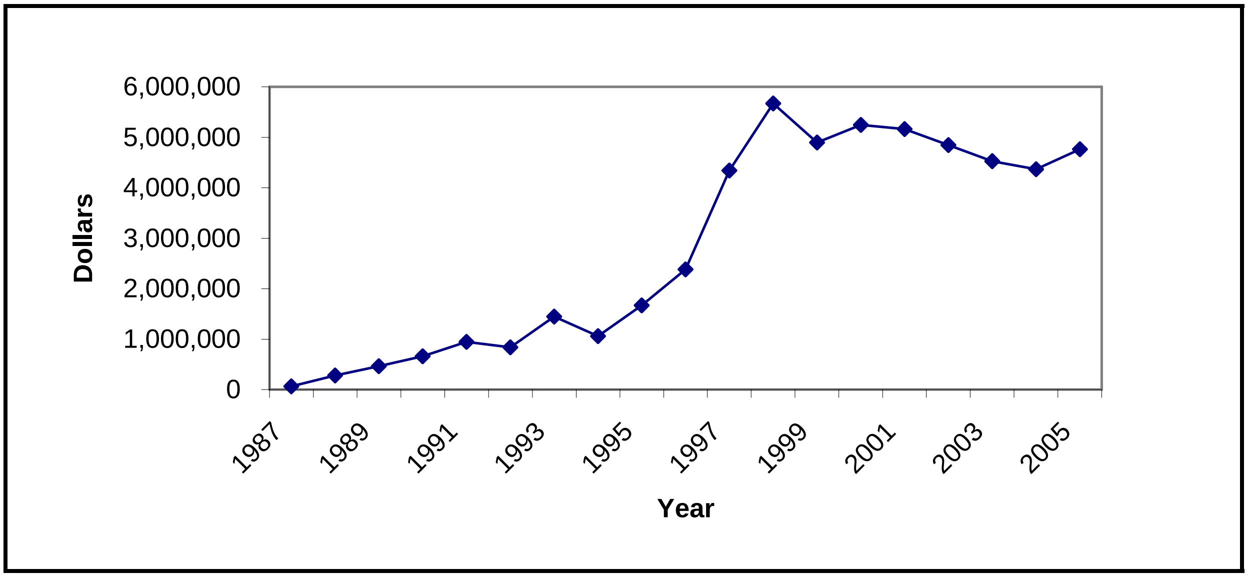
Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Figure 2-5. Pork Demand Expenditures as a Percentage of the Total Budget, 1987–2005



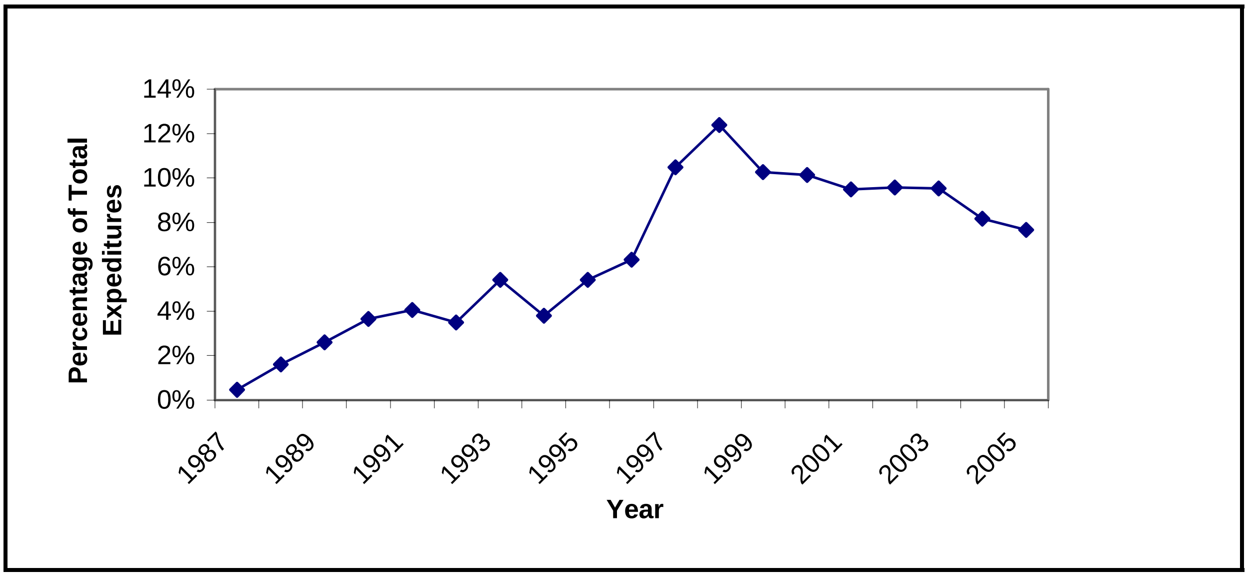
Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Figure 2-6. Foreign Market Development Expenditures, 1987–2005



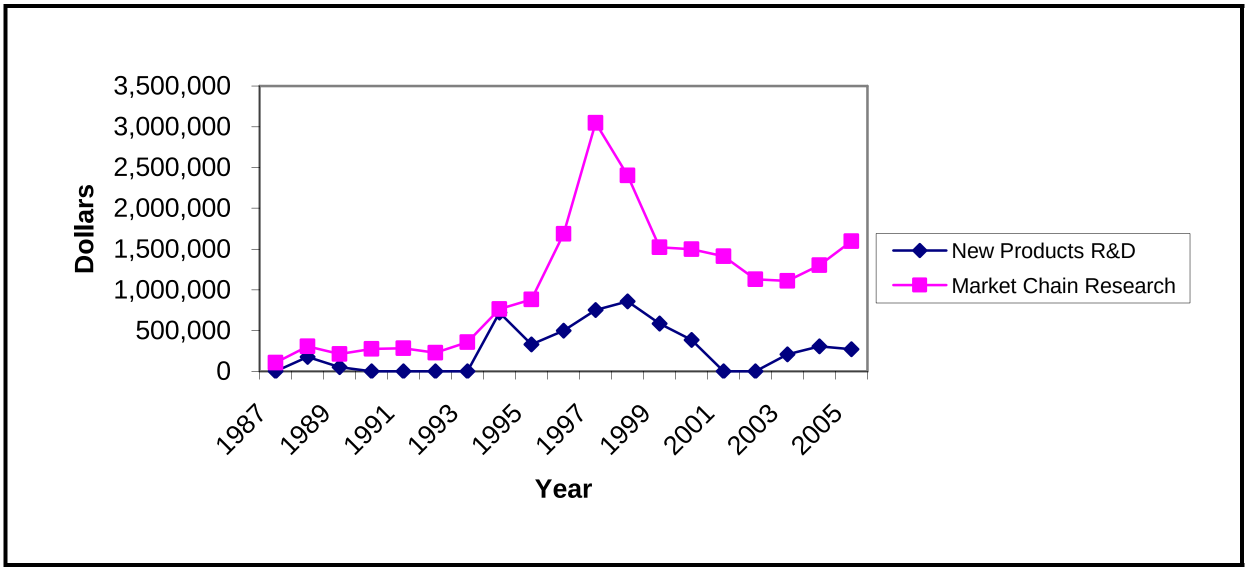
Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Figure 2-7. Foreign Market Development Expenditures as a Percentage of the Total Budget, 1987–2005



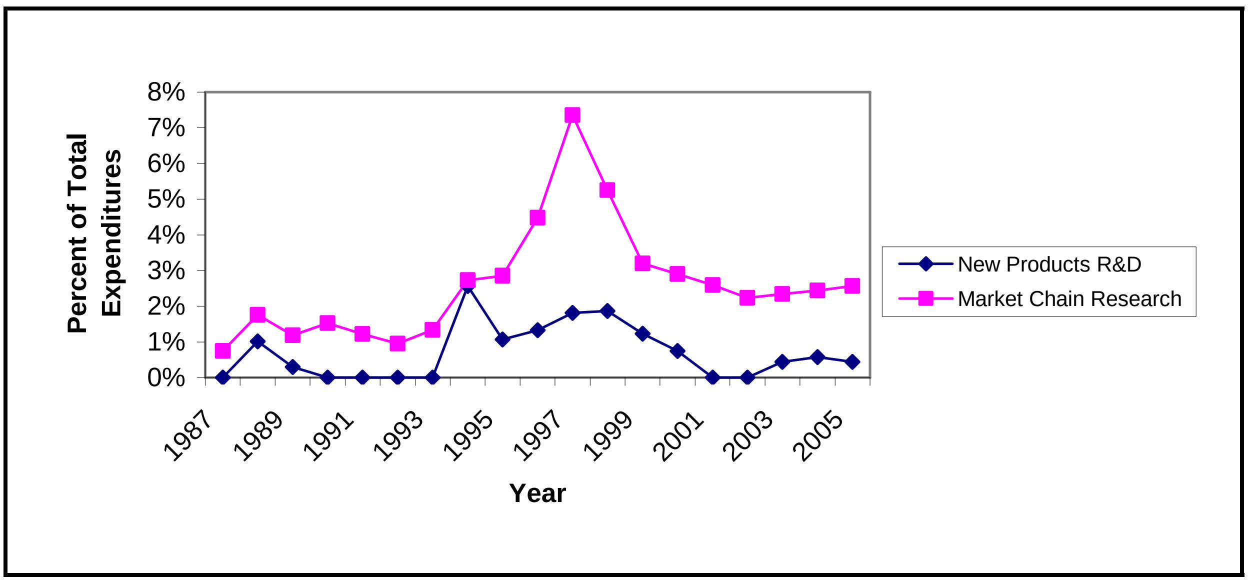
Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Figure 2-8. Postfarm Research Expenditures, 1987–2005



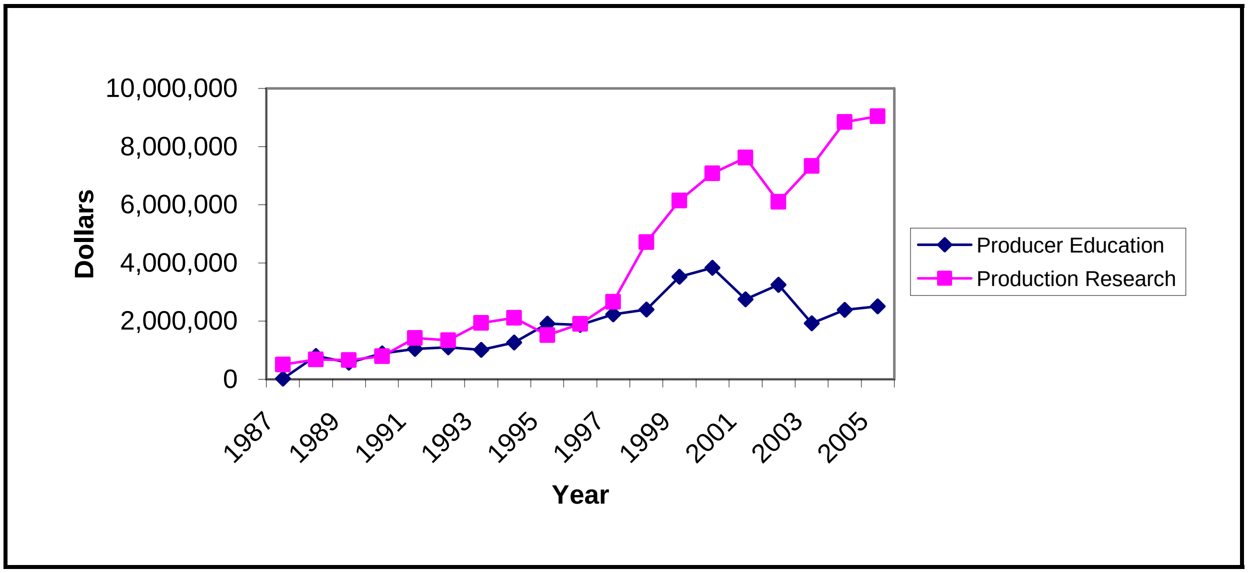
Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Figure 2-9. Postfarm Research Expenditures as a Percentage of the Total Budget, 1987–2005



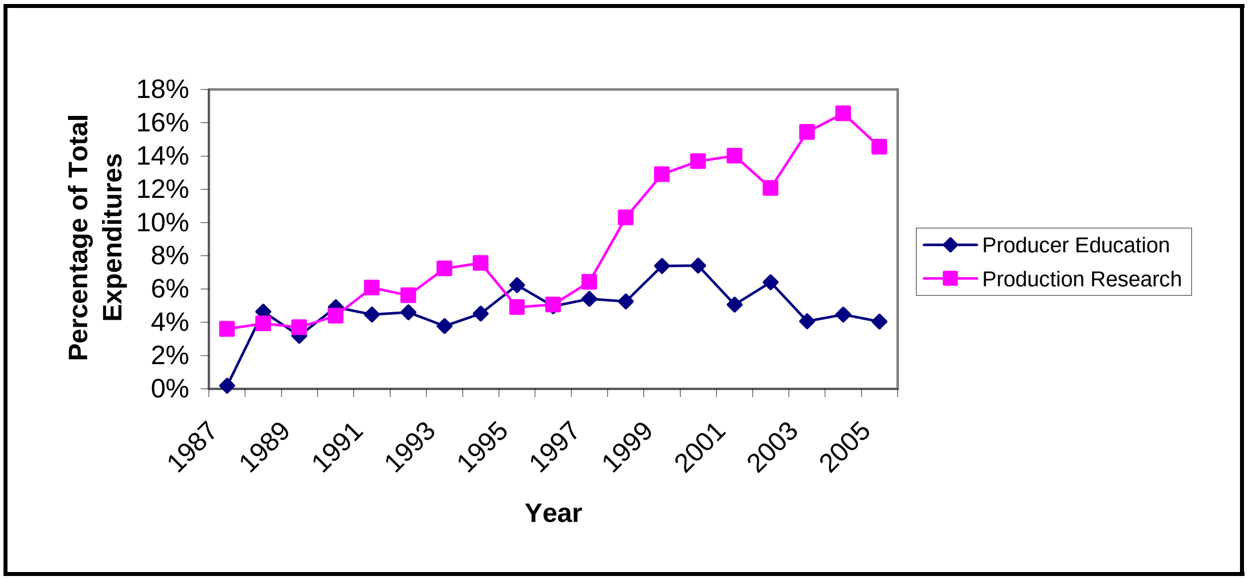
Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Figure 2-10. Farm Research and Education Expenditures, 1987–2005



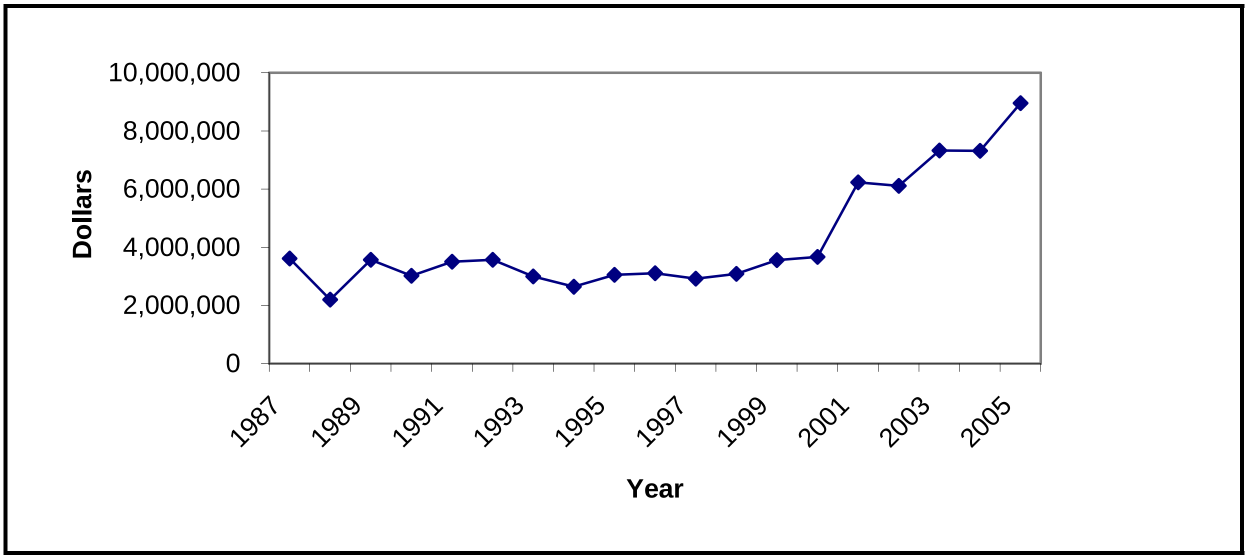
Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Figure 2-11. Farm Research and Education Expenditures as a Percentage of the Total Budget, 1987–2005



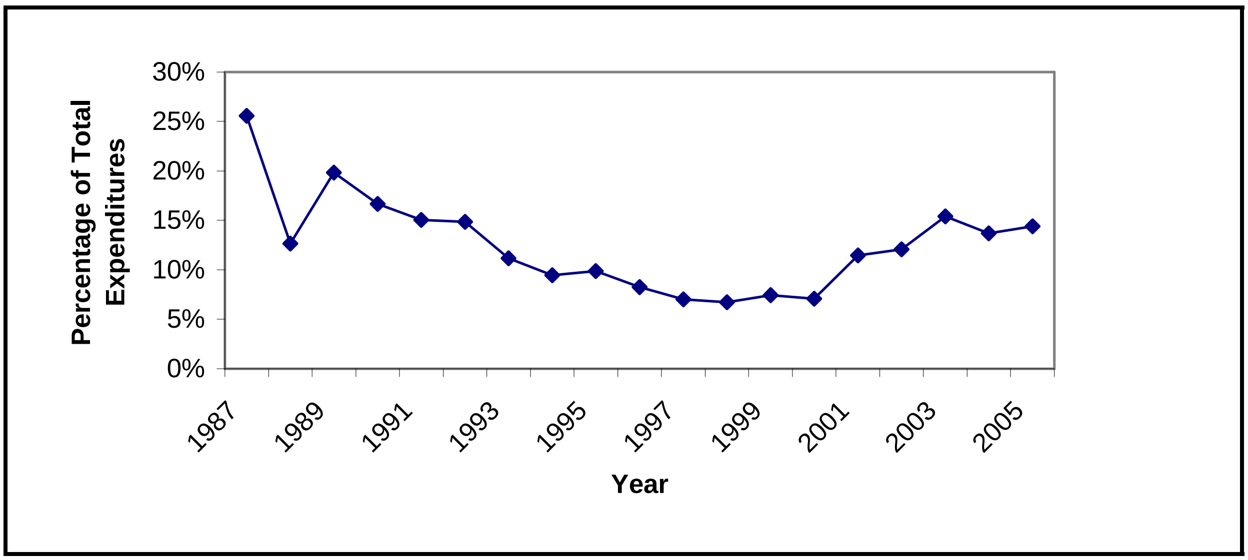
Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Figure 2-12. Overhead Expenditures, 1987–2005



Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Figure 2-13. Overhead Expenditures as a Percentage of the Total Budget, 1987–2005



Source: Meyer, Steve, National Pork Board. October 14, 2006. Personal communication (e-mail) with Robert Beach, RTI International.

Foreign market development became increasingly important through the 1980s and 1990s, spiking in 1998 at $5.6 million (representing 12% of the total budget). Since then, spending on this category has decreased to $4.7 million, or 8% of the total budget (see Figures 2-5 and 2-6).

The National Pork Board splits its research expenditures according to whether they affect the farm level or postfarm (i.e., hogs versus pork). Postfarm research dollars, shown in Figures 2-8 and 2-9, have fluctuated over time. Spending on new products research and development and market chain Research remained almost flat (and at times zero) until 1994, increased through the late 1990s, fell until 2002, and is now rising again. In contrast, spending on farm-level research, particularly production research, has trended upward since the program's inception (see Figures 2-10 and 2-11). Total dollars spent on production research have increased from approximately $500,000 in 1987 to over $9 million in 2005.

Overhead expenditures, shown in Figures 2-12 and 2-13, remained relatively stable until 2001, when the National Pork Board began absorbing legal fees associated with court cases seeking to end mandatory assessments. Averaged over the entire history of the program, overhead comprises 12% of the total budget. This is similar to other commodity checkoff programs, such as lamb, soybeans, cotton, and eggs, whose overhead rates range from 5% to 12.5% of the total budget.

The Pork Act requires that some of the checkoff funds collected each year be returned to the state pork producer associations. On average, about 20% of producer and importer checkoff receipts are returned to states for their own checkoff-funded projects.

The Pork Act requires that some of the checkoff funds collected each year be returned to the state pork producer associations. On average, about 20% of producer and importer checkoff receipts are returned to states for their own checkoff-funded projects (National Pork Board, 2005a). There are 44 state pork associations in the United States. Comparing state-level budgets versus the national board's budget, we see that the states spend almost equivalent amounts on promotion and consumer information, whereas the national board spends almost 10 times more on promotion than on consumer information.

2.3 PROGRAM ACTIVITIES

As described on the National Pork Board's Web site (www.pork.org), the mission of the Pork Checkoff Program is to "harness the resources of all producers to capture opportunity, address challenges and satisfy customers." A brief summary of Program activities as described on National Pork Board's Web site is provided below.

One of the primary activities of the Program is to build U.S. consumer demand for pork through its marketing campaign, "Pork. The Other White Meat.®"

One of the primary activities of the Program is to build U.S. consumer demand for pork through its marketing campaign, "Pork. The Other White Meat.®" According to www.pork.org, the campaign's slogan ranks in the top five of America's most memorable advertising slogans and 9 in 10 people recognize pork as the other white meat. The Program also conducts consumer research, promotional activities aimed at retail pork outlets, and promotions targeted to food service establishments and distribution systems. The Pork Information Bureau focuses on providing information to consumers both directly and through other outlets to inform consumers about menu, purchasing, and dietary decisions.

The Program also conducts activities to expand the market for U.S. pork in foreign markets. Export marketing programs are implemented in cooperation with the U.S. Meat Export Federation (USMEF). The Program conducts marketing activities to create acceptance among trade organizations and consumers in key international markets such as Japan, Mexico, Korea, China, Taiwan, Southeast Asia, Russia, Central Europe, and Latin America.

In addition, the Program provides funding for new product research and development and market chain research. For example, the Program develops marketing programs for pork in niche markets, markets in which consumers are looking for pork with specific attributes that are not being met by the traditional ways of producing and marketing pork.

The Program supports pork producers by conducting research and providing education in areas such as food safety, environmental management, animal care, biosecurity, animal welfare, and foreign animal disease.

The Program supports pork producers by conducting research in areas such as food safety, environmental management, animal care, biosecurity, animal welfare, and foreign animal disease. In 1989, the National Pork Board introduced the Pork Quality Assurance (PQA) Program, an educational program for producers. The PQA Program emphasizes good management practices in the handling and use of animal health products and encourages producers to review their approach to their herds' health programs. The Pork Checkoff Program also provides educational opportunities to producers throughout the year and across the country on production techniques, financial management, and the environment. Additionally, through the Pork Checkoff Program, producers have access to a quarterly magazine, newsletters, and Web sites that provide information for pork producers, consumers, and researchers.

The Pork Checkoff Program funds a variety of activities to achieve its mission and goals. As described on its Web site and in the National Pork Board's 2004 and 2005 Annual Reports, recent activities include the following:

- sponsoring the World Pork Expo, the world's largest pork industry trade show and exhibition
- conducting animal health research on porcine postweaning multisystemic wasting syndrome (PMWS) and on porcine reproductive and respiratory syndrome (PRRS)
- conducting environmental research to address air quality and odor concerns
- implementing producer programs such as Take Care—Use Antibiotics Responsibly program, Operation Main Street, and the Swine Welfare Assurance Program (SWAP)
- providing funding for industry scholarships to students planning graduate studies or careers in a swine-related field
- creating and distributing distance learning courses for producers on CDs
- funding the NichePork Marketing conference
- implementing the Other White Meat.® Don't be blah™ brand campaign

3 Industry Profile

Understanding changes taking place in the hog and pork markets and factors in addition to the Pork Checkoff Program that may have affected the supply and demand and profitability of U.S. hogs and pork is important for this analysis.

Understanding changes taking place in the hog and pork markets and factors in addition to the Pork Checkoff Program that may have affected the supply and demand and profitability of U.S. hogs and pork is important for this analysis. These factors need to be taken into account to the extent possible to generate accurate measures of the return to the Program. This section describes the basic structure of pork production from farm to consumer and presents historical data on production, consumption, and prices. The section concludes with a summary discussion of structural changes taking place in hog and pork production and consumption over time.

3.1 STRUCTURE OF THE PORK INDUSTRY

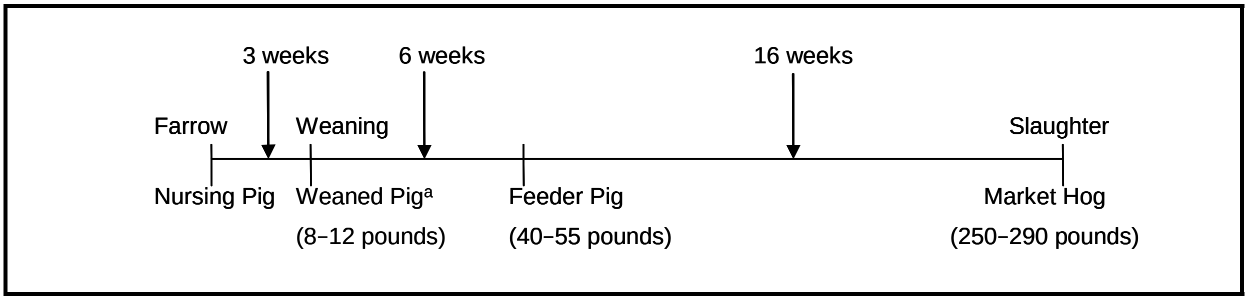
In recent years, numerous changes have taken place in the U.S. pork industry, defined here as the hog and pork markets. This section provides an overview of the industry structure.

3.1.1 Hog Market

There are three general stages of production for market hogs: farrow-to-wean stage, wean-to-feeder stage, and feeder-to-finish stage. Hogs are primarily produced by specialized operations that use separate production facilities for each stage of production (Muth et al., 2005). The length of time required for market hogs to move through all three stages is approximately 6 months. Figure 3-1 illustrates a typical timeline for hog production.

Figure 3-1. Hog Production Timeline

Capital-intensive production has solidified hog production methods into relatively precise segments.



Hog production has shifted over the past 15 years from the Corn Belt region of the United States to states such as North Carolina, Oklahoma, Utah, and Wyoming. As hog production has shifted, so has the location of pork slaughter facilities to reduce transportation costs from farms to slaughter plants.

