EXCHANGE RATE PASS-THROUGH:
A CASE OF CANADIAN IMPORTS OF FOREIGN AUTOMOBILES

A thesis presented to the School of Graduate Studies and Research of the University of Ottawa in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Economics.

by

David R. Sabiston

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Do mo chéile ionúin, Treasa,

De bharr a síor grá dom, a foighne buan agus a tuiscint nár staonadh riamh.

ABSTRACT

This thesis examines the role of exchange rate fluctuations on prices of automobiles imported into Canada over the period 1980(0) - 1990(4). The theoretical model is motivated by the desire to synthesize existing models which only identify portions of incomplete exchange rate pass-through. The model captures general demand and supply influences by defining a rational expectations, dynamic optimization problem, with firms maximizing profits with respect to prices, subject to linear demand curves and quadratic adjustment costs. An extension to the model accounts for the possibility of strategic price interaction between competitors and, equally important, nests the original model. The model also strengthens the link between theoretical foundations and empirical estimation by providing a natural framework for recent econometric developments. In particular, favourable unit root and cointegration tests permit the theoretical model to be respecified as an error correction model (ECM) such that long-run equilibrium relationships can be separated from the short-run dynamics of a system.

Following the theoretical foundations, each of the three separate automobile classifications (subcompact, compact/midsize, and large) is estimated using a traditional econometric approach, the Engle-Granger two-step procedure, and a Johansen [1991]/vector autoregressive (VAR) approach. Overall, results indicate that, regardless of the econometric methodology, U.S. automobile exporters pass through the largest amount of a change in exchange rates, followed in order by Germany and Japan. Knetter [1993] presents evidence to suggest little difference in pricing behaviour within common industries. Gross and Schmitt [1993] argue that the degree of pricing-to-market (PTM) varies across automobile sectors but remains similar within a given category. This thesis goes one step further and argues that pricing behaviour is different even within categories.

Finally, in ranking the econometric techniques in terms of "best fit", under the assumption that the Johansen procedure identifies cointegrating vectors, the Johansen/VAR methodology produces ECMs with greater parameter stability, lower probability of model misspecification and better forecasting ability.

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CHAPTER 1

INTRODUCTION

1.1 Exchange Rate Pass-Through, "Pricing-to-Market" and Estimation Techniques

Over the past decade, apprehension surrounding the degree of exchange rate volatility has influenced the direction of theoretical and empirical research on the relationship between exchange rates and firms' pricing policies for internationally traded goods. Simple purchasing power parity (PPP) relationships can no longer provide an adequate explanation for the observed pricing behaviour. On the theoretical front, analysis of this pricing behaviour has benefitted from the adoption of assumptions governing the "new trade theory"; namely, differentiated products, imperfect competition and/or increasing returns to scale. The emerging "pass-through" (PT) and "pricing-to-market" (PTM) literature has identified exchange rate fluctuations as a contributing factor to a firm's diverse pricing policies between domestic and foreign markets when measured in a common currency.[1] Notable developments include the modelling of *hysteresis* effects on exchange rate pass-through coefficients (Baldwin [1988], Dixit [1989], Froot and Klemperer [1989] and Ohno [1989]) and the recent movement away from static models towards more *dynamic* functional forms (Gagnon [1989], Kasa [1992] and Feenstra, Gagnon and Knetter [1993]).

There is a general consensus that changes in exchange rates are not fully passed through to prices of traded goods. Most studies reject the fundamental tenet of purchasing power parity (PPP) for both short-run and long-run time spans. A 10% appreciation of the Japanese yen, for example, is associated with a *less* than 10% increase in the dollar prices of Japanese exports to Canada. Note that this partial pass-through implies a *reduction of the yen price* of Japanese exports. If the reduction in the yen price

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[1] The term PTM is generally attributed to Krugman [1987]; other PT and PTM contributors include Athukorala and Menon [1994], Baldwin and Krugman [1986], Feenstra [1989], Fisher [1989], Gagnon and Knetter [1995], Giovannini [1988], Gross and Schmitt [1993], Hooper and Mann [1989], Knetter [1989;1993;1994], Marston [1990;1991], Melick [1990], Menon [1992;1993a;1993b;1995], Ohno [1989;1990], Parsley [1993], Schembri [1988], and Shinjo [1993].

for exports is not accompanied by a reduction in the yen price of an identical good destined for the domestic (Japanese) market, it can be argued that this partial pass-through is due to pricing-to-market (PTM) strategy. By definition, PTM is a strategic pricing policy designed to preserve foreign market share, frequently at the expense of the domestic market. In chapter 2, the literature demonstrates how the price differential for a good destined for domestic consumption and the identical good destined for export (measured in a common currency) is a function of: (a) the degree of competitiveness in both markets; (b) the respective demand functions; (c) the substitutability between export goods and competitors' goods in foreign markets; (d) the temporary versus permanent perception of changes in the exchange rate; and (e) the degree to which domestic and foreign markets are segmented by transportation and other transaction costs.[2]

On the other hand, if the yen price of domestic (Japanese) goods fall by an amount identical to Japanese exports, one cannot infer PTM strategy. If, for example, the appreciation lowers the costs of imported goods used in the production process, Japanese firms will be able to lower the yen price of all its goods (both domestic and foreign) by exactly the same amounts. However, in this case, we observe partial pass-through of the change in the exchange rate yet, no evidence to support PTM; incomplete pass-through is *not* a sufficient condition to infer "pricing-to-market". Consequently, one of the objectives of this thesis is to derive a "general" theoretical model of exchange rate pass-through, synthesizing existing models which identify only portions of incomplete pass-through (*i.e.*, PTM, markups and other demand-side models, supply-side models, *etc.*).

Unfortunately, empirical studies frequently diverge from their theoretical underpinnings. Often, this divergence is attributable to the lack of suitable data. Precise theoretical variables are unavailable

[2] Unless legal barriers prevent arbitrage, there is a limit to the price differential. As the price differential increases, "grey markets" arise whereby individuals can short-circuit the usual distribution routes in favour of direct involvement (arbitrage). See Krugman's [1987] example where U.S. consumers purchased European luxury automobiles directly from Europe.

and one must try to select adequate representations from available proxies. A more important factor accounting for this divergence, and one that is completely within control of the researcher, is the problem of data-mining. In an effort to find the "best fit", empirical estimations are subject to major transformation, to the point where the final accepted estimation model bears little resemblance to its theoretical counterpart. *Ad hoc* estimation procedures, which are guided by what Summers [1991] calls the researcher's "capacity for statistical pyrotechnics", tend to obfuscate the bond between theoretical foundations and empirical estimation. While data problems will inevitably occur, recent developments in the unit root and co-integration literature generate new techniques to bridge this gap - particularly within the realm of dynamic modelling - and provide applied economists with tools to conduct *controlled* experiments.[3] Consequently, one of the objectives of this paper is to derive a dynamic functional form such that these recent econometric developments provide a natural framework for the empirical estimation of a firm's optimal pricing decision.

This thesis is motivated by theoretical and empirical questions on exchange rate pass-through. However, it is important to recognize that policy-motivated issues can influence the decision whether to study a general model of exchange rate pass-through or to concentrate on specific sources of incomplete exchange rate pass-through (*i.e.*, PTM). If, for example, one is interested in how international competitiveness is affected by movements in the exchange rate - how prices of exports (imports) in foreign (domestic) markets change, subject to exchange rate fluctuations - PT measures are sufficient. On the other hand, if attention is directed towards contestable trading practices such as dumping, PTM estimates will indicate whether or not a country such as Japan is cross-subsidizing its export markets when

[3] Theoretical contributions to the co-integration literature include Banerjee *et al.* [1993], Davidson and MacKinnon [1993, Chapter 20], Engle and Granger [1987], Granger [1986], Johansen [1988], Johansen and Juselius [1990], MacKinnon [1991], and Stock [1987]. The following provide excellent surveys: Banerjee *et al.* [1993], Dolado and Jenkinson [1987], Dolado *et al.* [1990], Holden and Thompson [1992], Muscatelli and Hurn [1992], and Perman [1991]. For a practical guide on estimation procedures and hypothesis testing of co-integrated time series, see Dickey and Rossana [1994].

its currency appreciates. Other contemporary policy issues of concern, which have a bearing on exchange rate pass-through results, include: balance of trade problems; trade-induced inflation; and the effects of tariffs on prices of traded goods.

1.2 Contributions

This thesis contributes to both the theoretical and empirical literature on exchange rate pass-through. Theoretically, the model synthesizes existing exchange rate pass-through models which concentrate only on *specific* sources of incomplete pass-through. Respecified as an error correction model (ECM), it bridges the gap between recent empirical estimation techniques (*i.e.*, unit root tests, co-integration, Engle-Granger two-step procedure, and Johansen procedure) and the theoretical model by providing a *precise* econometric specification of short-run dynamics and long-run economic equilibrium relationships. The extension to the model is the first time a nesting procedure is used to test the viability of a strategic price interaction model of exchange rate pass-through.

Empirically, this is the first in-depth analysis of exchange rate pass-through of Canadian automobile imports to compare the classical linear regression approach, the Engle-Granger two-step procedure (Engle and Granger [1987]), and a vector autoregressive (VAR) approach based on the Johansen procedure (Johansen [1988;1991], and Johansen and Juselius [1990]).[4] The Johansen procedure/VAR estimation is used to nest the Engle-Granger two-step procedure - no prior studies have specifically nested competing econometric methodologies. Finally, this is the first time that static forecasts have been used to test parameter stability and model misspecification of exchange rate pass-through models. Moreover, no previous studies have used dynamic forecasts to determine whether ECM models derived from a Johansen/VAR approach are superior to ECM models constructed under the Engle-Grange procedure.

[4] The categories are subcompacts, compact/midsize and large automobiles. Source countries are Japan, South Korea, (West) Germany, Sweden and the United States.

The thesis is organized as follows. Chapter 2 discusses the historical development of exchange rate pass-through starting from the elasticity approach under fixed exchange rate regimes (Harberler [1949]). Chapter 3 discusses the criteria necessary for a "general" model of exchange rate pass-through. The model is presented as a rational-expectations dynamic optimization problem with firms facing linear demand curves and quadratic adjustment costs. The extension adds the element of strategic pricing behaviour by including competitors prices in the demand curve. Chapter 4 discusses each of the empirical methodologies and their appropriate tests. Chapter 5 presents the results and possible explanations. Chapter 6 summarizes the results with respect to previous studies and offers some insight to future areas of research. Finally, the supporting documentation is included in a series of appendices: Appendix A contains the mathematical derivations for the extension to the model; Appendix B discusses the sources, problems, and remedies for the data set; Appendix C and D contain the regression results (and tests) for the original model and the extension using a classical linear regression (CLR) approach; Appendix E contains unit root tests (Augmented Dickey-Fuller (ADF) and Phillps-Perron (PP)) for all variables; Appendix F and G contain regression results and tests of the original model and the extension using the Engle-Granger two-step procedure; Appendix H contains the regression results of the extension of the original model using the Johansen procedure and VAR estimation techniques; and Appendix I contains all the graphs relating to the dynamic forecasting analysis

CHAPTER 2

REVIEW OF THE THEORETICAL AND EMPIRICAL LITERATURE

2.1 Exchange Rate Pass-Through Under Fixed Exchange Rates (1949-1973)

Until the collapse of the Bretton Woods agreement in 1973, advances in the exchange rate pass-through literature were generally directed toward solving balance of trade problems. For countries attempting to correct a balance of trade deficit, the fundamental question was the required *magnitude* of the devaluation to reverse the trend. Would a devaluation of a given order be sufficient to alter the equilibrium import payments and export receipts in the proper direction?

Theoretical evaluations concentrated on the supply and demand approach introduced by Haberler [1949]. In his classic graphical analysis, he examined the effects of a devaluation of the domestic currency on the prices and quantities of exports and imports. The demand and supply curves are "representative bales" of exports and imports derived in their respective currencies. In the case of Canada and Japan, for example, a devaluation of the Canadian dollar with respect to the yen will have no effect on the demand for imports *measured in dollars*. What we observe is a shift in the supply of imports from Japan (measured in dollars) since the new dollar value at each quantity must correspond to the original yen value. Consequently, the supply shift is not parallel: the distance between the original and new curve represents the percentage change in the devaluation.

For example, suppose the dollar was devalued by 10% against the yen: Figure 2-a and Figure 2-b capture the essence of Haberler's analysis on the equilibrium prices and quantities of imports.

IMPORTS

Figure 2-a

Demand and Supply Analysis of Pass-Through in Domestic Currency

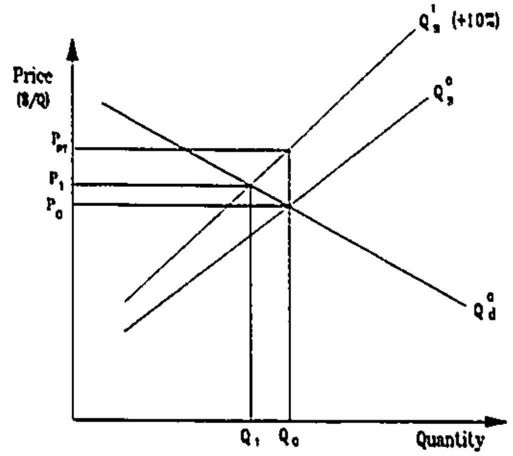
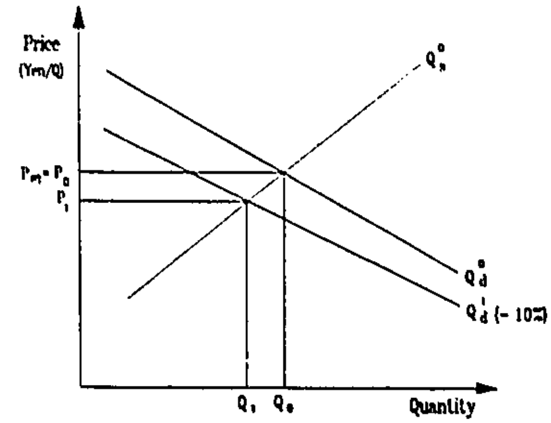


Figure 2-b

Demand and Supply Analysis of Pass-Through in Foreign Currency



In Figure 2-a, initial equilibrium price and quantity occur at P_0 and Q_0 respectively. A 10% dollar devaluation shifts the supply curve to Q_s^1 and eventually market forces drive the equilibrium price up to P_1 while the quantity falls to Q_1. Haberler's major concern was to determine the conditions under which a change in the exchange rate would have a "normal" effect on the balance of payments; that is, where a devaluation would improve the balance and with a revaluation having the opposite effect.[1] In this particular case, the dollar value of imports will fall providing the elasticity of demand exceeds unity.

This "elasticity approach" provided the foundation for theoretical advancements in international economics for many years. We can use this approach to examine the exchange rate pass-through for this simple static model. While Haberler does not discuss the dynamics of the equilibrium variables, his

[1] Haberler extended the well-known 'Marshall-Lerner' condition (Lerner [1944], Marshall [1923]) to examine how the demand and supply for traded goods determine the demand and supply curves for foreign exchange.

assumptions about the currency specification of the demand and supply schedules enable us to examine how market forces operate. Given the perfectly competitive framework for Japanese exporters, they are assumed to retain their selling price in yen at $P_{PT}=P_0$ (Figure 2-b); the devaluation forces an immediate increase in the dollar valuation P_{PT}, in Figure 2-a. From both diagrams, we observe an excess supply in the market at the new price, eventually driving down the price *in both currencies.*

We can think of the pass-through being divided into two time periods: the short run and the long run. In the short run, we have complete pass-through since the dollar price of imports increases by the full 10%. However, in the long run, when quantities adjust, the excess supply at this price (P_{PT}) ensures that the price - in both dollars and yen - falls sufficiently to restore equilibrium. In effect, Japanese exporters partially absorb the dollar devaluation (or the *yen revaluation*) by lowering yen export prices. By definition, therefore, the less responsive the yen price of imports for a given exchange rate change, the greater the pass-through. Under the customary assumption of downward sloping demand curves and upward sloping supply curves, the long-run pass-through coefficients generated in these models will always fall between zero and one.

The new equilibrium price P_1 will be a function of the elasticities of demand and supply for imports. Branson [1972] extends the analysis by deriving pass-through coefficients based on hypothetical elasticity values. Given a log-linear model with constant elasticities of demand and supply, Branson shows that the percentage change in the dollar price of imports with respect to a given percentage dollar devaluation, can be expressed as $(1 - k_m)$, where:

$$k_m = \frac{1}{\left[1 - \frac{d_m}{s_m}\right]} \tag{2.1}$$

The elasticities of demand and supply for imports, d_m and s_m, correspond to the curves in Figure 2-a.

Complete pass-through will occur when the demand for imports is perfectly inelastic or the supply for imports is perfectly elastic. Conversely, zero pass-through - a constant dollar price for imports despite changes in the exchange rate - is consistent with a perfectly elastic demand curve or a perfectly inelastic supply curve.

Combining the contributions of these two models, we can evaluate the dynamics for the pass-through coefficient. Following a devaluation of the dollar, the immediate effect is a one-to-one increase in the dollar price of imports. In the long run, once quantities adjust, the pass-through coefficient depends on our assumptions concerning the elasticity of demand and supply. Under "normal" demand and supply conditions, a devaluation of the dollar is associated with a pass-through coefficient which, over time, works its way *down* from an initial increase of 100%.

In his seminal work, Magee [1973] uses the elasticity approach to trace the movement of a country's trade balance following a devaluation. Rather than deriving the traditional "J-curve", Magee suggests that - given certain plausible assumptions - we may observe a veritable alphabet soup motion. Such possibilities include I-,L-,M-,N-,V-,and W-curves, as well as their inverses. However, for our purposes we can show that employing Magee's analysis may lead to a pass-through coefficient which works its way *up* from an initial value of *zero*. In an attempt to clarify some issues concerning the response of trade flows to exchange rate movements, Magee divides his analysis into three distinct time intervals: (a) the currency-contract period; (b) the pass-through period; and (c) the quantity adjustment period.

The currency-contract phase measures the immediate impact of an exchange rate devaluation/revaluation on the prices of traded goods whose contracts are negotiated *prior* to the exchange rate change. The critical factor is whether the contract is denominated in foreign or domestic currency. If all import contracts are denominated in dollars, a 10% dollar devaluation will have no effect on the dollar price (and total value) of imports during this period. This is equivalent to remaining at (P_0,Q_0) in

Figure 2-a. In essence, the foreign exporters absorb either all the exchange rate risk or the cost of hedging.[2] Conversely, if all imports are denominated in foreign currency, prices would immediately jump to P_{PT}.

Following the devaluation, new contracts are negotiated *before* quantities adjust. Magee designates the new prices which emerge as the "pass-through" effect. Clearly, this is a restrictive version of the standard definition. Under this scenario, pass-through is *either* zero *or* one depending upon which of the following two reasons is responsible for sticky quantities. (1) Demand for imports may be perfectly inelastic; particularly if the commodity is not easily substitutable. In this case, the dollar price increases by the full amount of the devaluation: (P_{PT},Q_0) in Figure 2-a. (2) Conversely, the supply curve may be perfectly inelastic in the short run if exporters cannot alter (willingly or not) their sales. Consequently, the dollar price remains fixed at P_0 and the pass-through is zero.

As we enter into the quantity adjustment phase where prices and quantities eventually reach P_1 and Q_1 respectively, the direction from which we approach these new equilibrium values will depend upon our assumptions governing the "pass-through" phase. A perfectly inelastic short-run demand curve which rotates to Q_d^0 (Figure 2-a) is associated with prices which work their way *down* from P_{PT}, whereas a perfectly inelastic short-run supply curve which rotates to Q_s^1 is associated with prices which move *up* from P_0. Therefore, the short-run dynamics of the pass-through coefficient can proceed from either direction.

Another issue of considerable importance relates to the *speed of adjustment.* Branson [1972] discusses the possibility that exporters might absorb any exchange rate movements in their profit margins. This pricing-to-market strategy, however, can only be a temporary response. Exporters in a revaluating

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[2] Magee [1974] extends his analysis on the currency-contract period. He offers a few explanations as to why the Japanese prefer to contract in U.S. dollars as opposed to yen: tradition and habit; they are relatively less risk averse; and as a competitive element. This competitive aspect ensures that they can retain or improve their market share when the dollar devaluates with respect to all major trading partners.

country who reduce profit margins can only withstand losses for a short period before they withdraw from the export industry, leading to a reduction in total industry output and increased foreign prices. On the other hand, exporters from devaluing countries who resist cutting the foreign price of their products benefit from increased profit margins. Greater than "normal" profits will attract new entrants eventually increasing total supply in the industry and forcing downward pressure on prices. Branson's analysis reiterates the intuition behind a perfectly competitive framework. While a significant portion of internationally traded goods are differentiated products which operate in an imperfectly competitive setting, Branson nevertheless addresses the pricing-to-market issue and its importance in the adjustment process for both prices and quantities. From his empirical work, he concludes (Branson [1972, p.55]):

> In general, I would say that the realignments are not being fully passed through especially on the side of U.S. imports. This means that, ... the favourable effects of the devaluation on the import side may take substantially longer to appear than econometric evidence on normal price lags would suggest.

This passage supports the anecdotal evidence associated with periods of currency realignments: adjustment is subject to considerable lags.

In Magee's paper [1974], price stickiness in the short run is attributed to the length of the currency-contract period. Specifically, there are three distinctive lags which occur between the time a foreign order has been placed and its arrival at the port of entry:

(1) *production lag* - time passage between acceptance of a foreign order and the date of exportation;

(2) *transportation lag* - time passage between date of exportation and date cargo arrives within customs territory (port of importation);

(3) *entry lag* - time passage between arrival of goods and when importer provides all required documents and pays all duties. This may also include the time required to transship goods from the point of importation to the point of entry.

By definition, the production lag may vary in length from weeks to literally hours. In the case of Japanese and German exports to the U.S., if goods are produced in anticipation of future orders, they may quickly be loaded on board a ship destined to foreign markets. If an order is placed while the ship is en route, a message will be relayed indicating the port of entry. Otherwise, the excess goods will be placed in warehouses at one (or more) of the scheduled ports. Magee [1974, p.132-133] calculates the individual lags for several commodities exported by Japan and West Germany to the United States during the realignment in 1971 and the final year of the Bretton Woods system in 1973. The following table summarizes the remarkable difference in lags between the two countries' automobile exports:

TABLE 2-1

Lags (in days) of Automobile Exports from Japan and Germany to U.S.

	1971		1973	
Mean Lags	*Japan*	*West Germany*	*Japan*	*West Germany*
Production	76	11	60	8
Transportation	21	12	20	18
Entry	11	7	20	7
Total (Days)	109	30	100	33

The major difference is due to the extremely short production lag of automobiles from Germany. Magee attempts to explain the results as either a statistical oddity or the availability of a large number of German automobiles for export. However, given the fact that automobiles account for roughly one third of Germany's exports to the United States during this period, it may simply be a case of recognizing the importance of major markets.

In the long run (the quantity adjustment period), price adjustment will be directly related to price movements during the (fixed-quantity) "pass-through" period. Prices may overshoot (P_{PT} in Figure 2-a) or undershoot (P_0 in Figure 2-a) their new long-run equilibrium position. Several factors, including the degree of competitiveness in the industry and the willingness to alter short-term profit margins, will dictate whether or not we can expect to observe symmetry in the time required for prices to adjust.

Several authors have attempted to measure the magnitude and/or speed of quantity adjustments (trade flows) as a factor of foreign price changes versus exchange rate changes.[3] Orcutt [1950, p.126] alludes to both producer and consumer costs of switching products in light of relative price changes:

> Thus small price changes and particularly those which appear to be of a temporary nature will be ignored. Little shifting will take place until the differential is at least sufficient to cover the costs of switching, whereas a large and fairly permanent change produced by depreciation would result in substantial substitution.

Orcutt is one of the first authors to articulate the distinction between temporary and permanent expectations of a variable. In this case, economic agents may react differently for a given change in domestic prices depending upon whether the change is perceived as temporaiy or permanent.

Leamer and Stern [1970] extend Orcutt's work, claiming that *how* domestic price changes are perceived (temporary versus permanent) will alter the *speed* at which quantities adjust. Domestic price changes which result from devaluations (permanent) are associated with a faster adjustment pace than foreign price changes (temporary) at a given exchange rate. In the long run, however, they note that the final adjustment would be identical since the perception of a foreign price change will switch from temporary to permanent the longer the change persists.

Junz and Rhomberg [1973] argue that the quantity adjustment response of a devaluation could be *either* faster or slower than foreign price changes. The adjustment process could be quicker given that exchange rate realignments are traditionally much larger than price changes and receive greater publicity. On the other hand, the process could be much slower if the reason for the realignment is to correct

[3] Contributors to this literature include: Goldstein and Khan [1976], Junz and Rhomberg [1973], Leamer and Stern [1970], Liu [1954], Orcutt [1950], and Wilson and Takacs [1979].

previous period(s) of disequilibria. The resource shifts required to correct these imbalances may involve considerable time. While their results indicate that exchange-rate changes and price changes have *identical* adjustment paths, the overall empirical evidence on the asymmetry proposition is inconclusive.

In summary, under the elasticity approach, the short-run pass-through coefficient is determined by the currency in which contracts are denominated and the short-run elasticities of demand and supply. Under the assumption of perfect competition, the long-run pass-through coefficient is no longer a function of the contract currency since purchasing power parity (PPP) prevails: arbitrage will ensure that a good sells for the same price (in a common currency) in both countries. It will be determined by the long-run elasticities of demand and supply. The speed at which we attain the long-run equilibrium is a function of the price and quantity lags inherent in the system. Price lags can be lengthened if: (a) firms permit their profit margins to absorb exchange rate realignments; or (b) the average length of contracts is extended. Quantity lags can be prolonged if: (a) economic agents face larger switching costs; (b) domestic price changes due to exchange rate changes (permanent) are mistaken for (temporary) foreign currency price changes; or (c) large resource shifts are necessary to offset previous periods of disequilibria.

2.2 Exchange Rate Pass-Through Under Flexible Exchange Rates (1973-1980)

With the collapse of the Bretton Woods agreement in the spring of 1973, a renewal of interest arose concerning the relationship between exchange rates and prices. Proponents for the disbandment of the gold standard argued that flexible rates would permit countries to pursue independent monetary policies.[4] One of the roles of the exchange rate was to "absorb" the emerging differences in inflation such that the prices of traded goods remained constant when measured in a common currency. This argument captures the general spirit that, under a flexible exchange rate regime, relative price levels could (and would) be

[4] See Artus and Young [1979] for a renewal on the debate between the merits of a fixed versus flexible exchange rate regime.

capable of influencing the exchange rate. However, one could easily argue that changes in the exchange rate can exert pressure on prices, particularly for traded goods. Most of the theoretical and empirical developments during the initial transition period can be classified under these two distinct causality relationships.

