Environmental Regulation and Implications for Competitiveness in International Pork Trade

Mark Metcalfe
University of California - Berkeley

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Department of Agricultural and Resource Economics, 207 Giannini Hall, University of California, Berkeley, CA 94720, phone: (510) 642-0262, fax: (510) 643-8911, email: metcalfe@are.berkeley.edu.

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Abstract

Environmental concerns linked to hog production are growing in the United States, Canada and the European Union and therefore new regulations controlling animal manure management are being imposed to address these concerns. This study determines that potential increases in U.S. and Canadian environmental regulation would have minimal effects on the relative competitiveness of their pork exports, while much more stringent EU regulation has the potential to significantly impact EU competitiveness and contribute to continued increases in the market share of U.S. and Canadian pork exports.

Introduction

World pork consumption has been increasing over the last decade and this change has led to increases in the quantity of pork traded internationally. Total pork trade in 2000 is projected to be approximately three million metric tons, which is a 43% increase over 1993 levels. Pork production in the United States has increased 9% in the last 10 years, and since 1995, the United States has taken on the role as a net exporter of pork to the world. Annual U.S. and Canadian exports for 2000 and beyond are estimated to exceed 540,000 metric tons, making these two countries the largest pork exporters and also establishing them as a competitive threat to traditional European pork exporters (USDA-FAS, 2000). The increases in U.S. and Canadian pork exports are due to recent improvements in the structure of the U.S. industry and also to recent sanitary restrictions imposed on pork exports from Taiwan (Foot and Mouth Disease) and the Netherlands (Classical Swine Fever) that have opened foreign markets (USDA-ERS, 1996; Shaw, Shaffer, Premakumar, and Hayes, 1997; Hayes, 1997; USDA-FAS, 1998; Hayes, 1998).

The European Union, specifically Denmark and the Netherlands, have had a continued presence in the international market for pork. The competitiveness of U.S. pork exports had traditionally been handicapped by problems associated with heterogeneous quality and small-scale production and despite a history of relatively low feed and labor costs, U.S. pork export quantities did not comprise a significant share of total world pork trade. The recent structural improvements in the U.S. hog and pork industries have facilitated the move to larger operations using production technologies that yield the consistent quality of pork that is demanded in the export market. Producers in the United States are now benefiting from the traditional low feed and labor costs as well as a new industry structure which has allowed U.S. pork to become competitive in the international market.

The new organization of larger and more concentrated U.S. domestic production has been accompanied by rising environmental concerns, which have in turn, driven increases in the stringency of the environmental regulation facing animal feeding operations (Metcalfe, 2000b). This increase in the stringency of environmental regulation is not restricted to the

United States alone as hog producers in Northern Europe and in Canada are also being forced to comply with tougher domestic environmental regulation (European Commission, 1991; Blom, 1996; Gardner, 1996; Leuck and Haley, 1996; Ministry of Agriculture, 1999; Srivastave and Bamford, 1999; Beghin and Metcalfe, 2000). In fact, binding constraints on the amount of available agricultural land in the animal production regions of the European Union and the resulting over-concentration of nutrients has forced EU policy makers to propose and implement regulations that are more stringent than those being considered in the United States and Canada. Increasing environmental regulatory stringency leads to higher environmental compliance costs for hog producers. The increasingly strict EU regulatory situation may cause compliance costs incurred in the European Union to dramatically exceed those in both the United States and Canada and seriously handicap EU pork competitiveness in the world market.

This study examines the effects on competitiveness occurring from increases in the stringency of environmental regulations that are being imposed on hog production in the United States, Canada and the European Union. As the United States continues to expand pork export quantities, what effect does increasing environmental regulation have on pork processing costs and therefore on the competitiveness of pork exports? This study highlights the environmental regulations facing the hog industry in the United States, Canada and the European Union and also develops an equilibrium displacement model to examine the consequences of increasing environmental compliance costs incurred by hog producers.

It is expected that increases in regulatory stringency will be greater in the European Union than in the United States or Canada. Using this stylized fact, the empirical analysis in this study shows that U.S. and Canadian exports increase at the expense of decreasing EU exports. European Union export losses are greatest in the important Japanese market where U.S. and Canadian exports are expected to increase from 1% to 9% depending on the eventual relative differences in compliance costs. This possible loss in competitiveness provides an incentive for EU processors to call for harmonization of environmental regulations across countries.

The next section of the paper provides background on competitiveness in the international pork market and also discusses the stringency of environmental regulations imposed in the United States, Canada and the European Union. The equilibrium displacement model is then developed and the results are discussed explaining the potential effects on exports resulting from potential increases in environmental regulation.

Competitiveness and Environmental Regulation

The concept of competitiveness is an elusive one. There are many definitions of a 'competitive' industry based on various measures such as: costs, productivity, trade patterns, market share, and profitability. Competitiveness in this study will be based on the widely accepted definition proposed by the Canadian Task Force on Competitiveness: *Competitiveness is the sustained ability to profitably gain and maintain market share* (Agriculture Canada, 1991). Figure 1 shows the market shares of the major pork exporting regions for the years 1993 through 2000. The obvious decrease in the competitiveness of Taiwanese exports (due to sanitary restrictions) and the continued presence of the European Union, the United States and Canada in the international pork market can be seen.

Denmark, France, the Netherlands, Germany, Belgium, and the United Kingdom are the major EU pork exporting countries, with Denmark alone accounting for 41% of total EU exports in 1999 (USDA-FAS, 2000). Denmark and the Netherlands export the majority of pork outside the EU community and these producers are very competitive in the international pork market because they produce a high quality product, that meets final consumer preferences in several export markets, and they have also historically benefited from large government support for exports under the EU Common Agricultural Policy (CAP) (Leuck, Haley, Liapis, and McDonald, 1995). The EU hog and pork industries are also very coordinated and benefit from the increased efficiency provided by this coordination. Even so, producers in the European Union incur feed, labor, and facility costs greater than those faced by producers in the United States and Canada (Brewer, Kliebenstein, and Hayenga, 1998). These higher production costs combined with increasing EU environmental regulation, CAP reforms reducing the protection afforded EU producers, and currently imposed sanitary restrictions, all provide opportunities for the U.S. and Canadian industries to expand their export market share.

