EXCHANGE RATE VOLATILITY AND BILATERAL TRADE FLOWS: AN ANALYSIS OF U.S. DEMAND FOR CERTAIN STEEL PRODUCTS FROM CANADA AND MEXICO

by

Joseph C. Pickard

Thesis submitted to the Faculty of the Virginia Polytechnic Institute and
State University in partial fulfillment of the requirements for the degree of

Master of Arts
In
Economics

Nancy A. Lutz, Chair

Richard Ashley

June 14, 2003
Falls Church, Virginia

Keywords: exchange rates, volatility, international trade, steel industry,
stochastic coefficients

EXCHANGE RATE VOLATILITY AND BILATERAL TRADE FLOWS: AN ANALYSIS OF U.S. DEMAND FOR CERTAIN STEEL PRODUCTS FROM CANADA AND MEXICO

Joseph C. Pickard

Abstract

This empirical study uses stochastic coefficients econometric modeling to forecast real exchange rate volatility and examine how expected and unexpected volatility affect bilateral trade flows of certain steel products between Canada, Mexico and the United States using monthly data for the seven-year period 1996-2002. The results of the model indicate that the effects of exchange rate volatility on bilateral trade flows for this sector are relatively minor, where sustained changes in the spot exchange rate, sectoral economic growth, and the price of goods being traded all exert more significant influence on trade levels than exchange rate volatility. However, the model results also tend to indicate that as exchange rate volatility increases, the well-developed U.S.-Canadian forward currency exchange market may present economic agents with profit opportunities through risk-portfolio diversification, resulting in a positive correlation between volatility and trade. For the less-developed U.S.-Mexican forward currency market, the model results indicate that the relationship between trade and volatility, both expected and unexpected, is weak and predominantly negative.

DEDICATION

To Allison, my love.

ACKNOWLEDGMENTS

I would like to take this opportunity to thank Aniene Porter, without whom I would not have entered the economics program, for her inexhaustible patience and unwavering support. Thanks very much to Dr. Nancy Lutz and Dr. Richard Ashley, without whom I would not have finished the program, for their invaluable time and guidance. Thanks also to my previous thesis committee members, especially Dr. Tom Lutton for his thoughtful comments throughout this process. Thanks to all the former Northern Virginia economics faculty members, especially Dr. Swamy for his brilliant model and Drs. Dreyer and DeRosa for sharing their international finance and trade wisdom. Thank you to my colleagues at the Pew Charitable Trusts and former colleagues at the Urban Institute for all of your generosity and kindness. Special thanks to my parents, brothers, and their spouses for their encouragement and support – emotional, intellectual, financial and otherwise. I'd also like to thank Allison's parents and family members for being so kind and supportive. Finally, thank you Allison for your unconditional love, understanding and encouragement.

TABLE OF CONTENTS

TABLES AND FIGURES

CHAPTER I: INTRODUCTION

Economic theory and statistical analyses tend to demonstrate a solid positive relationship between international trade and economic growth.[1] Less clear are the effects of increased international trade on income distributions. Determining which variables significantly influence international trade should nevertheless have important implications for economic development and, more broadly, societal welfare. Although numerous studies have focused on the effect of exchange rate volatility on international trade, neither theoretical nor empirical analyses have been successful in producing a consensus on the direction and magnitude of that effect. The empirical uncertainty may be the result of three common problems associated with econometric modeling, namely: (1) the true functional form of economic relationships are unknown; (2) at least one unidentified explanatory variable is typically excluded from econometric models; and (3) these unidentified excluded variables are most often incorrectly assumed to be uncorrelated with the included explanatory variables. This empirical study uses a stochastic coefficient model to address these issues in an examination of the effect of real exchange rate volatility on bilateral trade flows of certain steel products[2] between Canada, Mexico and the United States using monthly data for the seven-year period 1996-2002.

The results of the model indicate that the effects of exchange rate volatility on bilateral trade flows for a given sector are relatively minor, where the spot exchange rate, sectoral economic growth, and price of goods being traded all exert more significant influence on trade levels than volatility. However, the model results also tend to show that for a country with a well-developed forward exchange rate market, in this case Canada, increased expected exchange rate volatility may present profit opportunities, as indicated by the positive correlation between trade levels and volatility. For countries without well-developed forward markets, such as Mexico, opportunities to profit from exchange rate volatility are less apparent and the relationship between trade and volatility appears to be insignificant, although predominantly negative. The content of the paper is presented as follows: Chapter II reviews the theoretical and empirical literature; Chapter III explains the methodology of this study; Chapter IV presents the empirical results; and the paper concludes with Chapter V.

[1] See Ben-David, Nordström and Winters, 1999.
[2] U.S. Harmonized Tariff Schedule numbers 7308903, 7308906, and 73089095, which include iron or steel columns, pillars, posts, beams, girders, structures or parts of structures.

CHAPTER II: LITERATURE REVIEW

2.1 Economic Theory

Two general theoretical schools of thought exist that attempt to explain the effect of exchange rate volatility on international trade: the traditional school holds that higher volatility increases risk and therefore depresses trade flows, while the risk-portfolio school maintains that higher risk presents greater opportunity for profit and should increase trade. Both schools will be examined in greater detail.

2.1.1 Traditional School

Early study of this issue focused on firm behavior and presumed that increased exchange rate volatility would increase the uncertainty of profits on contracts denominated in a foreign currency and would therefore reduce international trade to levels lower than would otherwise exist if uncertainty were removed.[3] This uncertainty of profits, or risk, would lead risk-averse and risk-neutral agents to redirect their activity from higher-risk foreign markets to the lower-risk home market.[4] Côté, in her comprehensive review of the literature, points out that the traditional school has examined not only the presence of risk, but also its degree, which in turn depends upon such factors as whether production inputs are imported, the opportunity to hedge risk and the currency in which contracts are denominated.[5] Côté reviews theoretical studies by Clark (1973), Baron (1976), and Hooper and Kohlhagen (1978), among others, that are representative of the traditional school. More recent traditional school studies have tended to be empirical in nature, and are examined in greater detail below.

The Clark study in many ways lays the theoretical groundwork for the traditional school by examining bilateral trade and the behavior of risk-averse firms.[6] Numerous restrictions are imposed, including firms that only produce goods for export, limited hedging possibilities, contracts denominated in foreign currencies, no imported factor inputs and a perfectly competitive marketplace. Clark supposes that as the variance of exchange rate uncertainty increases, so does the uncertainty of profitability, where profits are expressed in the home currency. Utility is given as a quadratic function of profits: ($U(\pi) = a\pi + b\pi^2$), where b,

[3] See Farrell, et al (1983).
[4] See DeGrauwe (1996).
[5] See Côté (1994).
[6] See Clark (1973).

representing risk aversion, is less than zero. As uncertainty increases, Clark contends that a risk-averse firm will reduce the supply of goods to the level where marginal revenue actually exceeds marginal cost in order compensate for the additional risk, thereby maximizing utility.

The Baron study also looks at bilateral trade, but focuses on how the choice of invoicing currency affects an exporting firm's production and pricing decisions when exchange rates are volatile and the marketplace is not perfectly competitive.[7] Baron shows that exporting firms face greater price risk when invoices are denominated in the foreign currency and face greater quantity demand risk when the home currency is used. In response, as exchange rate uncertainty increases, risk-averse, profit-maximizing firms will increase prices when the foreign currency is used to invoice goods. Baron argues that the way in which a firm maximizes utility (minimizes risk) when the home currency is used for invoicing depends on the shape of the demand curve it faces: e.g., reducing prices when demand is linear, thereby increasing demand and decreasing profit variance (uncertainty).

Another traditional school examination of volatility and bilateral trade is that of Hooper and Kohlhagen[8]. They derive demand and supply schedules for individual firms, where the explanatory variables include the currency denomination of contracts, the degree of firms' risk aversion and the percentage of risk hedged in the forward market. Perhaps the most significant contribution of this study is how it allows nominal exchange rate volatility to only impact the amount of risk that remains unhedged. Their study includes a number of *a priori* assumptions, including the importer being a price-taker (where imports are assumed to be inputs used for producing goods that are sold domestically), the importer facing a known demand curve and exporters that sell all of their products abroad in a monopolistic market framework. They find that increased exchange rate volatility leads to both downward-shifting supply and demand curves, where quantities and prices decline when importers face the exchange rate risk (depending on demand elasticity and their degree of risk-aversion), and quantities decline and prices increase when exporters (suppliers) bear the risk.

One of the main objections to the traditional school is that it does not properly model how firms manage risk, not only through the use of derivatives, but also as an opportunity to increase profitability. For this we turn to the risk-portfolio school.

---

[7] See Baron (1976).
[8] See Hooper and Kohlhagen (1978).

2.1.2 Risk-Portfolio School

What is referred to here as the risk-portfolio school is not a unified body of thought, but is comprised rather of multiple theories, varying in complexity, but united in the opinion of the traditional school as unrealistic. DeGrauwe, in a straightforward attack on the traditional school, convincingly argues that due to the convexity of the profit function, exporters' return from favorable exchange rate movements and the accompanying increased output outstrip the decreased profits associated with adverse exchange rates and decreased output, and therefore: "As a result, risk-neutral individuals will be attracted by these higher profit opportunities."[9]

Although the convexity of the profit function may imply a positive correlation between trade and exchange rate risk, the more prominent tenet of the risk-portfolio school examines exchange rate risk in light of modern portfolio diversification theory. As summarized by Farrell, et al, economic agents maximize profitability by diversifying the risk levels in their investment portfolios by simultaneously engaging in low-, medium- and high-risk activity with corresponding *potential* rates of return.[10] Greater exchange rate volatility resulting in higher risk would then not discourage risk-neutral agents from engaging in trade, but would present an opportunity to diversify their risk portfolios and increase the likelihood of profitability. Côté likens this approach to derivative markets, where trade is viewed as an option that becomes more valuable as the exchange rate becomes more volatile.[11]

Two important theoretical papers from the risk-portfolio school are Broll and Eckwert (1999) and Dellas and Zilberfarb (1993).

