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Effects of Country-of-Origin Labeling on Meat Producers and Consumers

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Although several studies have estimated the costs of country-of-origin labeling (COOL), no previous study has documented how these costs will be distributed across the livestock sector or how producer and consumer welfare will be affected. This analysis presents an equilibrium displacement model of the farm, wholesale, and retail markets for beef, pork, and poultry that documents how producers and consumers will be affected by COOL. Findings reveal that as the costs of COOL are shifted from the producer to the processor and retailer, producers are made increasingly better off while consumers are made increasingly worse off. Further, an increase in *aggregate* consumer demand of 2% to 3% is likely sufficient to offset lost producer welfare due to COOL costs.

Key words: beef, country of origin, equilibrium displacement model, labeling, pork, poultry

Introduction

The 2002 Farm Security and Rural Investment Act (FSRIA) includes a provision requiring meat, fruits and vegetables, and peanuts to be labeled as to their country of origin. The original bill stipulated that the first two years of the program labeling will be voluntary, but country-of-origin labeling (COOL) will be mandatory by September 2004, with potentially hefty fines imposed on retailers who violate labeling requirements.[1] Terms of the COOL legislation stipulate:

> . . . a retailer of a covered commodity shall inform consumers, at the final point of sale of the covered commodity to consumers, of the country of origin of the covered commodity [Farm Security and Rural Investment Act of 2002, Title X, Subtitle I, Sec. 10816, Subtitle D, Sec. 282(a)(1)].

Covered commodities defined in the legislation include beef, pork, and lamb (both ground and muscle cuts), fish (both wild and farm-raised), fruits and vegetables, and peanuts. In order to receive a U.S. country-of-origin label, a livestock product must be derived from an animal that was exclusively born, raised, and processed in the United States. COOL labeling requirements are not applied to food service establishments (e.g., restaurants and cafeterias), nor do they apply to processed foods (e.g., beef in a can of beef stew).

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Review coordinated by DeeVon Bailey. Editor's note: As a result of the passage of the 2002 Farm Security and Rural Investment Act, country-of-origin labeling has emerged as an important subject of interest to researchers and policy makers. The editors have therefore chosen to publish two side-by-side articles addressing this topic (pp. 185–205 and 206–227).

[1] Ongoing legislation may change the mandatory start date for COOL to October 2006.

A number of individuals and organizations have put forth different estimates of the cost of implementing COOL and have focused primarily on the beef and/or pork sectors. These estimates vary depending on the assumptions underlying the analysis. Given that the U.S. Department of Agriculture (USDA) has not yet determined exactly how to implement mandatory COOL, it is impossible to know whose (if anyone's) assumptions are accurate. Perhaps a more significant problem with existing cost estimates for COOL is the fact that none provide insight into the impact COOL will have on meat prices and production, and ultimately on producer and consumer welfare. Further, no previous study has rigorously assessed how anticipated costs or potential benefits of COOL will be distributed among producers and consumers.

The purpose of this research is to determine how COOL affects the welfare of participants in the livestock sector. This analysis uses existing estimates of the cost of COOL to investigate the impact of these costs on producer and consumer surplus. Sensitivity analysis is used to determine how the incidence of costs (i.e., whether borne by producers or processors, or by retailers) affects the welfare of market participants. This research also investigates the degree to which consumer demand will need to increase to offset COOL costs, whether they are borne by the producer or the processor. These objectives are accomplished using an equilibrium displacement model adapted from Wohlgenant (1993).

This work represents an important extension of existing COOL studies. First, previous estimates of COOL's impact have focused on costs while ignoring the more important issue of welfare as measured by producer and consumer surplus. Simply reporting cost estimates can be misleading because costs, to some extent, can be passed through a marketing channel. The more relevant issue is how producer welfare is affected by a cost increase. Second, results of this research are not dependent on a single set of assumptions regarding the details of mandatory COOL implementation. Indeed, the impact of a number of different cost estimates—all based on different assumptions—are examined here. Finally, this study uses an equilibrium displacement model which characterizes the vertical structure of the livestock industry from producer to processor to consumer, as well as the horizontal relationship across the beef, pork, and poultry sectors. The advantage of this approach is that it reveals how the implementation of mandatory COOL in the beef and pork sectors will affect producer surplus in the poultry sector, a sector closely related to the beef and pork sectors but not required to implement COOL.

Review of Previous COOL Studies

In November 2002, the USDA's Agricultural Marketing Service (AMS) published a "Notice of Request for Emergency Approval of a New Information Collection." In this notice, AMS reported its estimate for the record-keeping costs associated with COOL. This estimate for all industries covered by COOL was \$1.968 billion. USDA/AMS estimated these costs would be distributed as follows: \$1 billion for producers, \$340 million for food handlers, and \$627.75 million for retailers.

Since the publication of the USDA/AMS cost estimate, others have developed their own estimates of the costs (both direct and indirect) associated with COOL. Notably, VanSickle et al. (2003) took exception with the USDA estimate, arguing mandatory record keeping at the producer level is not required to satisfy either the spirit or the letter of the law. They advocated labeling all imported products so that any product not labeled as an import would be assumed to be of U.S. origin. Using this assumption, VanSickle et al. estimated the record-keeping costs associated with COOL will be between $69.86 million and $193.43 million. One problem with the VanSickle et al. proposal is that it likely violates World Trade Organization guidelines and would be subject to challenge from any country claiming it was being adversely affected.

At the other end of the spectrum, a 2003 report by Sparks Companies, Inc., and *Cattle Buyers Weekly* estimated COOL will increase total costs by $3.66 to $5.60 billion dollars, not including the costs for the lamb and peanut sectors which are also covered by the COOL regulation. The Sparks estimate is based on the assumption that improved record-keeping systems will be required throughout the supply chain to verify country-of-origin labels.

Hayes and Meyer (2003) similarly concluded the costs of COOL implementation would be significant. Based on their estimates, a system with full traceability would raise farm-level production costs for pork by $10.22/head (or by a total of just over $1 billion). Hayes and Meyer also explored the potential impacts of COOL resulting from a segregated system. Assuming an own-price elasticity of pork of about −0.70, their projected $10/head increase in costs would result in a 7% decrease in retail pork demand. Further, they estimate that by 2010, U.S. pork exports could be reduced by 50% as a result of meat segregation due to COOL regulations. Grier and Kohl (2003) also predicted several negative consequences of COOL for the pork industry including the loss of over 1,000 independent pork producers, the eventual closing of three to five U.S. pork packing plants, lower hog prices, and an aggregate loss in economic activity in the United States of over $4 billion.

VanSickle et al. (2003) were decidedly more optimistic in their evaluation of the impacts of COOL. Extrapolating from willingness-to-pay estimates by Umberger et al. (2003), they calculated an "aggregate willingness to pay" in the beef industry alone of almost $3 billion. Van Sickle et al. also noted other potential benefits such as increased consumer confidence in the labeled product. Plain and Grimes (2003) questioned the relevance of using willingness-to-pay estimates to project benefits from COOL. They noted 69% to 73% of survey respondents in the study by Umberger et al. indicated a willingness to pay a premium for beef labeled as a U.S. product. They argue that since almost 90% of muscle cuts of beef and about 75% of ground beef are already of U.S. origin, consumers will not have to pay a premium for U.S. beef even though a fairly large percentage of them express a willingness to do so.

In August 2003, the U.S. General Accounting Office (GAO) concluded the USDA's initial cost estimates were too high and questioned many of the USDA's initial cost assumptions. In October 2003, the USDA released its "Proposed Rule on Mandatory County-of-Origin Labeling." In this document, the USDA estimated record-keeping costs of $582 million for the first year of development and ongoing costs of $458 million for maintenance and operation of record keeping. In addition to these direct record-keeping costs, the USDA projected additional capital costs could be as much as $3.9 billion.

