Effects of exchange rate volatility on export volume and prices of forest products

Sijia Zhang and Joseph Buongiorno

Abstract: The relative value of currencies varies considerably over time. These fluctuations bring uncertainty to international traders. As a result, the volatility in exchange rate movements may influence the volume and the price of traded commodities. The volatility of exchange rates was measured by the variance of residuals in a GARCH(1,1) model of the exchange rate. We estimated the effect of this exchange rate volatility on export quantity and price with autoregressive distributed lag models based on monthly data of US exports and prices to 14 countries for eight commodity groups. The most general and statistically significant results were obtained by pooling the time series data across destination countries and products. They suggested that an increase in exchange rate variability of 1% led to a short-run decrease in export quantity of 0.3%–0.4% and to a short-run decrease in export price of 0.1%. Both the quantity and the price effect faded away over time. The effects were less systematic and statistically significant for specific export destinations or individual products. Thus, in contrast with exchange rate level, exchange rate volatility may not be a major policy issue for US forest product exports.

Résumé : La valeur relative des monnaies varie considérablement dans le temps et ces fluctuations augmentent l'incertitude sur les marchés internationaux. En conséquence, la volatilité du taux de change peut influencer le volume et le prix des produits exportés. Nous avons mesuré la volatilité du taux de change par la variance des résidus du modèle GARCH(1,1). L'effet de la volatilité du taux de change sur le volume et le prix des produits exportés a été estimé avec des modèles autorégressifs à retards distribués à partir de données mensuelles sur les exportations des États-Unis et le prix des produits exportés vers 14 pays pour huit groupes de produits. Les résultats les plus généraux et statistiquement significatifs ont été obtenus en regroupant les séries chronologiques par pays et par produit. Ils indiquent qu'une augmentation de 1 % de la volatilité du taux de change entraîne une diminution à court terme de 0,3 % à 0,4 % du volume des exportations et de 0,1 % du prix des produits exportés. L'effet sur le volume et le prix disparaît avec le temps. Ces effets sont moins systématiques et statistiquement significatifs pour une destination ou un produit donné. Ainsi, contrairement au niveau du taux de change, sa volatilité ne semble pas être un enjeu politique majeur pour les exportations américaines de produits forestiers.

[Traduit par la Rédaction]

Introduction

Since the breakdown of the Bretton-Woods system of fixed exchange rates in 1973, the relative price of currencies between countries has varied considerably over time. These fluctuations bring uncertainty to international traders. As a result, the volatility in exchange rate movements may influence the volume of trade and the prices of commodities traded.

Yet, there is no consensus regarding the effects of the exchange rate volatility on trade (Clark et al. 2004). Past theoretical and empirical studies have obtained different results (Bahmani-Oskooee and Hegerty 2007). Early theoretical models suggest that exchange rate volatility reduces the volume of trade. They assume that higher exchange rate risk lowers the risk-adjusted expected revenue from trade, and the risk-averse international traders respond by favoring the domestic market (Wolf 1995). This view presumes that hedging on forward exchange market is not sufficient to offset the effect of the exchange rate risk exposure. Caporale and Doroodian (1994) did find that volatility has a strictly negative effect on trade volume. Viaene and de Vries (1992) found that this negative effect is strong in developing countries, which may be explained by the absence of forward markets for currencies and long-term currency contracts.

However, a positive effect of exchange rate volatility on trade is also theoretically possible. Due to the ability of firms to adjust production to exchange rate fluctuations, trade could actually benefit from increased exchange rate volatility. By this reasoning, exports are viewed as an option held by firms (Broll and Eckwert 1999). Like any other option, the value of the option to export can rise as volatility increases. Higher exchange rate volatility increases the potential gains from trade and therefore increases the trade volume. Sercu (1992) studied this relationship under different market structures, none of which leads to a negative effect. Empirically, McKenzie and Brooks (1997) did find a

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S. Zhang and J. Buongiorno.[1] Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, 1630 Linden Drive, Madison, WI 53706, USA.

[1]Corresponding author (e-mail: jbuongio@wisc.edu).

positive effect of exchange rate volatility on Germany's exports to, and imports from, the Unites States. Bredin et al. (2003) also found a positive effect of exchange rate volatility on exports from Ireland to the European Union.

Some theorists suggest that there may be no effect, positive or negative, of exchange rate volatility on trade. Baron (1976) showed that if firms know how their revenues depend on the future exchange rate and adjust their forward contract accordingly, the effect of the exchange rate volatility would be negligible. Sercu and Uppal (2003) concluded with a stochastic general-equilibrium model that the relationship between trade and exchange rate volatility is ambiguous. Indeed, McKenzie (1998) found effects in both directions, while Aristotelous (2001) reported a weak or no relationship between exchange rate volatility and trade.

There are fewer studies of the effect of exchange rate volatility on prices. If exchange rate volatility discouraged international trade, it would lead to higher prices and production in importing countries and to lower production and prices in exporting countries (Sercu 1992). Hooper and Kohlhagen (1978) suggested that the effect of exchange rate volatility on price depends on who bears the risk. They confirmed empirically that the exchange rate risk tends to have a positive effect on the price when the trading contract is invoiced in the importer's currency and a negative effect when invoiced in the exporter's currency. Kroner and Lastrapes (1993) found that the effect of exchange rate volatility has a stronger magnitude on export prices than volume, but the direction of the effect differs by country.

It is important to investigate trade by sector, as each may react differently to exchange rates (Rapp and Reddy 2000). In particular, a better understanding of the effects, if any, of exchange rate volatility on trade should help improve the forecast of trade volumes and prices and thus of the effects of monetary policies on the forest sector. This is a natural extension of what is already known about the effects of the level of exchange rate on trade (e.g., see Bolkesjø and Buongiorno 2006). Yet, it appears that Sun and Zhang (2003) is the only previous study for forest industries. They found that exchange rate volatility has a negative impact on total US exports of four forest products in the long term.

In such studies, it matters how one measures the variability of exchange rate. With short measurement periods, the series of the deviations of the rate of change of the exchange rate from the mean tend to be serially correlated, indicating sustained periods of high or low volatility (Baillie and Bollerslev 1989). Accordingly, since their introduction by Engle (1982), autoregressive conditional heteroskedastic (ARCH) models have become prevalent in measuring exchange rate volatility (Diebold and Nerlove 1989). In this respect, the ARCH model improves over the moving standard deviation of the rate of change used, for example, by Sun and Zhang (2003) by allowing for persistence of exchange rate variability. More efficient estimation is obtained with generalized autoregressive conditional heteroskedastic (GARCH) models (Bollerslev 1986). The rest of this paper reports on the effect of exchange rate volatility on export quantities and prices of forest products from the United States. It used monthly data of US export to 14 countries for eight commodity groups. The exchange rate volatility was measured with a GARCH model. The results suggest that the exchange rate volatility had in general little effect on US exports and prices.