On the one hand, we have economists who advocate a causal relationship from prices to exchange rates {e=f(p,...)}. These can be classified as models of *exchange rate determination*. Included in this group are those who, within a modern context, continue along the PPP paradigm, examining and testing the validity of revamped versions of Cassel's [1916] original contribution.[5] In its extreme form, the long-run equilibrium exchange rate is determined exclusively from the relative price ratio. Other models of exchange rate determination assume that price levels are just one of many variables which influence exchange rates. These encompass the portfolio balance approaches, the numerous interpretations of the "monetary" model, and even short-run PPP models.[6]

On the other hand, we have economists who advocate a causal relationship from exchange rates to prices {p=f(e,...)}. Typically, these "exchange rate pass-through" models have either microeconomic or macroeconomic underpinnings; although data availability during the transitional period (1973-1980) restricted the majority of the empirical studies to concentrate on macroeconomic issues.[7] At the microeconomic level, the conceptual framework is generally formulated with the notion of measuring the degree of price discrimination at the firm or industry level. Models based upon macroeconomic foundations attempt to explain how the degree of exchange rate pass-through can influence

[5] The list of contributors include: Genberg [1978], Isard [1977], Officer [1976;1978;1980], and Richardson [1978]. Note, however, that under a fixed exchange rate regime, PPP is associated with the opposite causality; exchange rates determine prices.

[6] See MacDonald and Taylor [1992] for a detailed survey on the monetary models and portfolio balance approaches.

[7] See Aliber [1976], Artus [1974], Kalter [1978], Kravis and Lipsey [1977], Kreinin [1977], Robinson, Webb and Townsend [1979], Spitäller [1980], and Tichy [1976].

macroeconomic variables such as trade flows and balance of trade/payment positions.

With flexible exchange rates, there is no a priori reason to believe that causality runs only in one direction. We can envisage some form of circular flow between exchange rates and prices with perhaps with one direction dominating and the other providing a feedback effect, but clearly, the extent is an empirical question. Occasionally, confusion can ensue when authors inadvertently intertwine the causality relationship. For example, prior to the devolution of the Bretton Woods agreement there was the concern that a flexible exchange rate regime may destabilize the price of traded goods; clearly a case of exchange rates affecting relative prices.[8] However, Dunn [1970] uses data from the Canadian experience with floating exchange rates (1950-1962) to refute this proposition. He argues that the relative price stability during this period can be attributed to individual firms pricing decisions (Dunn [1970, p.141]):

> ...the assumptions and constraints of perfect competition, or of even simple profit maximization, have little relevance to actual pricing decisions. Economists have suggested a variety of pricing goals and policies which are used in large American firms, and a strong preference for price stability is a feature of all of them.

Given his a priori assumption of price rigidity, combined with econometric evidence $\{p_t=f(e_t,e_{t-1})\}$ suggesting *no* systematic correlation between price movements and exchange rate changes, Dunn challenges the short-run version of PPP. However, as previously noted, under a floating regime the PPP paradigm has causality running from prices to exchange rates and not the reverse. In effect, what Dunn *infers* is that the lack of causality in one direction necessarily implies a lack of causality in the opposite direction without providing empirical (or theoretical) support. As a silver lining, however, Dunn's shortcoming emphasizes that the causality relationships (a) are linked in some manner and (b) require additional investigation.

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[8] See McKinnon [1963]; this argument rests on the assumption of *continuous* purchasing power parity and perfectly competitive markets - for any exchange rate movement, prices must adjust accordingly. In essence, the real exchange rate is assumed to be constant.

During this period, the number of publications dealing with exchange rate determination models eclipsed their exchange rate pass-through counterparts. This was due, in part, to the importance of understanding the fundamental behaviour of exchange rates under the new regime, and in part, to the growing frustration that forecasts of exchange rates based on existing theoretical and ad hoc intuitive models were inferior to the simple random walk model. However, this should not be construed as evidence endorsing one causality direction. *Both* paths have evolved over the years, yet one cannot overlook the fact that they are not necessarily mutually exclusive. Nevertheless, the scope of this thesis restricts causality in one direction only [p=f(e)]. By assumption, therefore, pricing strategies in the automobile sector do not influence exchange rates.

Although the flexible exchange rate regime officially started in March 1973, there was a transitional phase of a couple of years prior to this date where the industrialized nations recognized the need for adjustments in the foreign exchange market. One such resolution came in the form of the 1971 Smithsonian Agreement whereby all major currencies were realigned - most *revalued* with respect to the U.S. dollar. Kreinin [1977] examines the pass-through effects on import prices, export prices, volume of trade and terms of trade. His empirical study bridges the gap between the two regimes. One set of data examines the pass-through coefficients by comparing average prices in 1970 with average prices in 1972. The second set of data compares the average 1970 prices with the average 1973 prices.

Kreinin's [1977, p.301] motivation arises from his belief that the some of the current theoretical assumptions concerning the effects of exchange rate fluctuations are either incorrect or too vague; to the point where they can be interpreted as misleading:[9]

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[9] In particular, he questions the validity of the Mundell-Laffer (M-L) hypothesis. In essence, the M-L hypothesis advocates that exchange rate depreciations/appreciations cannot eliminate balance of payments problems and that exchange rate fluctuations contribute to world-wide inflation (due to asymmetry in price responses to exchange rate movements -- the "ratchet effect"). See Laffer [1973;1974] and Wanniski [1975] for additional comments.

> In sum, the pass-through effect of exchange rate adjustment has important implications, both for the balance of payments and for the propagation of inflation. But its extent is an empirical question and *cannot be determined by a priori considerations* (emphasis added).

Perhaps the most intriguing aspect of Kreinin's paper is the methodology adopted to estimate the pass-through coefficients. Rather than relying on the traditional regression models using quarterly or monthly data, he uses what is termed the "control country" approach to extract the portion of changes in prices attributed specifically to changes in exchange rates. Effectively, he has three data points (1970, 1972 and 1973) for all variables. With this limited information he infers the pass-through between two countries by comparing statistics with the control country. The "ideal" control country should be closely related to one of the countries in question and preferably have limited exchange rate movements over the period. Since these qualifications are rarely achieved, Kreinin resorts to the use of "control countries" - typically three or four.[10]

For example, consider the case of United States imports from Norway. Kreinin [1977, p.304] uses Finland as the control country since its exports to the United States are similar to the Norwegians and, more importantly, the Finnish mark/U.S. dollar exchange rate remained constant between 1970 and 1972. The relevant statistics are (Kreinin [1977, p.306]) :

TABLE 2-2

Pass-Through Coefficients using a "Control Country" Approach

	Norway	Finland
$\Delta ER^{\$}$	+8%	0%
ΔP_M^{US}	+16%	+14%

[10] Kreinin [1977, p.303] lists several other studies which use this econometric technique. While not as popular as the traditional regression methods, Kreinin argues that previous studies have provided "fruitful results" and are sufficiently robust to warrant its application to pass-through considerations.

where $\Delta ER^{\$}$ is the percentage change in the exchange rate with respect to the dollar between 1970 and 1972, and ΔP_M^{US} is the percentage change in the U.S. import price index during the same period. The effect of an 8% revaluation of the Norwegian krone on the dollar price of its exports to the U.S. is two percent (16% - 14%) since the effects of the control country imply that prices would increase by 14% in the absence of any exchange rate movements. Hence, the import pass-through coefficient is 25% (2% / 8%). For the case where the control country's exchange rate does change, Kreinin calculates upper and lower boundaries. For example, if the Finnish mark was revalued by 4%, we could calculate the U.S. import pass-through coefficient from Norway on the assumption that *none* of the Finnish increase in export prices to the U.S. was due to the revaluation, in which case we would derive our original result of 25%. Alternatively, we could assume that the Finns passed through all of the revaluation (4%); as such, only 10% (14% - 4%) of the Finnish increase in prices would have occurred in the absence of a mark revaluation. As a result, the upper bound for the Norwegian pass-through coefficient is 75% {(16% - 10%) / 8%}.

We can briefly summarize Kreinin's [1977, p.318] principal results:

TABLE 2-3

Pass-Through Coefficients from Fixed to Flexible Exchange Rates (1970-1973)

	*Estimated Pass-Through (1970-1972)**		*Estimated Pass-Through (1970-1973)**	
Country	Imports	Exports	Imports	Exports
United States	50%	100%	40%	40%
Japan	80%	85%	60%	75%
West Germany	60%	90%	n/a	n/a
Italy	100%	100%	n/a	n/a
Canada	90%	60%	n/a	n/a

*Import results defined in terms of percentage change in domestic prices while export results are defined in terms of percentage change in foreign import prices (100% - percentage change in country's domestic export price).

From these statistics, Kreinin [1977, p.319] notes that the U.S., West Germany and to a certain extent

Japan all "...appear to be 'price makers' on the buying side of the international market...". In addition, the importance of trade relations between Canada and United States is reflected in the mirror images of the pass-through coefficients for the two countries.

However, the most striking result is the drop in the pass-through coefficients (both export and import) for the U.S., and, to a certain extent, Japan after the first year of flexible exchange rates. Kreinin attributes these results to the *change in the direction of causality* between exchange rates and prices once the exchange rate regime switched from fixed to flexible currencies. He espouses Cassel's contention that under fixed exchange rates, changes in the exchange rate precipitate changes in prices, while under a flexible regime, causation runs from prices to exchange rates. Moreover, he contends that under fixed exchange rates, a devaluation worsens the terms of trade yet an equal depreciation under a flexible regime leads to an improvement in the terms of trade. By induction, he asserts that a 15% effective depreciation of the U.S. dollar from 1970-1973 (a period combining the two regimes) combined with a 3% improvement in the U.S. terms of trade is sufficient proof that causation runs from prices to exchange rates.[11] Yet a 22% effective appreciation of the yen over the same period gave rise to a 8% improvement in the Japanese terms of trade - implying causation from exchange rates to prices.[12] In other words, Kreinin [1977, p.324] argues that the Japanese were still operating under a fixed exchange rate regime while the Americans wholly embraced the concept of fully flexible exchange rates.

While it may be true that Japanese intervention in the currency markets may have been severe enough during the transitional period to preserve a "fixed position"; by itself, it does not substantiate

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[11] The terms of trade is calculated in the following manner (See footnote attached to Table 2-3):
= %Δ\$ export prices - %Δ\$ import prices
= (0.60 × 15%) - (0.40 × 15%)
= 9% - 6% = 3%.

[12] The change in the Japanese terms of trade (See footnote attached to Table 2-3):
= Δ%¥ export prices - Δ%¥ import prices
= (0.25 × 22%) - (0.60 × 22%)
= (-)5% - (-)13% = 8%.

Kreinin's claim that depreciations/devaluations have opposite effects on the terms of trade under the two different exchange rate regimes. It may well be the case that the observed reduction in the U.S. export pass-through coefficient (100% → 60%) was largely due to lags associated with exchange rate changes under the fixed regime; in which case an improvement in the terms of trade was the result of a devaluation under fixed exchange rates. Unfortunately, Kreinin does not provide any theoretical foundation for his claim and his section describing causality relationships is both incomplete and unduly confusing.

Robinson, Webb, and Townsend [1979] also examine the effect of exchange rate changes on relative prices during both exchange rate regimes. However, their stated objective is to test the validity of the "Scandinavian analysis", as espoused by Aukrust [1977]. In essence, the Scandinavian theory is an attempt to examine the dynamic response of prices to changes in exchange rates under the assumption that PPP prevails in the long run. Countries are assumed to be price-takers in the world market. A devaluation, therefore, has the immediate effect of increasing the home-currency price of both exports and imports. Wage-earners attempt to offset the loss of real income by demanding higher wages. The profitability of the exporting industries ensures that they are the first to acquiesce to the wage demands (Robinson, Webb, and Townsend [1979, p.28]):

> The principle of comparability then puts upward pressure on wages in domestic industries, and in the manufacturing sector the wage demands are met because they can easily be passed on in higher domestic prices, since the price of competing imports has gone up. This process will come to a natural end when wages have risen to a point that eliminates both the excess profits in the export sector and the initial loss or real income due to higher import prices. The economy will then be in equilibrium with the respective shares of wages and profits in GDP back at their original level.

In the long run, prices will have completely offset the movements in the exchange rate. In terms of the dynamics, the Scandinavian model predicts that (relative) export prices will be the first to move in line with the exchange rates and that (relative) wholesale prices ought to take slightly longer. However, the authors use Balassa's [1964] productivity assertion to argue that GDP deflators will not necessarily be equalized even after perfect competition has equalized prices of all manufactured goods. Specifically, countries with large productivity differentials (between the manufacturing sector and the rest of the economy) will, in the long run, exhibit an increase in relative GDP prices.

Not surprisingly, the countries with "successful" results were those whose economic realities corresponded to the assumptions of the Scandinavian model; small open economies, price-takers on world markets, and perfect competition in the home labour markets. Ironically, two Scandinavian countries, Norway and Denmark, did not fit the profile. The authors attribute this anomaly to the "unusual commodity composition of exports". Typically, the "unsuccessful" countries were the large, closed (at that time) economies such as Japan and the United States.

Unfortunately, there is a serious econometric problem with the regression procedure employed in this study. The OLS procedure of regressing export/wholesale prices on exchange rates generated results with high R^2 values (0.99) coupled with extremely low Durbin-Watson (< 0.50). Granger and Newbold [1974] show that such findings can lead to "spurious" relationships - due to non-stationary times series data - and conventional inference tests on the coefficients are invalid. Clearly, this criticism is applicable to all empirical surveys of the pass-through literature which apply conventional econometric methodology without first examining the time series properties of the data. Consequently, the validity of the estimated pass-through coefficients as representing the "true" parameters of the data generating process is questionable, at best.

Another minor problem with the study is its cursory approach to the relationship between exchange rates and prices under the two different exchange rate regimes. They discuss the possibility that the relationship may change under the two regimes, but do not provide any theoretical or empirical support except to mention that parity changes now appear to have a faster and larger effect on prices.

The above studies examine the relationships between exchange rates and prices from an aggregate perspective. The effectiveness of devaluations in eliminating trade deficits or the degree to which inflation is transmitted through exchange rate movements is based implicitly on microeconomic foundations. A number of articles, including Aliber [1976], Artus [1974], and Kalter [1978], address these issues associated with exchange rate pass-through using basic price theory and/or our knowledge of the role of the firm. Of note is Kalter's [1978] relatively unacclaimed paper which presents U.S. evidence pointing to prolonged differences between domestic and export prices (expressed in U.S. dollars) of certain manufactured goods. Kalter argues that the significant difference between the prices can be explained within a discriminating monopolist framework. Kalter's study not only heralds the arrival of an imperfectly competitive market structure as a central assumption of trade theory but also distinguishes between simple pass-through and what would later be known as "pricing-to-market". In addition, Kalter [1978, p.14] was one of the first authors to articulate the connection between "dumping" and profit-maximizing behaviour of monopolists:

> ...external shocks may have a differential effect upon the domestic and export price of the same good....if it is determined that, indeed, differential effects result, then one many conclude that: (1) Exchange rate changes are one factor explaining worldwide patterns of "dumping" and (2) The pricing of manufactured exports may be explained within the framework of a discriminating monopolistic model.

By the end of the 1970's, there was a general concern that models based upon traditional exchange rate theory could not offer realistic explanations for recent international monetary events. For example, Haberler-type elasticity models *can* explain the pass-through phenomenon, but since they operate under a perfectly competitive framework, they implicitly assume equality between domestic and internationally traded prices. These models *cannot* account for incomplete pass-through *and* the observed fact that domestic and foreign prices of identical goods vary significantly, even in the long run. Clearly, the choice of assumption concerning market structure must reflect the observed independence of a firm's pricing decisions abroad from its pricing decision in the domestic market. From the early 1980's, models of exchange rate pass-through followed the example of the "new trade" theory by emphasizing imperfect competition and, to a certain extent, increasing returns to scale.

2.3 *Exchange Rate Pass-Through Models under Flexible Exchange Rates (1980-1994)*

The adoption of an "industrial organization" (IO) approach by both international finance and international trade economists has created a proliferation of diverse theoretical and empirical models. This section is an extensive, although not complete, critical review of the recent literature on exchange rate pass-through.

I. Hysteresis Models

The term 'hysteresis' was first suggested by the Scottish physicist James Alfred Ewing whose work on the behaviour of electromagnetic properties of ferric metals produced curves which (Ewing [1881, p.22]):

> ..exhibit, in a striking manner, a persistence of previous states...to this action...the author now gives the name Hysteresis.

Over the past century, the term has entered the domain of the social sciences where it has been interpreted to represent any effects which remain after the initial cause responsible for the effects has been eliminated. Moreover, these hysteretic effects suggest that relationships between variables are a function of the past; i.e., they are *path dependent*. For example, in Ewing's experiments, the relationship between the present magnetic state of an iron bar and the amount of electric current supplied will depend upon whether the current has been increasing or decreasing.

Although the term has been in existence for a hundred years, the *concept* of hysteresis has been debated on both ontological and epistemological grounds since the late 17th century.[13] Earlier philosophical arguments concentrate on the scientific perspective of hysteresis. Leibniz, for example, contends that the current force or state of an object should be related to its current velocity and current mass only; its past history simply an irrelevant by-product (Leibniz [1875-90, vol. III, p.43] in Elster [1976, p.372]):

> En effect le temps ne sert de rien à cette estime. Voyant un corps d'une grandeur donnée aller avec une vistess donnée, ne pourra-t-on point estimer sa force san sçavoir en quel temps et par quels détours ou délais il a peutestre acquis cette vitesse qu'il a? Il me semble qu'on peut juger icy sur l'estat présent san sçavoir le passé. Quand il y a deux corps parfaitement égaux et semblables, et qui ont une même vitesse, mais acquise dans l'un par un choc subit, dans l'autre par quelque descente d'une durée notable, dira-t-on pour cela que leurs forces sont différents? Ce serait comme si on disoit qu'un homme est plus riche, à qui l'argent a cousté plus de temps à gagner.

In the last sentence, he alludes to the implausibility of ontological hysteresis in the social sciences. Two men possessing identical wealth, he argues, should be equally "rich" regardless of whether one toils his entire lifetime while the other is a "nouveau-riche". In other works (Leibniz [1875-90, vol. IV, p.507] in Elster [1976, p.372]), he qualifies the relationship between past and present by saying that while we may observe *traces* of the past on the present, we do not have outright hysteresis.

Cross [1993, p.55] argues that there are epistemological reasons for accepting hysteresis as a concept:

> If ontological hysteresis is taken to be implausible, this does not rule out epistemological hysteresis: the past may be able to influence the present only by the influences left on the present, but *explanations* of the present that rely on present variables alone may be inferior to hysteretic explanations that involve past variables as well (emphasis in original).

If we are unable to offer viable alternatives to hysteretic explanations, Cross argues that we have a much stronger case for epistemological hysteresis. In the classic example of the swinging pendulum, predictions

[13] Georgescu-Roegen [1971], Elster [1976], and Cross [1993] discuss the philosophical insights of hysteresis.

of its future path requires both present and past positions. We cannot remove the hysteresis explanation by simply introducing the instantaneous rate of change of the pendulum since, by definition, a time derivative incorporates past events.

It is this concept of epistemological hysteresis which has received attention in the unemployment and international trade theory during the past decade. It is also the foundation from which "Granger-causality" tests have emerged.

Attempts to formalize hysteretic dynamic systems fall under two general categories: linear relationships versus nonlinear relationships. Using discrete time linear systems, Wyplosz [1987] and Franz [1990] argue that hysteresis involves the presence of one (or more) unit roots. Suppose an endogenous variable X_t evolves in the following manner:

$$X_t = \alpha + \beta X_{t-1} + Z_t \tag{2.2}$$

where Z_t is an exogenous variable. If $\beta \neq 1$, the steady-state equilibrium solution $(X_t - X_{t-1})$ or $\bar{X}$ is :

$$\bar{X} = \frac{\alpha + \bar{Z}}{1 - \beta} \tag{2.3}$$

where past values of either Z or X do not influence the steady-state. However, with a unit root, $\beta = 1$, the path of X_t is now:

$$X_t = X_0 + \alpha T + \sum_{i=0} Z_{t-i} \tag{2.4}$$

where X_t is contingent on all past Z's plus the initial condition X_0. With this path dependent process, there can be an infinite number of solutions.[14] The major disadvantage of the linear approach is that hysteresis can only be viewed as a special case, rather than the rule, given that it is contingent upon unit or zero roots. As a result, this approach has received little theoretical support. However, Setterfield [1993] endeavours to rekindle interest by arguing that if the Z_t variables are "deeply endogenous" rather than exogenous such that:

$$(2.5) \qquad Z_t = f_t(X_{t-1}),\ where\ f \neq 0$$

and changes in Z_t do not cancel out over time (adjustment asymmetries), we will have satisfied our assumption of hysteresis in discrete linear systems without resorting to unit roots.

On the other hand, nonlinearities in dynamic processes have received considerable support as the source of hysteresis. One reason for their acceptance is the intuitive appeal of non-unique relationships; particularly when we operate under different sets of circumstances.[15] One of the more promising recent contributions is Krasnosel'skii's model (Krasnosel'skii and Pokerovskii [1989]) where current behaviour is a function of the ***extreme values*** of past shocks to the system. Unlike the linear unit root models where ***all past values*** are relevant, Krasnosel'skii's model has a selective memory. Paraphrasing Cross's [1993, p.65] succinct interpretation of Krosnosel'skii's work: "Some history is bunk".[16]

Similar to the resistance by Ewing's ferric metals to alter their present magnetic sates, economic

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[14] For the case of continuous time models, hysteresis is present when we observe a zero root in a system of differential equations (Giavazzi and Wyplosz [1985]).

[15] See for example, Ewing's "hysteresis loop" diagram reproduced in Cross [1993] and Franz [1990].

[16] Setterfield [1993, p.19] explains Krosnosel'skii's selective memory with a simple illustration of human behaviour. If an individual is robbed while taking a short cut home, it is highly probable that this one unfortunate incident (the extreme value) will dictate future considerations for travelling home, in spite of many "uneventful" trips along the same route.

variables can also display a certain degree of inertia. The possibility that the relationship between exchange rates and prices operates within an hysteretic environment has been advanced by numerous authors.[17] The arguments are typically based on the existence of inertia in *market shares* of manufactured goods (or market structure) combined with exchange rate fluctuations acting as the *source* of hysteresis.

On the demand side, *brand loyalty* can impart market inertia. Consumers may have reservations about the quality of unfamiliar brands, face high search costs to find pertinent information, or simply be unaware of competing brands. Alternatively, human and/or capital investment in the presently owned brand may be sufficiently high not to warrant a transfer in allegiance (i.e., IBM versus MacIntosh computers). In Froot and Klemperer's [1989] intertemporal profit-shifting model, a firm's current and future profits are a function of market-share (brand loyalty) investment. The aggressiveness of firms in pursuit of market shares in the first period of a two-period duopoly will depend critically on whether current and expected future exchange rate values are perceived as temporary or permanent. The ability to retain these market shares creates an hysteretic environment where we not only observe incomplete pass-through but pass-through coefficients which may vary over time. For example, consider an appreciation of the Canadian dollar which is deemed temporary in nature. Current dollar profits expressed in foreign currency now become more "valued" than future profits. Investment in consumer allegiance (by lowering dollar prices by the same percentage as the exchange rate) is not as attractive an option as increasing profit margins. Consequently, we will not observe full pass-through.[18] Appreciations of the dollar which are perceived to be permanent, on the other hand, do not create intertemporal profit-shifting opportunities. Rather, both current and future costs (expressed in dollars) fall, and firms compete with

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[17] See Baldwin [1988], Dixit [1989], Froot and Klemperer [1989], Krugman and Baldwin [1987], Melick [1990], and Ohno [1990].

[18] The authors (Froot and Klemperer [1989, p.637]) even argue that the future depreciation of the dollar may lower the value of future profits to the point where firms could conceivably *raise* the dollar price of their product when the dollar appreciates.

greater intensity resulting in lower current prices.

However, most of the hysteresis literature on exchange rate pass-through relies on supply-side reasons for market share inertia. In their attempt to explain the persistence of the U.S. trade deficit - in spite of the large dollar depreciation starting in 1985:1 - Krugman and Baldwin [1987] allude to the notion that large ***sunk costs*** can contribute to persistent effects on market structures once exchange rates return to "pre-shock" levels. In turn, changes in the general competitiveness of an industry will affect the exchange rate pass-through. In essence, the presence of sunk costs ensures market structure stability in the face of small exchange rate changes. However, once the exchange rate passes a certain barrier, foreign firms find it profitable to operate in the U.S. market. If the exchange rate returns to its previous level, these firms remain in the U.S. markets (assuming their operating profits are positive) since sunk costs are no longer included in profit-maximizing decisions. Consequently, the strong U.S. dollar of the early 1980's enabled foreigners to establish "beachheads" in the U.S. market, in contrast to U.S. firms who relinquished their foreign operations. The subsequent depreciation was insufficient to dislodge the new foreign firms, nor did it allow U.S. firms to re-establish operation in foreign markets. Conceptually, Krugman and Baldwin argue that while this line of logic is appealing, there is no clear-cut evidence that hysteresis contributed to the trade deficit problem.

While most of the earlier contributions concentrate on hysteresis in quantities, Baldwin [1988] extends the theoretical literature to include price hysteresis. His beachhead or sunk cost model assumes firms (domestic and foreign) engage in Cournot competition and the entry decision is based upon the sum of current and expected profits exceeding the original sunk costs plus the operating costs associated with each subsequent period. Firms are assumed to have perfect foresight with respect to exchange rate movements. The ensuing mark-up model estimation takes the form:

(2.6)

$$p_t = \alpha[\epsilon(m_t)] + \sum_{i=0}^{\infty} \beta_i (c^* e)_{t-i}$$

where p_t = price in U.S. dollars,

ε = price elasticity of demand, m_t = total number of firms,

c^* = marginal costs in foreign currency,

e = exchange rate ($/foreign), and all variables are in logs.

Baldwin argues that the structural break associated with price hysteresis will be reflected in a "jump" in the constant term alpha (α). Using intercept dummies to capture the once-and-for-all change in the intercept term, he finds evidence of structural breaks using CPI and WPI proxies for costs but not for normalized unit labour costs (NULC).

Unfortunately, evidence of structural breaks does not imply acceptance of Baldwin's beachhead model. Clearly, factors other than hysteresis may contribute to structural breaks; Baldwin does not explore possible alternative hypotheses. Another criticism of this paper is that the once-and-for-all effect of large exchange rate movements on prices of traded goods has no influence on the "true" exchange rate pass-through coefficient (β_0). Why does this coefficient remain constant in the face of structural changes? Is it plausible that exchange rate fluctuations which are insufficient to alter entry or exit decisions, yet large enough to affect prices, will always be symmetric regardless of the degree of competition in an industry? The relationship between exchange rates and prices requires additional clarification, particularly with respect to the long-run and short-run equilibrium.