Dellas and Zilberfarb examine trade decisions in the framework of a portfolio-savings decision model under uncertainty.[12] Their theoretical model assumes a small open economy with an individual domestic agent importing, exporting and consuming two products in two time periods, where asset markets are incomplete and the agent makes trade decisions with incomplete knowledge of price risk. Their study examines the effects of uncertainty both in the absence of a forward market and with complete and incomplete hedging opportunities. Without a forward

[9] See DeGrauwe (1996).
[10] See Farrell, et al (1983), p. 4: "As a technical matter, the movement of exchange rates is interpreted in the portfolio-diversification context in terms of the covariance structure of unanticipated changes or innovations."
[11] See Côté (1994).
[12] See Dellas and Zilberfarb (1973).

exchange market, the individual maximizes utility by choosing a quantity of exports X such that:

$$q = Eu(Y - X, PX)$$

where Y – X is the consumption of the exportable good and P is the real exchange rate, with first order condition:

$$E(-u_1 + Pu_2) = 0.$$

The effect of increased exchange rate volatility on trade depends on whether the function $g = u_2P - U_1$ is concave or convex, which is turn is determined by a degree of risk-aversion in the utility function.[13] With a forward exchange market, the domestic agent maximizes utility, $Eu(C_1, C_2)$, subject to the constraints:

$$C_1 = Y_1 - X_1 - X_2$$

$$C_2 = P_1X_1 + P_2X_2$$

With two products and incomplete forward market opportunities (X_1 representing an exportable good subject to risk and X_2 completely hedged), Dellas and Zilberfarb find that the effects of volatility on trade are ambiguous depending on the risk parameter α. With complete hedging possible and costless, individuals can insulate themselves from exchange rate risk and increased volatility does not depress trade levels. They then extend these findings to producers selling to both domestic and foreign markets and find results consistent with those for the individual domestic agent.

Broll and Eckwert's theoretical model demonstrates how higher exchange rate volatility increases the potential gains from trade.[14] Their study uses an international firm that sells its product either entirely at home or abroad, and must also determine which market to choose with incomplete knowledge of exchange rate volatility. Their theoretical construct results in a generally positive relationship between the variance of the foreign spot exchange rate and the volume of output and total export. As with Dellas and Zilberfarb, the increase in the value of the firm's option to export depends on the convexity of the relationship between profits and the exchange rate, and ultimately upon the degree of the firm's risk aversion.

[13] Ibid. See p. 643-644, "…if the utility function is of the constant relative risk aversion family, $(1/1-\alpha)C^{1-\alpha}$, where C is consumption and α is the coefficient of risk aversion, an increase in riskiness decreases the volume of trade if and only if the coefficient of relative risk aversion is less than unity."

[14] See Broll and Eckwert (1999).

2.1.3 Alternatives

DeGrauwe suggests a third, political-economic, theory.[15] This approach proposes that nations that have flexible exchange rate systems and experience exchange rate misalignments are susceptible to lobbying from failing industries to create or increase protection from trade. As a result, greater exchange rate volatility would decrease trade flows as a result of protectionist legislation or executive order. Critics of this approach, such as Côté, point out that 1) an industry's vulnerability due to adverse exchange rates often reflect deeper competitiveness issues and 2) flexible rates help absorb the output and unemployment costs of misalignments.[16] These counter-arguments speak more to the welfare effects of DeGrauwe's theory than to its validity. It is not difficult to produce modern examples of U.S. industries, even those industries suffering from non-exchange rate induced competitiveness problems, e.g. steel, that have successfully lobbied the federal government to increase tariffs on imports whose prices were argued to be artificially low. That firms successfully lobby governments to restrict imports (trade) is evident. A more salient problem with DeGrauwe's political-economic theory is how to quantify the degree of misalignment and the resulting effects of exchange rate induced lobbying on trade flows.

2.2 Empirical Analysis

Because theory has been unable to provide a definite answer as to whether the trade-enhancing effects of portfolio diversification outweigh the costs to risk-averse economic agents as exchange rate volatility increases, a great deal of recent research has been devoted to empirical analysis of this issue. The following section highlights the more significant empirical controversies and findings surrounding this issue, including sectoral versus aggregate analysis, nominal versus real exchange rates, measuring volatility and expected volatility, and the non-stationarity of financial time-series data.

2.2.1 Sectoral vs. Aggregate Analysis

The vast majority of related empirical analyses have focused on aggregate trade levels, i.e. changes in overall trade levels between two or more countries. The results of these studies have been largely contradictory, with some finding negative relationships between trade and volatility and others positive. (See Table 2.1.)

---

[15] See DeGrauwe (1988).
[16] See Côté (1994).

Table 2.1 Empirical Analyses, Volatility Measures and Results.			
Authors	***Title***	**Volatility Measures**	**Results**
Bailey and Tavlas (1988)	*Trade and Investment Under Floating Rates: the U.S. Experience*	1) Absolute value of quarterly percentage change in real effective rate and 2) deviation between real effective rate and forward effective rate	Not significant
Bélanger, et al (1988)	*Exchange Rate Variability and Trade Flows: Sectoral Estimates for the U.S.-Canada Case*	Square of forecast error defined as 90-day forward spread	Negative in 2 of 5 sectors
Brada and Méndez (1988)	*Exchange Rate Risk, Exchange Rate Regime and the Volume of International Trade*	Dummy for exchange rate regime	Positive for floating rate regimes
DeGrauwe and Verfaille (1988)	*Exchange Rate Variability, Misalignment, and the European Monetary System*	Variance of annual real exchange rate	Negative for nations outside the EMS
Koray and Lastrapes (1989)	*Real Exchange Rate Volatility and U.S. Bilateral Trade: A Var Approach*	12-month moving standard deviation of real exchange rate	Weak negative relationship
Pereé and Steinherr (1989)	*Exchange Rate Uncertainty and Foreign Trade*	2 measures of long-run uncertainty (misalignment)	Negative except for the U.S.
Asseery and Peel (1991)	*The Effects of Exchange Rate Volatility on Exports – Some New Estimates*	Squared residual from ARIMA process fitted to real exchange rate	Positive except for the U.K.
Bini-Smaghi (1991)	*Exchange Rate Variability and Trade: Why Is It So Difficult to Find Any Empirical Relationship*	Standard deviation of weekly rates of change of intra-EMS effective exchange rate within a quarter	Negative relationship
Feenstra and Kendall (1991)	*Exchange Rate Volatility and International Prices*	GARCH model	Negative for 2 of 3 countries
Kumar (1992)	*Real Effects of Exchange Risk on International Trade*	Standard deviation of monthly percentage change in real exchange rate over 12-month period	Mixed results
Frankel and Wei (1993)	*Trade Blocs and Currency Blocs*	Standard deviation of first difference of log of nominal and real exchange rate	Mixed results (negative in 1980, positive in 1990)
Kroner and Lastrapes (1993)	*The Impact of Exchange Rate Volatility on International Trade: Reduced Form Estimates using the GARCH-*	GARCH model	Mixed results (varied signs and magnitudes)

	in-mean Model		
Caporale and Doroodian (1994)	*Exchange Rate Variability and the Flow of International Trade*	GARCH model	Negative relationship
Sekkat (1997)	*Exchange Rate Variability and EU Trade*	Standard deviation of monthly exchange rate changes for given year	Insignificant
McKenzie and Brooks (1997)	*The Impact of Exchange Rate Volatility on German-U.S. Trade Flows*	ARCH model	Positive relationship
Arize (1998)	*The Long-Run Relationship Between Import Flows and Real Exchange-Rate Volatility: The Experience of Eight European Economies*	Deviations of difference between real effective exchange rate and predicted rate	Negative for 6 of 8 countries
Lee (1999)	*The Effect of Exchange Rate Volatility on Trade in Durables*	GARCH model	Weak negative relationship
Sauer and Bohara (2001)	*Exchange Rate Volatility and Exports: Regional Differences between Developing and Industrialized Countries*	1) Conditional variance of first-order ARCH model of real effect rate, 2) moving standard error of first-order AR process estimate of real effective rate, 3) moving standard error of trend model estimate of real effective rate	Negative relationship for less-developed countries

Sources: Côté and Farrell, et al.

As Côté indicates, because so much of the theory involved depends on the nature of the firm, and due to the contradictory findings of aggregate analysis, research focused on individual industrial sectors should produce more robust results.[17] With multiple-sector analysis, Côté identifies the following variables as most important: "…the size of the firm, its capital-labor ratio, the durability of the product, the diversification of sales, and the use of imported intermediate inputs."[18]

Two such studies by Belanger, et al, examine trade in several sectors between the United States and Canada.[19] Although their results tended to show decreased trade levels as nominal exchange rate volatility increased, the findings were not conclusive with significant findings in

[17] See Côté (1994).
[18] Ibid.
[19] See Belanger, et al (1988) and (1990).

only two of five sectors (industrial supplies and automobiles) analyzed in the first study, and two of 40 risk estimates in the second study.[20]

2.2.2 Nominal vs. Real Exchange Rate

There has been spirited discussion in the literature regarding which measure of the exchange rate is more appropriate, with valid arguments on both sides. The main benefit of using the nominal exchange rate lies in its simplicity and freedom from measurement bias. In addition, it can be argued that economic agents, especially in the short run, are concerned with only the nominal rate. For short-run trade contracts, an importer in country X will most likely examine only how the exchange rate has varied in the recent past and will similarly only require a short time-span for forecasting how that rate will change in the future. Most short-term traders will not need inflation adjusted exchange rate data over a long horizon. Economists, it is then argued, would be wise to use the variables that actually affect the decision-making process of the economic agents under investigation. In addition, there is little controversy as to what constitutes the nominal exchange rate, with the noon or end-of-day data reported by the major central banks used most commonly.

However, serious empirical problems may arise when the nominal rate is used. As Farrell, et al, express it, this is due in part because "…variations in nominal rates can offset and be offset by variations in national price levels."[21] In addition, if price levels fail to move in conjunction with exchange rates, as Côté points out, the risk to traders may increase as nominal exchange rate volatility decreases.[22] Therefore, studies that examine trade contracts over the medium to long term generally use the real (adjusted for inflation) exchange rate. This is because if the nominal exchange rate between countries X and Y remains stable over a given period of time, but country Y's inflation rate increases some n-amount over that of country X, the nominal exchange rate obviously does not present an accurate picture of the change in relative strength of the two respective currencies (purchasing power parity).