Export quantities for those markets important to the United States, Canada and the European Union are provided in Table 1. Japan is the largest pork import market in the world and in 1998, the United States, Canada, and the European Union supplied 68% of total Japanese imports, at the expense of banned Taiwanese exports. In 1996, before Taiwanese sanitary trade restrictions were imposed, Taiwan supplied 40% of Japanese imports and the United States, Canada and the European Union supplied only 39% (USDA-FAS, 1997, 1999a).

The analysis performed in this study concentrates exclusively on the changes in competitiveness resulting from changes in environmental compliance cost. Environmental legislation regulating animal feeding operations in the United States varies considerably across individual states and this regulation has been evolving rapidly over the last 10 years. The United States benefits from a low population density and an abundance of agricultural land and therefore is not facing the carrying capacity constraints that countries such as the Netherlands, Belgium, and Denmark are currently experiencing.

Animal feeding operations in the United States are regulated primarily at the state level through restrictions and requirements imposed on manure management systems and field application techniques. The stringency of this regulation varies from state to state but most states regulate some aspect of manure system construction and manure field application (Metcalfe, 2000b). It has been estimated that waste management costs in the U.S vary from $0.40 to $3.20 per hog, which is 1% to 8% of total hog production costs (Blauser, Forster, and Schnitkey, 1990; Zering, 1996; Fleming and Babcock, 1998; NPPC, 1999)

Environmental regulation in Canada is similar to the United States in that stringency varies across provinces. Most Canadian provinces set some type of standards to protect ground and surface water by controlling storage and field application of manure, but the costs associated with complying differ with the stringency of regulation. Low population density and greater land availability in rural areas are characteristics of Canada, and the United States, that lead to lower expected increases in compliance costs compared to the expected future increases in the European Union (Hacker and Du, 1993).

The 1991 European Community Nitrate Directive, the central legislation regulating European water quality, prescribes minimum water quality standards limiting nitrate from all potential sources. Most hog producing regions in Northern Europe do not currently satisfy the maximum acceptable nitrate concentrations that were set in this directive and it is believed that implementation of more drastic environmental policies will progressively bring these regions into compliance while simultaneously increasing costs for hog and pork production and limiting the competitiveness of EU exports (Leuck and Haley, 1996).

Denmark exports the largest percentage of EU pork and has extensive regulations imposing many engineering requirements and setback restrictions as well as nutrient field application standards (Danish Advisory Centre, 1993). Environmental regulation also discourages production on large hog operations by linking the size of operation and the required amount of land ownership necessary for manure disposal. The Danish EPA estimates the effective compliance cost is within the range of \$1.20 to \$1.50 per hog on a 1800 hog operation. The cost component induced by regulation of land ownership imposed additional costs of approximately \$14 per hog for large operations (Danish EPA, 1995).[1] The Danish government must continue to implement more stringent policies in order to reduce nitrate emissions by 100,000 tons per year, which represents about half of total agricultural emissions (Fortin and Salaun, 1995; Sommer, 1996; Office of Agricultural Affairs, 1998).

Animal production areas in the Netherlands currently violate 1991 European Community Nitrate Directive standards and, as in Denmark, compliance will require restricting applications of nitrogen on land to rates lower than are currently allowed. Dutch operations are regulated by phosphate quotas, regulations on waste treatment, restrictions on storage and field application, and more recently, direct output controls. The compliance costs of phosphate quotas, manure storage regulations, and field application restrictions are estimated as costing approximately \$4.05 per hog. The necessary future reductions in nitrogen emissions could impose costs on Dutch producers of up to $27.88 per hog. Therefore, it is likely that future regulation will compromise the competitiveness of the livestock industries in the Netherlands (Ministry of Agriculture, 1995; Derrick, Hendriks, and ten Have, 1996; Burton, 1997; Den Ouden, 1997; Vukina and Wossink, 1998).

Looking at regulation and compliance costs in the United States, Canada and the European Union demonstrates the relatively stringent and more costly restrictions that may be imposed on EU producers. The international competitiveness of U.S. and Canadian pork has been increasing given recent technological and operational changes and it is hypothesized that relatively lower environmental compliance costs are an additional source of comparative advantage for U.S. producers. The next section develops an equilibrium displacement model to examine this possibility.

Model

The equilibrium displacement model developed here is similar to the methodology used in past studies and consists of a series of log linear differential equations which represent supply, demand, and market clearing relationships in the U.S., Canadian and EU hog and pork industries (Muth, 1964; Sumner and Wohlgenant, 1985; Alston, 1986; Beghin, Brown, and Zaini, 1997). The effect on pork processors' costs are presumably small relative to overall pork processing costs and therefore the model is established in log linear form as the convenience afforded by this approximation is not outweighed by the loss of accuracy.

Variables considered as endogenous to the model are the proportional changes in the prices and quantities of pork processed and the proportional changes in the prices and quantities of the live hogs used as inputs in pork processing. Changes in environmental compliance costs are represented as exogenous 'shifts' in the marginal cost curves for live hog producers and the corresponding effects on the marginal costs of pork processors are then calculated. These changes in pork processing marginal costs are used to obtain changes in prices and examine changes in the market shares of pork exports. The model examines the competitiveness of exports in the top five U.S. pork export markets which are listed in

Table 1.