Dixit's [1989] main contribution to the sunk cost model of hysteresis is the implementation of financial economic techniques to calibrate the *width* of the "hysteresis band" or zone of inactivity. The central premise relies on comparing entry and exit decisions to exercising options; with greater exchange rate variability, the value placed on these options increases, with the end result being less frequently exercised options (i.e., wider hysteresis bands).

To generate an environment conducive to wide zones of inaction, Dixit assumes that exchange rates follow a random walk in continuous time (Brownian motion) while firms are risk neutral, have rational expectations and are price-takers. In addition to sunk entry costs (k), firms are also assumed to pay sunk exit costs (l). The width of the hysteresis band will be in part due to the relative size of the total sunk costs (k and l) to the "recurrent costs" (Dixit [1989, p.208]); smaller relative sunk costs reduce the zone of inactivity. He also examines the effect of a mean-reverting exchange rate process. Similar to Froot and Klemperer's [1989] temporary versus permanent appreciation argument, in this model firms require even greater current profits (losses) to enter (exit) the market. This will have a tendency to widen the hysteresis band.

The assumption of perfect competition ensures a pass-through coefficient of zero in the hysteresis band; the number of firms is constant, the dollar price is constant, hence foreign firms absorb all exchange rate movements in their profit margins. However, using various hypothetical configurations (numbers of firms, variable costs, sunk costs, linear demand/supply equations) Dixit generates pass-through coefficients close to unity when exchange rate fluctuations trigger entry or exit from an industry. For example, as the U.S. dollar appreciates, new foreign firms enter while incumbent firms expand production. Both scenarios lead to a decrease in the dollar price of the product. Dixit argues that these breaks in the relationship between exchange rates and prices "*could* provide a test of the hysteresis hypothesis for various industries" (p. 227, italics added). Unfortunately, similar to Baldwin [1988], this argument does not provide for an alternative to hysteresis as the reason for structural breaks. Even if we combine structural breaks with firm activity (i.e., number of new entrants, changes in capacity utilization, etc.) there is no guarantee that hysteresis is the source.

Ohno [1990] combines the ***corporate planning horizon*** with the existence of hysteresis to account for the different degrees of pass-through exhibited by Japanese and U.S. exporters during the large dollar fluctuations in the 1980's. Hysteresis takes the form of market share stickiness and firms must incur (linear) promotional costs to overcome the market inertia and expand business from one time period to the next. Corporate planning horizons are assumed to be *shorter* for U.S. firms. Ohno defends this assumption by suggesting that the majority of stockholders in the U.S. - individual and institutional alike - are more concerned with capital gains and quarterly profits than with long-term prospects. Japanese stockholders, however, consist mainly of other corporations under an umbrella organization ("keiretsu") who frequently share identical pursuits. Moreover, he argues that the higher cost of capital in the U.S. provides an incentive for firms to concentrate on short-run profits.

Using these promotional costs, Ohno constructs a simple Cournot duopoly (Japanese foreign firm and a U.S. domestic firm) with constant returns to scale and an exchange rate (¥/$) which has, *with certainty*, high values for even-numbered periods and low values for odd-numbered periods. This assumption of certainty ensures that two consecutive time periods will be identical regardless of the fact that there can conceivable be an infinite number of periods. Since the hysteretic effects occur solely when the exchange rate fluctuates, long-term profit maximization only requires consideration of an even-numbered period followed by an odd-numbered period.

Under the assumption that each firm takes the output of the other as given, the equilibrium output and prices can be calculated from each firm's reaction function. The general solution can be described as:

$$q^{*} = \left[\frac{1 + (\mathit{rival's\ unit\ costs}) - 2(\mathit{own\ unit\ cost})}{3}\right]$$

(2.7)

$$p^{*} = \left[\frac{1 + (\mathit{rival's\ unit\ costs}) - (\mathit{own\ unit\ cost})}{3}\right]$$

where q^* and p^* are equilibrium quantities and prices respectively.

By calibrating the theoretical model with assumed numerical values, Ohno undergoes a series of tests on the length of the planning horizons by the two firms and the severity of the exchange rate fluctuations. At low exchange rate fluctuations, neither firm responds since the gain from increased output is outweighed by the promotional costs. As the fluctuations increase in intensity, the Japanese firm begins to adjust output. Greater fluctuations will force both U.S. and Japanese firms to alter output. In the case of extreme fluctuations, the Japanese firm withdraws completely from the U.S. market. Finally, Ohno shows that firms with planning horizons oriented towards the long run will select pricing policies which lead to lower pass-through coefficients and higher market shares.

Melick [1990] offers an *indirect* empirical approach to exchange rate pass-through hysteresis by testing for coefficient stability in U.S. imports. Firstly, he estimates pass-through coefficients using three different theoretical specifications; a purely competitive model, an imperfectly competitive model (Nash price competitors), and the Hooper and Mann [1989] markup model. Subsequently, he tests for exchange rate parameter stability over the period 1973:1 to 1988:2 under the assumption that large U.S. dollar fluctuations may have changed the *aggregate* behaviour of foreign firms operating in the U.S.

Melick's *recursive* estimation procedures follow David Hendry's general-to-specific modelling techniques (Hendry [1987;1993]). An advantage of recursive estimation is the ease with which output can be translated graphically; one can examine recursively calculated parameter estimates and determine the precise time at which the relationship(s) deteriorates. His paper is also one of the first pass-through studies to implement and compare the Engle-Granger approach of single-equation estimation to Johansen's [1988] multi-equation procedure.

In spite of the level of econometric sophistication, Melick finds little evidence to support the claim that foreign firms alter their pricing behaviour during large exchange rate fluctuations. Indeed, the only favourable evidence (the Hooper-Mann model estimated using the Engle-Granger approach) is rejected on the basis of model misspecification.[19]

The empirical literature on price hysteresis typically concentrates on *aggregate values* of the traded-goods price indices. Cross-sectional data of this nature is readily available with little or no discrepancy amongst nations in the calculation of the indices. However, as Melick [1990] argues, the use of aggregate data to measure the structure and the stability of exchange rate pass-through can be misleading. For example, the absence of any structural change in the pass-through coefficient, in spite of large exchange rate fluctuations, is not necessarily an indictment against hysteresis. It is possible that a number of sectors exhibit different degrees of hysteresis but, *in the aggregate*, we are unable to reject the null hypothesis of stability. Consequently, empirical research should focus on disaggregate data (Melick [1990, p.22]):

> ...pass-through at the macroeconomic level is a complicated amalgamation of disparate industrial structures that involves more than one long-run equilibrium relationship between variables of interest. Efforts to relate pass-through coefficients to parameters from a theoretical model are best done at as disaggregate a level as possible.

II. Markup Models

(i) General Model (constant costs)

The most popular method to generate incomplete pass-through, or a pricing-to-market strategy, is to rely on some variation of the typical "markup" model whereby firms charge a price equal to a certain percentage of marginal costs. In its simplest form, this markup (or profit margin) is solely a function of each firm's (price) elasticity of demand. As a result, they are frequently referred to as demand-side, or demand-inducing, PT/PTM models. While more sophisticated versions (Dornbusch [1987], Fienberg

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[19] Hooper-Mann employ a polynomial distributed lag (PDL) with an AR(1) correction for serial correlation. Similar to Doornik and Hendry (1994, pp.216-7), Melick argues that the imposition of autoregressive error terms ***implies*** a common factor for the independent variable and all the dependent variables. Since Melick was unable to accept common factor restriction tests, by default, therefore, the source of autocorrelated residuals must be model misspecification. For a more technical analysis of common factor (COMFAC) models, see Sargan [1980] or Hendry [1993].

[1986], Hooper and Mann [1989], Yang and Hwang [1994]) include additional variables in the markup, price elasticity of demand is assumed to retain the greatest influence.

The importance of elasticity of demand suggests a strong correlation between the degree of competitiveness within a market (*i.e.*, market structure) and the degree of exchange rate pass-through. To illustrate this link between market structure and pass-through, consider the profit maximizing solution for a firm exporting commodity i to Canada:

(2.8) $$\max_{p_i} \pi = \left(p_i - \frac{c_i^*}{e}\right) q_i(p_i)$$

where p_i is the dollar price and q_i represents the demand function. The bilateral exchange rate, e, is in terms of foreign currency per dollar (for example, ¥/$) and c_i^*/e denotes the exporter's marginal cost in dollars.

Under the assumption of constant marginal costs and no domestic (Canadian) production, the first-order condition gives the familiar markup pricing scheme:

(2.9) $$p_i = \left(\frac{\eta_i}{\eta_i - 1}\right)\frac{c_i^*}{e}$$

where $\eta_i = -(\partial q_i/\partial p_i)(p_i/q_i)$ is the own-price elasticity of demand in the Canadian market.

To calculate the pass-through expression, we rearrange equation *(2.9)* into log form:

(2.10) $$\ln p_i = \ln \eta_i - \ln(\eta_i - 1) + \ln c_i^* - \ln e$$

and differentiate with respect to *lne* to derive:

$$(2.11)\qquad \frac{d\ln p_i}{d\ln e} = \left[\frac{d\ln\eta_i}{d\ln p_i} - \frac{d\ln(\eta_i - 1)}{d\ln p_i}\right]\frac{d\ln p_i}{d\ln e} + \frac{d\ln c_i^*}{d\ln e} - 1.$$

Gathering terms and taking into account constant marginal costs ($d\ln c_i^*/d\ln e = 0$), we express pass-through in the following manner:

$$(2.12)\qquad \frac{d\ln p_i}{d\ln e} = \frac{-1}{\left[1 - \frac{d\ln\eta_i}{d\ln p_i} + \frac{d\ln(\eta_i - 1)}{d\ln p_i}\right]}.$$

In the case where these exporting firms operate within a perfectly competitive environment (*i.e.*, there are many identical *exporting firms*), pass-through will be complete. Under such a scenario, demand is perfectly elastic ($\eta_i = \infty$) and the two terms in the denominator involving η_i will cancel each other out, resulting in:

$$(2.13)\qquad \frac{d\ln p_i}{d\ln e} = -1$$

On the other hand, an *exporting monopolist* facing the downward sloping industry demand curve has elasticities which vary throughout the price range. The exception, of course, is when the monopolist faces a constant elasticity of demand curve. In this case,

$$(2.14)\qquad \frac{d\ln\eta_i}{d\ln p_i} = \frac{d\ln(\eta_i - 1)}{d\ln p_i} = 0$$

and once again, we observe full pass-through. However, in cases where the industry demand curve is ***less convex than constant elasticity***, a monopolist's markup fluctuates with changes in the exchange rate, and we observe partial pass-through.

For example, it is relatively straightforward to show that a monopolist facing a linear demand curve, say $q_i = \alpha + \beta p_i$, has a pass-through coefficient between zero and one-half, exclusively. Elasticity is expressed in terms of the demand parameters and prices:

$$(2.15)\qquad \eta_i = -\frac{dq_i}{dp_i}.\frac{p_i}{q_i} = \frac{\beta p_i}{\alpha - \beta p_i}$$

such that,

$$(2.16)\qquad \frac{d\ln\eta_i}{d\ln p_i} = \frac{d\eta_i}{dp_i}.\frac{p_i}{\eta_i} = \frac{\alpha}{\alpha - \beta p_i}$$

and

$$(2.17)\qquad \frac{d\ln(\eta_i - 1)}{d\ln p_i} = \frac{d(\eta_i - 1)}{dp_i}.\frac{p_i}{\eta_i - 1} = \frac{\alpha\beta p_i}{(\alpha - \beta p_i)(-\alpha + 2\beta p_i)}.$$

Inserting equations *(2.16)* and *(2.17)* into *(2.12)*, we derive;

(2.18) $$\frac{d\ln p_i}{d\ln e} = -\frac{1}{\left[1 - \frac{\alpha}{(\alpha - \beta p_i)} + \frac{\alpha\beta p_i}{(\alpha - \beta p_i)(-\alpha + 2\beta p_i)}\right]}$$

implying,

(2.19) $$\frac{d\ln p_i}{d\ln e} = -\frac{1}{2}\frac{(\eta_i - 1)}{\eta_i},$$

where $\eta_i > 1$ by assumption (*i.e.*, monopolists can only operate on the elastic portion of the demand curve). Consequently, the maximum pass-through of 50% occurs as $\eta_i \rightarrow \infty$, or as the monopolist approaches his reservation price.[20]

Therefore, the general idea behind markup models is that, as we move away from either of the two extreme market structure classifications towards a monopolistic competitive framework, we expect exchange rate pass-through coefficients to vary between zero and one.

Mann [1986, p.367] provides an intuitive foundation for the recent literature on markup/profit margin models:

> Profit margins are a key link between the exchange rate and prices of traded goods that extends the analysis based on the law of one price. Relaxing the assumptions of perfect competition allows for short-run variations in the pass-through relationship observed in macroeconomic data.

Using a limit-pricing model with foreigners facing a "residual" demand curve, Mann discusses the main

[20] Reservation price is defined to be the lowest price at which demand for the product is zero.

microeconomic and macroeconomic factors which determine pricing strategy and profit margins.[21]

Mann's empirical conclusions also provide a benchmark for future research. While stability tests fail to reveal any structural breaks in the pass-through coefficients, aggregate and industry level data indicate a high correlation between profit margins for foreign firms exporting to the U.S. and the variability in the U.S. dollar exchange rate. Specifically, foreign profit margins decline slightly during the dollar depreciation phase (1997-80) and increase slightly during the appreciation phase (1981-85).

On the other hand, U.S. exporters do not reciprocate; profit margins do not change significantly with a change in the exchange rate. At an aggregate level, pass-through is close to 100%, however, the sustained appreciation *may* induce U.S. exporters to price somewhat more competitively than the historical evidence suggests. At the industry level, this is one of the first empirical papers to note that some U.S. exporters actually *increase profit margins* during dollar appreciations. Mann suggests this behaviour (in machinery products), for example, may be due to the fact that these products are differentiated to the point that foreign demand is inelastic, or, alternatively, the share of exports is so small that it is aggregate demand in the U.S. (on the rise during the appreciation of the dollar) which dictates export pricing strategy.

(ii) Hooper-Mann Model

In an effort to derive an empirically tractable model, Hooper and Mann [1989] extend Mann's [1986] analysis by specifying a functional form of the markup. In particular, the markup is assumed to depend upon "competitive" pressures within a market and "demand " pressures in all markets combined (Hooper and Mann [1989, p.300]):

[21] Microeconomic factors fall under the general heading of market structure; product differentiation, production technology with non-constant returns to scale *(i.e.*, upward sloping supply curves), oligopolistic frameworks and, wage and sales contracts which may limit price adjustments to changes in both costs and demand. Macroeconomic factors include the uncertainty surrounding business cycles and the volatility of exchange rates.

Competitive pressures in the U.S. market are measured by the gap between competitors' prices in the U.S. market and foreign production costs in dollars, while demand pressure on foreign output is measured by capacity utilization.

Markups (λ) are given as:

$$\lambda = \left[\frac{P^{\$}}{C^{*}\cdot ER}\right]^{\alpha}[CU^{*}]^{\beta}, \tag{2.20}$$

where $P^{\$}$ = average U.S. price level of good (*i.e.*, proxy for competitors' prices),
C^{*} = foreign marginal costs of production in foreign currency,
ER = exchange rate (domestic (U.S.)/foreign),
CU = capacity utilization,

and $0 \leq \alpha < 1$, $0 \leq \beta < 1$.

Substituting this equation into a pricing equation similar to (2.9) and taking logs gives:

$$pm^{\$} - er - c^{*} = \alpha(p^{\$} - er - c^{*}) + \beta cu^{*} \tag{2.21}$$

or, alternatively,

$$pm^{\$} = (1-\alpha)er + \alpha p^{\$} + (1-\alpha)c^{*} + \beta cu^{*} \tag{2.22}$$

where $pm^{\$}$ is the log of the imported good expressed in U.S. dollars. For any assumed level of capacity utilization, both equation *(2.21)* and *(2.22)* show that as competitive pressures ease ($\alpha \rightarrow 0$), markups remain constant and pass-through is complete.

In order to account for long-run as well as short-run implications, empirical estimation is in the form of constrained and unconstrained polynomial distributed lags (PDL's). Results indicate that:

(i) On the aggregate, pass-through coefficients are:

short-run: 20% (*i.e.*, contemporaneous values)
long-run: 50-60% (18 months)

and robust across different functional forms;

(ii) parameter stability tests are not as conclusive; most functional forms do not indicate structural breaks, however the unconstrained PDL's show a break in 1982.

The Hooper-Mann specification of the markup provides an intuitively appealing version of why we observe partial pass-through. Further, its simplicity in empirical estimation is equally attractive. As a result, other authors employ this framework to explore similar areas of interest. For, example, Melick [1990] uses three simple theoretical models of pass-through, including the Hooper-Mann specification, to estimate pass-through coefficients as well as coefficient stability.[22] Using a VAR approach, the Engle-Granger two-step procedure and traditional PDL specifications, he finds that none of the restrictions implied by these models is consistent with the (aggregate) data, leading to the conclusion that "efforts to relate the pass-through coefficients to parameters from a theoretical point are best done at as disaggregate a level as possible" (Melick [1990, p.227]). In spite of this divergence between actual and implied theoretical values, coefficients are stable over the data period, refuting the proposition that agents altered their behaviour (in aggregate) during the dollar appreciation.

Athukorala [1991] adopts the Hooper-Mann empirical specification in his study of the relationship between exchange rates and prices of manufactured *exports* from Korea. Using true price indexes rather than unit value indexes, he estimates the following regression for several aggregate categories of

[22] An analysis of Melick's [1990] paper is also covered under the "hysteresis models" section.

manufactured goods:

$$px_t = \alpha + \sum_{i=0}^{k} \beta_{1i} er_{t-i} + \beta_2 pf_t + \beta_3 dp_t + \beta_4 cp_{t-1} + \epsilon_t \tag{2.23}$$

where, px = *export* price in won,

er = exchange rate quoted in won ,

pf = competitors' prices (measured in destination currency),

dp = demand pressure (capacity utilization),

cp = unit production cost.

When prices in the exporting currency are the regressands, pass-through coefficients (ϕ) become:

$$\phi = 1 - \sum_{i=0}^{k} \beta_{1i} \tag{2.24}$$

Athukorala argues that the "competitiveness" of Korean export markets is reflected by the value of phi. If Korean exporters are essentially price takers (in foreign currency), changes in the exchange rate would translate into an equal change in the won price of exports, leaving the price valued in foreign currency intact; $\phi = 0$. Conversely, as the market power of Korean exporters increases, ϕ approaches 1.

Over the sample period 1980:I - 1989:I, Athukorala finds:

(a) Korean exporters absorb, on average, 72% of a given change in the exchange rate within one year, with the largest part of the adjustment occurring within two quarters. Although the pass-through is calculated at 28%, empirical tests show that it is not significantly different (at a 5% level) from zero;

(b) coefficients on pf are close to unity suggesting exporters keep prices in line with foreign competitors;

(c) coefficients on dp and cp are not statistically significant; and

(c) no evidence to support the proposition that exporters price strategically (*i.e.*, retain/gain market shares) depending upon whether the won is appreciating or depreciating.

In essence, Athukorala argues that, over the sample period, Korean exporters are price takers in all their foreign markets.

In a similar vein, Khosla [1991], uses the Hooper-Mann theoretical approach to demonstrate the effect of exchange rate fluctuations on the yen price of Japanese exports. He measures the extent of exchange rate pass-through in the export sector of the Japanese economy using data (1975:I - 1987:IV) from fourteen industry groups - including motor vehicles - and tests for structural breaks in the relationship as a means of verifying the hysteresis hypothesis. In short, his results reinforce the notion that homogeneous goods have a lower pass-through (adjusted or unadjusted for costs) than differentiated goods. In the case of motor vehicles, pass-through is consistently estimated at 60%. In addition, Chow tests at three time points (*e.g.*, 1981:I, 1983:I, and 1985:III) do not reveal structural breaks for most industries, thereby refuting the hysteresis hypothesis.[23]

By his own admission, however, Khosla's empirical estimation is quite *ad hoc* in nature. The initial regressions of the yen-denominated export prices have exchange rates as the sole explanatory variable. Subsequent regressions include lagged exchange rates and lagged gross-weight input prices (*e.g.*, raw materials, energy requirements). His questionable empirical specifications aside, however, he does present convincing arguments that changes in costs require greater attention (Khosla [1991, p.49]):

> The tendency in Japanese costs to move in line with exchange rate changes can be attributed, first, to the high import dependence of Japanese industry for its raw material and energy requirements, which makes it vulnerable to exchange rate, raw material, or energy price shocks. Second, technological progress can lower costs of production, giving the firms some leverage in holding down prices. Whatever the case, cost reduction

[23] These results are not surprising since the hysteresis proposition is based upon the appreciation of the U.S. dollar and subsequent "flood" of new competitors in the U.S. market. However, the hysteresis test is on the *total exports* by Japanese firms and not those exports solely earmarked for the U.S. market. If these tests are to be true indicators of (the lack of) hysteresis, then they can only be viable when the Japanese yen depreciates with respect to *all* its export destination currencies.

lower export prices and cause a *spurious pass-through problem*[24] (emphasis added).

Recognizing the importance of cost considerations in the Japanese case, Atukarala and Menon [1994] separate the pricing-to-market (PTM) behaviour from the total pass-through coefficient (TPT). The domestic cost variable in the Hooper-Mann markup is divided into labour costs and intermediate materials costs. The *exporting pricing equation* becomes:

$$px = \alpha + \beta_1 cu + \beta_2 pw + \beta_3 er + \beta_4 mc + \beta_5 wg + \beta_6 T + \epsilon, \tag{2.25}$$

where *px* = yen export price,
cu = capacity utilization,
pw = competitor's price in destination currency,
er = exchange rate (quoted in yen),
mc = cost of materials input,
wg = labour costs adjusted for productivity
T = trend effect to capture changes in productivity.

Given that $\beta_3 = \partial px / \partial er$ represents the direct effect of exchange rate changes on the yen price of exports, the PTM coefficient is $\beta_3 - 1$. The cost of intermediate materials (*mc*) is assumed to be represented by an equation of the form:

$$mc = \alpha + \delta_1 icu + \delta_2 ier + \delta_3 imp + \delta_4 iwg + \epsilon, \tag{2.26}$$

[24] Ito [1992, chapter 8] corroborates Khosla's argument; the relatively low share of labour in total manufacturing (30% compared to 70% for the U.S.) coupled with the unique wage-setting agreements in Japan suggests that exchange rate changes will primarily affect costs of intermediate inputs.

where icu = capacity utilization in the intermediate goods sector,

ier = nominal effective exchange rate for intermediate imports quoted in yen,

imp = cost of intermediate imports (in foreign currency) in the intermediate sector,

iwg = labour costs in the intermediate sector, adjusted for productivity.

To calculate the total pass-through (TPT), simply add both direct and indirect effects of exchange rate changes: TPT = $[(\beta_3+\delta_2\beta_4) - 1]$. Comparing PTM and TPT estimates over the range of manufactured goods, the difference between the two values vary from 6% for chemicals to 18% for metal products. The difference in the transportation equipment sector is only 7%. Atukorala and Menon [1994, pp.279-80] summarize the results from their version of the Hooper-Mann model:

> While it is evident that the PTM element is the dominant influence behind incomplete pass-through, the cost lowering effect of exchange changes seems to have provided Japanese exporters with considerable leverage in enduring the massive yen appreciation over recent years.

Despite its popularity, the Hooper-Mann interpretation of markups has two serious flaws. First and foremost, the functional form is completely *ad hoc* in the sense that it does not flow from any notion of profit maximization or dynamic optimization behaviour on the part of firms. This lack of theoretical content exposes it to the criticism that one can select virtually any variable to represent "competitive pressures" and/or "demand pressures" and still maintain an acceptable model. Such an approach provides the econometrician with ample opportunity to data-mine. Secondly, this model assumes *a priori* that the exchange rate pass-through is incomplete.[25] Unlike the general markup model, there is no provision for potential cases of complete pass-through or the occasional case of pass-through in excess of 100%. Ideally, a model which accounts for all possibilities is preferable to narrower models.

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[25] See the restriction on α in equation (2.20).

(iii) Industrial Organization Models

Using an industrial organizational approach consistent with the structure-conduct-performance paradigm, this group of models provides greater theoretical content to the selection of variables determining markups. For example, Fienberg [1986] develops a version of the dominant firm model. The k largest firms are assumed to maximize joint profits in order to determine the cartel price. The remaining price-taking firms (*e.g.*,the "competitive fringe") include both domestic and foreign producers. The profit maximization condition for the k dominant firms is:

$$p = \left[\frac{\eta_M - \epsilon_R(1 - C_k - M) - \epsilon_F M}{C_k + \eta_M - \epsilon_R(1 - C_k - M) - \epsilon_F M}\right] MC_k \tag{2.27}$$

where p = price (in destination currency),

η_M = elasticity of demand for the market,

ε_R = price elasticity of supply for the domestic competitive fringe,

ε_F = price elasticity of supply for the foreign competitive fringe,

C_k = k-firm concentration ratio,

MC_k = marginal cost,

M = import share.

As a result, in addition to the elasticity of demand, the markup includes elasticities of supply of domestic and foreign fringe producers, the k-firm concentration ratio and the share of imports. Unfortunately, Fienberg [1986, p.63] admits that one cannot calculate the theoretical solution for the exchange rate pass-through coefficient:

> By totally differentiating, the (expected) implication derived is that an increase in the real external value of the currency (E) is associated with lower domestic prices, $dp/dE < 0$. Another result is that the effect of exchange rate movements, entering directly through M, will differ depending on market concentration and import penetration. Unfortunately, both of these variables are endogenous in the model, precluding an explicit causal solution.

Rather, he relies on the results from Dornbusch [1987] to test the effect of exchange rate fluctuations on domestic (German) prices under various market structures.[26]

Marston's [1990] markup model concentrates on PTM behaviour by eliminating the portion of incomplete pass-through attributed to exchange rate induced cost shocks. By taking the *ratio* of a firm's export price to domestic price (expressed in domestic currency), the common portion of marginal costs cancel each other out. Mathematically, we have:

$$\frac{ep_x}{p_d} = \frac{\mu}{(\mu-1)} \cdot \frac{(\epsilon-1)}{\epsilon} \tag{2.28}$$

where e = exchange rate (domestic/foreign),
p_x = foreign currency export price,
p_d = domestic price,
μ, ε = price elasticity of demand in the export and domestic markets, respectively.

Given the specification of his profit function, this markup ratio is a function of *real* prices and *real* income in each market. Total differentiation of first order conditions gives PTM elasticities between 0 and 1 when markups are variable and demand curves less convex than constant elasticity.

However, Marston's major contribution centers around the ability to detect changes in this ratio due to exchange rate "surprises" (*i.e.*, unanticipated changes in the exchange rate). If firms preset their prices in foreign currency, Marston shows that nominal exchange rate surprises will have an effect on profit margins, albeit temporary, until firms have the opportunity to change prices.