The major controversy revolving around the use of the real exchange rate is how inflation is measured. For studies involving the United States, some economists use the Consumer Price Index, some the Producer Price Index, and some (with quarterly data) use the GDP deflator. The more difficult issue tends to be which foreign measure of inflation to use, and how it compares

---

[20] See Côté (1994).
[21] See Farrell, et al (1983).
[22] Ibid.

with the U.S. measure. For example, even in countries that use the same methodology for constructing a Consumer Price Index, the basket of goods used to calculate it invariably differs from that used in the U.S. A further complication for longer-run analysis is that many countries change the contents of the basket of goods used in constructing their price indexes as consumers' tastes change. Several recent studies have tried to resolve this issue by testing and retesting their data with both nominal and real exchange rates, with the general conclusion that the relationships examined are unchanged.[23]

2.2.3 Measuring Volatility

Of all the issues economists face when examining the effect of exchange rate volatility on trade, the most basic is how to measure volatility. Côté lists several of the more important considerations involved, including "…whether it should be bilateral or effective, real or nominal, and the appropriate way of measuring risk: short-run versus long-run horizon, ex ante versus ex post, sustained deviations from trend versus period-to-period movements."[24] Two common measures of volatility are 1) the standard deviation (or variance) of real and/or nominal exchange rate levels and 2) the differential between the forward and current exchange rates. Numerous other methods have been used including various ARIMA processes and GARCH models. (See Table 2.1.) No consensus has been reached on the best measure of volatility, and the tendency for exchange rate data to have skewed distributions or volatility clusters has been used to argue against the use of simple descriptive statistics to measure volatility. The statistical properties of financial time-series data will be examined in greater detail below. It is worthwhile to note here that many empirical analyses have stressed the importance of choosing the best measure of volatility without first properly defining the difference between expected and unexpected volatility.

Similar to much of modern consumer theory, where the expectations of consumers are what matter, so it is argued in certain international trade circles: that economic agents' expectations of exchange rate volatility are what effect trade levels. Farrell, et al, stress the importance of distinguishing between systematic and uncertain exchange rate changes, arguing that if traders are able to anticipate and plan for systematic changes, then the uncertain movements will largely determine shifts in ouput due to exchange rate volatility.[25] As a result of

---

[23] See McKenzie, et al (1997) and Thursby and Thursby (1987).
[24] See Côté (1994).
[25] See Farrell, et al (1983).

the importance of making this distinction, a large portion of the literature has been devoted not only to how to measure volatility, but also how to forecast it.

2.2.4 Forecasting Volatility

There has been considerable debate as to whether exchange rate movements are in any way predictable, or whether the data are entirely white noise. Forward rates were initially examined as unbiased predictors of spot rates, as it was assumed that the forward rates took into consideration interest rate ratios and current and speculative money demand. Goodman provides an early comparison of 23 different commercial exchange rate forecasting services.[26] The study divides the forecasting services into three major groups: "1) those that rely on an overall subjective evaluation of economic and/or technical factors to predict future spot exchange rates, 2) those that rely in whole, or in large part, on economic models, and 3) those that rely fully, or almost so, on technically-oriented decision rules such as the k percent or persistence type rules."[27] The later k percent group refers to financial investment strategies to buy or sell a currency after it has fallen or risen by some k percent. Goodman does not compare the first group with the others because, as subjective judgments, they are not replicable and therefore cannot be judged scientifically. For present purposes Goodman's second group of formal economic forecasting models is of greater interest. The formal economic models make up six of the 23 forecasting services. The variables that the designers of the economic models deemed most worthy of inclusion were relative inflation rates, interest rate premiums, balance-of-payments flows, and market participant sentiment. The various models were used to forecast movements in six currencies. Overall, the third, k-percent group produced the best forecasts. Goodman finds that the predictive power of the formal economic models to be poor, and concludes that volatility clustering does appear to be prevalent in the foreign exchange market.

2.2.5 Financial Time-Series Non-Stationarity

The non-stationarity of financial time-series data follows from the portfolio theory concept that the variance of investment portfolio returns, as a measure of risk, is not constant because the nature of asset-return volatility is time-varying. Bollerslev, et al, argue that financial time series, e.g. foreign exchange data, are typically "heteroskedastic, leptokurtic and exhibit volatility clustering."[28] McKenzie argues that earlier empirical studies therefore lack

---

[26] See Goodman (1979).
[27] Ibid.
[28] See Bollerslev, et al (1992).

significance, because the nature of exchange rate generating process is stochastic, and therefore violates standard regression assumptions.[29] Several studies test for the presence of non-stationarity by using an augmented Dickey-Fuller test statistic. Once the presence of non-stationarity is determined, a host of proposed solutions exist. Asseery and Peele, among others, use an error-correction model (ECM) to correct for the non-stationarity of export variables in their empirical study.[30] Engle introduced Autoregressive Conditional Heteroskedasticity (ARCH) models in 1982,[31] which examine the squared deviation of the rate of return from its mean for the previous time period when forecasting variance, and is intended to correct for volatility clustering -- high periods of volatility consistently followed by additional high volatility, and the same for low periods of volatility. ARCH estimation has since been generalized in the GARCH models used by McKenzie, among others.[32] The most generalized of these models, the Stochastic Coefficients (SC) model, was developed by Swamy.[33] Christou, et al, compare the ARCH model with the Stochastic (Random) Coefficients model as follows:

> "We utilize the ARCH model by assuming that the conditional mean, $E(y_t|y_{t-1}, y_{t-2}, \ldots, y_{t-p})$, of each asset return, y_t, is a linear function of $y_{t-1}, y_{t-2}, \ldots, y_{t-p}$, while its conditional variance, h_t, has an ARCH form shown below. The p^{th} order autoregressive model, AR(p), for y_t, combined with ARCH(q) errors, can be written as:
>
> $y_t = \beta 0 + \beta 1_{yt-1} + \ldots + \beta p_{yt-p} + \varepsilon t$, where
>
> $E(\varepsilon_t| y_{t-1}, y_{t-2}, \ldots, y_{t-p}) = 0$ and $var(\varepsilon_t|y_{t-1}, y_{t-2}, \ldots, y_{t-p}) =$
>
> $E(\varepsilon_{t2}| y_{t-1}, y_{t-2}, \ldots, y_{t-p}) = h_t$ with
>
> $h_t = \alpha 0 + \alpha 1\varepsilon_{2t-1} + \ldots + \alpha q\varepsilon_{2t-q}$.
>
> 'The ARCH model presented above assumes that the conditional variance of the error term of an equation changes over time in a specific way, even though the coefficients of the conditional mean of the equation are constants. Also, there is no serial correlation among the εt. In order to estimate this model without these restrictive assumptions, the RC procedure was used, whereby all the coefficients of the equation were also allowed to vary over time. In order to demonstrate the use of RC models for estimation, the following

[29] See McKenzie (1997).
[30] See Asseery and Peele (1991).
[31] See Engle (1982).
[32] See McKenzie (1997).
[33] See Chang and Swamy (2001).

procedure is applied {yt} is said to be a non-stationary process of a general type if it can be expressed in the following form:

$$y_t = \alpha_{1t} + x'_{2t}\alpha_{2t} + e'_t\delta_t$$

$$e_t = \psi_t x_{2t} + v_t$$

where the scalar α_{1t} represents the time-varying intercept, x_{2t}, is a p-vector of lagged dependent variables, α_{2t} is a p-vector of coefficients, e_t is an r-vector of variables, which in conjunction with $x_t = (1,x'_{2t})'$, completely determine y_t, δ_t is an r-vector of coefficients, ψ_t is an r x p matrix where v_t is an r-vector of errors. With substitution, this produces the Random {Stochastic}Coefficients model:

$$y_t = (\alpha_{1t} + v'_t\delta_t) + x's(\alpha_{2t} + \psi'_t\underline{\delta}_t) = x'_t\underline{\beta}_t$$

where $x_t = (1,x'_{2t})$, and $\beta_t = [(\alpha_{1t} + v'_t\underline{\delta}_t)', (\alpha_{2t} + \psi'_t\underline{\delta}_t)']'$,

where $\beta_t = \Pi z_t + R\underline{\varepsilon}_t$ and

$\underline{\varepsilon}_t = \Phi\underline{\varepsilon}_{t-1} + a_t$ and

$y_t = x'_t\Pi z_t + x'_t R\underline{\varepsilon}_t$."[34]

Christou, et al conclude that although the ARCH models are an improvement over standard regression techniques and forecast better than a random walk, more generalized models with time-varying coefficients are an improvement on the ARCH models.[35]

[34] See Christou, et al (1998).
[35] Ibid.

CHAPTER III: METHODOLOGY

3.1 Overview

This study attempts to improve on previous analysis by incorporating the most significant theoretical and empirical lessons from earlier studies and combining them with superior econometric modeling. As indicated in Chapter II above, it has been reasonably argued that sectoral analysis provides a richer opportunity for robust research than aggregate analysis, and is therefore the mode of analysis selected here. The steel sector, a subject of continuing public attention, was selected not only for its individual economic value, but also for its impact on large segments of the economy, including construction, automobiles and appliances, among others. Therefore, U.S. demand for certain steel products imported from Mexico and Canada is examined here. As the largest economy in the world, the United States was an uncomplicated selection for the consumer of steel products. Mexico and Canada were the exporters selected for three chief reasons: 1) the availability and reliability of trade data with these countries; 2) the North American Free Trade Agreement has all but eliminated tariffs for the steel products under consideration since 1996, thereby simplifying the demand equation estimates; and 3) Canada and Mexico represent a diversity of overall economic development which is seldom found in other trade studies. The specific product categories represented are those where Canada and Mexico are the largest exporters to the United States, and consist of U.S. Harmonized Tariff Schedule categories 7308903, 7308906 and 73089095 which include iron or steel columns, pillars, posts, beams, girders, structures or parts of structures used predominantly in non-residential construction. The size and structure of the world steel market today is the result in no small part of a tremendous overcapacity of supply.[36] The amount of steel traded internationally is therefore determined largely by demand, which is examined here exclusively.