Materials and methods

Data

The study used monthly data on United States export to 14 countries for eight commodity groups from January 1989 to November 2007. The commodity groups, defined at the four-digit SITC code level, were the eight groups of highest value of US forest product exports in 2007 (Table 1).

The destination countries were Australia, Belgium, Canada, France, Germany, Hong Kong, Italy, Japan, Republic of Korea, Mexico, the Netherlands, Spain, Taiwan, and the United Kingdom. For most products, the destination countries imported together more than 50% of total US exports. Canada, Mexico, and Japan were the largest importers.

The export prices were measured by the nominal unit value, in dollars, free alongside ship at US ports. Monthly export quantities and values from the United States to each country were obtained from the US International Trade Commission database (dataweb.usitc.gov/scripts/user_set.asp).

The nominal exchange rate data were monthly averages of daily noon buying rates in New York City compiled by the Federal Reserve Bank of St. Louis (research.stlouisfed.org). For the European currencies that were replaced by the euro in 2001, the euro/US dollars exchange rate was transformed to the original currency levels with the fixed euro conversion rates of 1999.

Figure 1 shows the US dollar exchange rate series relative to the base month of January 1989. The movements of the exchange rates of the European countries' currencies to the US dollar were very closely related, even before the change to the euro in 2001. The won of the Republic of Korea devaluated sharply during the Asia financial crisis of 1997, but it increased gradually in value afterwards, regaining almost its 1997 value by 2007. There was also a sharp increase in the in the peso to dollar exchange rate during the Mexican economic crisis of 1994. In contrast with the won, the value of the peso relative to the US dollar has continued to decrease since then.

GARCH model of exchange rate volatility

The measure of exchange rate volatility was based on the following autoregressive distributed lag (ADL) model (Granger 1969) of the monthly change in the rate of the US dollar exchange rate for the currency of a particular country:

$$[1] \qquad \Delta \ln s_t = \sum_{j=1}^{n} \beta_j \, \Delta \ln s_{t-j} + \varepsilon_t; \, \varepsilon_t | \varepsilon_{t-1} \sim N(0, h_t^2)$$

where s_t is the exchange rate in month t and the β_js are parameters. The error ε_t is normally distributed with mean zero and variance h_t^2.

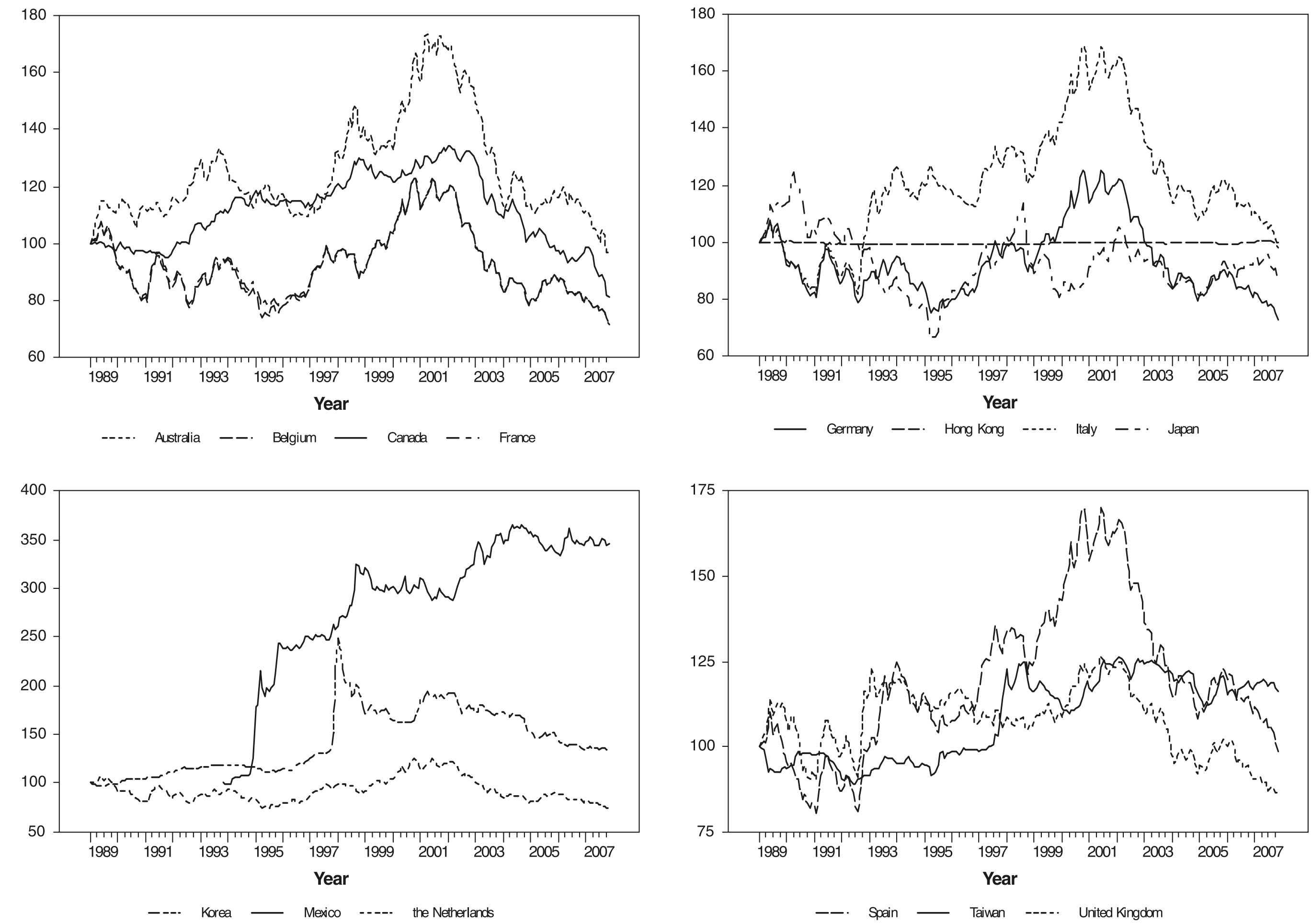
In a GARCH(p,q) model, h_t^2 depends on p lags of its own lags and on q lags of the squared error (Stock and Watson 2003, p. 563). The GARCH(1,1) specification was found to be sufficient for this application, as it has for most financial time series (Lamoureux and Lastrapes 1990). Therefore, the model adopted here was

Table 1. Commodities used in analyzing the effects of exchange rate volatility on US exports.