In general, his results indicate that Japanese firms altered their profit margins (1980:2 - 1987:12) in order to remain competitive. There is also some evidence which suggests that the PTM elasticities

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[26] Dornbusch's [1987] model of Cournot sellers shows that the more competitive an industry and/or the larger the share of imports, the greater the effect of exchange rate fluctuations on the dollar price of tradeable goods.

increase when the yen appreciates. Finally, with respect to the automotive sector, the PTM elasticity for small passenger cars is 50% whereas the cummulative elasticity for all passsenger cars is 95%.

Shinjo [1993] also examines the relative prices of Japanese products destined for export and domestic markets. However, in his version of equation *(2.9)*, the price elasticity of demand is substituted with a measure of domestic market concentration (Herfindahl Index) as well as a measure to detect the degree of product differentiation (share of wholesale margins in total sales). This is an *ad hoc* specification based upon the premise that; (a) firms in more concentrated markets have a better opportunity to engage in PTM behaviour as they can maintain high profit margins from domestic sales through collusion; and (b) the more differentiated the product, the faster export prices can adjust to exchange rate fluctuations. From his regression results, Shinjo [1993, pp.163-4] states:

> ...it confirms that the PTM behaviour is more pronounced among the type of goods whose domestic market is more oligopolistic as measured by the H index and that the PTM is not merely a short-run phenomenon, for the correlations with the H index remain significant even three years after the Plaza Accord. The highly significant positive coefficient of WX85 in row 2 suggests that firms in the differentiated markets have been able to "pass-through" more easily to the export price, in response to the foreign currency depreciation.

(iv) Knetter model

Knetter [1989;1993;1994] has a novel approach in estimating the general model pricing equation. Recognizing the difficulty in measuring marginal costs and markups, he extends Rosse's [1970] work by *inferring* these values from firm behaviour. For each destination, an exporter's price is a function of a common marginal cost, which may vary over time, and a destination-specific markup. Empirically, regressions take the following form:

(2.29) $$\ln p_{it} = \theta_t + \lambda_i + \beta_i \ln s_{it} + \mu_{it}$$

where p_{it} = price in *exporter's* currency,

θ_t = time effects (captures common marginal costs),

λ_i = destination-specific effect (proxy for markup),

s_{it} = exchange rate (destination currency/export currency)

μ_{it} = white noise error term.

In Knetter [1989], he subsequently tests the value of these coefficients to determine which market structure is responsible for incomplete exchange rate pass-through.[27] From his data (1978:I-1985:IV), he concludes that price discrimination is the key to understanding the pass-through relationship. U.S. exporters frequently *amplify* rather than attenuate the effect of changes in exchange rates on dollar prices of exports, whereas German exporters have a tendency to stabilize their destination-currency prices of exports.

One criticism of this work stems from the fact that many coefficients are quite similar across a broad spectrum of commodities. Does this imply, as Kasa [1992] suggests, that the curvature of these demand curves is similar? If not, there ought to be factors other than price discrimination to account for incomplete pass-through.

More importantly, there is some confusion as to exactly which variable represents the markup. The reader is left with the impression that only λ_i captures the destination-specific markup. However, since the expression in equation (2.29) contains a common marginal cost variable (θ_t), then by definition, any change in the exchange rate which impinges upon the export currency price ***must*** be the result of variations in the markup. Therefore, given that β_i represents the elasticity of markups with respect to

[27] In his tests for a purely competitive world market, price equals marginal costs and his null hypothesis is $\lambda_i=\beta_i=0$. In the case of price discrimination with constant elasticity of demand, $\beta_i=0$ is the null hypothesis, with λ_i capturing the (constant) destination-specific markup.

exchange rates, the assumed measure of markups, λ_i, should be replaced with $(\lambda_i+\beta_i)$. The ensuing high degree of collinearity between variables may explain why more than 50% of the reported statistics for β_i are statistically insignificant at the 5 percent level. Another indicator of high variances and standard errors is the obvious non-stationarity of the marginal costs variables as revealed in the graphs for German exports of large and small cars (Knetter [1989, pp.207-208]).

Knetter [1993] addresses some of these econometric problems by estimating the *differenced* form of equation (4.40):

$$\Delta \ln p_{it} = \theta_t + \beta_i \Delta \ln s_{it} + \epsilon_{it} \qquad (2.30)$$

In this interpretation, changes in markups are captured by the value β_i, which in turn is assumed to be determined by the convexity of demand curves in destination markets. PTM or "local currency price stabilization" (LCPS) as Knetter defines the term, occurs when β_i values lie between zero and minus one. Positive values confirm the "perverse" case where changes in markups amplify the effects of changes in exchange rates.

Despite the fact that pricing behaviour of automobile exports to Canada ranges from full pass-through (Germany) to negligible levels of pass-through (Japan), Knetter [1993, p.484] generalizes his results with the statement that:

> ...comparisons of source-country behavior within common industries indicate remarkably little evidence of differences in behavior. This is contrary to the impression generated by previous work on markup adjustment by Mann (1986), Knetter (1989), and Kenichi Ohno (1989). Formal F tests never reject identical price adjustment within industries, although the power of theses tests is admittedly weak.

Moreover, he suggests that destination-specific markup adjustment is similar across industries. In other words, there are no systematic differences across destinations; Japanese exporters, for example, treat the U.S. market in precisely the same manner as their other export markets. These results also contrast with the stylized facts of previous work done on *aggregate* data (Mann [1986], Knetter [1989], Ohno [1989], Menon [1991;1993b]), which suggest that U.S. exporters exhibit less LCPS than their Japanese or German counterparts. Knetter believes that this discrepancy reflects the *mix* of export industries in the aggregate data rather than any differences in behaviour for similar industries.

However, there is another plausible explanation for the apparent consistent behaviour across destinations and within industries. By his own admission, the F tests constructed to evaluate the null hypothesis of the constrained equations ($\beta_i=\beta_j=...$) have "low power". The reliability of this statistic is compromised when we consider the functional form of the estimated equations. Strictly speaking, if equation *(2.30)* follows directly from equation *(2.29)*, as implied (Knetter [1993, p.475]), then not only should marginal costs be differenced (*i.e.*,$\Delta\theta_t$) but the error term (ε_{it}) is actually a moving average [MA(1)] function ($\varepsilon_{it} = \mu_{it} - \mu_{it-1}$). This error term has an expected mean equal to zero but a variance twice as large ($2\sigma_\mu^2$) as that in equation *(2.29)*.[28] This will increase the standard error of the residual by

[28] Starting from the assumption that the error term in equation (4.40) has an expected mean equal to zero, a constant variance and is not correlated over time;

$$E(\mu_{it}) = 0$$

$$E(\mu_{it}\mu_{is}) = \begin{cases} \sigma_\mu^2 & \text{if } t=s \\ 0 & \text{if } t\neq s \end{cases}$$

where t,s = 0,±1,±2,±3...

Therefore, in equation (4.41) we can calculate the variance of the error term in the following manner:

$$\begin{aligned} &= E\left[\mu_{it}^2\right] - E\left[2\mu_{it}\mu_{it-1}\right] + E\left[\mu_{it-1}^2\right] \\ &= \sigma_\mu^2 + \sigma_\mu^2 \\ &= 2\sigma_\mu^2 \end{aligned}$$

approximately 40%, effectively enlarging confidence intervals for hypothesis testing. Therefore, when we examine confidence regions for a parameter vector (Kennedy [1992, ch. 4]), F tests are more apt to accept the null hypothesis of identical parameters even though the estimates themselves may appear quite different.

In addition, the model suffers from the problems associated with differenced regressions. These "growth-rate" models of the form $\Delta y_t = \alpha_0 \Delta x_t + \varepsilon_t$ can account for only short-run relationships between variables. The absence of data in level form precludes long-term relationships. If, for example, the variance of Δx_t is relatively large compared to the variance of Δy_t, the estimate of α_0 is small, even though the variables may have a cointegrating vector of one (*i.e.*, $y_t = x_t$).

(v) Strategic Behaviour Models

The theoretical foundations of these markup models explicitly account for strategic interaction between competitors. Pricing behaviour, including PTM, is assumed to depend upon the perception of rivals' reactions to changes in a competitor's behaviour.

Krugman [1987] constructs a simple static Cournot competition model where a European firm faces a U.S. competitor (perfect substitute) in the U.S. market. With constant marginal costs and a *constant elasticity of market demand*, each firm faces a perceived elasticity of demand equal to η/s where η = market elasticity and s = firm's market share.[29] If s = U.S. firm's market share and $s^* = (1 - s)$ = European firm's market share, then the optimal pricing decision for each firm is:

[29] Constant elasticity of market demand is chosen such that the results with a U.S. competitor (incomplete pass-through) can be compared to the monopoly position (complete pass-through).

$$p = \left[\frac{\eta}{\eta - s}\right] \qquad \textit{for the U.S. firm}$$

(2.31)

$$p = \left[\frac{\eta}{\eta - s^*}\right]\frac{c^*}{e} \qquad \textit{for the European firm,}$$

such that in equilibrium, market shares adjust to equate the pricing rules. The presence of market shares in the markups is responsible for incomplete pass-through. For example, if the European currency depreciates ($e\uparrow$), the price offered by the European firm falls. However, the price will not fall proportionately to the change in the exchange rate since the European firm's market share will rise and subsequently lead to an increase in the markup. Therefore, movements in market shares attenuate changes in the exchange rate.

Dornbusch [1987] presents several theoretical models illustrating how relative prices adjust in response to exchange rate movements. Each of these pricing models is based on the notion that price adjustments result from changes in relative unit labour costs. The underlying assumption, therefore, is that technology is linear with only labour as an input. With the assumption that wages are constant throughout the adjustment period - as are the number and location of firms within an industry - clearly,these models depict short-term movements. Of particular interest, is a Dixit-Stiglitz type model of imperfect competition with "representative consumers". By itself, the representative consumer utility function, where variety in consumption is important, will generate constant markups. However, in an extended version, Dornbusch considers strategic price interaction by means of conjectural variations. The pricing policy becomes:

(2.32) $$p = \left[\frac{\eta(1-\delta)}{\eta(1-\delta)-1}\right]\frac{w*}{e}$$

where p = price in domestic currency,

η = elasticity of demand,

δ = $(dP/P)/dP_i/P_i)$, the elasticity of aggregate industry price w.r.t the price of the i[th] competitor,

w = unit labour costs in foreign currency,

e = exchange rate (foreign currency / domestic currency).

Once again, we have a variable in the markup which attenuates exchange rate movements. Dornbusch illustrates, both graphically and mathematically, how foreign firms lower their dollar price less than proportionally to the reduction in their dollar unit labour costs. In turn, domestic firms lower their price but the *relative* price of domestic firms increases.[30]

Giovannini [1988] addresses the issue of firms' *expectations* in the pricing problem. He presents a model whereby a risk-neural firm sells its product in both domestic and foreign markets. Demand curves in both markets are a function of the firm's price, a vector of competitors' prices, as well as a vector of "shift" variables. Firms maximize (expected) discounted future profits based on all currently available information. However, he assumes that firms commit themselves to prices which are determined at the *outset* of each period and prior to the realization of exogenous variables (competitors' prices, factor costs, and shift variables). As a result of these fixed prices over the duration of each period, exchange rate "surprises" can lead to incomplete pass-through. Therefore, it is the stochastic nature of the exchange rate, along with price predetermination, which produces deviations from the law of one price in the short run.

In his empirical section, Giovannini produces evidence of deviations in PPP for products which can

[30] This is true for differentiated products only. For homogenious products, domestic firms match this reduction.

be considered homogeneous (*i.e.*, nuts and bolts, screws, ball bearings) in nature. This contradicts the general assumption that one requires some sort of differentiated product to generate PTM or deviations from the law of one price. One can reconcile the two positions once one understands the form of Giovannini's transaction imperfection. By forcing firms to precommit prices, ***any*** exchange rate surprise will create PTM *regardless* of the nature of the product.

Feenstra *et al.* [1993] examine the relationship between market share and exchange rate pass-through in the automobile sector from 1970-1988. Demand for variety i is a function of a vector of competitors' prices and total expenditure on all varieties. Under the assumption of Bertrand competition, competitors' prices are assumed to be constant. Therefore, from the first-order condition, the value of the elasticity of demand in the markup (η_i) is also a function of competitors' prices and total expenditure on all varieties. The static models discussed in the theoretical section indicate how countries with large market shares typically pass-through a greater portion of changes in the exchange rate. However, with smaller shares, the relationship exhibits a considerable degree of nonlinearity (Feenstra *et al.* [1993, p.11]):

> The general relationship that is suggested is a pass-through elasticity that might initially decline as market share rises, but will increase towards unity as market share approaches 100 percent.

Unfortunately, the empirical estimation deviates considerably from the theoretical content. The theory does not explore the dynamic adjustment paths, yet the authors use the Phillips-Loretan [1991] procedure for estimating long-run equilibrium relationships. Short-run departures from the long run are accounted for by including both lag and lead differences of the independent variables. Furthermore, the coefficient for the pass-through elasticity is assumed to depend on market shares (nonlinear specification) as well as source and destination effects (similar to Knetter [1989;1993]).

On the other hand, in their analysis of the Swiss automobile market, Gross and Schmitt [1993] find

PTM behaviour which is *independent* of market shares.[31] Similar to Feenstra *et al.* [1993], demand for variety i is a function of competitors' prices. However, through the use of conjectural variations, strategic price interaction varies from Bertrand competition to full collusion. From the first-order conditions, markups are a function of the curvature of the demand function (assumed to be linear) and the conjectural variations with respect to each competitor's price.

If prices are set in the buyer's currency, Swiss francs, Gross and Schmitt derive the typical symmetry between marginal cost effects and exchange rate effects on optimal prices. However, if profits are expressed in the currency of production and demand curves expressed in foreign currency prices, this symmetry no longer holds, *providing the competition between firms is not Bertrand.* Therefore, with the addition of conjectural variations, one can infer through the symmetry condition whether firms play a Bertrand game as well as the choice of currency in the pricing policy.

Using quarterly data from 1977:I to 1991:IV, they find relatively similar behaviour within classifications of automobiles, but different behaviour across classifications. They attribute the difference to variations in intensity of competition across categories; the greater the rivalry within an automobile category, the smaller the exchange rate pass-through. The conclusion that PTM is independent of market share is based upon the Japanese experience in the Swiss market. In spite of the increase in market share from 13% to 35% over the data period, the Japanese PTM coefficient remains constant.

Finally, Yang and Hwang [1994] address the issue of strategic price interaction by including the *relative* prices of competing goods in the demand curve along with foreign and domestic output. Similar to Branson and Marston [1989], they consider the behaviour of a firm selling to both domestic and foreign markets where marginal costs are assumed to be an increasing function of output and factor prices but declining over time in response to productivity growth. The first-order condition produces a markup which

[31] The Swiss market is selected upon the basis of its low tariff rate discrimination across source countries, and the absence of domestic production facilities.

is a function of relative prices (in a common currency), domestic output, and foreign output. Total differentiation of the markup equation produces an exchange rate pass-through elasticity which is a function of the price elasticity of demand and the elasticity of the markup with respect to prices.

Consequently, markups which contain variables other than elasticity of demand inevitably lead to exchange rate pass-through elasticities which are a function of "markup elasticities" as well as demand elasticities. Yang and Hwang reiterate a recurring theme which occurs when models contain strategic behaviour; namely, one can generate incomplete pass-through even if one assumes a constant elasticity of demand.

III. Adjustment Cost Models

In his seminal paper outlining the concepts of PTM, Krugman [1987] presents a simple dynamic supply-side model based on the assumption that "bottlenecks" occur when quantities adjust to exchange rate changes. If, for example, exporters cannot expand their sales to a market without incurring costly marketing and distribution costs (*e.g.*, improvements in service infrastructure), they will not adjust quantities if this capacity cannot be provided. Only in the long run, once the infrastructure is in place, will quantities and prices adjust. Moreover, Krugman also notes that if changes in the exchange rate are perceived as temporary, firms may decide not to invest in infrastructure in the first place. Consequently, under the assumption of adjustment costs, Krugman argues that the degree of PTM is a function of how recent the exchange rate has changed and whether the movement is viewed as temporary or permanent.

Unfortunately, Krugman does not elaborate on how the degree of PTM is influenced by the amount of time elapsed since the original exchange rate shock. It is not clear if the pass-through is initially zero and proceeds towards unity for *each and every exchange rate movement* or, alternatively, if PTM gradually moves towards unity (even at the initial stages) as an exporter who invests larger amounts in infrastructure no longer faces capacity constraints. Krugman also suggests that adjustment costs ought to be greater, the more rapid the expansion. Yet, in his model he adopts a linear adjustment schedule $\{h(dx/dt)\}$ whereas a quadratic specification of the form $\{h(dx/dt)^2\}$ might be more appropriate.

In a related area, Gagnon [1989], uses quadratic adjustment costs along with imperfect competition and rational expectations to model the dynamics of international trade flows. The objective of his paper is to provide a more rigorous theoretical model to explain the importance of lags and price elasticities with respect to the U.S. trade deficits of the 1980s. From his estimates, he suggests that lags in trade flows are primarily the result of significant adjustment costs.

In Gagnon and Knetter [1995], combine Knetter's [1989] static model of PTM with Gagnon's [1989] dynamic adjustment cost model to examine both short-run and long-run markup adjustments for several automobile-exporting countries. A modified version of equation (2.29) is estimated to derive the long-run cointegrating relationship. Combining this regression with the theoretical results from Gagnon's [1989] dynamic optimization problem, they follow the Engle-Granger two-step procedure to estimate the following error correction model:

$$(2.33) \qquad \Delta \ln p_{it} = \alpha_i^0 + \alpha_i^1 \Delta \ln p_{it-1} - \alpha_i^2 \Delta \ln e_{it} + \left[1 - \alpha_i^2 - \alpha_i^3\right]\left[\hat{\theta}_t - \hat{\theta}_{t-1}\right] - \alpha_i^4 \hat{\mu}_{t-1} + \epsilon_{it}$$

where, p_{it} = price in exporter's currency,

e_{it} = exchange rate (destination currency/export currency)

$\hat{\theta}_t$ = common marginal cost estimates from cointegrating equation, and

$\hat{\mu}_t$ = residual from cointegrating equation.

In general, their results indicate that PTM is pervasive in Japanese automobile exports, present to some degree in certain German categories and destinations, and practically absent from U.S. automobile exports. Results are also robust to different specifications and not particularly sensitive to sample periods selected. Differences in behaviour are attributed to:

(i) intensity of competition in automobile categories and/or markets;
(ii) differences in adjustment costs between producers; and
(iii) strategic behaviour.

However, the adjustment costs considered by Gagnon and Knetter do not arise from the typical marketing and distribution problems, but from production rigidities. Citing anecdotal evidence from *The Wall Street Journal* (March 5, 1991, p.A4), the hypothesis is that Japanese and German firms find it more costly, relative to U.S. firms, to adjust the level of labour inputs whenever there are shocks to the system. In essence, institutional features of labour markets in these countries preclude the possibility of adjusting inputs on a regular basis and therefore, naturally lend themselves to PTM behaviour.

Kasa [1992] provides the most thorough dynamic analysis of PTM with adjustment costs. Without specifying the exact nature of these costs, Kasa assumes that costs of adjusting quantities - which are destination specific - account for differences in *marginal costs* of supplying foreign markets. This dispersion of marginal costs creates deviations from PPP. One important addition to the model is the distinction between transitory and permanent exchange rate movements. Similar to Froot and Klemperer [1989], he assumes that firms will engage in intertemporal profit shifting (PTM) the more transitory the perception of an exchange rate shock. Other demand side sources of PTM are effectively eliminated by assuming constant elasticity of demand. The role of adjustment costs is further isolated by abstracting from any strategic interaction or market structure issues.

The theoretical model uses a dynamic optimization framework to examine the behaviour of a monopolist (German) supplying identical products to two foreign countries (U.S. and Canada). Maximizing the expected present discounted value of profits with respect to quantities:

$$\text{(2.34)} \qquad \underset{\{Q_t\},\{Q_t^*\}}{Max}\; E_0\sum_{t=0}^{\infty} \beta^t\left\{S_tP(Q_t,\theta_t)Q_t + S_t^*P^*(Q_t^*,\theta_t^*)Q_t^* - c(Q_t+Q_t^*) - \frac{1}{2}h\left(\frac{Q_t}{Q_{t-1}}-1\right)^2 - \frac{1}{2}h^*\left(\frac{Q_t^*}{Q_{t-1}^*}-1\right)^2\right\}$$

where, S_t, S_t^* = Deutsch mark price of U.S., Canadian dollar respectively, and

Θ_t, Θ_t^* = Demand shocks for U.S., Canadian market - observed *before* time t output decision.

Solving the second-order difference equations, the decision rules for supplying the U.S. and Canadian market are:

$$\text{(2.35)} \qquad \begin{aligned} q_t &= \lambda q_{t-1} + (1-\lambda)(1-\lambda\beta)\sum_{j=0}^{\infty}(\lambda\beta)^j E_t\tilde{q}_{t+j} \\ q_t^* &= \lambda^* q_{t-1}^* + (1-\lambda^*)(1-\lambda^*\beta)\sum_{j=0}^{\infty}(\lambda^*\beta)^j E_t\tilde{q}_{t+j}^* \end{aligned}$$

where $\tilde{q}$, $\tilde{q}^*$ are the "optimal" quantities in absence of adjustment costs and are functions of the exchange rates, demand shocks and elasticity of demand. Since demand elasticities are assumed constant and demand shocks have expected means equal to zero, the only variable which requires estimation of future values is the exchange rate. Following Hansen and Sargent [1981] Kasa uses the Wiener-Kolmogorov prediction formula to transpose the sum of all future values into an equation consisting of current and past values. By converting the two supply equations in terms of prices and taking their differences, he derives an expression for the *equilibrium relative price* for the two countries:

$$(2.36) \qquad \pi_t = \kappa + \lambda\pi_{t-1} + \gamma_1\Delta s_t + \gamma_2\Delta s_t^* + \gamma_3(s_{t-1}^* + p_{t-1}^*) + \nu_t$$

where, $\quad \pi_t = (s_t + p_t) - (s_t^* + p_t^*)$ = log of the DM price in the U.S. relative to Canada and, $\gamma_1 > 0$, $\gamma_2 < 0$.

Kasa tests the proposition that, under PTM, the Deutsch mark (DM) prices of U.S. imports will rise (fall) relative to prices in Canada when the U.S. dollar appreciates (depreciates). Offsetting changes in the Canadian dollar/ U.S. dollar exchange rate ($\Delta s_t = \Delta s_t^*$) can lead to PTM if the two countries have different stochastic processes for their exchange rates or if they have different adjustment costs (*i.e.*, $\gamma_1 \neq \gamma_2$). In general, his results suggest that adjustment costs are important in both countries. In particular, the adjustment costs for automobiles exported to the U.S. from Germany are relatively more important than other commodities.

Finally, Knetter [1994] uses a variation of his 1989 model to compare the relative importance of PTM due to adjustment costs versus PTM due to the "market share" hypothesis. The general idea is that if adjustment costs - in the form of capacity constraints *or* quantitative trade restrictions - are valid then they will only be binding during currency depreciations. Consequently, there will be an asymmetry in pricing responses; PTM will be greater when the exporter's currency depreciates. On the other hand, if an exporter's main objective is to increase market shares, the asymmetry pricing response is reversed. Assuming that market shares increase as the price of exporters' products (in destination currency) falls, a depreciation of the exporters' currency with constant markups or an appreciation of their currency with lower markups will reduce the destination-currency price. Therefore, under this assumption, PTM will be greater under an appreciating currency.

Knetter tests this asymmetry hypothesis by estimating equations containing appreciations and depreciations. While the data never strongly reject symmetric responses to appreciations and depreciations, industry level analysis appears to favour the market share hypothesis.

Knetter [1994, p.57] notes:

> All seven categories of automobiles in the data sample (three Jananese and four German) exhibit more PTM when the exporter's currency is appreciating. This is most surprising since the bottlenecks model seems particularly applicable to this industry - due to the possibility of genuine bottlenecks in distribution and the existence of fairly explicit quantity restrictions on Japnaese auto exports to a number of destination markets during the sample period.

Unfortunately, Knetter does not provide any insignt into why the adjustment cost (or "marketing bottleneck") assumption does not hold for the Japanese automobiles. Oddly enough, the adjustment cost model is favoured when all Japanese industries are pooled together even though individually, the majority favour the market share model.

IV. Institutional Models

Recently, there has been considerable interest in "institutional" features as a potential reason for explaining incomplete pass-through behaviour. Generally speaking, proponents of institutional models eschew the notion of sophisticated models based on imperfect competition or intertemporal profit-shifting, in favour of simple institutional barriers. They argue that by ignoring the institutional settings between trading partners, a valuable, if not obvious, reason explaining partial pass-through is neglected. Two of the more prominent institutional models rely on non-tariff barriers (NTB's) and the role of multinational corporations (MNC's) to solve the pass-through phenomenon.

(i) Non-Tariff Barriers (NTB's)

Bhagwati [1988] was one of the first to challenge contemporary models of pass-through based on "new trade" assumptions in favour of simple NTB assumptions. If, for instance, a quantity restriction imposed by a voluntary export restraint (VER) is binding, the price in destination currency received by the exporter is higher than the price which would prevail in an unregulated market (*i.e.*, exporters receive a premium for the NTB-restriced products). Subsequently, as long as the VER quantity is binding, depreciations of the destination currency will result in lower premiums for exporters rather than higher prices. For sufficiently large depreciations, the quantity restriction will no longer be binding and destination currency price will rise, although the exchange rate pass-through elasticity will be less than one. Citing evidence of a 25% increase in the coverage of U.S. imports by NTB's for the period of 1981-1986, Bhagwati reasserts his contention that institutional features, by themselves, can account for incomplete pass-through in the long run.

In his analysis of exchange rate pass-through for Australian imports of automobiles, Menon [1993b] illustrates the main results of NTB's using a downwards sloping demand curve and an "inverse L' supply curve. The horizontal section of the supply curve reflects the world price of the product under his small country assumption, whereas the vertical portion represents the binding quantity restraint. Small depreciations simply shift the horizontal portion of the supply curve upward while the vertical portion remains intact. If the quantity restraint remains binding, pass-through is zero. Only large depreciations shift the horizontal portion of the supply curve above the existing equilibrium price, effectively eliminating the need for quantity restrictions.

Menon [1993b, p.103] argues that his simple model explains the stylized facts for the Australian imports of automobiles:

> The massive depreciation of the AUD *[Australian dollar]* against the Japanese Yen and most Western European currencies during the 1985-1986 period had produced an outcome similar to the case described above, rendering quota protection for the industry redundant...the result was a less than fully subscribed quota pool.