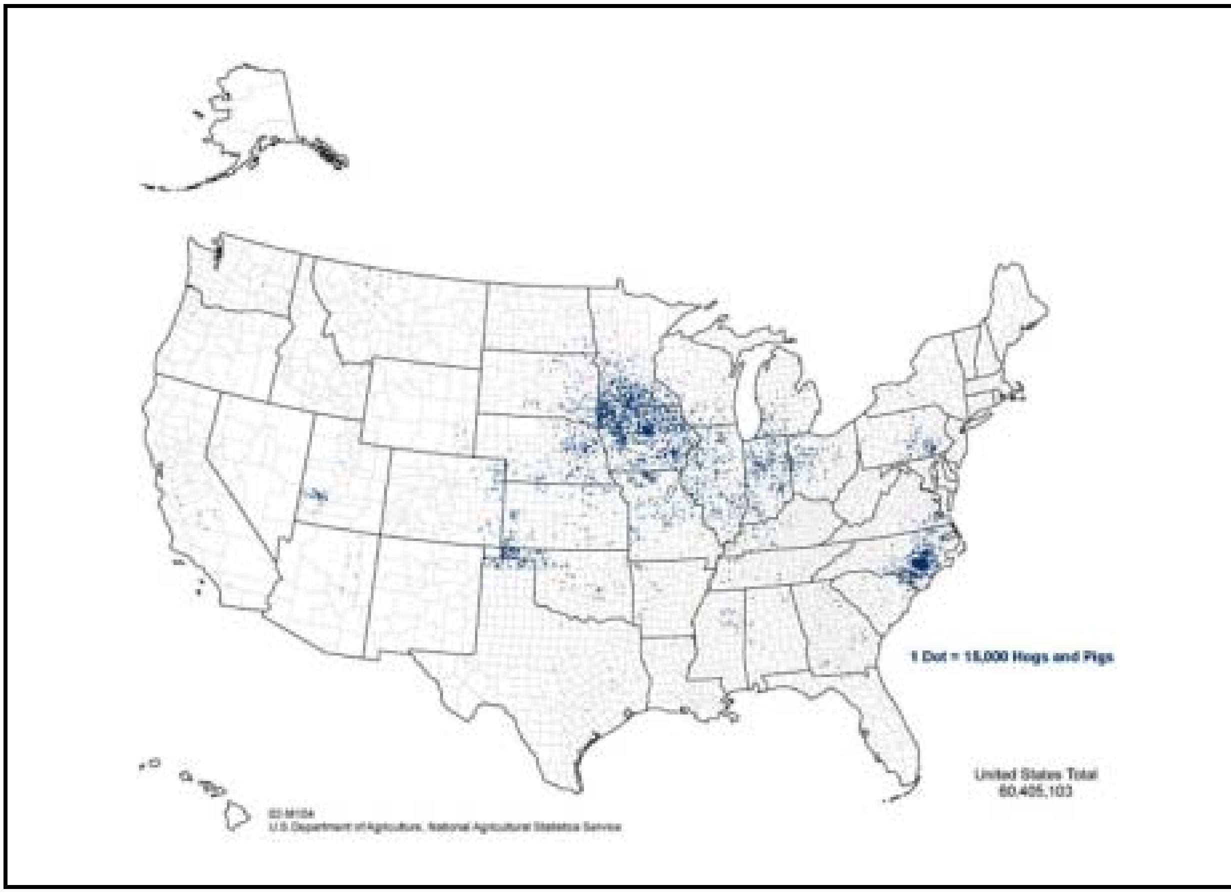
Hog production has historically been concentrated in the Corn Belt region of the United States so that hog-producing operations would be located near their feed supplies. States in this region include Iowa, Illinois, Minnesota, Indiana, and Nebraska. However, hog production has shifted over the past 15 years to states such as North Carolina, Oklahoma, Utah, and Wyoming. Many of the nontraditional hog-producing states now supply the Corn Belt States with feeder pigs. For example, in 2003 Iowa imported as many feeder hogs from Canada and other states as it produced locally (Haley, 2004), suggesting that producers in Iowa are becoming more specialized in feeding operations. Figure 3-2 maps the U.S. inventory of hogs in 2002.

As hog production has shifted, so has the location of pork slaughter facilities to reduce transportation costs from farms to slaughter plants. In 1990, almost 60% of U.S. slaughter capacity was located in Iowa and surrounding states. By 2003, North Carolina had become the second largest state in slaughter capacity. Large increases in hog inventories for nontraditional hog-producing states (e.g., Oklahoma and North Carolina) directly coincide with the opening of large slaughter facilities in those states.

The total U.S. inventory of hogs and pigs has remained relatively stable since 1990; however, there has been significant variation within the individual stages of production.

The total U.S. inventory of hogs and pigs (Figure 3-3) has remained relatively stable since 1990; however, there has been significant variation within the individual stages of production. The number of breeding hogs decreased 12% from 1990 to 2002. During the same period, the number of market hogs increased by more than 12%. To reconcile the difference between the decreasing size of the breeding herd and the increasing number of market hogs, we can compare the number of pigs born per litter and the number of pigs per

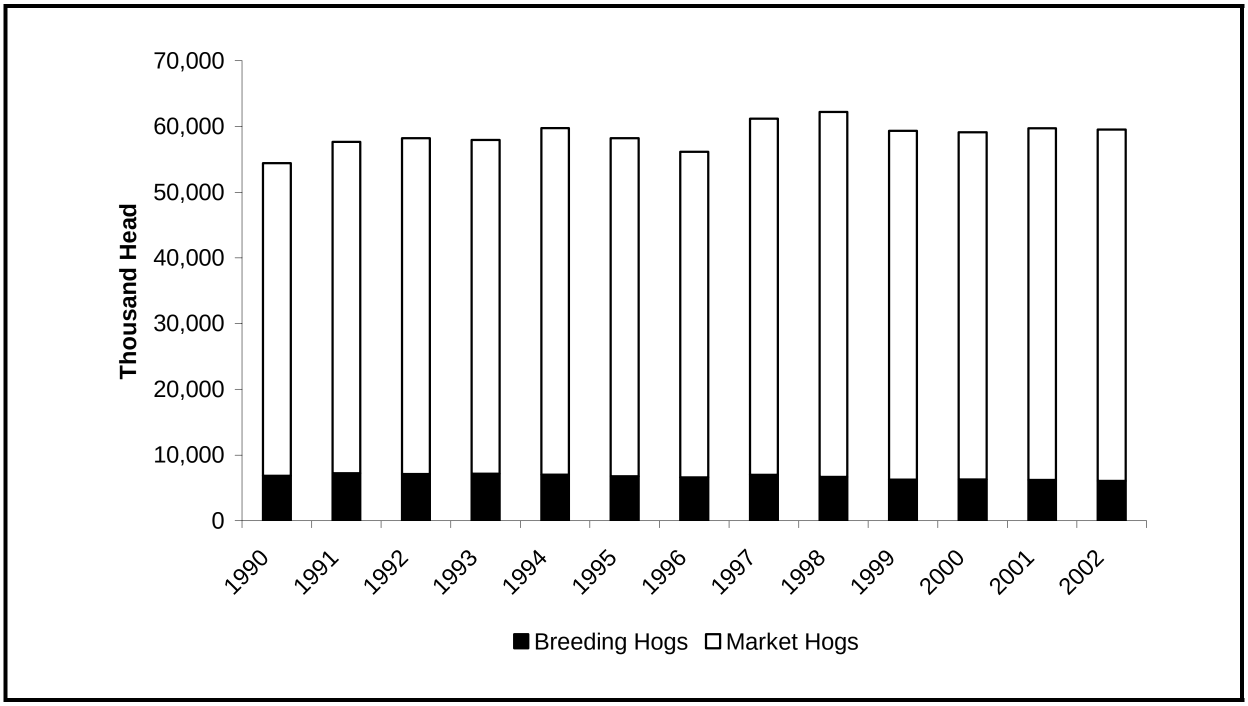
Figure 3-2. U.S. Inventory of Hogs and Pigs, 2002
Most of the hog production is conducted in the Corn Belt and the Southeast.



Source: U.S. Department of Agriculture, National Agricultural Statistics Service. 2004. "2002 Census of Agriculture." Washington, DC: USDA. <http://www.nass.usda.gov/research/atlas02/>.

breeding animal. The number of pigs per breeding animal per year grew by 57% between 1979 and 2001, with 29% of that increase attributed to the increase in the average litter size. The remaining 71% is attributed to the increase in the number of litters per sow per year (USDA-NASS, 2002). Collectively, this shows that the efficiency of the U.S. breeding herd is improving in terms of delivering more pigs from a smaller breeding herd. The difference between the decreasing breeding herd and the increasing number of market hogs is also partially offset by imported feeder hogs. Canada is the primary supplier of live hogs to the United States, providing 99.99% of the 7 million plus hogs imported in 2003 (Haley, 2004). More than 65% of those animals were imported as 10- to 40-pound feeder hogs that were fed to slaughter weight in the United States.

Figure 3-3. U.S. Inventory of Hogs and Pigs, December 1, 1990–2002
Hog and pig inventory categories include breeding hogs (all hogs kept for breeding purposes) and market hogs (all hogs from those less than 60 pounds to those greater than 180 pounds that are intended for sale as market hogs).



Source: U.S. Department of Agriculture, Economic Research Service. 2004c. "Red Meat Yearbook." Stock #94006. Washington, DC. <http://usda.mannlib.cornell.edu/data-sets/livestock/94006/>.

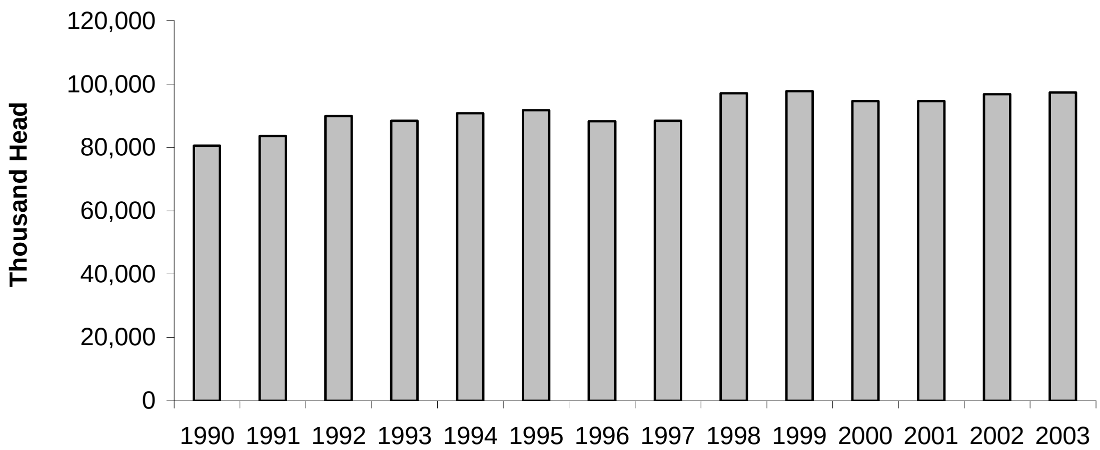
The net effect of the changing domestic herd and Canadian imports is a steadily growing number of market hogs (barrows and gilts) slaughtered by U.S. packers (Figure 3-4). Market hogs constitute over 96% of the hogs slaughtered in the country (USDA-GIPSA, 2002). The average annual growth in slaughter volume was just over 1% between 1990 and 2003.

3.1.2 Pork Market

In the United States, more hogs are slaughtered than any other type of red meat species.

In the United States, more hogs are slaughtered than any other type of red meat species. During FY 2004, 499 federally inspected plants slaughtered over 93 million market hogs, and 146 plants slaughtered approximately 3.6 million other hogs (see Table 3-1). In addition, 808 state-inspected plants (795 very small and 13 small plants) slaughtered some meat species in FY 2004. However, states do not provide information on the species slaughtered or the total volume slaughtered; thus, it is unknown how many hogs were slaughtered by state-inspected plants.

Figure 3-4. U.S. Commercial Barrow and Gilt Slaughter, 1990–2003
Commercial barrow and gilt slaughter includes animals slaughtered at federally inspected and nonfederally inspected plants but does not include animals slaughtered on the farm.



Source: U.S. Department of Agriculture, Economic Research Service. 2004c. "Red Meat Yearbook." Stock #94006. Washington, DC. <http://usda.mannlib.cornell.edu/data-sets/livestock/94006/>.

Table 3-1. Plant Inventories and Slaughter Volumes for Federal Plants that Slaughtered Hogs in FY 2004
Most hog slaughter plants only slaughter barrows and gilts, but some plants also slaughter sows and boars. In addition, some plants only slaughter sows and boars.

	Barrows and Gilts		Sows and Boars	
Size	**Number of Plants**	**Volume**	**Number of Plants**	**Volume**
Very small	384	1,114,227	80	70,593
Small	86	6,008,656	62	2,924,316
Large	29	86,328,228	4	601,335
Total	499	93,451,111	146	3,596,244

Source: RTI International. 2005. Enhanced Facilities Database. Research Triangle Park, NC: RTI.

Slaughter facilities typically specialize in either market hogs or other hogs. Market hogs weigh between 200 to 250 pounds at 5 to 8 months of age at slaughter, while other hogs are usually those used for breeding such as sows and boars. Focusing on one type allows companies to standardize equipment and increase the speed of production.

Although some facilities only slaughter and ship whole carcasses, the majority of facilities also perform fabrication processes. These fabrication processes involve breaking the carcass into large cuts called primals and then further cutting

Unlike beef, pork is rarely quality graded by USDA's Agricultural Marketing Service (AMS). Rather, slaughter facilities rely on other quality measures such as lean percentage, back fat, and loin-eye depth.

the primals to produce subprimals and portion cuts. These smaller cuts are shipped together as boxed pork, but they still need further processing or repackaging before they can be sold to consumers. Some facilities package case-ready meats that are ready to be sold at retail. Unlike beef, pork is rarely quality graded by USDA's Agricultural Marketing Service (AMS). Rather, slaughter facilities rely on other quality measures such as lean percentage, back fat, and loin-eye depth (Muth et al., 2005).

The U.S. Census Bureau (2005) identifies the range of output from pork slaughter plants as follows:

- pork, not canned or made into sausage
  - fresh and frozen whole and half carcasses
  - fresh and frozen primal and fabricated cuts, including trimmings
  - fresh and frozen variety meats (edible organs)
- pork, processed or cured
  - sweet-pickled or dry-cured pork (not smoked, cooked, canned, or made into sausage)
  - dry salt pork (not canned or made into sausage)
  - smoked hams and picnics (not canned)
  - smoked slab bacon
  - smoked sliced bacon
  - other smoked pork (not canned or made into sausage)
  - boiled ham, barbeque pork, and other cooked pork
- sausage and similar products
  - fresh sausage (pork sausage, breakfast links)
  - dry or semidry sausage (e.g., salami, cervelat, jerky, pepperoni, summer sausage, pork roll)
  - frankfurters
  - other sausage, smoked or cooked (e.g., bologna, liverwurst, Polish sausage)
- jellied goods and similar preparations (headcheese)
- canned meats

The variety of pork products produced by slaughter plants has changed since the 1970s. Pork was traditionally sold as whole carcasses and then cut up by a retailer. Now, slaughter plants ship smaller cuts packaged in boxes (i.e., boxed pork), portion cuts, and case-ready pork, as well as processed and ready-to-eat (RTE) pork.

Pork slaughter plants also produce pork by-products, many of which are important for a variety of uses. Over 80 industrial and medicinal by-products can be produced from a hog carcass.

3.2 HISTORICAL TRENDS

This section summarizes historical trends in hog production and pork consumption; hog and pork prices; pork revenue, expenses, and profitability; and pork trade.

3.2.1 Production and Consumption

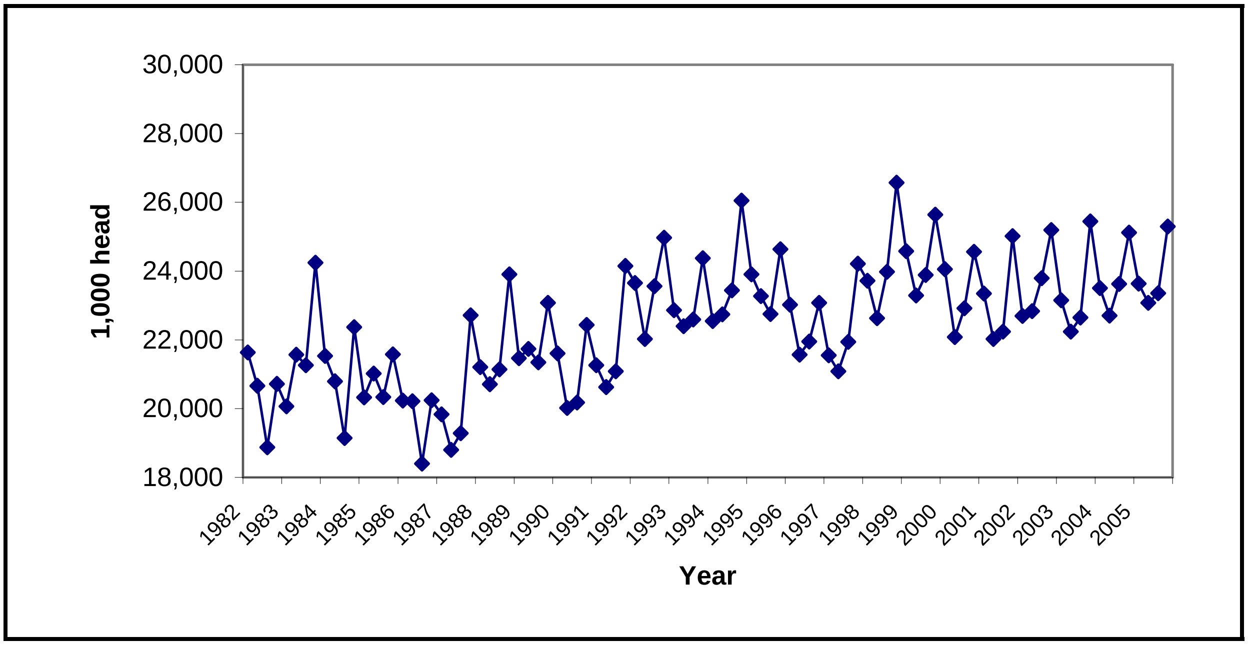
The production of hogs has generally trended upward from a low of 18.4 million hogs in 1986, peaking in 1998 at 27 million hogs before declining to 25 million hogs in 2005.

Figure 3-5 shows U.S. hog production for the period from 1982 to 2005. The production of hogs has generally trended upward from a low of 18.4 million hogs in 1986, peaking in 1998 at 27 million hogs, and declining to 25 million hogs in 2005. Figure 3-6 shows U.S. hog disappearance for the same time period. Disappearance is calculated as production plus imports minus exports. Because net trade is small relative to domestic production, disappearance is very similar to production.

Figure 3-7 shows U.S. pork production and disappearance for the period from 1982 to 2005. The production of pork has generally trended upward, with a low of 2.5 billion pounds in 1986 and a high of 4.3 billion pounds in 2005. The mean production of pork during this time period was 3.3 billion pounds. Disappearance is calculated as production plus imports minus exports using retail pork weight. Because net trade is very small relative to the domestic production of pork, disappearance is very similar to production.

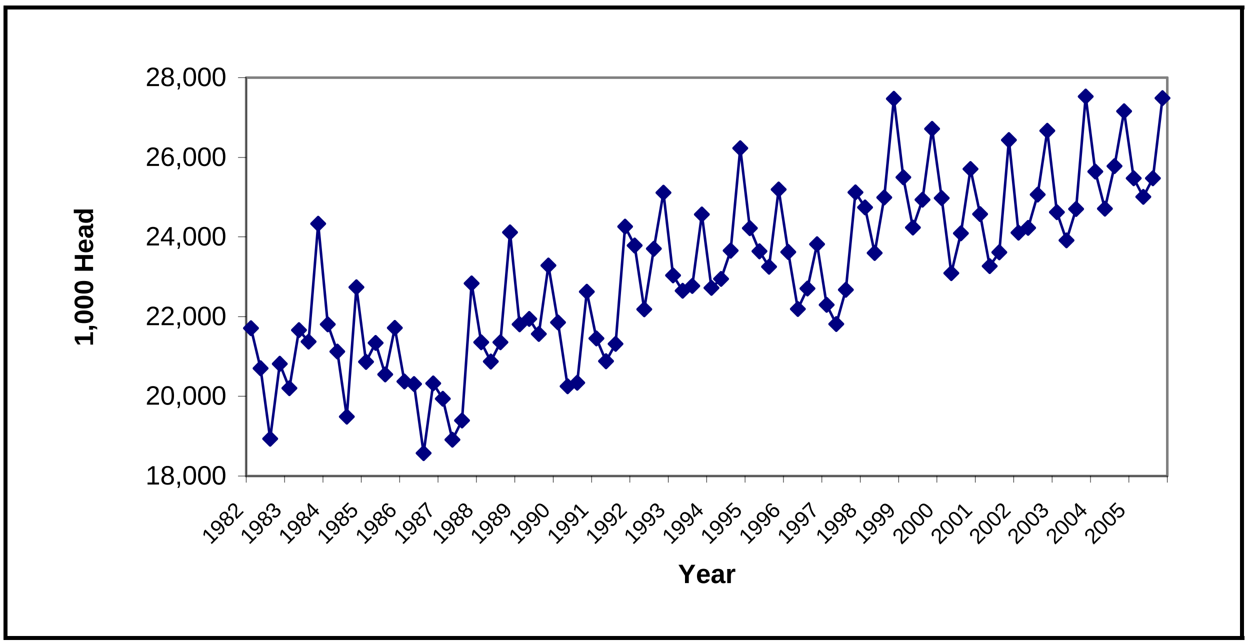
Figure 3-8 shows U.S. per capita pork consumption (retail weight) for the period 1982 to 2005. Per capita consumption of pork has remained relatively constant, with a low of 11.3 pounds in 1997 and a high of 14.3 pounds in 1994; the average per capita consumption was 12.7 pounds.

Figure 3-5. U.S. Hog Production, 1982–2005



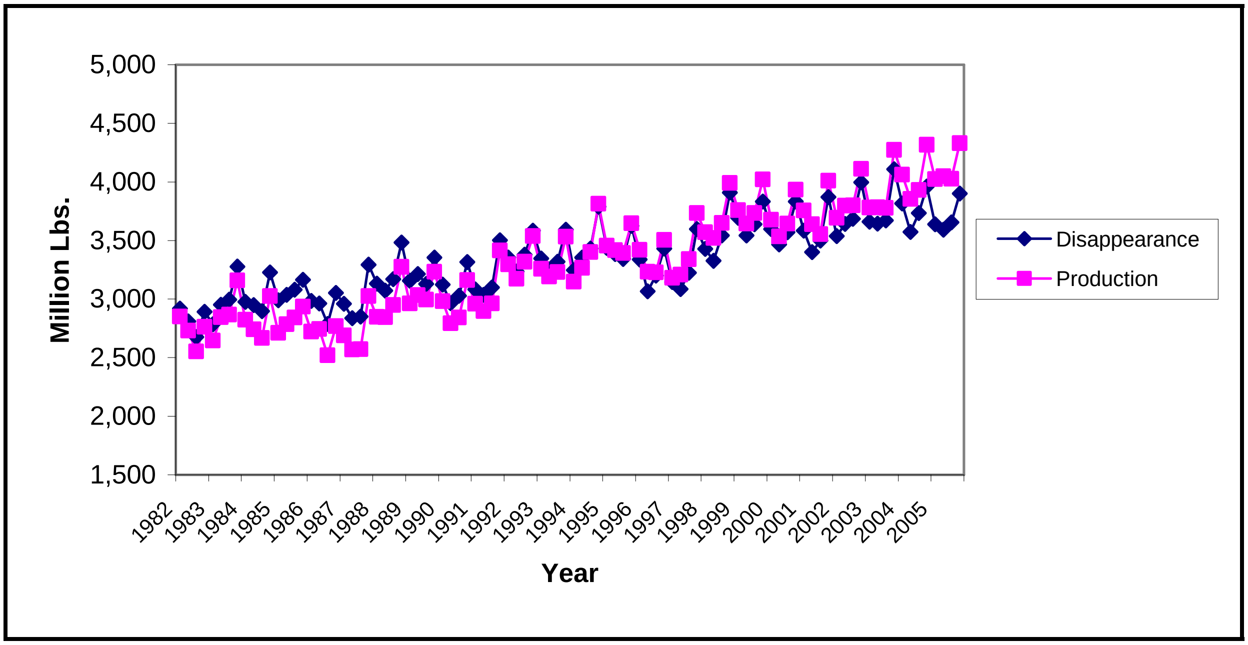
Source: Red Meat Yearbook. Available at
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354.

Figure 3-6. U.S. Hog Disappearance, 1982–2005



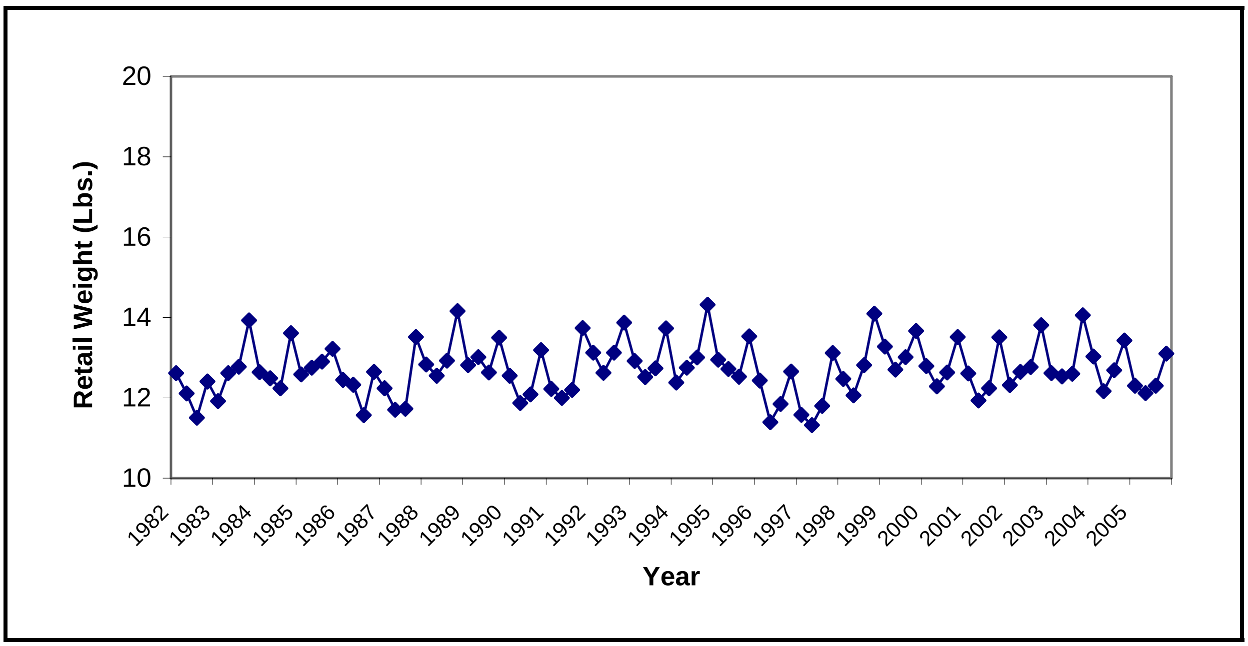
Source: Authors' calculations using data from Red Meat Yearbook.

Figure 3-7. U.S. Pork Production and Disappearance, 1982–2005



Source: Authors' calculations using data from Red Meat Yearbook.

Figure 3-8. U.S. Per Capita Pork Consumption, 1982–2005

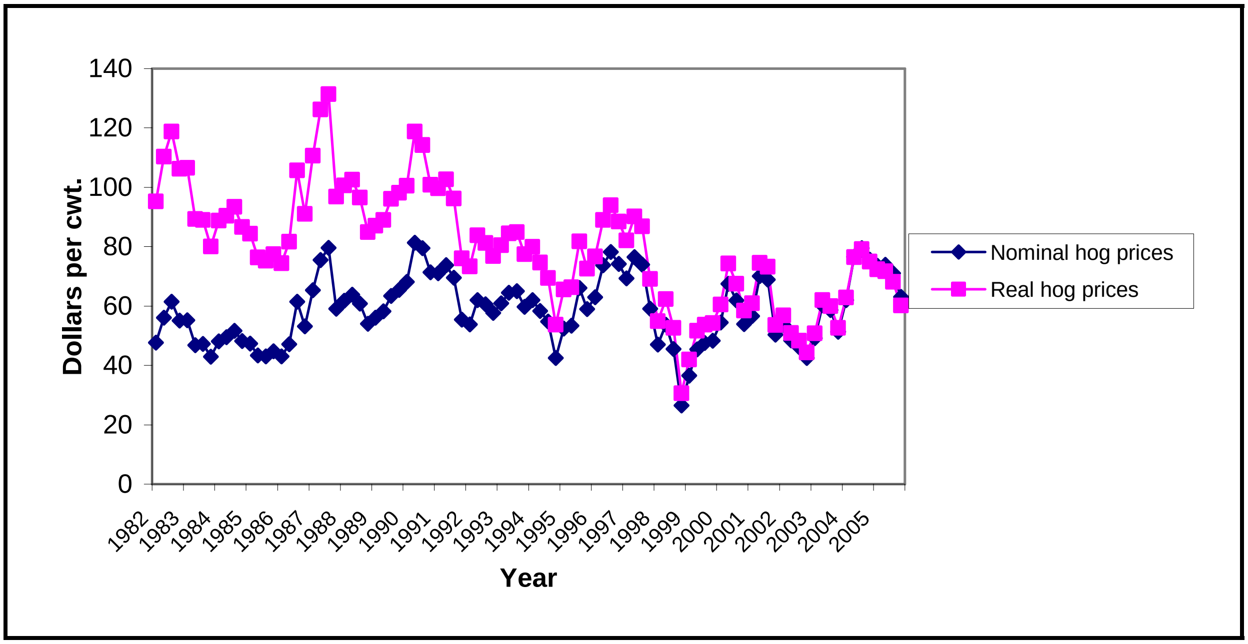


Source: Red Meat Yearbook. Available at
http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354.