SITC code	Products in US International Trade Commission database	Total value (10^6 2007 US$)
247.4	Coniferous woods, in the rough (stripped or not of bark or sapwood), or roughly squared, untreated with paint, stain, or other preservative	879
248.4	Wood of nonconiferous species, sawn or chipped lengthwise, sliced or peeled, whether or not planed, sanded, or finger-jointed, over 6 mm thick	1448
251.5	Chemical wood pulp, semibleached or bleached	3522
641.2	Paper and paperboard, uncoated, for writing, printing, etc., punch card stock and punch tape paper, in rolls or sheets; handmade paper and paperboard	1110
641.3	Paper and paperboard, used for writing, printing, or other graphic purposes, coated, impregnated, surface-colored, etc., in rolls or sheets	1160
641.4	Kraft paper and paperboard, uncoated, NES, in rolls or sheets	2773
641.7	Paper, paperboard, cellulose wadding and webs of cellulose fibers, coated, impregnated, covered, surface-decorated, etc., NES, in rolls or sheets	2713
642.1	Cartons, boxes, cases, bags, etc., of paper, paperboard, cellulose wadding or webs; box files, letter trays, etc., of paper or paperboard	1636

Note: Data from the US International Trade Commission (dataweb.usitc.gov/scripts/user_set.asp).

Fig. 1. Value of the US dollar exchange rate relative to base month, January 1989 to November 2007.



[2] $$h_t^2 = \gamma_0 + \gamma_h h_{t-1}^2 + \gamma_\varepsilon \varepsilon_{t-1}^2$$

where the γs are parameters. The standard deviation h_t of the conditional variance predicted by eq. 2 was the measure of exchange rate volatility. This measure was based on nominal exchange rates. Under the current flexible rate regime, fluctuations in nominal and real monthly exchange rates are highly correlated (Mark 1990). Comparing results from nominal and real exchange rate volatility represented with an ARCH model, McKenzie and Brooks (1997) concluded "it would be irrelevant whether the volatility coefficients are estimated from real or nominal exchange rate as the volatility is sourced solely from the nominal exchange rate."

The parameters of the eqs. 1 and 2 were estimated jointly by maximizing the sum of the conditional log likelihood functions (Engle and Kroner 1995) with software based on the BFGS algorithm (e.g., see Broyden 1970). We used a Lagrange multiplier (LM) test (Lee 1991) to test the GARCH(1,1) specification against the hypothesis of a constant variance of the exchange rate, i.e., $\gamma_h = \gamma_\varepsilon = 0$ in eq. 2.

ADL model of export quantity and price

As there is only one exchange rate for each country to which the United States exports, it is natural to seek measures of the effect of interest rate volatility for all US exports to a particular country. To increase the efficiency of the method, the disaggregation by commodity group was maintained. One model was thus developed for each country, with the data of all exports to each country pooled in a panel.

The following ADL model was specified for export volume:

$$[3] \qquad \Delta \ln x_{ikt} = \alpha_{ik} + \sum_{j=0}^{n} \delta_j \, \Delta \ln h_{i,t-j} + \sum_{j=1}^{m} \varphi_j \, \Delta \ln x_{ik,t-j} + u_{ikt}$$

where x_{ikt} is the US export quantity to country i of forest product k in month t and h_{it} is the measure of exchange variability defined above, the time-varying conditional standard deviation of the exchange rate series predicted with eq. 2. The errors u are assumed to be white noise stochastic processes.

The most general model pooled all of the time series across all products and countries. To assess the robustness of the results, the parameters α, δ, and φ were estimated by five different specifications (Hayashi 2000, pp. 323–335): (*i*) ordinary least squares with α_{ik} a constant across products and countries, (*ii*) fixed product effect with α_{ik} a constant varying by product only, (*iii*) fixed country effect with α_{ik} a constant varying by country only, (*iv*) fixed product and country effect with α_{ik} a constant varying by product and country, and (*v*) random effects with α_{ik} a random variable varying by product and country.

Less general versions of model 3 were also estimated for exports of each product, with fixed effects for each country, and for exports to each country with fixed product effects.

Given estimates of eq. 3, the short-term effect of exchange rate volatility on exports was

$$[4] \qquad \mathrm{SRM} = \sum_{j=0}^{n} \delta_j$$

and the long-run dynamic effect was

$$[5] \qquad \mathrm{LRM} = \left(\sum_{j=0}^{n} \delta_j \right) \Big/ \left(1 - \sum_{j=0}^{n} \varphi_j \right)$$

An ADL model analog to eq. 3 was specified for the export price p_{it}:

$$[6] \qquad \Delta \ln p_{ikt} = \lambda_{ik} + \sum_{j=0}^{n} \mu_j \, \Delta \ln h_{i,t-j} + \sum_{j=1}^{m} \nu_j \, \Delta \ln p_{k,it-j} + w_{it}$$

In the ADL models 3 and 6, h_t is legitimately an exogenous variable, as forest product exports have little if any influence on exchange rate variability. Furthermore, the autoregressive parts of the endogenous quantity and price equations can be viewed as reduced forms of a general model with many unknown exogenous variables (Zellner and Palm 1974). Thus, the multipliers 4 and 5 show how much exports and prices change with exchange rate volatility, allowing for full adjustment of all endogenous variables.

The number of lags in eqs. 1, 3, and 6 was kept to a minimum for efficiency but sufficient to make the model "dynamically complete" (Wooldridge 2006, pp. 202–204) and thus eliminate serial correlation in the residuals. The presence of serial correlation was tested with the Ljung–Box Q statistic with 12 lags.

Unit root tests

When time series are integrated, standard statistical methods like ordinary least squares may suggest relationships between variables that are actually independent (Granger and Newbold 1974). Valid inference with GARCH models also requires that the variables be stationary (Bollerslev 1986).

To test if the time series used here were stationary, unit root tests were carried out for each export quantity, price, and h_t series with the augmented Dickey–Fuller test based on the equation (Dickey and Fuller 1979)

$$[7] \qquad y_t - y_{t-1} = \pi + \rho y_{t-1} + \sum_{r=1}^{s} \theta_r (y_{t-r} - y_{t-r-1}) + \omega_t$$

If the hypothesis H_0: $\rho = 0$ could not be rejected with data in levels, suggesting that the series had a unit root, the data were differenced. The stationarity of these differenced series was then tested with the same method. The length of lags in the ADF test was selected based on the Bayesian information criterion (Schwarz 1978).