The model is first developed for U.S. pork processors and hog producers. Domestic demand for U.S. pork is a function of the price of U.S. pork and also of the prices of the Canadian and EU pork that is imported into the United States.[2] Therefore, the proportional change in U.S. pork is represented as

$$EQ_{us}^{us} = -\eta_{us}^{us} EP_{us}^{us} + \omega_{us}^{eu,us} EP_{us}^{eu} + \omega_{us}^{can,us} EP_{us}^{can}. \tag{1}$$

The operator $E(x) = dx/x = dlnx$ is used to represent proportional changes. The notation used to distinguish prices and quantities is, P_j^i, where i is the location where the pork is processed and j is the location where it is consumed. That is, EP_{us}^{eu}, is the price paid in the United States for pork that is processed in the European Union. The cross-price elasticities capture the substitution effect that occurs when the price of pork changes and the notation used is, $\omega_k^{i,j}$, where this represents the effect on the quantity of pork processed by region j which is consumed in market k when there is a change in the price of pork produced in i. For example the value, $\omega_{us}^{eu,can}$, would be the percentage change in the quantity of Canadian pork consumed in the United States resulting from a one percent change in the price of EU pork.

Foreign demand for U.S. pork exports is a function of U.S. pork export price and the prices of competing Canadian and EU exports. Canada and the European Union are competitors in the pork markets of Japan, Russia, and Hong Kong. The European Union does not export a significant amount of pork to either Canada or Mexico and therefore only the prices of U.S. and Canadian pork are considered in these markets (FAO, 1999).

The level of U.S. pork export prices are influenced by both transportation costs and trade policy. The transportation costs that are incurred moving pork are not insignificant, but for this study it is assumed that changes in environmental regulation do not significantly influence these costs and they are therefore excluded from the model.

Trade policy is an important factor influencing the price consumers pay for internationally traded pork. A two-tiered tariff rate quota (TRQ) policy is utilized in Japan and Mexico and the effects associated with trade policy in these two countries are examined in this model as a per unit effect incorporated in the prices paid by foreign consumers. Mathematically,

$$P_i^{*us} = P_i^{us} + t^i \tag{2}$$

where P_i^{*us} is the price consumers in market i pay for pork processed in the United States, t^i is the per unit tariff in market i and market i is one of the import markets examined: Japan, Canada, Mexico, Russia, or Hong Kong.[3] Equation (2) leads to the following relationship representing proportional changes in foreign consumer prices

$$EP_i^{*us} = \phi_i^{us} EP_i^{us} \tag{3}$$

The values ϕ_i^{us} are the ratio of the price received by U.S. processors to the price paid by consumers in market i, where consumer price is the processor price plus the tariff value. This ratio will be calculated for each of the TRQ rates in Japan and Mexico and the effect of changes in these rates on the model results will be examined.

Given these trade policy effects, proportional changes in the demand for U.S. pork within each foreign market is a function of foreign consumer prices for U.S. pork and the prices of Canadian and EU substitutes. This relationship is written as

$$EQ_i^{us} = -\eta_i^{us} \phi_i^{us} EP_i^{us} + \omega_i^{eu,us} \phi_i^{eu} EP_i^{eu} + \omega_i^{can,us} \phi_i^{can} EP_i^{can}. \tag{4}$$

Total export demand for U.S. pork is equal to the sum of pork exported to all five export markets and therefore the following relationship holds for proportional changes in the total quantity of U.S. pork exported

$$EQ_{TE}^{us} = \sum_{i=1}^{5} \gamma_i^{us} (-\eta_i^{us} \phi_i^{us} EP_i^{us} + \omega_i^{eu,us} \phi_i^{eu} EP_i^{eu} + \omega_i^{can,us} \phi_i^{can} EP_i^{can}), \tag{5}$$

where Q_{TE}^{us} is total U.S. exports and γ_i^{us} is the proportion of U.S. pork exported to market i.

Equation (5) shows that proportional changes in total U.S. exports are negatively related to the price of U.S. exports. This is expected because increasing marginal costs for U.S. processors increases the price of U.S. exports which in turn leads to a reduction in total U.S. export demand (a loss of competitiveness). Changes in competitors' pork prices are positively related to U.S. export quantity since increases in EU and Canadian environmental compliance costs leads to increases in EU and Canadian pork prices and therefore to an increase in the quantity of U.S. exports (a gain in competitiveness).

Total demand for U.S. processed pork is equal to the sum of demand in the domestic market and in all export markets. In terms of proportional changes, this implies

$$EQ_T^{us} = \beta^{us} EQ_{us}^{us} + (1 - \beta^{us}) EQ_{TE}^{us} \tag{6}$$

where β^{us} is the proportion of U.S. production that is consumed domestically.

Studies on the pork products industry suggests that producers exert market power which results in a mark-up of output price over marginal cost (Shroeter and Azzam, 1991; Morrison, 1997). Assuming demand elasticity in all markets remains constant for small changes in price, then in terms of proportional changes of prices and marginal costs in the model, it is true that

$$EP_j^i = E(MC^i), \tag{7}$$

where MC^i is the marginal cost of pork processors in i.[4] Utilizing this relationship and inserting equations (1) and (5) into equation (6), provides the following equation representing proportional changes in the quantity of U.S. pork demand as a function of the marginal costs of pork processors in the United States, the European Union and Canada,

$$EQ_T^{us} = -\kappa_{us}^{us} E(MC^{us}) + \kappa_{us}^{eu} E(MC^{eu}) + \kappa_{us}^{can} E(MC^{can}), \tag{8}$$

where $\kappa_{us}^{us} = [\beta^{us}\eta_{us}^{us} + (1-\beta^{us})\sum_{i=1}^{5}\gamma_i^{us}\eta_i^{us}\phi_i^{us}] > 0$, $\kappa_{us}^{eu} = [\beta^{us}\omega_{us}^{eu,us} + (1-\beta^{us})\sum_{i=1}^{5}\gamma_i^{us}\omega_i^{eu,us}\phi_i^{eu}] >$

0 and $\kappa_{us}^{can} = [\beta^{us}\omega_{us}^{can,us} + (1-\beta^{us})\sum_{i=1}^{5}\gamma_i^{us}\omega_i^{can,us}\phi_i^{can}] > 0$.

