Assessing the Impact of the Exchange Rate and Its Volatility on Canadian Pork and Live Swine Exports to the United States and Japan

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Abstract

A model of a representative Canadian pork exporter is developed to examine the impacts of the exchange rate and its volatility on pork and live swine exports. The pork export supply equation is expressed as a function of the expected level of real exchange rate and a time-varying variance of real exchange rate. An AR(p) model is used to represent the expected real exchange rate, and a GARCH(p, q) model is used to generate the time-varying variance. The same model is used to examine the sensitivity of pork exports to Japan from Canada, the United States, and Denmark.

The parameters of all pork and live swine export equations have theoretically consistent signs and many are significant. That is, the domestic price in the exporting country has a negative effect on exports because it is a major input price in the exporter's cost function while the price in the market of destination has a positive effect. The level of the exchange rate has a positive impact on pork exports while the volatility of the exchange rate has a negative impact. Most of the volatility parameters are not significant.

Key words: AR, autoregressive, exchange rate volatility, exports, GARCH.

ASSESSING THE IMPACT OF THE EXCHANGE RATE AND ITS VOLATILITY ON CANADIAN PORK AND LIVE SWINE EXPORTS TO THE UNITED STATES AND JAPAN

Introduction

Canada, the European Union, and the United States are the three biggest suppliers of pork in the world. Their combined share of the world pork market over the last four years is 83 percent.[1] Of the three leading pork-exporting countries, Canada has the smallest pork-swine sector. The average pork production in Canada, at 1,564 thousand metric tons (tmt), is only 9 percent compared to the 17,694 tmt pork production in the European Union and is only 18 percent of the 8,631 tmt pork production in the United States. However, in terms of trade, Canada's market share of total pork trade is one of the highest, at 23 percent (and would increase by another 9 percent if the meat equivalent of live hog exports is included), exceeding the 9 percent market share of the United States. As a result, Canada ranks first among the three countries for the proportion of its production that is exported—39 percent compared with 7 percent for both the European Union and the United States.[2] What this implies is that, of the three countries considered, Canada's pork-swine sector is most vulnerable to shocks in the world market, such as the volatility in the exchange rate.

Also, multilateral trade agreements such as the General Agreement on Tariffs and Trade (GATT) and regional trade agreements such as the North American Free Trade Agreement (NAFTA) have liberalized the North American market, making it operate more like a single market. Border duties have been significantly reduced or totally removed, and non-trade barriers are increasingly eliminated. Hence, it is expected that the trade pattern will continue to evolve based on fundamental economic forces that shape the comparative advantage of these countries.

The general objective of the study is to examine the impact of the exchange rate and its volatility on pork-swine trade. The specific objectives are to

1. analyze the impact of the exchange rate and its volatility on pork and live hog exports from Canada to the United States, and
2. compare the impacts of the exchange rate and its volatility on pork exports to Japan from Canada, the European Union, and the United States.

Background of the Pork Sector and Import Markets

The swine-pork sector in Canada is much smaller than that of the United States, but over the last three decades, its growth has exceeded that of its U.S. counterpart. In the 1970s, Canada's pork production was only 11.8 percent of the production in the United States. Significant growth in the 1980s increased the size of the swine-pork sector in Canada to 15.8 percent. It increased again to 16.5 percent in the 1990s. Strong domestic and export demand for pork and live swine, coupled with the availability of cheap grains and oilseeds and productivity improvements, has fueled the growth in the industry. Table 1 shows production data of the swine-pork sectors in the United States and Canada. Some differences in the productivity between the two countries are evident. For example, the United States has a higher slaughter rate and tends to have heavier animals at slaughter. Canada, on the other hand, has higher sow productivity in piglets per sow per year and a lower mortality rate. Canada's feeding practice also may be different. Although no species-specific feed consumption data are available, aggregate feed use data shown in Table 2 show the countries' respective feeding patterns. Canada uses three major feed grains: barley (39 percent), corn (27 percent), and wheat (24 percent). A similar mix is used in the European Union, except that more wheat (36 percent) is used instead of barley (only 29 percent). In contrast, the United States relies primarily on corn (82 percent). The other feed grains are used much less. In oilseed meals, Canada uses soy meal (84 percent) and rapeseed meal (16 percent). Again, the European Union has a similar oil meal mix but uses sunflower meal (9 percent) while the United States uses mostly soy meal (96 percent).

Canada has the highest proportion of production that is exported. In the 1970s, this represented 7 percent of production. It registered the highest increase, to 22 percent, in the 1980s and grew to 31 percent in the 1990s. The proportion exported last year was a high of 41 percent. In fact, the total export from Canada to the United States (including the meat equivalent of the live swine exports) is higher than the total export of the United

TABLE 1. Swine-pork sector in Canada and the United States.

	Canada			United States		
	1970s	**1980s**	**1990s**	**1970s**	**1980s**	**1990s**
	Thousand Metric Tons					
Pork						
Production	745	1,082	1,322	6,316	6,871	8,003
Imports	49	20	41	222	401	345
Exports	55	239	422	87	88	381
Consumption	739	862	940	6,444	7,186	7,962
Ending stocks	11	11	21	128	153	190
	Thousand Head					
Swine						
Swine stock	6,895	10,278	11,297	58,216	56,895	58,159
Sow stock	703	1,055	1,141	8,575	7,602	6,807
Piglets	10,953	15,416	19,956	89,513	90,234	98,744
Imports	1	1	4	98	654	2,500
Exports	99	645	2,501	15	37	103
Total slaughter	10,317	14,323	16,456	82,116	86,967	94,626
Sow slaughter	252	305	236	4,710	4,290	3,575
Other slaughter	10,064	14,017	16,220	77,406	82,678	91,051
Mortality	185	419	869	6,406	5,237	6,047
Productivity						
Weight (mt/hd)	0.072	0.075	0.080	0.077	0.079	0.085
Piglet/sow/year	15.62	14.61	17.36	10.44	11.98	14.54
Mortality (%)	1.04	1.61	2.75	4.36	3.53	3.84

Source: PS&D View, USDA-ERS.

TABLE 2. Feed consumption pattern in share of feed grains and oilseed meals (in percent)

	Canada	**United States**	**European Union**
Feed grains			
Corn	27.29	81.74	28.40
Barley	39.18	3.36	29.28
Sorghum	0.00	6.48	0.00
Wheat	24.31	6.53	35.94
Oats	9.22	1.90	4.35
Rye	0.00	0.00	2.03
Oilseed meals			
Soy meal	83.81	96.18	78.42
Sunflower meal	0.00	1.07	8.84
Rape meal	16.19	2.75	12.74

Source: PS&D View, USDA-ERS.