As with any economic analysis, the results of existing COOL analyses depend on the underlying assumptions. Some authors estimate costs based on a fully traceable system (e.g., Sparks Companies, Inc., 2003; Hayes and Meyer, 2003), while other estimates simply report costs for a segregated system (e.g., VanSickle et al., 2003). Although COOL regulations do not require full traceability, it is possible such a system might arise to reduce liability. From the onset, the USDA has been consistent in its contention that the law would require a traceable system, a stance in accord with other USDA labeling guidelines (e.g., organic). At present, however, it is difficult to evaluate whether any given assumption is reasonable (particularly with respect to costs) since regulations have not yet been finalized and implemented. In addition, it is difficult to assess the reliability of any particular cost estimate, as most of the parties who have released cost estimates have a vested interest in the outcome of COOL. For this reason, a more flexible approach to evaluating the potential impact of COOL is needed—an approach that permits consideration of alternative assumptions. This research introduces such an approach based on the equilibrium displacement model.

The Model

An equilibrium displacement model is used to determine the effects of COOL on meat producers and consumers (Wohlgenant, 1993). In general, the model comprises horizontally linked beef, pork, and poultry demands at the retail level as well as vertical linkages between the farm, wholesale, and retail sectors. Importantly, the model permits variable proportions by incorporating the elasticity of substitution between farm and marketing inputs. The benefit of employing this model is that it provides a straightforward means of incorporating the three potential effects of COOL on meat producers: the added cost to producers, the added cost to processors and retailers, and the potential increase in consumer demand. We begin by discussing a simple one-sector model.

One-Sector Model

Although a simple one-sector model ignores important issues such as substitutability between meats at the retail level and international trade, it is included here for two reasons. First, in multiple-sector models with endogenous feedback, it can be quite difficult to analytically determine the effect of an exogenous shock on the welfare of consumers (see Alston, 1991). Because one of the primary issues associated with COOL is identifying how costs are shared across the system, we are interested in determining how the increased costs of COOL will be borne by producers *and* consumers. To accomplish this, a one-sector model is employed. Second, the simple model provides clear insight into a number of issues because analytical solutions are readily obtained and manipulated. The one-sector model is specified as:

$$\hat{Q}_i^R = \eta_{ii}(\hat{P}_i^R - \delta_i), \tag{1}$$

$$\hat{P}_i^R = S_i\hat{P}_i^F - \gamma_i, \tag{2}$$

$$\hat{Q}_i^F = -(1 - S_i)\sigma_i\hat{P}_i^F - \sigma_i\gamma_i + \hat{Q}_i^R, \tag{3}$$

$$\hat{P}_i^F = (1/\varepsilon_i)\hat{Q}_i^F - k_i, \tag{4}$$

where the superscript R denotes retail prices and quantities, the superscript F denotes farm prices and quantities, and the subscripts i denote either beef or pork, depending upon which sector is analyzed. The terms $\hat{Q}_i^j$ and $\hat{P}_i^j$ are percentage changes in quantity and price of the ith meat at the jth market level, respectively [i.e., $\hat{X} = d\ln(X) \approx dX/X$].

Demand elasticities are represented by η_{ii}, S_i is the farmers' share of the retail dollar for the ith meat in decimal form, σ_i is the elasticity of substitution between meat i and marketing inputs, and ε_i is the supply elasticity of meat i.

Equation (1) represents retail meat demand in elasticity form; equation (2) is a markup equation (or inverse retail supply curve) assuming constant returns to scale in meat processing and retailing; equation (3) represents derived demand assuming constant returns to scale in meat processing and retailing; and equation (4) is the farm-level inverse supply curve for meat i. Exogenous shocks to the system of equations are given by δ_i, γ_i, and k_i, where δ_i represents the percentage change in the initial equilibrium price for meat i due to an exogenous demand shift (e.g., the percentage increase in consumer willingness to pay for the initial quantity of meat i due to the new labeling policy). Parameters γ_i and k_i represent exogenous shocks, expressed in percentage terms, to marketing and farm supply, respectively. In the case of COOL, γ_i and k_i will be negative to represent added costs to the system. The assumptions of the model are as follows: the meat processing and retailing industries are characterized by constant returns to scale,[2] the supply curve of marketing inputs is perfectly elastic, the displacement of supply and demand curves is parallel, and all sectors are characterized by perfect competition.

Analytical solutions for changes in farm price and quantity are written as:

$$\hat{P}^{F*} = \frac{-\varepsilon k - \gamma(\eta + \sigma) - \delta\eta}{\varepsilon + \sigma(1 - S) - \eta S}, \tag{5}$$

$$\hat{Q}^{F*} = \frac{-\varepsilon\left[\delta\eta + \gamma\eta + \gamma\sigma + k(\eta S - \sigma(1 - S))\right]}{\varepsilon + \sigma(1 - S) - \eta S}, \tag{6}$$

where the subscripts denoting meat type have been dropped for convenience.[3] Given these solutions, changes in producer surplus and consumer surplus are represented by:

$$\Delta PS = P^F Q^F(\hat{P}^{F*} + k)(1 + 0.5\hat{Q}^{F*}), \tag{7}$$

$$\Delta CS = -P^R Q^R(\hat{P}^{R*} - \delta)(1 + 0.5\hat{Q}^{R*}). \tag{8}$$

Given the analytical solutions above, some key issues can now be addressed. One question often asked in the COOL debate is how consumers will respond to the new labeling policy. At present, it is clear that COOL will introduce a cost to the production system (via γ and/or k in the model). Although evidence of consumer response to the policy is sparse, one can ask how much consumer demand would have to increase to offset any producer surplus losses which would be incurred from COOL. To analytically determine this value, first note that in equation (7), changes in producer surplus can be characterized by investigating changes in $(\hat{P}^{F*} + k)$. We set ΔPS equal to zero (meaning producers, in the aggregate, are neither benefited nor harmed by COOL), use equation

[2] Although economies of scale may exist at low output levels, existing research finds either very minimal returns to scale or constant returns to scale (e.g., Hahn and Green, 2000; MacDonald et al., 1999; Morrison Paul, 2001; Thurman, 1987). Our model could be altered to incorporate returns to scale following an approach such as employed by Cranfield (2002); however, empirical evidence on the magnitude of "returns to scale" parameters would generate very similar results to the model used in our analysis.

[3] The analytical solutions presented in Wohlgenant (1993) contain typographical errors. The formulas in equations (5) and (6) are the correct solutions.

(5), and solve $(\hat{P}^{F^*} + k)$ for δ. After a bit of algebra, the change in consumer demand needed to offset COOL costs is given by:

$$\delta^* = \frac{k(\sigma(1 - S) - \eta S)}{\eta} - \frac{\gamma(\eta + \sigma)}{\eta}. \tag{9}$$

Equation (9) can be used to address several issues. First, it is apparent that if $\sigma = 0$ (market is characterized by fixed proportions) and $\gamma = 0$ (costs are all borne by producers), then $\delta^* = -kS$, which implies, for example, that if producer costs are increased by 1% due to COOL, then retail demand must increase by $(0.01)S(100)\%$ to make producers welfare neutral, where again S is the farmers' share of the retail dollar.

Some simple comparative statics from equation (9) yield the following insights: (*a*) if producers' costs increase (i.e., k becomes more negative), then consumer demand must increase to make producers welfare neutral; (*b*) if packers' and retailers' costs increase (i.e., γ becomes more negative), then consumer demand must increase to make producers welfare neutral; (*c*) if COOL costs are borne totally by the producers ($\gamma = 0$; $k < 0$), and if σ (the elasticity of substitution between farm and marketing inputs) increases, then consumer demand must increase to make producers welfare neutral; and (*d*) if COOL costs are totally borne by packers and processors ($\gamma < 0$; $k = 0$), and if σ (the elasticity of substitution between farm and marketing inputs) increases, then consumer demand must *decrease* to make producers welfare neutral.

