An Economic Analysis of the National Pork Board Checkoff Program

Dr. Harry M. Kaiser
Cornell University

Executive Summary

The Pork Checkoff Program's (PCP) central mission is to increase the demand for hogs and pork products, reduce production costs, and improve the profitability of hog and pork producers. The program is funded by a mandatory assessment on U.S. hog producers and importers of hogs and pork products. Under existing agricultural legislation, the PCP is required to have an independent analysis of the economic effectiveness of the program conducted at least once every five years. Accordingly, the overall goal of the research is to independently evaluate the economic effectiveness of the programs funded by the Pork Promotion, Research, and Consumer Information Act of 1985. Specifically, this research addresses two important objectives:

1. Quantify and measure the economic benefit to producers of PCP-funded programs for the period 2011-2016 in terms of net return on investment.

2. Quantify and compute marginal rates of return on investment for alternative existing and potential checkoff-funded activities.

In this study, the impacts of all factors affecting domestic and export pork product demand for which data are available are measured statistically. In this way, the analysis nets out the impacts of other important factors besides NPB (and U.S. Meat Export Federation-USMEF) activities affecting pork demand and supply over time. In addition, the value of the incremental sales generated by NPB and USMEF activities are estimated. These benefits to hog and pork producers are then compared with the costs associated with the checkoff program.

The four econometric equations to be estimated include: (1) retail domestic pork demand, (2) retail domestic pork supply, (3) U.S. pork export demand, and (4) commercial farm pork supply. These four equations are used to test whether various pork checkoff activities such as advertising, export market development and promotion activities, production research, and post-farm gate research have a statistically significant impact on demand and supply.

The statistical results indicate that all three pork checkoff program demand enhancing activities have a positive and statistically significant impact on increasing per capita pork demand. Generic pork advertising has a two-year carry over effect with an elasticity of 0.034 meaning a 1% increase in advertising results in a 0.034% increase in per capita pork demand holding all other demand factors constant. The estimated non-advertising promotion elasticity is 0.026 meaning a 1% increase in non-advertising promotion expenditures results in a 0.026% increase in per capita pork demand holding other factors constant. Finally, demand enhancing pork research is found to have a lagged effect of four years, i.e., research four years ago has a significant impact on today's pork demand. Specifically, a 1% increase in demand enhancing research increases per capita pork demand by 0.003% holding all other factors constant.

The results indicate that U.S foreign market development programs have the effect of increasing the export demand for U.S. pork. The model indicates that there is a three-year carry-over effect of foreign market development. That is, current as well as three years of lagged foreign market development expenditures impact U.S. pork exports. The estimated results indicate that a 1% increase in foreign market development expenditures increase U.S. pork exports by 0.288% when holding other demand factors constant.

NPB-sponsored production-level research has a positive and statistically significant impact on hog supply. The elasticity for production research is 0.010. That is, a 1% increase in research expenditures results in a 0.010% increase in hog supply over four-years.

A simulation model, based on the estimated elasticities from the econometric model is constructed and simulated for the most recent 10-year period, 2007-2016. Based on the simulation results, it is clear that the NPB activities have impacted both prices and quantities in the market over this period. Foreign market development is found to have the largest impact on the farm-level hog price, a 1% increase in advertising increases the hog price by $0.0295 per cwt., holding all other factors constant. Advertising and non-advertising promotion have the second and third largest impact. Specifically, a 1% increase in advertising and non-advertising promotion increases the hog price by $0.013 per cwt. and $0.0099 per cwt., respectively. Demand enhancing research has the fourth largest impact of the hog price; a 1% increase in demand enhancing research increases the hog price by $0.0011 per cwt. Since farm production research increases supply, it has the impact of reducing the hog price. A 1% increase in this activity decreases the hog price by $0.0473 per cwt. holding constant all other factors. Collectively, a 1% increase in all five activities results in a $0.0061 per cwt. increase, holding all other factors constant.

All five NPB activities have positive impacts on commercial hog production. As expected, farm production research has the largest impact; on average over this period, a 1% increase in NPB-sponsored production research increases hog production by almost 1.2 million pounds per year, holding all other variables constant. A 1% increase in foreign market development increases production by approximately 660,000 pounds per year. A 1% increase in generic pork advertising and non-advertising promotion increases production by 289,701 pounds and 221,536 pounds, respectively per year. Demand enhancing research has the smallest impact on hog production. A 1% increase in all five NPB activities combined increases hog production by almost 2.4 million pounds per year.

All five NPB activities benefit hog producers in terms of increasing producer profits. Even though farm production research decreases the hog price, it has the largest positive impact on producer profits of all five activities. A 1% increase in farm production research increases producer profits by $10.76 million per year, holding all other factors constant. Foreign market development has the next highest impact on producer profits. A 1% increase in this activity results in a $3 million per year increase in producer profits. A 1% increase in advertising and non-advertising promotion results in respectively a $2.95 million and $2.25 million per year increase in producer profits. Finally, demand enhancing research has the smallest impact; a 1% increase in this activity leads to a $242,694 increase in producer profits.

The highest marginal benefit-cost ratio (BCR), which is sometimes called a return on investment, is for production research. Based on the period 2006-2015, an extra dollar invested in production research yields $83.30 in producer surplus. The next highest return is for foreign market development, where an extra dollar invested yields $24.70 in producer surplus. Generic pork advertising and non-advertising promotion have marginal BCRs of 14.2 and 12.4, respectively. Finally, demand enhancing research has a marginal BCR of 8.3. Collectively, the overall marginal BCR for all five activities is $25.50 for an additional dollar invested in the NPB. The overall BCR is higher than the 2006 RTI study, which found an overall BCR of 13.8, and higher than the 2012 (Kaiser) study that found an overall BCR of 17.4.

An Economic Analysis of the National Pork Board Checkoff Program

The National Pork Board's (NPB) central mission is to increase the demand for hogs and pork products, reduce production costs, and improve the profitability of hog and pork producers. The program is funded by a mandatory assessment on U.S. hog producers and importers of hogs and pork products. Under existing agricultural legislation, the NPB is required to have an independent analysis of the economic effectiveness of the program conducted at least once every five years. Accordingly, the purpose of the research reported here is to conduct such an economic evaluation for the most recent period of performance for the NPB, 2011-2015. The overall goal of the research is to independently evaluate the economic effectiveness of the programs funded by the Pork Promotion, Research, and Consumer Information Act of 1985. Specifically, this research has two important objectives: (1) quantify and measure the economic benefit to producers of NPB-funded programs for the period 2011-2015 in terms of net return on investment; and (2) quantify and compute marginal rates of return on investment for alternative existing and potential checkoff-funded activities.

In this study, the impacts of all factors affecting domestic and export pork product demand for which data are available are measured statistically. In this way, the analysis nets out the impacts of other important factors besides NPB[1] activities affecting pork demand and supply over time. In addition, the value of the incremental sales generated by NPB activities are estimated. These benefits to hog and pork producers are then compared with the costs associated with the NPB.

[1] On the export side, the contributions from the U.S. Meat Export Council (USMEF) and the Foreign Agricultural Service of the USDA are measured in terms of their returns to hog producers. The NPB provides some of USMEF's funds for developing foreign markets for U.S. pork products.