The supply of U.S. pork is based on the marginal cost of U.S. pork processors. Exogenous increases in the environmental compliance costs incurred by U.S. hog producers will lead to increases in the price of hogs and therefore to increases in the marginal cost of U.S. pork processing. Proportional changes in the marginal costs of U.S. pork processors are a function of the change in U.S. hog price and U.S. pork quantity. This is represented as

$$E(MC^{us}) = \lambda^{us}\alpha_p^{us}EP_h^{us} + \frac{1}{\epsilon_p^{us}}EQ_T^{us}. \tag{9}$$

where λ^{us} represents the second partial derivative of the cost function with respect to quantity and hog input price[5], α_p^{us} is the proportion of hog price in marginal cost, EP_h^{us} is the price of hogs in the United States, and ϵ_p^{us} is the elasticity of U.S. pork supply.

A representation for the derived demand for hogs is obtained through differentiation of the total cost function for pork processors with respect to the hog input price and therefore proportional changes in the quantity of hogs demanded by U.S. hog producers are assumed to be a function of the price of hogs and the total quantity of pork processed

$$EQ_h^{us} = -\eta_h^{us}EP_h^{us} + \lambda^{us}\xi^{us}EQ_T^{us}, \tag{10}$$

where Q_h^{us} is the quantity of U.S. hogs demanded, $\eta_h^{us}$is the demand elasticity of U.S. hogs, and the product of $\lambda^{us}\xi^{us}$ is the scale elasticity of live hog inputs used in U.S. pork processing.

The supply of hogs is derived from the marginal cost of hog production and is therefore influenced by the amount of environmental compliance costs incurred by hog producers. Changes in the environmental regulations imposed on U.S. hog producers leads to changes in the cost of hog production as producers incur additional manure management costs. These additional costs are referred to as the increase in U.S. environmental compliance costs. Marginal hog cost is obtained from the total cost function and then proportional changes in marginal cost are calculated with respect to changes in compliance costs such that

$$EP_h^{us} = \alpha_R^{us} ER^{us} + \frac{1}{\epsilon_h^{us}} EQ_h^{us}, \tag{11}$$

where R^{us} is U.S. compliance cost, α_R^{us} is the proportion of environmental compliance costs in total hog production cost and ϵ_h^{us} is the supply elasticity of hog production. Assuming equilibrium in the hog market, equating equations (10) and (11), and then substituting for EP_h^{us} in equation (9) provides the proportional change in the total quantity of U.S. pork processed in terms of changes in U.S. pork processing marginal cost and U.S. environmental compliance cost.

$$EQ_T^{us} = \psi^{us}[(\epsilon_h^{us} + \eta_h^{us})E(MC^{us}) - \epsilon_h^{us}\lambda^{us}\alpha_p^{us}\alpha_r^{us}ER^{us}], \tag{12}$$

where $\psi^{us} = \epsilon_p^{us}/(\epsilon_p^{us}(\lambda^{us})^2\xi^{us}\alpha_p^{us} + \epsilon_h^{us} + \eta_h^{us}) > 0$. Equating pork demand with pork supply, equation (8) and (12), closes the model and yields the relationship of proportional changes in the marginal costs of U.S. pork processors with the changes in U.S. environmental compliance costs and changes in EU and Canadian pork processors' marginal costs.

$$E(MC^{us}) = \left[\frac{N^{us}}{\Omega^{us}}\right] ER^{us} + \left[\frac{\kappa_{us}^{eu}}{\Omega^{us}}\right] E(MC^{eu}) + \left[\frac{\kappa_{us}^{can}}{\Omega^{us}}\right] E(MC^{can}), \tag{13}$$

where $N^{us} = \psi^{us}\epsilon_h^{us}\lambda^{us}\alpha_p^{us}\alpha_r^{us} > 0$ and $\Omega^{us} = \psi^{us}(\epsilon_h^{us} + \eta_h^{us}) + \kappa_{us}^{us} > 0$. Equation (13) shows that increases in the U.S. environmental compliance costs imposed on hog producers leads to increases in the marginal cost of U.S. pork processors. It also captures an indirect effect such that the increasing marginal costs of EU and Canadian pork processors leads to increasing marginal costs for U.S. processors. This indirect effect on U.S. pork processors' marginal costs is due to increases in U.S. pork output resulting from increases in U.S. output.[6]

Analogous relationships for the marginal costs of EU and Canadian pork processors are also calculated in a manner similar to equations (1) through (13) above. These equations, as well as their derivations, are provided in the appendix in order to simplify presentation.

Using equation (13) as well as the appendix equations (24) and (34), provides the following three equations directly relating changes in the marginal costs of pork processors to the changes in environmental regulatory costs in the three production regions.

$$
\begin{aligned}
E(MC^{us}) &= A_1 ER^{us} + A_2 ER^{eu} + A_3 ER^{can}, \\
E(MC^{eu}) &= A_4 ER^{us} + A_5 ER^{eu} + A_6 ER^{can}, \\
E(MC^{can}) &= A_7 ER^{us} + A_8 ER^{eu} + A_9 ER^{can},
\end{aligned}
\tag{14}
$$

where the values for all A_i are calculated using the parameters in the model[7]. The relationships in equation (15) are used to calculate changes in marginal costs and then these changes are used in equations (5), (17), and (27) to obtain changes in total U.S., EU and Canadian exports respectively.

Most of the necessary parameter estimates are collected from past analyses of the pork and hog industries, while the remaining parameters that could not be found in past studies, are calculated in Metcalfe (2000a). All of the parameters values are provided in Table 2.