(ii) Multinational Corporation (MNC) strategies

Menon [1993a;1993b] claims that the role played by MNC's contributes more to the literature on exchange rate pass-through than NTB's. In an environment plagued with exchange rate volatility, he highlights three strategies available to MNC's which can reduce the risks associated with uncertainty and unfavourable shocks.

Firstly, he cites evidence of widespread use of "internal exchange rates" for intra-firm transactions. The use of internal exchange rates enables foreign affiliates, for example, to insulate their pricing decision from large "external" or current exchange rate fluctuations. Secondly, MNC's frequently provide flexible internal credit arrangements for affiliates who face considerable exchange rate volatility. By prolonging the timing of payments until a more favourable exchange rate returns, the link between an affiliate's pricing decision and current exchange rates is further reduced. Thirdly, the choice of currency denomination for intra-firm transactions will also affect pricing decisions (Menon [1993a, p88]):

> By invoicing in the currency of the importing country, and with the ability to determine the timing of payments, the MNC is in a position to bypass exchange rate fluctuations that occur in the interim. The bargaining problem that besets arms-length trade does not apply to intra-firm trade, and the invoicing currency becomes a choice variable that can be used to facilitate competitive pricing strategies or balancing global exchange rate risk within the MNC.

Rangan and Lawrence [1993] suggest that the large presence of U.S. multinational activity combined with "data problems" can account for the apparent pricing behaviour discrepancy between Japanese (or German) exporters and their U.S. counterparts. There is ample empirical evidence that U.S. exporters engage in considerably less PTM than other G-7 countries. Yet, in their personal survey, the authors find that 80% of respondents claim pricing decisions are made in local markets and roughly 60% retained constant local currency prices during the dollar's decline from 1985 to 1989. However, the U.S. Bureau of Labor Statistics (BLS) shows that the export price index moves in tandem with the domestic (U.S.)

wholesale price index over this period.[32]

Rangan and Lawrence [1993,p.346] argue that:

> The key to resolving this apparent contradiction lies in the last explanation offered above: data problems. In particular, in an important number of cases, official U.S. export prices do not actually indicate the prices paid by *final purchasers* of U.S. products abroad (emphasis in original).

Therefore, given that a substantial portion of U.S. manufacturing exports (40%) is through intra-firm transactions, the authors argue that BLS data are biased towards intra-firm pricing decisions and have little to offer in the way of U.S. strategic pricing decisions towards *foreigners*.

There is one important question the authors do not address. If biased export price indices result in U.S. exporters passing through the full amount of exchange rate shocks, why do countries such as Japan and Germany - who, through analogous arguments presumably face similar biases - only pass-through a portion of exchange rate changes? The answer depends upon who is responsible for absorbing the exchange rate shock; the parent company or its affiliate(s). Rangan and Lawrence assume that *foreign affiliates* of U.S. parent companies act as a buffer. They claim that U.S. MNC's charge identical prices (in dollars) to all their affiliates who, in turn, make the decision on what destination-currency price should be charged in foreign markets. The main reason U.S. MNC's follow this particular practice is to avoid prosecution under foreign antidumping laws and/or U.S. antitrust laws.

However, in Menon's [1993b] study of Japanese automobile exports to Australia, evidence presented by the Prices Surveillance Authority [1989, p.51] indicate that *parent MNC's* absorb exchange rate shocks:

[32] The authors question BLS methods of acquiring data for domestic and export prices. These prices are collected through mail surveys where, frequently, the same department within a corporation is responsible for answering both surveys. Rangan and Lawrence argue that there is an incentive (*i.e.*, the possibility of prosecution for price discrimination) to provide identical figures for both markets.

> ...imports by subsidiaries of multinational companies from parent companies overseas are frequently denominated in Australian dollars... In this way, the parent company bears the cost of exchange rate movements, at least in the short-term. The parent company can balance its global exchange risk, while allowing greater stability of prices and profit margins in Australia, where domestic producers may be the major source of competition.

Unlike their U.S. counterparts, Menon argues that Japanese MNC's maintain a tighter rein on their affiliates, appear to be less concerned with antitrust legislation, and concentrate on eliminating exchange rate risk across all foreign markets.

Supporters of the institutional approach to pass-through argue that their position has not received proper attention in the literature and merits further investigation. Be that as it may, it is not clear that institutional responses, by themselves, justify a separate account of PTM behaviour. What is clear, however, is that MNC strategic behaviour is geared towards stabilizing destination-currency prices; regardless of whether the parent company or its affiliates absorb exchange rate movements. As such, it does not differ, in principle, from market share models such as Froot and Klemperer [1989] or Feenstra *et al* [1993] where firms are assumed to retain market share in face of exchange rate volatility. Nor does it differ from the vast array of markup models which retain destination-currency price stability through profit margin adjustments. What institutional models do provide is the *transmission methods* of how firms are able to retain market share and how firms are able to adjust profit margins.

CHAPTER 3

A THEORETICAL MODEL OF EXCHANGE RATE PASS-THROUGH

3.1 Introduction

From the previous chapter, it is evident that there are numerous approaches to account for incomplete the pass-through of exchange rates. Different conclusions, regarding the nature and extent of changes in exchange rates on the prices of traded manufactured goods, can be traced to differences in theoretical models (and assumptions) and/or differences in econometric methodologies.[1] The central theoretical contributions of this thesis are the formulation of a model which synthesizes two existing dichotomies in the exchange rate pass-through literature, and an extension to this model which "nests" competing models.

(i) Demand-side Versus Supply-side Dichotomy

The first dichotomy relates to the roles of demand-side versus supply-side influences on exchange rate pass-through. With the exception of Kasa [1992], the past decade has produced models which rely solely upon demand-side effects (Athukorala [1991], Hooper and Mann [1989], and Mann [1986]) ***or*** solely on supply-side effects (Dixit [1989], Krugman [1987], and Krugman and Baldwin [1987]) to explain the phenomenon of incomplete exchange rate pass-through.

Demand-side models operate on the premise that the effects of exchange rates on prices of imported goods operate through profit margins (markups). Although the determinants of profit margins vary (Fienberg [1986], Hooper and Mann [1989], and Yang and Hwang [1994]), the dominant variable is the price elasticity of demand. Under general conditions, a constant elasticity of demand will ensure *full* pass-

[1] Differences in econometric methodologies also include differences in *data selection* (*i.e.*, data frequency, level of data aggregation, data "proxies", *etc.*).

through of exchange rate changes. Demand schedules less convex than constant elasticity generate incomplete pass-through whereas demand schedules more convex lead to an amplification of the effect of exchange rates on prices (*i.e.*, pass-through in excess of 100%). From a demand-side perspective, therefore, a simple linear demand curve can capture incomplete pass-through.

Supply-side models attribute incomplete pass-through to some form of adjustment cost. The typical case occurs where firms incur significant non-production infrastructure costs when changes in the exchange rate dictate an increase in quantity supplied. For example, if exporters cannot expand their sales to a market without incurring costly marketing and distribution costs (*e.g.*, improvements in infrastructure), "bottlenecks" develop such that quantities, and therefore prices, will not respond - at least in the short run.[2] In the long run, as infrastructure problems are surmounted both prices and quantities adjust. If, as Krugman [1987] suggests, adjustment costs are greater the more rapid the adjustment, it would be appropriate to model these costs as *quadratic* rather than linear.

One reason for the initial development and subsequent proliferation of these two separate approaches is the displeasure with traditional models incorporating both demand and supply effects. The elasticity approach, along the lines of Harberler [1949], Branson [1972] and Magee [1973], has two major weaknesses. Firstly, it assumes that suppliers fully pass-through changes in exchange rates, in the sense that supply curves rotate by the full percentage (See Figure 2-a, Chapter 2, below) of the movement in exchange rates.[3] This assumption about supply responses is acceptable for cases of perfect competition, however, when industries are classified as imperfectly competitive, it is reasonable to assume that supply responses vary according to the degree of competition, the degree of substitutability between exports and

[2] Production-induced adjustment costs in the form of bottlenecks can also lead to partial pass-through. Whether these bottlenecks occur in the form of capacity constraints or high costs of changing levels of employed labour or other factors of production, it is clear that output will not respond to movements in exchange rates.

[3] The fact that the new equilibrium price implies incomplete pass-through of exchange rates is due to the usual assumptions of upward-sloping supply curves and downward-sloping demand curves.

domestically produced products, the level of government regulation, the importance of adjustment costs, *etc.* Secondly, the elasticity approach does not address the issue of dynamics. There is a complete lack of information on how prices adjust from one equilibrium position to the next. The absence of short-run dynamics is a concern for *all* types of static models, not just the elasticity approach.

Clearly, a "general" model of exchange rate pass-through which synthesizes the effects attributable to demand-side influences as well as the effects attributable to supply-side influences must meet three basic criteria. Firstly, it should be able to account for incomplete pass-through under different market structures. Specifically, it should encompass perfectly competitive situations similar to the elasticity approach. Yet, it should also account for incomplete pass-through under conditions of imperfect competition where markups over marginal cost can vary in response to changes in exchange rates. These include models of incomplete pass-through based on market segmentation (*i.e.*, pricing-to-market (PTM)) such as Knetter [1989;1993], Marston [1990], and Yang and Hwang [1994]. They also consist of models based on imperfect substitutability between domestic and imported goods such as Isard [1977] and Richardson [1978].

Secondly, it should account for incomplete pass-through which arise as a direct result of prohibitive adjustment costs. In particular, it should be capable of explaining the possibility of bottlenecks in the production/distribution process which occurs when changes in exchange rates exert pressure on quantities supplied.

Finally, the model must be able to account for a firm's pricing behaviour over time. A general model which incorporates time-generated dynamics will account for pricing decisions which are contingent upon the stochastic properties of forcing variables. In the case of exchange rate pass-through, a firm's decision whether to alter its destination-currency price in light of an exchange rate fluctuation will not only depend upon current rates and movements, but also the perception of any *future* exchange rate movements. For example, exchange rate movements which are expected to "mean-revert" will lead to pricing decisions in stark contrast to exchange rate movements which are perceived to be permanent. Even within "mean-reverting" expectation models, pricing decisions may differ.[4] In addition, firms which invest time, resources, and money into export markets expect to remain in these markets for a considerable length of time. Occasionally, this leads to short-run decisions which differ from long-run plans. For example, if the exchange rate of a country exporting products appreciates significantly, firms may take a wait-and-see approach; preferring to let profit margins suffer in the short run rather than pass-through the change in exchange rates into higher foreign prices and risk losing a portion of their market share. If, however, the appreciation does not revert within a specific time frame, the firm may adjust its expectations of the appreciation (*i.e.*, from temporary to permanent) and pass through the full value of the appreciation. Therefore, the model should be capable of separating short-run dynamic behaviour from long-run fundamental equilibrium relationships.

(ii) *Theoretical Versus Empirical Dichotomy*

The second dichotomy examines the discrepancy between the specification of theoretical models and the empirical estimation of these models. The fact that significant differences arise, between what a model or system of equations predicts and how this model or system is econometrically estimated, can be explained in two manners.

The first explanation is a data-related problem, often beyond the control of the researcher, but important nevertheless. These discrepancies frequently arise from the lack of suitable data. Unable to find a precise theoretical variable, one must improvise and select a proxy. For a given pool of proxy variables, it is possible for estimation results to differ significantly across choices. Unfortunately, data selection problems continue to exist - particularly at the disaggregate level. The short-run solution is to recognize that estimation results, statements of inference and policy conclusions are each subject to data

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[4] See footnote 18, Chapter 2, below.

limitations.

A more important factor accounting for this discrepancy, and completely within control of the researcher, is the problem of data-mining. For any given choice of data, the underlying desire to find a "empirical formula" leads to and empirical specification which, at times, has only the vaguest resemblance to the theoretical model. For example, Hooper and Mann [1989; p.300] assume that markups are a function of:

> ...competitive pressures in the U.S. market and demand pressures in all markets combined. Competitive pressures in the U.S. market are measured by the gap between the competitors' prices in the U.S. market and foreign production costs in dollars, while demand pressure on foreign output is measured by capacity utilization.

The choice of these variables to represent responses in markups to changes in exchange rates does not come from any theoretical maximization problem. Rather, one suspects it comes from its intuitive appeal as well as data availability.

A more common form of data-mining is the inclusion of lagged values of a variable. A lagged *endogenous* variable is added at the estimation state to reduce the probability of autocorrelation and/or a lagged *exogenous* variable is added to account for dynamic interactions.

It stands to reason, therefore, that a good "general" model of exchange rate pass-through can avoid the dichotomy between theoretical models and their empirical counterparts by forging stronger links between the two. If one is truly to account for dynamics or *a priori* beliefs, these concerns ought to be implemented at the theoretical level rather than imposed arbitrarily during the estimation procedure.

This chapter is organized as follows. The next section derives the theoretical model based upon the issues raised in this introduction. Section 3.3 discusses the issues related to the extension of the original model. This includes the rationale for the extension, a brief discussion on contemporary issues surrounding the association between conjectural variations and long-run equilibria of dynamic game theory and nesting possibilities of rival models under various assumptions. Finally, section 3.4 briefly summarizes the chapter.

3.2 Theoretical Model

Given the above criteria, the specified model consists of a rational-expectations dynamic optimization problem, whereby a firm with a differentiated product faces a linear demand curve and quadratic adjustment costs:

$$(3.1) \qquad \underset{(p_{it+\tau})}{Max}\ V_t = E_{t-1}\sum_{\tau=0}^{\infty} b^{\tau}\left[p_{it+\tau}q_{it+\tau} - \left(\frac{C^{*}(q_{it+\tau})}{e_{it+\tau}}\right) - \frac{f}{2}(q_{it+\tau} - q_{it+\tau-1})^2\right],$$

subject to a given p_{it-1} and where E_{t-1} is the mathematical expectations operator, p_t represents the price in Canadian dollars, e_t is the bilateral exchange rate expressed as foreign currency per Canadian dollar, $C^{*}(q_{it+\tau})$ is the foreign cost function, adjustment costs are condensed in the parameter f and b^{τ} is the discount factor. Initially, the linear demand curve is of the form: $q_{it+\tau} = a_i - \alpha_i p_{it+\tau}$; the extension considers strategic price interaction amongst competitors.

The first-order conditions of equation *(3.1)* generate a system of Euler equations that can be solved using standard dynamic optimization techniques:[5]

$$(3.2) \qquad p_{it+\tau+1} = \frac{\lambda_1 a}{f\alpha_i^2\left(1-\frac{1}{\lambda_2}\right)} + \lambda_1 p_{it+\tau} + \frac{\lambda_1}{f\alpha_i}\sum_{j=0}^{\infty}\left(\frac{1}{\lambda_2}\right)^j E_{t+\tau}\left(\frac{C_q^*}{e}\right)_{it+\tau+1+j}$$

$\tau = -1,0,1...$

The firm's marginal cost C_q^*/e expressed in Canadian dollars and the lagged price of the product are the only two explanatory variables in this model.

The distinct roots λ_1 and λ_2 are created from the factorization of:

$$1 + \frac{\Gamma}{b}L + \frac{1}{b}L^2 = (1 - \lambda_1 L)(1 - \lambda_2 L) = 1 - (\lambda_1 + \lambda_2)L + \lambda_1\lambda_2 L^2$$

[5] See Hansen and Sargent [1980], Kennan [1979], and Sargent [1987, Chapter 9] for a comprehensive review of these techniques. In order to solve the second-order difference equations and avoid an "explosive" result, one needs upper and lower boundary conditions. The lower boundary condition is given by the initial level of p_{it-1} whereas the upper boundary condition, known as the terminal or *transversality condition*, is calculated as:

$$\lim_{T\to\infty} \frac{\partial V_T}{\partial p_{it+T}} p_{it+T} = 0 = \lim_{T\to\infty} b^T \left[a_i - \alpha_i(2-\alpha_i f)p_{it+T} + \alpha_i^2 f p_{it+T-1} + \alpha_i \frac{c_q^*}{e_{it+T}}\right] p_{it+T} .$$

The transversality condition will hold if:

(a) $(C_q^*/e)_{it+\tau}$ is of exponential order less than $1/\sqrt{b}$; and

(b) the solution for $p_{it+\tau}$ is of an exponential order less than $1/\sqrt{b}$.

where

$$\Gamma = \left[-\frac{1}{f\alpha_i} - (1 + b)\right]. \tag{3.3}$$

In order to estimate equation *(3.2)*, one must specify a tractable solution for the infinite geometrically declining sums of expected future marginal costs. A popular method is Hansen and Sargent's [1981] approach using the Wiener-Kolmogorov prediction formula. In essence this prediction formula takes advantage of forcing variables which are assumed to be generated by a vector ARMA process. The problem is specified as:

$$y_t = E_t\sum_{j=0}^{\infty} \lambda^j[x_{t+j}\,|\,\Omega_t] \tag{3.4}$$

where λ^j is a scaler and $|\lambda| < 1$, x_t is a p×1 vector of variables, and Ω_t is the relevant information set. If there is a q dimensional stochastic process z_t which generates Ω_t, such that $\Omega_t = \{z_s: -\infty < s \leq t\}$, then current and past values of z capture all the information in Ω_t. Hansen and Sargent [1981, p.256] also note that "As a special case, x_t can be a subvector of z_t". Applying the Wold Decomposition Theorem to the z process and implementing the Wiener-Kolmogorov prediction formula, equation *(3.4)* becomes:

$$y_t = D(L)z_t + F(L)u_t \tag{3.5}$$

where D(L) and F(L) are finite order lag polynomials and u_t is the error term, which is assumed to be orthogonal to Ω_{t-1} and $u_t \in \Omega_t$. If one considers the 'special case' of Hansen and Sargent's [1981] model, the stochastic process of marginal costs (in Canadian dollars) follows an AR(1) process:

$$\left(\frac{C_q^*}{e}\right)_{it} = \rho\left(\frac{C_q^*}{e}\right)_{it-1} + \xi_t \tag{3.6}$$

where ξ_t is white noise and $\rho < 1$.

Taking expectations will eliminate the random error term, and future values can be expressed as:

$$\left(\frac{C_q^*}{e}\right)_{t+j} = \rho^j\left(\frac{C_q^*}{e}\right)_t \tag{3.7}$$

for $j \geq 1$.

Substituting this expression into equation *(3.2)* gives:

$$p_{it+\tau+1} = \frac{\lambda_1 a}{f\alpha_i^2\left(1-\frac{1}{\lambda_2}\right)} + \lambda_1 p_{it+\tau} + \frac{\lambda_1}{f\alpha_i\left(1-\frac{\rho}{\lambda_2}\right)}\left[\frac{C_q^*}{e}\right]_{it+\tau+1}. \tag{3.8}$$

There are two features of equation *(3.8)* which require additional investigation. Firstly, one notes that parameter ρ measures the relative importance of the permanent component of exchange rate movements. Consequently, as perceptions of exchange rate movements change from temporary to permanent $(\rho \rightarrow 1)$, pass-through coefficients become larger. Secondly, the fact that only *contemporaneous* values of (dollar) marginal cost enter the equation is due to the assumption governing the data generating process (DGP) for marginal cost. A one-period lagged value of marginal cost will enter the equation if the DGP is an AR (2) process as opposed to an AR (1).[6]

One of the advantages of selecting a "non-anticipative" representation for sequences of expected future variables is the ease with which one can transform the results into error correction models (ECM). For example, suppose we have the following bivariate autoregressive-distributed lag (ADL) equation:

$$p_t = \alpha p_{t-1} + B_0\left[\frac{C_q^*}{e}\right]_t + B_1\left[\frac{C_q^*}{e}\right]_{t-1} + \xi_t \quad \textit{where} \;\; \xi_t \sim N(0,\sigma_\xi^2)\,. \tag{3.9}$$

We can reparameterize this expression in the form:

$$\begin{aligned}\Delta p_t &= (\alpha - 1)p_{t-1} + B_0\Delta\left[\frac{C_q^*}{e}\right]_t + (B_0 + B_1)\left[\frac{C_q^*}{e}\right]_{t-1} + \xi_t \\ &= B_0\Delta\left[\frac{C_q^*}{e}\right]_t + (\alpha - 1)\left(p - \gamma\left[\frac{C_q^*}{e}\right]\right)_{t-1} + \xi_t\end{aligned} \tag{3.10}$$

[6] Nickell [1985] provides mathematical calculations for other data generating processes including random walks with a drift, random walks with a moving average (MA) error, and second-order autoregressive (AR(2)) with a unit root and drift.

where $\gamma = \{B_0 + B_1 / 1 - \alpha\}$ - the long-run relationship,

B_0 = impact effect,

$(\alpha - 1)$ = feedback effect, and

$(p - \gamma[C^*_t/e])_{t-1}$ = error correction mechanism.

One of the features of an ECM is that it has the ability to isolate short-run dynamics $[\beta_0(\alpha-1)]$, from long-run economic relationships (γ). As such, it satisfies the primary objective of separating short-run dynamic behaviour from long-run equilibrium behaviour. Secondly, one can take advantage of the isomorphism between ECM's and cointegrated variables.[7] Engle and Granger [1987] show that if the variables are nonstationary but cointegrated, there exists an appropriate ECM. Conversely, if an ECM represents an adequate model specification, the variables must be cointegrated.

3.3 Extension to the Model

One of the fundamental assumptions of the original model is that a firm's optimal pricing strategy is independent of competitors' actions. In the automotive industry, however, one observes an oligopolistic market structure.[8] A key feature of oligopolistic industries is a mutual interdependence amongst the behaviour of firms; decisions by one firm prompts other firms to react in some manner. Typically, decisions on whether or how to respond will depend upon the perceived magnitude of threat. Firms may react in a similar fashion (*e.g.*, lower prices to match competitors' reductions in prices), or choose a strategy from a number of alternatives; differentiate their product in some aspect, increase advertising

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[7] Intuitively, if there is a long-run relationship between two (or more) ***nonstationary*** variables, they will be ***cointegrated*** if deviations from the long run are stationary; ***i.e.***, the individual time series profiles drift together (Charemza and Deadman [1993, Chapter 5], Kennedy [1992, Chapter 16] and, Engle and Granger [1991, Chapter 1]). The formal definition is presented in the section on estimation.

[8] For a survey of traditional oligopoly models, see Hay and Morris [1991, Chapter 3], and Thompson and Formby [1993, Chapter 13].

expenses, extend customer service or warranties, *et cetera.*

Given the number of available options, modelling rivals' responses involves the creation of a more complex decision-making process for each firm. Since there is a general lack of data on most of the strategic responses, mutual interdependency is confined to pricing strategies. In particular, one assumes that only changes in rivals' prices will elicit a response. Consequently, the extension accour: s for strategic price interaction between competitors by deriving the optimal pricing strategy subject to a new demand curve:

$$q_{it+\tau} = a_i - \alpha_i p_{it+\tau} + \sum_{j \neq i} \beta_j p_{jt+\tau}. \tag{3.11}$$

With this new specification, it is clear that calculation of the second-order difference equations as well as the transversality conditions requires the use of *conjectural variations* (CVs); namely $\partial p_{jt+\tau}/\partial p_{it+\tau}$ Despite the criticisms of adopting a conjectural variation approach (Friedman [1983, p.110]) to oligopolistic game-theoretical issues, it remains a popular choice, particularly for applied work (Dixit [1988], Eaton and Grossman [1986], Herguera [1994]). In its defense, it can be argued that the use of CVs enables relatively easy comparison of Cournot-Nash, Bertrand-Nash, and perfectly collusive behaviour.

However, the debate surrounding the validity of CVs as an appropriate assumption governing firms' behaviour is typically discussed within the context of a static framework. In a recent paper, Dockner [1992, p.378] examines the relationship between the long-run equilibrium of a dynamic game and the conjectural variation equilibrium of a corresponding static game:

> It turns out, that the steady state closed-loop (subgame-perfect) equilibrium of the dynamic game coincides with a static conjectural variations equilibrium with nonzero conjectures. Hence, in the limit, if the steady state closed-loop equilibrium is stable, it is *possible* and *justified* to interpret a conjectural variations equilibrium as the outcome of dynamic strategic interactions. With the simplifying assumptions of linear demand and quadratic costs we are able to sharpen our predictions. In this case, the steady state closed-loop (subgame-perfect) equilibrium of the asymmetric dynamic game corresponds to a conjectural variations equilibrium with *constant* and *symmetric* conjectures. This result suggests that it is not only possible to relate conjectural variations to dynamic competition, but also to justify the choice of constant and symmetric conjectures across firms as they correspond to firms' equilibrium behaviour [emphasis in original].

Moreover, if adjustment costs and/or discount rates change, *ceteris paribus*, there will be different steady state values of the closed-loop game giving different (endogenous) conjectures. Dockner also shows that the greater the adjustment cost parameter, the closer an industry approaches static Cournot behaviour.

Therefore, maximizing:

$$(3.1) \qquad \underset{(p_{it+\tau})}{Max}\ V_t = E_{t-1}\sum_{\tau=0}^{\infty} b^{\tau}\left[p_{it+\tau}q_{it+\tau} - \left(\frac{C^{*}(q_{it+\tau})}{e_{it+\tau}}\right) - \frac{f}{2}(q_{it+\tau} - q_{it+\tau-1})^2\right],$$

subject to:

$$(3.11) \qquad q_{it+\tau} = a_i - \alpha_i p_{it+\tau} + \sum_{j \neq i} \beta_j p_{jt+\tau}.$$

leads to the following optimal decision rule:[9]

[9] See Appendix A for the complete derivation.

(3.12)
$$p_{it+\tau+1} = \left[-\frac{\lambda_1 a}{f\alpha_i \phi_{it+\tau}\left(1-\frac{1}{\lambda_2}\right)} + \frac{\lambda_1}{f\alpha_i}\sum_{k=0}^{\infty}\left(\frac{1}{\lambda_2}\right)^k E_{t+\tau}\left(\frac{C_q^*}{e}\right)_{it+\tau+1+k} + \lambda_1 p_{it+\tau}\right]$$
$$+ \frac{1}{\alpha_i}\sum_{j\neq i}\beta p_{jt+\tau+1} - \frac{\lambda_1}{\alpha_i}\sum_{j\neq i}\beta p_{jt+\tau} - \frac{\lambda_1}{f\alpha_i^2}\sum_{k=0}^{\infty}\left(\frac{1}{\lambda_2}\right)^k E_{t+\tau}\left(\sum_{j\neq i}\beta p_{jt+\tau+1+k}\right)$$

where,

(3.13)
$$\phi_{it+\tau} = \frac{\partial q_{it+\tau}}{\partial p_{it+\tau}} = -\alpha_i + \sum \beta_j \frac{\partial p_{jt+\tau}}{\partial p_{it+\tau}}.$$

In this case, competitors' past, current, and expected future prices have an effect on the pricing decisions of each firm. As a result, one needs to specify the solution for the infinite geometrically declining sums of expected future prices for each competitor, in addition to the solution for expected future marginal costs. Once again, if one assumes the 'special case' of the Wiener-Kolmogorov prediction formula whereby competitors prices follow an AR (1) data-generating process:

(3.14)
$$p_{jt+\tau} = \delta p_{jt+\tau-1} + \xi_{t+\tau},$$

where ξ_t is white noise and $\delta < 1$.