The simple model outlined by equations (1)–(4) can also be used to address another issue: how are producers affected by the increased costs imposed on the meat packers and retailers by COOL? To consider this issue, we again return to equation (7) and note that the sign of (7) is determined by the sign of $(\hat{P}^{F^*} + k)$. Thus, we seek to determine when $(\hat{P}^{F^*} + k) > 0$. Specifically, what conditions must hold for producer surplus to *increase* when packers and processors incur additional costs, such as those imposed by COOL.

After a bit of algebra, for producer surplus to increase when packers and processors incur additional costs (assuming producers bear none of the COOL costs), we find that $|\eta| < \sigma$. In other words, if the absolute value of the retail elasticity of demand for beef is less than the elasticity of substitution between beef and marketing inputs, then producers might actually benefit from COOL if all COOL costs are borne by packers and retailers even if consumer demand for beef does not increase. As shown later in the analysis, this condition is a plausible scenario for the beef sector, but is less likely for pork. This is not to say that COOL will affect σ, but only that the magnitude of σ will most definitely have an effect on the welfare changes associated with COOL. The key is that magnitude of σ relative to η strongly affects whether and to what extent farmers are benefited or harmed by costs imposed on the marketing sector.

Three-Sector Model

Although the simple one-sector model provides some clarity about the issues affecting the distribution of costs in a sector, it ignores substitutability between meats at the retail level. The three-sector model, ignoring trade for the moment, is given as follows:

$$\hat{Q}_B^R = \eta_{BB}(\hat{P}_B^R - \delta_B) + \eta_{BP}(\hat{P}_P^R - \delta_P) + \eta_{BC}(\hat{P}_C^R - \delta_C), \tag{10}$$

$$(11)\qquad \hat{Q}_P^R = \eta_{PB}(\hat{P}_B^R - \delta_B) + \eta_{PP}(\hat{P}_P^R - \delta_P) + \eta_{PC}(\hat{P}_C^R - \delta_C),$$

$$(12)\qquad \hat{Q}_C^R = \eta_{CB}(\hat{P}_B^R - \delta_B) + \eta_{CP}(\hat{P}_P^R - \delta_P) + \eta_{CC}(\hat{P}_C^R - \delta_C),$$

$$(13)\qquad \hat{P}_B^R = S_B\hat{P}_B^F - \gamma_B,$$

$$(14)\qquad \hat{P}_P^R = S_P\hat{P}_P^F - \gamma_P,$$

$$(15)\qquad \hat{P}_C^R = S_C\hat{P}_C^F - \gamma_C,$$

$$(16)\qquad \hat{Q}_B^F = -(1 - S_B)\sigma_B\hat{P}_B^F - \sigma_B\gamma_B + \hat{Q}_B^R,$$

$$(17)\qquad \hat{Q}_P^F = -(1 - S_P)\sigma_P\hat{P}_P^F - \sigma_P\gamma_P + \hat{Q}_P^R,$$

$$(18)\qquad \hat{Q}_C^F = -(1 - S_C)\sigma_C\hat{P}_C^F - \sigma_C\gamma_C + \hat{Q}_C^R,$$

$$(19)\qquad \hat{P}_B^F = (1/\varepsilon_B)\hat{Q}_B^F - k_B,$$

$$(20)\qquad \hat{P}_P^F = (1/\varepsilon_P)\hat{Q}_P^F - k_P,$$

$$(21)\qquad \hat{P}_C^F = (1/\varepsilon_C)\hat{Q}_C^F - k_C,$$

where the subscripts B, P, and C denote beef, pork, and chicken, respectively. Equations (10)–(12) are demand equations for beef, pork, and chicken, respectively, in elasticity form; equations (13)–(15) are mark-up equations for each meat (or inverse retail supply curves); equations (16)–(18) represent derived demand for beef, pork, and chicken, respectively; and equations (19)–(21) are farm-level inverse supply curves for beef, pork, and chicken, respectively. An additional assumption of the three-sector model is that the products (beef, pork, and chicken) are independent in production with no specialized factors in common.

Once parameter values have been assigned, the above system of equations can be solved using matrix algebra. The result is an explicit solution for changes in endogenous variables, which are percentage changes in prices and quantities of beef, pork, and chicken at the retail and farm levels. Once these values have been determined, the change in producer surplus for meat i can be calculated as:

$$(22)\qquad \Delta PS_i = P_i^F Q_i^F(\hat{P}_i^{F*} + k_i)(1 + 0.5\hat{Q}_i^{F*}),$$

where the asterisks in the superscripts denote the solutions to the system of solved equations.

Three-Sector Model Incorporating Trade

Because one of the primary issues surrounding COOL is the effect of the policy on trade, we extend the model as outlined by equations (10)–(21) to incorporate imports of beef and pork. With COOL, consumers will be able to differentiate between foreign and domestic meat, and this model extension takes into account this substitution possibility.[4] Most trade models simply treat imported and exported goods as identical products at the retail level, but with COOL, consumers can differentiate between imported and domestic meats. As such, five interrelated demand equations are needed: demand for domestic beef, demand for foreign beef, demand for domestic pork, demand for foreign pork, and demand for chicken (which we treat as a single homogeneous commodity). To the extent COOL increases consumer demand, it will likely only increase demand for domestic meat; thus demand shifters are included only for domestic meat products. We now must also incorporate five supply equations, the first three being identical to equations (19)–(21) for domestic production, and two additional equations denoting foreign supplies of beef and pork to the United States. To complete the model, we add in the corresponding equations at the marketing level for foreign meats. The complete model contains 20 equations: five retail demand equations, five mark-up equations, five derived demand equations, and five supply equations. The entire model is provided in the appendix.

Methods

To apply the model to the beef, pork, and chicken industries, values are assigned to the model parameters. Rather than attempting to directly estimate these values, following Cranfield (2002), Wohlgenant (1993), James and Alston (2002), and others, we rely on preexisting estimates of parameter values reported in the literature. This approach is taken because there already exist credible estimates of the parameter values in the literature. Table 1 reports model parameters and the sources for the parameter values. The single-sector model outlined in equations (1)–(4) only makes use of the parameters relating to beef or pork, depending upon which sector is analyzed. The three-sector model outlined in equations (10)–(21) makes use of all the parameters defined in table 1. The three-sector model with trade uses all values outlined in table 1, along with additional demand parameters that specify how domestic meat demand responds to changes in prices of foreign beef and pork, and vice versa. In general, we set these values equal to their domestic counterparts, but use economic intuition to determine the remaining values.[5] We also set the foreign elasticities of supply at 10, following Lemieux and Wohlgenant (1989).

The remaining values needed to implement the models are cost estimates. In the subsequent analysis, several different scenarios are analyzed. These scenarios vary by the magnitude of the cost estimate and by who bears the cost. To determine the potential costs of COOL, we use the estimates reported by VanSickle et al. (2003) for a low estimate of COOL costs, and estimates reported by Sparks Companies, Inc. (2003) for a high estimate of COOL costs. To translate the cost estimates reported in these papers into the percentage cost shifts (γ and k) required in the model, we follow Unnevehr, Gomez, and Garcia (1998) and divide total annual costs from COOL by total annual revenue of the respective industry.

[4] Because the food service sector is exempt from COOL regulations, there is potential for the marketing channel to divert foreign meat to the food service establishments and domestic meat to the retail establishments. Our aggregate-level model, while not drawing a distinction between food service and retail establishments, does take into account substitutability between domestic and foreign meat. If the USDA requires full traceability (as it appears might happen), then all parties in the marketing channel will bear record-keeping costs regardless of whether they sell only domestic or foreign beef.

[5] The complete set of values is provided in the appendix.