States to all other countries. For example, in 2000, the United States imported 686 tmt of pork equivalent from Canada and exported only 592 tmt.

Canada also differs from the European Union and the United States in terms of the market destination of its pork exports. Although the market shares of the European Union and the United States are different in various markets, they seem to share a common strategy. The European Union and the United States have significant market shares, 29 percent and 50 percent, respectively, in the lucrative and expanding pork export markets in Asia. Also, both the European Union and United States seem to be successful in penetrating emerging markets such as the Russian Federation, with respective market shares of 30 and 21 percent. The third largest share of their pork exports go to geographically close markets. For the European Union, this is the Central and Eastern European Countries and countries from the Former Soviet Union, accounting for 35 percent of its exports. For the United States the North American market accounts for 26 percent of its exports (see Figure 1). In contrast, Canada ships most of its exports to the United States, which accounts for 64 percent of its total pork exports (see Figure 2).[3] In effect, while the European Union and the United States have expanded export market shares in regions with strong consumer preference for pork but with limited resources for its production (e.g., Asia), Canada has concentrated its pork exports to the United States, which is also very competitive in pork production.

As shown in Table 3, the major suppliers of pork in the United States import market are Canada, Denmark, the Netherlands, and the "others" category, which includes Poland and Hungary. Canada is the largest supplier, with its share increasing from 57 percent in 1994, 69 percent in 1997, and 76 percent in 2000. The trade pattern between Canada and the United States has changed over the years, especially in terms of the product mix. Figure 3 shows Canadian exports of pork, slaughter-ready hogs, and feeder hogs to the United States. Up until the first quarter of 1998, pork imports from Canada had been stable, while the increase in imports was mostly in the form of slaughter-ready hogs. Hayes and Clemens (1999) claim that the combined effect of an inefficient eastern packing sector and capacity-constrained western packing sector forced Canadian live animals into the United States. However, a combination of factors, including closure of some processing plants in the United States and new investments in meat processing in

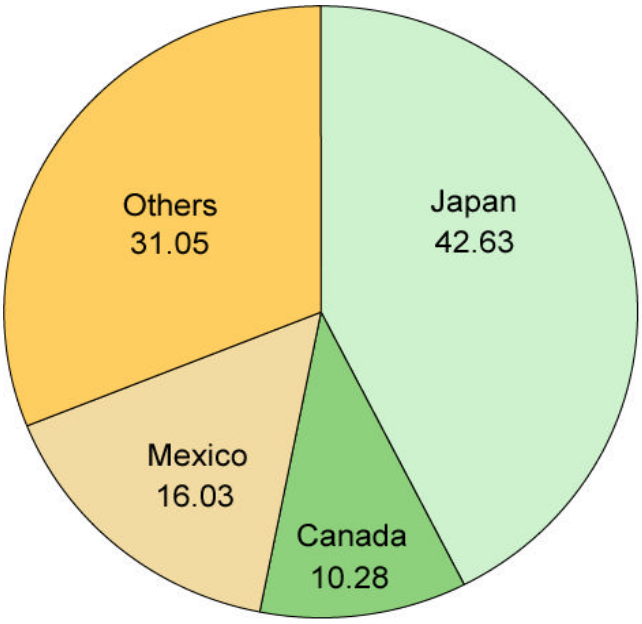

FIGURE 1. Proportion of U.S. pork exports by country of destination

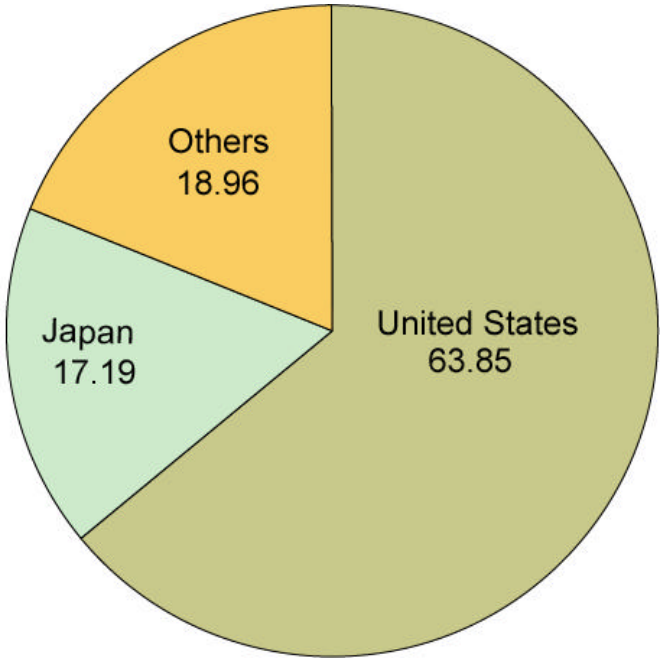

FIGURE 2. Proportion of Canadian pork exports by country of destination

TABLE 3. Country share of pork supplier in the U.S. pork import market

Year	Quantity (000 lbs)	Country Share (%)			
		Canada	Denmark	Netherlands	Others
1994	743,805	56.71	32.88	2.25	8.16
1995	664,288	68.35	21.76	1.61	8.29
1996	619,731	70.67	19.72	1.37	8.25
1997	634,059	68.63	19.53	1.28	10.55
1998	705,392	69.64	19.21	1.41	9.74
1999	827,114	74.64	16.06	1.20	8.10
2000	966,909	76.27	15.30	1.11	7.31

Source: *Livestock Dairy and Poultry Outlook*, USDA-ERS.