Taking expectations will eliminate the random error term, and future values can be expressed as:

(3.15) $$p_{jt+\tau} = \delta^{\tau} p_{jt}$$

for $\tau \geq 1$.

Substituting this expression into equation *(3.12)* gives:

(3.16) $$p_{it+\tau+1} = \left[- \frac{\bar{\lambda}_1 a}{f\alpha_i \phi_{it+\tau}\left(1 - \frac{1}{\bar{\lambda}_2}\right)} + \bar{\lambda}_1 p_{it+\tau} + \frac{\bar{\lambda}_1}{f\alpha_i\left(1 - \frac{\rho}{\bar{\lambda}_2}\right)} \left(\frac{C_q^*}{e}\right)_{it+\tau+1} \right] + \left(\frac{1}{\alpha_i} - \frac{\bar{\lambda}_1}{f\alpha_i^2\left(1 - \frac{\delta}{\bar{\lambda}_2}\right)}\right) \sum_{j \neq i} \beta_j p_{jt+\tau+1} - \frac{\bar{\lambda}_1}{\alpha_i} \sum_{j \neq i} \beta_j p_{jt+\tau}$$

where $\bar{\lambda}_1$, $\bar{\lambda}_2 = f(\phi_{it+\tau})$.

One of the appealing features of the extension is its ability to "nest" or "encompass" the original non-interactive model.[10] If, for example, *all* $\beta_j = 0$, then not only will each of the terms outside the square brackets equal zero, but $\phi_{it+\tau} = -\alpha_i$ such that the term inside the square brackets is identical to equation *(3.8)*. In other words, the linear demand function reverts to its original specification. On the other hand, however, even if each of the competitors is playing a Bertrand game such that all conjectural variations are equal to zero $(\partial p_j/\partial p_i = 0, j \neq i)$, it is possible that the original version and the extension will differ.

[10] Although the terms "nest" and "encompass" are frequently used interchangeably, there exists a number of encompassing procedures which enable separate rival models to be compared even though neither model is a nested version of the other (Charemza and Deadman [1993, Chapter 8]).

The following table lists the theoretical comparisons of the rival models under various assumptions concerning values of β_j and conjectural variations:

TABLE 3-1

Comparing Coefficients between Original Model (3.8) and Extension (3.16)

	$\frac{\partial p_j}{\partial p_i} = 0$	$\frac{\partial p_j}{\partial p_i} \neq 0$
$\beta_j = 0$	identical equations (3.2)	identical equations (3.2)
$\beta_j \neq 0$	identical constant term, lagged p_i coefficient, and exchange rate pass-through coefficient $(\tilde{\lambda}_i = \lambda_i)$	all parameters differ

By definition, therefore, the exchange rate pass-through coefficients will differ between the two versions if $\beta_j \neq 0$ *and* firms believe that competitors will match some fraction of its own price changes (*i.e.*, non-Bertrand games).

3.4 Summary

The theoretical model derived in this chapter is based upon three major considerations. Firstly, there is a need to incorporate both demand and supply influences on a firm's exchange rate pass-through behaviour. Secondly, theoretical specifications should have a legitimate, compatible and tractable econometric solution, rather than estimating in an *ad hoc* manner. Thirdly, the model should be able to distinguish short-run dynamic behaviour from long-run equilibrium relationships. A dynamic optimization model based upon behaviour consistent with rational expectations theory, along with a linear demand curve and adjustment costs addresses each of the pertinent issues. The resulting partial adjustment model can be respecified as and error correction model (ECM). The advantage of ECM estimation is that it separates long-run relationships from short-run dynamics.

The extension to the model accounts for the possibility of strategic price interaction between competitors. It "nests" the original model and a table of restrictions indicates how parameters differ, if at all, under the two models. Moreover, as the following chapter on estimation explains, the extension can also be used to "nest" competing econometric methodologies.

CHAPTER 4

EMPIRICAL METHODOLOGY

4.1 Introduction

In spite of recent advancements in econometrics, particularly within the time series literature, there is relatively little agreement on how applied econometricians ought to proceed with their research agendas (Gerrard [1995], Gilbert [1986], Pagan [1987], Pagan and Wickens [1989], and Phillips and Loretan [1991]). Gerrard [1995] alleges that the emergence of different econometric methodologies reflects the general methodological dissent in economics. Using Blaug's [1992, p. xii] definition of methodology,

> ...a study of the relationship between theoretical concepts and warranted conclusions about the real world; in particular, methodology is that branch of economics where we examine ways in which economists justify their theories and the reasons they offer for preferring one theory over another.

he argues that there are two conflicting approaches on the subject of methods of theory appraisal: deductivism and empiricism. Deductivism takes an axiomatic approach; policy implications of economic theory are correct if they are deduced from axioms in a logically consistent fashion.[1] The "truth-status" of an axiomatic approach, therefore, ***can not*** be refuted by empirical evidence. Empirical evidence merely determines the applicability of economic theory to specific situations. Moreover, this applicability is based on the presumption that significant transitory effects, which often are omitted from the theory, are not present. Blaug [1992] labels this approach to empirical investigation as "verificationism".

At the other end of the spectrum, proponents of empiricism insist that the "truth-status" of any economic theory should be consistent with the observed data. Economic theories are accepted if the

[1] Axioms are assumed to be self-evident truths. The deductivism view has it roots in works by John Stuart Mill [1836].

empirical evidence is unable to reject the implications of the theories. Under this approach, theories should be presented as potentially falsifiable.

The role of empirical evidence differs significantly under these two methods of theory appraisal. Deductivism relegates empirical investigation to a secondary role, preferring to accept economic theories based upon their axiomatic and logical merits. In contrast, empiricists accept theories solely on the basis of their congruence with the empirical evidence.[2] It is not surprising, therefore, to find these two distinct approaches as philosophical foundations for alternative econometric methodology. Each of the following three prominent methodologies exhibit a deductivism or empiricism bias: the classical linear model (CLR); Sims' [1980] atheoretical vector autoregression (VAR) time series model; and the London School of Economics (LSE) approach.

The CLR model is the traditional (North American) textbook technique towards applied econometrics. Economic theory provides the *deterministic* portion of the econometric model. A random error term captures the *stochastic* portion of the model which may arise if variables are omitted, variables are not measured with accuracy, and/or there is an inherent randomness in human behaviour. A random term with all the appropriate properties (expected mean value of zero, constant variance, and no serial correlation) ensures that the estimators have the desirable properties of unbiasedness, asymptotic efficiency, and asymptotic consistency. After the initial estimation, diagnostic tests are conducted in order to assess the performance of the model. Wrong theoretical signs, statistically insignificant parameters and/or serial correlation, among other problems, each justify a respecification of the model.

Typically, respecification either introduces new variables and/or employs different estimation techniques. For example, a low Durbin-Watson (DW) statistic may be interpreted as an omission of variables problem; in which case a new variable is added. Alternatively, a low DW statistic might be

[2] A model is deemed "congruent" with the evidence if diagnostic tests indicate that it passes a series of specific criteria.

construed as evidence of positive serial correlation; in which case a researcher might re-estimate using the Cochrane-Orcutt procedure. This respecification procedure illustrates both the *ad hoc* and path-dependent nature of the CLR approach.

The CLR methodology is based upon the deductivism view. The initial econometric model is assumed to be correct. Poor diagnostics indicate estimation rather than theoretical problems. As Gerrard [1995 p.230] articulates, the CLR approach:

> ...immunizes economic theory from empirical criticism by interpreting anomalous evidence as an estimation problem, not a potential falsification of the model specified by economic theory.

On the other hand, Sims' [1980] atheoretical time series approach advocates the empiricist view. Sims methodology is based upon the argument that there are few, if any, truly exogenous variables; all variables are inevitably interdependent. Given that all variables are endogenous, a simultaneous equations model using the CLR approach imposes "incredible" restrictions on the system. Moreover, equations can only be estimated if the regressors are lagged values of the endogenous variables. Consequently Sims suggests a VAR approach whereby each variable is a function of its own lagged value and lagged values of all other variables in the system.[3] Therefore, VARs represent *reduced-form* equations without restrictions imposed by economic theory. The objective is to derive a parsimonious representation of the model - through data-driven restrictions - which is consistent with the data. Once an adequate representation is accepted, theoretical implications can be tested using the estimated VARs.

This methodology has been criticized on several fronts. The testing of competing economic theories is suspect, given that one is dealing with reduced-form equations rather than structural equations. Cooley and LeRoy [1985] argue that VARs are not suitable for testing exogeneity nor are they appropriate for

[3] See Cooley and LeRoy [1985], Runkle [1987], and Spencer [1989] for explanations, criticisms, and controversy surrounding the VAR methodology.

policy evaluation. However controversial, the VAR methodology remains a popular choice for econometric estimation; apart from its appeal to those who favour the empiricist philosophy, VARs have an excellent forecasting record against competing simultaneous equations estimators.

Although Sargan [1961;1964;1980;1983] provides the foundation, it is Hendry's [1993] "general-to-specific" methodology which brings the LSE tradition to prominence. In brief, the LSE methodology lies somewhere between the deductivism approach to CLR estimation and the empiricism approach to atheoretical estimation.

Similar to Sims' methodology, the LSE approach starts from a general model with the maximum number of regressors and the longest possible lag values for any given data constraint. Once again, the modelling strategy is to pare down the number of regressors (and lags) through diagnostic tests. Unlike Sims' approach, and more in line with CLR estimation, the models are *structural* in nature, relying on economic theory to provide the long-run causality relationships. For example, the models frequently take an error correction form whereby long-run equilibria is dictated by economic theory and short-run dynamics are data-driven. However, the modelling process of the LSE approach is considered a misspecification problem, while the CLR approach treats it as an estimation problem. The objective is to continue respecifying until the model achieves congruency. Hendry's criteria for congruence are:[4]

(i) data coherence;
(ii) data admissible functional forms;
(iii) theory consistent models;
(iv) parameter constancy;
(v) rival model encompassing.

Although not without its critics (see Darnell and Evans [1990]), the appeal of this approach is its ability to provide a balance between deductivism and empiricism (Gerrard [1995, p.232]):

> Overall the LSE approach, as formalized in Hendry's general-to-specific methodology, offers a practical implementation of the scientific (falsificationist) method. Economic

[4] See Kennedy [1992, p.83] for a detailed explanation on these criteria.

theory and empirical evidence interact in a meaningful way in the search for good empirical models.

This thesis employs, to a certain degree, elements of each of these three methodologies. The reason for selecting different methodologies is three-fold. Firstly, as stated in the introduction, one of the central objectives of this thesis is to bridge the gap between theoretical models and the associated empirical methodology. Estimation procedures are more intuitively appealing if the links to theoretical foundations are clearly delineated. For example, and notwithstanding potential non-stationary data problems, certain static profit-maximizing models of exchange rate pass-through (Athukorala and Menon [1994], Hooper and Mann [1989], Khosla [1991], Knetter [1989;1993], Mann [1986], and Menon [1993b]) naturally lend themselves to CLR estimation given the fact that all contemporaneous regressors are considered exogenous. Similarly, dynamic optimization models, such as the model specified in this thesis, are also predisposed to CLR estimation providing the only difference is the inclusion of lagged endogenous (*i.e.*, pre-determined) variables and/or lagged exogenous variables.

In contrast, if some of the contemporaneous regressors are endogenous variables, OLS single-equation estimation or multiple-equation estimation (*e.g.*, Zellner's [1962] seemingly unrelated regressions (SUR)) is no longer valid.[5] The problem is simultaneous equation bias; endogenous variable regressors become contemporaneously correlated with the error terms. The traditional response is to solve the system in its reduced form and extract structural parameters from these estimates. Apart from the possibility of encountering identification difficulties (*i.e.*, the inability to derive unique structural parameters from the reduced-form parameters), this approach also suffers from the general criticism of CLR modelling expressed earlier. An alternative solution would be to express the system of equations as a VAR or adopt an approach similar to the LSE methodology. Given that the *extension* to the theoretical model in this thesis includes prices of competing automobiles as regressors, it is fitting to estimate the model using

[5] Exceptions are the highly restrictive recursive systems (see Kennedy [1992, p.164]).

different methodologies; one under the assumption that competing prices are exogenous, and another under the assumption that they are endogenous.

Secondly, different methodologies are chosen to determine whether one econometric modelling technique encompasses the other(s). The proposition is analogous to the concept of model-nesting. If, for example, the extension to the model assumes the presence of contemporaneously endogenous regressors and a general-to-specific LSE or VAR approach eliminates all these endogenous regressors, the accepted model contains exogenous regressors only. As a result, LSE/VAR modelling strategies confirm the econometric specification of CLR models (*i.e.*, CLRs encompass LSEs/VARs). Conversely, an initial CLR model specification which results in poor diagnostic tests requires a respecification of both the theoretical and empirical model. If the solution is to include additional variables, an alternate method of estimation is essential if the new variables in question are endogenous.

Finally, by selecting different approaches, one can compare one's results with a greater collection of previous work in exchange rate pass-through. In some cases, different methodologies *may* produce identical results. It is possible for certain parameters estimates to be robust across different specifications; in spite of separate philosophical foundations. However, it can also be the case that different methodologies produce quite different results. In such cases, the question is whether *relative* results remain valid. For example, suppose pass-through for Japanese exports of large automobiles to Canada is estimated to be 60% under a CLR-type model but only 25% under a LSE model. Even if the nominal figures are (statistically) significantly different, the question to ask is whether both methodologies indicate that Japanese exporters are *relatively* more reluctant to pass-through changes in exchange rates than their competitors. In this sense, the use of different methodologies can help to corroborate certain conceptions about exchange rate pass-through behaviour even though individual parameter estimates differ.

This chapter is organized as follows. The next section (4.2) reviews the estimation techniques applied in the thesis. Following the classification in Phillips and Loretan [1991, p.415], the first part reviews the unrestricted regressions approach (CLR) using Recursive Least Squares (RLS) and R^{th}-order Autoregressive Least Squares (RALS).[6] The second part reviews the estimation procedure for unit root regressions. The last part examines the techniques of the Engle-Granger representation and the Johansen procedure under the general heading of restricted regressions. The final section (4.3) outlines static and dynamic forecasting procedures.

4.2 *Estimation Techniques*

I. *Unrestricted Regressions*

The first modelling procedure starts from the premise that none of the basic assumptions governing the CLR model is violated. As a result, for a linear regression model of the form:

$$(4.1) \qquad y = X\beta + \mu, \qquad E[\mu\mu'] = \sigma^2 I,$$

then the Gauss-Markov Theorem (Davidson and MacKinnon [1993, p.159]) states that:

> The OLS estimator $\hat{\beta} \equiv (X'X)^{-1}X'y$ of the parameters of β of the linear regression model is the **best linear unbiased estimate** or **BLUE** for short. This means that if $V(\hat{\beta})$ is the covariance of $\hat{\beta}$ under a DGP belonging to the model (4.1), and $V(\breve{\beta})$ is the covariance matrix of any other unbiased estimator $\breve{\beta}$, linear in the vector y, then $V(\breve{\beta})$ - $V(\hat{\beta})$ is a positive semidefinite matrix.

Following the theoretical implications of the dynamic optimization problem, the model is initially estimated as:

[6] Phillips and Loretan [1991, p.415] define "unrestricted" regressions as those which are not restricted by the imposition of unit roots. Similarly, "restricted" regressions are restricted by the imposition of unit roots.

$$p_{it} = \beta_{0i} + \beta_{1i}p_{it-1} + \beta_{2i}\left[\frac{C_q^*}{e}\right]_{it} + \epsilon_{it} \tag{4.2}$$

where β_{1i} = elasticity of the import price (in Cdn. \$) with respect to the last periods price, and

β_{2i} = elasticity of the import price (in Cdn. \$) with respect to marginal cost (in Cdn. \$).[7]

Apart from providing the price elasticity of marginal cost, β_{2i} also captures the pass-through (PT) effect. Note, however, the theoretical imposition of symmetry between the exchange rate and the marginal cost in foreign currency. In effect, this implies that the pricing behaviour of an exporter will be identical regardless of where he faces, say, a 5% increase in marginal costs (expressed in source-country currency) or a 5% exchange rate appreciation. Since all variables are expressed in log form, this restriction is tested by separating the two variables:

$$p_{it} = \beta_{0i} + \beta_{1i}p_{it-1} + \beta_{2i}C^*_{q\,it} + \beta_{3i}e_{it} + \epsilon_{it}, \tag{4.3}$$

and applying a Wald test $(\beta_{2i} + \beta_{3i} = 0)$.

Equations (4.2) and (4.3) are estimated using a variation of OLS called recursive least squares (RLS).[8] To illustrate the concept of recursive estimation, suppose one examines the case of a single equation:

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[7] In all equations, the i subscript refers to the i^{th} country. Given data restrictions on individual firms, one assumes that there is one firm per country. Each country has three potential regressions depending on data availability; subcompacts, compact/mid-size and large automobiles. The subscript denoting this specific category is deliberately omitted to avoid cluttering the notation.

[8] Initial estimations were run on Doornik and Hendry's PC-GIVE (Version 7) econometric software package.

$$y_t = \beta' x_t + \mu_t \tag{4.4}$$

where β is assumed constant and μ_t represents white noise. If one selects a sub-sample t from the complete sample period (1...T), the least squares estimate for the parameters is:

$$\hat{\beta}_t = \left(X_t' X_t\right)^{-1} X_t' Y_t \; ; \qquad X_t = \left(x_1 \ldots x_t\right), \quad Y_t = \left(y_1 \ldots y_t\right). \tag{4.5}$$

Increasing the sample size by an additional observation requires the calculation of new matrices:

$$\begin{aligned} X_{t+1}' X_{t+1} &= X_t' X_t + x_{t+1} x_{t+1}' \, , \\ X_{t+1}' Y_{t+1} &= X_t' Y_t + x_{t+1} y_{t+1} \, . \end{aligned} \tag{4.6}$$

However, the calculation of $\hat{\beta}_{t+1}$ does not require the inversion of the $(X_{t+1}'X_{t+1})$ matrix. Instead:

$$\left(X_{t+1}' X_{t+1}\right)^{-1} = \left(X_t' X_t\right)^{-1} - \frac{\lambda_{t+1} \lambda_{t+1}'}{\left(1 + \lambda_{t+1}' x_{t+1}\right)} \, , \tag{4.7}$$

where $\lambda_{t+1} = (X_t'X_t)^{-1} x_{t+1}$. As a result, sequential estimates of $\hat{\beta}_{t+1}$ parameters requires only a minimal increment in computational complexity. Similarly, an updating formula for the residual sum of squares (RSS) is calculated as:

$$RSS_{t+1} = RSS_t + \frac{v_{t+1}^2}{\left(1 + \lambda_{t+1}' x_{t+1}\right)} \, , \tag{4.8}$$

where $v_t = y_t - x_t'\hat{\beta}_{t-1}$. Following the calculations of RSS_{t+1}, one can derive the standard error of the estimate and the standard errors of all parameters:

$$\hat{\sigma}_{t+1} = \sqrt{\frac{RSS_{t+1}}{t - k + 1}}\,,$$

(4.9)

$$s.e.(\hat{\beta}_{t+1}) = \frac{\hat{\sigma}_{t+1}}{\sqrt{(X_{t+1}'X_{t+1})}}\,.$$

Combining sequences of RSS_t and associated sequences of $\hat{\beta}_t$, one can calculate Chow [1960] tests for parameter constancy evaluation. Part of the appeal of PC-GIVE lies in its recursive procedures as a means to accept/reject the Lucas critique (Lucas [1976]), since the resulting statistics enable the researcher to investigate issues of parameter constancy and super exogeneity (Favero and Hendry [1992]).[9]

In an effort to reveal other potential econometric problems, the following set of diagnostic tests are conducted:

(i) Hansen test - based on Hansen [1992], a parameter *instability* statistic is computed for all β_i's and σ^2. Non-constant parameters (* or **) reveal weak models;

(ii) LM [(χ^2(r)] - Lagrangian Multiplier test for r^{th} order residual correlation under H_0: no autocorrelation;

(iii) ARCH [(χ^2(r)] - AutoRegressive Conditional Heteroscedasticity test is essentially an LM test for autocorrelated *squared* residuals;

(iv) Bera-Jarque [(χ^2(r)] - based on Jarque and Bera [1980], a statistic is constructed to determine whether or not the distribution of the residual is *normal*. This joint test verifies that the skewness (3rd "moment") and the excess kurtosis (4th "moment") are zero; hence the null is a normal distribution;

[9] PC-GIVE provides a visual representation of parameter constancy by graphing the sequences of β_t (±2*s.e.), RSS_t, v_t (±2*s.e.), and scaled (5% critical values) Chow tests.

(v) White test - based on White [1980], this is a test for heteroscedasticity. The null is homoscedasticity against an alternative which specifies a variance dependent upon the original regressors as well as their squared values;

(vi) Wald test - a test for symmetry between the exchange rate and the marginal cost expressed in foreign currency;

(vii) RESET test - based on Ramsey [1969], this is a test for model misspecification. The null is correct specification against an alternative that powers of the dependent variable (i.e., $\hat{p}_t^2, \hat{p}_t^3$,...) have been omitted.

In the event that these tests reveal serious autocorrelation problems, the equation is re-estimated using a technique called r^{th}-order autoregressive least squares (RALS). RALS is a technique which assumes that autocorrelated residuals are the result of an autoregressive error process which, in turn, arises whenever a dynamic process has common factors in its lag polynomials (COMFAC models). Doornik and Hendry [1994, p.217] argue that:

> Perhaps the greatest *non sequitur* in the history of econometrics is the assumption that autocorrelated residuals entail autoregressive errors as is entailed in 'correcting serial correlation using Cochrane-Orcutt'. Dozens of misspecifications in time series data will induce residual autocorrelation without corresponding to common factors in the lag polynomials of the underlying general model (emphasis in original).

To illustrate Doornik and Hendry's [1994] point, suppose we have the following simple first-order polynomial lag:

$$(4.10) \qquad y_t = \alpha_1 y_{t-1} + \beta_0 x_t + \beta_1 x_{t-1} + \mu_t ,$$

where μ_t is white noise. This equation can be rewritten as:

(4.11)
$$(1 - \alpha_1 L)y_t = \beta_0\left(1 + \frac{\beta_1}{\beta_0}L\right)x_t + \mu_t \,.$$

If the roots are equal at this lag length (*i.e.*, 1) such that:

(4.12)
$$\alpha_1 = -\frac{\beta_1}{\beta_0} \qquad or \qquad \beta_0\alpha_1 + \beta_1 = 0 \,,$$

they will cancel each other and equation (4.11) becomes:

(4.13)
$$y_t = \beta_0 x_t + \frac{\mu_t}{(1 - \alpha_1 L)} \,.$$

Replacing α_t with the more traditional notation of ρ, we have:

(4.14)
$$y_t = \beta_0 x_t + \epsilon_t \,; \qquad \epsilon_t = \rho\epsilon_{t-1} + \mu_t \,.$$

Doornik and Hendry [1994] argue that estimations of equation (4.14) which produce tests showing that $\rho \neq 0$ does not prove that there are valid common factor restrictions. In fact, they claim that the order of testing should be to investigate the validity of common factors first followed by a test of the null hypothesis, H_o: $\rho = 0$. Otherwise, if no common factors are found, and $\rho \neq 0$, the model is misspecified and a Cochrane-Orcutt correction of the model is not a legitimate procedure.

In terms of the methodology, RALS minimizes:

$$\sum_{t=1}^{T} \mu_t^2 = f(\beta,\rho) \ . \tag{4.15}$$

This leads to a non-linear least squares problem which necessitates an iterative solution. Although the default for the autocorrelation order is "data-frequency + 1" (*e.g.*, 5, for quarterly data), users can set the order and specify the maximum number of iterations, convergence tolerance, and whether to minimize *f(β,ρ)* sequentially over the order or with respect to the highest order.

The extension to the original model accounts for possible strategic price interaction between competitors. Accordingly, theoretical implications of the dynamic optimization problem requires estimation in the form:

$$p_{it} = \gamma_{0i} + \gamma_{1i}p_{it-1} + \gamma_{2i}\left(\frac{C_q^*}{e}\right)_{it} + \gamma_{3i}\sum_{j\neq i} \beta_j p_{jt} + \gamma_{4i}\sum_{j\neq i} \beta_j p_{jt-1} + \mu_{it} \ . \tag{4.16}$$

Following the identical format for the initial model, equation (4.16) is estimated using RLS. If equations exhibit autocorrelation, they are tested for common factors and re-estimated using the RALS procedure. Once again, the theoretical imposition of symmetry between the exchange rate and the marginal cost expressed in foreign currency is tested by separating the two variables:

$$p_{it} = \gamma_{0i} + \gamma_{1i}p_{it-1} + \gamma_{2i}C_q^* + \gamma_{3i}e_{it} + \gamma_{4i}\sum_{j\neq i} \beta_j p_{jt} + \gamma_{5i}\sum_{j\neq i} \beta_j p_{jt-1} + \mu_{it} \tag{4.17}$$

and applying a Wald test ($\gamma_{2i} + \gamma_{3i} = 0$).

II. Stationarity, Unit Roots, and Cointegration

Until recently, traditional econometric analysis assumed that variables of interest were stationary.[10] If not, stationarity was assumed to be the result of a deterministic trend and removal of this trend would render the process stationary. However, with the seminal paper by Nelson and Plosser [1982], and supported by Perron [1988, p.325]:

> It appears, indeed, that the nonstationarity of most macroeconomic variables is best construed as stochastic rather than deterministic.

As a result, Student-t statistics no longer display asymptotically normal distributions (Stock and Watson [1988]), and statistical inferences arising from regressions containing stationary variables are misleading.[11] To avoid this problem, time series analysis now incorporates ***unit root*** procedures to determine the presence of stationarity by examining the data generating processes (DGP's) for each variable. If the levels are not stationary, additional unit root tests are employed to determine the exact order of integration: a nonstationary time series is considered to be integrated of the order d, or I(d), if differencing the series d times is sufficient to transform it into a stationary series.

The original unit root tests proposed by Dickey and Fuller [1979] (DF) consist of estimating the following regression:

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[10] ***Strictly*** stationary processes have properties (*i.e.*, all"moments") which are invariant to a change in the time origin; the conditional and joint probability density distributions at times $t_1, t_2, \ldots, t_n$ are identical for times $t_{1+k}, t_{2+k}, \ldots t_{n+k}$. ***Weakly*** stationary processes, on the other hand, only assume that the first two moments (mean, variance) remain constant and covariances depend only on the time difference k. See Harvey [1991, Chapter 1] and Mills [1991, p.64-65] for more details.