Table 1. Variable Definitions and Values Used in Analysis

Parameter	Definition	Value
η_{BB}	Own-price elasticity of demand for beef[a]	-0.56
η_{BP}	Cross-price elasticity of beef with respect to pork[a]	0.10
η_{BC}	Cross-price elasticity of beef with respect to chicken[a]	0.05
η_{PB}	Cross-price elasticity of pork with respect to beef[a]	0.23
η_{PP}	Own-price elasticity of demand for pork[a]	-0.69
η_{PC}	Cross-price elasticity of pork with respect to chicken[a]	0.04
η_{CB}	Cross-price elasticity of chicken with respect to beef[a]	0.21
η_{CP}	Cross-price elasticity of chicken with respect to pork[a]	0.07
η_{CC}	Own-price elasticity of demand for chicken[a]	-0.33
S_B	Beef farmers' share of retail dollar[b]	0.48
S_P	Pork farmers' share of retail dollar[b]	0.27
S_C	Chicken farmers' share of retail dollar[b]	0.50
σ_B	Elasticity of substitution between beef and marketing inputs[c]	0.72
σ_P	Elasticity of substitution between pork and marketing inputs[c]	0.35
σ_C	Elasticity of substitution between chicken and marketing inputs[c]	0.11
ε_B	Own-price elasticity of supply for beef[d]	0.15
ε_P	Own-price elasticity of supply for pork[d]	0.40
ε_C	Own-price elasticity of supply for chicken[d]	0.65
$P_B^F Q_B^F$	Total farm revenue for beef ($ millions)[e]	$24,394
$P_P^F Q_P^F$	Total farm revenue for pork ($ millions)[f]	$12,883
$P_C^F Q_C^F$	Total farm revenue for chicken ($ millions)[g]	$15,341

Sources:
[a] Brester and Schroeder (1995)
[b] USDA/ERS, average value from years 1998–2002
[c] Wohlgenant (1989)
[d] Wohlgenant (1993)
[e] Livestock Marketing Information Center (LMIC), average value from years 2001–2002 for steers and heifers
[f] LMIC, average value from years 2001–2002 for barrows and gilts
[g] LMIC, average value from years 2001–2002 for broilers

Statistics reported by VanSickle et al. (2003) imply (ignoring initial start-up costs) recurring annual costs from COOL would range from about $36 million to $132 million (depending upon whether producers bear any COOL costs) for the beef sector, and $25 million to $32 million for the pork sector. Dividing these values by the revenue figures reported in table 1 shows that COOL would increase costs by about 0.5% for beef and about 0.25% for pork. These values are taken to represent the lower-bound cost estimates of COOL.

To obtain an upper bound on COOL cost estimates, we use the statistics reported by Sparks Companies, Inc. (2003). Sparks reports COOL would cost the beef sector approximately $1.620 billion and the pork sector approximately $452 million. Dividing these statistics by the revenue figures reported in table 1 suggests COOL would increase costs by about 6.5% for beef and about 3% for pork. Several scenarios are investigated for both lower-bound and upper-bound estimates in the analysis where these costs are borne in different proportions by producers and marketers (processors and retailers).

Results

Tables 2 and 3 present results for the single-market model for beef, assuming a different own-price elasticity of demand in each table. Note, in both of these tables, three different levels of cost increases are considered and demand is assumed to be unchanged by COOL. In addition to investigating the impact of different levels of cost increases, this analysis considers the incidence of cost increases (i.e., whether the cost increase is borne by producers or marketers). Four possibilities are examined for the incidence of cost increases: (*a*) all of the increase is imposed on producers, (*b*) the increase is split equally between producers and marketers, (*c*) one-fourth of the increase is borne by producers and three-fourths by marketers, and (*d*) all of the cost increase is borne by marketers.

In every scenario, table 2 reveals the effect of an increase in costs due to COOL is negative for consumer surplus. Declines in consumer surplus range from -\$23.06 million (when cost increases are at the low end of estimates and are all borne by producers) to -\$3,550.87 million (when cost increases are at the high end of estimates and are all borne by marketers). In three of the four cost scenarios, producer surplus declines as costs increase; however, the most striking result in table 2 is that if all of the cost increase is borne by marketers, producer surplus actually increases even though consumer demand is left unchanged in the model. As noted in the discussion of the analytical model, this outcome is a result of the fact that the absolute value of the own-price elasticity of demand for beef is less than the value of the elasticity of substitution between beef and marketing inputs. In table 2, the absolute value of the own-price elasticity of demand for beef is 0.56, and the value of the elasticity of substitution is 0.72. Even though table 2 shows a case where producer welfare could increase due to the policy, it is important to note that aggregate welfare (consumer + producer surplus) is never made better off by the policy. Indeed, in the last column where producers benefit from the policy, consumer demand would have to increase from 8.2% (low cost estimate) to 10.8% (high cost estimate) to make consumers welfare neutral.

In the literature, it is possible to find estimates for the own-price elasticity of demand for beef which fall above and below the elasticity of substitution. Consequently, we also report results from a single-market model for beef using an own-price elasticity of demand that is larger (in absolute value) than the elasticity of substitution, as shown in table 3. Note that in this case, producer surplus declines with any cost increase, regardless of the incidence of the cost. Changes in producer surplus range from -\$8.14 million when cost increases are at the low end of estimates and all borne by marketers to -\$1,315.62 when costs are at the high end of estimates and all borne by producers.

One interesting result observed from tables 2 and 3 is that as costs are increasingly borne by the processors and retailers, consumers are made increasingly worse off. This situation poses a complex problem for proposals such as the one put forth by VanSickle et al. (2003), advocating that policies pass all costs of COOL on to marketers. Such an approach, while beneficial for producers, is quite harmful to consumers if they do not react in a positive manner to the new label.

Tables 2 and 3 also report the magnitude of demand increase which would be required to exactly offset any loss in producer surplus due to the cost increase. For example, results in table 3 indicate that if all costs are borne by producers and COOL increases producers' costs by 6.5%, then consumer demand (willingness to pay) must increase by 6.24% to make producers no worse off than they were before COOL was imposed.

Table 2. Effect of COOL Costs on Beef Producers and Consumers: Single-Market Model Assuming No Demand Change (own-price elasticity of demand = -0.56)

	Scenarios			
Description	All Cost Borne by Producers	Cost Shared: 50/50	Cost Shared: 25/75	All Cost Borne by Marketers
Low Cost Estimate (0.5%):				
▸ Change in producer surplus ($ mil.)	-$98.87	-$37.15	-$6.27	$24.60
▸ Change in consumer surplus ($ mil.)	-$23.06	-$150.76	-$214.54	-$278.28
▸ Percentage change in farm quantity	-0.06%	-0.02%	-0.01%	0.02%
▸ Percentage change in farm price	0.10%	0.10%	0.10%	0.10%
▸ Increase in demand (willingness to pay) needed to make producers welfare neutral	0.57%	0.22%	0.04%	—
Medium Cost Estimate (3%):				
▸ Change in producer surplus ($ mil.)	-$592.34	-$222.75	-$37.64	$147.69
▸ Change in consumer surplus ($ mil.)	-$138.29	-$900.80	-$1,279.63	-$1,656.84
▸ Percentage change in farm quantity	-0.37%	-0.14%	-0.02%	0.09%
▸ Percentage change in farm price	0.57%	0.59%	0.60%	0.61%
▸ Increase in demand (willingness to pay) needed to make producers welfare neutral	3.45%	1.29%	0.22%	—
High Cost Estimate (6.5%):				
▸ Change in producer surplus ($ mil.)	-$1,280.68	-$482.24	-$81.54	$320.16
▸ Change in consumer surplus ($ mil.)	-$299.36	-$1,940.32	-$2,749.40	-$3,550.87
▸ Percentage change in farm quantity	-0.79%	-0.30%	-0.05%	0.20%
▸ Percentage change in farm price	1.23%	1.27%	1.29%	1.31%
▸ Increase in demand (willingness to pay) needed to make producers welfare neutral	7.47%	2.80%	0.47%	—

As costs increase and as producers bear a larger portion of the cost, the magnitude of the shift in demand needed to offset the impact of the cost increase becomes greater. With reference to table 2, given a large cost increase paid entirely by producers, it would take an increase in demand of approximately 7.5% to make up for lost producer surplus.