This independent evaluation was carried out by Dr. Harry M. Kaiser. Dr. Kaiser is one of the most eminent agricultural economists in the world who has extensively studied the economics of commodity promotion programs. Dr. Harry M. Kaiser is the Gellert Family Professor in the Dyson School of Applied Economics and Management at Cornell University where he teaches and conducts research in the areas of price analysis, marketing, and quantitative methods. He has written 150 refereed journal articles, five books, 17 book chapters, and over 150 research bulletins. Dr. Kaiser has conducted over 130 economic evaluation studies of domestic and international checkoff programs in the United States, Canada, and Europe on such commodities as fluid milk, cheese, butter, salmon, peanuts, red meat, pork, raisins, walnuts, blueberries, potatoes, beef, wheat, watermelons, high-valued-agricultural commodities, and bulk agricultural commodities. In 2005, Kaiser was the lead author of a book on all commodity checkoff programs in California. In 2006, 2010, and 2015, Dr. Kaiser was a principal (or co-principal) investigator on three comprehensive economic studies investigating the overall benefits and costs of all FAS programs to cooperators and the general economy.

National Pork Board Program Expenditures

The NPB was implemented in 1986 and is designed to increase the overall demand (both domestic and foreign) for U.S. hogs and pork products, decrease farm production costs, improve farm efficiency, and improve the overall profitability of hog and pork production. The NPB is funded by a mandatory assessment of 0.4% of the market value of all hogs sold in the United States. In addition, this program collects assessments on hogs and pork products from foreign markets imported into the United States. Collectively, this program raises around $60 million on an annual basis.

The NPB invests in a variety of activities to accomplish its overall objectives of improving profitability for the hog and pork sectors. In this report, these activities are divided into five broad categories:

- Domestic media advertising,
- Domestic non-advertising promotion,
- Foreign market development,
- Farm-level, production research, and
- Pork product, "demand-enhancing" research.

Figure 1 illustrates the percent of the NPB budget spent on each of these activities on average for the period 2011-2015. On average, non-advertising promotion expenditures was the largest category of the NPB budget, accounting for 29% of the spending. This was followed in importance by advertising (27%) and production-level research (20%). NPB contributions to foreign market development expenditures represented 19% of the budget in the past five years, while pork product research comprised 5%. The relative magnitudes of these five activities have varied, considerably, over time.

Domestic generic pork advertising once accounted for the majority of the NPB expenditures. Figure 2 displays generic pork advertising from 1986, which is the year the Pork checkoff program began, through 2015 in real, inflation-adjusted (2010) dollars. These expenditures are devoted to all domestic media advertising such as television, radio, print, outdoor, and web advertising. Generic pork advertising steadily increased from 1976 until reaching a high in 1998. Since 1998, generic pork advertising generally declined until 2010, but since then is trending upward.

Figure 3 presents generic non-advertising promotion expenditures over this time period,

Figure 1. Percent of NPB expenditures by major activity in 2011-15.

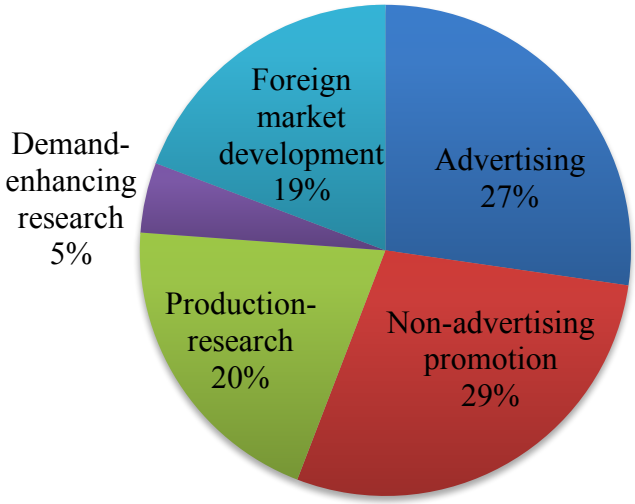


Figure 2. Real, inflation-adjusted generic pork advertising expenditures.

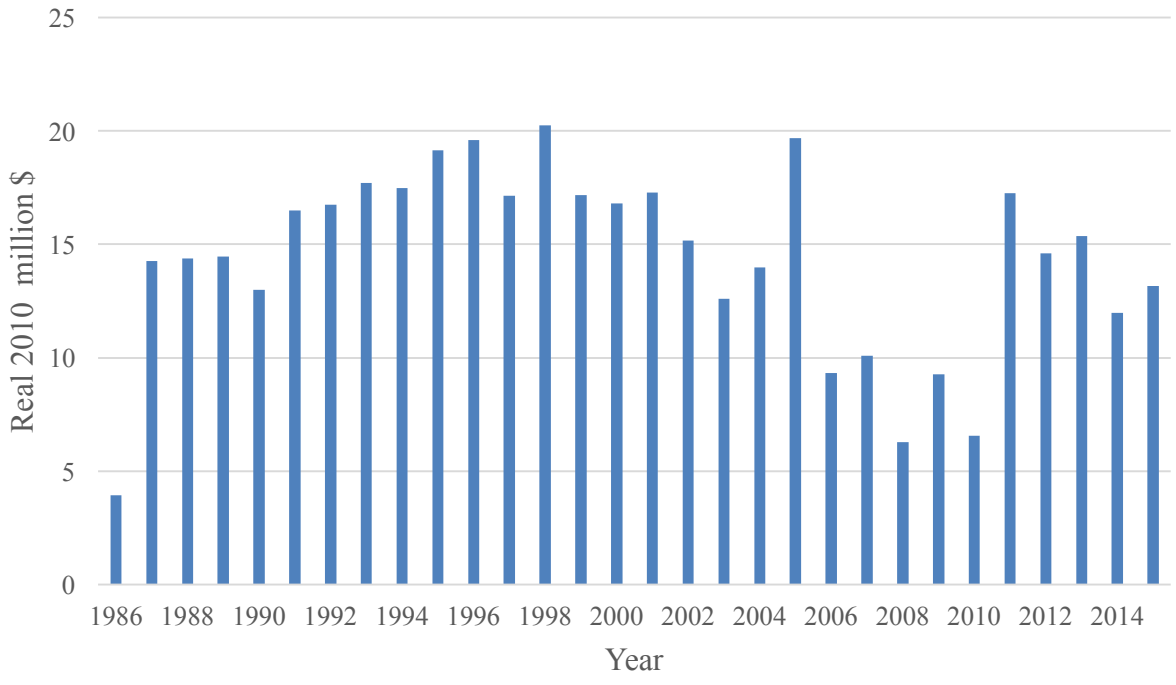
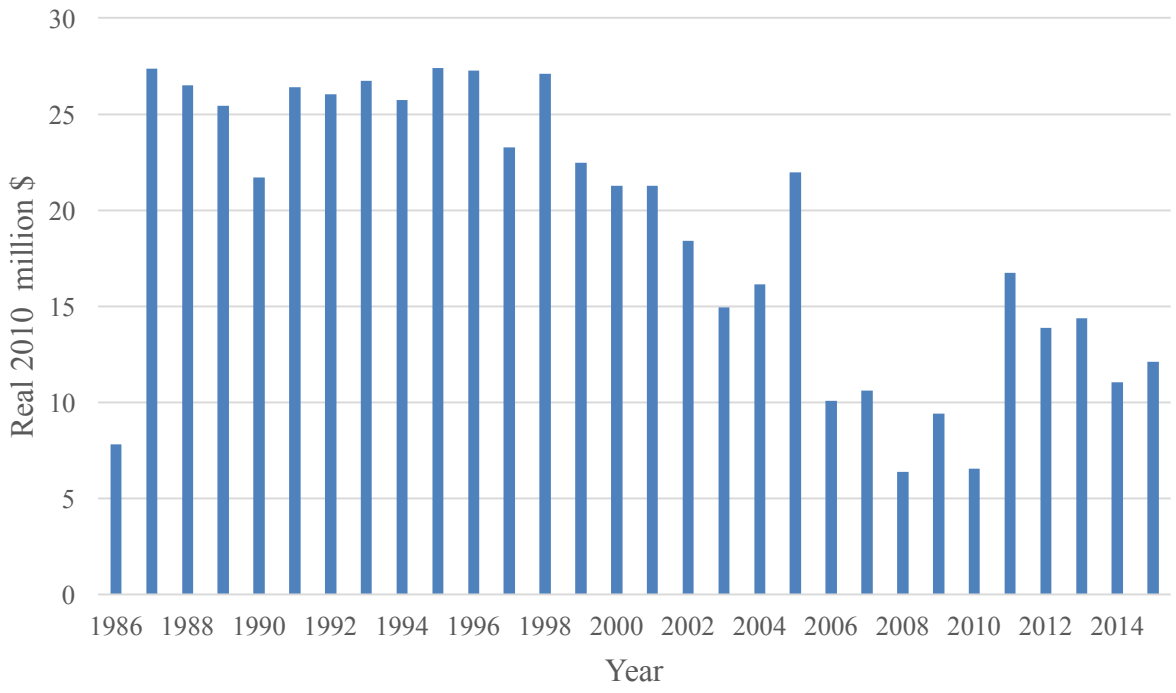