To guard against possible low power of the ADF test, we also tested for stationarity with the KPSS test (Kwiatkowski et al. 1992) with a short lag length (4 months) for high power (Lee and Schmidt 1996).

Results

Exchange rate volatility

Table 2 shows the stationarity test results for the log of the exchange rate series. Based on both the ADF and KPSS tests, there was strong evidence of unit root for the level of the exchange rate but much weaker evidence for the monthly changes of exchange rate. Thus, eqs. 1 and 2 were estimated in first differences.

The estimation results of the GARCH eqs. 1 and 2 are given in Table 3. The second and third columns show that the relative change in exchange rate was strongly and positively correlated from one month to the next. Except for the Republic of Korea, one or two lags of the relative change in

Table 2. Unit root tests for the US dollar exchange rate with currencies of selected countries from January 1989 to November 2007.

		ADF test				KPSS test (with lag length = 4)	
Country	Observations	$\log s_t \sim I(1)$	Lags	$\Delta\log s_t \sim I(1)$	Lags	$\log s_t \sim I(0)$	$\Delta\log s_t \sim I(0)$
Australia	227	–1.00	2	–11.04***	1	4.59***	0.48*
Belgium	227	–1.61	1	–9.88***	1	2.43***	0.16
Canada	227	0.12	1	–11.01***	0	5.13***	0.89***
France	227	–1.57	1	–10.08***	1	2.37***	0.16
Germany	227	–1.62	1	–10.04***	1	2.54***	0.16
Hong Kong	227	–2.38	0	–12.04***	1	5.96***	0.11
Italy	227	–1.25	2	–10.08***	1	8.84***	0.28
Japan	227	–2.42	1	–10.93***	0	3.45***	0.05
Republic of Korea	227	–1.76	2	–10.58***	1	13.66***	0.18
Mexico	169	–3.73***	1	–10.52***	0	10.84***	0.55**
Netherlands	227	–1.61	1	–10.06***	1	2.55***	0.16
Spain	227	–1.22	2	–10.07***	1	9.87***	0.28
Taiwan	227	–1.22	1	–10.72***	0	18.47***	0.10
United Kingdom	227	–1.29	2	–11.03***	1	3.81***	0.19

Note: Asterisks indicate rejection of the null hypothesis at the ***1%, **5%, and *10% significance level.

exchange rate were enough to yield white noise residuals, as shown by the Ljung–Box Q statistic.

The Lagrange multiplier test supported the hypothesis of a GARCH(1,1) process for the variance of the exchange rate of nine of the 14 countries, and for 10 countries, either ε^2_{st-1} or h^2_{t-1} or both were statistically different from zero at the 5% confidence level.[2]

Figure 2 shows the residuals of the exchange rate eq. 1 and the GARCH (1,1) bands, which are $\pm h_t$ computed from eq. 2. These bands quantify the changing volatility of the exchange rate over time. Where and when the conditional standard deviation bands are wide, there is considerable volatility in the exchange rate regression error and thus large uncertainty about the exchange rate forecasts.

The exchange rate volatilities of Belgium, France, Germany, Japan, and the Netherlands were very stable, at about ±2.5% per month. The exchange rates of the Republic of Korea won and of the New Taiwan dollar were very volatile in 1997–1998. There was also high volatility of the value of the Mexican peso in 1994–1995. The volatility of the Canadian dollar seems to have increased from 2003 to 2007. For Hong Kong, there was much relative change in volatility over time, but the magnitude of the volatility was quite small, being less than a tenth of the magnitude in European countries.

Stationarity tests

The stationarity tests of the level and first difference of the logarithm of the exchange rate volatility variable $\ln h_{it}$, used in eqs. 3 and 6, are given in Table 4. The results, especially the KPSS test, showed that the hypothesis of stationarity in level was not tenable, while one could not reject the hypothesis that the first difference was stationary. Thus, the volatility variable entered ADL eqs. 3 and 6 as $\Delta \ln h_{it}$.

Table 5 presents the ADF unit root test results for the logarithm of US export quantities and prices by product and destination country. The last column also shows each import country's share of the total US exports of each commodity in 2007. Canada, Mexico, and Japan were the main importers of US forest products. The Republic of Korea and Italy imported a significant fraction of a few US products. The imports of each European country were not large, but Europe as a whole held an important share of US forest products.

For several series in levels, the hypothesis that they had unit roots, i.e., that they were not stationary, could not be rejected. However, for the series of first differences, the hypothesis of a unit root was always rejected at a high significance level. The KPSS tests, not shown here, confirmed that the stationarity hypothesis could be accepted for the series of first differences. Thus, the export and price equations were estimated in the first differences of the logarithm as in eqs. 3 and 6, i.e., in terms of relative monthly changes of exports and prices as a function of the relative monthly changes of exchange rate volatility.

Effects of exchange rate volatility on exports and prices

Table 6 shows the results obtained by pooling all the time series across destination countries and products.

For export volume, the short-run effect of volatility was remarkably stable across methods. A 1% increase in volatility led to a 0.37% decrease in export volume. The effect was statistically significant at least at the 1% level. The long-run effect of volatility was also very similar across methods. It was much smaller than the short-run effect: a 1% increase in volatility led after full adjustment to a 0.1% decrease in export volume. This small long-run effect was statistically significant only with the estimation done with random product and country effects.

For export price, the effect of exchange rate volatility was also stable across methods. Like for volume, the effect was

[2] For some countries, we could not reject the hypotheses that $\gamma_h + \gamma_\epsilon = 1$, i.e., that the model was IGARCH(1,1). However, the parameters in Table 3 were maintained because the IGARCH constraint smoothed out the variability of the measure of exchange rate volatility, while variability is essential to capture the effect of volatility.

Table 3. Parameters of GARCH(1,1) models of monthly relative changes in US dollar exchange rate with currencies of selected countries from January 1989 to November 2007.