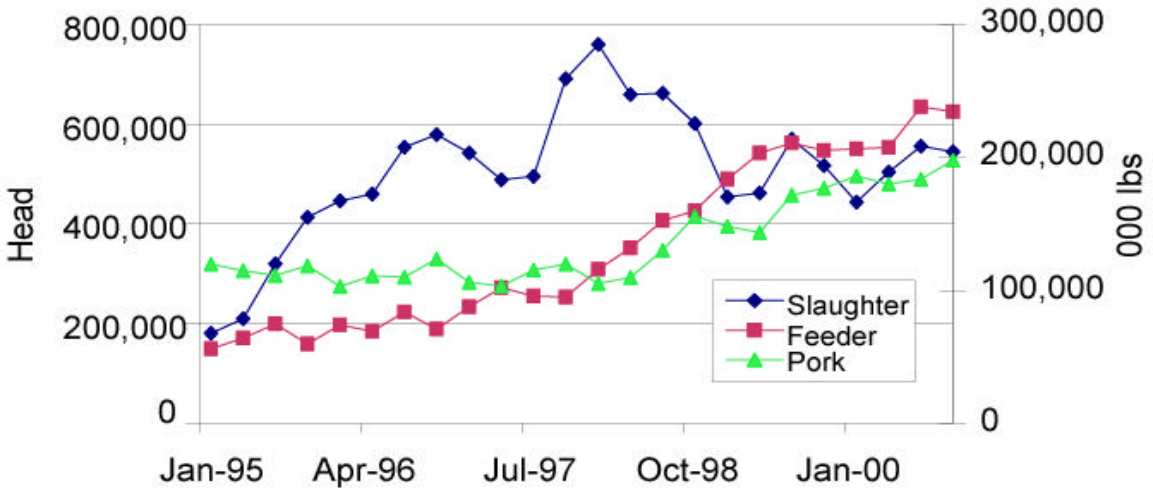

FIGURE 3. Canadian exports of pork, slaughter-ready hogs, and feeder hogs to the United States

Canada, shifted the product mix away from slaughter-ready hogs to pork exports. Also, while exports of slaughter-ready hogs has declined since 1998, exports of feeder hogs posted significant increases, accounting for more than half of total live swine exports from Canada to the United States in more recent years. This was driven by structural changes in the U.S. Midwest hog industry, increased investment in weaner operations in Canada, contractual arrangements, and a favorable Canadian dollar. Exports of feeder

pigs to Iowa and Minnesota accounted for 77 percent of total exports. Most of these feeder pigs come from Manitoba and Ontario, which accounted for 96 percent of total feeder pig exports.

Also, Hayes and Clemens (1999) project that with the termination of grain transportation subsidies, pork production in Canada will move from the East to the West. They say that this likely will induce a trade pattern whereby pork and hogs will be exported from western Canada to the United States, while the population centers in eastern Canada can be supplied from the eastern Corn Belt states.

The evolution of Canada's trade in pork and live swine with the United States has been greatly shaped by favorable macroeconomic factors. Figure 4 shows Canada's exchange rate and its general price level relative to the United States. The movement of both Canada's exchange rate and price levels has improved the country's competitive advantage relative to the United States, explaining the significant increases in pork and live swine trade. Since 1990, the value of Canadian currency has continued to depreciate relative to U.S. currency, declining from CA$1.17 per US$1.00 in 1990 to CA$1.55 in 2001. During the same period, the general price level in Canada has declined relative to

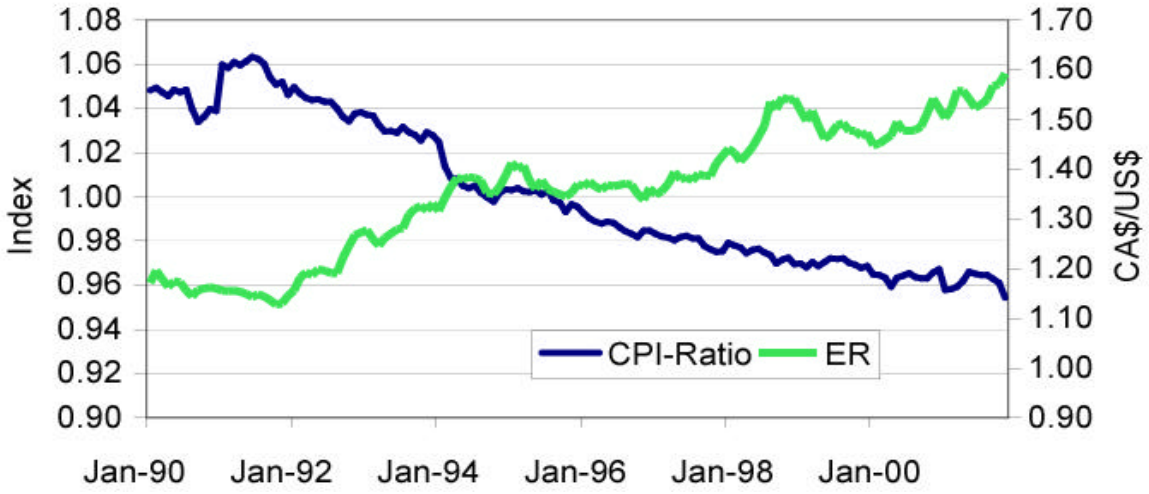

FIGURE 4. Canadian exchange rate (CA$/US$) and relative general price level (CPI Canada/CPI U.S.)

the general price level in the United States. The price ratio declined from 1.04 in 1990 to 0.96 in 2001. This implies that hog producers in Canada who export to the United States face an increasingly lower cost relative to their U.S. counterparts, assuming the same level of productivity, while the value of their products in Canadian dollars is increasing. Both factors are favorable in increasing production and export.

Canada is also becoming a significant player in the lucrative Japanese pork import market. But it has to compete with other major pork producers-exporters. Japan is the largest pork importer in the world, with imports of 920 tmt in 2001, representing 40 percent of world trade.[4] The mix of Japan's pork imports is 70 percent frozen and 30 percent fresh-chilled. In the early 1990s, Taiwan and the United States dominated the fresh-chilled market. Since Taiwan's foot-and-mouth disease outbreak in 1997 and Japan's banning of its products, the United States and Canada now account for 90 percent of the fresh-chilled import market in Japan (see Tables 4 through 6). For the frozen pork market, Denmark is the leading supplier, with a share of 43 percent. The Canadian share in this market is 18 percent, and the U.S. share is 16 percent.

The GATT rules have radically altered Japan's import policies. Although the gate price is maintained, it is effectively decoupled from the stabilization price band and was subject to reduction commitments until 2000. The variable levy has been converted into a specific tax and, together with the ad valorem duty, is subject to reduction commitments. The implementation of the specific tax stipulates that specific taxes that make the import price (CIF [cost, insurance, and freight] and duties included) more than the standard import price (i.e., gate price with ad valorem duties applied) are exempt. Only an ad valorem tax is imposed for pork imports with CIF prices higher than the standard import price.

Japan also has a safeguard provision intended to protect importers from excess surges in imports. When the cumulative sum of pork imports at the end of each quarter exceeds the average of the last three years by 119 percent, the safeguard can be invoked where the gate price is raised by 24 percent and is in effect for the rest of Japan's fiscal year (ending March 31). Since implementation of the GATT agreement, Japan has invoked the safeguard provision only three times; the latest covered the period August 2001 to March 2002.