Figure 3. Real, inflation-adjusted generic pork non-advertising promotion expenditures.

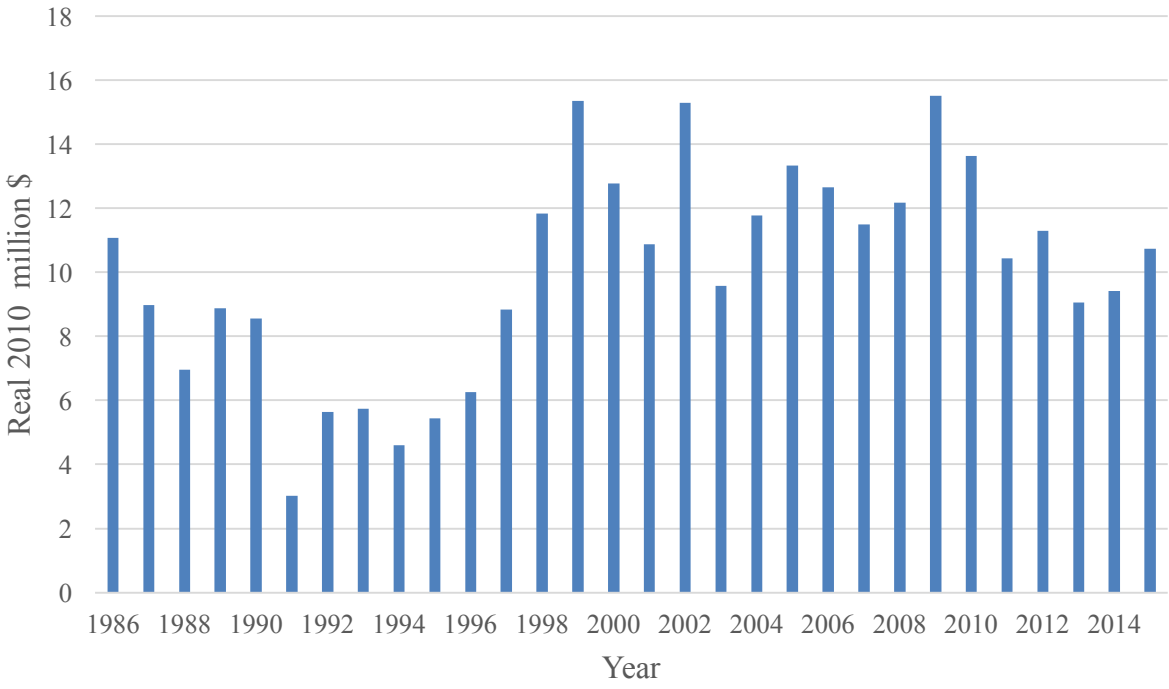


which include all non-media demand enhancing activities such as merchandising, food service marketing, consumer research, and consumer public relations. Expenditures on these activities were significantly higher in the late 1980s and 1990s. Since 2000, spending on promotion has trended downwards, however, have been on the upswing since 2010.

Over time, foreign markets have become an important source of demand for U.S. pork products. For example, in 1987 pork exports only represented 0.7% of commercial disappearance. By 2015, this figure grew to 24.3%. This growth in export demand was enhanced by the foreign market development programs of the NPB, combined with the U.S. Meat Export Federation (USMEF), and matching dollars are provided by U.S. Department of Agriculture (USDA)/Foreign Agricultural Service (FAS). Specifically, export marketing

programs are designed to stimulate export demand in important international markets for U.S. pork products including Japan, Mexico, South Korea, China, Taiwan, Southeast Asia, Russia, Central Europe, and Latin America. Figure 4 presents total expenditures on pork foreign market development by the NPB, the U.S. Meat Export Federation, and the USDA/FAS. Combined foreign market development expenditures have increased steadily over time, increasing from just under $9 million in 1987 to $11 million in 2015. Since 2009, export marketing expenditures have declined by 23.5%.

Figure 4. Real, inflation-adjusted NPB, USMEF, and government pork export promotion expenditures.



NPB-sponsored production-level research has steadily grown in importance over time, as depicted in Figure 5. This type of research is designed to improve farm efficiency and lower

costs in hog production, and producer education to raise the level of expertise of hog producers. In 1987, around $0.5 million was spent on this research. By 2015, this grew to almost $17 million.

NPB-sponsored research on pork products has been more sporadic over time, as shown in Figure 6, but has been trending upwards. This category of research includes new pork product design and development, as well as market chain research designed to improve the efficiency of pork processing. In 1987, there were no funds allocated to pork product research, but by 2015 there was over $3 million spent.

Figure 5. Real, inflation-adjusted Pork Checkoff Program expenditures on production-level research.