3.2.2 Prices

Figure 3-9 shows U.S. hog prices in nominal and real terms for the period 1982 to 2005. There has been a general downward trend in hog prices. During this time period, hog prices have ranged from a high of $81 per hundredweight (cwt) in 1990 to a low of $26 per cwt in 1998, with an average price of $59 per cwt (nominal terms).

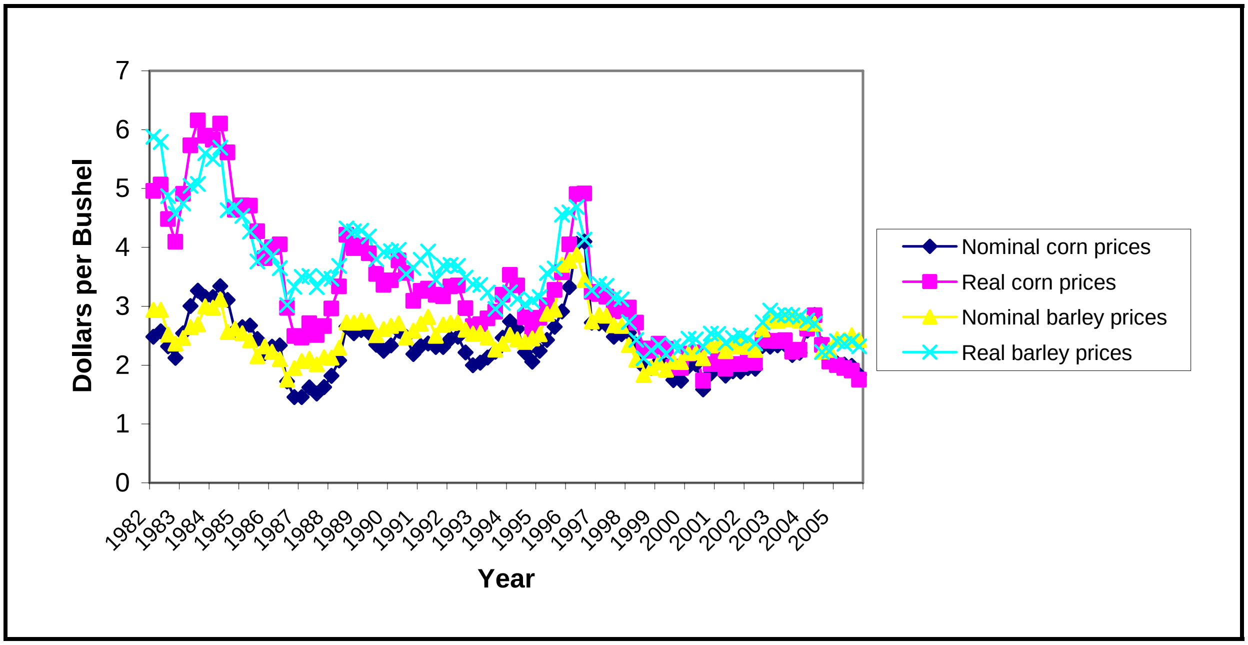
Figure 3-9. U.S. Hog Prices, 1982–2005



Source: Red Meat Yearbook. Available at http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1354.

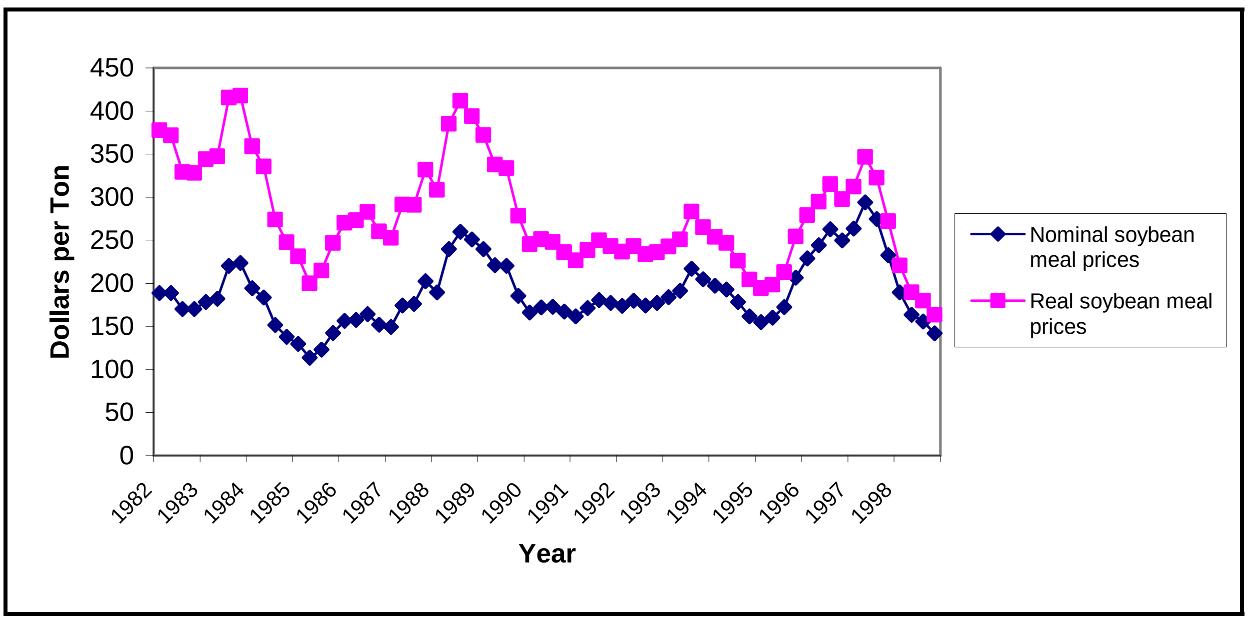
Figure 3-10 shows U.S. prices for corn and barley (1982 through 2005), and Figure 3-11 shows U.S. prices for soybean meal (1982 through 1998) in nominal and real terms. Corn and barley prices have generally declined, with the exception of 1988 and 1996 when prices increased and then declined. Soybean meal prices have been much more variable; prices peaked at $294 per ton in the second quarter of 1997 and were at a low of $113 per ton in the second quarter of 1985 (nominal terms). During the 1982 to 2005 time period, the average price of corn was $2.34 per bushel, and the average price of barley was $2.53 per bushel (nominal terms). From 1982 to 1998, the average price of soybean meal was $189 per ton (nominal terms).

Figure 3-10. U.S. Corn and Barley Prices, 1982–2005



Source: Corn price and barley price are from USDA ERS Feed Grain Yearbook http://www.ers.usda.gov/Data/FeedGrains/FeedYearbook.aspx.

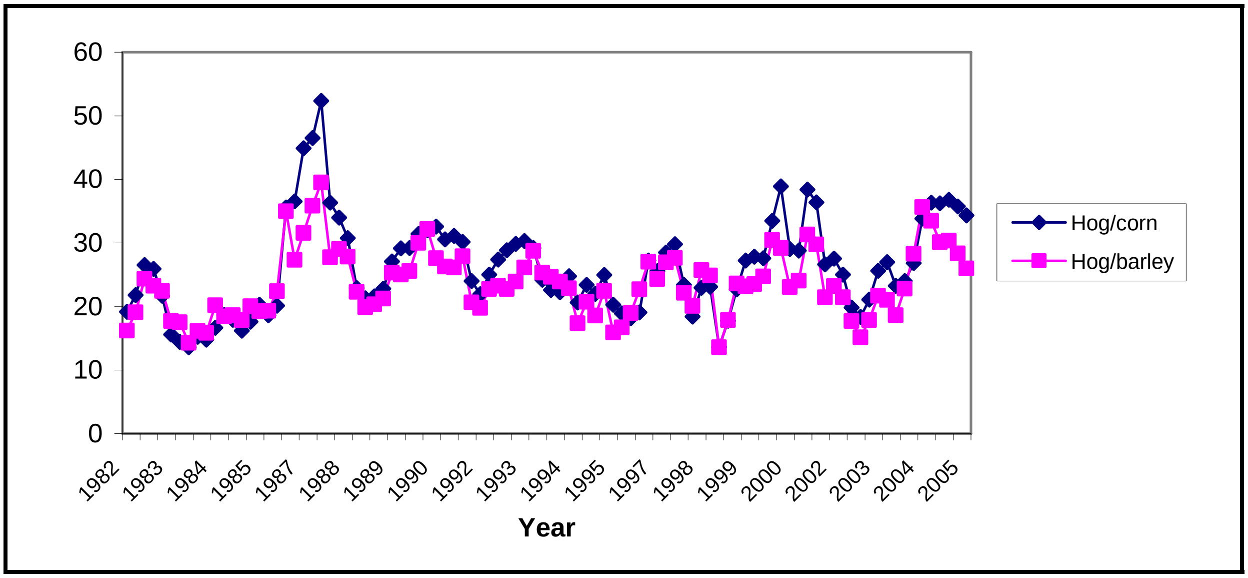
Figure 3-11. U.S. Soybean Meal, 1982–1998



Source: Bridge Commodity Research Bureau.

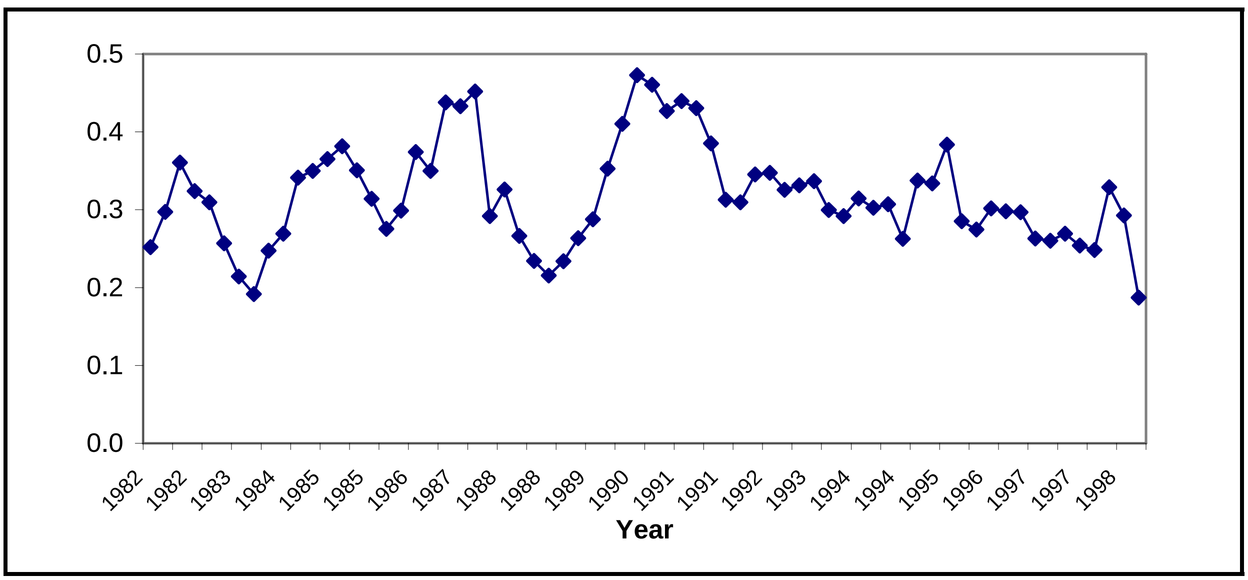
We computed the ratio of hog prices to input prices (see Figure 3-12 for corn and barley and Figure 3-13 for soybean meal). The ratios are similar for corn and barley, with average ratios of 26.2 and 23.7, respectively. Although it appears that the ratio for soybean meal is much lower, with an average of 0.32, it is measured on a dollar-per-ton basis (whereas corn and barley are measured on a dollar-per-bushel basis).

Figure 3-12. Hog/Corn and Hog/Barley Input Price Ratios, 1982–2005



Source: Authors' calculations using data from Red Meat Yearbook.

Figure 3-13. Hog/Soybean Meal Input Price Ratio, 1982–1998

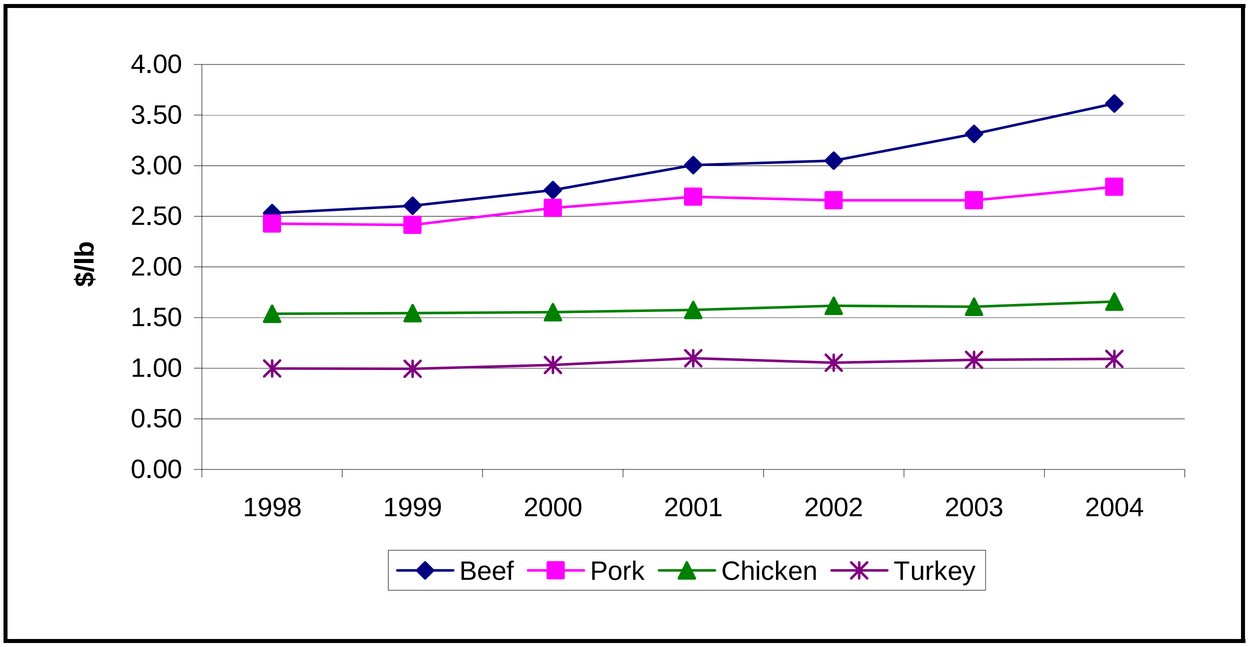


Source: Authors' calculations using data from Red Meat Yearbook.

Pork products have consistently been less expensive than beef and more expensive than poultry on a per-pound average basis over the past 7 years.

Pork products have consistently been less expensive than beef and more expensive than poultry on a per-pound average basis over the past 7 years. Figure 3-14 shows that the average nominal retail price for pork has risen by almost 15%, increasing from less than $2.43 per pound in 1998 to $2.79 per pound in 2004. In comparison, retail beef prices increased by more than 40% from 1998 to 2004. Adjusting the prices in Figure 3-14 for inflation indicates that real retail prices for pork rose in 2000 and 2001 but are now back at 1998 levels. Producers' use of indoor production facilities and other changes in production methods have decreased the seasonality of production (Mark and Hunnicutt, 2004) and subsequently decreased the magnitude of seasonal price swings.

Figure 3-14. Nominal Meat and Poultry Retail Prices, 1998–2004 ($/lb)



Sources: U.S. Department of Agriculture (USDA), Economic Research Service (ERS). August 2004b. *Poultry Yearbook.* Washington, DC: USDA. <http://usda.mannlib.cornell.edu/data-sets/livestock/89007/>.

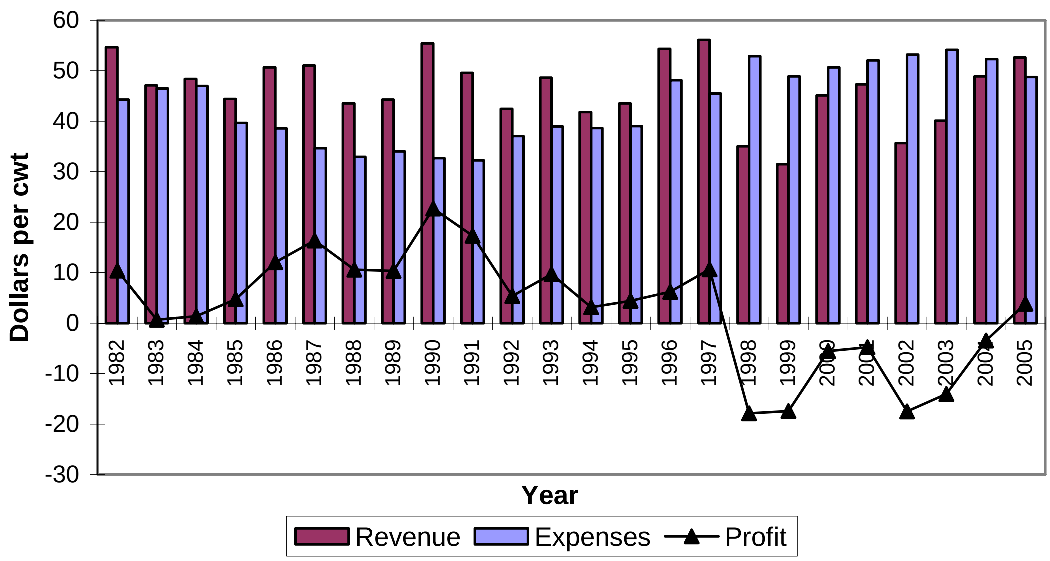
U.S. Department of Agriculture (USDA), Economic Research Service (ERS). 2004c. *Red Meat Yearbook*. Stock #94006. Washington, DC: USDA, ERS. <http://usda.mannlib.cornell.edu/data-sets/livestock/94006/>.

U.S. Department of Agriculture (USDA), Economic Research Service (ERS). 2005. *Livestock, Dairy, & Poultry Outlook.* Washington, DC: USDA, ERS. <http://www.ers.usda.gov/publications/ldp/>.

3.2.3 Pork Revenue, Expenses, and Profitability

Figures 3-15, 3-16, and 3-17 illustrate annual revenue, expenses, and profit for operations that farrow-to-finish, farrow-to-feeder, and feeder-to-finish, respectively, from 1982 to 2005. All three types of operations have experienced both profits and losses over the time period shown, with average profits of $2.89/cwt for farrow-to-finish, $9.26/cwt for farrow-to-feeder, and $0.04/cwt for feeder-to-finish. Hog producers, particularly farrow-to-finish and feeder-to-finish operations, sustained economic losses from 1998 through 2004 based on these estimates of average performance. In practice, there is quite a bit of variation around these averages, however.

Figure 3-15. Farrow-to-Finish Annual Revenue, Expenses, and Profit, 1982–2005



Source: U.S. Department of Agriculture, Economics Research Service. 2006. "Commodity Costs and Returns: US and Regional Cost and Return Data." Available at: http://www.ers.usda.gov/Data/CostsAndReturns/testpick.htm. Accessed January 4, 2007.

3.2.4 Pork Trade

The United States is a net importer of live hogs and is the world's second largest exporter of pork products, behind the European Union.

The United States is a net importer of live hogs (Figure 3-18). Virtually all live hogs imported into the United States are from Canada. The total number of hogs imported increased dramatically since 1990, while the type of hogs imported changed concurrently. In 1990, 77% of the Canadian hogs were slaughter hogs and 23% were feeder pigs. By 2003, the numbers switched: 33% of imported hogs were slaughter hogs

Figure 3-16. Farrow-to-Feeder Annual Revenue, Expenses, and Profit, 1982–2005

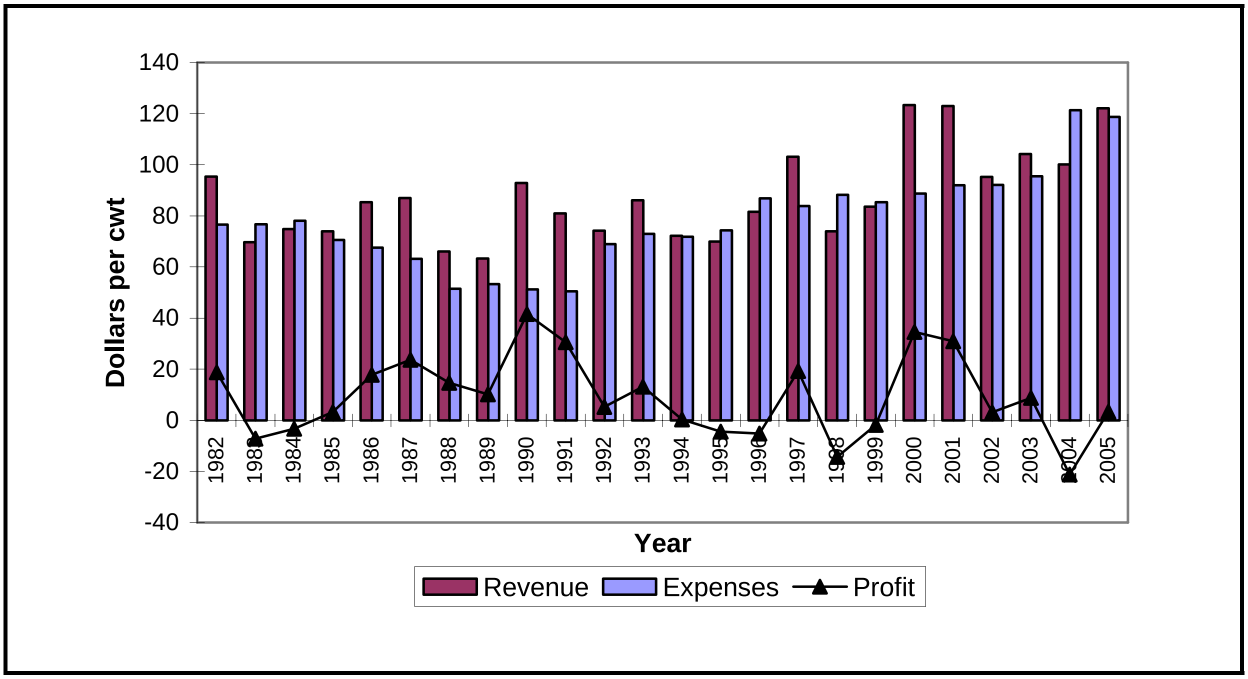


Figure 3-17. Feeder-to-Finish Annual Revenue, Expenses, and Profit, 1982–2005

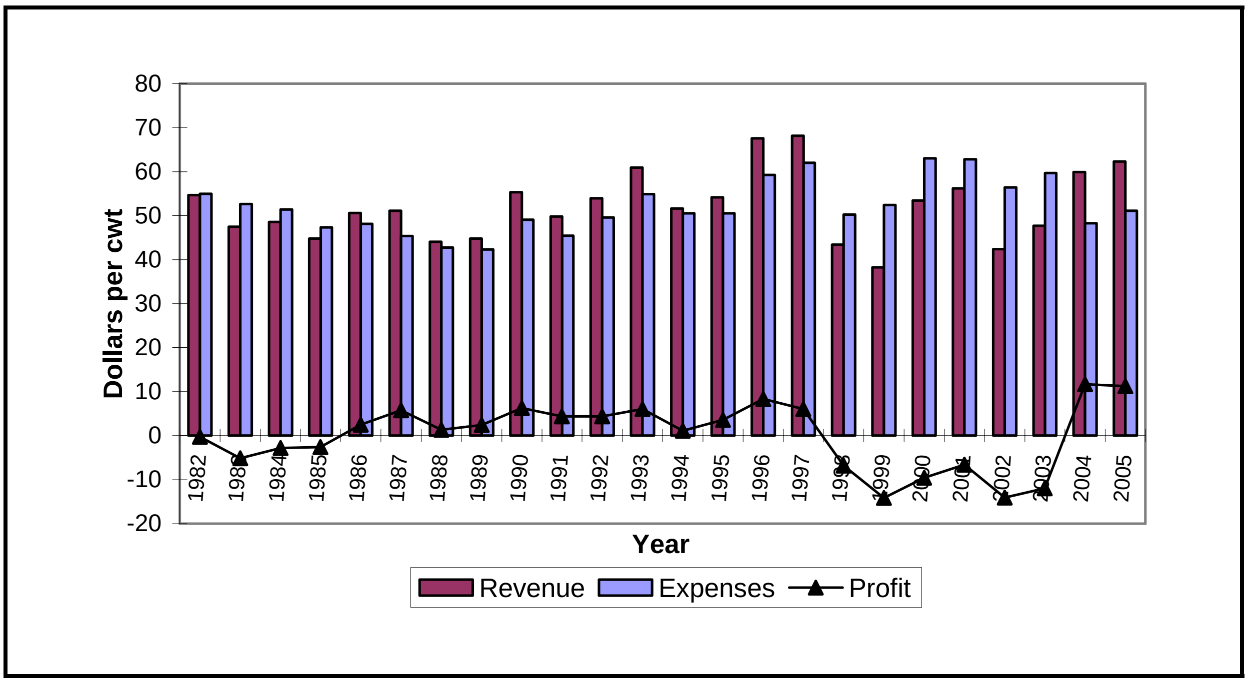
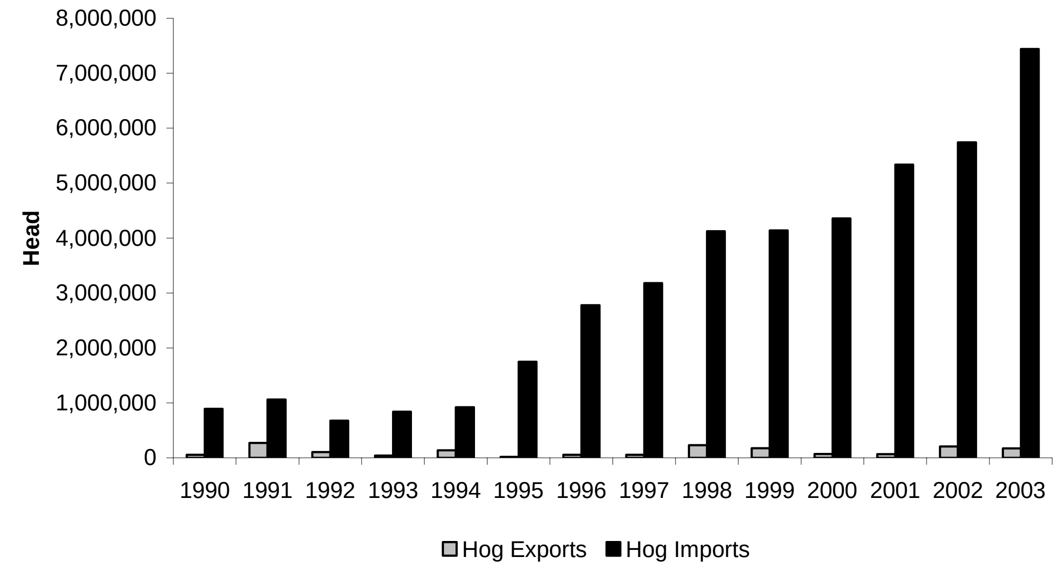


Figure 3-18. Total U.S. Hog Imports and Exports, 1990–2003
The United States is a net importer of live hogs. Live animal trade is typically restricted to North America.