Country	$\Delta \ln s_{t-1}$	$\Delta \ln s_{t-2}$	Constant	ε^2_{t-1}	h^2_{t-1}	LM	$Q(12)$
Australia	0.30 (0.08)***	–0.16 (0.08)**	0.00002 (0.00003)	0.12 (0.06)**	0.84 (0.09)***	5.77*	20.11
Belgium	0.33 (0.06)***		0.0006 (0.0004)	–0.03 (0.03)	–0.17 (0.81)	0.78	11.39
Canada	0.22 (0.07)***		0.00002 (0.00001)	0.17 (0.08)**	0.74 (0.12)***	5.71**	12.48
France	0.33 (0.06)***		0.0006 (0.0004)	–0.04 (0.03)	–0.15 (0.68)	1.13	12.16
Germany	0.33 (0.06)***		0.007 (0.0004)**	–0.03 (0.03)	–0.28 (0.64)	0.71	11.95
Hong Kong	0.30 (0.07)***		0.000001 (0.00000003)**	1.35 (0.29)***	0.15 (0.07)**	34.36***	20.61
Italy	0.33 (0.06) ***		0.00009 (0.00008)	0.09 (0.07)	0.74 (0.19)***	3.50*	17.83
Japan	0.22 (0.06) ***	–0.18 (0.06)***	0.0008 (0.0003)***	0.15 (0.07)**	–0.38 (0.39)	13.62***	18.64
Republic of Korea	0.32 (0.07)**		0.000005 (0.00003)	0.87 (0.16)***	0.54 (0.05)***	4.75*	60.02***
Mexico	0.23 (0.11)**		0.0004 (0.00006)***	0.45 (0.12)***	0.10 (0.08)	10.43***	18.34
Netherlands	0.33 (0.06)***		0.0007 (0.0004)	0.03 (0.03)	0.26 (0.69)	0.59	12.27
Spain	0.31 (0.06)***		0.00002 (0.00002)	0.03 (0.03)	0.93 (0.07)***	1.19	13.75
Taiwan	0.36 (0.07)***		0.00002 (0.000009)***	0.23 (0.08)***	0.61 (0.10)***	11.35***	16.80
United Kingdom	0.17 (0.07)***		0.00005 (0.00003)	0.16 (0.07)**	0.74 (0.11)***	14.85***	20.92

Note: Standard errors are given in parentheses. Asterisks indicate rejection of the null hypothesis at the ***1%, **5%, and *10% significance level. LM is the Lagrange multiplier test of the ARCH/GARCH effect. $Q(12)$ is the Ljung–Box statistic for up to 12th-order serial correlation of the residuals.

negative. The short-run and long-run effects were both small. A 1% increase in volatility led to a 0.10% decrease in price in the short run and to a 0.026% decrease in price in the long run. The short-run and long-run effects were statistically significant at the 10% level only.

For the volume equation, lag lengths $m = n = 12$ were enough to ensure residual white noise. For the price equation, the lag length of the price variable had to be increased to $m = 13$. The Ljung–Box Q statistics in Table 6 confirm that the models were "dynamically complete" (Wooldridge 2006, p. 400) with this specification.

Table 7 shows the results obtained for each destination country by pooling the time series data across products. There were considerable differences between countries. For export volume, the short-run effect of exchange rate volatility was negative for nine of the 14 countries, but it saw statistically significant only for the Republic of Korea and for Mexico. The long-run effect had the same sign as the short-run, but it was always smaller than the short-run effect and never statistically significant.

The price results (Table 7) varied even more between countries. The short-run effect of exchange rate volatility on prices was negative for eight of the 14 destination countries and statistically significant for three countries, but it was positive and statistically significant for Mexico. The long-run effect had the same sign as the short-run and it was always smaller. It was statistically significant, and negative, for Spain and Italy only.

Table 8 shows the results obtained for each product by pooling the time series data across countries. For export volume, the short-run effect of exchange rate volatility was negative for five of the eight products but significantly so only for nonconiferous wood (SITC 248.4) and kraft paper and paperboard (SITC 641.4). The long-run multipliers had the same sign as the short-run, were always smaller in absolute value, and were satistically significant at the 5% level for nonconiferous wood and kraft paper and paperboard.

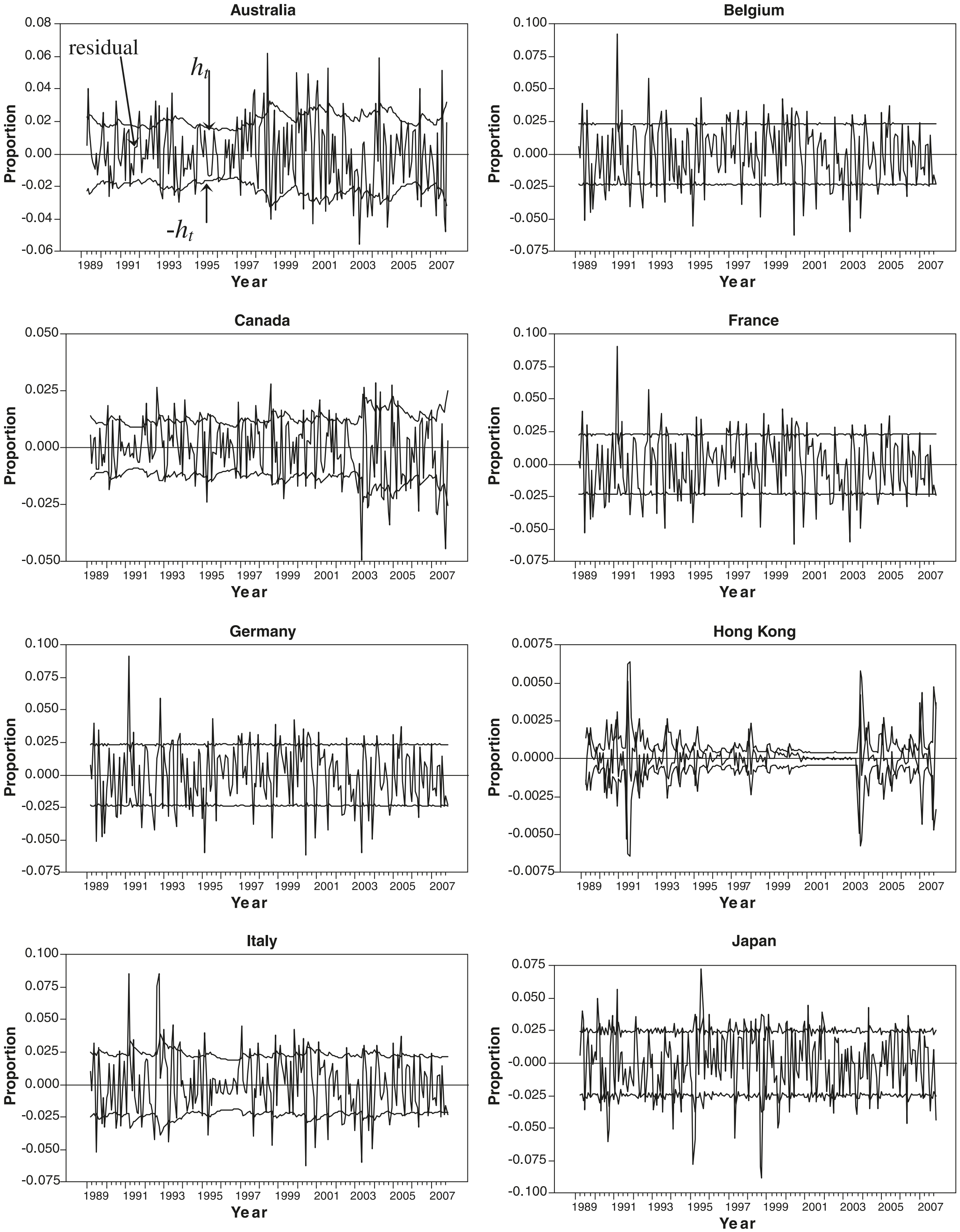
For export price (Table 8), the short-run effect of exchange rate volatility was negative for five of the eight products but significantly so only for nonconiferous wood (SITC 248.4), chemical wood pulp (SITC 251.5), and paper and paperboard (SITC 641.3). The long-run effect was of the same sign as the short-run, smaller in magnitude, and statistically significant for the same three products.