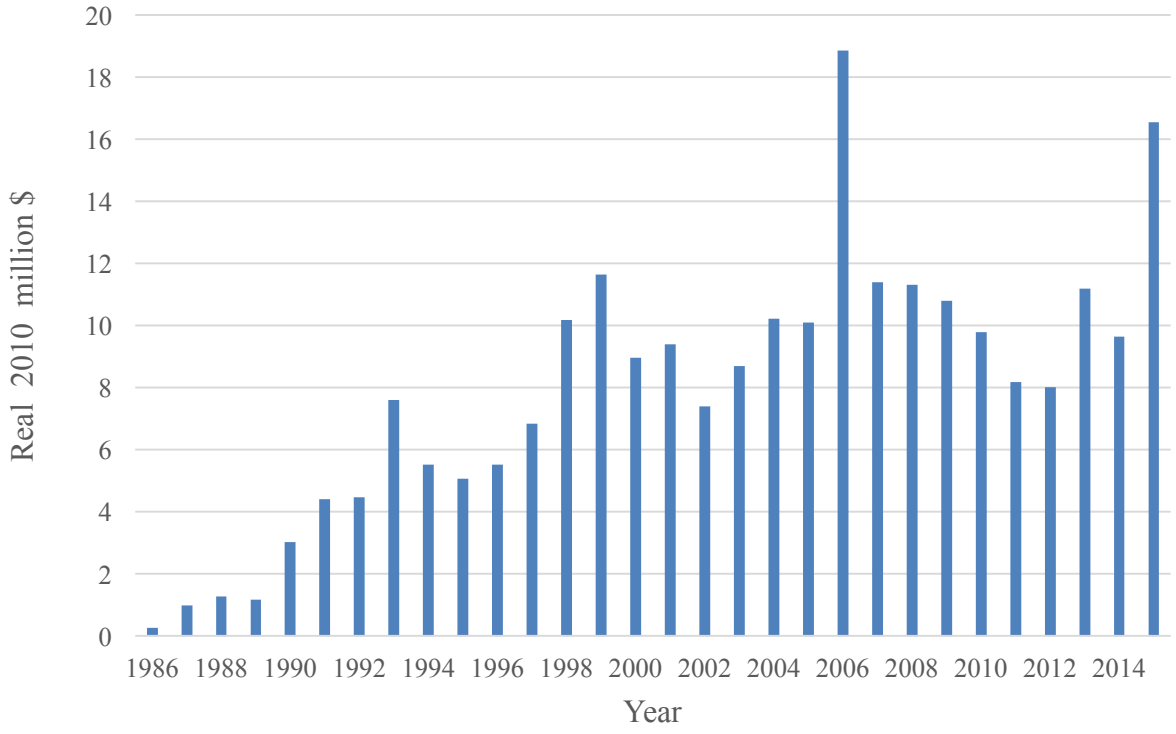
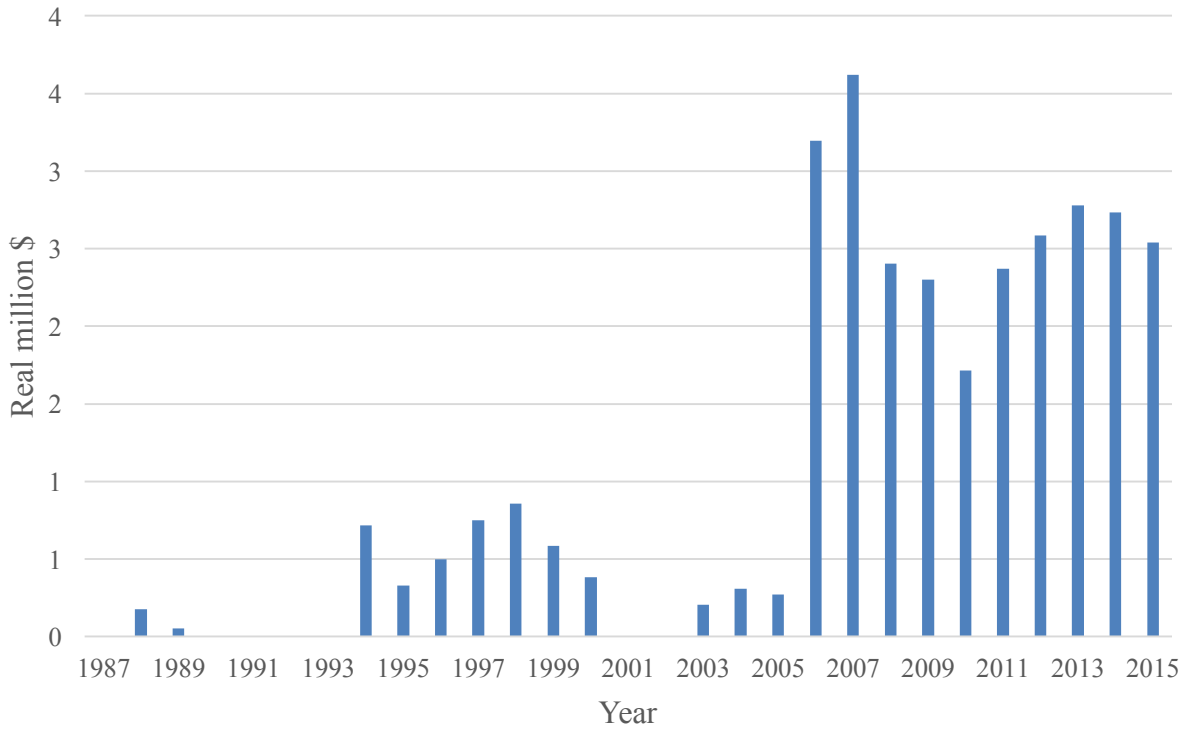


Figure 6. Real, inflation-adjusted PCP demand enhancing research expenditures.



Methodology

This study quantifies the relationship between the advertising, promotion, and research efforts of the NPB and the domestic and international demand and supply for hogs and pork. Several econometric models are estimated. The econometric approach quantifies economic relationships using economic theory and statistical procedures with data. It enables one to simultaneously account for the impact of a variety of factors affecting demand and supply for a commodity. By casting the economic evaluation in this type of framework, one can filter out the effect of other factors and, hence, quantify directly the net impact of the NPB's activities on hog and pork demand and supply.

The four econometric equations to be estimated include: (1) retail domestic pork demand, (2) retail domestic pork supply, (3) U.S. pork export demand, and (4) commercial farm pork supply. The model also includes two equilibrium conditions requiring retail domestic and international demand to equal retail domestic supply, and a farm-to-retail conversation equation to assure that farm supply is equal to domestic and international demand. The four econometric equations are used to test whether various activities by the NPB such as advertising, export market development and promotion activities, production research, and post-farm gate research have a statistically significant impact on demand and supply.

To compare the relative importance of each factor on pork demand or supply, the results from the econometric model are converted into "elasticities." An elasticity measures the percentage change in pork demand or supply given a 1% change in a specific demand or supply factor, holding all other factors constant. For example, the computed own price elasticity of demand measures the percentage change in pork quantity demanded given a 1 percent change in price, holding constant all other pork demand determinants. Since elasticities are calculated for each demand and supply factor in each model, one can compare them to determine which factors have the largest impact on pork demand and supply.

Retail Pork Demand and Supply

The domestic demand equation for pork is estimated with retail per capita consumption as the dependent variable measured in pounds for each calendar year from 1976 through 2015. The following demand determinants are included to ascertain their impacts on annual domestic pork demand:

1. Retail price for pork products ($/cwt.),

2. Retail price for beef products ($/cwt.),
3. Retail price for broilers ($/cwt.),
4. Per capita disposable income,
5. Time trend,
6. Generic pork advertising expenditures,
7. Generic pork non-advertising promotion expenditures,
8. Demand-enhancing research expenditures by the pork checkoff program.

Mathematically, the pork domestic demand model is represented by the following equation:

$$\ln(PCCON_t) = \beta 0 + \beta 1 \ln(PPORK_t/CPI_t) + \beta 2 \ln(PBEEF_t/CPI_t) + \beta 3 \ln(PBROIL_t/CPI_t) + \beta 4 \ln(PCINC_t/CPI_t) + \beta 5 \ln(TREND_t) + \beta 6 \ln (PADV_{t-n}) + \beta 7 \ln (PROM_t) + \beta 8 \ln (DRES_{t-n})$$

where: $PCCON_t$ is per capita pork domestic consumption year t, $PPORK_t$ is retail price for pork products in year t, CPI_t is the retail consumer price index for all items in year t, $PBEEF_t$ is retail price for beef products in year t, $PBROIL_t$ is the retail price for broiler products in year t, $PCINC_t$ is per capita disposable income in year t, $TREND_t$ is a linear trend term in year t, $PADV_{t-n}$ is generic pork advertising in year t, year t-1, and so on, $PROM_t$ is generic pork non-advertising promotion in year t, and $DRES_{t-n}$ is pork checkoff program sponsored demand enhancing research in year t, year t-1, and so on. In this equation, "ln" is the natural logarithmic operator, and the βs are the coefficients to be estimated with statistical regression analysis. All monetary variables such as PPORK, PBEEF, PBROIL, PCINC, PADV, PROM, and DRES are deflated by the retail consumer price index for all items to account for the effects of inflation over time. Hence, all monetary variables are expressed on a "real", inflation adjusted, rather than nominal basis. All variable definitions for the econometric model are listed together in Appendix Table 1.