The econometric model used to both forecast exchange rate volatility and estimate the demand for steel is the Stochastic Coefficients (SC) model developed by Swamy and generated by the Stochastic Coefficients Estimation Program (SCEP) software.[37] The SC model, as the most generalized estimator, is particularly well-suited to examining exchange rate and trade relationships. Each time-varying coefficient is comprised of three components representing a direct effect, indirect effect (concomitant value) and error term. Selection of the proper

[36] See American Iron and Steel Institute.
[37] See Chang and Swamy (2001).

concomitant values is the key to proper stochastic estimation. The direct, non-stochastic component can be either a linear or non-linear function of the known variables, where the indirect, stochastic component may be serially correlated. As a result, the SC model addresses three common problems associated with standard regression analysis: (1) the true functional form of economic relationships are unknown; (2) at least one unidentified explanatory variable is typically excluded from econometric models; and (3) these unidentified excluded variables are most often incorrectly assumed to be uncorrelated with the included explanatory variables.[38] The SC model takes the general mathematical form as presented by Christou, et al, above.

3.2 Econometric Model

The econometric modeling process was composed of two stages: 1) forecasting expected monthly CAN$/US$ and MexPeso/US$ volatility levels, and 2) estimating U.S. demand for steel from Canada and Mexico. These stages are examined below.

3.2.1 SC Exchange Rate Volatility Model

Given the general SC model formulation:

$$y_t = x_t'\beta_t,$$

$$\beta_t = \Pi z_t + R\varepsilon_t \text{ and}$$

$$\varepsilon_t = \Phi\varepsilon_{t-1} + a_t,$$

for the volatility model y_t represents the monthly variance of the real spot exchange rate levels. [See Chapter II for a review of measuring volatility and real versus nominal levels.] The real exchange rate was first determined by taking the spot exchange rate and adjusting for inflation shifts in the U.S. and abroad using the respective Consumer Price Indices. For example, the daily real CAN$/US$ exchange rate here is equal to the noon daily spot CAN$/US$ x ($CPI_{U.S.}/CPI_{CAN}$), with C.P.I. index level January 1996 = 100 for both countries. Next, the variance of the daily real spot exchange rates was calculated for each month for the period March 1995 to August 2002.

The matrix x_t consisted of three explanatory variables for the MexPeso/US$ volatility forecasts equal to the real exchange rate variances for the preceding three, six and 12-month time periods. The use of past volatility data in forecasting future volatility levels has widely been used both in economic and technical forecast services.[39] The CAN$/US$ estimation has a fourth

[38] Ibid.
[39] See Goodman (1979).

variable equal to the monthly variance of the corresponding daily 90-day forward exchange rates. This additional variable reflects the fact that the MexPeso/US$ forward market is extremely small compared to the CAN$/US$ forward market (neither the Federal Reserve System nor the Banco de Mexico release MexPeso/US$ forward rates).[40] This crucial difference limits the extent to which traders can hedge their foreign exchange exposure and raises the costs of doing so. The smaller forward market therefore reduces the number of market participants and, presumably, the quality of their forecasts.

For each of the three, six and 12-month volatility variables, a concomitant $\{z_t\}$ value representing the indirect effect was included in the form of the volatility of the respective interest rate differentials (or premiums) for the corresponding period. The volatility of interest rate premiums was calculated by first taking the absolute value of the difference between the average overnight lending rates, using the U.S. Federal Reserve's Federal Funds Rate, the Bank of Canada's Bank Rate, and the Banco de Mexico's Tasa de Interés Interbancaria de Equilibrio (TIIE), and then calculating the variance of these premiums for the corresponding three, six and 12-month periods. The idea to include the interest rate differentials as indirect variables comes from interest parity theory. A subject of ongoing debate, interest parity theory holds that the exchange rate should be a function of the difference between expected interest rate levels.[41] Because interest parity theory has not demonstrated that interest rate premiums play a unique role in determining exchange rate levels, the volatility of the interest rate premiums are included here as only indirectly affecting the volatility of exchange rates.

Forecasts for each monthly real exchange rate volatility level were then created, producing expected (forecast) and unexpected (forecast error) volatility values that were plugged into the import demand estimations. For the results from the volatility model, see Chapter IV, Empirical Results, and Appendix A.

3.2.2 SC Steel Demand Model

Given the general SC model once more:

---

[40] See Banco de Mexico.

[41] See Krugman and Obstfeld (2000) for a more detailed description of interest parity theory and some of its shortcomings.

$$y_t = x_t'\beta_t,$$

$$\beta_t = \Pi z_t + R\varepsilon_t \text{ and}$$

$$\varepsilon_t = \Phi\varepsilon_{t-1} + a_{t,}$$

the quantity of steel demanded in the U.S. (QUAN) was estimated as a function of the direct of effect of the following $\{x_t\}$variables:

PCAN/PMEX = Price of Canadian/Mexican steel,

PWORLD = Average Price of Steel from World's Largest Exporters to the U.S.,

U.S.CAP = U.S. Steel Industry Capacity Utilization Rate,

NONRES = U.S. Non-Residential Put-in-Place Construction,

EX = Real Foreign Spot Exchange Rate,

VOL = Expected Real Exchange Rate Volatility, and

UN VOL = Unexpected Real Exchange Rate Volatility

In addition to the explanatory variables above, several others were tested for their explanatory efficacy before being rejected, including freight and insurance costs, foreign tariff levels, and an index of demand for cement, stone, glass and clay products also used in non-residential construction. Data were unavailable for an additional sought-after variable, the monthly percentage of contracts denominated is U.S. dollars for these steel products.[42]

The average world price and U.S. steel industry capacity utilization rates are included as substitute goods for imports from Canada and Mexico on the assumption that as the price of steel from international competition decreases and U.S. steel output increases, demand for steel from Canada or Mexico may decrease. The average world price represents the prices of imports from the largest exporters of steel to the U.S. for the products under consideration, namely from Japan, Korea, Germany, the United Kingdom, Spain, China, Brazil, Taiwan, the Netherlands, and Canada or Mexico. For both countries the level of U.S. non-residential put-in-place construction represents not only a complimentary good, but also serves as a proxy for the state of the U.S. economy overall. The real spot exchange rate was calculated in the same fashion as for the volatility model. The results of the volatility model provided the data for the expected and

[42] Anecdotal evidence suggests that the percentage of steel contracts denominated in U.S. dollars may be as high as 80-85% for trade with Canada and Mexico. See American Metal Markets.

unexpected volatility levels, which may be viewed as proxies for the relative hedged and unhedged amounts of foreign exchange risk.

A single, dummy concomitant value was used for the steel demand model representing labor union strikes in the steel sectors in Canada and Mexico, with 0 entered for no labor strike during that month and 1 entered for steelworkers on strike. As with the explanatory variables, several other concomitant values were tested for their explanatory efficacy before selecting the labor dispute variable, which is intuitively appealing as effecting the price of steel produced in Canada and Mexico directly, and effecting the quantity demand for steel, denominated ultimately in U.S. dollars and used primarily for nonresidential construction in the United States, indirectly. The results from the steel demand model are also presented in Chapter IV, Empirical Results.

3.2.3 Data

Monthly data from March 1996 through August 2002 were collected for this study (additional data from 1995 were used for the lagged interest and exchange rate volatility levels). The period of investigation closely follows the dates of NAFTA tariff reduction and/or elimination for the steel products examined. Data were provided by the U.S. International Trade Commission, the American Iron and Steel Institute, the Board of Governors of the Federal Reserve System, the U.S. Bureau of Labor Statistics, the U.S. Census Bureau, the Bank of Canada, and the Banco de Mexico. All quantity values are expressed in kilos, all prices are expressed in real 1996 dollars, U.S. steel capacity utilization is expressed as a percentage, and all exchange rates are real 1996 rates. All data were transformed into natural logarithms prior to estimation to allow for non-linear relationships.

CHAPTER IV: EMPIRICAL RESULTS

4.1 Volatility Model

The forecasting results of the SC Exchange Rate Volatility Model are presented in Appendix A. The volatility forecast average percentage error overall for Canada was 7.95% and was 27.30% for Mexico. The difference in the volatility forecast errors may be related to the difference in size and scope of the forward currency exchange markets, although forecasts run without the forward exchange rate volatility variable for the Canada-U.S. relationship still produced forecasts superior to the Mexico-U.S. forecasts. In terms of the ability of the model to predict month-to-month changes in the level of volatility, the model accurately predicted that volatility would increase or decrease from the previous month 61% of the time for both Canada and Mexico, or for 46 of the 75 monthly changes. This represents an improvement on the forecasting of the economics-based models reviewed by Goodman for their three-month forecasts (50% accuracy) and matches the performance of the six-month forecasts (61%).

4.2 Steel Demand Model

The results of the SC Steel Demand Model are presented in Tables 4.1 and 4.2 below.