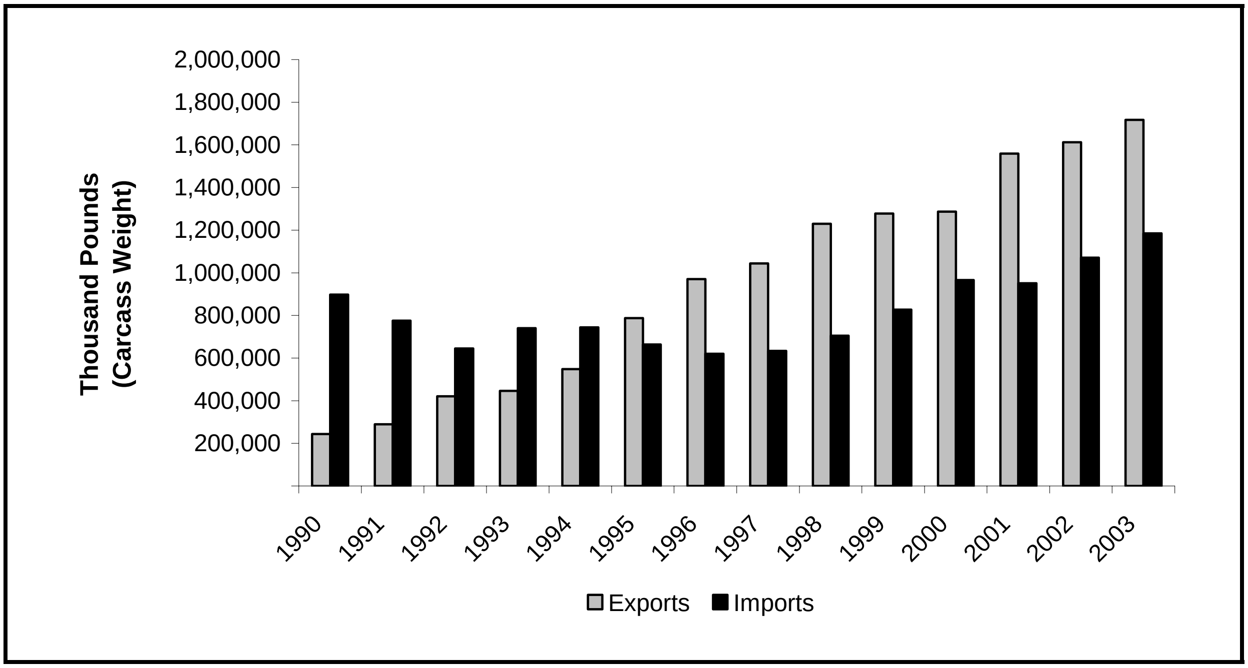
Source: U.S. Department of Agriculture, Economic Research Service. 2004c. "Red Meat Yearbook." Stock #94006. Washington, DC. <http://usda.mannlib.cornell.edu/data-sets/livestock/94006/>.

and 67% were feeder pigs. Approximately 95% of the feeder pigs are shipped to the Midwest and Corn Belt states. Slaughter hog shipments are more dispersed, but the majority of shipments are destined for the western states (Haley, 2004). Mexico consumes over 80% of U.S. live exports. From mid-1980 to the early 2000s, nearly two-thirds of live exports were slaughter hogs, and approximately one-third were breeding animals (USDA-ERS, 2004a).

The United States is the world's second largest exporter of pork products, behind the European Union (USDA-Foreign Agricultural Services [FAS], 2006). Pork exports increased from over 1.3 billion pounds in 2000 to just over 2 billion pounds in 2004. In 2004, pork exports were valued at $2 billion.

The United States has recently become a net exporter of pork products (Figure 3-19). Over three-quarters of the U.S. pork exports are sent to Japan, Mexico, and Canada. Japan, the world's largest pork importer, consumes 42% of U.S. pork exports (USDA-ERS, 2004a).

Figure 3-19. Total U.S. Pork Imports and Exports, 1990–2003
The United States has become a net exporter of pork products. Canada, Denmark, and the Netherlands are the primary sources of imported pork. Japan, Mexico, and Canada are the primary destinations for exported U.S. pork.



Source: U.S. Department of Agriculture, Economic Research Service. 2004c. "Red Meat Yearbook." Stock #94006. Washington, DC. <http://usda.mannlib.cornell.edu/data-sets/livestock/94006/>.

Canada and Denmark continue to be the primary suppliers of imported pork to the United States. Expansion in the Canadian hog industry and lower costs relative to Denmark have allowed Canada to become the dominant foreign supplier (USDA-ERS, 2004a). The United States tends to import more fresh or chilled pork, and export more frozen pork.

Discovery of BSE in North American cattle affected pork trade. But given the changes in international meat trade, it is difficult to determine how much of the recent increase in pork exports is directly attributable to the discovery of BSE. Japan and Mexico, previously important export markets for U.S. beef, increased U.S. pork imports by 10% and 70%, respectively (Truit, 2004). In addition, some domestic consumers substituted pork for beef as beef prices hit record high levels, in part because of the U.S. ban on imports of live Canadian cattle.

3.3 STRUCTURAL CHANGES

Recent trends in the pork industry include higher concentration in hog production and slaughter and more vertical arrangements through the use of contracts

Recent trends in the pork industry include higher concentration in hog production and slaughter and more vertical arrangements through the use of contracts (Muth et al., 2003).

Plant specialization has been facilitated by vertical integration within the industry. Integration allows processors to ensure their supply of pork by managing all phases of the production process. Pork processors have become increasingly integrated through production contracts for feeder and weaner pigs and through direct ownership of breeding stock and market hogs. According to Muth et al. (2003), Smithfield Foods and Premium Standard Farms are completely vertically integrated, owning every stage of the production process from genetic research to product packaging.

The Herfindahl-Hirschman Index (HHI) is a measure of industry concentration that is calculated as the sum of each firm's squared percentage of total commercial slaughter and can vary from close to 0 to 10,000. Industry concentration for hog slaughter facilities has been relatively stable in recent years, at a level near 1,000. Industries with an HHI below 1,000 are considered "competitive" industries by the U.S. Department of Justice. Based on the value of the HHI for the pork industry, the industry is slightly above the values for a "competitive" industry and would be classified as a moderately concentrated industry.

4 Conceptual Approach to Evaluating the Pork Checkoff Program

We provide background information on the theory informing the development of our market models and present our theoretical model of the hog and pork markets.

This section discusses the conceptual structural model developed to describe the hog and pork markets. We provide background information on the theory informing the development of our market models and present our theoretical model of the hog and pork markets. Estimation of this model provides estimates of the parameters necessary for evaluation of the Program (see Section 5). In Section 6, the estimated parameters are used to simulate the market impacts of changes in Program expenditures and to calculate the benefits of Program activities and associated rates of return.

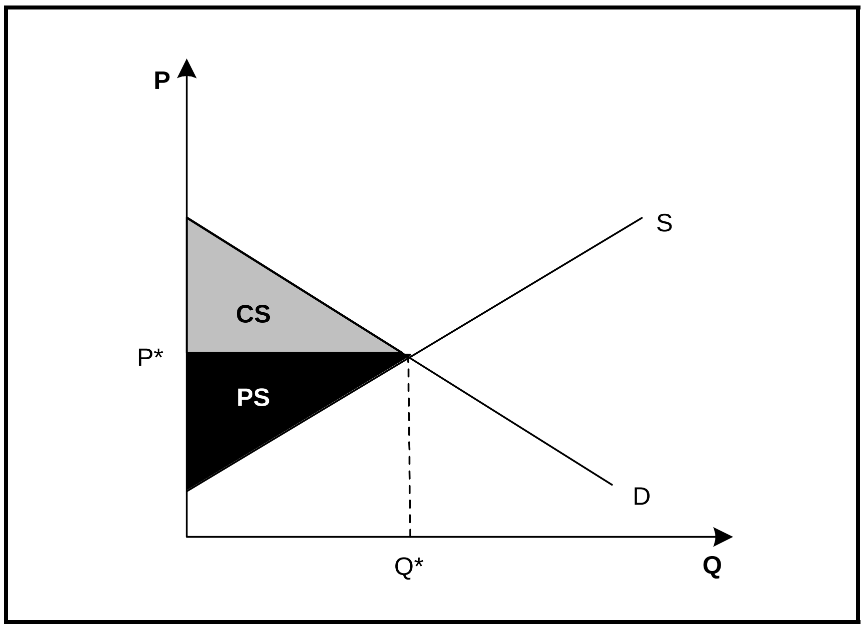
4.1 THEORETICAL FOUNDATION

Expenditures on generic pork research and promotion may affect both the demand for pork and the supply of pork. Producers may benefit in either case because spending on promotion will increase consumer demand for retail products (and therefore the derived demand for hogs), while research on marketing methods (storage, transport, processing, and distribution services) will directly increase the demand for pork by meat processors, and research on farm production methods will reduce the costs of producing hogs. All of the potential effects of the Program mentioned above have positive benefits to producers, but returns may differ across expenditure categories and a key question from the producer perspective is whether the gains from a given Program activity outweigh the costs.

4.1.1 Supply and Demand Curves

Figure 4-1 displays a simple linear supply and demand relationship in a typical competitive market. Demand curves normally slope downward because, everything else being equal, consumers will purchase more of a product as its price declines. Supply curves, on the other hand, generally slope upward because the higher the price of a good, the more producers are willing to make available. Increased hog prices encourage additional hog production because of the action of profit-maximizing producers. As the return on hog production increases relative to the return on alternative activities, producers will choose to produce more hogs.

Figure 4-1. Supply and Demand Curves



Supply and demand curves show the quantity of a good that will be supplied and demanded, respectively, at each price. The intersection of these two curves determines the market equilibrium price (P*) and quantity (Q*). The market equilibrium is the only point at which the quantity that buyers want to purchase is equal to the quantity that sellers are willing to make available.

For these two-dimensional supply and demand curves, it is assumed that all factors other than price are held constant. If any factor that affects demand or supply (other than price) changes (e.g., the level of Program expenditures), then there will be a shift in the affected curve. In other words, rather than moving along the curve as in the case of a change in price, there will be a change in the quantity demanded (supplied) at every price following the shift in demand (supply) when one of these other factors changes.

Assuming pork promotion activities are successful, consumers will place a higher value on these products than they did previously, and this higher valuation will be reflected in an increase in the quantity of pork products demanded at every price along the entire retail demand curve.

For example, one goal of the Pork Checkoff Program is to make consumers aware of the advantages of pork through promotional expenditures. Assuming pork promotion activities are successful, consumers will place a higher value on these products than they did previously, and this higher valuation will be reflected in an increase in the quantity of pork products demanded at every price along the entire retail demand curve. Because the demand for retail pork has increased, there will be an increased derived demand for hogs facing hog producers.[1] Another activity performed under the Program is agricultural research. Successful agricultural research will typically have effects such as increases in yield and/or lower production costs. Either of these effects would lead to an increase in the supply of hogs at any given price (possibly with some lag).

4.1.2 Consumer Surplus

Consumer surplus is the maximum amount that consumers would have been willing to pay for the quantity of a good purchased less their expenditures on that good. Thus, consumer surplus is a measure of the gain that consumers get from being able to purchase a good for less than their valuation of that good. The demand curve represents the maximum amount that consumers would be willing to pay for each unit of output. Therefore, consumer surplus is measured as the distance between the demand curve and the equilibrium price summed across all units of the good purchased. When there is an increase in demand for a good (rightward shift of the demand curve), this means consumers' valuation of the good has increased. Although an increase in demand will also increase equilibrium price, other things being equal, the increase in valuation typically outweighs the increase in price so that consumer surplus rises.

4.1.3 Producer Surplus

Producer surplus, on the other hand, is the total revenue that producers receive for their product less the minimum amount

[1] This market linkage is discussed in more detail later in this section.

necessary for them to make the product available. The supply curve represents the minimum amount that sellers would be willing to accept for each unit of output, which is equal to their marginal costs. In the case of an outward shift in demand, the price that producers receive will increase for all units sold and they will be able to sell more units. Both of these effects will increase producer surplus.

4.1.4 Welfare Changes from Program Expenditures

In evaluating the economic effects of programs and policies, including the Pork Checkoff Program, it is the changes in consumer and producer surplus resulting from the program or policy that are of interest rather than the absolute surplus values.

In evaluating the economic effects of programs and policies, including the Pork Checkoff Program, it is the changes in consumer and producer surplus resulting from the program or policy that are of interest rather than the absolute surplus values. The primary emphasis in this report is changes in producer surplus, which are essentially equal to changes in producer profit, assuming fixed costs of production are unaffected by the Program.

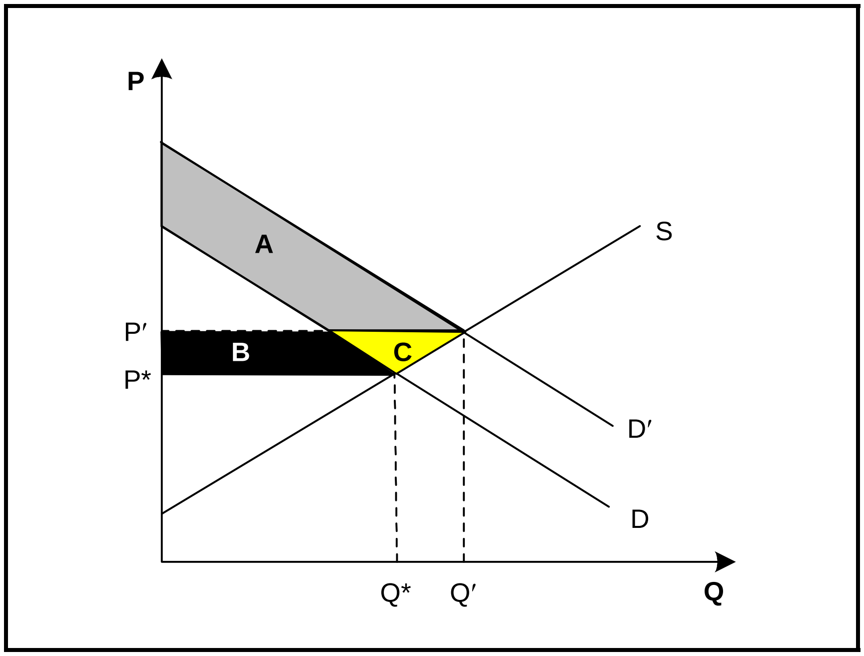
Figure 4-2 illustrates an example of changes in consumer and producer surplus. An increase in demand from D to D′ leads to an increase in equilibrium price from P* to P′ and an increase in equilibrium quantity from Q* to Q′. As a result of these changes, consumer surplus increases by A–B, and producer surplus increases by B+C.[2] Overall, the total surplus to consumers and producers increases by the area A+C following this increase in demand. It will generally be the case that both consumers and producers will benefit from Program activities that increase demand and/or supply.

Figure 4-3 shows the impact of promotion and research on prices, quantities, consumer surplus, and producer surplus for a single commodity in a multistage production system, such as pork.[3] Derived demand at the farm level (D_f) is equal to retail

[2] Consumer surplus increases by the area A–B because consumers gain the area A as a result of their increased willingness to pay for this product but lose area B because the price of each unit has increased. Producer surplus increases by B+C because producers both get a higher price and sell a greater quantity as a result of the increased demand.

[3] This figure shows two stages of the production process (retail and farm levels) assuming fixed input proportions and a perfectly elastic (flat) supply curve for the intermediate product. In addition, this figure shows impacts in the absence of trade effects for simplicity and clarity of presentation.

Figure 4-2. Change in Consumer and Producer Surplus due to Demand Increase



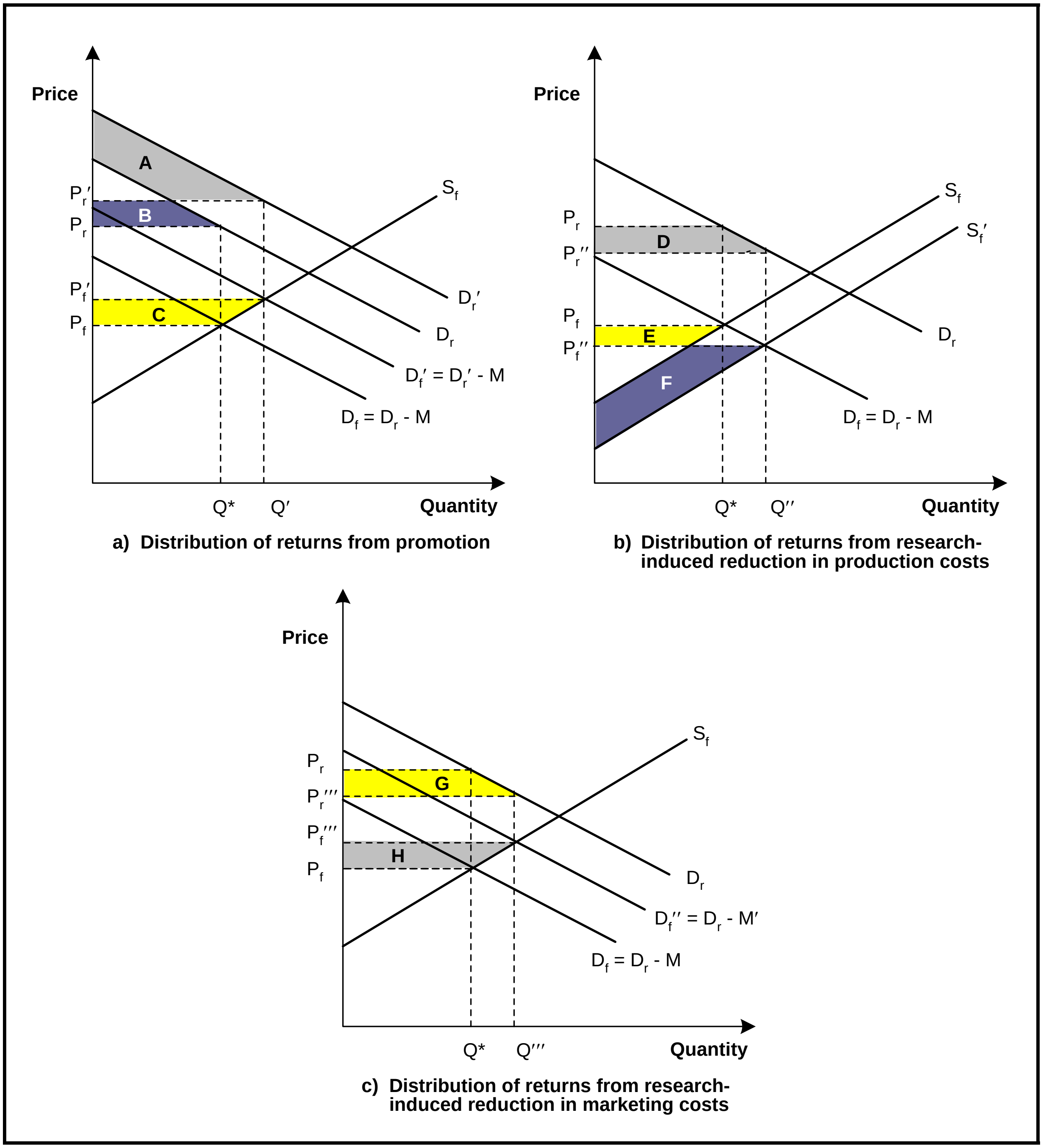
demand (D_r) less the constant absolute margin (M) at each quantity value.[4] The market is initially in equilibrium where the farm supply curve (S_f) intersects the derived demand curve (D_f). Quantity produced and sold to consumers is given by Q*. Price at the farm level is P_f and price to consumers is P_r.

Suppose promotion causes retail demand to increase from D_r to D_r' and farm-level demand to increase from D_f to D_f'. Farm price increases from P_f to P_f', the retail price increases from P_r to P_r', and quantity produced and consumed increases from Q* to Q′. Consumers gain the area A–B and producers gain the area C in Figure 4-3a.

Figure 4-3b shows a research-induced reduction in production costs where the farm supply shifts down parallel from S_f to S_f'. Farm price falls to P_f'', retail price falls to P_r'', and quantity rises to Q″. Consumer surplus increases by the area D, and producer surplus increases by the area F–E.

[4] The margin M is the difference between farm prices and the price to consumers, which represents "marketing" costs and includes all of the processing, transportation, etc., that take place between the farm and retail levels.

Figure 4-3. Distribution of Returns from Research and Promotion in a Multistage Production System



a) Distribution of returns from promotion

b) Distribution of returns from research-induced reduction in production costs

c) Distribution of returns from research-induced reduction in marketing costs

As shown in Figure 4-3c, a research-induced reduction in the costs associated with the production of intermediate pork products that leads to a reduction in absolute margin from M to M′ will cause the derived demand for hogs to increase from D_f to D_f''. This will increase consumer surplus by the area G and producer surplus by the area H.

4.2 STRUCTURAL MODEL

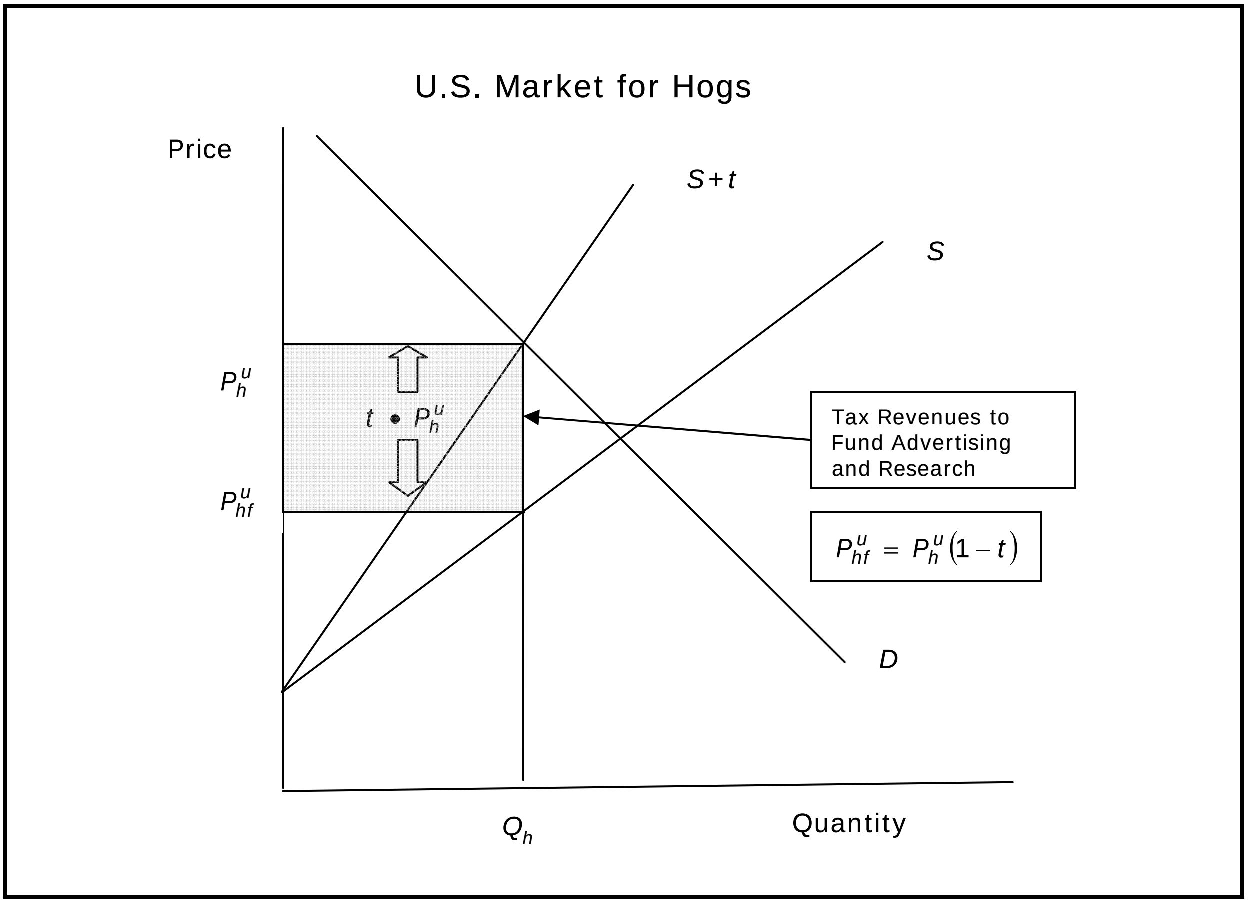
It is expected that the activities performed under the Pork Checkoff Program will simultaneously cause each of the three types of shifts shown in Figure 4-3 to occur in the domestic hog and pork markets.

It is expected that the activities performed under the Pork Checkoff Program will simultaneously cause each of the three types of shifts shown in Figure 4-3 to occur in the domestic hog and pork markets. This is because the Program engages in promotion designed to increase retail demand, research into new products that is aimed at increasing processors' demand for hogs, and production research and producer education intended to reduce production costs or increase productivity. In addition, there is a shift in the supply curve resulting from the assessment itself. The assessment increases the cost of production, resulting in a decrease in supply, all else equal. The assessment t levied on hog value, which is a form of *ad valorem* tax, can be shown to affect the market-clearing price for hogs (P_h^u) and the prices producers receive (P_{hf}^u) by creating a wedge equal to $t \bullet P_h^u$ and generating tax revenues equal to $t \bullet P_h^u \bullet Q_h$ as shown in Figure 4-4. Because the assessment and the results of agricultural research shift the supply curve in opposite directions, the net shift of the supply curve depends on which effect is larger.

In assessing the effectiveness of checkoff programs, net benefits to producers attributable to activities funded by the checkoff must be separated from those due to other factors influencing commodity markets.

In assessing the effectiveness of checkoff programs, net benefits to producers attributable to activities funded by the checkoff must be separated from those due to other factors influencing commodity markets. Numerous external factors may affect agricultural industries, including government policies and regulations (Muth et al., 2005; Wohlgenant, 2005), biotechnology (Lemieux and Wohlgenant, 1989), animal health issues, human health and nutrition information (Kinnucan et al., 1997; Verbeke and Ward, 2001), trade restrictions, food safety issues (Piggott and Marsh, 2004), changes in consumer income, and other factors.

Figure 4-4. Supply Shift from Assessment and Revenue Raised



To assess these changes in supply and demand resulting from the Program, we developed a structural model of the U.S. hog and pork industries. The linkages between the relevant market levels must be included to ensure that all of the Program impacts are considered.