Results

Exogenous changes in this model occur because of increases in the environmental compliance costs facing U.S., EU, and Canadian hog producers. Examination of waste management cost studies suggests that these increases can be expected to range up to 200% in the United States and Canada and may reach upwards of 500% in the more stringently regulated European Union (Blauser, Forster, and Schnitkey, 1990; Wossink, 1994; van Hofreither, 1995; Zering, 1996; Lauwers, 1998; Martens, 1998; Fleming and Babcock, 1998). Therefore, to reflect realistic possible scenarios, results are presented with U.S. and Canadian compliance costs increasing 0%, 100% and 200% while European Union compliance costs increase 100%, 300% and 500%.

The results for changes in U.S., EU, and Canadian export quantities are provided in Tables 3, 4 and 5 respectively. Overall, it can be seen that U.S. exports increase in all of the scenarios examined. This increase in U.S. exports comes at the expense of decreasing EU exports resulting from the inevitable increases in compliance costs that will occur in EU pork processing. Canadian pork exports increase in most all scenarios expect those where Canadian compliance costs increase more than U.S. costs. The magnitudes of these changes are significant when increases in compliance costs are asymmetric across countries. That is, when one production region experiences relatively greater increases in compliance costs, there is a corresponding decrease in that region's export quantity.

It should be noted that given the short run aspect of the model, there are no EU pork exports to Canada and Mexico and therefore there is no competition for U.S. exports in these markets. So, even as U.S. prices increase, there is little loss in U.S. export quantities to these markets. It would have to be expected that given U.S. price increases, over some time period there would be entry of EU pork exports into the Canadian market to offset this result.

Gains in total U.S. export quantities range from 0.5%, when U.S. compliance cost increases are high relative to EU and Canadian increases, to a gain of 12.6% when U.S. increases are low compared to those in the European Union and Canada. The largest gains are in the important Japanese market where U.S. exports climb approximately 1% when U.S. compliance costs are relatively high to 9% when U.S. cost increases are relatively low. The largest percentage increases occur in the Russian and Hong Kong markets. These increases reach upwards of 40% when EU compliance costs are high.

Losses in total EU exports range from about 4% to 24%. Large losses for EU exports are expected since compliance cost increases in the European Union will be much greater than those in the United States and Canada. The largest percentage losses for EU exports occur in Russia, the United States, and Japan. Gains for Canadian pork export quantities are more modest than the gains experienced by the United States. These increases reach a maximum of 6.5% when Canadian compliance cost increases are relatively low. The largest increases occur in the markets of Russia, Hong Kong, and Japan.

Sensitivity analysis is performed on the model to examine the effect of the following parameters which are either unknown or have multiple values and therefore effects are examined over a range: the price elasticity of U.S. domestic pork demand (η_{us}^{us}), price elasticity of derived demand for hogs (η_h^i), the elasticity of marginal cost with respect to pork quantity (ϵ_p^i), trade policy effects in the Japanese and Mexican markets (ϕ_1^i, ϕ_3^i), and the cost share of U.S. compliance cost (α_r^i). All sensitivity results show that the model is robust when these parameters are altered over estimated ranges.

Conclusion

Environmental regulations controlling the manure management aspects of hog production are becoming more stringent in the United States, Canada and the European Union. This increasing regulatory stringency results in increases in the compliance costs incurred by hog producers and these increases in hog production costs are passed on to the pork processing sector. The increases in U.S. and Canadian pork export quantities over the last five years have been a result of the increasing competitiveness of these industries in world markets and the results of this study suggest that relatively lower compliance costs could provide an additional source of competitiveness for these industries.

Export quantities of U.S. pork were 530,000 metric tons in 1999, which is an increase of 364% since 1990, and export value exceeded $1 billion, a 214% increase over this same time period. Exports to the Japanese market in particular quadrupled in volume and free trade agreements continue to open this and other markets to U.S. pork exports. Given these increases, exports now account for over 6% of total U.S. pork production and are important to the economic health of the industry (USDA-FAS, 1999b). Although environmental regulation is expected to increase in the United States, this does not significantly affect the competitiveness of U.S. exports and in fact, the relatively more stringent regulations that may be imposed in the European Union actually help to increase the competitiveness of U.S. pork. Canadian exports also experience an increase given relatively more stringent European Union regulations. The most dramatic effects occur for EU pork processors who experience large decreases in export quantities and this result suggests benefits to EU processors from a move towards harmonized environmental regulations.

Endnotes

[1] This value is calculated without accounting for the revenue generated through cultivation of the land and therefore this figure is an upper bound on the cost of the land requirement on large hog farms.

[2] It is assumed that the prices of other livestock that act as pork substitutes are not significantly affected by changes in hog production costs and because this model is interested in examining only those factors that respond to a change in the stringency of environmental regulation faced by hog producers, prices of these substitutes are not included in the domestic demand function.

[3] Note that the value for t varies for Japan and Mexico depending on current TRQ tariff rates.

[4] Derivation of equation (7) in Metcalfe (2000a)

[5] Imposing the mathematical condition that the order of differentiation is inconsequential and using Shepard's lemma, reveals that this value is also the change in hog demand with respect to the change in processed pork quantity. This restriction is imposed in equation (10).

[6] This model is looking at the short run and does not allow for expansion of the industry. Therefore, increases in quantity must be produced using existing capacity which leads to increasing marginal cost.

[7] Presentation of the mathematical expressions of all A_i variables is not enlightening and is therefore excluded from the paper. These expressions are available from the author.