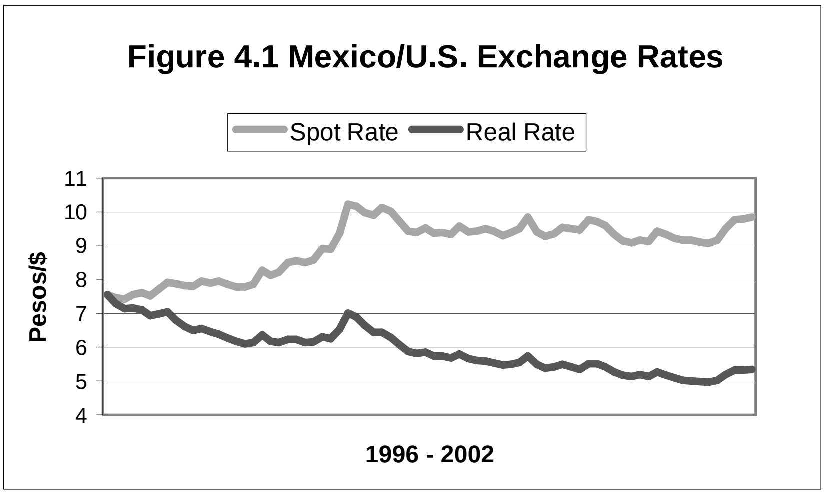
Table 4.1 Coefficients of Variation, T-Ratios and Standard Errors -- Beta Matrices.								
	LN CONST	**LN PCAN**	**LN PWORLD**	**LN U.S.CAP**	**LN NONRES**	**LN EX**	**LN VOL**	**LN UNVOL**
Canada								
7308903								
Coefficient of Variation (Pi Matrix)	-16.718	0.071	-0.343	0.595	1.258	3.213	0.039	0.012
T-Ratio	-1.685†	0.318	-0.442	1.512*	3.010‡	2.309†	0.536	0.808
Standard Error	9.921	0.222	0.077	0.393	0.418	1.392	0.073	0.014
7308906								
Coefficient of Variation (Pi Matrix)	-16.843	-0.684	-0.047	-0.224	1.397	0.590	0.076	0.001
T-Ratio	-1.344*	4.426‡	-0.559	-0.401	2.714‡	0.313	1.301*	0.015
Standard Error	12.533	0.155	0.084	0.559	0.515	1.881	0.058	0.039
73089095								
Coefficient of Variation (Pi Matrix)	-8.440	-0.043	-0.022	0.570	0.856	3.966	0.008	0.001
T-Ratio	-0.841	-0.292	-0.177	1.347*	2.111†	3.979‡	0.225	0.052
Standard Error	10.031	0.147	0.123	0.423	0.406	1.000	0.033	0.0127
Mexico								
7308903								
Coefficient of Variation (Pi Matrix)	7.151	-0.002	-0.361	-0.068	0.441	-1.311	0.020	0.010
T-Ratio	0.615	-0.013	-1.877†	-0.123	0.936	-1.344*	0.671	0.504
Standard Error	11.635	0.175	0.192	0.547	0.471	0.976	0.030	0.019
7308906								
Coefficient of Variation (Pi Matrix)	-24.161	0.230	-0.220	0.841	1.261	2.594	0.046	0.032
T-Ratio	-0.732	1.223	-0.593	0.544	0.949	0.987	0.467	0.394
Standard Error	33.009	0.188	0.371	1.547	1.328	2.629	0.099	0.081
73089095								
Coefficient of Variation (Pi Matrix)	17.352	-0.349	0.249	-0.328	0.034	-1.469	-0.045	0.001
T-Ratio	1.097	-2.114†	1.042	-0.478	0.054	-1.338*	-0.528	-0.039
Standard Error	15.815	0.165	0.239	0.686	0.630	1.097	0.086	0.018

*10% significance level.
†5% significance level.
‡1% significance level.

Table 4.2 Coefficients of Variation, T-Ratios and Standard Errors -- Gamma Matrices.								
	LN CONST	**LN PCAN**	**LN PWORLD**	**LN U.S.CAP**	**LN NONRES**	**LN EX**	**LN VOL**	**LN UNVOL**
Canada								
7308903								
Coefficient of Variation (Pi Matrix)	-0.005	0.012	0.056	-0.022	-0.083	0.008	-0.196	0.019
T-Ratio	-1.974†	1.835†	1.863†	-1.976†	-2.022†	1.819†	-1.827†	0.655
Standard Error	0.002	0.007	0.030	0.011	0.041	0.004	0.107	0.029
7308906								
Coefficient of Variation (Pi Matrix)	-0.002	-0.007	-0.065	-0.008	-0.029	-0.003	-0.064	0.031
T-Ratio	-0.740	0.610	-0.679	-0.734	-0.754	0.688	-0.645	0.739
Standard Error	0.002	0.011	0.095	0.010	0.038	0.004	0.099	0.042
73089095								
Coefficient of Variation (Pi Matrix)	0.003	-0.021	0.036	0.013	0.050	-0.005	0.123	0.007
T-Ratio	1.064	-1.072	1.028	1.071	1.093	-0.972	1.016	0.196
Standard Error	0.003	0.019	0.035	0.012	0.046	0.005	0.121	0.034
Mexico								
7308903								
Coefficient of Variation (Pi Matrix)	0.0002	0.001	0.001	0.002	0.004	0.001	0.070	0.003
T-Ratio	0.295	1.260	1.011	0.537	0.248	0.568	1.153	1.404*
Standard Error	0.001	0.001	0.001	0.004	0.015	0.002	0.061	0.002
7308906								
Coefficient of Variation (Pi Matrix)	0.002	-0.002	-0.003	0.008	0.039	0.003	0.023	-0.001
T-Ratio	0.930	-0.244	-0.149	0.727	0.968	0.700	0.139	-0.131
Standard Error	0.002	0.007	0.023	0.011	0.041	0.005	0.165	0.005
73089095								
Coefficient of Variation (Pi Matrix)	-0.000	-0.002	-0.001	0.000	-0.004	0.000	0.034	0.002
T-Ratio	-0.166	-0.565	-0.649	0.012	-0.198	0.036	0.532	0.74
Standard Error	0.001	0.003	0.002	0.005	0.018	0.002	0.064	0.002

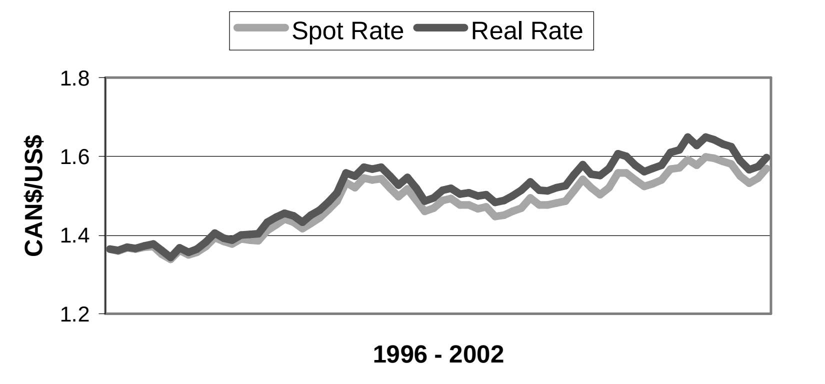
*10% significance level.
†5% significance level.
‡1% significance level.

For the real spot exchange rate variable, an increase in the rate represents a depreciation of the non-U.S. currency. Therefore, as the Mexican peso and Canadian dollar depreciate and imports become less expensive for U.S. consumers, a positive relationship between trade and the spot exchange rate is expected. The results from Table 4.1 may at first seem contradictory, as they show a positive relationship for Canada in all three cases (significantly so in two of three) and a negative relationship for two of the three Mexican categories. Figures 4.1 and 4.2 demonstrate the reason for this divergence.



The difference between real and nominal exchange rates is determined by the relative rates of inflation for the countries examined. Although the MexPeso/US$ nominal spot rate has increased (a depreciation of the peso) since 1996, the real spot rate shows that, adjusted for the relatively higher Mexican inflation levels for the period, the U.S. dollar has actually depreciated. Because of the short-term nature of many of the trade contracts for the steel products under consideration, and because of the overcapacity of steel supply, it may be concluded that the nominal spot rate is of more interest to traders that the real rate. This does not effect the relationship between trade and the spot exchange rate with Canada because U.S. and Canadian inflation levels tend to move in unison.

Figure 4.2 Canada/U.S. Exchange Rates



When retested with nominal exchange rates, the coefficient on the spot exchange rate variable for Mexico was found to be positive in all three cases and significant at the 1% level in one instance. Coefficients and t-ratios (in parentheses) for nominal Mexico/U.S. exchange rates were as follows: HTS No. 7308903: 0.10 (0.21); HTS No. 7308906: 4.68 (2.78); HTS No. 73089096: 0.24 (0.28).

For the remaining variables, a solid and positive relationship between non-residential construction activity and U.S. demand for the steel products predominates in five of six cases, with three statistically significant results, all of which are positive. Negative relationships exist between the quantity demanded and product price in only three of six cases, but the two statistically significant results are both negative. The effects of changes in U.S. steel industry capacity utilization rates and the average world prices on demand for steel from Canada and Mexico are mixed, and may result from using *overall* U.S. steel capacity instead of rates for the specific product categories and imperfect substitution between goods, respectively.

The relationship between trade levels and volatility is not strong. For Canada no coefficient is greater than 0.06 and for Mexico no coefficient is smaller than -0.06. However small, the correlation between trade and volatility (both expected and unexpected) for Canada is positive in all six cases, although significantly so in only one. For Mexico no volatility coefficient is significant, although four of the six expected and unexpected coefficients are negative. This leads to the conclusion that for products traded in the short-term between countries with well-established forward currency exchange markets, exchange rate volatility does not depress trade flows, and in some instances may increase them slightly. This does not appear to be the case for trade between countries without well-established forward markets.

4.3 Statistical Adequacy

Tests of skewness/kurtosis, serial correlation, and heteroskedasticity are provided in Appendix B. Chang, et al suggest that conventional hypothesis tests and test statistics such as R-squared, F, and Durbin Watson statistics may not be valid for stochastic coefficient models.[43] They note that SC model validation is more appropriately judged by the model's explanatory power, fits within and out-of-sample, and robustness with respect to the concomitants. Table 4.3 below presents the model's forecasting results.

Table 4.3 Steel Demand Forecasts.

	LN CONST	LN PCAN	LN PWORLD	LN U.S.CAP	LN NONRES	LN EX	LN VOL	LN UNVOL	LN QUAN	LN QUAN EST.	Error %
Canada											
7308903	-16.718	0.070	-0.030	0.597	1.257	3.215	0.035	0.010	16.381	16.345	0.223
7308906	-16.842	-0.693	-0.032	-0.208	1.410	0.589	0.060	0.031	14.774	14.525	1.686
73089095	-8.4596	-0.046	-0.022	0.561	0.871	3.957	0.002	0.008	16.123	16.060	0.393
	LN CONST	**LN PMEX**	**LN PWORLD**	**LN U.S.CAP**	**LN NONRES**	**LN EX**	**LN VOL**	**LN UNVOL**	**LN QUAN**	**LN QUAN EST.**	**Error %**
Mexico											
7308903	7.151	0.0005	-0.362	-0.067	0.446	-1.313	0.018	0.011	14.482	14.874	2.704
7308906	-24.159	0.261	-0.195	0.855	1.337	2.601	-0.008	-0.011	14.837	14.978	0.952
73089095	17.353	-0.348	0.249	-0.325	0.046	-1.468	-0.063	-0.0006	14.985	14.905	0.534

The model appears to forecast U.S. demand for imported steel extremely well, with overall average percentage errors of 0.77% for imports from Canada and 1.40% for imports from Mexico.