These findings were found to be stable whether the estimation was done by pooling with ordinary least squares or with fixed product effect (as in Table 7) or with fixed country effect (as in Table 8). In all cases, lag lengths of $m = n = 12$ for the volume equations and of $m = 13$ and $n = 12$ for the price equations were found to be sufficient to obtain white noise residuals, as indicated by the Q statistics in Tables 7 and 8.

Summary and conclusion

This paper investigated the effects of exchange rate volatility on the exports of US forest products to 14 main destination countries with monthly data from January 1989 to November 2007. The exchange rate volatility was measured by the conditional standard deviation of the residuals in a GARCH(1,1) model of the exchange rate. The relationship between ex-

Fig. 2. Residuals from the exchange rate equation (eq. 1) and GARCH(1,1) bands measuring exchange rate volatility. *Fig. 2 continued next page*.



change rate volatility and export quantities and prices was modeled with an ADL model linking current exports or prices to exchange rate volatility and past exports or prices.

The most general results were obtained by pooling all of the time series data across destination and product. With this model, a rise in exchange rate volatility of 1% led to a 0.37% decrease in export volume in the short run (i.e., within 1 year). The long-run effect on volume exported was still negative but negligible.

However, the disaggregation by country showed that the negative effect of exchange rate variability on exports was negative and statistically significant only in the short run

Fig. 2 (*concluded*).

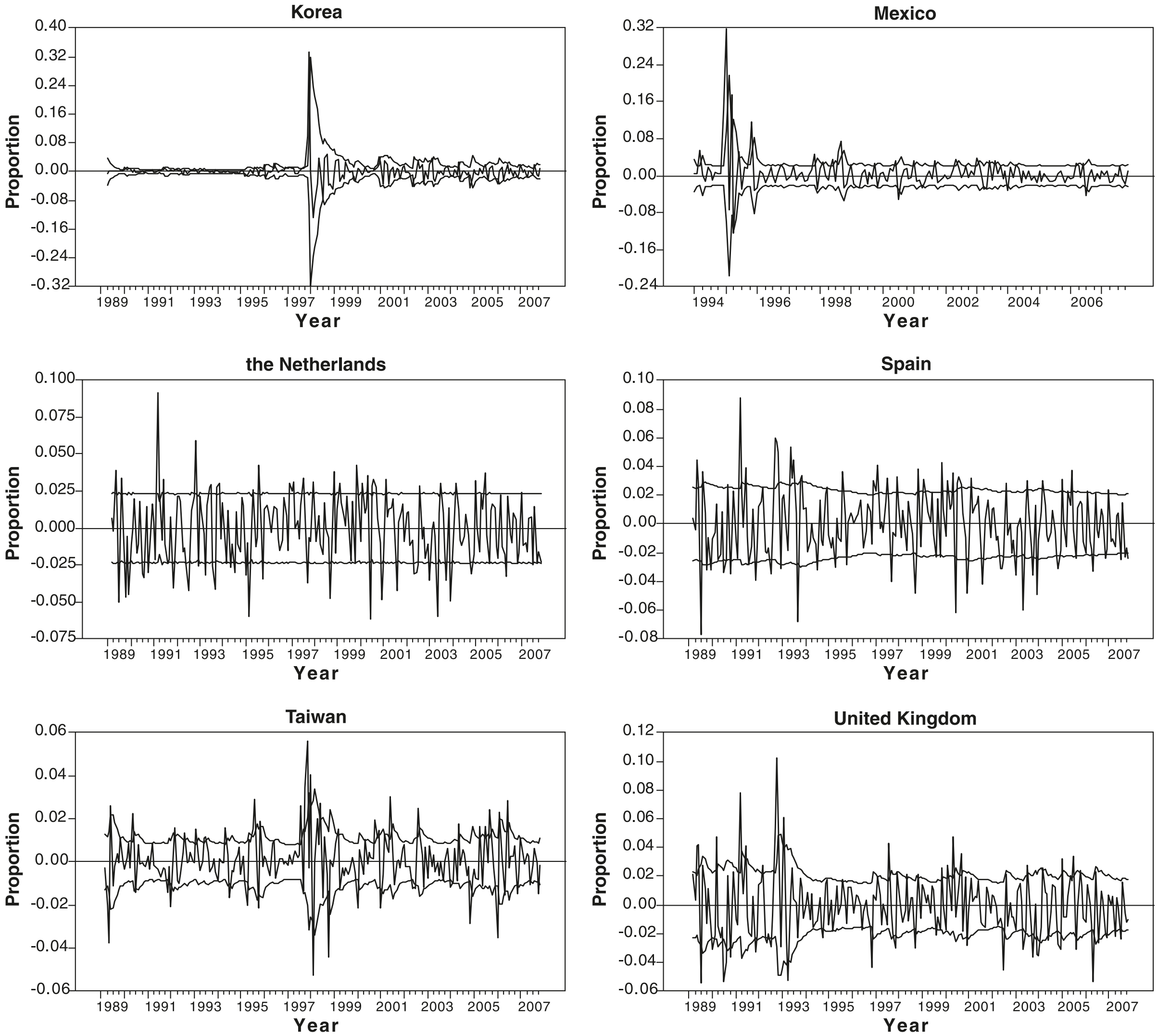


Table 4. Unit root tests of the volatility of the US dollar exchange rate with the currencies of selected countries from January 1989 to November 2007.