Table 1: U.S. and EU Pork Exports - 1998

	U.S.	EU	Canada
		(metric tons)	
Japan	167,458	172,114	53,402
Hong Kong	17,439	99,432	6,500
China	7,746	44,137	*
S. Korea	5,069	45,695	2,569
Russia	37,657	307,484	9,434
E. Europe	*	169,755	11,286
Canada	32,298	*	-
Mexico	43,824	*	10,611
U.S.	-	77,800	214,241
Total	**557,000**	**1,002,000**	**432,000**

* Exports are minimal

Source: USDA-FAS

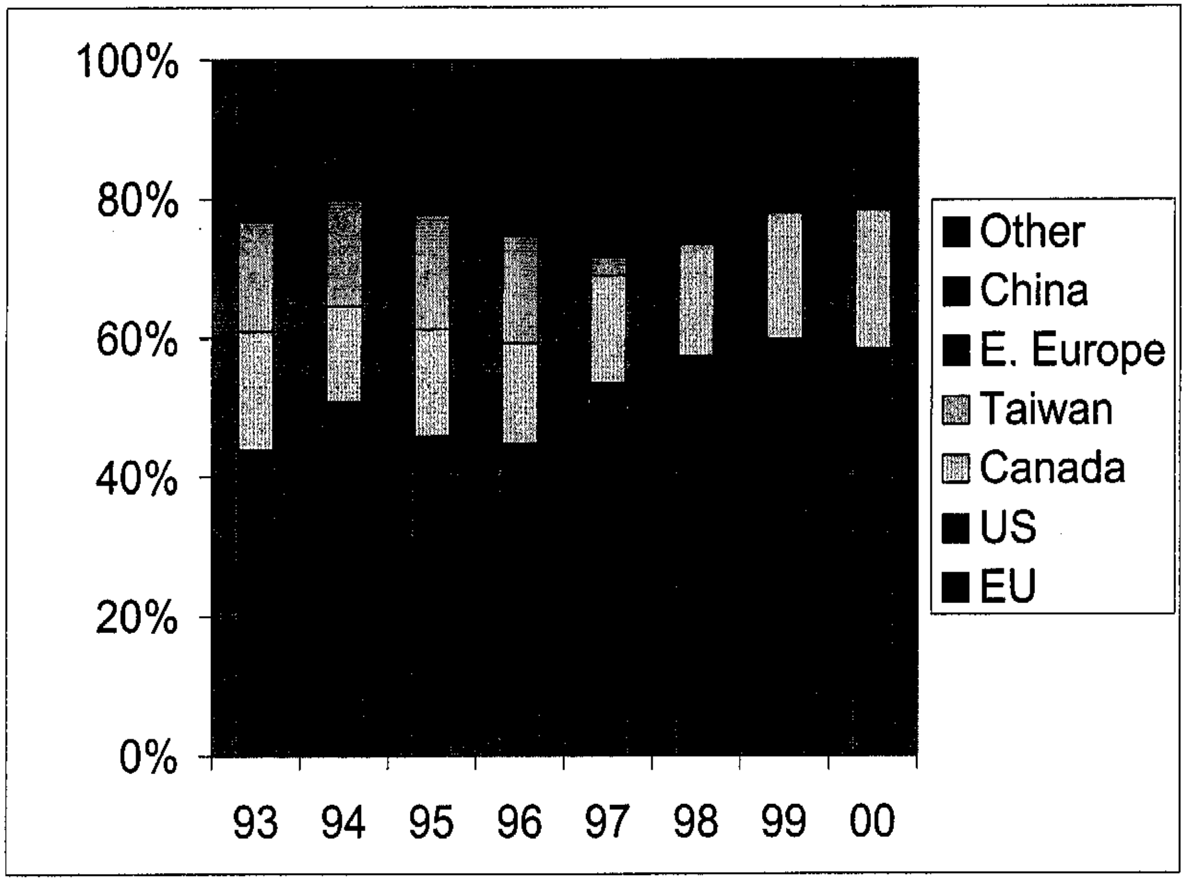

Figure 1: Major Pork Exporters 1993-1998

Table 2: Parameter Values

Parameter		i=*us*	i=*eu*	i=*can*	Parameter		i=*us*	i=*eu*	i=*can*
β^i	b	0.935	0.941	0.735	η^i_i	efi	1.00	0.77	1.00
λ^i	h	1.39	1.39	1.39	η^i_1	d	1.10	1.10	1.10
ξ^i	bh	0.722	0.756	0.673	η^i_2	d	0.21	0.21	0.21
ϕ^i_{ns}	a	1	1	1	η^i_3	d	6.28	6.28	6.28
ϕ^i_1	a	0.456	0.456	0.456	η^i_4	d	1.78	1.78	1.78
ϕ^i_2	a	1	1	1	η^i_5	d	0.46	0.46	0.46
ϕ^i_3	a	0.833	-	0.833	η^i_{us}	ef	1.00	1.00	1.00
ϕ^i_4	a	1	1	1	γ^i_{us}	bh	-	0.118	0.757
ϕ^i_5	a	1	1	1	γ^i_1	bh	0.576	0.262	0.196
ε^i_h	g	0.628	0.628	0.628	γ^i_2	bh	0.148	-	-
ε^i_p	k	3	3	3	γ^i_3	bh	0.105	-	0.030
η^i_h	k	0.75	0.75	0.75	γ^i_4	bh	0.101	0.468	0.003
α^i_r	a	0.045	0.190	0.045	γ^i_5	bh	0.068	0.151	0.015
α^i_h	cj	0.700	0.622	0.700					

Sources: [a] calculated in this study, [b] USDA-FAS Statistics, [c] Lawrence, Schroeter, and Hayenga (1998), [d] FAPRI (1999)

[e] Skold, Grundmeier, and Johnson (1989), [f] Moschini and Melike (1989), [g] Holt and Johnson (1988), [h] NPPC (1999a)