TABLE 4. Country share of fresh-chilled pork supplier in the Japanese pork import market

Year	Quantity (tons)	Country Share (%)				
		U.S.	Canada	S. Korea	Denmark	Others
1994	141,150	38.09	2.55	1.68	0.40	57.28
1995	164,603	47.27	2.96	1.94	0.09	47.74
1996	168,103	45.79	4.66	2.73	0.04	46.78
1997	128,779	75.02	14.04	9.80	0.33	0.82
1998	149,534	68.91	14.22	13.51	0.14	3.22
1999	181,478	64.85	17.41	11.97	0.21	5.56
2000	192,937	67.30	22.78	0.05	0.23	9.64

Source: Agriculture and Livestock Industries Corporation.

TABLE 5. Country share of frozen pork supplier in the Japanese pork import market

Year	Quantity (tons)	Country Share (%)				
		U.S.	Canada	S. Korea	Denmark	Others
1994	361,893	5.94	6.69	2.47	36.65	48.25
1995	369,902	8.34	6.35	3.54	29.38	52.40
1996	495,236	13.27	6.71	6.03	24.51	49.48
1997	388,668	13.71	11.03	12.61	39.13	23.52
1998	396,198	15.72	11.53	18.47	36.64	17.65
1999	471,284	12.49	13.54	11.41	44.35	18.20
2000	457,383	15.56	18.40	0.13	42.60	23.31

Source: Agriculture and Livestock Industries Corporation.

TABLE 6. Country share of total pork supplier in the Japanese pork import market

Year	Quantity (tons)	Country Share (%)				
		U.S.	Canada	S. Korea	Denmark	Others
1994	503,043	14.96	5.53	2.25	26.48	50.78
1995	534,505	20.33	5.30	3.04	20.36	50.96
1996	663,339	21.51	6.19	5.20	18.31	48.80
1997	517,447	28.97	11.78	11.91	29.47	17.87
1998	545,732	30.29	12.27	17.11	26.64	13.70
1999	652,762	27.04	14.62	11.57	32.08	14.69
2000	650,320	30.91	19.70	0.11	30.03	19.25

Source: Agriculture and Livestock Industries Corporation.

Model

Literature Review

With major domestic policy reforms, such as the termination of the grain transportation subsidy in Canada and the removal of trade barriers in NAFTA, the North American market is becoming a single market. This implies that the trade pattern in this market will be shaped largely by fundamental factors affecting the comparative advantage of the respective countries. In particular, the movement of the exchange rate will have a strong influence on trade outcomes.

A number of studies have been conducted on the effect of the exchange rate and its volatility on trade, but the literature does not speak with consensus. For example, Bini-Smaghi (1991), Arize (1995), Chowdhury (1993), and Gervais and Larue (2001) have found a negative influence of exchange rate volatility on trade volumes. In contrast, Asseery and Peel (1991); Bailey, Tavlas, and Ulan (1986); Gotur (1985); and Mohanty, Meyers, and Smith (2000) have reported either a negative impact or the absence of any effect of exchange rate volatility on trade volumes.

Several studies have focused on the impact of the exchange rate on Canada's export of pork and live swine. For example, Zhao, Klein, and Santos (2001) used a vector autoregression (VAR) model to examine the effects of exchange rate fluctuations on live hog trade between the United States and Canada. They found that Canada's exchange rate does not "Granger-cause"[5] the U.S. live hog imports from Canada. Based on an impulse response analysis, they concluded that exchange rates have a tendency to raise the level of U.S. hog imports in the very short run.[6] Gervais and Larue (2001) studied the impacts of exchange rate volatility on Canadian pork exports to the United States. They directly measured exchange rate volatility using a moving average of the absolute difference between the previous forward and current spot rates and the standard deviation of the exchange rate. As in Zhao, Klein, and Santos 2001, an impulse response analysis was conducted but with one difference: a measure of exchange rate volatility was directly included as one variable in the system. They concluded that there is a significant long-term negative correlation between exchange rate volatility and exports.

Model

This study differs from earlier studies in several respects. First, whereas earlier studies used time-series methods, this study develops and estimates a structural model. One limitation of the standard VAR analysis is that only lag variables enter into the system for identification purposes. Unless the VAR residuals are given structure and estimated, the contemporaneous relationships of variables are lumped into the VAR residual series. In contrast, the strength of structural models is that a theoretical structure can be built into the model to explain the relationships of the relevant variables. Both the contemporaneous relationships of variables and the dynamics are captured in a structural model. Second, a generalized autoregressive conditional heteroskedasticity (GARCH) model is used to represent the volatility of the exchange rate series. Third, a real exchange rate is used rather than a nominal one. This is important in this particular case because Canada's exchange rate has continued to depreciate relative to the U.S. dollar while at the same time Canada's general price level is declining relative to that of the United States. Fourth, the same method is applied to both pork and live swine exports from Canada to the United States, as well as to pork exports to Japan from Canada, the United States, and Denmark.

To theoretically derive the estimating equations, a model of a representative firm involved in pure trade in pork (export) in Canada is developed. Both the output price and the real exchange rate can be random. But because the specific focus of the study is on the exchange rate, the model is developed with the real exchange rate (defined as Canadian dollar per U.S. dollar with differential inflation accounted for) as the only variable with a time-varying variance. It easily can be extended to include a random output price as well. For our purposes, the real exchange rate is assumed to have a normal distribution,

$$r \sim N(r^e, s_r^2), \tag{1}$$

where r^e is the mean and s_r^2 is the variance. The firm's net profit (p) in Canadian dollars is defined as revenue less cost, that is,

$$p = p_w.r.Q - c(Q, p_d, w \mid \Phi), \tag{2}$$

where p_w is the output price (or U.S. price in U.S. dollars), Q is the level of export, $c(\bullet)$ is the cost function with arguments, p_d is input price (or domestic price in Canada), and w is a vector of prices of other inputs. From (1) and (2), profit also is normally distributed, with mean and variance given in (3):

$$p \sim N(\{p_w.r^e.Q - c(Q, p_d, w \mid \Phi)\}, \{p_w^2.Q^2.s_r^2\}). \tag{3}$$

Given a CARA utility function, the expected utility can be expressed in the form

$$E(V) = -e^{-l(p^e - 0.5 l s_p^2)}. \tag{4}$$

It is a common result that the maximization of (4) can be equivalently expressed as

$$Max \quad E(V) = Max(p^e - 0.5 l s_p^2). \tag{5}$$

Substituting the first and second moments of profit from (3) to the maximization problem in (5), we get

$$\underset{Q}{Max} \quad (\{p_w.r^e.Q - c(Q, p_d, w \mid \Phi)\} - 0.5 l \{p_w^2.Q^2.s_r^2\}). \tag{6}$$

The first- and second-order conditions of (6) are

$$p_w.r^e - c_q(Q, p_d, w \mid \Phi) - l\, p_w^2.Q.s_r^2 = 0 \tag{7}$$

and

$$H = -c_{qq}(Q, p_d, w \mid \Phi) - l.p_w^2.s_r^2 < 0, \tag{8}$$

which requires $c_{qq} \geq 0$.