[11] Granger and Newbold [1974] and Granger [1986] document the ambiguous statistical properties of regressions containing nonstationary time series data.

(4.18) $$\Delta y_t = \delta y_{t-1} + \epsilon_t ,$$

where ϵ_t is white noise, and testing the null hypothesis H_0: $\delta = 0$, against the alternate, H_1: $\delta < 0$. Rejection of the null hypothesis of a unit root implies that y_t is integrated of order zero (I(0)). If the null hypothesis is true, it is clear that one is regressing a nonstationary variable (y_{t-1} is I(1)) onto a stationary variable (Δy_t is I(0)) such that the Student-t statistic does not have its asymptotic normal distribution. This distribution is not known with certainty and a number of authors (Fuller [1976], Guilkey and Schmidt 1989], and Davidson and MacKinnon [1993]) present Monte-Carlo simulated results of their τ and or z statistics.[12] In addition, these statistics will vary depending on the specification of equation (4.18); the presence of a deterministic trend and/or time trend will generate different values for τ and z.

If, however, the null hypothesis is not rejected, it may be the case that y_t is integrated of a higher order or perhaps it is not integrated at all. Therefore, to explore the possibility that y_t is I(1), one simply takes the first difference of (4.18):

(4.19) $$\Delta\Delta y_t = \delta \Delta y_{t-1} + \epsilon_t ,$$

and tests for the null hypothesis that unit roots exist. If the null hypothesis is now rejected, the differenced time series Δy_t is I(0) indicating that the variable in its level form, y_t, is I(1). Higher orders of integration can be tested in a similar fashion.

One of the criticisms of the DF tests is that it does not address the issue of potential problems associated with serial correlation. If ϵ_t is not white noise, regressors will be correlated with the error

[12] The τ statistics are derived from a test which is computed in the same manner as the regular t statistic for $\delta = 0$ whereas the z statistic comes from a test which is computed using the *estimated* parameter $\hat{\delta}$.

terms ($E(y_{t-1}\epsilon_t) \neq 0$) such that OLS is no longer BLUE. Dickey and Fuller's [1981] solution to this problem is to include lagged values of the left-hand side variable as a proxy of autocorrelation. The ensuing Augmented Dickey-Fuller (ADF) specification of equation (4.18) is:

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta y_{t-i} + \epsilon_t . \tag{4.20}$$

The choice of lag values (k) for Δy_{t-i} depends upon two criteria. It should be sufficiently small, in order to maximize the degrees of freedom, yet it should be large enough to ensure that the error term ϵ_t is white noise.

However, given the fact that any additional regressors will, by definition, reduce the degrees of freedom, the ADF approach to unit roots will have a reduced "power of the test".[13] Perron [1988] and Phillips [1987] (PP) suggest a non-parametric adjustment of the DF test statistic. Perron [1988] argues that the asymptotic (as well as finite sample) distribution of the test statistic(s) depends upon the correlation pattern of the residuals. In particular, the distributions depend on the ratio of $\sigma^2/\sigma_\epsilon^2$, where:

[13] The "power of the test" is defined to be the probability of ***not*** making a Type II error or the probability of rejecting a false (null) hypothesis. Therefore, a low power of the test implies a high probability of accepting a false hypothesis. In the case of unit root tests, the null hypothesis is H_0: a unit root exists.

(4.21)

$$\sigma^2 = \lim_{T\to\infty} \frac{E(S_T^2)}{T} \quad , \quad S_T = \sum_{j=1}^{T} \epsilon_j$$

$$\sigma_\epsilon^2 = \lim_{T\to\infty} \frac{\sum_{j=1}^{T} E(\epsilon_j^2)}{T}$$

If the errors are such that $\sigma^2 = \sigma_\epsilon^2$, the asymptotic distributions of the test statistics are invariant to the structure of the innovations. Perron [1988, p.307] shows that this condition will hold if the errors are independently, identically, distributed $(0,\sigma^2)$ or if they are martingale differences (with minor conditions) and states that:

> ...the purpose of the transformation is to obtain a test statistic whose limiting distribution is independent of the nuisance parameters σ_ϵ^2 and σ^2. In effect, the proposed statistics change the original regression statistics by using sample information on the values of σ_ϵ^2 and σ^2 to account for additional correlation in the innovations.

In order to derive a consistent estimator of σ^2 and σ_ϵ^2, Perron adopts the Newey and West [1987] estimator:

(4.22)

$$\hat{\sigma}^2 = \frac{\sum_{t=1}^{T} \epsilon_t^2}{T} + 2\,\frac{\sum_{s=1}^{l} \omega(s,l) \sum_{t=j+1}^{T} \epsilon_t \epsilon_{t-j}}{T}$$

where

(4.23)

$$\omega(s,l) = 1 - \left(\frac{s}{l+1}\right)$$

represents a lagged weighting scheme of the correlation pattern of the residuals.

In short, modification of the test statistic accomplishes three objectives. It removes the effect of autocorrelation on the asymptotic distribution, it retains the original level of degrees of freedom and it has the identical asymptotic critical values as those tabulated in the DF approach. As a comparison between the ADF versus the PP approach, Perman [1991,p.10] discusses the relevance of each test:

> Where uncertainty exists regarding the dynamic structure of the time series in question, and where the random component may be non-white noise in quite general ways, the Phillips and Perron tests can be superior. In particular, the power of DF/ADF tests is likely to be low for series where moving-average terms are present or where the disturbances are heterogeneously distributed; the non-parametric adjustments are likely to raise the power of the tests in these circumstances.

The literature on unit root tests continues to develop; in part due to the importance of nonstationary problems in applied econometrics and in part due to the conviction that current unit root tests still have low power. For the purpose of this thesis, only ADF and PP unit tests are performed.

Generally speaking, if *two* variables, X_t and Y_t are both I(d), a linear combination of the two creates a third variable, Z_t, which is also I(d). Similarly, linear combinations of two variables with *different* orders of integration produce a third variable which is integrated to the higher order of the two variables; the variance of the higher order dominates. However, there are cases where linear combinations of two I(d) variables result in an I(0) variable. If such cases exist, the variables in question are said to be ***cointegrated***.[14] In this simple example, if X_t and Y_t, are both I(1), such that:

$$Z_t = Y_t - \lambda X_t \tag{4.24}$$

[14] For a technical approach to cointegration and the econometric analysis of nonstationary data, see Banerjee *et al* [1993]. For basic surveys of cointegration, unit roots and dynamic models, see Dickey *et al* [1991], Dolado *et al* [1990], Holden and Thompson [1992], and Muscatelli and Hurn [1992].

and Z_t is I(0). X_t and Y_t, are cointegrated with $[1,-\lambda]$ representing the *"cointegrating vector"*.[15] Formally, we can introduce the concept from Engle and Granger [1987, p.253]:

> Definition: The components of the vector x_t are said to be *co-integrated of order d,b* denoted $x_t \sim CI(d,b)$, if (i) all components of x_t are I(d); (ii) there exists a vector $\alpha(\neq 0)$ so that $z_t = \alpha' x_t \sim I(d-b)$, $b>0$. The vector α is called the *cointegrating vector.* (italics in original)

In the case of equation (4.24), $x_t = \{Y_t, X_t\} \sim CI(1,1)$ and the cointegrating vector α is equal to $[1,-\lambda]$. In the two-variable case, Holden and Thompson [1992, pp.7-8] show that if one variable is normalised to 1 (*e.g.*, Y_t), then λ is a unique coefficient, in the sense that no other value will give a Z_t series which is I(0).

Cointegration analysis addresses one of the central objectives of this thesis; linking theoretical models with an appropriate empirical specification. The appeal of a cointegration approach lies in two properties which suggest that the functional form of a model is an important consideration and ought to be chosen with care. The first property relates to the usage of variables in their level form as opposed to their logarithmic values. If variables are cointegrated in levels, their logarithmic transformations will also be cointegrated. However, the converse is not necessarily true; the fact that variables display cointegration in log form does not imply cointegration in levels. Therefore, specific functional forms are *implied* if one finds cointegration in logarithms but not in levels (*e.g.*, under this criteria, only constant-elasticity demand curves are permissible). Secondly, since the value of Z_t in equation (4.24), with its constant mean and variance, is often interpreted as the *error term* of a regression between Y_t and X_t, it implies that the two variables will never drift far apart. Intuitively, equation (4.24) represents the *long-run equilibrium relationship* between Y_t and X_t. Consequently, over time, the values of Y_t will converge to λX_t or, alternatively, the values of X_t will converge to $\lambda^{-1} Y_t$. One can (statistically) determine the direction of

[15] One could also include a constant term in equation (4.24) to allow for the possibility of Z_t having a non-zero mean. The cointegrating vector would remain as $[1,-\lambda]$.

causality between the two variables by examining the results of Granger-causality tests (Granger [1969], Sargent [1976;1979]) or Sims-GMD-causality tests (Sims [1972], Geweke, Meese, and Dent [1983]). Alternatively, one can simply assume the direction of causality based on *a priori* assumptions.

Tests for cointegration (CI(d,b) where b=d) between variables is analogous to tests for unit roots. Using the estimated residuals ($\hat{Z}_t$) from equation (4.24), the ADF equation becomes:

$$\Delta \hat{Z}_t = \delta \hat{Z}_{t-1} + \sum_{i=1}^{k} \delta_i \Delta \hat{Z}_{t-i} + \epsilon_t . \tag{4.25}$$

In addition, the ADF test statistics for equation (4.25) can be transformed by the Phillips-Perron modification procedure to remove any effect that autocorrelation may have on the asymptotic distribution of these test statistics. Using the SHAZAM (v.7) COINT procedure, cointegration tests (ADF and PP) are estimated for $\hat{Z}_t$'s derived from the original model:

$$\begin{aligned} \hat{Z}_{it} &= p_{it} - \lambda_0 \left(\frac{C_q^*}{e} \right)_{it} , \\ \hat{Z}_{it} &= p_{it} - \lambda_0 C_q^* + \lambda_1 e_{it} . \end{aligned} \tag{4.26}$$

Similarly, cointegration tests are estimated for $\hat{Z}_t$'s derived from the extension to the original model:

$$\hat{Z}_{it} = p_{it} - \lambda_0\left(\frac{C_q^*}{e}\right)_{it} + \lambda_1\sum_{j \neq i}\beta_j p_{jt} + \lambda_2\sum_{j \neq i}\beta_j p_{jt-1}\,,$$

(4.27)

$$\hat{Z}_{it} = p_{it} - \lambda_0 C_q^* + \lambda_1 e_{it} + \lambda_2\sum_{j \neq i}\beta_j p_{jt} + \lambda_3\sum_{j \neq i}\beta_j p_{jt-1}\,.$$

Each of the cointegrated regressions accepted by the SHAZAM procedure is estimated by OLS. Stock [1987] demonstrates how the OLS estimator of the cointegrating parameters is "superconsistent", converging to the true parameter at a much faster rate (*i.e.*, proportional to T rather than proportional to $\sqrt{T}$).[16] Subsequently, for each cointegrating regression, a model is constructed and estimated using the Engle-Granger approach and the Johansen procedure.

III. Restricted Regressions (Imposition of Unit Roots)

(i) Engle-Granger Representation

Cointegration offers one solution to the problem of nonstationarity. However, the *static* nature of long-run equilibrium relationships, generated by cointegration analysis, precludes any *dynamic* interaction between variables in the short run. In particular, the relationship offers no explanation as to how the variables return to equilibrium for any given shock to the system. This inability to capture transitional movements suggests that cointegrated relationships, by themselves, have limited value.

Differencing variables offers another solution to the problem of nonstationarity. Autoregressive integrated moving average (ARIMA) models, for example, can be quite flexible in their dynamic specification. However, models which incorporate only differenced variables ignore the role of long-term

[16] Superconsistency arises because the denominator of the bias portion of the OLS estimate, $(X'X)^{-1}$, increases faster than usual ($T \rightarrow \infty$) since the X data do not fluctuate around a constant level. As the denominator becomes relatively larger than the numerator, the bias portion of the estimate disappears quicker than the usual least square estimate under BLUE assumptions.

equilibrium relationships. Any advantage which these models may have over traditional CLR models in forecasting proficiency is offset by the inability to explain economic relationships.

It would seem reasonable, therefore, to derive a modelling technique which not only takes advantage of the properties associated with cointegrated variables but is also able to account for dynamic interaction. This is precisely what Engle and Granger [1987] accomplish in their seminal paper. They argue that if Y_t and X_t are I(1) *and* cointegrated CI (1,1), there exists an error correction model (ECM) representation of the variables in the form:[17]

$$\Delta Y_t = \beta_0 + \beta_1 \hat{Z}_{t-1} + \sum_i \beta_{2i} \Delta X_{t-i} + \sum_i \beta_{3i} \Delta Y_{t-i} + \epsilon_t \,, \tag{4.28}$$

where $\hat{Z}_{t-1}$ = residuals from the cointegrating regression in equation (4.24), and
$\epsilon_t \sim$ iid $(0,\sigma_\epsilon^2)$.

The variable $\hat{Z}_{t-1}$ represents the degree of disequilibrium between Y_t and X_t in the previous period. Therefore, changes in Y_t not only depend on changes in X_t but also on the degree of disequilibrium between Y_t and X_t. Clearly, the appeal of an ECM approach is that it is able to account for the dynamics of the system, yet incorporate equilibrium relationships which are guided by economic theory. Econometrically, the main advantage of an ECM specification, other than the "superconsistency" of the estimates, is that all of the regressors are, by definition, stationary. Moreover, they are not likely to be correlated with each other or with the error term.

Following the two-step procedure suggested by Engle and Granger [1987], all potential cointegrating relationships are first estimated. For the case of the original model, where p_{it}, $(C_f^*/e)_{it}$, C_{fit}^*, and e_{it} are all

[17] Engle and Granger [1987] show that an isomorphism exists between ECM's and cointegrated variables: if Y_t and X_t are both I(1) and cointegrated, there exists and ECM representation and conversely, ECM's generate cointegrated series.

I(1), CI (1,1) regressions similar to equations (4.26) and (4.27)) are estimated and the residuals tested for stationarity. Once cointegrating regressions are established, ECM's in the form of equation (4.28) are estimated. The actual regressors as well as their lag lengths are determined by the theoretical model in chapter 3. As a result, the ECM's estimated for the original model, as specified in equation *(3.10)*, are:

(4.29)

$$\Delta p_{it} = \gamma_0 \Delta \left[\frac{C_q^*}{e}\right]_{it} + \gamma_1 \left(p_{it-1} - \lambda_0 \left[\frac{C_q^*}{e}\right]_{it-1}\right) + \epsilon_t \ ;$$

$$\Delta p_{it} = \gamma_0 \Delta C^*_{q_{it}} + \gamma_1 \Delta e_{it} + \gamma_2 \left(p_{it-1} - \lambda_0 C^*_{q_{it-1}} - \lambda_1 e_{it-1}\right) + \epsilon_t \ ,$$

where ϵ_t is assumed to be white noise. Similarly, for the case of the extension to the original model, where p_{it}, p_{jt}, $(C_q^*/e)_{it}$, C^*_{qit}, and e_{it} are all I(1), CI (1,1) regressions are estimated and the residuals once again tested for stationarity. Following the theoretical implications (equation *(3.16)*) for the actual regressors and their lag lengths, the following ECM's are estimated:

(4.30)

$$\Delta p_{it} = \gamma_0 \Delta \left[\frac{C_q^*}{e}\right]_{it} + \gamma_1 \left(p_{it-1} - \lambda_0 \left[\frac{C_q^*}{e}\right]_{it-1} - \sum_{j \neq i} \lambda_{1j} p_{jt-1}\right) + \epsilon_t \ ;$$

$$\Delta p_{it} = \gamma_0 \Delta C^*_{q_{it}} + \gamma_1 \Delta e_{it} + \sum_{j \neq i} \Delta p_{jt} + \gamma_3 \left(p_{it-1} - \lambda_0 C^*_{q_{it-1}} - \lambda_1 e_{it-1} - \sum_{j \neq i} \lambda_{2j} p_{jt-1}\right) + \epsilon_t \ .$$

Once the second stage of the Engle-Granger two-step procedure is complete, one can use standard tests for statistical inference (t-tests) in order to select the "best" model.

(ii) Johansen Procedure

Unfortunately, there are three major concerns with the Engle-Granger two-step procedure. Firstly, the omission or inclusion of variables in the cointegrating regression can seriously alter the cointegration results.[18] Frequently, variables which one would expect to be cointegrated in the long run will only do so in the presence of an additional variable(s). While this may have the advantage of forcing the researcher to examine all potential structural changes which may have occurred during the time span under consideration, it can also lead to serious data-mining. Researchers can simply insert/delete dummy variables or proxy variables until a good fit is found. Correcting the model in such a manner introduces all the problems associated with specific-to-general modelling techniques.

Secondly, Holden and Thompson [1992] and Charemza and Deadman [1993], among others, highlight the problem of *uniqueness* when there are two or more explanatory variables. For example, it may be the case that several cointegrating vectors exist between variables, however, the Engle-Granger two-step procedure only calculates *one* vector. Since this single cointegrating vector is effectively a linear combination of all cointegrating vectors, one is faced with an identification problem (Holden and Thompson [1992; p.30]).

The third concern relates to the properties of the OLS estimator of the cointegrating regressions. Although the OLS estimates in the cointegrating regression are consistent (asymptotically "superconsistent"), in small sample sizes, they are not efficient. Banerjee *et al.* [1986] establish that there can be significant bias with small sample sizes, particulary when the R^2 statistic is considerably below the value of one. They suggest minimizing the bias by estimating equation (4.28) in *one* step. This would involve substituting the $\hat{Z}_t$'s with Y_t and X_t, estimating the equation, and finally testing the stationarity of the residuals. Alternatively, Engle and Yoo [1987] suggest reducing this bias by extending the Engle-

[18] For example, Muscatelli and Papi [1990] find a valid cointegrating vector of money, prices, incomes, and interest rates only when a proxy for financial innovations during the 1970s and 1980s is introduced.

Granger two-step procedure into a ***three-step*** procedure. This third step consists of regressing the residuals from the ECM onto lagged values of the original (independent) cointegrating variables and correcting the original long-run estimates by a fraction of the third-step estimates. This method reduces the bias, produces standard errors of the estimates which are asymptotically normal, and is the asymptotic equivalent to maximum likelihood estimation.

The Johansen procedure addresses the issues raised with respect to the Engle-Granger two-step procedure.[19] Firstly, it is based upon a vector autoregressive (VAR) representation. By definition, this "atheoretical" approach includes variables inferred from theoretical assumptions, dummy variables as well as proxy variables. In short, any variable which may be remotely connected to the economic relationship under investigation is introduced into the system of equations. Secondly, the procedure is capable of identifying and calculating the maximum possible cointegrating regressions through the use of canonical correlation methods and the resulting eigenvalues and eigenvectors revealed by the matrix of correlation coefficients. Therefore, the problem of uniqueness encountered in the Engle-Granger two-step procedure is eliminated. Finally, the Johansen procedure uses the maximum likelihood estmator (MLE). One of the advantages of the MLE technique is that it has many desirable asymptotic properties (unbiased, consistent, efficient, and distributed normally) which are particularly appealing for situations where only a small sample size exits.

To understand the Johansen procedure, consider first a typical unrestricted VAR in the form:

$$Y_t = \sum_{l=1}^{k} A_l Y_{t-l} + \epsilon_t , \qquad (4.31)$$

---

[19] See Johansen [1988;1991] and Johansen and Juselius [1990;1992]. For a thorough review of estimation and hypothesis testing of cointegrated series with the Johansen procedure, see Dickey and Rossana [1994].

where Y_t is a vector of q variables (both endogenous and exogenous). ε_t is assumed to be contemporaneously correlated but not autocorrelated, and each of the vectors A_i does not have any zero elements. By adding Y_{t-1}, Y_{t-2},... ,Y_{t-k} and $A_1 Y_{t-2}$, $A_2 Y_{t-3}$,...$A_{k-1} Y_{t-k}$ to both sides of equation (4.31), we derive a *cointegrating transformation* of the type:

(4.32)
$$\Delta Y_t = \sum_{i=1}^{k-1} \Gamma_i \Delta Y_{t-i} + \Pi Y_{t-k} + \epsilon ,$$

where $\Gamma_i = -I + A_1 + ... + A_i$;

I = *unit matrix;*

$\Pi = -(I - A_1 - ... - A_k)$.

Equation (4.32) is in essence an error-correction model with matrix Π capturing the long-run equilibrium relationships. For q variables in the vector Y_t , the dimension of Π is q x q. Johansen [1988;1991] concentrates on the *rank* of Π and considers three possibilities:

(1) Rank (Π) = 0; This can only occur if Π is a null matrix. Equation (4.32) becomes a VAR in first differences only and there is no cointegration.

(2) Rank (Π) = q; In the case of a full rank, the vector process Y_t is stationary, such that all variables are I(0) and the correct model should be estimated in levels rather than differences. Note that it would also contradict any assumption that each of the variables is I(1).

(3) Rank (Π) = r. Under the assumption that 0 < r < q, there will be *r cointegrating vectors*. In this general case, Π can be represented as:

(4.33) $$\Pi = \alpha\beta',$$

where α and β are two q x r matrices.

Matrix β is called the cointegrating matrix, as $\beta' Y_t$ is I(0) while matrix α is called the adjustment or feedback matrix since it calculates the speed at which a variable returns to its long-run value following a disturbance to the system. Since the values of α and β' cannot be estimated directly without imposing arbitrary constraints, Johansen [1988;1991] suggests estimating the space spanned by α and β' using the following step-by-step procedure:[20]

(1) Select an autoregressive order k for the model.

(2) Regress ΔY_t on the lagged differences ΔY_{t-1}, ΔY_{t-2}, ..., ΔY_{t-k+1}. Construct a vector of residuals and denote by R_{0t}.

(3) Regress Y_{t-k} on the lagged differences ΔY_{t-1}, ΔY_{t-2}, ..., ΔY_{t-k+1}. Construct a vector of residuals and denote by R_{kt}.

(4) Compute the "squared canonical correlations" [*i.e.*, eigenvalues] between the residuals (R_{0t} and R_{kt})

[20] Determining the space spanned by α and β' is important since the product, $\alpha\beta'$, can be the result of many different matrices. For example, for any nonsingular r x r matrix, H, $(\alpha H^{-1})(H\beta') = \alpha\beta'$.

and denote as $\hat{\varrho}_1^2 > \hat{\varrho}_2^2 > \hat{\varrho}_3^2 ... > \hat{\varrho}_q^2$.[21]

(5) For each eigenvalue $\hat{\varrho}_i^2$, calculate the following ***trace test*** statistic:

$$\text{(4.34)} \qquad \textit{Trace Test} = -T \sum_{i=r+1}^{q} \ln\left(1 - \hat{\varrho}_i^2\right).$$

Under the null hypothesis that there are at most r cointegrating vectors, (H_0: $r \leq r_0$, H_1: $r > r_0$) the LR statistic is a function of {q-r} vector Brownian motion. Starting from r = 0, if the null is rejected, one examines sequentially the possibility that $r \leq 1, r \leq 2, ..., r \leq q$.

(6) Once the number of cointegrating vectors (r) is confirmed, the first r eigenvectors associated with the $\hat{\varrho}_1^2, ... \hat{\varrho}_r^2$ are the *cointegrating vectors*, β.

Empirical implementation of the Johansen procedure is performed using the PC-FIML (Full Information Maximum Likelihood) portion of Doornik and Hendry's [1994] PC-GIVE version 8.0 econometric software package. In addition to the trace test, the program also calculates the ***maximum eigenvalue*** statistic:

[21] The squared canonical correlations ($\hat{\varrho}_i^2$) are the solutions to the deteminantal equation:

$$| \varrho_i^2 S_{kk} - S_{k0} S_{00}^{-1} S_{0k} | = 0 ,$$

where

$$S_{ij} = \frac{\sum_{t=1}^{T} R_{it} R_{jt}'}{T} ; \qquad i,j = 0,k .$$

$$(4.35) \qquad \textit{Maximum eigenvalue} = -T \ln\left(1 - \varrho_{r+1}^2\right).$$

Similar to the trace test, the distribution of the maximum eigenvalue test statistic is also a function of vector Brownian motion. However, the null hypothesis is H_0: $r = r_0$ and is compared with the alternate hypothesis H_1: $r = r_0 + 1$.[22]

The critical values for both the trace test and the maximum eigenvalue test are those selected from Osterwald-Lenum [1992]. PC-FIML also calculates a small-sample "corrected" version of these critical values as discussed by Reimers [1992] whereby T in equations (4.34) and (4.35) is replaced by {T - qk}.

The Johansen procedure for cointegration is generally preferred to the Engle-Granger procedure since the power of the test is higher and the statistical properties of the MLE method are considered better than OLS for small sample sizes (Kremers, Ericsson, and Dolado [1992], Reinhart [1995]). However, direct comparisons between the two should be regarded with caution since they are based upon two different methodologies. In particular, the Engle-Granger two-step procedure assumes, *a priori*, the endogenous-exogenous nature of the variables while the Johansen procedure starts from the typical VAR model assumption that there are no exogenous variables. Charemza and Deadman [1993, pp.201-202] present the theory that the Johansen procedure may, under certain conditions, confirm the validity of the Engle-Granger two-step estimation methodology:

> Suppose for instance that the Johansen procedure indicates the existence of only one cointegrating vector. If the estimated cointegrating coefficients have, after normalization, economically sensible signs and are roughly similar in size to those estimated by the Engle-Granger method, this could be regarded as some confirmation of the single equation model to which the Engle-Granger method was applied. If, on the other hand, the number of cointegrating vectors found by the Johansen procedure is greater than one, it is likely that the endo-exogenous division of variables in this model is imperfect and that the model under consideration should consist of not one but two or more equations.

[22] Johansen and Juselius [1990] demonstrate that the maximum eignevalue test has greater power than the trace test.

The VAR modelling approach using the Johansen procedure is completed in the following manner. Following acceptance of a cointegrating rank of r, individual restrictions on α and β' are imposed to derive *unique* cointegrating regressions. These restrictions are based upon theoretical constraints and are tested with LR statistics having an asymptotic chi-square distribution. Once the unique cointegrating regressions are accepted, the model, equation (4.32), is "pared down" in order to find the best parsimonious VAR representation.