Table 4 presents results of the single-market model for pork.[6] Estimates of cost increases for the pork industry due to COOL are considerably lower than for beef because of the more integrated structure of the pork market. Thus, for this analysis, the three levels of cost increases considered for the pork industry are lower than the increases considered for the beef industry. For pork, declines in consumer surplus range from -$15.30 million to -$1,263.58 million. Producer surplus losses range from -$13.01 million to -$202.20 million. The increase in demand required to offset the loss in producer surplus ranges from a demand increase of 0.12% corresponding to a small cost increase borne exclusively by marketers, to an increase of 1.92% corresponding to a large cost increase born exclusively by producers. Again, as costs are moved from the producers to the processors and retailers, consumers are made increasingly worse off.

Although the single-market models are useful for investigating how costs are distributed in a system and for determining how consumer demand would have to change to

[6] Because the elasticity of substitution between pork and marketing inputs is quite low in relation to the absolute value of common estimates for the own-price elasticity of pork, it seems unnecessary to conduct sensitivity analysis on the value of the own-price elasticity. Thus only one table of results is presented for the pork model.

Table 3. Effect of COOL Costs on Beef Producers and Consumers: Single-Market Model Assuming No Demand Change (own-price elasticity of demand = -0.78)

	Scenarios			
Description	All Cost Borne by Producers	Cost Shared: 50/50	Cost Shared: 25/75	All Cost Borne by Marketers
Low Cost Estimate (0.5%):				
▸ Change in producer surplus ($ mil.)	-$101.58	-$54.87	-$31.51	-$8.14
▸ Change in consumer surplus ($ mil.)	-$20.35	-$133.02	-$189.28	-$245.50
▸ Percentage change in farm quantity	-0.06%	-0.03%	-0.02%	-0.01%
▸ Percentage change in farm price	0.08%	0.03%	-0.01%	-0.03%
▸ Increase in demand (willingness to pay) needed to make producers welfare neutral	0.48%	0.26%	0.15%	0.04%
Medium Cost Estimate (3%):				
▸ Change in producer surplus ($ mil.)	-$608.54	-$328.94	-$188.95	-$48.85
▸ Change in consumer surplus ($ mil.)	-$122.02	-$794.05	-$1,127.44	-$1,459.06
▸ Percentage change in farm quantity	-0.38%	-0.20%	-0.12%	-0.03%
▸ Percentage change in farm price	0.50%	0.15%	-0.03%	-0.20%
▸ Increase in demand (willingness to pay) needed to make producers welfare neutral	2.88%	1.56%	0.89%	0.23%
High Cost Estimate (6.5%):				
▸ Change in producer surplus ($ mil.)	-$1,315.62	-$711.85	-$409.12	-$105.81
▸ Change in consumer surplus ($ mil.)	-$264.08	-$1,708.07	-$2,417.68	-$3,119.05
▸ Percentage change in farm quantity	-0.81%	-0.44%	-0.25%	-0.07%
▸ Percentage change in farm price	1.09%	0.33%	-0.05%	-0.44%
▸ Increase in demand (willingness to pay) needed to make producers welfare neutral	6.24%	3.37%	1.94%	0.50%

offset a particular cost, the model ignores consumers' ability to substitute between different meats as prices change due to COOL. As previously noted, in the multiple-market model, it is impossible to arrive at analytical solutions for changes in consumer surplus. However, changes in producer surplus for all sectors represented in the model can be readily obtained using the multiple-market model. Table 5 presents results from the beef, pork, and chicken joint market model under a number of different scenarios related to the level of cost increase, the allocation of the cost increase, and changes in demand.

A few points about table 5 bear special attention. First, under the assumption of constant demand, (i.e., consumer demand does not change after COOL is implemented), any increase in costs for beef and pork resulting from COOL (regardless of who pays the costs) increases producer surplus for the poultry industry. Second, assuming constant demand, beef and pork producers are generally worse off under COOL if they bear any more than about one-fourth of the cost increase. Third, assumptions related to demand clearly have an important impact on resulting producer surplus estimates. For example, if beef and pork demand increase by as little as 2%, producer surplus in the pork industry will increase in spite of COOL except in the case where costs are at the high end of estimates and are borne completely by producers. Finally, while there are several cases where it appears all producers (beef, pork, and chicken) benefit from COOL, this result does not imply that aggregate welfare increases. As documented in tables 2, 3, and 4, although an increase in the cost to marketers increases welfare for producers, it harms consumers. As such, consumer demand shifts (δ) would have to be quite large to

Table 4. Effect of COOL Costs on Pork Producers and Consumers: Single-Market Model Assuming No Demand Change

	Scenarios			
Description	All Cost Borne by Producers	Cost Shared: 50/50	Cost Shared: 25/75	All Cost Borne by Marketers
Low Cost Estimate (0.25%):				
▸ Change in producer surplus ($ mil.)	-$16.90	-$14.95	-$13.98	-$13.01
▸ Change in consumer surplus ($ mil.)	-$15.30	-$60.76	-$83.48	-$106.20
▸ Percentage change in farm quantity	-0.05%	-0.05%	-0.04%	-0.04%
▸ Percentage change in farm price	0.12%	0.01%	-0.05%	-0.10%
▸ Increase in demand (willingness to pay) needed to make producers welfare neutral	0.16%	0.14%	0.13%	0.12%
Medium Cost Estimate (1%):				
▸ Change in producer surplus ($ mil.)	-$67.54	-$59.77	-$55.88	-$51.99
▸ Change in consumer surplus ($ mil.)	-$61.19	-$242.74	-$333.33	-$423.81
▸ Percentage change in farm quantity	-0.21%	-0.19%	-0.17%	-0.16%
▸ Percentage change in farm price	0.48%	0.04%	-0.18%	-0.40%
▸ Increase in demand (willingness to pay) needed to make producers welfare neutral	0.64%	0.57%	0.53%	0.49%
High Cost Estimate (3%):				
▸ Change in producer surplus ($ mil.)	-$202.20	-$178.97	-$167.35	-$155.72
▸ Change in consumer surplus ($ mil.)	-$183.41	-$725.65	-$995.15	-$1,263.58
▸ Percentage change in farm quantity	-0.63%	-0.56%	-0.52%	-0.49%
▸ Percentage change in farm price	1.43%	0.11%	-0.55%	-1.21%
▸ Increase in demand (willingness to pay) needed to make producers welfare neutral	1.92%	1.70%	1.59%	1.48%

make consumers, as a whole, in favor of COOL, especially if costs are primarily borne by marketers.

A final specification of the equilibrium displacement model was used to examine the impact of COOL on producer surplus when trade is considered. Assumptions related to cost levels and demand shifts are the same as in the model without trade (table 5). Regarding the allocation of costs, it is assumed foreign producers bear none of the costs associated with COOL. Domestic and foreign marketers bear a cost proportional to their aggregate share of the market. For example, if domestic beef accounts for 85% of total supply in the U.S. retail market, then COOL costs allocated to the marketing sector were paid 85% by domestic marketers and 15% by foreign marketers. Table 6 presents results of the multiple-market model with trade. Overall, results are similar to those presented in table 5. While the levels of changes in producer surplus are different when trade is considered, the basic pattern of gains and losses in relation to cost and demand changes remains the same.