To assess these changes in supply and demand resulting from the Program, we developed a structural model of the U.S. hog and pork industries that accounts for some of these key external factors where data are available. The linkages between the relevant market levels must be included to ensure that all of the Program impacts are considered. The framework for such a market linkage model is found in Piggott, Piggott, and Wright (1995); Wohlgenant (1993); and Wohlgenant and Clary (1993), among others. The retail pork market consists of pork processors, U.S. consumers, and foreign importers of U.S. pork. The hog market consists of U.S. hog producers, pork processors, and Canadian suppliers of excess Canadian hogs. To model the impact of Program promotion and research activities on the demand and supply for hogs and pork, we define the structural market model for hogs and pork as follows:

Model of Hog / Pork Markets

$I_h^u = I\left(I_{h-1}^u, P_{hf}^u, R_h^u, W_h^u\right)$	[U.S. inventory of sows]	(4.1)
$PL_h^u = PL\left(R_h^u, W_{pl}^u\right)$	[U.S. pigs per litter]	(4.2)
$WP_h^u = WP\left(P_{hf}^u, W_{wp}^u\right)$	[U.S. pounds per hog]	(4.3)
$Q_h^u = PL_h^u \cdot WP_h^u \cdot I_{h-2}^u$	[U.S. hog production]	(4.4)
$P_h^u = d_h\left(Q_h, N_h^u, W_p^u, P_p^u\right)$	[U.S. demand for hogs]	(4.5)
$P_{hf}^u = P_h^u(1-t)$	[Net hog price-gross hog price relationship]	(4.6)
$Q_h^c = m_h^c\left(P_h^c, W_p^c, W_h^c, Y_p^c\right)$	[Canada net trade in hogs]	(4.7)
$Q_p = s_p^u\left(Q_h, N_h^u, P_p^u, W_p^u\right)$	[U.S. retail supply of pork]	(4.8)
$Q_p^u = d_h\left(P_p^u, A_p^u, Y_p^u\right)$	[U.S. demand for pork]	(4.9)
$Q_p^{oc} = x_p^{oc}\left(P_p^{oc}, Y_p^{oc}, A_p^{oc}\right)$	[Export demand for U.S. pork]	(4.10)
$P_h^c = p_h^c\left(P_h^u, Z_h\right)$	[Canada-U.S. hog price linkage]	(4.11)
$P_p^{oc} = p_p^{oc}\left(P_p^u, Z_p\right)$	[Other countries-U.S. pork price linkage]	(4.12)
$Q_h = Q_h^u + Q_h^c$	[Market-clearing condition for hog market]	(4.13)
$Q_p = Q_p^u + Q_p^{oc}$	[Market-clearing condition for pork market]	(4.14)

Definitions:

I_h^u = inventory of farrowing sows at the end of the quarter (minus 1 subscript denotes lagged one quarter),

P_h^u = the price of hogs in the United States,

P_{hf}^u = the price of hogs received by the hog farmer in the United States,

t = tax rate on hog value assessed on hog producers by the National Pork Board

R_h^u	=	production research expenditures by the National Pork Board (this is also called hog supply expenditures [HSE] in the econometric analysis in Section 5),
W_h^u	=	other exogenous factors influencing supply of farrowing sows (i.e., corn prices, technical change),
PL_h^u	=	pigs per litter,
W_{pl}^u	=	other exogenous factors influencing pigs per litter (i.e., technical change caused by other factors other than National Pork Board expenditures),
WP_h^u	=	average weight per hog marketed,
W_{wp}^u	=	other exogenous factors influencing average weight per hog marketed (i.e., technical change, seasonal factors),
Q_h^u	=	total liveweight of hogs produced in the United States,
Q_h	=	total liveweight of hogs sold to U.S. packers (i.e., total quantity [in liveweight] of hogs demanded by U.S. packers),
N_h^u	=	marketing research expenditures by the National Pork Board (this is the same as the hog demand expenditure [HDE] used for econometric analysis in Section 5),
W_p^u	=	other exogenous factors influencing demand for hogs (i.e., index of processing costs, other technical change),
Q_h^c	=	quantity of Canadian hogs exported to the United States,
P_h^c	=	price of Canadian hogs,
W_p^c	=	exogenous factors affecting demand for Canadian hogs,
W_h^c	=	exogenous factors affecting Canadian supply of hogs,
Y_p^c	=	exogenous factors affecting Canadian demand for pork,
Q_p	=	quantity of pork supplied in the United States,
P_p^u	=	retail price of pork in the United States,

A_p^u = promotion expenditures by the National Pork Board (this is the same as the pork demand expenditure [PDE] variable used in the econometric analysis in Section 5),

Y_p^u = other exogenous factors influencing retail demand for pork (e.g., prices of beef, poultry, income, promotion expenditures by the Beef Board),

Q_p^u = quantity of pork demanded by U.S. consumers,

Q_p^{oc} = quantity of U.S. pork demanded by consumers in other countries,

P_p^{oc} = price of pork in other countries,

A_p^{oc} = expenditures by the National Pork Board on foreign promotion (this is the same as the foreign market development [FMD] variable used for econometric analysis in Section 5),

Y_p^{oc} = other exogenous factors influencing export demand for U.S. pork,

Z_h = exogenous factors influencing hog price linkage, and

Z_p = exogenous factors influencing pork price linkage.

The distinction between the expected effects of generic and branded promotion is that generic expenditures are designed to increase demand for a given commodity, while branded expenditures are designed primarily to increase the demand for a particular company's product.

An additional potentially important exogenous variable that may affect retail pork demand that we examined was branded pork promotion expenditures. The distinction between the expected effects of generic and branded promotion is that generic expenditures are designed to increase demand for a given commodity, while branded expenditures are designed primarily to increase the demand for a particular company's product. To accurately estimate the impact of the generic research and promotion activities funded by the Program on the hog and pork markets, we need to consider possible interactions between generic and branded promotion activities.

Branded advertising expenditures, while directed at promoting the specific product of a particular firm, could also increase market demand and therefore producer returns. This is especially true if the advertising message emphasizes product attributes common to the product class (e.g., pork). This point is discussed in Clary (1993). If the impact of branded advertising is not considered, then the results of the estimation may be biased. The direction of the bias is not clear, however, because branded and generic promotion could be either substitutes or complements for one another.

We attempted to assess these interaction effects by including data on branded pork promotion in initial models. However, these variables were not included in the final models estimated empirically because their inclusion did not reveal statistically significant effects of branded promotion and their exclusion led to little change in estimates of other parameters.[5] This may imply that branded pork expenditures primarily affect the demand for specific brands of pork rather than increasing demand for the commodity. However, the branded advertising data series available was generated from a combination of data provided by Gary Brester, Montana State University (2006) for 1982 through 1998 and data we compiled from LNA, Inc. reports for 1999 through 2005. Although we attempted to follow similar procedures to those employed by Dr. Brester, the newer data series may not be consistent with the earlier series. It is certainly possible that if more consistent and complete data on branded promotional expenditures related to pork products were available, we may find a significant effect on pork demand. Given available time and resources for conducting this project, we were unable to devote the considerable resources necessary to go back to hard copy publications from earlier years and reconstruct a series that would be more consistent over time. Because of these data issues, we cannot definitively conclude that branded advertising did not have an effect on pork demand, although we did not identify one in our modeling.

The parameter estimates obtained from this model will provide us with measures of the responsiveness of quantity demanded and supplied to price, promotion, and research (as well as other relevant variables).

The equations presented above can be estimated econometrically, which provides us with estimates of the statistical relationship between the respective prices and quantities and all of the variables included in the model affecting that price or quantity. The parameter estimates obtained from this model will provide us with measures of the responsiveness of quantity demanded and supplied to price, promotion, and research (as well as other relevant variables). The responsiveness of one economic variable to another is typically reported as an elasticity, which measures the percentage change in one variable resulting from a given

[5] More details on the statistical insignificance of branded pork advertising are provided in the next section.

percentage change in another variable. For example, the price elasticity of demand is a measure of how responsive quantity demanded is to price. If the price elasticity of demand is –0.3, this means that a 1% increase in the price of the product will lead to a decline in quantity demanded of 0.3%.[6]

The price elasticities of supply and demand are especially important for this analysis because they play a large role in determining the distribution of net benefits from promotion and research between producers and consumers. In general, as the supply elasticity becomes larger, implying that producers will increase production by a larger percentage in response to a given change in price, producers benefit less from Program activities and consumers benefit more. In addition, as the demand elasticity becomes larger (in absolute value), implying consumers are more responsive to price changes, the benefits to producers will be reduced, other things being equal.

In the next section, we discuss the empirical specifications of the structural equations contained in the above hog/pork markets and provide the rationale for choosing these specifications. The parameter estimates for these specifications will then serve as inputs in the simulation model that calculates rates of returns for the National Pork Board's research and promotion expenditures.

[6] The price elasticity of demand will typically be negative because an increase in price normally leads to a decrease in quantity and vice versa. However, other elasticity measures may be positive or negative depending on whether the variables being compared tend to change in the same direction or not.

5 Econometric Estimation and Results

Following the conceptual approach developed in Section 4, we implemented our models empirically to generate the necessary parameter estimates.

Following the conceptual approach developed in Section 4, we implemented our models empirically to generate the necessary parameter estimates. This section describes the data used; our lag structure; and our econometric models of domestic demand for hogs; supply of pork; domestic supply of hogs; import demand for Canadian hogs; our domestic meat demand system for the three major species consumed in the United States: beef, pork, and poultry; and export demand for U.S. pork. It provides a discussion of alternative model specifications considered and explains the rationale for choosing the final models presented. The results obtained from these econometric models were used in simulation models, described in Section 6, to evaluate the benefits and costs of the Program.

5.1 DATA DESCRIPTION

The data used in the econometric modeling come from various sources in the public domain, with the exception of commodity research and promotion expenditures, which are not in the public domain and must be obtained from the appropriate organizations or researchers with access to these data. For this project, we used quarterly data on prices of hogs and pork, prices of substitute meats, input costs, hog and pork quantities produced and consumed in the United States, income, and trade data obtained from a variety of public data sources, as well as Pork Checkoff research and promotion expenditures provided by the National Pork Board; generic beef promotion expenditures from Dr. Ron Ward; and branded beef, pork, and poultry promotion expenditures from Dr. Gary Brester through 1998 and author calculations from Leading National Advertisers data from 1999 to 2005.[1]

These data are the type of publicly available data typically used for evaluations of commodity research and promotion programs and generally considered to be the best available for conducting such evaluations. One potential alternative would be using more detailed consumer purchase data from individual households maintaining diaries or panel data from sources such as the Nielsen Group. However, to make full use of these data would require data on promotion and research, as well as all of our other independent variables at matching intervals and regions. Although such an analysis would be of interest and would provide a complementary method of assessing returns, the National Pork Board research and promotion data were not readily available at this level of detail, and estimating a household demand model was not feasible within the time frame for analysis and available resources.

The food safety index variables for beef, pork, and poultry are designed to approximate public perception of the safety of meat products.

Table 5-1 describes each variable used in the study and provides summary statistics. Most of the variables are self-explanatory, although the construction of the food safety indexes deserves a little elaboration. The food safety index variables for beef, pork, and poultry are designed to approximate public perception of the safety of meat products. We updated the newspaper article count indices used in Piggott and Marsh (2004) through 2005 for each of the three meat species. Specifically, the Piggott and Marsh food safety data series were obtained by searching the top 50 English language newspapers using the academic version of the Lexis-Nexis search engine. Keywords searched were “food safety” or “contamination” or “product recall” or “outbreak” or “*Salmonella*” or “*Listeria*” or “*E. coli*” or “Trichinae” or

[1] As noted in the previous section, we included branded promotion in initial models but did not find significant effects. Therefore, the variable was dropped from our final models to simplify estimation and simulation.

Table 5-1. Data Summary Statistics and Description

Variable Description	Sample Period	Unit	Mean	Maximum	Minimum	Standard Deviation	Source
U.S. per capita beef consumption	1982(1)–2005(4)	Pounds	17.4	20.8	15.0	1.34	ERS *Red Meat Yearbook*
U.S. per capita pork consumption	1982(1)–2005(4)	Pounds	12.7	14.3	11.3	0.65	ERS *Red Meat Yearbook*
U.S. per capita poultry consumption	1982(1)–2005(4)	Pounds	20.9	26.6	13.7	3.46	ERS *Red Meat Yearbook*
Retail beef price	1982(1)–2005(4)	$/lb	2.88	4.23	2.23	0.51	ERS *Red Meat Yearbook*
Retail pork price	1982(1)–2005(4)	$/lb	2.23	2.88	1.68	0.35	ERS *Red Meat Yearbook*
Weighted poultry price	1982(1)–2005(4)	$/lb	0.94	1.11	0.72	0.10	ERS *Red Meat Yearbook*
Beef safety index	1982(1)–2005(4)	News count	234	1,283	3	258	Updated Piggott and Marsh (2004)
Pork safety index	1982(1)–2005(4)	News count	62	395	0	62	Updated Piggott and Marsh (2004)
Poultry safety index	1982(1)–2005(4)	News count	235	1,547	6	230	Updated Piggott and Marsh (2004)
Beef Board's promotion expenditure (BDE)	1987(1)–2005(4)	Dollars	6,523,125	12,686,017	1,228,955	2,523,672	Ron Ward, University of Florida
National Pork Board's promotion expenditure (PDE)	1987(1)–2005(4)	Dollars	5,602,683	12,290,393	1,747,492	2,180,867	National Pork Board
National Pork Board's hog demand expenditure (HDE)	1987(1)–2005(4)	Dollars	332,517	1,369,593	0	310,458	National Pork Board

(continued)

Table 5-1. Data Summary Statistics and Description (continued)

Variable Description	Sample Period	Unit	Mean	Maximum	Minimum	Standard Deviation	Source
National Pork Board's hog supply expenditure (HSE)	1987(1)–2005(4)	Dollars	1,418,600	3,754,551	56,428	1,096,493	National Pork Board
National Pork Board's foreign market development expenditure (FMD)	1987(1)–2005(4)	Dollars	705,607	2,463,260	0	654,454	National Pork Board
National Pork Board's overhead expenditures	1987(1)–2005(4)	Dollars	1,057,949	3,399,632	379,765	563,607	National Pork Board
National Pork Board's expenditures on marketing chain research (MCR)	1987(1)–2005(4)	Dollars	264,895	1,070,187	0	247,159	National Pork Board
Branded pork expenditures	1982(1)–2005(4)	Dollars	11,226,399	25,832,000	2,097,900	5,024,002	1982–1998 from Gary Brester, Montana State University; 1999-2005 from LNA, Inc., various issues
U.S. commercial hog slaughter	1987(1)–2005(4)	1,000 head	23,709	27,608	18,911	1,845	ERS *Red Meat Yearbook*
Commercial hog average liveweight	1987(1)–2005(4)	Pounds	256.8	271	245	6.97	ERS *Red Meat Yearbook*
Number of sows farrowed	1987(1)–2005(4)	1,000 head	2,925	3,377	2,524	163	*Quick Stats*, NASS, USDA
Number of pigs per litter	1987(1)–2005(4)	Number	8.4	9.1	7.6	0.45	*Quick Stats*, NASS, USDA
Iowa-Southern Minnesota Barrow and Gilt Price	1987(1)–2005(4)	$/cwt	61.2	81.3	26.6	11.1	ERS *Red Meat Yearbook*

(continued)

Table 5-1. Data Summary Statistics and Description (continued)

Variable Description	Sample Period	Unit	Mean	Maximum	Minimum	Standard Deviation	Source
Average corn price received by farmers	1987(1)–2005(4)	$/bushel	2.28	4.10	1.46	0.46	*Quick Stats*, NASS, USDA
U.S. hog import	1982(1)–2005(4)	Head	688,261	2,209,856	49,960	650,819	ERS *Red Meat Yearbook*
U.S. pork import	1987(1)–2005(4)	1,000 pounds carcass weight	220,759.5	310,152.2	144,105.8	50,383.3	ERS *Red Meat Yearbook*
U.S. pork export	1987(1)–2005(4)	1,000 pounds carcass weight	248,032.6	705,361.5	18,891	180,792.2	ERS *Red Meat Yearbook*
Average Canadian hog price	1982(1)–2005(4)	Ca $/cwt	69.36	96.58	34.77	11.48	*Hog Statistics*, Ag Canada
U.S. personal consumption expenditure	1982(1)–2005(4)	Billion US $	4,898.8	8,927.8	2,018	1,951.3	Bureau of Economic Analysis
Canadian disposable income	1982(1)–2005(4)	Million Ca $	502,882.2	802,164	259,044	151,338.6	Statistics Canada
Portland #2 barley price	1982(1)–2005(4)	$/bushel	2.53	3.88	1.76	0.38	ERS *Feed Grain Yearbook*
Hourly earnings of production workers in animal processing and slaughtering	1987(1)–2005(4)	$/hour	9.27	11.64	7.26	1.38	Bureau of Labor Statistics

(continued)

Table 5-1. Data Summary Statistics and Description (continued)

Variable Description	Sample Period	Unit	Mean	Maximum	Minimum	Standard Deviation	Source
Producer price index for fuels and related products	1987(1)–2005(4)	1982=100	90.6	180.1	64.8	22.7	Bureau of Labor Statistics
Trade-volume weighted gross Domestic products of U.S. pork importers	1989-2005	Billion US $	423.99	558.85	267.53	79.51	Individual country data from CIA the *Word Factbook*; Trade volume from ERS *Red Meat Yearbook*

"Staphylococcus" or "foodborne."[2] From this base series, the search was narrowed to collect information on beef, pork, and poultry separately. The search criteria for this purpose were (1) "beef" or "hamburger" for beef; (2) "pork" or "ham" for pork; and (3) "chicken," or "turkey," or "poultry" for poultry.

We generated distributions around our estimated elasticities and benefit-cost ratios to provide information on the precision with which these values can be measured with available data and analysis techniques.

Although we are confident that we used the best available data for this analysis within our time and resource constraints, it is important to note that no data available are perfect. USDA does not collect consumption data directly but estimates consumption based on disappearance dat, (i.e., production less net trade adjusted for shrinkage factors in moving from liveweight to retail weight). In addition, the available price data are not necessarily entirely reflective of what consumers are actually paying for pork products or of what processors are paying for hogs. The retail price data are not fully volume weighted and do not reflect food consumed away from home, which has been growing in importance over time. In addition, the hog price data are not fully consistent over time because of changes in reporting and marketing practices over time. The spot market has been shrinking in market share as more hogs are sold under contract, which has made the spot price less representative of what processors are actually paying for hogs.

As with any analysis, data that provide imperfect measures of the underlying variables of interest contribute to reduced precision of econometric parameter estimates. We generated distributions around our estimated elasticities and benefit-cost ratios to provide information on the precision with which these values can be measured with available data and analysis techniques.

5.2 THE POLYNOMIAL INVERSE LAG FOR PROMOTION AND RESEARCH EXPENDITURES

An important empirical question that applies across all of our econometric models is determining the appropriate lag

[2] "BSE" was not used as a keyword because we wanted to keep the updated food safety indexes as consistent as possible with the original Piggott and Marsh series which did not have BSE as a keyword. Omitting BSE from the search criteria is not believed to be problematic, because inspection of the series reveals that the major BSE events in Europe, Canada, and the United States were captured in the data.

structure for assessing the effects of promotion and research expenditures. Determination of the appropriate lag structure has major importance for calculating program effectiveness, and the treatment of the timing of effects has been an area of criticism of past studies on the effectiveness of generic promotion and research (e.g., Kinnucan and Zheng [2005]). Thus, we discuss our methodology for estimating lag structures empirically before presenting the individual econometric models and results.

Both promotion and research expenditures are expected to affect not just the period in which the expenditures occur, but future periods as well.

Both promotion and research expenditures are expected to affect not just the period in which the expenditures occur, but future periods as well. Depending on the type of activities covered by a given expenditure, the peak impact will not necessarily occur in the contemporaneous period. For instance, a lag may occur between research expenditures and the observed benefits of the associated research. In addition, campaigns to increase consumer awareness of and demand for a product may alter attitudes more quickly than purchasing behavior due to inventory effects and the timing of purchases following the campaign. This is less likely to be the case for quarterly pork consumption data; however, because the frequency of purchases would typically be greater than quarterly. In addition to potential delays in expenditures reaching their peak effect on supply and/or demand, research and promotion expenditures typically have carryover effects in future periods after this peak, although the impact will generally decline over time as the effects of advertising and promotion messages wear off.

In estimating supply and demand responses to the National Pork Board's promotion and research expenditures, it is important to specify a lag structure that is flexible, allowing us to appropriately represent the effects of their promotion and research activities over time, but that places sufficient structure on the distribution to allow us to estimate the distribution empirically and to avoid spurious results that may result from including unstructured lagged variables. In this study, we adopt a flexible distributed lag technique, the polynomial inverse lag (PIL), proposed by Mitchell and Speaker (1986). The PIL has several advantages over other commonly used lag structures such as the Almon (1965) lag. First, the researcher does not need to specify *a priori* the lag length or impose an end point restriction, because the PIL has an infinite distributed lag structure. Second, the PIL is linear in the transformed exogenous variables (i.e., the promotion and research expenditures). As we explain below, this latter property makes it convenient to test for the best specification for the lag structure.

Consider the following regression equation:

$$Y_t = b + \sum_{i=0}^{\infty} w_i X_{t-i} + e_t , \tag{5.1}$$

where Y_t is the dependent variable in period t , X_τ is the independent variable in period τ , b is a collection of other explanatory variables and their associated coefficients, and e_t is the regression residual. Y_t could be, for instance, U.S. per capita demand for pork, and X_τ would then be National Pork Board expenditures on promotion in period τ with $\tau \le t$. Although the empirical specifications of supply and demand of hogs and pork later in this chapter may take more complicated functional forms, Eq. (5.1) can be used to provide a simple illustrative example of how the PIL works. In Eq. (5.1), the infinite lag distribution for X means that it cannot be estimated directly. To derive an estimable form of Eq. (5.1), Mitchell and Speaker (1986) propose the following transformation of Eq. (5.1):

$$Y_t = b + \sum_{j=2}^{n} a_j Z_{jt} + R_t + e_t , \tag{5.2}$$

where $$Z_{jt} = \sum_{i=0}^{t-1} \frac{X_{t-i}}{(i+1)^j} , \; j = 2, \ldots, n,$$

$$R_t = \sum_{j=2}^{n} \sum_{i=t}^{\infty} \frac{a_j X_{t-i}}{(i+1)^j},$$

and n is the degree of polynomial for PIL structure that has to be empirically determined. With the sample t=1,2,...,T, data are available to calculate Z_{jt} , but the remainder term R_t cannot be calculated from the data because it includes infinite lags. Mitchell and Speaker showed that with t greater than eight, R_t becomes negligible. Therefore, a practical solution to the unobserved R_t problem is to delete the first eight data points and conduct an econometric analysis on the remaining data without the R_t term.

After dropping the first eight data points, the Z_{jt}'s ($t=9,10,11,...,T$) are computed as follows:

For $j = 2$

$$Z_{2t} = \sum_{i=0}^{t-1} \frac{X_{t-i}}{(i+1)^2} = \frac{X_t}{1^2} + \frac{X_{t-1}}{2^2} + \frac{X_{t-2}}{3^2} + \frac{X_{t-3}}{4^2} + \ldots + \frac{X_1}{t^2};$$

For $j = 3$

$$Z_{3t} = \sum_{i=0}^{t-1} \frac{X_{t-i}}{(i+1)^3} = \frac{X_t}{1^3} + \frac{X_{t-1}}{2^3} + \frac{X_{t-2}}{3^3} + \frac{X_{t-3}}{4^3} + \ldots + \frac{X_1}{t^3};$$

For $j = 4$

$$Z_{4t} = \sum_{i=0}^{t-1} \frac{X_{t-i}}{(i+1)^4} = \frac{X_t}{1^4} + \frac{X_{t-1}}{2^4} + \frac{X_{t-2}}{3^4} + \frac{X_{t-3}}{4^4} + \ldots + \frac{X_1}{t^4};$$

For $j = 5$

$$Z_{5t} = \sum_{i=0}^{t-1} \frac{X_{t-i}}{(i+1)^5} = \frac{X_t}{1^5} + \frac{X_{t-1}}{2^5} + \frac{X_{t-2}}{3^5} + \frac{X_{t-3}}{4^5} + \ldots + \frac{X_1}{t^5};$$

and so on, until reaching the term Z_{nt}. A remaining issue is selection of the appropriate n—the degree of the polynomial. The selection process can start with a relatively high degree, say, $n = 5$, and then Eq. (5.2) can be written as

$$Y_t = b + a_2 Z_{2t} + a_3 Z_{3t} + a_4 Z_{4t} + a_5 Z_{5t} + e_t. \tag{5.3}$$

To determine the optimal n, regression Eq. (5.3) is fit a number of times, successively dropping the highest-degree terms in succession. The choice of appropriate degree is determined by the ability of the model to fit the data. This amounts to choosing n by selecting the model with the lowest estimated variance, calculated as the sum of squared residuals divided by the degrees of freedom.

Finally, the weights (w_i) on X_τ in Eq. (5.1) can be recovered using estimates of a_j ($j = 2,\ldots,n$). The formula for calculating weight w_i is

$$w_i = \sum_{j=2}^{n} \frac{a_j}{(i+1)^j}, \quad i = 0,\ldots,t-1. \tag{5.4}$$

Eq. (5.4), along with estimated values for the a_j, was used to calculate the weights on current and lagged research and promotion expenditures in each of the following sections describing our econometric models.

5.3 DOMESTIC DEMAND FOR HOGS AND PORK SUPPLY

The model of the pork processing sector consists of two equations: hog demand and pork supply. The model is derived from the assumption that processors choose pork output and quantities of factors (hogs and marketing inputs) in order to maximize profit. The conditional profit function (conditional on the quantity of hogs purchased) can be written as

$$\pi = \pi(P_p, Q_h, \boldsymbol{W}, N_h) \tag{5.5}$$

where P_p is the price of pork, Q_h is the quantity of hogs procured by packers, $\boldsymbol{W}$ is a vector of marketing inputs, and N_h is funds spent on marketing research by the National Pork Board. The input demand relation for hogs and the conditional output supply function for pork can be obtained by differentiating the profit function, Eq. (5.5), with respect to Q_h and P_p respectively:

$$\frac{\partial \pi}{\partial Q_h} = \pi_n(P_p, Q_h, \boldsymbol{W}, N_h) = P_h \tag{5.6}$$

$$\frac{\partial \pi}{\partial P_p} = \pi_p(P_p, Q_h, \boldsymbol{W}, N_h) = Q_p \tag{5.7}$$

Eq. (5.6) is the inverse output (pork) price constant input demand for hogs, and Eq. (5.7) is the conditional supply function for pork. These functions are homogenous of degree zero in prices and symmetric such that $\frac{\partial \pi_k}{\partial Q_h} = \frac{\partial \pi_h}{\partial P_k}$. The assumption is made that packers are price takers in producing pork and procuring hogs. This assumption can be tested by testing the symmetry restriction (Wohlgenant, 2001). If the restriction fails to hold this could be evidence of market power in the market for pork, market for hogs, or both.

For empirical analysis, the assumption is made that the relationships can be modeled as linear relationships. While other functional forms are available, this functional form has the advantage that it is theoretically consistent and is easy to estimate. The equations to estimate then have the general form:

$$\begin{aligned} P_h &= \alpha_h + \beta_{hh}Q_h + \beta_{ph}P_p + \beta_{hw}W + \beta_{hn}N + u_h \\ Q_p &= \alpha_p + \beta_{ph}Q_h + \beta_{pp}P_p + \beta_{pw}W + \beta_{pn}N + u_p \end{aligned} \tag{5.8}$$

subject to the restriction $\beta_{ph} = \beta_{ph}$ if symmetry holds. The variables u_h and u_p are error terms, and W now represents an index of marketing inputs. We assume first-order autocorrelation in the residuals by specifying that the covariances between the error terms are zero. With the equation for marketing inputs not included, the assumption is made that the autocorrelation parameters in each equation are equal (Berndt and Savin, 1975).

The homogeneity restriction is not imposed directly because prices are deflated by the consumer price index. The reason it is not imposed is because the index of marketing inputs does not include all variable inputs used in processing and marketing of pork. The model is estimated both with and without the symmetry restriction imposed. We find that the restriction is strongly rejected so it is not imposed on the model. This could potentially indicate market power in the hog and/or pork markets, but this possibility was not explored further because it is not a focus of this study.

The models were estimated over the period 1987:2 through 2005:4 using the iterated seemingly unrelated regressions estimator.

The models were estimated over the period 1987:2 through 2005:4 using the iterated seemingly unrelated regressions (ITSUR) estimator.[3] Three dummy variables and an intercept were included to account for seasonality. Also a dummy variable for the fourth quarter of 1998 was included to account for the abnormally low hog prices in that quarter due to constrained slaughter capacity. A linear time trend was also included to account for changes in capital stock and other omitted variables. Marketing research is assumed to affect processing and distribution costs with a lag. The polynomial inverse lag distribution was used to model the lag distribution. The approach to modeling this lag distribution was similar to

[3] The model was also estimated with iterated three-stage least squares (IT3SLS) using as instruments all the exogenous variables of the model, current and lagged retail prices of beef and poultry, current and lagged per capita personal disposable income, current and lagged population, current and lagged corn price, and current and lagged beginning-of-the-period number of sows farrowing. Because the results with IT3SLS were very close to the estimates with ITSUR, only the ITSUR results are reported.

that used in modeling promotion in pork demand. Specifically, five terms were initially included, and one term was deleted for each model until dropping an additional term would result in a significant reduction in fit. This approach led to three terms being included.