		ADF t test				KPSS test (with lag length = 4)	
Country	Observations	$\ln h_t \sim I(1)$	Lags	$\Delta\ln h_t \sim I(1)$	Lags	$\ln h_t \sim I(0)$	$\Delta\ln h_t \sim I(0)$
Australia	224	–2.25*	0	–15.67***	0	1.60***	0.091
Belgium	225	–18.07***	0	–10.77***	6	0.43*	0.012
Canada	225	–2.88**	0	–15.24***	0	2.05***	0.104
France	225	–17.72***	0	–10.70***	6	0.39*	0.012
Germany	225	–19.92***	0	–10.89***	6	0.47**	0.013
Hong Kong	225	–6.43***	0	–10.17***	5	0.67**	0.054
Italy	225	–4.32***	0	–15.91***	0	0.60**	0.018
Japan	225	–20.95***	0	–13.50***	4	0.16	0.012
Republic of Korea	224	–3.02**	0	–13.95***	0	1.69***	0.059
Mexico	167	–5.60**	0	–8.47***	5	0.72**	0.017
Netherlands	225	–19.71***	0	–10.91***	6	0.45*	0.013
Spain	225	–1.73	0	–14.96***	0	2.22***	0.046
Taiwan	225	–4.31***	0	–16.17***	0	0.14	0.021
United Kingdom	225	–3.39**	0	–14.83***	0	1.14***	0.024

Note: Asterisks indicate rejection of the null hypothesis at the ***1%, **5%, and *10% significance level.

Table 5. Augmented Dickey-Fuller t test results for US export quantity, x_t, and price, p_t, by country and product, from January 1989 to November 2007.

Country	SITC code	$\log p_t \sim I(1)$	Lags	$\Delta\log p_t \sim I(1)$	Lags	$\log x_t \sim I(1)$	Lags	$\Delta\log x_t \sim I(1)$	Lags	%
Australia	641.2	–3.18**	3			–5.87***	1			2.3
	641.3	–3.25**	2			–2.33	2	–18.66***	1	3.3
	642.1	–4.79***	2			–1.99	4	–11.85***	3	0.6
Belgium	248.4	–3.96***	2			1.08	12	–7.60***	11	1.1
	641.7	–3.21**	2			–4.97***	1			1.9
Canada	247.4	–3.38**	1			–4.58***	2			23.0
	248.4	–4.01***	1			–2.07	12	–5.28***	11	26.9
	251.5	–3.89***	0			–4.45***	1			3.6
	641.2	–2.77*	1			–3.12**	1			50.6
	641.3	–3.96***	1			–1.29	12	–7.47***	11	48.5
	641.4	–3.48***	1			–2.59*	1			19.0
	641.7	–2.50	1	–13.37***	1	–1.78	2	–16.06***	1	24.6
	642.1	–4.55***	1			–1.38	17	–5.87***	11	35.1
France	248.4	–5.17***	2			1.55	12	–7.24***	11	0.6
	251.5	–2.75*	1			–5.48***	1			3.2
	641.3	–4.94***	1			–4.03***	1			2.3
	641.7	–7.77***	0			–8.47***	0			1.7
	642.1	–4.72***	2			–7.16***	0			0.7
Germany	248.4	–4.23***	1			–1.64	1	–14.44***	1	2.2
	251.5	–2.53	1	–20.15***	0	–9.04***	0			6.8
	641.3	–6.78***	1			–6.16***	1			1.1
	641.4	–1.82	1	–25.62***	0	–6.24***	1			2.1
	641.7	–1.99	6	–12.42***	5	–4.69***	1			3.4
Hong Kong	248.4	–5.79***	2			–1.59	1	–7.61***	9	1.8
	641.2	–3.89***	1			–3.43**	1			1.9
	641.3	–3.81***	2			–3.62***	2			0.6
Italy	248.4	–4.75***	2			–3.07**	14			7.7
	251.5	–2.49	0	–16.27***	0	–3.74***	2			11.5
	641.4	–3.00**	1			–7.10***	1			4.6
	641.7	–5.77***	2			–6.13***	1			1.4
Japan	247.4	–2.90**	1			–3.86***	0			45.6
	248.4	–4.15***	1			–2.27	0	–9.16***	6	2. 7
	251.5	–3.11**	0			–9.70***	0			8.5
	641.3	–3.86***	3			–3.30**	2			5.7
	641.4	–2.73*	2			–3.17**	2			2.1
	641.7	–3.97***	2			–5.05***	1			11.3
	642.1	–5.13***	2			–2.56	3	–12.33***	3	1.1
Republic of Korea	247.4	–4.06***	1			–1.49	12	–7.64***	11	14.0
	248.4	–5.54***	2			–2.81*	1			0.8
	251.5	–2.70*	2			–5.72***	1			4.7
	641.7	–13.53***	0			–9.90***	0			4.0
	641.4	–3.58***	2			–3.45**	2			1.5

Table 5 (*concluded*).

Country	SITC code	$\log p_t \sim I(1)$	Lags	$\Delta\log p_t \sim I(1)$	Lags	$\log x_t \sim I(1)$	Lags	$\Delta\log x_t \sim I(1)$	Lags	%
	641.3	–10.59***	0			–4.45***	1			0.5
Mexico	248.4	–5.98***	1			–3.69***	1			7.0
	251.5	–2.32	1	–9.87***	2	–3.59***	2			13.4
	641.2	–3.13**	1			–2.04	1	–17.03***	0	17.9
	641.3	–2.10	1	–13.86***	1	–2.31	2	–13.35***	1	16.6
	641.4	–3.28**	1			–3.07**	1			11.6
	641.7	–4.80***	1			–2.94**	1			11.8
	642.1	–1.96	0	–13.48***	0	–1.82	12	–5.13***	11	49.2
Netherlands	248.4	–2.85*	1			–2.42	1	–14.90	1	0.7
	251.5	–3.13**	1			–3.75***	3			4.3
	641.2	–2.24	4	–12.68***	3	–2.57	4	–12.73***	3	3.2
	641.3	–4.23***	1			–5.45***	0			2.0
	641.4	–3.22**	2			–4.44**	1			0.9
	641.7	–9.22***	0			–7.09***	0			4.0
Spain	248.4	–3.14***	4			–1.64	11	–12.81***	3	5.8
	641.4	–2.90**	1			–2.88**	2			2.7
Taiwan	248.4	–3.98***	2			–1.78	1	–23.20***	0	1.1
	641.3	–4.54***	2			–3.10**	2			0.3
United Kingdom	248.4	–6.56***	2			–5.21***	2			4.5
	251.5	–2.85*	1			–3.03**	3			3.0
	642.1	–4.81***	2			–3.78***	3			0.7
	641.3	–3.81***	2			–3.42**	2			2.3
	641.4	–2.34	1	–23.16***	0	–2.38	1	–16.45***	1	1.5
	641.7	–3.62***	2			–4.32***	1			2.2

Note: Asterisks indicate rejection of the null hypothesis at the ***1%, **5%, and *10% significance level. % is the percentage of total US export of the commodity in 2007 value.