The retail price for pork products is expected to be negatively related pork demand, i.e., a lower price results in higher quantity demanded reflecting the law of demand. The retail prices for beef and broiler products are included because they represent the most important substitute products for pork. The relationship between PCCON and PBEEF (and PBROIL) is expected to be positive because beef and broilers are substitutes for pork. The relationship between per capita income pork demand is expected to be positive, i.e., as consumers become wealthier, the demand for pork should increase. The time trend term is included to capture changes in consumer preferences for pork over time.

The last three variables in the model are pork checkoff program activities. Generic pork advertising is expected to have a positive impact on per capita pork demand. Generic advertising is measured by NPB expenditures on media advertising. It is well documented in the literature that advertising has a "carry-over effect" on demand, i.e., past, as well as current advertising has an effect on current demand. To deal measure this carry-over effect, a lag specification begins with expenditures from one years ago, two years ago, and so on is estimated and the model with the best statistical fit is chosen as the final model. As was the case in the last evaluation of the pork checkoff program, the best model uses advertising expenditures lagged two years.

Generic pork non-advertising promotion is expected to have a positive impact on pork demand, but unlike advertising, only current promotion expenditures are included as no carry-over effect is detected in several specifications. That is, the impacts of pork non-advertising promotion are more immediately felt and not as long-lasting as advertising. This may be true because advertising is more "informational" in nature while non-advertising promotion activities are aimed at more instantaneous purchases of the products via discounts, etc.

Finally, NPB expenditures on pork demand enhancing research are included, and are expected to have a positive impact on pork demand. Because research is expected to have a lagged effect before it is felt, a lag specification begins with expenditures from two years ago, three years ago, and so on, and the model with the best statistical fit is chosen as the final model. The best model uses demand enhancing research expenditures lagged four years.

In addition to the retail pork demand model, a retail pork supply model is estimated. This model is represented mathematically by the following equation:

$$\ln(RSUP_t) = \eta 0 + \eta 1 \ln(PPORK_t/HOGP_t) + \eta 2\ TREND_t + \eta 3 \ln(RSUP_{t-1})$$

where: $RSUP_t$ is total retail supply of pork in year t, $PPORK_t$ is retail price for pork products in year t, $HOGP_t$ is the hog price in year t, and $TREND_t$ is a linear time trend variable for year t to measure technological progress in the pork retail sector over time. In this equation, "ln" is the natural logarithmic operator, and the ηs are the coefficients to be estimated with statistical regression analysis. The output-input price ratio ($PPORK_t/HOGP_t$) is expected to be positive reflecting the law of supply. The trend variable is also expected to be positive since it is capturing technological growth in the retail supply chain, which has a positive impact on supply. Retail pork supply, lagged one year, is also included in the model to represent capacity constraints in pork retailing from one year to the next.

The following data sources were used for the variables in the model: PCCON, PPORK, CPI, PBEEF, PBROIL, PCINC, RSUP, and HOGP come from the Livestock Marketing Information Center, PADV, PROM, and DRES come from the National Pork Board.

Econometric Results. The retail pork demand model is estimated in logarithmic form with annual data from 1976 through 2015. The elasticities are summarized in Table 1. The R-squared indicates that the explanatory variables explain 86% of the variations in annual per

capita demand for U.S. pork. The elasticity signs are consistent with economic theory and all estimated coefficients (except the broiler prices) are statistically significant at the 1% significance level or better. The broiler price is not statistically significant and therefore omitted from the model. Several econometric diagnostic tests performed indicate no statistical problems with the model.

Table 1. Retail pork demand elasticities.

Demand Factor	Elasticity	P-value
Retail pork price	-0.411	0.000
Retail beef price	0.120	0.009
Per capita disposable income	0.537	0.000
Time trend	-0.367	0.000
Generic pork advertising	0.034	0.000
Generic non-advertising promotion	0.026	0.001
Demand-enhancing research	0.003	0.000
R-Square	0.86	

The estimated own price elasticity is negative and equal to -0.411. The interpretation of this is a 1% increase in the retail pork price, holding all other demand factors constant, leads to a 0.411% decrease in per capita pork quantity demanded. As expected, beef is found to be a substitute for pork with an elasticity of 0.12. That is, a 1% increase in the beef price, holding all other demand factors constant, results in a 0.12% increase in pork demand. Both the own and cross price elasticities of demand are inelastic indicating that U.S. consumers are not very sensitive to small price changes when making their purchase decisions. This result is common in the food and agricultural economics literature.

Per capita disposable income has a positive impact on pork demand, indicating that pork

is what economists refer to as a "normal good, " i.e., demand increases as consumer income increases. Indeed, the estimated income is the most important driver of per capita pork consumption with an estimated income elasticity of 0.537. That is, a 1% increase in per capita income results in a 0.537% increase in per capita pork demand, holding constant all other demand factors.

The statistical results indicate that all three pork checkoff program demand enhancing activities have a positive and statistically significant impact on increasing pork demand. Generic pork advertising has a two-year carry over effect with an elasticity of 0.034. The estimated non-advertising promotion elasticity is 0.026 meaning a 1% increase in non-advertising promotion expenditures results in a 0.026% increase in per capita pork demand. Finally, demand enhancing pork research is found to have a lagged effect of four years, i.e., research four years ago has a significant impact on today's pork demand. Specifically, a 1% increase in demand enhancing research increases per capita pork demand by 0.003% holding all other factors constant.

Because there is error inherent in any statistical model, a 99% confidence interval is computed for the three pork checkoff program elasticities. This interval can be interpreted as the range of possible values where one can be confident that the true population elasticity could be expected to fall 99% of the time. The 99% confidence interval for the generic pork advertising elasticity is (0.012, 0.056). The 99% confidence interval for the generic pork non-advertising promotion elasticity is (0.003, 0.048). The 99% confidence interval for the demand enhancing research elasticity is (0.0008, 0.005). Because the lower bound estimates of the elasticities of all three NPB activities are greater than zero, this adds credence to the conclusion that the NPB activities have had a positive and statistically significant impact on pork demand.

The retail pork supply model is estimated in logarithmic form (except for the TREND

term) with annual data from 1976 through 2015. The elasticities are summarized in Table 2. The R-squared indicates that the explanatory variables explain 90% of the variations in annual retail supply of U.S. pork. The elasticity signs are consistent with economic theory and all estimated coefficients are statistically significant at the 1% significance level or better. Several econometric diagnostic tests performed indicate no statistical problems with the model.

Table 2. Retail pork supply elasticities.