[43] See Chang, et al (2000).

CHAPTER V: CONCLUSION

Stochastic coefficients estimation represents an improvement on existing econometric models used to analyze exchange rate and trade data. The results of the models indicate that the effects of exchange rate volatility on bilateral trade flows are small, but may differ depending on the presence of a well-developed forward market. There is minimal support for this conclusion in the literature, where Coes finds a negative relationship between volatility and trade for countries where a forward market is absent.[44] Empirical evidence supporting the conclusion that exchange rate volatility does not depress trade flows for countries with well-developed forward markets had not previously been well established. However, even in countries where forward markets are accessible, hedging foreign exchange risk still presents costs to the investor and some economists have suggested that trade has grown more slowly under the floating rate system since the breakdown of Bretton Woods than it otherwise would have under a fixed rate system.[45]

Even if increased exchange rate volatility does depress trade flows for countries without a well-developed forward market, does that imply diminished economic growth and overall societal welfare for those countries? Some argue that decreased trade as a result of volatility may lead to a more efficient distribution of the burden associated with exchange rate risk, and that welfare may increase even as trade flows decrease.[46] As explained by Farrell, et al, the reasoning for this is as follows:

> "If reductions in trade attributable to risk aversion are offset by the beneficial effects of trading in currencies that are neither overvalued nor undervalued (more in line with the notions of comparative advantage), potential world output and the level of trade may rise in an efficient manner….A permanent contraction of trade may be beneficial if it contributes to overall economic efficiency; in this event, trade reductions should not be considered the net cost of exchange rate variability. Moreover, such reductions may be the consequence of an exchange rate system that allows the authorities to pursue national goals pertaining to real growth and inflation."[47]

The effects on currency valuations and overall societal welfare by changing trade levels resulting from exchange rate volatility is therefore a field ripe for further research.

---

[44] See Coes (1981) and Bowen, et al (1998).
[45] See Krugman and Obstfeld (2000).
[46] See Thursby and Willett (1981).
[47] See Farrell, et al (1983).

REFERENCES

American Iron and Steel Institute Web site: http://www.steel.org.

American Metal Markets Web site: http://www.amm.com.

Arize, Augustine C. 1998. "The Long-Run Relationship Between Import Flows and Real Exchange-Rate Volatility: The Experience of Eight European Economies." *International Review of Economics and Finance* 7(4): 417-435.

Asseery, A. and D.A. Peel. 1991. "The Effects of Exchange Rate Volatility on Exports – Some New Estimates." *Economic Letters* 37: 173-177. October.

Ashtar, M. and R. Spence Hilton. 1984. "Effects of Exchange Rate Uncertainty on German & U.S. Trade." Federal Reserve Bank of New York. *Quarterly Review.* Spring: 7-16.

Bailey, Martin J. and George S. Tavlas. 1988. "Trade and Investment Under Floating Rates: the U.S. Experience." *Cato Journal*: 421-449. Fall.

Banco de Mexico Web site: http://www.banxico.org.mx.

Baron, David P. 1976. "Flexible Exchange Rates, Forward Markets, and the Level of Trade." *American Economic Review* 66: 253-266. June.

Bélanger, Denis, Sylvia Gutiérrez and Jacques Raynauld. 1988. "Exchange Rate Variability and Trade Flows: Sectoral Estimates for the U.S.-Canada Case." *Cahiers de Recherche* IEA-8901. École des Hautes Études Commerciales.

Bélanger, Denis, Sylvia Gutiérrez, Daniel Racette and Jacques Raynauld. 1992. "The Impact of Exchange Rate Variability on Trade Flows: Further Results on Sectoral U.S. Imports from Canada." *North American Journal of Economics and Finance* 3: 888-892. Spring.

Ben-David, Dan, Håkan Nordström and L. Alan Winters. 1999. "Trade, Income Disparity and Poverty." *World Trade Organization Special Studies*, No. 5, Geneva: WTO Publications.

Bini-Smaghi, Lorenzo. 1991. "Exchange Rate Variability and Trade: Why Is It So Difficult to Find Any Empirical Relationship?" *Applied Economics* 23: 927-935.

Bollerslev, T., R.Y. Chou and K.F. Kroner. 1992. "ARCH Modelling in Finance." *Journal of Econometrics* 52: 5-59.

Bowen, Harry P., Abraham Hollander and Jean-Marie Viaene. 1998. Applied International Trade Analysis. Ann Arbor: University of Michigan Press.

Brada, Josef C. and José A. Méndez. 1988. “Exchange Rate Risk, Exchange Rate Regime and the Volume of International Trade.” *KYLOS* 41: 263-280.

Broll, Udo and Bernhard Eckwert. 1999. “Exchange Rate Volatility and International Trade.” *Southern Economic Journal* 66(1): 178-185.

Caporale, Tony and Khosrow Doroodian. 1994. “Exchange Rate Variability and the Flow of International Trade.” *Economic Letters* 46: 49-54.

Chang, I-Lok and P.A.V.B. Swamy. 2001. Stochastic Coefficients Estimations Program (SCEP): A User’s Guide.

Chang, I-Lok, P.A.V.B. Swamy, Charles Hallahan and George S. Tavlas. 2000. “A Computational Approach to Finding Causal Economic Laws.” *Computational Economics* 16: 105-136.

Chowdhury, Abdur R. 1993. “Does Exchange Rate Volatility Depress Trade Flows? Evidence from Error Correction Models.” *The Review of Economics and Statistics* 75 (4): 700-706. November.

Christou, Costas, P.A.V.B. Swamy and George Tavlas. 1998. “A General Framework for Predicting Returns from Multiple Currency Investments.” *Journal of Economic Dynamics and Control* 22: 977-1000.

Clark, Peter B. 1973. “Uncertainty, Exchange Risk, and the Level of International Trade.” *Western Economic Journal* 11: 302-313. September.

Côté, Agathe. 1994. “Exchange Rate Volatility and Trade: A Survey.” Bank of Canada. *Working Paper* 94-5. May.

De Grauwe, Paul. 1996. International Money: Postwar Trends and Theories: Second Edition. Oxford: Oxford University Press.

De Grauwe, Paul. 1988. “Exchange Rate Variability and the Slowdown in Growth of International Trade.” *IMF Staff Papers*: 63-84. March.

De Grauwe, Paul and Guy Verfaille. 1988. “Exchange Rate Variability, Misalignment, and the European Monetary System.” In Richard C. Marston (ed.) Misalignment of Exchange Rates: Effects on Trade and Industry. Chicago: University of Chicago Press.

Dellas, Harris and Ben-Zion Zilberfarb. 1993. “Real Exchange Rate Volatility and International Trade: A Reexamination of the Theory.” *Southern Economic Journal* 59: 651-657. April.

Dickey, D. and W. Fuller. 1979. “Distribution of the Estimators for Autoregressive Times Series with a Unit Root,” *Journal of the American Statistical Association* 74: 427-431.

Dwyer, L., D.C. Nguyen and S. Rajapakse. 1996. "The Volatility of Australia's Exchange Rate: a Synthesis." *Economic Analysis and Policy* 26(1): 25-44.

Engle, R.F. 1982. "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of UK Inflation." *Econometrica* 504: 987-1007.

Engle, R. and C.W.J. Granger. 1987. "Cointegration and Error Correction: Representation, Estimation, and Testing." *Econometrica* 55: 251-276.

Farrell, Victoria S., Dean A. DeRosa and T. Ashby McCown. 1983. "Effects of Exchange Rate Variability on International Trade and other Economic Variables: A Review of the Literature." Board of Governors of the Federal Reserve System. *Staff Studies 130*. December.

Feenstra, Robert C. and Jon D. Kendall. 1991. "Exchange Rate Volatility and International Prices." National Bureau of Economic Research, Working Paper No. 3644.

Flood, Robert P. and Andrew K. Rose. 1999. "Understanding Exchange Rate Volatility Without the Contrivance of Macroeconomics." *The Economic Journal* 109: F660-F672. November.

Frankel, Jeffrey A. and Shang-Jin Wei. 1993. "Trade Blocs and Currency Blocs." National Bureau of Economic Research, Working Paper No. 4335.

Friedman, Milton. 1953. "The Case for Flexible Exchange Rates." *Essays in Positive Economics*. Chicago: University Press.

Goodman, Stephen H. 1979. "Foreign Exchange Rate Forecasting Techniques: Implications for Business and Policy." *The Journal of Finance* 34(2): 415-427. May.

Greene, William H. 1997. Econometric Analysis: Third Edition. Upper Saddle River, NJ: Prentice-Hall, Inc.

Hooper, Peter and Steven W. Kohlhagen. 1978. "The Effect of Exchange Rate Uncertainty on the Prices and Volume of International Trade." *Journal of International Economics* 8: 483-511. November.

Johansen, Soren. 1991. "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Regressive Models," *Econometrica* 59: 1551-1580.

Johansen, Soren and K. Juselius. 1990. "Maximum Likelihood Estimation and Inference on Cointegration –with Application to the Demand for Money," *Oxford Bulletin of Economics and Statistics* 52: 169-210.

Koray, Faik and William D. Lastrapes. 1989. "Real Exchange Rate Volatility and U.S. Bilateral Trade: A Var Approach." *The Review of Economics and Statistics* 7 (4): 708-712. November.

Kroner, Kenneth F. and William D. Lastrapes. 1993. “The Impact of Exchange Rate Volatility on International Trade: Reduced From Estimates Using the GARCH-in-Mean Model. *Journal of International Money and Finance* 12: 298-318. June.

Krugman, Paul R. and Maurice Obstfeld. 2000. International Economics: Theory and Policy: Fifth Edition. Reading, Mass.: Addison-Wesley Longman, Inc.

Kumar, Vikram. 1992. “Real Effects of Exchange Risk on International Trade.” Federal Reserve Bank of Atlanta, Working Paper No. 92-5.