Figures 1 and 2 illustrate the welfare changes for beef and pork, respectively, under the assumption of no demand change. As shown in figure 1, if beef producers bear more than 25% of the costs associated with COOL, then welfare losses can be expected. While all cost assumptions (low, medium, and high) predict similar welfare changes when producers bear about 25% of the costs, they generate vastly divergent predictions if producers bear most of the cost. Figure 2 shows similar results for pork, with one primary exception: the welfare-neutral point, in terms of percentage of costs borne, is about

Table 5. Effect of COOL Costs on Changes in Meat Producer Surplus: Multiple-Market Model without Trade ($ millions)

Description	All Cost Borne by Producers	Cost Shared: 50/50	Cost Shared: 25/75	All Cost Borne by Marketers
	SCENARIO: *— No Demand Change —*			
Low Cost Estimate (Beef = 0.5%, Pork = 0.25%):				
▸ Change in beef producer surplus	-97.67	-31.85	1.07	33.99
▸ Change in pork producer surplus	-15.17	-3.87	1.78	7.43
▸ Change in chicken producer surplus	2.21	13.24	18.76	24.28
Medium Cost Estimate (Beef = 3%, Pork = 1%):				
▸ Change in beef producer surplus	-587.14	-199.07	-4.69	189.93
▸ Change in pork producer surplus	-57.37	6.03	37.78	69.56
▸ Change in chicken producer surplus	12.31	75.81	107.62	139.47
High Cost Estimate (Beef = 6.5%, Pork = 3%):				
▸ Change in beef producer surplus	-1,266.10	-417.61	10.55	435.36
▸ Change in pork producer surplus	-179.99	-35.71	29.01	109.22
▸ Change in chicken producer surplus	28.26	170.85	234.29	314.29
	SCENARIO: *— 2% Demand Increase for Beef and Pork —*			
Low Cost Estimate (Beef = 0.5%, Pork = 0.25%):				
▸ Change in beef producer surplus	191.94	257.87	293.14	323.83
▸ Change in pork producer surplus	144.53	155.88	123.54	167.25
▸ Change in chicken producer surplus	-71.21	-60.21	-53.65	-49.21
Medium Cost Estimate (Beef = 3%, Pork = 1%):				
▸ Change in beef producer surplus	-298.41	90.36	285.09	480.05
▸ Change in pork producer surplus	102.12	165.84	197.75	229.68
▸ Change in chicken producer surplus	-61.14	2.16	33.87	65.63
High Cost Estimate (Beef = 6.5%, Pork = 3%):				
▸ Change in beef producer surplus	-978.58	-128.57	301.16	725.91
▸ Change in pork producer surplus	-21.10	123.89	145.90	269.54
▸ Change in chicken producer surplus	-45.24	96.91	169.72	239.90
	SCENARIO: *— 5% Demand Increase for Beef and Pork —*			
Low Cost Estimate (Beef = 0.5%, Pork = 0.25%):				
▸ Change in beef producer surplus	627.32	693.43	726.49	759.56
▸ Change in pork producer surplus	385.56	397.00	402.72	408.45
▸ Change in chicken producer surplus	-180.91	-169.96	-164.49	-159.01
Medium Cost Estimate (Beef = 3%, Pork = 1%):				
▸ Change in beef producer surplus	135.66	525.46	720.71	916.20
▸ Change in pork producer surplus	342.84	407.03	439.17	471.35
▸ Change in chicken producer surplus	-170.88	-107.88	-76.32	-44.71
High Cost Estimate (Beef = 6.5%, Pork = 3%):				
▸ Change in beef producer surplus	-546.34	305.95	736.02	1,162.71
▸ Change in pork producer surplus	218.71	364.78	430.29	511.50
▸ Change in chicken producer surplus	-155.06	-13.58	49.37	128.75

Table 6. Effect of COOL Costs on Changes in Meat Producer Surplus: Multiple-Market Model with Trade ($ millions)

Description	All Cost Borne by Domestic Producers	Cost Shared by Domestic Producers and Marketers: 50/50	25/75	All Cost Borne by Marketers
		SCENARIO: *— No Demand Change —*		
Low Cost Estimate (Beef = 0.5%, Pork = 0.25%):				
▸ Change in beef producer surplus	-97.63	-31.31	1.85	35.03
▸ Change in pork producer surplus	-15.15	-2.67	3.58	9.82
▸ Change in chicken producer surplus	2.24	13.45	19.06	24.67
Medium Cost Estimate (Beef = 3%, Pork = 1%):				
▸ Change in beef producer surplus	-586.92	-195.42	0.69	197.04
▸ Change in pork producer surplus	-57.26	9.13	42.38	75.66
▸ Change in chicken producer surplus	12.46	76.94	109.24	141.58
High Cost Estimate (Beef = 6.5%, Pork = 3%):				
▸ Change in beef producer surplus	-1,265.59	-410.41	18.88	559.77
▸ Change in pork producer surplus	-179.72	-22.10	57.00	329.64
▸ Change in chicken producer surplus	28.61	173.50	246.28	408.18
		SCENARIO: *— 2% Demand Increase for Beef and Pork —*		
Low Cost Estimate (Beef = 0.5%, Pork = 0.25%):				
▸ Change in beef producer surplus	190.63	257.06	290.28	323.51
▸ Change in pork producer surplus	143.78	156.33	162.60	168.88
▸ Change in chicken producer surplus	-72.10	-60.92	-55.33	-49.73
Medium Cost Estimate (Beef = 3%, Pork = 1%):				
▸ Change in beef producer surplus	-299.54	92.66	289.12	485.81
▸ Change in pork producer surplus	101.47	168.19	201.60	235.04
▸ Change in chicken producer surplus	-61.90	2.37	34.57	66.81
High Cost Estimate (Beef = 6.5%, Pork = 3%):				
▸ Change in beef producer surplus	-979.42	-122.72	307.34	849.19
▸ Change in pork producer surplus	-21.60	136.80	216.29	490.27
▸ Change in chicken producer surplus	-45.81	98.63	171.18	332.57
		SCENARIO: *— 5% Demand Increase for Beef and Pork —*		
Low Cost Estimate (Beef = 0.5%, Pork = 0.25%):				
▸ Change in beef producer surplus	623.96	690.57	723.88	757.20
▸ Change in pork producer surplus	383.65	396.29	402.61	408.93
▸ Change in chicken producer surplus	-183.15	-172.03	-166.46	-160.90
Medium Cost Estimate (Beef = 3%, Pork = 1%):				
▸ Change in beef producer surplus	132.49	525.74	722.72	919.93
▸ Change in pork producer surplus	341.02	408.23	441.89	475.58
▸ Change in chicken producer surplus	-173.01	-109.04	-76.99	-44.90
High Cost Estimate (Beef = 6.5%, Pork = 3%):				
▸ Change in beef producer surplus	-549.20	309.79	740.98	1,284.27
▸ Change in pork producer surplus	217.05	376.61	456.69	732.67
▸ Change in chicken producer surplus	-156.99	-13.23	58.97	219.61

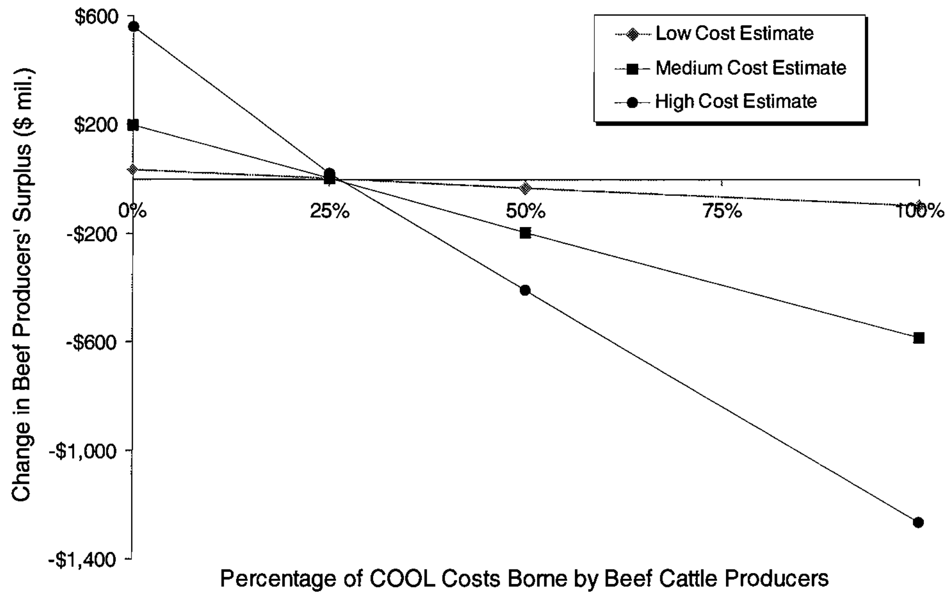

Figure 1. Effects of COOL on changes in beef producer surplus from multiple market model with trade and no demand change