Supply Factor	Elasticity	P-value
Retail pork price	0.078	0.003
Hog price	-0.078	0.003
Time trend	0.004	0.000
Retail pork supply in the previous year	0.373	0.002
R-Square	0.90	

Since an output (pork price) to input (hog price) ratio is specified, the own price elasticity and the input price elasticity are the same in absolute value. The results indicate that the own-price elasticity of supply is 0.078, which is inelastic. It is not at all surprising that this elasticity is so small given that the retail market does not influence the supply of pork as much as the farm hog market. That is, holding all other supply factors constant, a 1% increase in the retail pork price results in a 0.078% increase in quantity supplied by pork retailers. The impact of the hog price is exactly the negative of the retail price impact. The trend variable is positive and statistically significant, which has had a positive impact on retail pork supply. Finally, retail supply in the previous year is positive and statistical significant; a 1% increase in the previous year's supply increases current year pork supply by 0.373% holding all other supply factors constant.

Pork Export Demand Model

An export demand equation for U.S. pork is estimated with exports of U.S. pork as the dependent variable. U.S. exports are measured on a quantity basis (million pounds) for each calendar year from 1984 through 2015.[2] The following export demand determinants are included to ascertain their impacts on annual pork export demand:

1. Unit value (price) of annual pork exports from the U.S. in dollars per pound,
2. Unit value (price) of annual pork exports from all other countries in dollars per pound,
3. Average annual world (net of U.S.) GDP,
4. Annual exchange rate per U.S. dollar for U.S. agricultural trade constructed by the Economic Research Service, USDA,
5. U.S. pork exports lagged one year,
6. Total annual foreign market development expenditures (USMEF, USDA/FAS, and NPB combined).[3]

Mathematically, the pork export demand model is represented by the following equation:

$$\ln(X_t) = \alpha 0 + \alpha 1 \ln(USP_t/WCPI_t) + \alpha 2 \ln(ROWP_t/WCPI_t) + \alpha 3 \ln(GDP_t/WCPI_t) + \alpha 4 \ln(ER_t) + \alpha 5 \ln(X_{t-1}) + \alpha 6 \text{ PDL } \ln(ER((FAS_t+NPB_t+USMEF_t))/WCPI_t)$$

where: X_t is U.S. pork exports year t, USP_t is U.S. unit value of pork exports in year t, $WCPI_t$ is the world consumer price index in year t, $ROWP_t$ is the unit value of all non-U.S. pork exports (rest-of-the-world) in year t, GDP_t is gross domestic product in the world net of the U.S. in year t, ER_t is the U.S. agricultural trade exchange rate constructed by the Economic Research Service, USDA in year t, and FAS_t, NPB_t, $USMEF_t$ are FAS, NPB and USMEF foreign market

[2] A more recent time period is used compared to the other equations because of difficulty obtaining foreign market development data prior to 1984.

[3] Expenditures by USMEF, NPB and FAS are used for a variety of activities in foreign markets designed to enhance U.S. export meat demand including advertising, promotion, trade servicing, technical assistance, and other activities. In this report, I use the term "foreign market development" as short hand for all these activities.

expenditures in year t. In this equation, "ln" is the natural logarithmic operator, PDL is a polynomial distributed lag term, and the αs are the coefficients to be estimated with statistical regression analysis. All monetary variables such as USP, ROWP, GDP, and foreign market development expenditures are deflated by the world consumer price index to account for the effects of inflation over time. Hence, all monetary variables are expressed on a "real", inflation adjusted, rather than nominal basis.

The U.S. pork price is computed as the total value of exports divided by the total quantity of exports and come from the Livestock Marketing Information Center. Hence, price is computed as a unit value measure and reflects the overall category including muscle cuts, variety meats and processed pork products. The U.S. price is expected to have a negative impact on imports of U.S. pork, i.e., a lower U.S. price increases the quantity demanded of U.S. pork imports reflecting the law of demand. The ROWP is also computed as a unit value for all "pork meat" exports from the world excluding the U.S. These data come from the USDA Global Agricultural Trade System (GATS) data set. The export price of all competing countries is included because these countries are the other source for pork exports in the foreign markets and the chief competitors to U.S. pork. The relationship between the ROW price and the export demand for U.S. pork is expected to be positive because ROW pork is a close substitute with U.S. pork.

The relationship between GDP and the demand for U.S. pork is expected to be positive, i.e., as countries become wealthier, the demand for U.S. pork should increase. The exchange rate (ER) has been shown to be an important determinant of the demand for U.S. exports. The relationship between ER and the export demand for U.S. pork is expected to be negative. As the U.S. dollar becomes cheaper, U.S. pork becomes relatively less expensive and hence export

demand increases. Exports, lagged one year, are included as an explanatory variable to reflect rigidities in international markets, i.e., exports last year should be correlated with exports this year.

This analysis combines USDA/FAS with NPB and USMEF expenditures to measure the total foreign market development impact. Market promotion activities have a carry-over effect. To capture this carry-over effect, current and lagged foreign market development expenditures are included in the model.[4] Similar to Dwyer (1995), foreign market development expenditures are multiplied by the exchange rate variable, ER, to reflect the impact of the relative value of the dollar on promotion effectiveness. This variable is then deflated by dividing it by the world price deflator so that foreign market development expenditures are expressed in real, inflation adjusted terms.

The following data sources are used for the variables: the quantity U.S. pork exports come from Livestock Marketing Information Center. GDP, ER, and WCPI come from the international macroeconomic data set of the Economic Research Service, USDA. Annual pork USDA/FAS, NPB, and USMEF export promotion expenditures come from FAS, NPB, and USMEF.

Econometric Results. The export demand model is estimated in logarithmic form with annual data from 1984 through 2015. The elasticities are summarized in Table 3. The R-squared indicates that the explanatory variables explains 99% of the variations in export demand for U.S. pork. The elasticity signs are consistent with economic theory and all estimated coefficients are statistically significant at better than the 1% significance level. Several econometric diagnostic tests performed indicate no statistical problems.

[4] Specifically, the model is specified as a second-degree polynomial distributed lag with both end point restrictions imposed. Various lag lengths are run, and a specification of current and three years of lags on foreign market development expenditures results in the best model.

Lagged exports are a significant determinant of current exports. The estimated elasticity for lagged exports is 0.651 indicating a 1% increase in last year's U.S. pork exports increases this year's exports by 0.651% holding all other factors constant.

The prices of U.S. and ROW pork are also significant factors in explaining annual variations in exports of U.S. pork. The estimated own-price elasticity is -0.675 indicating that a 1% increase in the U.S. pork price decreases U.S. pork exports by 0.675%. The elasticity of exports of U.S. pork with respect to ROW prices is 0.264.

The value of the U.S. dollar has the most important impact on export demand. The elasticity estimate is -1.532. That is, a 1% increase in the value of the U.S. dollar decreases exports of U.S. pork by 1.532%, holding all other demand determinants constant.

Table 3. Pork export demand elasticities.

Demand Factor	Elasticity	P-value
Exports lagged one year	0.651	0.000
U.S. price	-0.675	0.010
Rest of world price	0.264	0.003
Rest of world GDP	0.411	0.095
U.S. weighted exchange rate	-1.532	0.003
Pork foreign market development	0.288	0.000
R-Square	0.99	

World GDP net of U.S. GDP is positive indicating that U.S. pork is a normal good. The elasticity for GDP is 0.411. In other words, holding all other demand factors constant, a 1% increase in world GDP results in a 0.411% increase in pork exports of U.S.