Using (7), comparative statics analysis gives

$$\frac{\partial Q}{\partial r^e} = \frac{-p_w}{H} > 0 \tag{9}$$

and

$$\frac{\partial Q}{\partial s_r^2} = \frac{l\, p_w^2 Q}{H} < 0. \tag{10}$$

That is, it is expected that an increase in the level of the exchange rate increases supply (in [9]), while more volatility in the exchange rate reduces supply (in [10]).

The solution to the first-order condition in (7) gives the standard supply function, which is of the form

$$Q = (p_w, p_d, r, w, s_r^2 \mid l, \Phi), \tag{11}$$

where (λ and Φ) is a vector of parameters underlying the utility and production functions of the firm.

Assuming linearity and adding a random term in (11), the form of the estimating supply equation is

$$Q_t = a_0 + \sum_{i=1}^{n} a_{1i} p_{w,t-i} + \sum_{i=1}^{n} a_{2i} p_{d,t-i} + \sum_{i=1}^{n} a_{3i} r_{t-i}^e + \sum_{i=1}^{n} a_{4i} s_{r,t-i}^2 + e_t . \tag{12}$$

To complete the model, laws of motion for the conditional expected real exchange rate and the conditional expected variance of real exchange rate need to be specified. Although the case for including the second moment in supply models is well established, the empirical question as to how to adequately represent a time-varying variance is far from settled. The literature does not speak with consensus on this matter, but the parametric autoregressive conditional heteroskedasticity (ARCH) (Engle 1982) and GARCH (Bollerslev 1986, 1987), models have become the "standard."[7] In this formulation, the law of motion governing the time-varying variance is conditioned on the squared prediction error and its own lags.

The expected real exchange rate is assumed to be adequately described by an AR(p) process of the form

$$r_t = A(L).r_{t-1} + m_t , \tag{13}$$

while the time-varying variance of the real exchange rate is assumed to be adequately described by a GARCH(p,q) process of the form

$$h_t = d + B(L)m_{t-1} + C(L)h_{t-1} . \tag{14}$$

where $A(L)$, $B(L)$, and $C(L)$ are matrices of coefficients and (L) is a lag operator.

Results

Data and Estimation

Monthly data from October 1994 to November 2001 were used in the study. The nominal exchange rate and the Consumer Price Index (CPI) were taken from the International Financial Statistics database of the International Monetary Fund. U.S. data on pork and live swine imports from Canada and U.S. pork prices were taken from the *Livestock, Dairy, and Poultry Outlook* and the U.S. Redmeat Yearbook database of the U.S. Department of Agriculture's Economic Research Service (USDA-ERS Various). Canadian pork prices were taken from the *Annual Livestock Market Review* of Agriculture Canada. Data on the second part of the study were from the Agriculture and Livestock Industries Corporation of Japan. Table 7 gives the definition of the relevant variables in the model.

TABLE 7. Data used in the estimation

Data in Monthly Fequency	Units
Canada-U.S. Trade	
Canada pork exports to the U.S.	Thousand pounds carcass weight
Canada live swine exports to the U.S.	Thousand head
Index monthly average hog price Ontario	CA$ per kilogram deadweight
Barrow-gilt price national base 51%-52% lean	US$ per cwt liveweight
Canadian exchange rate	CA$ per US$
Canadian Consumer Price Index	Index 1995=100
U.S. Consumer Price Index	Index 1995=100
U.S.-Canada-Denmark trade with Japan	
U.S. pork exports to Japan	Tons in boneless equivalent
Canada pork exports to Japan	Tons in boneless equivalent
Denmark pork exports to Japan	Tons in boneless equivalent
Denmark exchange rate	Kroner per US$
Japan exchange rate	Yen per US$
Denmark Consumer Price Index	Index 1995=100
Japan Consumer Price Index	Index 1995=100
U.S. pork price (weighted average)	CIF Japan Yen per kilogram
Canada pork price (weighted average)	CIF Japan Yen per kilogram
Denmark pork price (weighted average)	CIF Japan Yen per kilogram

Equations (12), (13), and (14) comprise the entire system of equations to be estimated. The system has three endogenous variables: the quantity of pork exports (number of live swine exports), expected real exchange rate, and expected variance of the real exchange rate. Since all Full Information Maximum Likelihood algorithms are sensitive to the initial values, these were first generated using the simplex algorithm, which is robust to the specified initial values. This robustness is a product of the algorithm's search method in finding the global optimum using functional evaluation rather than an evaluation of derivatives. Next, the final estimates were generated using the Broyden, Fletcher, Goldfard, and Shanno algorithm. The estimations were made in RATS Windows Version 4.21.

The law of motion of the stochastic real exchange rate is assumed to be adequately described by an autoregressive process of order p. The Box-Jenkins procedure (Box and Jenkins 1976) is employed to identify the order of the AR process. Figure 5 shows the autocorrelation function (ACF) and partial autocorrelation function (PACF) of the real exchange rate of Canada. The autocorrelation is slowly decaying. The standard errors (computed using Bartlett's formula) indicate that only the ACFs after the eleventh lag are not significantly different from zero. On the other hand, the PACF cuts off after the first lag.