[i] Shaw et.al (1997), [j] DECANETHUS (1999), [k] range used

Table 3: Changes in U.S. Export Quantities

EU Cost Increase	**Canadian Cost Increase 0%**	**100%**	**200%**
0% Increase in U.S. Compliance Costs			
100%	2.3%	2.7%	3.1%
	(8,082)	(8,985)	(9,888)
300%	1.9%	7.5%	7.8%
	(24,247)	(25,150)	(26,053)
500%	3.3%	12.2%	12.6%
	(40,412)	(41,315)	(42,218)
100% Increase in U.S. Compliance Costs			
100%	1.4%	1.8%	2.1%
	(4,000)	(4,903)	(5,806)
300%	6.1%	6.5%	6.8%
	(20,164)	(21,068)	(21,971)
500%	10.9%	11.3%	11.6%
	(36,329)	(37,232)	(38,135)
200% Increase in U.S. Compliance Costs			
100%	0.5%	0.8%	1.2%
	(82)	(820)	(1,723)
300%	5.2%	5.6%	5.9%
	(16,082)	(16,985)	(17,888)
500%	10.0%	10.4%	10.7%
	(32,247)	(33,150)	(34,053)

Change in metric tons in parenthesis

Table 4: Changes in EU Export Quantities

EU Cost Increase	**Canadian Cost Increase 0%**	**100%**	**200%**
	0% Increase in U.S. Compliance Costs		
100%	-4.7%	-4.6%	-4.5%
	(-53,947)	(-53,237)	(-52,526)
300%	-14.3%	-14.2%	-14.1%
	(-161,843)	(-161,132)	(-160,422)
500%	-23.8	-23.7%	-23.6%
	(-269,739)	(-269,028)	(-268,317)
	100% Increase in U.S. Compliance Costs		
100%	-4.3%	-4.2%	-4.1%
	(-49,884)	(-49,173)	(-48,462)
300%	-13.8%	-13.7%	-13.6%
	(-157,780)	(-157,069)	(-156,358)
500%	-23.3%	-23.2%	-23.1%
	(-265,675)	(-264,964)	(-264,254)
	200% Increase in U.S. Compliance Costs		
100%	-3.7%	-3.7%	-3.6%
	(-45,820)	(-45,110)	(-44,399)
300%	-13.3%	-13.2%	-13.1%
	(-153,716)	(-153,005)	(-152,295)
500%	-22.8%	-22.7%	-22.6%
	(-261,612)	(-260,901)	(-260,190)

Change in metric tons in parenthesis

Table 5: Changes in Canadian Export Quantities

EU Cost Increase	Canadian Cost Increase 0%	100%	200%
	0% Increase in U.S. Compliance Costs		
100%	0.6%	-0.2%	-1.1%
	(2,341)	(-873)	(-4,089)
300%	1.9%	1.0	0.2%
	(7,024)	(3,809)	(593)
500%	3.3%	2.4	1.5%
	(11,707)	(8,491)	(5,276)
	100% Increase in U.S. Compliance Costs		
100%	2.2%	1.3%	0.4%
	(7,831)	(4,616)	(1,401)
300%	3.5%	2.6%	1.7%
	(12,514)	(9,299)	(6,084)
500%	4.8%	3.9%	3.0%
	(17,197)	(13,982)	(10,767)
	200% Increase in U.S. Compliance Costs		
100%	3.7%	2.8%	1.9%
	(13,322)	(10,106)	(6,891)
300%	5.1%	4.2%	3.3%
	(18,004)	(14,789)	(11,574)
500%	6.4%	5.5%	4.6%
	(22,687)	(19,472)	(16,257)

Change in metric tons in parenthesis

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Appendix

EU Pork and Hog Markets

$$EQ_{eu}^{eu} = -\eta_{eu}^{eu} EP_{eu}^{eu} \tag{15}$$

$$EP_i^{*eu} = \phi_i^{eu} EP_i^{eu} \tag{16}$$

$$\begin{aligned} EQ_{TE}^{eu} \quad = \quad & -[\gamma_{us}^{eu}\eta_{us}^{eu}\phi_{us}^{eu} + \sum_{i=1}^{5} \gamma_i^{eu}\eta_i^{eu}\phi_i^{eu}]EP_i^{eu} \\ & +[\gamma_{us}^{eu}\omega_{us}^{us,eu}\phi_{us}^{us} + \sum_{i=1}^{5} \gamma_i^{eu}\omega_i^{us,eu}\phi_i^{us}]EP_i^{us} \\ & +[\gamma_{us}^{eu}\omega_{us}^{can,eu}\phi_{us}^{can} + \sum_{i=1}^{5} \gamma_i^{eu}\omega_i^{can,eu}\phi_i^{can}]EP_i^{can} \end{aligned} \tag{17}$$

$$EQ_T^{eu} = \beta^{eu} EQ_{eu}^{eu} + (1-\beta^{eu}) EQ_{TE}^{eu} \tag{18}$$

$$EQ_T^{eu} = -\kappa_{eu}^{eu} E(MC^{eu}) + \kappa_{eu}^{us} E(MC^{us}) + \kappa_{eu}^{can} E(MC^{can}) \tag{19}$$

where

$\kappa_{eu}^{eu} = \beta^{eu}\eta_{eu}^{eu} + (1-\beta^{eu})[\gamma_{us}^{eu}\eta_{us}^{eu}\phi_{us}^{eu} + \sum_{i=1}^{5}\gamma_i^{eu}\eta_i^{eu}\phi_i^{eu}] > 0$

$\kappa_{eu}^{us} = (1-\beta^{eu})[\gamma_{us}^{eu}\omega_{us}^{us,eu}\phi_{us}^{us} + \sum_{i=1}^{5}\gamma_i^{eu}\omega_i^{us,eu}\phi_i^{us}] > 0$