Kwiatkowski, D., P. Phillips, P. Schmidt, and Y. Shin. 1992. “Testing the Null Hypothesis of Stationary Against the Alternative of a Unit Root,” *Journal of Econometrics* 54: 159-178.

Lastrapes, William D. and Faik Koray. 1990. “Exchange Rate Volatility and U.S. Multilateral Trade Flows.” *Journal of Macroeconomics* 12: 341-362. Summer.

Lee, Jaewoo. 1999. “The Effect of Exchange Rate Volatility on Trade in Durables.” *Review of International Economics* 7(2): 189-201.

McCulloch, Rachel. 1983. “Unexpected Real Consequences of Floating Exchange Rates.” *Essays in International Finance* 153. Princeton, NJ: Princeton University.

McKenzie, Michael D. and Robert D. Brooks. 1997. “The Impact of Exchange Rate Volatility on German-U.S. Trade Flows.” *Journal of International Financial Markets, Institutions and Money* 7:73-87.

Merton, Robert. 1980. “On Estimating the Expected Return to the Market: An Exploratory Investigation.” *Journal of Financial Economics* 8: 323.361.

Mussa, Michael M. 1986. “Nominal Exchange Rate Regimes and the Behavior of the Real Exchange Rate.” *Carnegie-Rochester Series on Public Policy*: 117-213.

NAFTA Secretariat. 1994. "NAFTA Text: Final Version, Including Supplementary Agreements."

Pakko, Michael R. and Howard J. Wall. 2001. “Reconsidering the Trade-Creating Effects of a Currency Union.” Federal Reserve Bank of St. Louis. September/October.

Pereé, Eric and Alfred Steinherr. 1989. “Exchange Rate Uncertainty and Foreign Trade.” *European Economic Review* 33: 1241-1264. July.

Rose, Andrew K. 2001. “Currency Unions and Trade: The Effect is Large.” Presented at the *Economic Policy* panel meeting in Stockholm. April.

Saavides, Andreas. 1992. “Unanticipated Exchange Rate Variability and the Growth of International Trade.” *Weltwirtschaftliches Archiv* 128: 446-463.

Sauer, Christine and Alok K. Bohara. 2001. “Exchange Rate Volatility and Exports: Regional Differences between Developing and Industrialized Countries.” *Review of International Economics*, 9(1): 135:152.

Sekkat, Khalid. 1997. “Exchange Rate Variability and EU Trade.” Final Report to the Commission of the EU (DGII): Brussels. November.

Swamy, P.A.V.B. and George Tavlas. 1994. “Connections Between GARCH and Stochastic Coefficients (SC) Models.” *Economic Letters* 46: 7-10.

Thursby, Marie C. and J.G. Thursby. 1987. “Bilateral Trade Flows, the Linder Hypothesis and Exchange Risk.” *Review of Economics and Statistics* 69: 488-495.

Thursby, Marie C. and Thomas D. Willett. 1981. “The Effects of Flexible Exchange Rates on International Trade and Investment: Historical Views and Current Analysis.” Columbus: Ohio State University, and Claremont, CA: Claremont Graduate School.

APPENDIX A

Exchange Rate Volatility Estimation						
	CANADA			MEXICO		
Date	LN Volatility	LN Volatility Forecast	% Error	LN Volatility	LN Volatility Forecast	% Error
Mar-96	-10.14	-9.17	9.61%	-7.40	-3.91	47.10%
Apr-96	-10.88	-8.79	19.18%	-6.05	-5.09	16.00%
May-96	-10.29	-10.28	0.03%	-6.69	-7.64	14.33%
Jun-96	-11.04	-10.26	7.10%	-5.89	-7.61	29.19%
Jul-96	-10.47	-9.67	7.70%	-7.00	-8.19	17.01%
Aug-96	-10.85	-10.92	0.66%	-7.33	-8.40	14.55%
Oct-96	-9.30	-10.82	16.41%	-3.90	-6.09	56.35%
Nov-96	-9.75	-9.85	1.11%	-7.71	-5.08	34.20%
Dec-96	-9.29	-8.74	5.95%	-7.79	-6.02	22.76%
Jan-97	-8.24	-8.59	4.27%	-7.69	-5.61	27.09%
Feb-97	-8.88	-8.59	3.26%	-6.58	-5.30	19.33%
Mar-97	-9.28	-9.17	1.21%	-6.90	-5.64	18.25%
Apr-97	-10.07	-9.96	1.10%	-7.45	-7.17	3.85%
Jun-97	-9.59	-8.97	6.42%	-8.01	-5.87	26.71%
Jul-97	-9.72	-8.36	14.02%	-6.44	-5.85	9.24%
Aug-97	-10.14	-9.59	5.44%	-8.17	-6.56	19.72%
Sep-97	-10.42	-9.35	10.26%	-8.00	-6.42	19.75%
Oct-97	-8.00	-8.63	7.93%	-3.63	-7.65	111.02%
Nov-97	-9.01	-9.11	1.11%	-6.16	-7.36	19.46%
Dec-97	-9.25	-8.87	4.15%	-7.11	-6.88	3.31%
Jan-98	-8.05	-9.30	15.52%	-4.78	-6.81	42.51%
Feb-98	-8.31	-8.94	7.56%	-6.11	-6.08	0.44%
Mar-98	-9.97	-9.24	7.36%	-7.13	-7.62	6.75%
Apr-98	-9.10	-10.48	15.18%	-7.72	-7.53	2.44%
May-98	-8.77	-9.53	8.66%	-4.93	-8.30	68.49%
Jun-98	-9.25	-8.79	4.94%	-5.73	-7.39	28.96%
Jul-98	-7.76	-8.69	11.89%	-6.81	-7.82	14.82%
Aug-98	-6.91	-9.80	41.83%	-2.94	-7.34	150.11%
Sep-98	-7.84	-10.09	28.64%	-4.35	-7.06	62.36%
Oct-98	-9.31	-8.82	5.19%	-5.50	-4.98	9.44%

Nov-98	-8.05	-10.26	27.38%	-7.17	-5.35	25.48%
Dec-98	-9.26	-8.80	4.96%	-6.12	-6.24	1.89%
Jan-99	-8.92	-9.76	9.41%	-3.94	-7.10	80.04%
Feb-99	-8.72	-8.74	0.14%	-6.00	-5.07	15.56%
Mar-99	-9.03	-8.90	1.40%	-5.10	-7.80	52.73%
Apr-99	-8.03	-9.10	13.37%	-5.58	-7.46	33.70%
May-99	-9.25	-8.89	3.81%	-4.77	-6.70	40.43%
Jun-99	-9.18	-8.72	5.08%	-5.33	-5.43	1.83%
Jul-99	-7.37	-8.54	15.88%	-7.47	-3.16	57.65%
Aug-99	-8.86	-8.93	0.79%	-6.72	-4.06	39.65%
Sep-99	-8.64	-8.99	4.08%	-8.07	-6.33	21.53%
Oct-99	-8.82	-8.53	3.36%	-5.75	-8.93	55.28%
Nov-99	-10.31	-8.77	14.93%	-6.09	-8.35	37.01%
Dec-99	-8.16	-8.34	2.27%	-6.62	-7.01	5.91%
Jan-00	-9.22	-8.68	5.83%	-6.82	-6.38	6.42%
Feb-00	-9.41	-8.87	5.76%	-6.62	-5.96	9.96%
Mar-00	-8.87	-8.62	2.83%	-7.18	-5.65	21.36%
Apr-00	-8.20	-8.78	7.08%	-6.96	-5.92	14.84%
May-00	-8.95	-8.78	1.93%	-6.29	-5.92	5.86%
Jun-00	-9.46	-8.76	7.31%	-5.03	-5.02	0.19%
Jul-00	-9.02	-8.83	2.11%	-6.41	-4.03	37.03%
Aug-00	-9.70	-10.09	4.00%	-6.81	-3.99	41.39%
Sep-00	-8.73	-9.88	13.20%	-6.31	-4.27	32.34%
Oct-00	-8.45	-8.95	5.93%	-6.38	-5.07	20.60%
Nov-00	-8.49	-8.94	5.35%	-5.91	-4.28	27.57%
Dec-00	-8.09	-7.88	2.66%	-6.24	-7.92	27.08%
Jan-01	-9.16	-7.97	12.98%	-6.19	-4.23	31.62%
Feb-01	-7.57	-8.75	15.63%	-8.03	-3.34	58.40%
Mar-01	-8.10	-9.23	14.04%	-6.87	-3.74	45.53%
Apr-01	-7.92	-9.34	17.81%	-6.92	-6.68	3.42%
May-01	-9.23	-8.52	7.61%	-5.82	-7.23	24.18%
Jun-01	-9.24	-9.20	0.34%	-7.79	-5.83	25.25%
Jul-01	-8.25	-9.22	11.79%	-6.12	-9.29	51.80%
Aug-01	-9.44	-9.41	0.35%	-7.92	-9.38	18.43%
Sep-01	-9.19	-9.37	1.86%	-5.90	-8.33	41.26%

Oct-01	-9.00	-9.08	0.98%	-5.39	-5.13	4.73%
Nov-01	-8.94	-8.91	0.33%	-7.56	-6.49	14.06%
Dec-01	-8.14	-8.87	8.97%	-7.46	-6.85	8.12%
Jan-02	-9.00	-9.02	0.15%	-7.86	-6.55	16.71%
Feb-02	-9.06	-9.25	2.09%	-8.14	-6.52	19.88%
Mar-02	-9.51	-8.92	6.20%	-8.26	-6.29	23.82%
Apr-02	-8.05	-7.78	3.37%	-5.51	-6.91	25.45%
May-02	-7.60	-8.61	13.29%	-6.57	-7.13	8.54%
Jun-02	-8.26	-8.60	4.19%	-5.51	-5.80	5.33%
Jul-02	-6.59	-8.38	27.17%	-5.86	-5.32	9.12%
Aug-02	-7.83	-8.63	10.25%	-6.76	-6.06	10.35%
AVERAGE			**7.95%**			**27.30%**