The statistical results indicate that U.S foreign market development programs have the effect of increasing the export demand for U.S. pork. The model indicates that there is a three-year carry-over effect of foreign market development. That is, current as well as three years of

lagged foreign market development expenditures impact U.S. pork exports. The estimated results indicate that a 1% increase in foreign market development expenditures increase U.S. pork exports by 0.288%.

Because there is error inherent in any statistical model, a 99% confidence interval is computed for the foreign market development elasticity. This interval can be interpreted as the range of possible values where one can be confident that the true population promotion elasticity could be expected to fall 99% of the time. The 99% confidence interval for the elasticity is (0.139, 0.437).

Hog Supply Model

U.S. hog production is measured on a quantity basis (million pounds, carcass basis) for each calendar year from 1976 through 2015. Of key interest here is the impact of production-research expenditures sponsored by the NPB on hog production. If the production-level research is effective, it should have the results of improving yields and thereby increasing supply.

The following supply determinants are included to ascertain their impacts on annual hog supply:

1. Expected price of hogs measured on a per cwt. basis,
2. Total production costs,
3. Lagged expenditures on production research by the NPB,
4. Production lagged one year.

Mathematically, the hog supply model is represented by the following equation:

$$\ln(FSUP_t) = \gamma 0 + \gamma 1 \ln (HOGP_{t-1}/CPI_{t-1}) + \gamma 2 \ln(COST_{t-1}/CPI_{t-1}) + \gamma 3 \ln(RES_{t-n}/CPI_{t-n}) + \gamma 4 \ln (FSUP_{t-1})$$

where: $FSUP_t$ is U.S. hog production in year t, $HOGP_{t-1}$ is the hog price in the previous year t-1, CPI_t is the consumer price index for all items, $COST_{t-1}$ is total costs in year t-1, $TREND_t$ is a linear trend term, and RES_{t-n} are lagged values of NPB expenditures on production-level research. In this equation, "ln" is the natural logarithmic operator, and the γs are the coefficients to be estimated with statistical regression analysis. All monetary variables are deflated by the CPI for all items and therefore reflected in real, inflation adjusted terms.

Farm supply in the previous year ($FSUP_{t-1}$) is included to capture biological constraints on production from year to year. It is assumed that hog producers have naive price expectations, where the expected price is a function of the price in the previous year. Total costs of producing feeder pigs and the costs of finishing those pigs are used as the measure of production costs, which impact the supply curve. A negative relationship is expected since increases in costs discourage increases in supply. Both current and one-year lagged costs are initially specified, and the final model includes costs lagged one year. This indicates that there is a one year lagged response between production output decisions in response to costs, which is not uncommon in livestock industries where there are lags between planned and realized output.

The impact of NPB production-level research is hypothesized to have a positive, but delayed effect on supply. This type of research should have a positive effect on supply as it is designed to decrease farm costs and improve managerial ability. It takes time to do research, and the impact of research on actual production is often not felt for years. To measure this time effect, a lag model is used with a host of alternative lag lengths. The final model included NPB research expenditures lagged two years. The 2007 RTI found a three-quarter lag impact of production-level research on hog supply, which is slightly shorter than the findings here. The

relatively short duration found in both studies may be due to the following explanation summarized in the Beach et al. (2007) study:

> "As with post-farm 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." (Research Triangle, Inc., 2007, page 5-20).

The following data sources were used for the variables: commercial hog production and the hog price came from Livestock Marketing Information Center. COST came from the Iowa State University "Estimated Costs and Returns Series." The source of the data is http://www.econ.iastate.edu/estimated-returns/. The production-level research expenditures came from the NPB.

Econometric Results. The hog supply model is estimated in logarithmic form with annual data from 1976 through 2015. The elasticities are summarized in Table 4. The R-squared indicates that the explanatory variables explain 95% of the variations in farm supply for U.S. hogs. The elasticity signs are consistent with economic theory and all estimated coefficients, except for the trend term, are statistically significant at better than the 10% significance level. Several econometric diagnostic tests performed found no statistical problems.

The expected price is positive and statistically significant from zero. The own-price elasticity is equal to 0.1, i.e., a 1% increase in price this year, holding all other supply factors constant, results in a 0.1% increase in hog quantity supplied next year. The elasticity of hog supply with respect to total production costs is -0.089. That is, a 1% increase in costs this year results in a 0.089% decrease in hog supply next year. Supply lagged one year has a very large

positive effect on supply in the current year. Specifically, a 1% increase in hog supply in the previous year causes a 0.981% increase in supply in the current year. This is not surprising given the reproductive life cycle of hogs.

The statistical results indicate that NPB-sponsored production-level research has a positive and statistically significant impact on hog supply. The elasticity for production research is 0.010. That is, a 1% increase in research expenditures results in a 0.010% increase in hog supply over four-years. The 99% confidence interval for the production-level research elasticity is (-0.008, 0.028).

Table 4. Commercial hog supply elasticities.

Supply Factor	Elasticity	P-value
Supply lagged one year	0.981	0.000
Expected price	0.100	0.004
Total production costs	-0.089	0.017
Production research	0.010	0.062
R-Square	0.95	

Equilibrium Displacement Model

This study uses an equilibrium displacement model (EDM) to simulate the impacts of the NPB on domestic and international markets.

The net benefits of each of the five NPB activities are measured through simulation of the EDM using a marginal analysis. That is, the endogenous variables in the model such as prices and quantities are simulated under two scenarios: (1) baseline scenario where all exogenous variables (e.g., NPB expenditures) are set equal to historical levels, and (2) counterfactual scenario, where NPB expenditures are increased by 1% above their historical levels. The

differences between the two scenarios determine the impacts of a 1% increase in expenditure levels on prices, quantities, and producer profits (producer surplus). Producer surplus is a measure used by economists that is similar to profitability or net revenue. Technically, it is defined as the total revenue (price times quantity sold) minus the area of the supply curve under the price. To compute the corresponding marginal benefit-cost ratio (BCR), the increase in producer surplus due to the 1% simulated increase in NPB expenditures was divided by the 1% increase in costs.

The EDM consists of several equations and endogenous variables as follows (for simplicity, the only exogenous variables presented are for the five NPB activities):

(1)	Qrd = f(PPORK | PADV, PROM, DRES)	Retail pork demand
(2)	Qrs = f(PPORK)	Retail pork supply
(3)	Qx =f (USP | FAS+NPB+USMEF)	Export pork demand
(4)	Qfs = f(HOGP*(1-t) | FRES)	Farm supply
(5)	USP = f(PPORK)	Export price-retail price linkage
(6)	Qrs = Qrd + Qx	Market clearing condition
(7)	Qfs = δ Qrs	Farm to retail conversion

where the seven endogenous variables are defined as follows: Qrd is retail pork demand, Qrs is retail pork supply, PPORK is retail price for pork, Qx is export pork demand, USP is the U.S. unit value (export price) for pork exports, Qfs is commercial farm pork supply, and HOGP is the farm hog price. The exogenous variables are defined as follows: PADV is pork advertising expenditures, PROM is pork non-advertising promotion expenditures, DRES is demand-enhancing pork product research expenditures, FAS+NPB+USMEF is total expenditures on foreign market development, FRES is farm-level, production research expenditures by the NPB, t is the assessment rate for the NPB, and δ is a conversion factor from farm to retail quantity. The EDM transforms these seven equations by taking the logarithmic differential of each

equation, setting them equal to zero, and then solving the seven equations for the seven endogenous variable values.