$\kappa_{eu}^{can} = (1-\beta^{eu})[\gamma_{us}^{eu}\omega_{us}^{can,eu}\phi_{us}^{can} + \sum_{i=1}^{5}\gamma_i^{eu}\omega_i^{can,eu}\phi_i^{can}] > 0$

$$E(MC^{eu}) = \lambda^{eu}\alpha_p^{eu} EP_h^{eu} + \frac{1}{\epsilon_p^{eu}} EQ_T^{eu} \tag{20}$$

$$EQ_h^{eu} = -\eta_h^{eu} EP_h^{eu} + \lambda^{eu}\xi^{eu} EQ_T^{eu} \tag{21}$$

$$EP_h^{eu} = \alpha_R^{eu} ER^{eu} + \frac{1}{\epsilon_h^{eu}} EQ_h^{eu} \tag{22}$$

$$EQ_T^{eu} = \psi^{eu}[(\epsilon_h^{eu} + \eta_h^{eu})E(MC^{eu}) - \epsilon_h^{eu} \lambda^{eu} \alpha_p^{eu} \alpha_r^{eu} ER^{eu}] \tag{23}$$

where

$\psi^{eu} = \epsilon_p^{eu} / (\epsilon_p^{eu} (\lambda^{eu})^2 \xi^{eu} \alpha_p^{eu} + \epsilon_h^{eu} + \eta_h^{eu}) > 0$

$$E(MC^{eu}) = \left[\frac{N^{eu}}{\Omega^{eu}}\right] ER^{eu} + \left[\frac{\kappa_{eu}^{us}}{\Omega^{eu}}\right] E(MC^{us}) + \left[\frac{\kappa_{eu}^{can}}{\Omega^{eu}}\right] E(MC^{can}) \tag{24}$$

where

$N^{eu} = \psi^{eu} \epsilon_h^{eu} \lambda^{eu} \alpha_p^{eu} \alpha_r^{eu} > 0$

$\Omega^{eu} = \psi^{eu}(\epsilon_h^{eu} + \eta_h^{eu}) + \kappa_{eu}^{eu} > 0$

Canadian Pork and Hog Markets

$$EQ_{can}^{can} = -\eta_{can}^{can} EP_{can}^{can} + \omega_{can}^{us,can} EP_{can}^{us} \tag{25}$$

$$EP_i^{*can} = \phi_i^{can} EP_i^{can} \tag{26}$$

$$\begin{aligned} EQ_{TE}^{can} \quad = \quad & -[\gamma_{us}^{can} \eta_{us}^{can} \phi_{us}^{can} + \sum_{i=1}^{5} \gamma_i^{can} \eta_i^{can} \phi_i^{can}] EP_i^{can} \\ & +[\gamma_{us}^{can} \omega_{us}^{eu,can} \phi_{us}^{eu} + \sum_{i=1}^{5} \gamma_i^{can} \omega_i^{eu,can} \phi_i^{eu}] EP_i^{eu} \\ & +[\gamma_{us}^{can} \omega_{us}^{us,can} \phi_{us}^{us} + \sum_{i=1}^{5} \gamma_i^{can} \omega_i^{us,can} \phi_i^{us}] EP_i^{us} \end{aligned} \tag{27}$$

$$EQ_T^{can} = \beta^{can} EQ_{can}^{can} + (1 - \beta^{can}) EQ_{TE}^{can} \tag{28}$$

$$EQ_T^{can} = -\kappa_{can}^{can} E(MC^{can}) + \kappa_{can}^{us} E(MC^{us}) + \kappa_{can}^{eu} E(MC^{eu}) \tag{29}$$

where

$\kappa_{can}^{can} = \beta^{can}\eta_{can}^{can} + (1-\beta^{can})[\gamma_{us}^{can}\eta_{us}^{can}\phi_{us}^{can} + \sum_{i=1}^{5}\gamma_i^{can}\eta_i^{can}\phi_i^{can}] > 0$

$\kappa_{can}^{eu} = (1-\beta^{can})[\gamma_{us}^{can}\omega_{us}^{eu,can}\phi_{us}^{eu} + \sum_{i=1}^{5}\gamma_i^{can}\omega_i^{eu,can}\phi_i^{eu}] > 0$

$\kappa_{can}^{us} = \beta^{can}\omega_{can}^{us,can} + (1-\beta^{can})[\gamma_{us}^{can}\omega_{us}^{us,can}\phi_{us}^{us} + \sum_{i=1}^{5}\gamma_i^{us}\omega_i^{us,can}\phi_i^{us}] > 0$

$$E(MC^{can}) = \lambda^{can}\alpha_p^{can} EP_h^{can} + \frac{1}{\epsilon_p^{can}} EQ_T^{can} \tag{30}$$

$$EQ_h^{can} = -\eta_h^{can} EP_h^{can} + \lambda^{can}\xi^{can} EQ_T^{can} \tag{31}$$

$$EP_h^{can} = \alpha_R^{can} ER^{can} + \frac{1}{\epsilon_h^{can}} EQ_h^{can} \tag{32}$$

$$EQ_T^{can} = \psi^{can}[(\epsilon_h^{can} + \eta_h^{can})E(MC^{can}) - \epsilon_h^{can}\lambda^{can}\alpha_p^{can}\alpha_r^{can} ER^{can}] \tag{33}$$

where

$\psi^{can} = \epsilon_p^{can}/(\epsilon_p^{can}(\lambda^{can})^2\xi^{can}\alpha_p^{can} + \epsilon_h^{can} + \eta_h^{can}) > 0$

$$E(MC^{can}) = \left[\frac{N^{can}}{\Omega^{can}}\right] ER^{can} + \left[\frac{\kappa_{can}^{eu}}{\Omega^{can}}\right] E(MC^{eu}) + \left[\frac{\kappa_{can}^{us}}{\Omega^{can}}\right] E(MC^{us}) \tag{34}$$

where

$N^{can} = \psi^{can}\epsilon_h^{can}\lambda^{can}\alpha_p^{can}\alpha_r^{can} > 0$

$\Omega^{can} = \psi^{can}(\epsilon_h^{can} + \eta_h^{can}) + \kappa_{eu}^{eu} > 0$