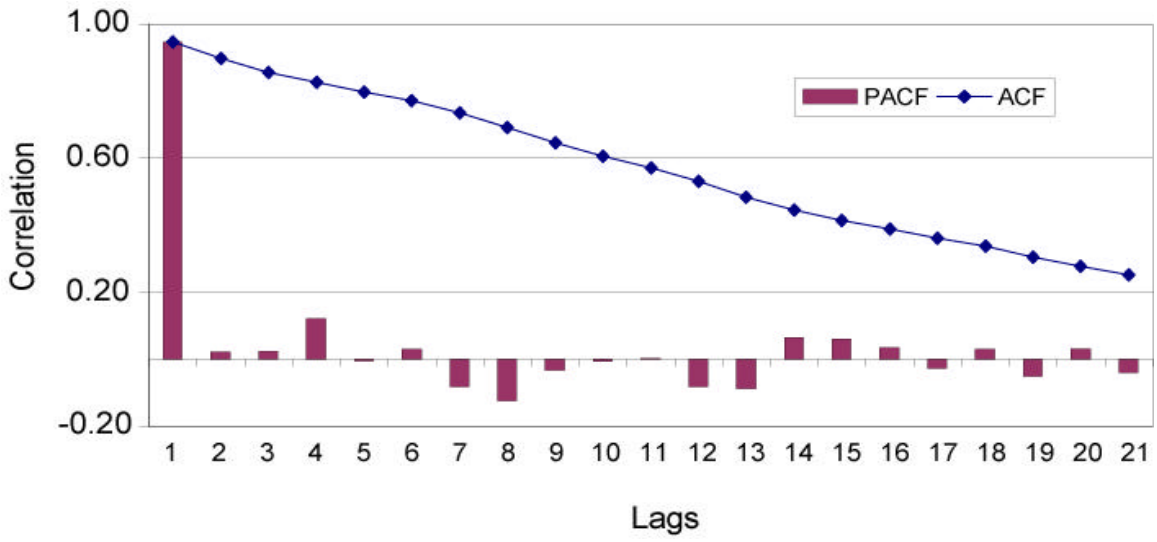

FIGURE 5. Autocorrelation function and partial autocorrelation function of the logarithm of the real exchange rate for Canada

The behavior of the ACF and PACF suggests that the real exchange rate follows an AR process with its order determined by the number of significant spikes in the PACF. In this case the order is one – AR(1).[8] Also, a Ljung-Box test was conducted on the ACFs of the residual of the AR(1) of the real exchange rate. The Q-test statistic is 13 with a significance level of 0.66, accepting the null hypothesis that the ACFs of the residual series are jointly equal to zero. That is, the residual ACFs and PACFs of the AR(p) model approximate a white noise process.

Discussion

The results of the pork export equation model are presented in Table 8. All the signs of the coefficients are theoretically consistent and many are statistically significant. That is, the pork export supply of the representative exporting firm is negatively affected by the domestic price in Canada. This is the case because the domestic price in Canada

TABLE 8. Parameter estimates of the pork export model, Canada to United States

Equation/Variable	Coefficient	Std Errors	t-Statistics	Significance
Pork export model				
Intercept	2.657	3.347	0.794	0.427
Canada pork price	-1.133	0.649	-1.747	0.081
Canada pork price L1[a]	-0.311	0.629	-0.495	0.621
U.S. pork price	0.911	0.623	1.462	0.144
U.S. pork price L1	0.839	0.651	1.289	0.197
Expected exchange rate	18.902	5.896	3.206	0.001
Expected exchange rate L1	-12.996	6.290	-2.066	0.039
Variance exchange rate	-1919.845	1244.070	-1.543	0.123
Real exchange rate model				
Intercept	-0.009	0.011	-0.847	0.397
Real exchange rate L1	0.884	0.108	8.173	0.000
Real exchange rate L2	-0.067	0.157	-0.426	0.670
Real exchange rate L3	-0.020	0.143	-0.138	0.890
Real exchange rate L4	0.052	0.150	0.347	0.728
Exc rate variance model				
Intercept	0.000	0.000	1.524	0.127
Variance exchange rate L1	0.119	0.068	1.751	0.080
Squared residual L1	0.557	0.251	2.221	0.026

Note: All variables are in logarithms except for the variance of the real exchange rate.
[a] L means lag and the numbers that follow are the order of the lag (e.g., L1 is lag 1 year).

enters as a major input price of the cost function as the firm purchases the pork for export in the Canadian market. On the other hand, the price of pork in the United States has a positive impact on the pork export of the representative firm. This is the case because the exporting firm sells its final product in the U.S. market, where the U.S. price is the output price. The significance of the U.S. price parameter is only 0.14. The level of the real exchange rate has a significant positive impact on the pork export of the representative firm. That is, as the Canadian dollar depreciates relative to the U.S. dollar, the firm will export more pork to the U.S. market. The effect of currency devaluation can be seen either as an increase in the nominal output price, expressed in Canadian dollars, faced by the exporting firm or as a decrease in the firm's cost of purchasing pork in the domestic market in Canada, expressed in U.S. dollars. Either way, the firm's export supply function increases with the depreciation of the Canadian dollar, resulting in a positive sign in the parameter associated with the level of exchange rate. This is consistent with the expect sign given in equation (9). Finally, the pork export of the representative firm is negatively affected by the volatility of the real exchange rate. The statistical significance of this parameter is 0.12. This result is consistent with the behavior of a risk-averse firm that is faced with some randomness in its decision rule. Sandmo (1971) formally showed that if the risk behavior of agents is accounted for in the optimization problem, the marginal condition includes the second moment of the random variable in a term collectively called risk premium. In particular, assuming a Sandmo world, risk-averse agents are shown to be willing to pay a premium to trade away risk for its certain equivalent, making their optimal decision fundamentally different under the no-risk or risk-neutral case. Gervais and Larue (2001) found the same impact of exchange rate volatility in their analysis. Also, this is the expected impact of exchange rate volatility on export supply as derived in equation (10).

A similar analysis was conducted on the export of live swine from Canada to the United States. Table 9 shows the results, which are similar to the pork export model. That is, the domestic price of pork in Canada has a negative impact on live swine export to the United States because it enters into the cost function of the representative firm. The price of swine in the United States has a positive impact on export because it is the final output price faced by the firm when it sells the live swine in the U.S. market. Also, the Canadian

TABLE 9. Parameter estimates of the live swine export model, Canada to United States

Equation/Variable	Coefficient	Std Errors	t-Statistics	Significance
Pork export model				
Intercept	18.305	18.785	0.974	0.330
Canada pork price	-2.389	0.430	-5.550	0.000
Canada pork price L1	-1.469	0.387	-3.794	0.000
U.S. pork price	2.374	0.413	5.743	0.000
U.S. pork price L1	2.363	0.386	6.125	0.000
Expected exchange rate	2.265	2.191	1.034	0.301
Expected exchange rate L1	6.725	2.269	2.964	0.003
Variance of exchange rate	-263143.106	168035.080	-1.566	0.117
Real exchange rate model				
Intercept	0.002	0.002	1.054	0.292
Real exchange rate L1	1.073	0.069	15.554	0.000
Real exchange rate L2	-0.070	0.102	-0.682	0.495
Real exchange rate L3	-0.029	0.102	-0.288	0.773
Real exchange rate L4	0.026	0.095	0.271	0.787
Exc rate variance model				
Intercept	6.81E-06	8.12E-07	8.397	0.000
Variance exchange rate L1	-4.83E-05	1.94E-04	-0.249	0.803
Squared residual L1	9.30E-01	5.53E-03	168.175	0.000