The EDM is a static model that assumes instantaneous adjustment. The crucial parameters to the model are the own price elasticities of demand and supply and the elasticities for the five NPB activities. In the EDM, the estimated coefficients from the econometric model are used. For variables that had a carry-over effect such as advertising and research, the sum of the current and lagged coefficients are used.

The EDM is simulated for the most recent 10-year period, 2006-2015. The focus here is on computing a marginal BCR, which is based on a small change (1%) between two equilibrium levels. As argued in the Beach et al. (2007) study, "with declining marginal returns to research and promotion, these estimates of marginal returns can be considered conservative lower bounds for the point estimates of historic average returns that have been generated by the Pork Checkoff Program." Hence, these estimates can be thought of as a lower bound on the true average impacts.

Simulation Results

Based on the econometric parameters and the EDM, it is clear that the NPB activities have impacted both prices and quantities in the market over the time period 2006-2015. Table 5 presents the marginal impacts of a 1% increase of the NPB activities on key market variables. Foreign market development is found to have the largest impact on the farm-level hog price, a 1% increase in advertising increases the hog price by $0.0295 per cwt., holding all other factors constant. Advertising and non-advertising promotion have the second and third largest impact. Specifically, a 1% increase in advertising and non-advertising promotion increases the hog price

by $0.013 per cwt. and $0.0099 per cwt., respectively. Demand enhancing research has the fourth largest impact of the hog price; a 1% increase in demand enhancing research increases the hog price by $0.0011 per cwt. Since farm production research increases supply, it has the impact of reducing the hog price. A 1% increase in this activity decreases the hog price by $0.0473 per cwt. holding constant all other factors. Collectively, a 1% increase in all five activities results in a $0.0061 per cwt. increase, holding all other factors constant.

All five NPB activities have positive impacts on commercial hog production. As expected, farm production research has the largest impact; on average over this period, a 1% increase in NPB-sponsored production research increases hog production by almost 1.2 million pounds per year, holding all other variables constant. A 1% increase in foreign market development increases production by approximately 660,000 pounds per year. A 1% increase in generic pork advertising and non-advertising promotion increases production by 289,701 pounds and 221,536 pounds, respectively per year. Demand enhancing research has the smallest impact on hog production. A 1% increase in all five NPB activities combined increases hog production by almost 2.4 million pounds per year.

All five NPB activities benefit hog producers in terms of increasing producer surplus. Even though farm production research decreases the hog price, it has the largest positive impact on producer surplus of all five activities. A 1% increase in farm production research increases producer surplus by $10.76 million per year, holding all other factors constant. Foreign market development has the next highest impact on producer surplus. A 1% increase in this activity results in a $3 million per year increase in producer surplus. A 1% increase in advertising and non-advertising promotion results in respectively a $2.95 million and $2.25 million per year

increase in producer surplus. Finally, demand enhancing research has the smallest impact; a 1% increase in this activity leads to a $242,694 increase in producer surplus.

Table 5. Marginal impacts of NPB activities on price, production, and producer surplus.

Pork Checkoff Program Activity	Change in farm hog price ($/cwt. 2010 dollars)	Change in farm commercial production lbs	Change in producer surplus (2010 dollars)
Pork advertising	0.0130	289,701	2,947,013
Pork non-advertising promotion	0.0099	221,536	2,253,595
Foreign market development	0.0295	660,198	3,022,188
Farm production research	-0.0473	1,177,651	10,761,272
Demand enhancing research	0.0011	23,858	242,694
All five expenditure categories combined	0.0061	2,372,944	19,226,761

How do these marginal benefits compare with the marginal costs? To answer this question, the following benefit-cost ratio is computed for each NPB activity:

$$BCR = \Delta PS/\Delta Costs$$

where: ΔPS is the change in producer surplus (i.e., industry-wide profits to hog producers) associated with the 1% increase in the NPB activity, and $\Delta Cost$ is the respective change in cost. Overhead for administering the NPB is incorporated in the costs by increasing each activity expenditures by 12.7%, which is the overall average overhead associated with the NPB.

Table 6 presents the marginal BCRs for the five activities and the overall combined return. In the right-most column, the estimated marginal BCRs from the previous report by Kaiser (2012) are also listed. The highest marginal BCR is for production research. Based on the period 2006-2015, an extra dollar invested in production research yields $83.30 in producer surplus. The next highest return is for foreign market development, where an extra dollar

invested yields $24.70 in producer surplus. Generic pork advertising and non-advertising promotion have marginal BCRs of 14.2 and 12.4, respectively. Finally, demand enhancing research has a marginal BCR of 8.3. Collectively, the overall marginal BCR for all five activities is $25.50 for an additional dollar invested in the NPB. The overall BCR is higher than the Beach et al. (2007) study, which found an overall BCR of 13.8, and higher than the 2012 (Kaiser) study that found an overall BCR of 17.4.

All of these figures presented are "point estimates," which are estimates rather than exact measures. That is, there is uncertainty about the precision of these estimates and therefore it is useful to construct confidence intervals around these point estimates. The confidence intervals give a lower and upper bound to the point estimate where one can be reasonable confidant that the true measurement lies. It is especially important to estimate the lower bound confidence interval for the BCR, which is done and the results are presented in Table 7.

Table 6. Marginal benefit-cost ratio by NPB activity.

Pork Checkoff Program activity	Current study marginal BCR	2012 Study marginal BCR
Pork advertising	14.2	18.0
Pork non-advertising promotion	12.4	2.6
Foreign market development	24.7	19.1
Farm production research	83.3	52.4
Demand enhancing research	8.3	3.0
All five expenditure categories combined	25.5	17.4

The lower bound of the 99% confidence interval for the marginal BCR for all five NPB activities combined is 3.7, which is well above 1.0. Hence, one can be reasonable assured that an extra dollar invested in the NPB would return greater than one dollar in producer surplus to the industry. In fact, all the NPB, except farm production research, have lower bound marginal

BCRs greater than 1.0. This finding gives credence to the conclusion that the NPB has been profitable to hog producers over this period.

Table 7. Lower bound for 99% confidence interval for marginal BCRs.

Pork Checkoff Program Activity	Marginal benefit-cost ratio
Pork advertising	5.0
Pork non-advertising promotion	1.4
Foreign market development	11.9
Farm production research	0.0
Demand enhancing research	2.4
All five expenditure categories combined	3.7

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Appendix Table 1. Definition of all variables in the econometric model.

PCCON = Per capita pork consumption,
PPORK = Retail price for pork products,
CPI = Consumer price index for all items,
PBEEF = Retail price for beef products,
PBROIL = Retail price for broiler products,
PCINC = Per capita disposable income,
TREND = time trend variable, 1976=1, 1977=2,…,
PDL = Polynomial distributive lag,
PADV = Generic pork advertising expenditures,
PROM = Generic non-advertising pork promotion expenditures,
DRES = Pork demand research expenditures,
RSUP = Retail pork supply,
HOGP = Hog price,
X = Exports of U.S. pork,
USP = Unit value of U.S. pork exports,
WCPI = World consumer price index,
ROWP = Unit value of other country pork exports,
GDP = Gross Domestic Product of world net of U.S.,
ER = U.S. agricultural trade exchange rate constructed by the Economic Research Service,
FAS = Foreign market development expenditures by the USDA/FAS,
NPB = Foreign market development expenditures by the NPB,
USMEF = Foreign market development expenditures by the USMEF,
FSUP = Commercial farm supply,
COST = Total hog production costs,
RES = NPB expenditures on production-level research,