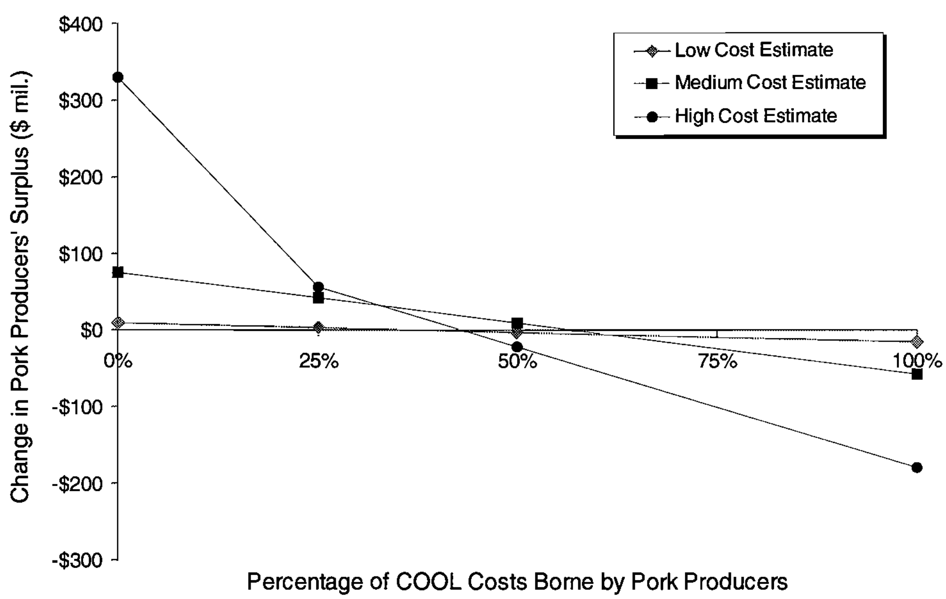

Figure 2. Effects of COOL on changes in pork producer surplus from multiple market model with trade and no demand change

50% for pork producers, where it was about 25% for beef producers. That is, unless pork producers bear more than about 50% of the costs associated with COOL, they could actually benefit from the policy even if demand does not change. The primary reason for this result is that the cost estimates are relatively higher for beef than pork. If a relatively higher cost is imposed on beef than pork, then pork producers can expect to benefit due to consumers substituting away from the now relatively more expensive beef to relatively less expensive pork.

In addition to the direct welfare losses captured by the model, it is important to recognize that there could be other indirect welfare losses due to COOL. For example, hog and cattle producers in the northern United States depend on imports of stocker cattle and feeder pigs from Canada. These U.S. producers will likely lose as a result of COOL because they will no longer be able to claim U.S. origin. Consequently, COOL could increase the incentive of Canadian producers to feed these animals until slaughter rather than exporting them to the United States.

Summary and Conclusions

In this study, an equilibrium displacement model was constructed to investigate the impact of cost increases associated with country-of-origin labeling (COOL) requirements on producer and consumer welfare. The approach employed in this study is unique in two respects. First, this methodology yields results that are not contingent upon any single set of assumptions related to COOL implementation. Second, this approach permits an investigation of the impact of COOL, while explicitly considering the interrelationships among beef, pork, and poultry markets. Third, rather than simply examining aggregate costs of COOL, this approach permits costs to be passed throughout the market via supply and demand elasticities, thereby providing insight into how costs will be distributed among producers and consumers of the various meats.

Results of this study highlight an important issue for policy makers and those charged with implementing policy, because the way USDA interprets COOL provisions of the Farm Bill when writing regulations for its implementation will have a tremendous impact on who benefits from and who is harmed by COOL. Results of the single-sector model indicate that a regulatory structure in which most costs are borne by marketers, with producers exempt from all but minimal requirements for documentation and record keeping, will have a relatively small negative impact on producers but a relatively large negative impact on consumers (unless COOL does, as some argue it will, lead to an increase in demand). In contrast, a regulatory structure in which most costs are ultimately borne by producers will have a much larger negative impact on producer surplus. To the extent that retailers and packers require documentation from producers on the origin of their livestock, producers will bear a larger portion of the regulatory burden and larger welfare losses.

Results from the multi-market model again highlight the importance of the allocation of COOL costs. If half or more of the costs are borne by producers (which, as noted, would also likely imply high implementation costs), the negative impact on producer surplus will be quite large. In fact, in this scenario, the most likely beneficiaries of COOL will be chicken producers, who will benefit from the substitution from pork and beef. Another interesting result is that because cost estimates are relatively higher for beef than pork, pork producers could benefit while beef producers lose because consumers can substitute away from relatively more expensive beef to relatively less expensive pork.

One result evident from the analysis is that consumers' reaction to COOL will have a major impact on the welfare effects of the legislation. If COOL increases demand for covered products, losses in producer surplus will be offset. The degree to which the effects of higher costs are offset depends on the magnitude of demand shifts resulting from COOL. Results suggest a 2% increase in aggregate demand (including all meat cuts and meat consumed at home and away from home) for pork would offset the negative impact on producer surplus unless cost increases are quite large and borne almost exclusively by producers. A 2% increase in aggregate demand for beef (including all meat cuts and meat consumed at home and away from home) would be sufficient to offset negative changes in consumer surplus if COOL implementation costs are low; however, if COOL implementation costs fall into the upper half of current estimates, a 2% demand increase may not be sufficient to offset reductions in producer surplus.

Loureiro and Umberger (2003) estimated premiums for "U.S. Certified" steak and hamburger would be 58% and 38%, respectively, if origin labels were implemented. Further, Umberger et al. (2003) found willingness-to-pay premiums as high as 19% for beef steak advertised as "Guaranteed USA: Born and Raised in the U.S." for consumers in Colorado and Illinois. The demand shock in our model (δ) is an aggregate shock representing total increase in demand for all cuts and for meat consumed at home and away from home, the latter of which is not included in the COOL policy. Therefore, it is unclear how the estimates reported by Loureiro and Umberger, and Umberger et al., would translate into an aggregate shock as specified in our model. Perhaps a more relevant question is why country-of-origin labels have not voluntarily appeared in the market if consumer willingness to pay exceeds costs. Several processors such as Premium Standard Farms and Smithfield have the ability to advertise these claims without a government mandate. It is unlikely these firms would forego the profits of a country-of-origin label if such profits indeed exist. It is difficult to make a case for market failure in the cause of COOL, which highlights the need to identify how the costs of the mandatory COOL policy will be distributed throughout the marketing channel.

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Appendix:
Model Incorporating Trade

The equilibrium displacement model incorporating international trade is given below.