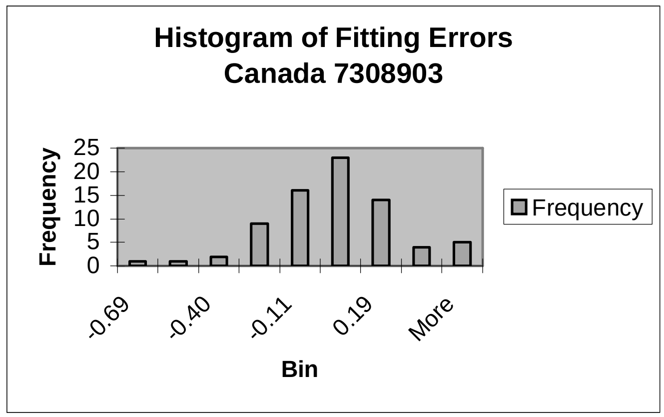
APPENDIX B

TESTS OF STATISTICAL ADEQUACY

SC Steel Demand Model

Canada 7308903

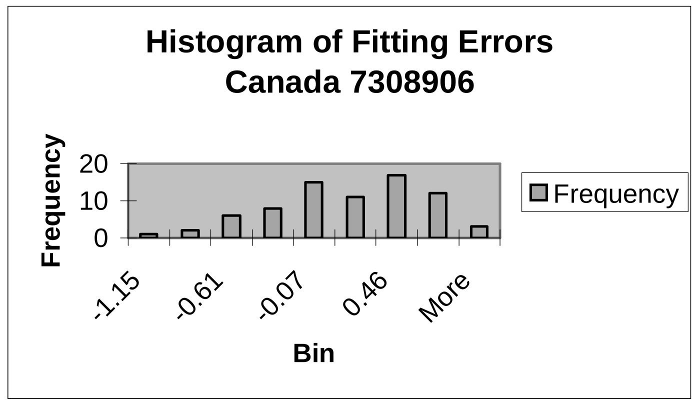
Fitting Error e(t) Descriptive Statistics	
Mean	-0.0523
Standard Error	0.0264
Standard Deviation	0.2289
Sample Variance	0.0524
Kurtosis	0.5140
Skewness	-0.0217
Range	1.1709
Minimum	-0.69302
Maximum	0.47787
Results of OLS Regression of e(t) on e(t-1)	
Coefficient	0.851
T-statistic	13.768
R^2	0.708
Durbin Watson and Breusch-Pagan Test Statistics	
Durbin Watson	0.300
Breusch-Pagan	14.715



SC Steel Demand Model

Canada 7308906

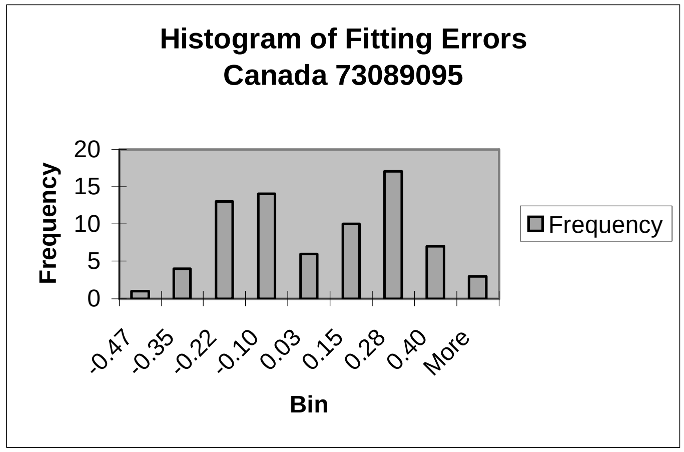
Fitting Error e(t) Descriptive Statistics	
Mean	0.0221
Standard Error	0.0558
Standard Deviation	0.4834
Sample Variance	0.2337
Kurtosis	-0.6398
Skewness	-0.2658
Range	2.1466
Minimum	-1.1481
Maximum	0.9985
Results of OLS Regression of e(t) on e(t-1)	
Coefficient	0.875
T-statistic	15.338
R^2	0.762
Durbin Watson and Breusch-Pagan Test Statistics	
Durbin Watson	0.252
Breusch-Pagan	8.705



SC Steel Demand Model

Canada 73089095

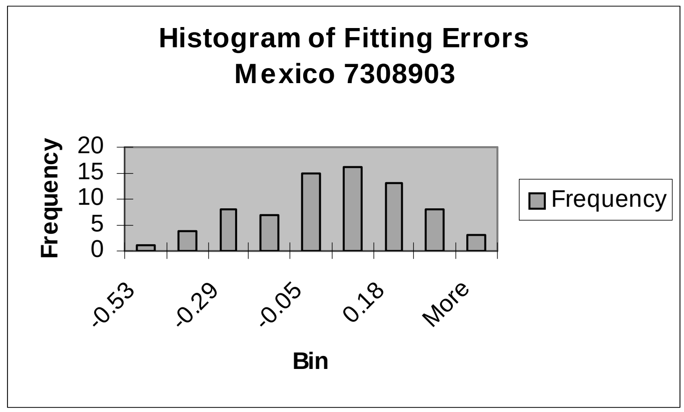
Fitting Error e(t) Descriptive Statistics	
Mean	-0.0011
Standard Error	0.0296
Standard Deviation	0.2566
Sample Variance	0.0658
Kurtosis	-1.0886
Skewness	0.0189
Range	1.0012
Minimum	-0.4728
Maximum	0.5284
Results of OLS Regression of e(t) on e(t-1)	
Coefficient	0.832
T-statistic	12.587
R^2	0.685
Durbin Watson and Breusch-Pagan Test Statistics	
Durbin Watson	0.343
Breusch-Pagan	4.6215



SC Steel Demand Model

Mexico 7308903

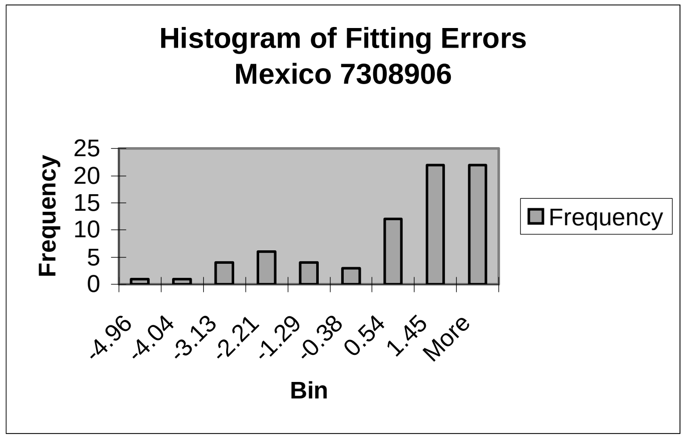
Fitting Error e(t) Descriptive Statistics	
Mean	-0.0568
Standard Error	0.0248
Standard Deviation	0.2150
Sample Variance	0.0462
Kurtosis	-0.4635
Skewness	-0.0867
Range	0.9501
Minimum	-0.5292
Maximum	0.4209
Results of OLS Regression of e(t) on e(t-1)	
Coefficient	0.559
T-statistic	5.676
R^2	0.260
Durbin Watson and Breusch-Pagan Test Statistics	
Durbin Watson	0.885
Breusch-Pagan	1.731



SC Steel Demand Model

Mexico 7308906

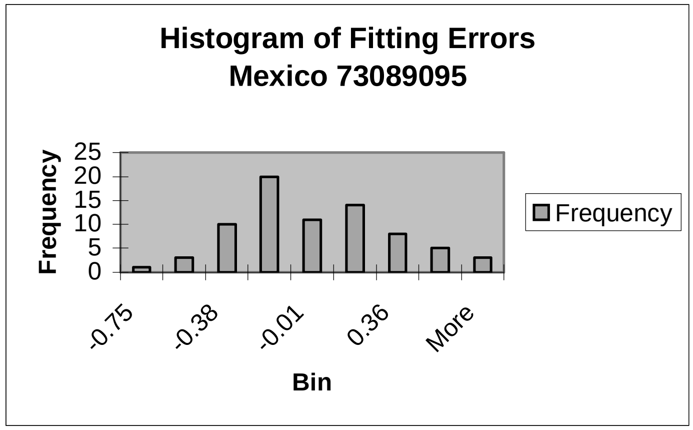
Fitting Error e(t) Descriptive Statistics	
Mean	0.2725
Standard Error	0.2160
Standard Deviation	1.8705
Sample Variance	3.4988
Kurtosis	0.2931
Skewness	-1.1740
Range	7.3272
Minimum	-4.9584
Maximum	2.3688
Results of OLS Regression of e(t) on e(t-1)	
Coefficient	0.951
T-statistic	25.074
R^2	0.983
Durbin Watson and Breusch-Pagan Test Statistics	
Durbin Watson	0.106
Breusch-Pagan	20.525



SC Steel Demand Model

Mexico 73089095

Fitting Error e(t) Descriptive Statistics	
Mean	-0.0813
Standard Error	0.0382
Standard Deviation	0.3304
Sample Variance	0.1092
Kurtosis	-0.5123
Skewness	0.3249
Range	1.4832
Minimum	-0.7513
Maximum	0.7319
Results of OLS Regression of e(t) on e(t-1)	
Coefficient	0.743
T-statistic	9.433
R^2	0.523
Durbin Watson and Breusch-Pagan Test Statistics	
Durbin Watson	0.517
Breusch-Pagan	6.474



VITA

Joseph Conlin Pickard is the youngest of three sons born and raised in Huntingdon Valley, Pennsylvania, just outside the city of Philadelphia. Like his older brothers, he graduated from LaSalle College High School in Wyndmoor, PA. He then attended Loyola College in Baltimore, Maryland and spent his junior year abroad at the Katholieke Universiteit Leuven in Belgium. He received his B.A. in Political Science from Loyola in 1992. Upon graduation, he moved to Washington, D.C. with several friends and began work as a paralegal for the Law Offices of Douglas R. Stevens. Since then, he has held full-time administrative and program positions for the Academy for Educational Development, the Urban Institute, and currently with The Pew Charitable Trusts, while completing his Master's degree in Economics from Virginia Tech at night. After graduating, Joe plans on pursuing the Ph.D. in Economics and is engaged to be married to Allison Mowery in October 2003.