The results are provided below, with the estimated parameter shown in front of each variable and the standard error shown in parentheses below the parameter.

U.S. inverse demand for hogs:

$$\underset{}{\hat{hogp}_t} = \underset{(0.3818)}{1.6731} \underset{(0.000039)}{-0.00029}\, hogq_t + \underset{(0.0793)}{0.2364}\, rppork_t + \underset{(0.1026)}{0.14565}\, imc_t$$

$$\underset{(0.0223)}{-0.1106}\, q1 \underset{(0.0306)}{-0.10734}\, q2 \underset{(0.0271)}{-0.11152}\, q3 \underset{(0.0399)}{-0.05847}\, d984 + \underset{(0.000653)}{0.00188}\, t$$

$$\underset{(7.447\text{E}-7)}{-2.78\text{E}-6}\, z2mcr_t + \underset{(2.381\text{E}-6)}{8.157\text{E}-6}\, z3mcr_t \underset{(1.652\text{E}-6)}{-5.35\text{E}-6}\, z4mcr_t$$

$N = 75$

$\hat{\rho} = \underset{(0.0753)}{0.6216}$

Pork supply:

$$\hat{porkq}_t = \underset{(74.147)}{-238.066} + \underset{(0.00746)}{0.7185}\, hogq_t + \underset{(14.8307)}{61.0236}\, rppork_t + \underset{(17.2376)}{0.0369}\, imc_t$$

$$+ \underset{(4.1113)}{13.2217}\, q1 + \underset{(5.7750)}{2.2301}\, q2 \underset{(5.0882)}{-4.2274}\, q3 + \underset{(7.3581)}{7.6066}\, d984 + \underset{(0.2685)}{1.2922}\, t$$

$N = 75$

$\hat{\rho} = \underset{(0.0753)}{0.6216}$

where $hogp_t$ is the deflated hog price ($/lb), $hogq_t$ is the total quantity of hogs marketed (liveweight), *porkq* is the total quantity of pork produced defined by the product of commercial hog slaughter (number) and commercial hog average slaughter weight (carcass weight), $rppork_t$ is the deflated retail price of pork ($/lb), imc_t is an index of marketing costs (Fisher Ideal Index of labor and energy costs), *q* is a dummy variable representing quarter of year (1=Jan.–Mar.; 2=Apr.–June;

3=July–Sept.), *d*984 is a dummy variable equaling one in the fourth quarter of 1998 and zero otherwise (to account for severe processing capacity constraint in this quarter), the $zmcr_t$ are the marketing research distributed lag variables, and t is a linear time trend.[4]

Overall, the results are reasonable and consistent with prior expectations.

Overall, the results are reasonable and consistent with prior expectations. The price of hogs is negatively related to the quantity of hogs slaughtered and positively related to the retail price of pork. In the hog supply equation, quantity of pork produced is positively related to the quantity of hogs slaughtered and positively related to the retail price of pork. The index of marketing costs is not statistically significant in either equation. There is a positive and significant trend in both equations, and the dummy variable for the fourth quarter of 1998 has negative and positive signs, respectively, in the hog inverse demand and pork supply equations as anticipated. The three quarterly dummies are negative (and mostly significant) in the hog demand equation, reflecting the fact that demand for pork is typically strongest in the last quarter of the year. On the other hand, two of the three dummies in the pork supply equation are positive (although only the first quarter is statistically significant), indicating pork produced is typically lower (relative to hog slaughter) in the last quarter of the year. This difference likely reflects differences in the distribution of primal and subprimals produced that apparently have lower yields in the final quarter of the year relative to the other three quarters.

The elasticities of demand and supply are calculated at the sample means. The own-price flexibility[5] of demand for hogs is estimated to be –2.406; the elasticity of hog price with respect to the retail price of pork is estimated to be 0.887; the elasticity of pork production with respect to the quantity of hogs slaughtered is estimated to be 0.99; and the elasticity of pork production with respect to the retail price of pork is estimated to be 0.04.

Postfarm research expenditures were only included in the hog demand equation because hypothesis testing indicated that the

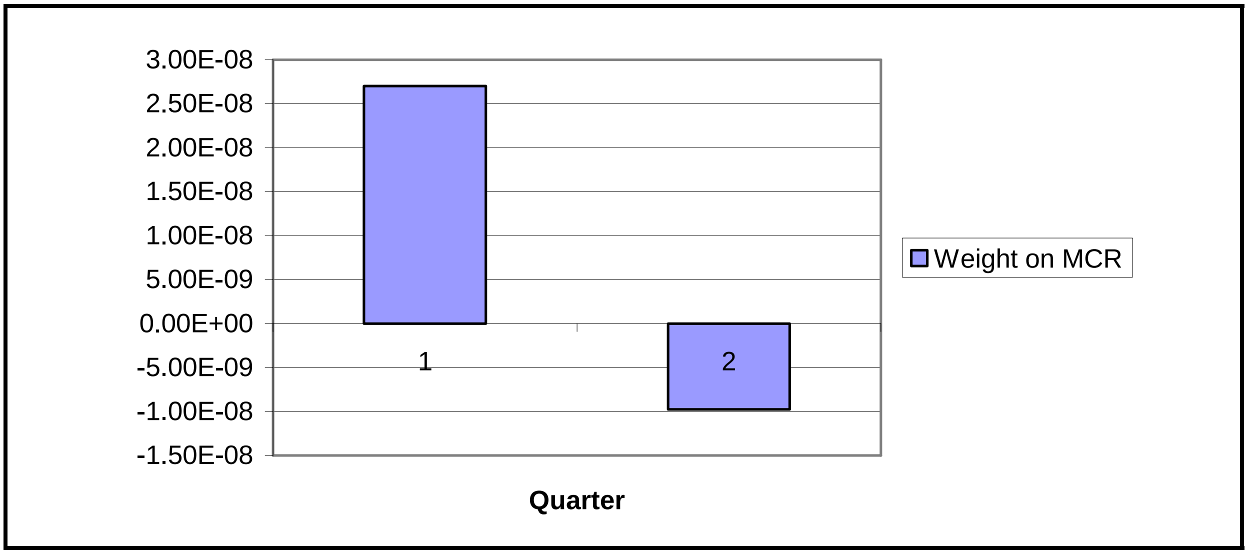
[4] All prices were deflated using the consumer price index for all items.

[5] Flexibilities in inverse demand relationships are analogous to elasticities for regular demand relationships. Flexibility is a measure of the responsiveness of price to an incremental change in quantity.

postfarm research terms were jointly not significantly different from zero in the pork supply equation. Therefore, they were deleted from the model. Following the procedure described in the section above, sequential testing starting from five terms of the polynomial inverse lag distribution indicated the most preferred model contains three terms.

The first two weights (contemporaneous quarter and one lagged quarter) of this lag distribution are shown in Figure 5-1.

Figure 5-1. Calculated Weights on Marketing Chain Research Expenditure



The market research effect is concentrated in the current quarter. At the sample means, the elasticity of hog price with respect to a change in the cumulative effect of market research over the current and lagged quarter is 0.006.

The chart shows that the market research effect is concentrated in the current quarter. At the sample means, the elasticity of hog price with respect to a change in the cumulative effect of market research over the current and lagged quarter is 0.006. If only the current quarter is included, the elasticity is 0.0095. Weights were calculated for additional time periods (up to 28 quarters), and in all cases the weights were negative after the first quarter. Whether these effects are truly negative is unclear, but we considered it unlikely that postfarm research would reduce hog demand in future periods. It is very possible that the negative weights are simply reflecting approximation errors. The polynomial inverse lag distribution is an infinite lag distribution and is a very flexible function. This flexible functional form, as with any functional form, can only give an approximation to the true unknown lag distribution. We view these negative estimates on more distant lags as spurious as a result of approximation errors and therefore ignore them in the calculation of the postfarm research elasticity.[6]

This finding implies a very short lag for postfarm research, but we feel a short lag is fairly reasonable based on discussion with hog industry experts because much of this research is short term and can be adopted by processors fairly quickly.

5.4 DOMESTIC SUPPLY OF HOGS

The supply of hogs consists of three components: number of farrowing sows, pounds of live hogs per market hog, and number of pigs per litter. The product of these three variables adjusted for mortality gives the production of swine per quarter. Specifically,

$$Q_h^u = PL_h^u \bullet WP_h^u \bullet \alpha \bullet I_{h-2}^u$$

where α is a proportionality factor (assumed to be constant) showing the proportion of pigs surviving. The number of farrowing sows is determined as an investment problem of the firm. Producers have an inventory of sows that they add to (respectively, subtract from) in each quarter depending on their perception of future market conditions. The investment decision is a function of the present discounted value of expected future quasi-rents from adding to the herd size. Expected future quasi-rents depend on expected future market hog prices and expected future feed prices (primarily corn prices). The general form of the inventory equation expresses end-of-the-quarter number of farrowing sows as a function of beginning-of-the-quarter number of farrowing sows, expected future market hog prices, and expected future corn prices. In addition, if technological change affects the investment decision, then provisions should be made for those effects. Three variables were entertained: number of pigs per litter to reflect improved genetics, National Pork Board expenditures on production research, and a time trend to reflect long-term changes in productivity and effects of omitted variables. Of all these effects, only the time trend was retained. The other variables did not have a statistically significant effect on hog supply.

With regard to expectations, the assumption is made that producers form what is called quasi-rational expectations.

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[6] The first-quarter lagged weight (negative) is used in the calculation to give us a conservative estimate of the rate of return.

Specifically, producers are assumed to look at past trends in prices in forecasting future prices. Nerlove and Bessler (2001) show that this approach to modeling is consistent with theory and empirically has merit over alternative approaches to modeling price expectations. Based on this analysis, it was found that a parsimonious model for hog price forecasting was the price lagged five quarters. For corn prices, corn price in the previous quarter seems sufficient to produce a parsimonious model for forecasting corn prices. This suggests that corn price in the previous quarter and hog price lagged five quarters would be appropriate prices for the inventory equation.[7] These prices are deflated by the consumer price index to convert nominal values to real values. In addition, three quarterly dummy variables are included in the model to account for seasonality in production. The model was estimated by ordinary least squares over the time period 1987:2 through 2005:4.

The estimated inventory of sows (sowsfar) equation is

$$\underset{}{\widehat{sowsfar}_t} = \underset{(383.3)}{2333} + \underset{(0.1139)}{0.1969}\ sowsfar_{t-1} + \underset{(1.028)}{2.612}\ hogp_{t-5} - \underset{(25.221)}{59.569}\ cornp_{t-1}$$

$$-\underset{(36.955)}{66.551}\ q1 + \underset{(38.819)}{230.419}\ q2 + \underset{(37.020)}{32.035}\ q3 - \underset{(1.199)}{1.427}\ t$$

N = 71, R^2 = 0.5905

DW = 2.037; p-value for testing positive autocorrelation = 0.4601;

p-value for testing negative autocorrelation = 0.5399;

where $hogp_{t-5}$ is the hog price lagged five quarters (chosen to be consistent with biological lags in hog production), *cornp* is the price of corn, and DW is the Durbin-Watson test for the null hypothesis of no autocorrelation. The test statistic suggests not rejecting the null at any conventional levels.

[7] As a check on this specification for price expectations, the model was alternatively estimated with lagged prices of hogs and corn for up to five quarters. This specification indicated quite clearly that five lags and one lag were appropriate for hogs and corn. As in the other applications, the effect of production research was also analyzed systematically by testing down from a model including five terms of the polynomial inverse lag distribution to no terms. The results indicated that the model without any production research was preferred.

At the sample means, the estimated short-run own price elasticity of supply is 0.07; the long-run elasticity is estimated to be 0.09.[8]

The second component of supply response is number of pounds of live hogs per hog marketed. This equation reflects the short-run supply response of the firm. This variable would be expected to be influenced to some extent by the hog–corn price ratio, as well as the quarter of the year. In addition, technical change could have an influence through improvements in feed efficiency. This effect is accounted for by including a time trend and production research expenditures by the National Pork Board. As in the case of the inventory equation for farrowing sows, only the time trend is retained. A systematic evaluation of the influence of production research showed that production research had no significant effect in this equation.

The estimated equation for number of pounds liveweight per market hog (lvwt/nhog) is as follows:

$$(lv\hat{w}t_t \; / \; nhog_t) = \underset{(0.957)}{245.149} + \underset{(0.0089)}{0.296}\; t - \underset{(0.547)}{1.103}\, q1 - \underset{(0.550)}{1.199}\; q2$$

$$- \underset{(0.555)}{5.284}\, q3 + \underset{(0.0289)}{0.0783}\; (hogp_t \; / \; cornpr_t)$$

N = 76, R^2 = 0.9416

DW = 0.857; p-value for testing positive autocorrelation <0.0001;

$\hat{\rho}$ = 0.570

where $nhog_t$ denotes number of market hogs in quarter t, $\hat{\rho}$ is the estimated first-order autocorrelation coefficient. The estimated supply elasticity at the sample means is 0.008.

[8] This estimate is calculated as the short-run elasticity divided by 1 – the coefficient on lagged inventory, 0.07/(1–0.1893) = 0.09. This is not quite a long-run estimate but is better regarded as reflecting the joint impact of price expectations and adjustment costs on long-run supply behavior. These supply adjustment parameters reflect the effects of past adjustments on supply response through changes in price on supply behavior and past effects on prices that influence price expectations. In the simulations to follow, this creates no problem as long as we would not expect producers to behave differently if the checkoff program did not exist. This seems to be a reasonable assumption in this context because the changes we observe over time with respect to production research are small in relation to changes resulting from fluctuations due to weather and input markets (e.g., fluctuations in corn prices).

The final equation to estimate is the number of pigs per litter. This equation is specified as a function of distributed lags of production research as well as a time trend to account for long-run effects of other research. In addition, a dummy variable for 1988 is included to account for the effects of the severe drought experienced that year. Moreover, there was indication of higher order autocorrelation in the error term. Models beginning with five autoregressive terms were tested down and the model with one and three lags was found to be the preferred model.

The estimated equation for pigs per litter (pigs/litter) is as follows:

$$
\begin{aligned}
(\hat{pigs}_t \ / \ litter_t) = \underset{(0.0843)}{7.665} \ + \underset{(0.00446)}{0.0215} \ t \ \underset{(5.242\text{E}-7)}{-8.124\text{E}-7} \ z2hse_t \ \underset{(1.500\text{E}-6)}{+2.818\text{E}-6} \ z3hse_t \\
\underset{(9.870\text{E}-7)}{-1.993\text{E}-6} \ z4hse_t \ \underset{(0.0413)}{-0.0906} \ d88
\end{aligned}
$$

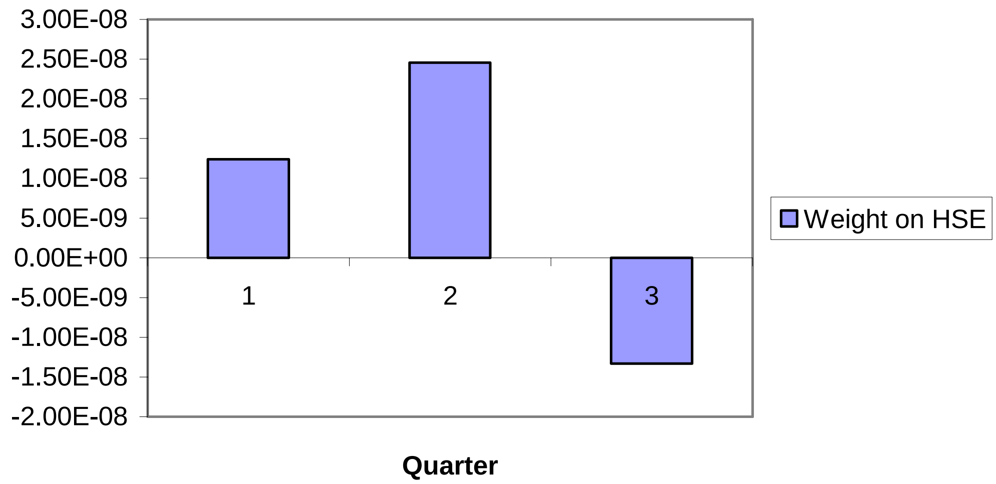
$$N = 76, R^2 = 0.9830,$$

$$\hat{\rho}_1 = \underset{(0.0950)}{-0.5749}, \ \hat{\rho}_3 = \underset{(0.0967)}{-0.2932}$$

where $d88$ is a dummy variable taking the value 1 for each quarter within 1988 and zero otherwise, and the $zhse$ variables denote the distributed lag variables for the PIL distribution for production research. A systematic testing of alternative lag structures with the polynomial lag distribution indicated three terms should be included.

The first three terms of the lag distribution (current quarter and first two lagged quarters) implied by this relationship are shown below in Figure 5-2. The lag distribution shows a peak at a one-quarter lag. Beyond that point, all calculated lags (lags were calculated through 28 quarters) were found to be negative. As in the case of hog demand, we believe these negative weights are spurious, likely the result of approximation error caused by use of the flexible polynomial inverse lagged functional form. The elasticity of pigs per litter with respect to production

Figure 5-2. Calculated Weights on Production Research Expenditures (HSE)



research expenditures over the three weights is estimated to be 0.004. If only the first two (positive) weights are included, the elasticity is 0.006.

As with postfarm research, our findings imply a short lag on production research, although production research has a one-quarter lag before reaching its peak and we included an additional quarter in calculating the elasticity. Although agricultural research in general has substantial lags, we believe that lags are likely to be shorter for the activities of the National Pork Board. Much of the production research is related to improved nutrition, where experiments can be run within a period of months rather than years. In addition, a substantial component of the agricultural research undertaken with Pork Checkoff funds is devoted to producer education. Disseminating new research and information to producers is expected to have effects shortly after the education program takes place.

5.5 EXPORT SUPPLY OF CANADIAN HOGS

Export supply of hogs from Canada into the United States can be viewed as excess supply of hogs from Canada—the difference between Canadian quantity supplied of hogs and quantity demanded of Canadian hogs. In principle, the relationship would depend on the determinants of supply of Canadian hogs and determinants of demand for Canadian hogs.

Supply determinants would include feed prices (primarily barley prices), past hog prices, and past feed prices. Demand determinants would include input costs in processing pork in Canada (e.g., wage rates in meat processing, energy prices), Canadian population, per capita income, price of beef, and price of chicken.

The estimated excess supply of Canadian hogs to the United States is

$$
\begin{aligned}
\log(pho\hat{g}impt_t) &= \underset{(7.8986)}{2.6115} + \underset{(0.0723)}{0.1721}\, q1 + \underset{(0.0709)}{0.0252}\, q2 + \underset{(0.0689)}{0.0872}\, q3 \\
&+ \underset{(0.0548)}{0.8680} \log(phogimpt_{t-1}) + \underset{(0.1415)}{0.2010} \log(cahogp_{t-5}) + \underset{(0.6785)}{1.6871} \log(uspce_t) \\
&- \underset{(0.9175)}{0.8959} \log(cainc_t)
\end{aligned}
$$

$N = 91, \bar{R}^2 = 0.9364,$

$\text{D.W.} = 2.058, \hat{\rho} = -0.037$

where *phogimpt* is the number of hogs imported from Canada divided by the U.S. population; $cahogp_{t-5}$, similar to the specification for U.S. hog supply, is the five-quarter lagged average Canadian hog price deflated by Canadian CPI; *uspce* is the real U.S. per capita personal consumption expenditure; and *cainc* is the real Canadian per capita disposable income. The sample period is from 1982(2) through 2005(4) with the first five data points removed from estimation because of the five-quarter lagged hog price.

The number of hogs imported from Canada is found to be positively related to hog imports in the previous quarter. The estimated coefficient on *uspce* is significant and has the expected sign. Consistent with prior expectations, the coefficient on *cainc* is negative, although not statistically significant. The price of Canadian hogs five quarters ago is found to positively affect current hog export to the United States, although this relationship is not precisely estimated. That is, the coefficient $oncanogp_{t-5}$ is not statistically different from zero at the conventional 5% or 10% levels. Nonetheless, we calculated the estimated price elasticity for U.S. imports of Canadian hogs to be 0.201.

5.6 DOMESTIC DEMAND FOR PORK

We modeled domestic demand for pork in a demand system framework that contains the major meat species consumed by Americans: beef, pork, and poultry (chicken and turkey).

We modeled domestic demand for pork in a demand system framework that contains the major meat species consumed by Americans: beef, pork, and poultry (chicken and turkey). A demand system is chosen over a single equation approach because a system approach for closely related goods corresponds well to an underlying consumer preference structure and is fully consistent with consumer demand theory. Specifying demand in this way reduces the chances of misspecification and estimation with seemingly unrelated regressions (SUR) provides efficiency gains. This is very important because estimates of demand response to promotion from a misspecified demand model would, at best, generate dubious returns on investment estimates. Because generic promotion accounts for the largest share of the total National Pork Board expenditures, we devoted substantial effort to specification of our meat demand system.

We employ the Generalized Almost Ideal Demand System (GAIDS) and augment the system to include generic promotion and food safety effects (Piggott and Marsh, 2004). Consider the following generalized expenditure function:

$$E(\mathbf{p}, u) = \mathbf{p}'\mathbf{c} + E^*(\mathbf{p}, u) \tag{5.9}$$

where $\mathbf{p}$ is a 3×1 vector of prices of beef, pork, and poultry; $\mathbf{c}$ is a 3×1 vector of precommitted beef, pork, and poultry quantities; and u is utility. The quantities contained in $\mathbf{c}$ can be thought of as subsistence levels of meats that a household consumes in each period regardless of prices (or as reflecting consumer preferences for some minimum level of variety in their meat consumption). In the demand system literature, the term E^* is called the supernumerary expenditure, meaning it is the remaining expenditures to be allocated among competing meats after subsistence quantities of meats have been purchased.

The GAIDS model (Bollino, 1990) can be written in budget share form as

$$w_i = \left(\frac{p_i c_i}{M}\right) + \left(\frac{M^*}{M}\right)\left(\alpha_i + \sum_j^N \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{M^*}{P}\right)\right) + e_i \tag{5.10}$$

where

$$\ln P = \delta + \sum_{j=1}^{N} \alpha_j \ln p_j + \frac{1}{2} \sum_{k=1}^{N} \sum_{j=1}^{N} \gamma_{kj} \ln p_k \ln p_j \ ;$$

i, j = b for beef, p for pork, and c for poultry; e_i is a stochastic error term; $N = 3$; and c_i, α_i, γ_{ij}, β_i, and δ are parameters to be estimated. Within-equation and cross-equation demand restrictions implied by economic theory can be imposed using parametric restrictions. The homogeneity condition is imposed by $\sum_{j=1}^{N} \gamma_{ij} = 0$, adding up by $\sum_{i=1}^{N} \beta_i = 0$ and $\sum_{i=1}^{N} \alpha_i = 1$, and symmetry by $\gamma_{ij} = \gamma_{ji}, i \neq j$.

Demand shifters such as food safety information, seasonality, and importantly promotion expenditures can be incorporated into the demand system using a translating procedure.

Demand shifters such as food safety information, seasonality, and importantly promotion expenditures can be incorporated into the demand system Eq. (5.10) using a translating procedure originally proposed by Pollak and Wales (1981). This procedure specifies the precommitted quantities **c** as a function of the demand shifters. This procedure has the desirable property that the resultant elasticity estimates are invariant to unit of measurement of the nonprice and nonincome demand shifters (Alston, Chalfant, and Piggott, 2001). Following Piggott (1997) and Piggott and Marsh (2004), we adopt a linear specification and write the precommitted quantities as

$$\begin{aligned} c_i &= c_{i0} + \kappa_{i1} qd1 + \kappa_{i2} qd2 + \kappa_{i3} qd3 + \varphi_i D0205 + \tau_i T \\ &\quad + \phi_{i,b} bfs_t + \phi_{i,p} pks_t + \phi_{i,c} pys_t \\ &\quad + \sum_{j=2}^{n} \omega_{i,j,b} ZBDE_{jt} + \sum_{j=2}^{n} \omega_{i,j,p} ZPDE_{jt} \end{aligned} \tag{5.11}$$

where $qd1, qd2, qd3$ are three quarterly dummy variables; $D0205$ is a dummy variable equal to one for year 2002 through 2005 and zero for all other years[9]; bfs_t, pks_t, and pys_t denote, respectively, the media food safety indexes for beef, pork, and poultry; $ZBDE$ and $ZPDE$ are the polynomial inverse lags for generic beef (BDE) and pork (PDE) promotion expenditures; n is the appropriate lag length to be determined through statistical testing; $c_{io}, \kappa_i, \varphi_i, \tau_i, \phi_{ib}, \phi_{ip}, \phi_{ic}, \omega_{i,j,b}, \omega_{i,j,p}$ are parameters, along with those in equation Eq. (5.10), to be

[9] This dummy variable was included based on plots of residuals from partial leverage regressions identifying a structural change that has taken place since 2002. Possible explanations for this structural change observed in our meat demand system include the high protein/low carbohydrate diet fad and public concern over BSE and avian influenza during this period.

estimated by regression. Note that we restrict the lag length for both beef and pork promotions to be equal. This does not seem to be an implausible assumption and has the benefit of making statistical testing later in this section tractable.

Piggott and Marsh (2004) find that only contemporaneous food safety information affects U.S. meat demand. Following their finding, we maintain that only contemporary food safety media indices enter Eq. (5.11).

In the econometric analysis, the demand for beef, pork, and poultry is treated as weakly separable from outside goods. The system Eq. (5.10) is estimated using iterated nonlinear estimation techniques. Because of the singular nature of the share system, one of the equations must be deleted. Although choice of the equation to delete does not affect the econometric results, we chose to delete the poultry equation and estimate the beef and pork equations. Homogeneity and symmetry conditions are imposed during estimation.

Although the Pork Checkoff Program was initiated in 1987, the sample period for the demand system estimation is from 1982(1) to 2005(4). There are several justifications for using this longer time frame. First, the GAIDS model is nonlinear in its parameters, which complicates estimation and can present difficulties with convergence. We experimented with running the nonlinear estimation procedure in SAS using only the sample period when the checkoff program was in place, namely, 1987(1) through 2005(4). However, model nonconvergence prevented us from pursuing this strategy. We found that adding 20 more data points (1982[1] through 1986[4]) caused the model to converge rapidly. Second, even after "forcing" the model to converge by setting the δ term to zero,[10] we had difficulty finding a downward-sloping demand curve for pork using the 1987 through 2005 sample. This is extremely troublesome because a negative relation between price and quantity demanded is the fundamental law of demand. However, the problem disappeared when the full 1982 through 2005 sample was used to estimate the model. In fact, the results improved to the extent that 100% of the

[10] A number of authors have found that the δ term in the AIDS is difficult to estimate and recommend settling it to zero without affecting estimates of elasticities (e.g., Deaton and Muellbauer [1980]; Moschini, Moro, and Green [1994]).

observations satisfied the curvature requirements of negative semidefiniteness of the Slutsky matrix. This suggests that the 1982 through 1986 sample period contains important information helping to identify the demand relationships. Third, we found that the economic effects of generic promotion on meat demand are very small compared with price and expenditure effects. Based on this finding, we believed that including the pre-1987 years in the sample would not greatly affect our estimates of the effectiveness of generic promotions.

Inferences concerning the appropriate degree of polynomial (n) for generic beef and pork promotion and autocorrelation structure were investigated using likelihood ratio (LR) tests. The test statistic for LR test is

$$LR = 2(LL^U - LL^R),$$

where LL^U and LL^R are the maximized log-likelihood value in the unrestricted and restricted models, respectively.