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Table 6. Short- and long-run multiplier of exchange rate variability on US export volume and price estimated by pooling time series data across countries and products with different methods.

	Export volume			Export price		
Method	Short run	Long run	*Q*(12)	Short run	Long run	*Q*(12)
Ordinary least squares	–0.368***	–0.098	4.3	–0.096*	–0.026*	15.9
Fixed product effect	–0.372***	–0.098	4.2	–0.096*	–0.026*	16.4
Fixed country effect	–0.372***	–0.099	4.2	–0.097*	–0.026*	16.2
Fixed product and country effect	–0.375***	–0.099	4.3	–0.098*	–0.026*	16.7
Random effects	–0.364***	–0.098***	6.7	–0.094*	–0.026*	20.6*
Observations	13 542			13 556		
Maximum lag length	12			13		

Note: Asterisks indicate rejection of the null hypothesis at the ***1%, **5%, and *10% significance level. *Q*(12) is the Ljung–Box statistic for up to 12th-order serial correlation in the residuals.

Table 7. Short- and long-run effects of exchange rate variability on US export volume and price to different countries estimated by pooling time series data across products.

		Export volume			Export price		
Country	Observations	Short run	Long run	*Q*(12)	Short run	Long run	*Q*(12)
Australia	633	–1.78	–0.45	1.9	0.93*	0.22*	2.2
Belgium	424	–17.46	–4.46	4.3	9.77	3.40	2.0
Canada	1682	0.56	0.12	7.9	–0.06	–0.04	15.4
France	1060	–3.26	–0.91	7.4	–1.98	–0.50	15.0
Germany	1060	–3.24	–0.89	4.6	–1.56	–0.36	3.0
Hong Kong	636	0.05	0.02	2.1	–0.19	–0.06	3.4
Italy	848	–1.28	–0.23	5.1	–1.06***	–0.42**	11.7
Japan	1463	0.22	0.07	2.2	0.22	0.07	3.0
Republic of Korea	1266	–0.65***	–0.14	–0.1	–0.23***	–0.04	12.0
Mexico	1078	–0.41**	–0.14	3.1	0.29***	0.10	4.5
Netherlands	1272	3.70	1.07	2.5	2.50	0.75	9.9
Spain	424	–3.60	–0.67	3.7	–1.99***	–0.80***	1.3
Taiwan	424	–1.23	–0.29	3.3	0.09	0.02	5.2
United Kingdom	1272	0.00	0.00	0.9	–0.15	–0.04	5.2
Lag length		12			13		

Note: Asterisks indicate rejection of the null hypothesis at the ***1%, **5%, and *10% significance level. *Q*(12) is the Ljung–Box statistic for up to 12th-order serial correlation in the residuals.

Table 8. Short- and long-run effects of exchange rate variability on US export volume and price of different products estimated by pooling time series data across countries.

		Export volume			Export price		
SITC code	Observations	Short run	Long run	*Q*(12)	Short run	Long run	*Q*(12)
247.4	420	0.05	0.01	3.5	–0.13	–0.05	1.2
248.4	2694	–0.43***	–0.12***	8.3	–0.12**	–0.03**	4.6
251.5	1846	0.02	0.005	3.6	–0.16**	–0.11**	1.2
641.2	1001	–0.51	–0.17	0.4	0.25	0.08	0.1
641.3	2269	–0.31	–0.09	2.0	–0.42*	–0.09*	6.2
641.4	2044	–0.97**	–0.20**	2.5	0.003	0.001	12.7
641.7	2058	–0.46	–0.10	4.1	–0.04	–0.01	5.7
642.1	1210	0.22	0.05	10.4	0.42	0.10	9.9
Lag length		12			13		

Note: Asterisks indicate rejection of the null hypothesis at the ***1%, **5%, and *10% significance level. *Q*(12) is the Ljung–Box statistic for up to 12th-order serial correlation in the residuals.

and only for the Republic of Korea and Mexico. In the late 1990s during the so-called "Asian financial crisis", the dollar exchange rate of the Republic of Korea's won devaluated sharply (Fig. 1) and experienced extreme volatility (Fig. 2). The exchange rate volatility increased more than 10 times in less than a month. Such an extreme change in exchange rate volatility seems to have decreased significantly the volume of US forest product exports. In Mexico, there was an abrupt devaluation and consequent instability of the exchange rate of the peso in 1995 (Figs. 1 and 2).

Disaggregation by product showed a negative significant effect of exchange rate variability on exports of nonconiferous wood and kraft paper and paperboard in the short run, decreasing but still statistically significant in the long run. In contrast, Sun and Zhang (2003) found, with annual data, a long-run negative effect of exchange rate variability on total US exports of chips, logs, dissolving pulp, and bleached sulfate pulp, although the "short-run dynamics varied by commodity" (Sun and Zhang 2003).

The most general price result suggested that, over all of the countries and products, a 1% rise in exchange rate volatility induced a 0.1% decrease in the price in the short run (within 1 year), and the effect was still negative, statistically significant, but negligible in the long run.

Disaggregation by country showed negative and statistically significant effects of volatility on price for Italy, the Republic of Korea, and Spain, but for Mexico, the effect was positive and statistically significant. Disaggregation by product showed a negative and statistically significant effect of volatility on price for nonconiferous wood, chemical wood pulp, and coated paper and paperboard.

Bearing in mind that statistical significance is not the only or the best criterion of economic inference (Zilliak and McCloskey 2007), we conclude that a negative relationship between exchange rate volatility and US export and prices of forest products was borne out by the most general results of this study, i.e., when all of the data were pooled across products and destination countries.

However, when the data were disaggregated by product or country, the effect was statistically significant only in a few cases. A possible explanation of this uncertain effect of exchange rate volatility is that the proliferation of financial hedging instruments over the past 20 years has reduced the vulnerability of exporters to risk arising from erratic currency movements (Clark et al. 2004).

In summary, exchange rate volatility per se may not be a major policy issue for US forest product exports. However, the level of exchange rate does matter (e.g., see Bolkesjø and Buongiorno 2006).

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