Note: All variables are in logarithms except the variance of real exchange rate.

exchange rate has a positive influence on the live swine export. That is, more live swine product is exported when the Canadian currency depreciates relative to the U.S. dollar. This result is consistent with the findings of Zhao, Klein, and Santos (2001). The variability of the real exchange rate has a negative impact on live swine exports with a significance level of 0.12. It should be noted that considerations concerning available processing capacity also largely influence live swine import by the United States. That is, the representative firm in Canada is still able to supply more live hogs to the United States even with the presence of variability in the exchange rate because U.S. importers want to ensure profitable levels of capacity utilization in their processing plants, especially during months when slaughter-ready hogs in the United States are not abundant. Also, the mix between export of slaughter-ready and feeder pigs from Canada to the United States has changed over time, with feeder pigs gaining increasing share in the recent period.

Finally, the same methodology was applied in analyzing the impact of the exchange rate and its volatility on pork exports to Japan from its major suppliers, including Canada, the United States, and Denmark. The results in Tables 10 through 12 show a similar pattern across all three countries: all the signs of parameters in the pork export equation are theoretically consistent. The pork domestic price in the respective exporting countries has a negative sign and is significant because it enters as a major input price in the cost function of pork exporters. The pork price in Japan has a positive sign because it is the final output price faced by exporters. However, it is not significant in all three exporting countries. The lack of significance of the Japanese pork price likely is caused by the distortions in the Japanese import market created by domestic and trade policies, including the gate price, pork price band, and safeguards with "variable, levy-like" protection. The exchange rate level has a positive impact on pork exports. It is small and

TABLE 10. Parameter estimates of the pork export model, United States to Japan

Equation/Variable	Coefficient	Std Errors	t-Statistics	Significance
Pork export model				
Intercept	22.342	3.307	6.755	0.000
U.S. pork price	-3.890	1.352	-2.876	0.004
U.S. pork price L1	1.605	1.450	1.107	0.268
Japan pork price	0.315	0.546	0.576	0.564
Japan pork price L1	0.460	0.545	0.845	0.398
Expected exchange rate	1.536	4.979	0.309	0.758
Expected exchange rate L1	-0.107	4.909	-0.022	0.983
Variance exchange rate	-206.012	480.587	-0.429	0.668
Real exchange rate model				
Intercept	-0.435	0.309	-1.405	0.160
Real exchange rate L1	1.329	0.189	7.035	0.000
Real exchange rate L2	-0.650	0.284	-2.285	0.022
Real exchange rate L3	0.539	0.338	1.595	0.111
Real exchange rate L4	-0.510	0.387	-1.316	0.188
Exc rate variance model				
Intercept	0.001	0.000	1.590	0.112
Variance exchange rate L1	0.234	0.305	0.768	0.442
Squared residual L1	-0.452	0.621	-0.727	0.467

Note: All variables are in logarithms except for the variance of the real exchange rate.

not significant in the U.S. pork export equation, but it is large and significant in the pork equation for Canada and Denmark. This differential result may stem from the fact that the United States exports mostly fresh-chilled pork while Canada and Denmark export frozen pork. Japanese importers may be more price sensitive for frozen pork than for fresh-chilled pork. This reasoning is also supported by the size of the parameter associated with the domestic price of the exporting country. It is smallest in the case of the United States and largest in the case of Denmark.

Summary and Conclusion

Canada is a large pork exporter on world markets, second only to the European Union. Of all pork exporting countries, Canada has a relatively small swine-pork sector, yet it has the highest proportion of domestic production that is exported, at 39 percent of its production.

TABLE 11. Parameter estimates of the pork export model, Canada to Japan

Equation/Variable	Coefficient	Std Errors	t-Statistics	Significance
Pork export model				
Intercept	48.421	3.173	15.261	0.000
Canada pork price	-8.368	2.092	-4.000	0.000
Canada pork price L1	2.976	2.110	1.411	0.158
Japan pork price	0.635	0.495	1.283	0.199
Japan pork price L1	0.243	0.476	0.510	0.610
Expected exchange rate	9.094	2.834	3.209	0.001
Expected exchange rate L1	-2.889	2.725	-1.060	0.289
Variance exchange rate	-484.579	841.893	-0.576	0.565
Real exchange rate model				
Intercept	-0.377	0.236	-1.599	0.110
Real exchange rate L1	1.292	0.199	6.489	0.000
Real exchange rate L2	-0.480	0.300	-1.600	0.110
Real exchange rate L3	0.256	0.379	0.674	0.500
Real exchange rate L4	-0.415	0.371	-1.119	0.263
Exc rate variance model				
Intercept	0.001	0.001	1.372	0.170
Variance exchange rate L1	0.111	0.195	0.568	0.570
Squared residual L1	-0.345	0.784	-0.440	0.660

Note: All variables are in logarithms except for the variance of the real exchange rate.

This makes its swine-pork sector more vulnerable to shocks in the world pork market. Canadian pork exports destined for the United States account for 64 percent of Canada's total exports. With the North American market becoming a single market after NAFTA, trade outcomes will be driven more by fundamental factors affecting comparative advantage, such as the exchange rate. The purpose of this paper is to analyze the response of pork and live swine exports from Canada to the United States to the level of the exchange rate and its volatility. Also, Canada is competing with major pork exporters such as the United States and Denmark in the lucrative Japanese pork import market. This study also compares the sensitivity of these countries' Japanese exports to the level of their exchange rates and exchange rate volatilities relative to the Japanese Yen.