Table 5-2 presents the LR test results for the joint significance of generic beef and pork promotion. The test was performed under three different autocorrelation correction (for the residual matrix **R** of the system Eq. [5.10]) schemes: (1) a null **R** matrix ($\mathrm{N-R^{matrix}}$) with all elements restricted to zero (i.e., no autocorrelation); (2) a diagonal **R** matrix ($\mathrm{D-R^{matrix}}$) with all diagonal elements restricted to be equal and all off-diagonal elements restricted to zero; and (3) a full **R** matrix ($\mathrm{F-R^{matrix}}$) where all elements are nonzero. Under all specifications, we reject the null hypothesis that generic beef and pork expenditures are not jointly significant.

To investigate the distributed lag structure of generic beef and pork promotion effects, we tested alternative degrees of polynomial for beef and pork promotion expenditures (BDE and PDE). The results in Table 5-2 indicate that, in all three autocorrelation corrections, the LR test fails to reject the null hypothesis that the coefficients on the fourth degree polynomials of BDE and PDE are zero (i.e., $\omega_{i,4,b} = \omega_{i,4,p} = 0$). Under all three autocorrelation correction schemes, the null hypothesis that the highest degree polynomial for both BDE and PDE is two is rejected in favor of a third ($n = 3$) degree polynomial for both generic promotion activities. Thus, we use a third degree polynomial for both generic beef and generic pork promotion in our econometric estimation.

Table 5-2. Hypothesis Tests for the Significance of Generic Promotion

Model	H_0 : No - Ads [a] $H_a : n = 2$	$H_0 : n = 2$ $H_a : n = 3$	$H_0 : n = 3$ $H_a : n = 4$
$N - R^{matrix}$	**24.13** [c]	**18.12**	8.04
$D - R^{matrix}$	**19.53**	**15.88**	5.61
$F - R^{matrix}$	**18.56**	**16.04**	5.32
df [b]	6	6	6
$\chi_{0.05,df}$ [d]	12.59	12.59	12.59

[a] No-Ads denotes a model with no generic promotion variables included.

[b] df denotes degree of freedom.

[c] Bold numbers indicate statistical significance at 5% level.

[d] Critical value for chi-square distribution at 5% level.

Table 5-3 presents LR test results for alternative autocorrelation corrections under various lag length specifications for generic beef and pork promotions. When $n = 3$, a diagonal specification for the **R** matrix is preferred to no autocorrelation correction.

The test results in Tables 5-2 and 5-3 together suggest that the preferred model is the one with $n = 3$ for BDE and PDE and with a diagonal **R** matrix. This suggests that only $ZBDE_{2t}$, $ZBDE_{3t}$, $ZPDE_{2t}$, and $ZPDE_{3t}$ enter the specification for precommitted quantities in Eq. (5.11).

Finally, it is important to explore the possibility that branded pork advertising affects U.S. pork demand. This is empirically critical because expenditures on branded pork advertising surpass those on generic pork promotion. If branded pork advertising indeed enhances pork demand, omitting it from the econometric model may introduce omitted-variable bias. In the current setting, it could result in overestimating the effectiveness of generic promotion. To test for the significance of branded pork advertising in affecting pork demand in general, we included the polynomial inverse lags of U.S. branded advertising expenditures into the GAIDS model. The branded pork advertising data cover the period 1982(1) through 2005(4). The 1982(1) through 1998(4) data were kindly supplied by Dr. Gary Brester at Montana State University. We collected the 1999(1) through 2005(4) data using various issues of the *Class/Brand QTR $* published by the Leading National Advertisers.

Table 5-3. Hypothesis Tests for Autocorrelation Corrections

Model	$H_0 : N - R^{matrix}$ $H_a : D - R^{matrix}$	$H_0 : N - R^{matrix}$ $H_a : F - R^{matrix}$	$H_0 : D - R^{matrix}$ $H_a : F - R^{matrix}$
No Ads	**11.78**	**14.88**	3.10
$n = 2$	**7.18**	9.31	2.13
$n = 3$	**4.93**	7.23	2.29
$n = 4$	2.50	4.50	1.99
Degree of freedom	1	4	3
$\chi_{0.05,df}$	3.84	9.49	7.82

We experimented with a number of alternative lags for branded pork expenditures. In no case did we find statistical significance of any of the coefficients on the polynomial lags.

We experimented with a number of alternative lags for branded pork expenditures. In no case did we find statistical significance of any of the coefficients on the polynomial lags. Typically, the p-values for these coefficients are in the magnitude of 0.7 to 0.9, indicating that the estimates are not at all close to statistical significance. The likelihood ratio test for joint significance of all parameters on branded pork expenditures failed to reject the null hypothesis that branded pork advertising does not affect generic pork demand. Moreover, inclusion of branded pork advertising in the GAIDS system caused little change in the parameter estimates on other variables (including the generic promotion variables). Thus, we decided to drop branded pork advertising from the regression to simplify estimation and simulation, but the reported results should not be subject to the omitted variable bias discussed in Kinnucan and Zheng (2005) given the lack of statistical significance of these variables. The insignificance of branded pork advertising in affecting pork demand is consistent with the hypothesis that brand advertising may cause consumer substitution between brands while leaving the total demand for pork unchanged. However, it is possible that more complete data on branded advertising could reveal significant effects.

Table 5-4 reports the estimated coefficients and their standard errors for the preferred GAIDS model. The adjusted R^2 is 0.982 for the beef equation and 0.894 for the pork equation.[11]

Table 5-4. Estimated Parameters for the Generalized Almost Ideal Demand Model for U.S. Meat Consumption with Food Safety and Generic Advertising Variables[a]

Parameters	Estimates	Parameters	Estimates
δ	15.8019 (13.6695)	τ_p	0.0596** (0.0111)
α_b	6.3235 (5.2406)	τ_c	0.1566** (0.0169)
α_p	–1.7911 (1.8978)	ϕ_{bb}	–0.0014** (0.0003)
γ_{bb}	4.1095 (2.2963)	ϕ_{bp}	–0.0023 (0.0013)
γ_{bp}	–1.2118 (0.9188)	ϕ_{bc}	–0.0003 (0.0002)
γ_{pp}	0.3114 (0.3491)	ϕ_{pb}	–0.0016** (0.0003)
β_1	0.4925** (0.1326)	ϕ_{pp}	–0.0017 (0.0012)
β_2	–0.1689** (0.0520)	ϕ_{pc}	–0.0007 (0.0004)
c_{10}	14.1665** (1.1223)	ϕ_{cb}	–0.0019** (0.0004)
c_{20}	7.3004** (1.3069)	ϕ_{cp}	–0.0017 (0.0018)
c_{30}	7.1534* (3.6867)	ϕ_{cc}	–0.0015* (0.0007)
κ_{b1}	–0.1488 (0.0999)	$\omega_{b,2,b}$	–2E–7 (1.281E–7)
κ_{b2}	0.5022** (0.0981)	$\omega_{b,3,b}$	2.497E–7 (1.306E–7)
κ_{b3}	0.8423** (0.0872)	$\omega_{p,2,b}$	–1.36E–7 (9.379E–8)
κ_{p1}	–1.1915** (0.0851)	$\omega_{p,3,b}$	1.897E–7 (9.905E–8)

(continued)

[11] Because we are estimating a system of share equations, one of the equations must be excluded from estimation. In this case, the poultry equation was excluded, which is why R^2 is not reported for poultry. Parameters for the excluded equation can be recovered using the symmetry, homogeneity, and adding-up conditions.

Table 5-4. Estimated Parameters for the Generalized Almost Ideal Demand Model for U.S. Meat Consumption with Food Safety and Generic Advertising Variables[a] (continued)

Parameters	Estimates	Parameters	Estimates
κ_{p2}	–1.5868** (0.0911)	$\omega_{c,2,b}$	–3.23E–7** (1.18E–7)
κ_{p3}	–1.1941** (0.0779)	$\omega_{c,3,b}$	3.709E–7** (1.26E–7)
κ_{c1}	–2.3966** (0.1083)	$\omega_{b,2,p}$	1.824E–7 (1.691E–7)
κ_{c2}	–1.5827** (0.1184)	$\omega_{b,3,p}$	–2.68E–7 (1.718E–7)
κ_{c3}	–1.1027** (0.1037)	$\omega_{p,2,p}$	5.273E–7** (1.855E–7)
φ_b	–1.2831** (0.2593)	$\omega_{p,3,p}$	–5.94E–7** (1.962E–7)
φ_p	–1.7978** (0.2948)	$\omega_{c,2,p}$	8.562E–7** (3.067E–7)
φ_c	–2.34596** (0.5345)	$\omega_{c,3,p}$	–9.06E–7** (3.233E–7)
τ_b	0.0597** (0.0129)	ρ [b]	0.2055** (0.0815)
Log Likelihood = 816.5807			

[a] ** and * indicate statistical significance at the 1% and 5% levels, respectively.

[b] The estimated diagonal elements of the **R** matrix.

This suggests a good model fit. Inspecting the results in Table 5-4 indicates that a number of the coefficients are individually significant at the 1% or 5% level. Based on results from the preferred model, the constant components (c_{i0}'s) of the precommitted quantities are estimated to be 14.2 pounds of beef, 7.3 pounds of pork, and 7.2 pounds of poultry. When compared with the sample means, these estimates suggest that these constant components account for a significant portion of total meat consumption.[12]

Of particular interest for this task are the estimated coefficients (the $\omega_{i,j,p}$'s) on the pork promotion variables. The coefficients on *ZPDE* in the pork and poultry equations are highly significant with p-values less than 1%, suggesting the economic effects of pork promotion on meat demand are precisely estimated.

[12] The percentages are 81% for beef, 57% for pork, and 34% for poultry.

To investigate the economic significance of price, expenditure, food safety, and promotion effects on meat demand, we computed elasticities of demand with respect to price, expenditure, and generic advertising using our parameter estimates reported in Table 5-4. These point estimates of elasticities are presented in Table 5-5. We also conducted Monte Carlo simulations to generate distributions around key elasticity estimates. The results of these simulations are presented in Section 6.

Table 5-5. Estimated Price, Expenditure, Food Safety, and Generic Advertising Elasticities Without Structural Change for Pork Advertising between 1987–1998 and 1999–2005[a]

	Beef q	Pork q	Poultry q
Uncompensated (Marshallian) Price Elasticities			
Beef p	–0.7835	–0.2610	–0.0598
Pork p	–0.1222	–0.6526	–0.1785
Poultry p	–0.1051	–0.2196	–0.4190
Expenditure Elasticities			
Expenditure	1.0108	1.1333	0.6573
Food Safety Elasticities			
Beef safety	–0.0011	–0.0019	0.0048
Pork safety	–0.0024	0.0014	0.0036
Poultry safety	0.0027	–0.0005	–0.0055
Long-Run Generic Advertising Elasticities[b]			
Generic beef ads	–0.0013	0.0119	–0.0137
Generic pork ads	–0.0287	0.0207	0.0380

[a] The price, food safety, and expenditure elasticities are sample averages over the period 1982(1)–2005(4). Advertising elasticities are averages over the 1987(1)–2005(4) period.

[b] The long-run advertising elasticities are calculated assuming that advertising expenditures have been constant over a period of nine quarters. The results are not sensitive if more than nine quarters of stable promotion expenditures are assumed.

The Marshallian own-price elasticities of demand are –0.784 for beef, –0.653 for pork, and –0.419 for poultry. These estimates all fall within the ranges typically reported in the economics literature.

The Marshallian own-price elasticities of demand are –0.784 for beef, –0.653 for pork, and –0.419 for poultry. These estimates all fall within the ranges typically reported in the economics literature. Note that all of our cross-price elasticities are negative, which implies that all of our meats are complements. This result is consistent with Piggott and Marsh (2004) and is at least partially reflective of the choice of functional form. Because we are estimating a conditional demand system and the version of GAIDS we are using contains precommitted quantities, it is not unexpected that we find complementarity, especially when precommitted quantities account for a relatively large share of consumption. For instance, an increase in the price of a product will result in increased expenditures to purchase the precommitted quantity of that product. Because this is a conditional demand system, we hold meat expenditures fixed. Thus, an increase in spending on fulfilling purchases of precommitted quantities reduces the amount of supernumerary income remaining for meat purchases. It is certainly possible that an increase in the price of one product could cause a large enough substitution towards other products that the quantities of those products purchased would increase even with less supernumerary income. However, in our case, at least at the sample means, it results in a reduction in the supernumerary quantity purchased for all three meats in every case.

The estimated own-food safety elasticities of demand are negative for beef and poultry, indicating that negative publicity about these two species adversely affects their own demands. The own-food safety elasticity of demand for pork is estimated to be positive although not significant at any conventional level. This is not surprising given that there has been much less negative publicity about pork than both beef and poultry over the last 2 decades, and that the coefficients on pork media index (ϕ_{bp}, ϕ_{pp}, and ϕ_{cp}) are not statistically different from zero in all equations in Table 5-4.

Of most interest to the National Pork Board is the own-promotion elasticity of pork demand, which is estimated to be 0.0207. Based on this estimate, a 1% increase in the National Pork Board's promotion expenditure (PDE) would result in a 0.0207% increase in domestic pork consumption. This is not a trivial economic effect considering the huge quantity of pork consumed in the United States.

The own-promotion elasticity of demand for beef is estimated to be negative, a somewhat counterintuitive result. However, the magnitude of this estimate (–0.0013) is small, indicating little economic significance. In contrast, the cross effects of beef promotion on demand for pork and poultry are much larger in magnitude. The beef promotion elasticity of pork demand is 0.0119, suggesting generic beef advertising positively affects pork demand. The beef promotion elasticity of poultry demand is –0.0137, implying that generic beef promotion hurts demand for poultry.

Of most interest to the National Pork Board is the own-promotion elasticity of pork demand, which is estimated to be 0.0207 in Table 5-4. Based on this estimate, a 1% increase in the National Pork Board's promotion expenditure (PDE) would result in a 0.0207% increase in domestic pork consumption.

This is not a trivial economic effect considering the huge quantity of pork consumed in the United States.

To investigate whether the effectiveness of PDE in affecting pork demand has changed since the last program evaluation in 1998, we conducted an additional econometric analysis of the demand system by interacting a dummy variable named "post98" with the coefficients on pork promotion variables. The post98 variable is defined to be equal to one for years after 1998 and zero otherwise. This analysis amounts to adding two interaction terms ($post98 * ZPDE_{2t}$ and $post98 * ZPDE_{3t}$) to each equation in Eq. (5.11). The joint significance of the six interaction terms is tested using the LR test. The maximized log likelihood is 826.295 for the unrestricted model and 816.581 for the restricted model. Therefore, the LR test statistic is 2*(826.295–816.581)=19.428. With six degrees of freedom, the critical value for X^2 distribution is 12.59 at the 5% level. Hence, we had strong statistical evidence that the effectiveness of National Pork Board's promotion effort, as measured by PDE, differs between the previous evaluation period of 1987 through 1998 and 1999 through 2005.

To evaluate the magnitude of such changes, using parameter estimates from the unrestricted model, we estimated price, food safety, and expenditure elasticities over the entire sample period and the promotion elasticities of demand before and after 1999. These elasticity estimates are presented in Table 5-6. Notice that the price, food safety, and expenditure elasticities compare favorably with the corresponding estimates from the restricted model in Table 5-5. As was the case without structural change presented earlier, each of the Marshallian cross-price elasticities are negative, indicating that these meats are complements in this GAIDS conditional demand system.

Table 5-6. Estimated Price, Expenditure, Food Safety, and Generic Advertising Elasticities with Structural Change for Pork Advertising between 1987–1998 and 1999–2005[a]

	Beef q	Pork q	Poultry q
Uncompensated (Marshallian) Price Elasticities[a]			
Beef p	–0.7614	–0.2824	–0.0707
Pork p	–0.1232	–0.6413	–0.1887
Poultry p	–0.1092	–0.2401	–0.3788
Expenditure Elasticities			
Expenditure	0.9938	1.1638	0.6382
Food Safety Elasticities			
Beef safety	–0.0023	–0.0007	0.0057
Pork safety	–0.0047	0.0023	0.0077
Poultry safety	0.0052	–0.0022	–0.0090
Long-Run Generic Advertising Elasticities (1987–1998)			
Generic beef ads	0.0066	0.0027	–0.0208
Generic pork ads	–0.0213	0.0181	0.0279
Long-Run Generic Advertising Elasticities (1999–2005)			
Generic beef ads	0.0025	0.0053	–0.0118
Generic pork ads	–0.0226	0.0206	0.0218

[a] The price, food safety, and expenditure elasticities are sample averages over 1982(1)–2005(4).

In terms of the estimated effect of generic promotion on demand, the own-promotion elasticity of beef demand is now positive both before and after 1999, a more intuitive result. For pork promotion, the own-promotion elasticity of demand increased from 0.0181 for 1987 through 1998 to 0.0206 in 1999 through 2005. This increment of 0.0025 in promotion elasticity could potentially accrue nonnegligible economic benefits to hog farmers. Of course, this depends on the estimated supply elasticity of pork, elasticities of hog demand and supply, and other model parameters.

5.7 FOREIGN DEMAND FOR U.S. PORK

Conceptually, export demand for U.S. pork is excess demand for pork from the United States by other countries. Over time the relative importance of countries importing pork from the United States has changed. It used to be that Japan, Taiwan, Canada, and Denmark were important in trade with the United

States. In recent years, Brazil, Russia, and Mexico have become important markets.

The estimated export demand for U.S. pork is

$$
\begin{aligned}
\hat{netrd}_t = \; & \underset{(142932)}{246407} - \underset{(31006)}{5357.1}\, quarter1 - \underset{(27679)}{3768.6}\, quarter2 - \underset{(25785)}{12622}\, quarter3 \\
& + \underset{(0.1009)}{0.6483}\, netrd_{t-1} - \underset{(139.7)}{73.4089}\, winc - \underset{(39629)}{85837}\, ppork + \underset{(1.7254)}{5.7583}\, Z2FMD \\
& - \underset{(27.7945)}{93.0642}\, Z3FMD + \underset{(131.0343)}{430.8418}\, Z4FMD - \underset{(224.5686)}{727.2936}\, Z5FMD \\
& + \underset{(119.6541)}{383.8210}\, Z6FMD
\end{aligned}
$$

$N = 67, \bar{R}^2 = 0.9075$

$\text{D.W.} = 2.132, \hat{\rho} = -0.071$

where *netrd* is U.S. net trade in pork; *winc* is the trade-volume weighted average GDP of major U.S. pork importers, which include Mexico, Canada, Japan, Russia, South Korea, Taiwan, and Hong Kong; *ppork* is the real U.S. retail pork price, assuming the law of one price, this price is used to proxy the price paid by foreign importers; and $Z2FMD - Z5FMD$ are the second to fifth degree polynomial inverse lags for the National Pork Board's foreign market development expenditures (FMD). We obtained annual GDP data in U.S. dollars for the above importing countries from the Central Intelligence Agency's *World FactBook* and then interpolated these annual data to quarterly frequencies.

The sample for the export demand estimation starts in 1989 and ends in 2005. The eight data points over the period 1987 through 1988 were deleted during the construction of the polynomial inverse lags for the National Pork Board's foreign market development expenditures (FMD), following the recommendation by Mitchell and Speaker (1986). The polynomial inverse lag distribution was applied to the FMD. We started with five terms and found all were highly statistically significant. The coefficient on retail pork price is negative, consistent with a priori expectations, and significant. The coefficient on weighted GDP is unexpectedly negative, although statistically insignificant. This may not be too surprising given that *winc* is a very coarse approximation to the true but unobservable foreign demand shifters.

The average price elasticity of pork export demand over the sample is estimated to be –1.564. Using Eq. (5.4) and the above parameter estimates to calculate the weights on current and lagged FMD, we found that the first three weights (current quarter, lagged one and two quarters) are positive after which all calculated lagged weights of the distribution become negative. Following a similar argument to that for marketing research in hog demand, we truncated the distribution after a two-quarter lag. The estimated average FMD elasticity of export demand is 0.3121.

5.8 CONCLUSIONS

The models of domestic hog demand and supply, pork demand and supply, import demand for Canadian hogs, and U.S. pork net trade all provide good fits to the data and generate theoretically plausible parameter estimates. Based on our estimation results, there is strong evidence that generic pork promotion increases domestic pork consumption. In addition, the National Pork Board’s expenditures on production research (HSE), marketing chain research (MCR), and foreign market development (FMD) appear to increase hog supply, hog demand, and foreign demand for U.S. pork, respectively.

These parameter estimates are used in the following section to generate estimates of the net change in producer surplus and return on investment associated with the four categories of National Pork Board expenditures. The parameters that allow us to make these calculations are the promotion and research elasticities, as well as the supply and demand price elasticities. Although we have found strong evidence for significant demand and supply shifts resulting from Program expenditures, it still remains to examine the benefits to producers relative to Program costs to guarantee that producers are benefiting overall as a result of the Pork Checkoff Program.

6 Equilibrium Displacement Model and Simulated Rates of Return

In this section, we use the estimated parameters from the previous section to estimate the benefits of Program expenditures.

In this section, we use the estimated parameters from the previous section to estimate the benefits of Program expenditures. Estimating the net benefits involves changing Pork Checkoff expenditures and simulating market conditions under alternative levels of program activity. The marginal change in producer surplus was calculated for production research (HSE), marketing research (HDE including MCR), domestic promotion (PDE), foreign market development (FMD), and the combination of the four by increasing the relevant National Pork Board expenditures by 1% and simulating market conditions. These changes in producer surplus were then divided by associated changes in stakeholder assessments necessary to fund the activity to calculate benefit-cost ratios.

6.1 EQUILIBRIUM DISPLACEMENT MODEL

Taking a logarithmic differential approximation to Eqs. (4.1) through (4.14), setting differentials other than those for expenditures by the National Pork Board (N_h^u , A_p^u , A_p^{oc} , R_h^u) and the checkoff tax rate (t) to zero, and rearranging so that the exogenous terms are on the right-hand side yields[1]:

[1] Only those variables affected by changes in checkoff variables will change. Therefore, other exogenous variables in the model are

$$\tilde{I}_h^u - \varepsilon_{ipph}^u \tilde{P}_{hf}^u = 0 \tag{6.1}$$

$$\widetilde{PL}_h^u = \varepsilon_{plr}^u \tilde{R}_h^u \tag{6.2}$$

$$\widetilde{WP}_h^u - \varepsilon_{wtph}^u \tilde{P}_{hf}^u = 0 \tag{6.3}$$

$$\tilde{Q}_h^u - \tilde{I}_h^u - \widetilde{PL}_h^u - \widetilde{WP}_h^u = 0 \tag{6.4}$$

$$\tilde{P}_h^u - \phi_{phqh}\tilde{Q}_h - \phi_{phpp}\tilde{P}_p^u = \phi_{phn}\tilde{N}_h^u \tag{6.5}$$

$$\tilde{P}_h^u - \tilde{P}_{hf}^u = [t/(1-t)]\tilde{t} \tag{6.6}$$

$$\tilde{Q}_h^c - \varepsilon_{qhph}^c \tilde{P}_h^c = 0 \tag{6.7}$$

$$\tilde{Q}_p - \phi_{qppp}\tilde{P}_p^u - \phi_{qpqh}\tilde{Q}_h = 0 \tag{6.8}$$

$$\tilde{Q}_p^u - \eta_{qppp}^u \tilde{P}_p^u = \eta_{qpa}^u \tilde{A}_p^u \tag{6.9}$$

$$\tilde{Q}_p^{oc} - \eta_{qppp}^{oc} \tilde{P}_p^{oc} = \eta_{qpa}^{oc} \tilde{A}_p^{oc} \tag{6.10}$$

$$\tilde{P}_h^c - \tilde{P}_h^u = 0 \tag{6.11}$$

$$\tilde{P}_p^{oc} - \tilde{P}_p^u = 0 \tag{6.12}$$

$$\tilde{Q}_h - s_h^u \tilde{Q}_h^u - (1 - s_h^u)\tilde{Q}_h^c = 0 \tag{6.13}$$

$$\tilde{Q}_p - s_p^u \tilde{Q}_p^u - (1 - s_p^u)\tilde{Q}_p^{oc} = 0 \tag{6.14}$$

An EDM effectively captures all market linkages modeled as well as endogeneity of prices and quantities, providing advantages over other methods of combining the estimates from multiple econometric models.

where $\tilde{x}$ denotes a proportional change in *x,* defined for any variable x as $\tilde{x} = d\ln x \approx \frac{\Delta x}{x} = \frac{[x^1 - x^0]}{x^0}$, with the superscripts 0 and 1 denoting the initial and new values, respectively; t is the percentage tax on hog sales revenue used to finance advertising and research expenditures by the National Pork Board. An EDM effectively captures all market linkages modeled as well as endogeneity of prices and quantities, providing advantages over other methods of combining the estimates from multiple econometric models.

fixed at their original values. The log differential model also abstracts from time dimension so that enough time is assumed to pass to reach the new equilibrium. For example, for hog supply response, the supply elasticity is a combination of elasticities for one-quarter lag and five-quarter lag. Also, the effect of checkoff funds allocated to research and promotion are for the cumulative effect over time.

Based on the parameter estimates in Section 5, the elasticities denoted in Eqs. (6.1) through (6.14) can be defined as follows:

ε^{u}_{ipph} = 0.09 = elasticity of farrowing sows with respect to price of hogs,

ε^{u}_{plr} = 0.006 = elasticity of pigs per litter with respect to production research,

ε^{u}_{wtph} = 0.008 = elasticity of weight per hog with respect to price of hogs,

ϕ_{phqh} = –2.406 = elasticity of hog price with respect to total quantity of hogs marketed (own-price flexibility of inverse demand function for hogs procured by U.S. pork packers),

ϕ_{phpp} = 0.887 = elasticity of hog price with respect to retail pork price,

ϕ_{phn} = 0.012 = elasticity of hog price with respect to marketing research,

ε^{c}_{qhph} = 0.201 = elasticity of hogs imported from Canada with respect to price of hogs,

ϕ_{qppp} = 0.040 = elasticity of pork supplied with respect to the price of pork,

ϕ_{qpqh} = 0.990 = elasticity of pork supplied with respect to quantity of hogs marketed,

η^{u}_{qppp} = –0.641 = elasticity of pork demanded by U.S. consumers with respect to the price of pork,

η^{u}_{qpa} = 0.0206 = elasticity of pork demanded by U.S. consumers with respect to promotion,

η^{oc}_{qppp} = –1.564 = elasticity of U.S. produced pork demanded by consumers in other countries with respect to price of pork,

η^{oc}_{qpa} = 0.3121 = elasticity of U.S. produced pork demanded by consumers in other countries with respect to promotion,

s^{u}_{h} = 0.9383 = U.S. producers' share of total hog quantity (1999–2005 average), and

s^{u}_{p} = 0.9632 = U.S. consumers' share of total pork quantity (1999–2005 average).