Demand Equations

(A1) $$\hat{Q}^R_{BD} = \eta_{BD,BD}(\hat{P}^R_{BD} - \delta_{BD}) + \eta_{BD,P}(\hat{P}^R_{PD} - \delta_{PD}) + \eta_{BD,C}(\hat{P}^R_C - \delta_C) + \eta_{BD,BF}\hat{P}^R_{BF} + \eta_{BD,PF}\hat{P}^R_{PF},$$

(A2) $$\hat{Q}^R_{PD} = \eta_{PD,BD}(\hat{P}^R_{BD} - \delta_{BD}) + \eta_{PD,PD}(\hat{P}^R_{PD} - \delta_{PD}) + \eta_{PD,C}(\hat{P}^R_C - \delta_C) + \eta_{PD,BF}\hat{P}^R_{BF} + \eta_{PD,PF}\hat{P}^R_{PF},$$

(A3) $\hat{Q}_C^R = \eta_{C,BD}(\hat{P}_{BD}^R - \delta_{BD}) + \eta_{C,PD}(\hat{P}_{PD}^R - \delta_{PD}) + \eta_{C,C}(\hat{P}_C^R - \delta_C) + \eta_{C,BF}\hat{P}_{BF}^R + \eta_{C,PF}\hat{P}_{PF}^R,$

(A4) $\hat{Q}_{BF}^R = \eta_{BF,BD}(\hat{P}_{BD}^R - \delta_{BD}) + \eta_{BF,P}(\hat{P}_{PD}^R - \delta_{PD}) + \eta_{BF,C}(\hat{P}_C^R - \delta_C) + \eta_{BF,BF}\hat{P}_{BF}^R + \eta_{BF,PF}\hat{P}_{PF}^R,$

(A5) $\hat{Q}_{PF}^R = \eta_{PF,BD}(\hat{P}_{BD}^R - \delta_{BD}) + \eta_{PF,PD}(\hat{P}_{PD}^R - \delta_{PD}) + \eta_{PF,C}(\hat{P}_C^R - \delta_C) + \eta_{PF,BF}\hat{P}_{BF}^R + \eta_{PF,PF}\hat{P}_{PF}^R.$

The subscripts *BD*, *PD*, *C*, *BF*, and *PF* represent domestic beef, domestic pork, chicken, foreign beef, and foreign pork, respectively. The remaining variables are defined in the text.

Inverse Retail Supply Equations

(A6) $\hat{P}_{BD}^R = S_{BD}\hat{P}_{BD}^F - \gamma_{BD},$

(A7) $\hat{P}_{PD}^R = S_{PD}\hat{P}_{PD}^F - \gamma_{PD},$

(A8) $\hat{P}_C^R = S_C\hat{P}_C^F - \gamma_C,$

(A9) $\hat{P}_{BF}^R = S_{BF}\hat{P}_{BF}^F - \gamma_{BF},$

(A10) $\hat{P}_{PF}^R = S_{PF}\hat{P}_{PF}^F - \gamma_{PF}.$

Derived Demand Equations

(A11) $\hat{Q}_{BD}^F = -(1 - S_{BD})\sigma_{BD}\hat{P}_{BD}^F - \sigma_{BD}\gamma_{BD} + \hat{Q}_{BD}^R,$

(A12) $\hat{Q}_{PD}^F = -(1 - S_{PD})\sigma_{PD}\hat{P}_{PD}^F - \sigma_{PD}\gamma_{PD} + \hat{Q}_{PD}^R,$

(A13) $\hat{Q}_C^F = -(1 - S_C)\sigma_C\hat{P}_C^F - \sigma_C\gamma_C + \hat{Q}_C^R,$

(A14) $\hat{Q}_{BF}^F = -(1 - S_{BF})\sigma_{BF}\hat{P}_{BF}^F - \sigma_{BF}\gamma_{BF} + \hat{Q}_{BF}^R,$

(A15) $\hat{Q}_{PF}^F = -(1 - S_{PF})\sigma_{PF}\hat{P}_{PF}^F - \sigma_{PF}\gamma_{PF} + \hat{Q}_{PF}^R.$

Inverse Primary Supply Equations

(A16) $\hat{P}_{BD}^F = (1/\varepsilon_{BD})\hat{Q}_{BD}^F - k_{BD},$

(A17) $\hat{P}_{PD}^F = (1/\varepsilon_{PD})\hat{Q}_{PD}^F - k_{PD},$

(A18) $\hat{P}_C^F = (1/\varepsilon_C)\hat{Q}_C^F - k_C,$

(A19) $\hat{P}_{BF}^F = (1/\varepsilon_{BF})\hat{Q}_{BF}^F,$

(A20) $\hat{P}_{PF}^F = (1/\varepsilon_{PF})\hat{Q}_{PF}^F.$

Parameter values used to implement the model are shown in table A1.

Table A1. Parameter Values Used in Model Incorporating Trade

Parameter	Definition	Value
$\eta_{BD,BD}$	Own-price elasticity of demand for domestic beef	-0.56
$\eta_{BD,PD}$	Cross-price elasticity of domestic beef with respect to domestic pork	0.10
$\eta_{BD,C}$	Cross-price elasticity of domestic beef with respect to chicken	0.05
$\eta_{BD,BF}$	Cross-price elasticity of domestic beef with respect to foreign beef	0.20
$\eta_{BD,PF}$	Cross-price elasticity of domestic beef with respect to foreign pork	0.05
$\eta_{PD,BD}$	Cross-price elasticity of domestic pork with respect to domestic beef	0.23
$\eta_{PD,PD}$	Own-price elasticity of demand for domestic pork	-0.69
$\eta_{PD,C}$	Cross-price elasticity of domestic pork with respect to chicken	0.04
$\eta_{PD,BF}$	Cross-price elasticity of domestic pork with respect to foreign beef	0.10
$\eta_{PD,PF}$	Cross-price elasticity of domestic pork with respect to foreign pork	0.20
$\eta_{C,BD}$	Cross-price elasticity of chicken with respect to domestic beef	0.21
$\eta_{C,PD}$	Cross-price elasticity of chicken with respect to domestic pork	0.07
$\eta_{C,C}$	Own-price elasticity of demand for chicken	-0.33
$\eta_{C,BF}$	Cross-price elasticity of chicken with respect to foreign beef	0.21
$\eta_{C,PF}$	Cross-price elasticity of chicken with respect to foreign pork	0.07
$\eta_{BF,BD}$	Cross-price elasticity of foreign beef with respect to domestic beef	0.20
$\eta_{BF,PD}$	Cross-price elasticity of foreign beef with respect to domestic pork	0.05
$\eta_{BF,C}$	Cross-price elasticity of foreign beef with respect to chicken	0.05
$\eta_{BF,BF}$	Own-price elasticity of demand for foreign beef	-0.56
$\eta_{BF,PF}$	Cross-price elasticity of foreign beef with respect to foreign pork	0.10
$\eta_{PF,BD}$	Cross-price elasticity of foreign pork with respect to domestic beef	0.10
$\eta_{PF,PD}$	Cross-price elasticity of foreign pork with respect to domestic pork	0.20
$\eta_{PF,C}$	Cross-price elasticity of foreign pork with respect to chicken	0.04
$\eta_{PF,BF}$	Cross-price elasticity of foreign pork with respect to foreign beef	0.23
$\eta_{PF,PF}$	Own-price elasticity of demand for foreign pork	-0.69
S_{BD}	Domestic beef farmers' share of retail dollar	0.48
S_{PD}	Domestic pork farmers' share of retail dollar	0.27
S_C	Chicken farmers' share of retail dollar	0.50
S_{BF}	Foreign beef farmers' share of retail dollar	0.48
S_{PF}	Foreign pork farmers' share of retail dollar	0.27
σ_{BD}	Elasticity of substitution between domestic beef and marketing inputs	0.72
σ_{PD}	Elasticity of substitution between domestic pork and marketing inputs	0.35
σ_C	Elasticity of substitution between chicken and marketing inputs	0.11
σ_{BF}	Elasticity of substitution between foreign beef and marketing inputs	0.72
σ_{PF}	Elasticity of substitution between foreign pork and marketing inputs	0.35
ε_{BD}	Own-price elasticity of supply for domestic beef	0.15
ε_{PD}	Own-price elasticity of supply for domestic pork	0.40
ε_C	Own-price elasticity of supply for chicken	0.65
ε_{BF}	Own-price elasticity of supply for foreign beef	10.00
ε_{PF}	Own-price elasticity of supply for foreign pork	10.00