A structural theoretical model of a representative pork exporter in Canada was developed and estimated. The pork equation for exports from Canada to the United States had theoretically consistent signs and statistically significant parameters. The domestic pork

TABLE 12. Parameter estimates of the pork export model, Denmark to Japan

Equation/Variable	Coefficient	Std Errors	t-Statistics	Significance
Pork export model				
Intercept	90.855	14.137	6.427	0.000
Denmark pork price	-16.903	5.531	-3.056	0.002
Denmark pork price L1	5.030	5.511	0.913	0.361
Japan pork price	0.380	0.602	0.631	0.528
Japan pork price L1	0.415	0.487	0.853	0.393
Expected exchange rate	13.292	6.860	1.938	0.053
Expected exchange rate L1	-0.689	6.489	-0.106	0.915
Variance exchange rate	-444.639	756.630	-0.588	0.557
Real exchange rate model				
Intercept	-0.376	0.216	-1.737	0.082
Real exchange rate L1	1.227	0.150	8.189	0.000
Real exchange rate L2	-0.462	0.236	-1.956	0.051
Real exchange rate L3	0.485	0.326	1.487	0.137
Real exchange rate L4	-0.582	0.349	-1.667	0.095
Exc rate variance model				
Intercept	0.001	0.000	2.672	0.008
Variance exchange rate L1	0.184	0.063	2.893	0.004
Squared residual L1	-0.929	0.164	-5.655	0.000

Note: All variables are in logarithms except for the variance of the real exchange rate.

price in Canada has a negative impact on pork trade while the U.S. pork price has a positive effect. The level of the Canadian exchange rate relative to the U.S. dollar has a positive impact on pork exports. The volatility of the Canadian exchange rate has a negative effect on pork trade. The results in the live export equation are almost the same.

The pork export equations for Canada, the United States, and Denmark all showed theoretically consistent signs. The domestic price parameter was negative and significant while the pork price in Japan was positive but not significant. Policy-induced distortions in the Japanese market may explain the lack of significance of the Japanese pork price. Pork exports of the three countries are positively affected by the level of their exchange rates relative to the Japanese Yen and are negatively affected by the volatility of their currencies. The parameter associated with the level of exchange rate was significant for Canada and Denmark but not for the United States. This may be because Japanese importers are more price sensitive for frozen pork products than for fresh-chilled. The United States exports more fresh-chilled pork while Canada and Denmark export frozen pork products. Pork exports were negatively affected by the volatility of the exchange rate of the three countries relative to the Japanese Yen, but the parameters were not significant.

Endnotes

1. Market share is computed based on net exports.
2. This does not include the meat equivalent of live hog export from Canada to the united States.
3. Excludes the pork equivalent of live swine trade.
4. World trade is total net imports of major countries covered by the Food Agricultural Policy Research Institute.
5. That is, it is not very helpful (in a statistical sense) in forecasting the live hog import series. See Granger and Newbold 1974.
6. This reflects more on the impact of the exchange rate rather than on its volatility.
7. Holt and Aradyula (1990) applied this model in poultry.
8. To avoid bias, an AR(4) is estimated in the model. This may result in lower precision.

References

Agriculture and Livestock Industries Corporation (ALIC). Various. *ALIC Monthly Statistics.* Tokyo, Japan. Various issues.

Agriculture Canada. Annual Livestock Market Review. Various. Ottawa, Ontario, Canada. *http://www.agr.gc.ca/misb/aisd/redmeat/redmsece.html* (accessed April 2002).

Arize, C.A. 1995. "The Effects of Exchange Rate Volatility on U.S. Exports: An Empirical Investigation." *Southern Economic Journal* 62: 34-43.

Asseery, A., and D.A. Peel. 1991. "The Effects of Exchange Rate Volatility on Exports." *Economic Letters* 37: 173-77.

Bailey, M.J., G.S. Tavlas, and M. Ulan. 1986. "The Exchange Rate Variability and Trade Performance: Evidence for the Big Seven Industrial Countries." *Weltwirtschaftliches Archil* 122: 466-77.

Bini-Smaghi, L. 1991. "Exchange Rate Variability and Trade: Why Is It So Difficult to Find Empirical Relationships?" *Applied Economics* 23: 927-36.

Bollerslev, T. 1986. "Generalized Autoregressive Conditional Heterskedasticity." *Journal of Econometrics* 31: 307-27.

———. 1987. "A Conditionally Heteroskedastic Time Series Model for Speculative Prices and Rates of Return." *Review of Economics and Statistics* 69: 542-547

Box, G.E.P., and G.M. Jenkins. 1976. *Time Series Analysis: Forecasting and Control*, rev. ed. San Francisco: Holden-Day.

Chowdhury, R.A. 1993. "Does Exchange Rate Volatility Depress Trade Flows? Evidence from Error-Correction Models." *Review of Economics and Statistics* 75: 700-6.

Engle, R.F. 1982. "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation." *Econometrica* 50: 987-1007.

Gervais, J-P., and B. Larue. 2001. "The Effects of Enhanced Financial Volatility on Agricultural Commodity Trade: The Impacts of Exchange Rate Volatility on Canadian Pork Exports to the U.S." Paper presented at the 2001 American Agricultural Economics annual meeting, August 5-8, Chicago, IL.

Gotur, P. 1985. "Effects of Exchange Rate Volatility on Trade: Some Further Evidence." *International Monetary Fund Staff Papers* 32: 475-512.

Granger, C.W.J., and P. Newbold. 1974. "Spurious Regression in Econometrics." *Journal of Econometrics* 26: 1045-66.

Hayes, J.D., and R. Clemens. 1999. "The Market for U.S. Meat Exports in Eastern Canada." CARD Working Paper 99-WP 229, Center for Agricultural and Rural Development, Iowa State University.

Holt, M.T., and S. Aradyula. 1990. "Price Risk in Supply Equations: An Application of GARCH Time-Series Models to the U.S. Broiler Market." *Southern Economic Journal* 57: 230-42.

International Monetary Fund. No date. International Financial Statistics [on-line database]. Washington, D.C. *http://imf.largo.apdi.net/_largomain/largomain.asp* (accessed April 2002).

Mohanty, S., W. Meyers, and D.B. Smith. 2000. "The Effects of Exchange Rate Volatility on U.S. Agricultural Exports." Unpublished.

Sandmo, A. 1971. "On the Theory of the Competitive Firm Under Price Uncertainty." *American Economic Review* 61: 65-73.

U.S. Department of Agriculture, Economic Research Service (USDA-ERS). Various. Livestock Dairy and Poultry Outlook. Washington, D.C. *http://usda.mannlib.cornell.edu/* (accessed April 2002).

———. Various. PS&D View [database on-line]. Washington, D.C. *http://usda.mannlib.cornell.edu/* (accessed April 2002).

———. No date. Red Meat Yearbook [database on-line]. *http://usda.mannlib.cornell.edu/* (accessed April 2002). Washington, D.C.

Zhao, Z., N.L. Klein, and J. Santos. 2001. "The Effects of Exchange Rate Fluctuations on Live Hog Trade between the U.S. and Canada." Paper presented at the 2001 American Agricultural Economics Association annual meeting, Chicago, IL, August 5-8.