In all, the model consists of 14 equations, 14 endogenous variables, and 5 exogenous variables that can be summarized as follows:

Endogenous:
$I_h^u, PL_h^u, \; WP_h^u, Q_h^u, P_h^u, P_{hf}^u, Q_h^c, Q_p, Q_p^u, P_p^u, Q_p^{oc}, P_h^c, P_p^{oc}, Q_h$

Exogenous: N_h^u , A_p^u , A_p^{oc} , R_h^u , t

Following the approach proposed by Piggott (2003), Eqs. (6.1) through (6.14) can be written in matrix form as **MY = X** where

$$Y' = \left[\tilde{I}_h^u \quad P\tilde{L}_h^u \quad W\tilde{P}_h^u \quad \tilde{Q}_h^u \quad \tilde{P}_h^u \quad \tilde{P}_{hf}^u \quad \tilde{Q}_h^c \quad \tilde{Q}_p \quad \tilde{Q}_p^u \quad \tilde{P}_p^u \quad \tilde{Q}_p^{oc} \quad \tilde{P}_h^c \quad \tilde{P}_p^{oc} \quad \tilde{Q}_h \right]$$

$$\boldsymbol{M} = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & -\varepsilon_{ipph}^u & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 0 & -\varepsilon_{wtph}^u & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-1 & -1 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -\phi_{phpp} & 0 & 0 & 0 & -\phi_{phqh} \\
0 & 0 & 0 & 0 & -1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & -\varepsilon_{qhph}^c & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -\phi_{qppp} & 0 & 0 & 0 & -\phi_{qpqh} \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -\eta_{qppp}^u & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & -\eta_{qppp}^{oc} & 0 \\
0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -1 & 1 & 0 & 1 & 0 \\
0 & 0 & 0 & -s_h^u & 0 & 0 & -(1-s_h^u) & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & -s_p^u & 0 & -(1-s_p^u) & 0 & 0 & 0
\end{bmatrix}$$

$$X' = \left[0 \quad \varepsilon_{plr}^u \tilde{R}_h^u \quad 0 \quad 0 \quad \phi_{phn} \tilde{N}_h^u \quad [t/(1-t)]\tilde{t} \quad 0 \quad 0 \quad \eta_{qpa}^u \tilde{A}_p^u \quad \eta_{qpa}^{oc} \tilde{A}_p^{oc} \quad 0 \quad 0 \quad 0 \quad 0 \right]$$

This system can be solved for the proportional changes in endogenous variables, given by **Y** = $\mathbf{M}^{-1}\mathbf{X}$. These proportional changes can be used to calculate changes in prices and quantities and changes in hog producer welfare. The change in welfare for hog producers can be measured by the change in producer surplus (ΔPS_h). The formula for change in producer surplus, assuming a pivotal supply shift, is

$$\Delta PS = \frac{P_{hf}^u Q_h^u}{2} \left[\frac{\Delta P_{hf}^u}{P_{hf}^u} \left(1 + \frac{\Delta Q_h^u}{Q_h^u} \right) + \frac{1}{\varepsilon_{qhph}^u} \frac{\Delta Q_h^u}{Q_h^u} \right] \tag{6.15}$$

where $\varepsilon_{qhph}^u = \varepsilon_{ipph}^u + \varepsilon_{wtph}^u$ is the elasticity of supply of U.S. hogs with respect to the U.S. price of hogs, and the changes in prices and quantities are calculated using the model results at the new equilibrium, which depend on all of the elasticities presented above. In the next section, we simulate changes in producer surplus that result from marginal increases in production research, marketing research, domestic promotion, and foreign market development expenditures, as well as a combination of all expenditure categories.

6.2 SIMULATED BENEFIT-COST RATIOS FOR 1999–2005

Based on our equilibrium displacement model above, our estimated parameters, and average levels of prices, quantities, Program expenditures, and other variables from 1999 through 2005, a 1% increase in annual domestic promotion expenditures would have resulted in an average farm-level hog price increase of $0.00956/cwt. Increases in postfarm research or foreign market development of 1% would increase farm-level hog prices by $0.00413/cwt and $0.00609/cwt, respectively.

This section reports simulation results from a marginal increase in Pork Checkoff expenditures (we assume a 1% increase for calculation purposes). As noted above, we chose to model the returns within an EDM because it provides a comprehensive method that accounts for linkages in our structural model, as well as endogeneity of prices and quantities. We focused on calculating marginal returns because the EDM is more appropriately used for small changes from baseline equilibrium levels. With declining marginal returns to research and promotion, these estimates of marginal returns can be considered conservative lower bounds for the point estimates of historical average returns that have been generated by the Pork Checkoff Program.

Based on our equilibrium displacement model above, our estimated parameters, and average levels of prices, quantities, Program expenditures, and other variables from 1999 through 2005, a 1% increase in annual domestic promotion expenditures would have resulted in an average farm-level hog price increase of $0.00956/cwt. Increases in postfarm research or foreign market development of 1% would increase farm-level hog prices by $0.00413/cwt and $0.00609/cwt, respectively. A 1% increase in production research, on the other hand would reduce farm-level hog price by $0.0095/cwt. This is due to the increase in hog supply and the estimated inelastic demand for hogs. A 1% increase in all expenditure categories would raise the farm-level hog price by $0.01026/cwt, increase U.S. hog supply by 478,096 (liveweight) pounds, and benefit U.S. producers by $1,809,166 in producer surplus.

Incorporating the estimated changes in prices and quantities resulting from marginal changes in Pork Checkoff activities and the average levels of prices and quantities over the 1999 through 2005 period, we calculated net changes in producer surplus using Eq. (6.15). This net change in producer surplus for hog producers was then divided by the change in assessment paid by domestic producers to calculate the marginal benefit-cost ratio associated with these activities. The marginal benefit-cost ratio is defined as

$$Benefit - cost\ ratio = \frac{\Delta producer's\ surplus_{hog}}{\Delta Board\ expenditure}. \tag{6.16}$$

Before presenting the simulation results, there is a remaining issue to address for calculating net returns. In addition to the four National Pork Board expenditure categories used for estimation in this study (HSE, HDE, PDE, and FMD or using the EDM notations N_h^u, A_p^u, A_p^{oc}, R_h^u), overhead costs account for 12.7% of the total Board expenditure on average. In the econometric analysis, these costs were not allocated to any of the research or promotion activity. However, overhead activities are necessary for coordinating and overseeing the other functions. Given the importance of overhead in National Pork Board's total outlay, it is inappropriate to ignore this cost category in calculating benefit-cost ratios. Overlooking overhead cost will overestimate the net benefits for hog farmers resulting from research and promotion activities.[2]

We allocate overhead expenditures proportionately to each of the four research and promotion activities. The proportion of overhead that goes to a particular activity is determined by the share of expenditures on this activity in total research and promotion outlays. For example, in the fourth quarter of 2005, PDE, HSE, HDE, and FMD account for 53.4%, 27.8%, 3.7%, and 15.1%, respectively, of the Board's expenditures on research and promotion. Given these shares, we allocated 53.4%, 27.8%, 3.7%, and 15.1% of the overhead cost in 2005(4) to PDE, HSE, HDE, and FMD, respectively. Because these shares fluctuate from quarter to quarter, the percentage of overhead that goes to each activity changes over time.

[2] This statement should be qualified to some extent. Because some components of the overhead costs are fixed, increasing research and promotion expenditures does not necessarily raise overhead expenditures proportionately. The simulation exercise later in this section assumes a 1% change in research and promotion expenditures results in a 1% change in overhead costs. Although not an innocuous assumption, without further information on how the Program's overhead costs are incurred, it appears to be a reasonable approach to the issue. To the extent that overhead costs change by less than 1%, our estimates of producer benefits would underestimate the true benefits accrued to producers.

We simulated the effects of a 1% increase in each National Pork Board expenditure category individually and for all four categories combined, both with and without accompanying increases in tax rate to provide the money necessary to fund incremental activities, on hog producer surplus during the period 1999 through 2005. In addition, because postfarm research and production research are likely be related (i.e., production research and producer education may be necessary before postfarm marketing innovations can be implemented), we simulated the returns to a combination of those two expenditures categories. We increase both by 1% simultaneously while holding the other expenditure categories constant. We report changes in producer surplus resulting from a simultaneous increase in both research or promotion activity and tax rate. This provides important information to the Board as it makes resource allocation and assessment-level decisions.

The point estimates calculated for marginal benefit-cost ratios for the Pork Checkoff Program are presented in Table 6-1.

Table 6-1. Simulated Marginal Benefit-Cost Ratios Under Various National Pork Board Expenditure and Tax Rate Change Scenarios (1999–2005)[a]

Effects of a 1% Increase in	Benefit-Cost Ratio without Tax Increase	Benefit-Cost Ratio with a Simultaneous tax Increase[b]
Production research (HSE)	20.5	19.5
Marketing chain research (HDE)	57.2	56.2
Domestic demand promotion (PDE)	8.1	7.1
Foreign market development (FMD)	29.0	28.0
Production research and marketing chain research combined (HSE and HDE)	25.4	24.4
All four expenditure categories	14.8	13.8

[a] Producer benefits are measured in 2004 dollars.

[b] The magnitude of tax rate increase is calculated such that the 1% increase in research and promotion expenditures is equal to the increase in tax revenue.

At the 1999 through 2005 average level of spending on market research, our point estimate indicates that an extra dollar invested on market research would bring $57.22 to hog farmers

Table 6-1 indicates that marketing chain research generates the highest marginal return. Foreign market development is the second most profitable activity, followed by production research, and domestic promotion. At the 1999 through 2005 average level of spending on market research, our point estimate indicates that an extra dollar invested on market research would bring $57.22 to hog farmers. If the 1% increase in market research is accompanied by an increase in tax rate, the benefit is $56.22 per dollar invested.

Table 6-2 provides the simulated changes in producer surplus, hog price received by farmers, and quantity of U.S. hogs sold assuming the tax is increased simultaneously to fund the increase in expenditures.

Table 6-2. Simulated Marginal Changes in Producer Surplus, Farm-Level Hog Price, U.S. Hogs Sold under Various National Pork Board Expenditure and Tax Rate Change Scenarios (1999–2005)

Effects of a 1% Increase In	Change in Producer Surplus (2004 dollars)	Change in Farm-Level Hog price ($/pound, 2004 dollars)	Change in US hogs Sold (liveweight pounds)
Production research (HSE)	$572,683	–0.0000950	279,527
Marketing chain research (HDE)	$258,198	0.0000413	41,466
Domestic demand promotion (PDE)	$597,539	0.0000956	95,962
Foreign market development (FMD)	$380,715	0.0000609	61,141
Production research and marketing chain research	$830,885	–0.0000540	320,993
All four expenditure categories	$1,809,166	0.0001026	478,096

For the National Pork Board's foreign market development activity, an additional dollar spent would increase hog producer surplus by $29.04

For the National Pork Board's foreign market development activity, an additional dollar spent would increase hog producer surplus by $29.04 if it is not accompanied by a tax increase. A simultaneous tax increase would reduce producer surplus to $28.05 per dollar invested.

At the current level of spending on generic promotion, a 1% increase in promotion expenditures would bring $8.13 to producers per dollar spent.

At the current level of investment on production research, a 1% increase in this expenditure will increase producer surplus by $20.49 per dollar invested.

Domestic promotion accounted for 79% of total research and promotion expenditures by the National Pork Board during 1987 through 1998. Although its share has declined over the past several years, domestic promotion still makes up 63% of the Program's outlay on research and promotion during the 1999 through 2005 period. Our estimate suggests that, at the current level of spending on generic promotion, a 1% increase in promotion expenditures would bring $8.13 to producers per dollar spent. If the National Pork Board chooses to finance the increment in promotion expenditure by a tax increase, the benefit-cost ratio will be reduced to 7.13.

At the current level of investment on production research, a 1% increase in this expenditure will increase producer surplus by $20.49 per dollar invested. The return would be lower ($19.49) if the tax rate is increased to finance the extra expenditure on production research. One reason that the estimated return on production research is not even higher is the high (in absolute value) own-price flexibility of demand for hogs (holding pork price constant), estimated at –2.406 in the previous section. This parameter estimate means that a moderate shift in hog supply would be accompanied by a large drop in hog price. Therefore, a large portion of the gain in producer surplus resulting from productivity improvement is offset by the decline in hog price.

Estimating marginal returns to production research is also complicated by the difficulty in adequately defining the counterfactual. Supply shifts in hog and pork production would presumably be smaller and possibly even negative over time if depreciation in the knowledge stock (e.g., antibiotics may lose effectiveness over time if bacteria develop resistance, average hog health may decline if new diseases are introduced that have less effective treatments than current diseases, human capital may decline as time passes since information/training was provided) would outpace additions from research without Pork Checkoff funding. Maintenance research (i.e., research that does not necessarily lead to increases in productivity but rather prevents productivity from declining) clearly plays an important role in agriculture, but we do not have sufficient information to adequately measure the extent to which Pork Checkoff production research may serve in this capacity.

The point estimates of price, expenditure, and advertising elasticities are generally within the range of those estimated in previous studies.

The point estimates of price, expenditure, and advertising elasticities are generally within the range of those estimated in previous studies. Our domestic promotion elasticity was 0.0206 for 1999 through 2005, which is a bit larger in magnitude than previous published studies other than Piggott (1997). Brester and Schroeder (1995), Kinnucan et al. (1997), Boetel and Liu (2003), and Hyde and Foster (2003) all found smaller elasticities for promotion (<0.007) than our estimate, and none found statistically significant effects of pork promotion. Piggott (1997) estimated a statistically significant elasticity of 0.034 for pork promotion. In the previous evaluation of the Pork Checkoff Program conducted by Davis et al. (2001), they estimated a much larger promotion elasticity than any of the published studies, with an elasticity of 0.11. However, Kinnucan and Zheng (2005) cite the Davis et al. (2001) estimates as a case of implausibly high promotion elasticity/own-price elasticity.

Although any economic model, especially one as complex as ours, is an imperfect representation of reality, we attempted to account for some of the most important criticisms of past generic research and promotion evaluations.

Although any economic model, especially one as complex as ours, is an imperfect representation of reality, we attempted to account for some of the most important criticisms of past generic research and promotion evaluations (e.g., as summarized in Kinnucan and Zheng [2005]) in developing our models. Kinnucan and Zheng (2005) raise concerns about the previous Pork Checkoff evaluation relying on a single-equation model rather than a meat demand system, not accounting for income or meat expenditures in their demand model, and incorporating a lag structure that had beef advertising affect pork demand in the same quarter as expenditures but no effects for pork promotion expenditures until 11 quarters after the expenditure (with no effects for the first 10 quarters). In this study, we rely on a meat demand system that deals with the first two points and uses a flexible lag structure that we tested extensively to determine the preferred lag structure and that yields lag structures that appear more plausible than used in the previous study. Our demand system also accounts for cross-commodity impacts of beef and pork promotion on beef, pork, and poultry demand.

Although we generate marginal benefit-cost ratios, which do not provide exactly the same information as the average benefit-cost ratios generated by Davis et al. (2001), our estimates can be considered a lower bound on the point estimate of average return assuming Program expenditures have reached a point such that marginal returns are declining.

Although we generate marginal benefit-cost ratios, which do not provide exactly the same information as the average benefit-cost ratios in Davis et al. (2001), our estimates can be considered a lower bound on the point estimate of average return assuming Program expenditures have reached a point such that marginal returns are declining. Keeping in mind that our models are specified with very different structures, the qualitative implications of our findings have many similarities to those of the previous evaluation.

Similar to the previous evaluation of the Pork Checkoff Program, we find marketing chain research (HDE) to have the largest estimated return. Davis et al. estimate average benefit-cost ratios of 116.3 and 197.5 in their time-series and structural models, respectively. Our point estimate of marginal benefit-cost ratio, accounting for increasing assessments to fund these activities, is 56.2. The category with the second highest marginal return in our model is foreign market development (FMD), with an estimated ratio of 28.0, which is higher than the 12.5 average return estimated in the previous study's structural model (they did not include FMD in the time-series model). In contrast to the previous study, which estimated the benefit-cost ratio for production research and extension (HSE) to be negative, between –1 and –9.2, we estimate a fairly sizable marginal benefit-cost ratio of 19.5. Finally, for domestic pork promotion (PDE), the category that tends to receive the majority of Pork Checkoff funding, we estimate a benefit-cost ratio of 7.1. The previous evaluation of the program estimated an average ratio between 15.3 and 22.5.

The overall point estimate generated for the marginal return to Pork Checkoff Programs from our study is 13.8, which is within the range of estimates from Davis et al. for overall average return (4.8 to 26.2) and just slightly below the value of 16 that they suggest using as an overall average return to the Pork Checkoff Program for 1986 through 1998.

The overall point estimate generated for the marginal return to Pork Checkoff Programs from our study is 13.8, which is within the range of estimates from Davis et al. for overall average return (4.8 to 26.2) and just slightly below the value of 16 that they suggest using as an overall average return to the Pork Checkoff Program for 1986 through 1998. If the models were directly comparable, this would suggest that overall marginal returns are less than average, which is expected, assuming declining returns to research and promotion activities, but that additional expenditures above historical levels would still be quite profitable for the average hog producer. Although the models differ considerably, they yield qualitatively similar conclusions for the effectiveness of the Program.

Although the point estimates suggest very strong returns to producer investment in Pork Checkoff activities, another important consideration in assessing the returns to the Program and individual components is the variability surrounding these estimates. As with any economic model, the "true" values of parameters are unknown and must be estimated. In addition to the point estimate, econometric models also generate measures of precision on that estimate. The following section describes a sensitivity analysis conducted to assess the precision of our point estimates and present more information on the distribution of estimated returns.

6.3 SENSITIVITY ANALYSIS

The estimates of the rate of return and the associated changes in producer surplus, farm-level hog prices, and hog quantity supplied presented above are based on point estimates of the model parameters. As noted previously, these values should be thought of as estimates rather than exact measurements. Generally, studies that measure the demand and supply responses to advertising and research report point estimates and do not calculate the precision with which these estimates are measured.[3] For example, the point estimate for return to an extra dollar may be presented as if, e.g., a 7 to 1 return is guaranteed, but there would actually be substantial uncertainty surrounding this estimate. It may be more informative to know how precisely this 7 to 1 ratio is measured.[4] Thus, we generate and present distributions around key parameters and measures of interest.

Table 6-3 presents 90% confidence intervals for the 6 NPB activities listed in Table 6-1 with and without a simultaneous increase in assessment. We used the Monte Carlo integration technique described in Piggott (2003) to generate empirical distributions for the benefit-cost ratios. We consider,

[3] A plausible explanation for not reporting precision of the estimated return on investment is that it was not calculated as part of the evaluation because the cost entailed by this exercise is not negligible. The cost of conducting this precision analysis increases as the underlying demand and supply econometric models get more sophisticated.

[4] Both of our peer reviewers that reviewed the draft report suggested placing distributions around the estimates as the single most important issue to consider adding for the final report.

Table 6-3. Median Values and 90% Confidence Intervals for the Simulated Marginal Benefit-Cost Ratios Under Various National Pork Board Expenditure and Tax Rate Change Scenarios (1999–2005)[a b]

Effects of a 1% Increase in	Median and 90% Confidence Interval for the Benefit-Cost Ratio without Tax Increase[c]	Median and 90% Confidence Interval for the Benefit-Cost Ratio with a Simultaneous Tax Increase[d]
Production research (HSE)	26.96 (–3.75 124.97)	25.97 (–4.69 123.84)
Marketing chain research (HDE)	71.57 (–46.69 195.94)	70.57 (–47.73 194.90)
Domestic demand promotion (PDE)	11.40 (–10.38 59.64)	10.39 (–11.39 58.68)
Foreign market development (FMD)	33.71 (9.39 83.81)	32.67 (8.35 82.84)
Production research and marketing chain research	33.49 (1.03 121.09)	32.53 (0.07 119.92)
All four expenditure categories	21.10 (3.09 65.52)	20.11 (2.09 64.37)

[a] Producer benefits are measured in 2004 dollars.

[b] A 90% confidence interval indicates a 90% statistical probability that the true estimate falls in this range.

[c] The 90% confidence intervals are in parentheses.

[d] The magnitude of the tax rate increase is calculated so that the 1% increase in research and promotion expenditures is equal to the increase in tax revenue.

Although the mean returns generally indicate large returns to producers, the confidence intervals reflect that we, as econometricians, can only measure these values with some imprecision.

simultaneously, uncertainties in estimating all demand and supply elasticities that were used in Eqs. (6.1) through (6.14) of the EDM model. In so doing, the estimated ranges of benefit-cost ratios are wider than if one is to consider uncertainty in one National Pork Board activity at a time, while holding all other estimated elasticities fixed at their point estimates.[5] Although the mean returns generally indicate large returns to producers, the confidence intervals reflect that we, as econometricians, can only measure these values with some imprecision. This imprecision reflects imperfect data, other factors that are influencing markets that cannot be captured, and the imperfect ability of economic models to capture all the complexities of reality.

[5] Although evaluating one source of uncertainty at a time renders a tighter confidence interval for the investigated National Pork Board activity, it may result in an overly optimistic estimate of profitability for this activity. For this reason, we decided to take the comprehensive approach by considering all sources of uncertainty simultaneously, although doing so entails greater analytical resources.

Confidence intervals are larger for some categories than others, reflecting differences in data quality, the ability of the expenditure data to accurately represent the Program activity level, and the number of parameters needed for rate of return calculations (because each parameter is associated with a distribution around its point estimate), as well as differences in underlying variability in the effects of the categories modeled.

Results in Table 6-3 indicate that three of the six combinations of National Pork Board activities analyzed have a lower bound on their confidence intervals greater than zero (both with and without accounting for additional assessments to fund the additional activity). In other words, we can say, at a 90% confidence level, these activities would result in a positive marginal return to hog farmers for additional dollars invested.[6] These activities are foreign market development with and without a commensurate tax increase, production research and marketing chain research with and without a simultaneous tax increase, and a simultaneous increase in all four National Pork Board expenditure categories with and without a tax increase. Notice that the medians of the simulated return distributions are not exactly the same as the point estimates reported in Table 6-1; they tend to be higher. This is because we have discarded random draws that violate theoretical curvature restrictions or imply demand or supply curves that contradict the fundamental economic theories of demand and supply. That is, demand has to be downward sloping, while supply has to be upward sloping.

For HSE, HDE, and PDE, although these expenditures are profitable on average, the returns are measured imprecisely. As with any investment activity, there is some uncertainty regarding the magnitude of net benefits. The confidence intervals for these three categories include negative values, indicating that our simulations show that it is possible for these activities to result in negative returns with certain combinations of parameter values. For instance, it is possible that a random draw from the parameter distributions results in a case where pork promotion has minimal effect on pork demand, but has a substantial positive cross-effect on poultry that results in

[6] Note that the marginal benefit-cost ratio only needs to be greater than zero, not one, for the program to be profitable. This is because when the producer surplus is calculated, the cost of the checkoff assessment to hog producers has been taken into account.

reallocation of expenditures away from pork and negative impacts on pork producers. There are numerous parameters involved in the simulations in order to capture complexities of the market and uncertainty surrounding the true value of each parameter. Thus, random draws from the estimated distribution can result in combinations of parameters where the returns to generic promotion and research would be negative. The probability of these negative outcomes depends on the estimated distributions of all the parameters.

The imprecision partly arises from the wide ranges of values for the demand and supply elasticities implied by the estimated demand and supply parameters in Section 5. These elasticities are calculated as functions of the econometric parameter estimates. Although most of these parameters are individually precisely estimated and statistically significant, it does not suggest that the elasticities derived from them are necessarily statistically different from zero at conventional levels of significance.

While some categories have larger point estimates than others, it is important for decision makers to consider the distributions of potential returns in addition to the point estimates.

In addition, there is considerable overlap between the distributions estimated for different Program categories. This indicates uncertainty regarding the relative returns to each category. In fact, none of these point estimates of rates of return are statistically significantly different from one another at any standard level of significance. While some categories have larger point estimates than others, it is important for decision makers to consider the distributions of potential returns in addition to the point estimates. Important questions for consideration include the extent to which one point estimate must exceed another to justify reallocation given the uncertainties and the optimal risk-return tradeoffs.

Table 6-4 presents the means and standard errors of the simulated demand and supply elasticities. Note that the means of these elasticities are not exactly equal to their point-estimate counterparts in Eqs, (6.1) through (6.14). This is because the simulated values were obtained by discarding random draws that did not satisfy the underlying demand and supply theories, while the point estimates are based on averages of the sample data. The four elasticities related to National Pork Board's promotion and research expenditures are of particular interest. The Monte Carlo analysis indicates that only the elasticity of export demand with respect to foreign market development is at least twice as large as its standard errors, while the other three promotion and research elasticities are not precisely measured.

Table 6-4. Simulated Demand and Supply Elasticities and Their Standard Errors[a]

Elasticity of	Mean	Standard Error
Pork demanded by U.S. consumers wrt[b] to pork price	–0.5575	0.1718
Pork demanded by U.S. consumers wrt promotion (PDE), 1999–2005	0.0285	0.0318
U.S. produced pork demanded by consumers in other countries wrt pork price	–1.4965	0.6356
U.S. produced pork demanded by consumers in other countries wrt promotion (FMD)	0.3203	0.1209
Hogs imported from Canada wrt hog price	0.2242	0.1237
Farrowing sows wrt to hog price	0.0707	0.0296
Live weight per hog wrt to hog price	0.0081	0.0030
Pigs per litter wrt production research (HSE)	0.0065	0.0043
Pork supplied wrt pork price	0.0398	0.0098
Hog price wrt pork price	0.9458	0.3182
Hog price wrt total quantity of hogs marketed	–2.6399	0.3454
Hog price wrt marketing research (HDE)	0.0121	0.0119

[a] We had 100,000 initial random draws from the variance-covariance matrix of the underlying parameters of the supply and demand equations in Section 5. Following Piggott (2003), we discarded draws that implied upward-sloping (Hicksian) demand curves and downward-sloping supply curves. Doing this reduced the number of usable draws to 6,295. These draws are the basis for simulating the confidence intervals for the benefit-cost ratios and the means of the demand and supply elasticities and their standard errors.

[b] wrt=with respect to.

Finally, following Piggott (2003), we report results from the sensitivity analysis in an alternative way. Table 6-5 reports the probabilities that a marginal increase in Board expenditures on these activities would result in a net welfare gain to hog producers, taking into account the variability in all estimated parameters. For example, there is a 96.9% probability that a 1% increase in all expenditure categories and the tax rate would bring positive net gains to hog farmers. Similarly, FMD (99.5%), HSE and HDE combined (95.1%), and HSE (91.3%) have probabilities greater than 90%. The probabilities for PDE and HDE activities are lower, between 78.3% and 83.9%, highlighting the fact that returns to these individual subcategories are not as precisely estimated.

Table 6-5. Estimated Probabilities that the Net Gains to Hog Producers Are Greater Than Zero Under Various National Pork Board Expenditure and Tax Rate Change Scenarios (1999–2005)[a]

1% Increase in	Probabilities: Without a Tax Increase	Probabilities: With a Tax Increase
Production research (HSE)	0.924	0.913
Marketing chain research (HDE)	0.839	0.835
Domestic demand promotion (PDE)	0.808	0.783
Foreign market development (FMD)	0.997	0.995
Production research and marketing chain research	0.955	0.951
All four expenditure categories	0.976	0.969

[a] The magnitude of tax rate increase is calculated such that the 1% increase in research and promotion expenditures is equal to the increase in tax revenue.

6.4 CONCLUSIONS

We found benefit-cost ratios to be positive for all point estimates of Program activities and combinations of activities, but some of our return measures can be measured only imprecisely.

To determine the marginal rate of return associated with the Program, we simulated what the market for hogs and pork would look like with a marginal increase in Program expenditures. This was done by increasing expenditures on research and promotion expenditures and tax rate by 1% and using our econometric estimates of supply and demand parameters to simulate supply and demand changes. We use the benefit-cost ratio to measure the marginal profitability of each Program research and promotion activity. For the Program to be beneficial to producers the benefit-cost ratio will have to exceed zero by enough such that the return to investment exceeds the opportunity costs for those funds (i.e., the benefits overweigh costs). We found benefit-cost ratios to be positive for all point estimates of Program activities and combinations of activities, but some of our return measures can be measured only imprecisely.

Another interesting question is whether the marginal rate of return on research and promotion differ. If so, this implies that a reallocation of expenditures toward activities with higher returns would improve net benefits to hog producers. Our results, consistent with those of Davis et al. (2001), indicate that marketing research aimed at enhancing hog demand generates the highest returns based on the point estimates. The second most profitable activity at the margin is foreign market development targeted at increasing foreign demand for U.S. pork. Production research closely follows foreign market development in marginal returns to producers generated from our simulations, which is in contrast to the previous study that found negative returns to these activities. Domestic promotion that aims to increase domestic demand for pork and accounts for the largest share of Program expenditures is found to yield a more modest rate of return at the margin than other Program activities, although still quite profitable for the average hog producer. The point estimate of the benefit-cost ratio for this activity is about 7.14 when the tax rate is simultaneously increased to finance the additional spending. However, marginal returns cannot be measured precisely. Although some distributions are more heavily weighted towards larger positive values, the distributions for all of the categories overlap with one another, indicating that the estimated differences in rates of return are not statistically significant. The imprecision associated with the category-level returns precludes definitive conclusions regarding the optimal allocation of Program funding across categories.

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