4.3 Forecasting

Apart from the obvious benefit of predicting future values, forecasting techniques are employed to test whether a model is misspecified and/or exhibits parameter instability. Models which demonstrate parameter stability and are correctly specified over a sample period may not fare as well over a given forecast interval. This may be due, in part, to certain limitations arising from the choice of sample period. For example, a model specified solely on data gathered during an upward portion of a business cycle may perform poorly during a downward portion. Alternatively, poor forecasting ability, in spite of sample-period parameter stability and (apparently) correct specification, may be due to improper econometric methodology. Applying classical linear regression analysis with nonstationary data, for example, frequently produces remarkably high correlations between actual and the fitted values of dependent variables. The associated high R^2 values *reflect* the nonstationarity and do not, by themselves, indicate sensible models. Doornik and Hendry [1994,pp.48-49] discuss how easily one could accept a model if nonstationarity is ignored:

> The obvious features of the graph are the very close fits (owing to the integrated and non-stationary nature of the variables and, as before, should not be taken as evidence for the goodness of the system representation); the close tracking of the apparent change in trend (again, a *post-hoc* feature which least-squares essentially ensures will occur irrespective of its correctness); and the relatively random (white noise) appearance of the residuals in

> the final column. However, we have ignored the I(1) nature of the data in setting implicit critical values: since these would generally be larger, and no hypothesis yet suggests rejection, no practical problems result (emphasis in original).

Based on the above statements, forecasting analysis (and tests) are particularly appropriate for this thesis. Firstly, there are a number of cases where the sample size imposes certain limitations. In the compact/midsize category, inclusion of Korean data reduces the data sample from 1980(1) - 1990(4) to 1985(1) - 1990(4). During this latter period, the Canadian dollar depreciated significantly, after abnormally high levels, against other major currencies. Consequently, there is a good probability that any model based on this sample period may not be appropriate for forecasting during periods when the Canadian dollar is appreciating against these currencies. Also, in the large automobile category, the 1988(1) structural break -caused by the reclassification of automobiles - restricts the sample period. It may be the case that a model based on pre-1988(1) data does not accurately describe post-1988(1) data.

Secondly, three different econometric methodologies are used to estimated exchange rate pass-through models. Forecasting analysis can be employed to select the "best" model/appropriate methodology. Given that CLR analysis can produce spurious relationships in the presence of nonstationary data, comparisons are restricted to models generated by the Engle-Granger two-step procedure and the Johansen/VAR methodology, where all variable are stationary. Recall that one of the problems associated with the Engle-Granger two-step procedure is the fact that only one cointegrating regression is specified. If the "true" model contains more than one cointegrating regression, the Johansen procedure will capture this feature, and, the subsequent VAR estimation should produce a better model. This hypothesis is tested using forecasting tests/graphs generated by PC-FIML.

The two traditional forecasting methodologies are "causal" forecasting and time series forecasting. Causal forecasting is an extension of CLR econometric methodology. Once parameters for the causal relationships are estimated, it is simply a matter of entering values from the independent variables and calculating the effect on the dependent variable. Due to specification errors (missing variables, wrong functional forms) and/or conditional errors (wrong forecasts for independent variables), these models display poor forecasting accuracy in the short run, forcing econometricians to make continuous adjustments. The time series approach, in the form of ARIMA models, forecasts a variable solely as a function of past values of the variable itself. Although this method of extrapolating forecasts ignores economic relationships, it frequently outperforms their causal forecasting competitors.

There is a general tendency in the literature towards combining different types of forecasts, linear or otherwise, as a means of producing superior forecasting accuracy (Kennedy [1992; p. 272], Clemens [1989]). Combining forecasts can temper the effects that outliers or extreme shocks to the system may impose on any individual forecast methodology. For example, the effects attributed to a once-and-for-all shock can continue over several time periods if lagged dependent variables (*e.g.*, ARIMA models) are included as regressors. The identical shock will be treated differently by causal econometric models. If certain shocks influence a model but are not specifically incorporated, econometricians use their judgement and experience to determine how these shocks will affect forecasts. The appeal of an ECM methodology is that any forecasting analysis implicitly incorporates elements of each of the two traditional methodologies since ECM's synthesize the CLR and VAR econometric methodologies (*i.e.*, they contain differenced variables as well as long-run cointegrating relationships).

Although forecasting terminology is relatively constant across the literature, certain issues require clarification is order to understand the forecasting features of Doornik and Hendry's [1994] PC-FIML software package. Typically, forecasting known variables is called *ex post* or *static* forecasting while forecasting unknown variables is called *ex ante* or *dynamic* forecasting. Doornik and Hendry [1994], however, define static forecasting as forecasts which use ***actual*** values for any lagged information required to calculate the forecast, whereas dynamic forecasts use ***previously calculated*** forecasts for any lagged information, if required. To illustrate this point, consider a simple single equation model:

$$(4.36) \qquad y_t = \pi_1 y_{t-1} + \pi_2 y_{t-2} + \pi_3 x_t + \epsilon_t \,,$$

where variable x_t is assumed exogenous and known over the period t = 1, 2, ... T, T+1, T+2, ... T+H. If the parameters $\hat{\pi}_i$ are estimated over t = 1, 2, ... ,T and one elects to forecast over a 3-year horizon, (H=3), the static forecasts are:[23]

$$(4.37) \qquad \begin{aligned} \hat{y}_{T+1} &= \hat{\pi}_1 y_T + \hat{\pi}_2 y_{T-1} + \hat{\pi}_3 z_{T+1} \,, \\ \hat{y}_{T+2} &= \hat{\pi}_1 y_{T+1} + \hat{\pi}_2 y_T + \hat{\pi}_3 z_{T+2} \,, \\ \hat{y}_{T+3} &= \hat{\pi}_1 y_{T+2} + \hat{\pi}_2 y_{T+1} + \hat{\pi}_3 z_{T+3} \,, \end{aligned}$$

and the dynamic forecasts are:

$$(4.38) \qquad \begin{aligned} \hat{y}_{T+1} &= \hat{\pi}_1 y_T + \hat{\pi}_2 y_{T-1} + \hat{\pi}_3 z_{T+1} \,, \\ \hat{y}_{T+2} &= \hat{\pi}_1 \hat{y}_{T+1} + \hat{\pi}_2 y_T + \hat{\pi}_3 z_{T+2} \,, \\ \hat{y}_{T+3} &= \hat{\pi}_1 \hat{y}_{T+2} + \hat{\pi}_2 \hat{y}_{T+1} + \hat{\pi}_3 z_{T+3} \,. \end{aligned}$$

In addition, PC-FIML also calculates *h-step* forecasts which can be viewed as a combination of Doornik and Hendry's definition of static and dynamic forecasts. For example, let $\hat{y}_{T+i,h}$ denote the h-step forecast for period T+i , (i≥h). These h-step forecasts use ***estimated*** values of lagged variables which

[23] In both static and dynamic forecasts, all tests are based on the assumption that parameter estimates remain constant over the forecast period and are ***not*** updated.

are less than h periods, and *actual* values, if required, for lagged variables greater and equal to h periods. In the extreme case, for example, the 1-step forecasts for equation (4.36) are identical to equations (4.37) or (4.38) depending whether one assumes static or dynamic forecasts. The estimates for 2-step forecasts are:

$$\begin{aligned}
\hat{y}_{T+2,2} &= \hat{\pi}_1\hat{y}_{T+1,1} + \hat{\pi}_2 y_T + \hat{\pi}_3 z_{T+2} , \\
\hat{y}_{T+3,2} &= \hat{\pi}_1\hat{y}_{T+2,1} + \hat{\pi}_2 y_{T+1} + \hat{\pi}_3 z_{T+3} , \\
&\vdots \\
\hat{y}_{T+l,2} &= \hat{\pi}_1\hat{y}_{T+l-1,1} + \hat{\pi}_2 y_{T+l-2} + \hat{\pi}_3 z_{T+l} . \qquad (4.39)
\end{aligned}$$

Similarly, the estimates for the 3-step forecasts are:

$$\begin{aligned}
\hat{y}_{T+3,3} &= \hat{\pi}_1\hat{y}_{T+2,2} + \hat{\pi}_2\hat{y}_{T+1,1} + \hat{\pi}_3 z_{T+3} , \\
\hat{y}_{T+4,3} &= \hat{\pi}_1\hat{y}_{T+3,2} + \hat{\pi}_2\hat{y}_{T+2,1} + \hat{\pi}_3 z_{T+4} , \\
&\vdots \\
\hat{y}_{T+l,3} &= \hat{\pi}_1\hat{y}_{T+l-1,2} + \hat{\pi}_2\hat{y}_{T+l-2,1} + \hat{\pi}_3 z_{T+l} . \qquad (4.40)
\end{aligned}$$

Therefore, using Doornik and Hendry's terminology, static forecasts are identified with 1-step forecasts, where as dynamic forecasts are identified with 1, 2, 3, ..., H-step forecasts.

Each of the models generated by the Engle-Granger and Johansen procedures is tested for both parameter stability and misspecification through a series of *six test* statistics associated with the 1-step static forecast.[24] These tests are a function of the forecast errors (e_{T+i}) and/or the error term (v_t) associated with the initial estimation for t = 1, 2, ... ,T. In essence, these test statistics compare variances between the in-sample period and the forecast period. Variances which are significantly different from the appropriate χ^2 distribution will reject parameter stability and/or imply that the model is misspecified. Using Doornik and Hendry's notation, consider the following system of equations:

(4.41) $$y_t = \Pi w_t + v_t, \quad t = 1,2,...T$$

where, y_t = endogenous variable (nx1),

$w_t = (y_{t-1},..., y_{t-m}, z_{t-1},...z_{t-r})$,

z_t = weakly exogenous variables (qx1)

This system of equations can be written in a more compact form:

(4.42) $$Y = \Pi W' + V'$$

where, $Y' = y_1, y_2, ... , y_T$ (nxT),

$W' = w_1, w_2, ... , w_T$ (kxT),

$\Pi = \pi_1, \pi_2, ... , \pi_k$ (nxk),

$V' = v_1, v_2, ... , v_T$ (nxT).

---

[24] Forecast intervals which are used to test misspecification of dynamic models such as ECM's are frequently called *post-sample prediction tests.*

The multivariate estimates of the coefficients (Π) and the residual covariance matrix (Ω) are:

(4.43)
$$\hat{\Pi}' = (W'W)^{-1}W'Y\,;$$
$$\hat{\Omega} = \frac{\hat{V}'\hat{V}}{T-k}\,.$$

The 1-step forecasts for each period t = T+1, ... , T+H are given as:

(4.44)
$$\hat{y}_{t+l} = \hat{\Pi} w'_{t+l}$$

such that the forecast error for each period is:

(4.45)
$$\begin{aligned} e_{T+l,1} &= y_{t+l} - \hat{y}_{T+l,1} \\ &= \Pi w'_{T+l} + v'_{T+l} - \hat{\Pi} w_{T+l} \\ &= (\Pi - \hat{\Pi}) w'_{T+l} + v'_{T+l}\,. \end{aligned}$$

Assuming that $E(\hat{\Pi}) = \Pi$, then the expectation of the forecast error $E(e_{t+l,l}) = 0$ such that the variance of the error term is:

$$
\begin{aligned}
V[e_{T+l,1}] &= E(e_{T+l,1})^2 \\
&= E\left[\left((\Pi - \hat{\Pi})w'_{T+l}\right)^2 + \left(v'_{T+l}\right)^2\right] \\
&= \Omega\, w_{T+l}(W'W)^2 w'_{T+l} + \Omega \\
&= \Omega\left(1 + w_{T+l}(W'W)^2 w'_{T+l}\right) \\
&= \Psi_{T+l} \,.
\end{aligned}
\tag{4.46}
$$

However, some of the tests require the *total variance matrix* of all forecast errors. Therefore by stacking the H rows on top of each other, we derive the total vector of forecast errors;

$$
e = (\Pi - \hat{\Pi})W'_H + V'_H \,, \tag{4.47}
$$

whose variance is equal to:

$$
V[e] = \Omega \otimes \left(I_H + W_H(W'W)^{-1}W'_H\right) = \Psi \,. \tag{4.48}
$$

Using the above derivations, and under the null hypothesis of parameter constancy, the six tests are:

$$
\begin{aligned}
\xi_1 &= \sum_{l=1}^{H} e'_{T+l}\bar{\Omega}^{-1}e_{T+l} \\
\xi_2 &= \sum_{l=1}^{H} e'_{T+l}\bar{\Psi}^{-1}_{T+l}e_{T+l} \\
\xi_3 &= e'\bar{\Psi}^{-1}e \\
\eta_i &= (nH)^{-1}\xi_i \qquad i = 1,2,3
\end{aligned}
\tag{4.49}
$$

where $\xi_i \sim \chi^2(nH)$,

$\eta_i \sim F(nH, T - k)$,

n = number of equations to be estimated,

H = number of forecasts.

Rejection of the null hypothesis under ξ_1 implies that there is a fundamental structural change between the estimation period and the forecast period. It is not an indictment against the model *per se*, but it does imply that forecasts based upon the model are not reliable. Rejection of the null hypothesis under ξ_2 and ξ_3, however, not only imply parameter instability across the two periods but also model misspecification (Kiviet [1986]). The η_i tests are degrees-of-freedom corrections for the ξ_i tests and have better small-sample properties (Doornik and Hendry [1994; p.197]).

Dynamic forecasts/variances can be derived in a similar fashion as equations *(4.41) - (4.48)*. The analysis requires the specific lag structure of the endogenous variables. Using the identical notation, suppose that the system has only one lag of the dependent variable:

(4.49)
$$y_t = \pi_1 y_{t-1} + \pi_2 z_t + v_t .$$

At time T+h (for h = 1,2,...,H), equation (4.49) can be expressed as:

(4.50)
$$y_{T+H} = \pi_1 y_{T+h-1} + \pi_2 z_{T+H} + v_{T+H} .$$

Substituting backwards, Y_{T+H} in equation *(4.50)* can be replace with:

$$y_{T+h} = \pi_1(\pi_1 y_{T+h-2} + \pi_2 z_{T+h-1} + v_{T+h-1}) + \pi_2 z_{T+h}\, v_{T+h}$$

$$(4.51) \qquad = \pi_1^h y_T + \sum_{j=0}^{h-1} \pi_1^j \pi_2 z_{T+h-j} + \sum_{j=0}^{h-1} \pi_1^j v_{T+h-j}\,.$$

The forecast at time interval h is:

$$(4.52) \qquad \hat{y}_{T+h,h} = \hat{\pi}_1^h y_t + \sum_{j=0}^{h-1} \hat{\pi}_1^j \hat{\pi}_2 z_{T+h-j}\,,$$

and under the assumption of parameter constancy, the forecast error is:

$$e_{T+h,h} = y_{T+h} - \hat{y}_{T+h,h}$$

$$(4.53) \qquad = \sum_{j=0}^{h-1} \pi_1^j v_{T+h-j}\,.$$

Therefore, the *variance* of the forecast error is:

$$V\left[e_{T+h,h}\right] = E\left[\sum_{i=0}^{h-1} \sum_{j=0}^{h-1} \pi_1^i v_{T+h-i} v'_{T+h-j} \pi_1^{j'}\right]$$

$$(4.54) \qquad = \sum_{j=0}^{h-1} \pi_1^j \Omega \pi_1^{j'}\,,$$

where $E[v_i v_j'] = 0$ for $i \neq j$, and

$E[v_i v_j'] = \Omega$ for $i = j$.

PC-FIML calculates the path of forecast values, in addition to forecast errors and variances. Since test statistics are not available for dynamic forecasts, comparisons between forecasting ability of models generated by the Engle-Granger two-step procedure and models generated by the Johansen/VAR methodology are presented graphically. Each graph consists of the actual post-sample value, the forecast values and forecast error bars measuring 95% confidence intervals.

CHAPTER 5

ESTIMATION RESULTS

5.1 Introduction

Estimation results are presented following the chronological order of the empirical methodology discussed in chapter 4.[1] Apart from providing consistency across chapters, it also reflects a contemporary approach to selecting the appropriate methodology. A theoretical model is first estimated using the traditional regression technique of ordinary least squares (OLS). If problems arise, they are treated with the usual remedies; a Cochrane-Orcutt procedure for serial corelation, generalized least squares (GLS) for heteroscedasticity, etc. The second step consists of applying unit root tests (augmented Dickey-Fuller (ADF) and Phillips-Perron (PP)) to the data, as a means of validating the results derived from the first step. The problems associated with the statistical properties of OLS estimators, whenever the data are nonstationary, are well documented (Granger [1986], Stock and Watson [1988]). Researchers will frequently interchange the first and second step. If, for example, unit root tests indicate that the data are stationary, they will proceed with OLS estimation. If unit root tests indicate nonstationary data, they may decide to avoid OLS estimation, given the statistical problems, and proceed to the next step. However, for comparison reasons, it is alway interesting to see how OLS estimation fares against other methods of estimation. The third step, assuming unit root tests reveal nonstationary data, is to derive the level of integration for all variables. Once the levels of integration have been found, the fourth step is to determine the presence of cointegration amongst variables. In the absence of cointegration, one must ensure that estimation involves only *stationary* transformations of the data. In the presence of cointegration, the model is respecified as an error correction model (ECM), in order to capture both long-

[1] For a summary of data sources, data problems and remedies, see Appendix B.

run relationships and short-run dynamics. In order to derive the cointegrating regressions and estimate the model parameters, one must decide whether to employ an Engle-Granger two-step procedure, or a Johansen/VAR approach. Since both models are econometric embodiments of different methodologies on theory appraisal (see introduction in chapter 4), the decision may be based on one's *a priori* beliefs. Once again, for comparison purposes, both methodologies are employed.

All estimation results are contained in Appendices C through H. Rather than presenting all parameter estimates and test results, each section in this chapter has tables highlighting the salient points, with particular attention on the exchange rate pass-through coefficients.

This chapter is organized as follows. Section 5.2 contains the results of the original model and extension, using recursive ordinary least squares (RLS) and r^{th}-order autoregressive least squares (RALS), where applicable, rather than a Cochrane-Orcutt procedure (see section 4.2 for comparisons). Section 5.3 discusses the results from the unit root regressions. Section 5.4 provides cointegrating regressions and the results of both the Engle-Granger two-step estimation and the Johansen/VAR estimation using full information maximum likelihood (FIML) estimation. Finally, section 5.5 discusses numerical results from the static forecasts, and compares graphical representations of dynamic forecasts under the Engle-Granger two-step procedure and the Johansen/VAR approach.

5.2 Unrestricted Regressions

I. Original Model

The first set of results are derived from RLS and RALS estimation procedures on the original model (equation *(4.2)*). All parameter estimates, standard errors, and statistical tests for the initial regressions are presented in Appendix C. The following table summarizes the initial *pass-through estimates*:

TABLE 5-1

Pass-Through Coefficients from Original Model (CLR Estimation)

$$p_{it} = \beta_0 + \beta_1 p_{it-1} + \beta_2 (c_q^*/c)_{it} + \varepsilon_t$$

	Japan	U.S.	Sweden	Germany	Korea
Subcompacts	13%	64%	N/A	45%	17%
Mid-size	7%[†]	65%	10%	8%	-14%
Large	25%	28%	N/A	29%	N/A

[†] RAL estimation, N/A = Not Applicable

As a "first pass" at estimating pass-through coefficients, *TABLE 5-1* duplicates previous research on the pricing behaviour of exporters (Gagnon and Knetter [1995], Hooper and Mann [1989], Knetter [1989], Marston [1990], and Shinjo [1993]). For example, the U.S. has a significantly higher coefficient for both subcompact and compact/mid-size autos, and is virtually tied with Japan and Germany for the highest in the large automobile segment. This supports the evidence that U.S. exporters do not generally price to the market, but rather retain the price in U.S. dollars.[2] On the other hand, Japanese automobile exporters typically have the lowest pass-through in each segment of the automobile market; supporting the position that they absorb exchange rate fluctuations in their profit margins. The reluctance to pass-through currency appreciations is also evident from the behaviour of the West German exporters, although to not as significant a degree as their Japanese counterparts.

Similar to Gagnon and Knetter [1995], one can also interpret the variation in pass-through

[2] One can argue that the "Big Three" U.S. automobile exporters (General Motors, Ford, and Chrysler) can afford to retain their price in U.S. dollars given the preferential treatment in accordance with the 1965 United States-Canada Automotive Products Trade Agreement (the Auto Pact). One of the provisions of the Auto Pact ensures a ***duty-free*** exchange of vehicles provided certain Canadian production quotas on behalf of the Big Three's Canadian subsidiaries are satisfied (Acheson [1989], Dunn [1987], Holmes [1992], Keely [1983]). As a result, U.S. exporters are currently enjoying a 9.2% Free on Board (F.O.B.) advantage over those countries who face the most favoured nation tariff (Japan, Germany, and Sweden) and a 6% F.O.B. advantage over countries who pay the general preferential tariff rate (South Korea). Consequently, full pass-through of Canadian dollar depreciations (up to ~10%) ,***ceteris paribus***, will not necessarily jeopardize U.S. exporters' Canadian market shares. Over the U.S. sample period, the most favoured nation (MFN) tariff has declined gradually from a high of 12.8% whereas the general preferential (GP) tariff paid by South Korea was only imposed in 1987 after three years of duty-free status as a "developing nation".

coefficients as an indication of the relative competitiveness in each segment of the auto market. The lower the average value, the more competitive the market structure. In order of decreasing competitiveness we have: compacts/mid-size, large, and subcompacts. Surprisingly, the subcompact market appears the least competitive of the three segments. This is in part due to the relatively high German pass-through. The German exception can be attributed to the fact that it has its own niche or reputation, with consumers more willing to accept higher prices before considering an alternative import. However, high German and U.S. coefficients are offset by low pass-throughs from both Asian countries, indicating a certain degree of competitiveness among some members in this segment. In the large automobile segment, there is a remarkably consistent pass-through of 25% - 30% by each of the participants. Given the higher profits per unit on larger automobiles, it is unlikely that firms would be willing to lose market share to competitors; hence the similar pricing behaviour. Finally, the *negative* pass-through coefficient for the South Korean imports indicating *prima facie* a tenuous relationship. Yet, it confirms anecdotal evidence suggesting that Hyundai was dumping their automobiles on the Canadian market during the mid-1980's (Brett [1987], Daw [1987], Milner [1987]).

II. Extension to Original Model

The second set of results are derived from RLS estimation on the extension to the original model (equation *(4.6)*). This extension tests whether strategic price interaction between competitors is a valid assumption pertaining to the market structure. This model nests the original specification, in the sense that if the parameter estimates for competitors' prices are not statistically significant, the model reduces to its original form. All parameter estimates, standard errors and statistical tests are presented in Appendix D. The pass-through coefficients are summarized in the following table:

TABLE 5-2

Pass-Through Coefficients from Extension (CLR Estimation)

$$p_{it} = \gamma_0 + \gamma_1 p_{it-1} + \gamma_2 (C_q^*/e)_{it} + \Sigma\gamma_{3j} p_{jt} + \Sigma\gamma_{4j} p_{jt-1} + \varepsilon_t$$

	Japan	*U.S.*	*Sweden*	*Germany*	*Korea*
Subcompacts	46%	-62%	-	38%	18%
Mid-size	33%	86%	20%	70%	-76%
Large	16%	35%	-	42%	-

Apart from the large negative pass-through coefficients for U.S. subcompacts and Korean mid-size automobiles, the results reiterate the findings from the initial model. For example, Japanese pass-through coefficients are lower than U.S. and German coefficients in both the mid-size and large automobile sector, while the U.S. and German coefficients are quite similar in these two categories. While the relative comparisons remain true, a number of the nominal variables differ significantly. This is in part due to the fact that the structure of the regressions in Appendix D (*TABLE 5-2*) are based solely upon a model generated by theoretical foundations. As such they are not the "best" models in terms of their goodness-of-fit. Many of the coefficients are not statistically significant and a general-to-specific modelling procedure would provide a sound basis to pare down the number of variables. The discrepancy can also be attributed to the fact that the regression values in *TABLE 5-1* and *TABLE 5-2* suffer from the problems associated with non-stationary data, in the sense that coefficients of misspecified models are generally not robust to modifications, however minor.

Overall, competitors prices are not statistically significant, suggesting that strategic price interaction is not prevalent. The only notable exception is in the large automobile category where Japanese prices and German prices (with a one period lag) influence U.S. prices.

5.3 *Unit Root Regressions*

When variables exhibit nonstationary tendencies, statistical inferences are not feasible since the Student-t statistic no longer displays an asymptotically normal distribution. Therefore, when dealing with time series data, it is incumbent upon the researcher to ensure that any regression analysis is performed on stationary variables. Each of the variables is subjected to augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests to determine the level of integration. These tests differ slightly from the equations in chapter 4, ((4.20)-(4.23)) in the sense that they include a constant term as well as a time variable to account for trend-stationarity:[3]

$$\Delta y_t = \mu + \beta t + \delta y_{t-1} + \sum_{l=1}^{k} \delta_l \Delta y_{t-l} + \epsilon_t \tag{5.1}$$

where μ is a constant equal to the mean of the process and t is a time trend. These two variables capture the *deterministic* portion of a trend while the error term (ε_t) captures the *stochastic* portion. The results are reported in Appendix E and indicate that:

(a) we cannot reject the hypothesis that all variables (prices, exchange rates and costs) for each country are I(1);

(b) the PP tests do not reject the I(1) transformations more readily than the ADF tests.

Result (a) implies that we must exercise caution when using the typical OLS analysis. Stock and Watson [1988] provide general guidelines for regression analysis containing integrated regressors. Under

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[3] If a time series has a non-zero drift, then estimation should include both a constant and a time trend (in the specification of the ADF) since Perron [1988] notes that under such cases, non-inclusion of a trend term will bias the test in favour on non-rejection of the unit root null hypothesis.

certain conditions, we can have consistent estimators for the coefficients of interest, however, they will not display asymptotically 'normal' distributions. As mentioned, the critical values are not applicable and statistical inferences are misleading. Result (b) reaffirms the concern over the ADF's low 'power of the test'. Having confirmed the order of integration for each variable, the subsequent step is to select the desired econometric methodology.

5.4 Restricted Regressions

I. Engle-Granger Representation

(i) Original model

The first step in the Engle-Granger two-step procedure is to determine cointegrating relationships between all variables. Every possible combination of country, automobile type, price, cost (in Canadian dollars and foreign currency), and exchange rate is estimated using the COINT procedure from SHAZAM (V.7). Based upon the results of the ADF and PP tests on the residuals, each of the *eight* accepted equations are presented in the following table:

TABLE 5-3

Cointegrating Regressions

Country	Auto Type	Variables	Trend	Test
Japan	Mid-size	$p_{it},(C^*_q/c)_{it}$	Yes	ADF,PP
Japan	Mid-size	p_{it},C^*_{qit},c_{it}	Yes	ADF,PP
U.S.	Mid-size	$p_{it},(C^*_q/c)_{it}$	Yes	PP
U.S.	Mid-size	p_{it},C^*_{qit},c_{it}	Both	PP
Korea	Mid-size	p_{it},C^*_{qit},c_{it}	Both	ADF,PP
Japan	Subcompact	p_{it},C^*_{qit},c_{it}	Yes	ADF,PP
Germany	Subcompact	$p_{it},(C^*_q/c)_{it}$	Yes	PP
Germany	Subcompact	p_{it},C^*_{qit},c_{it}	Both	PP

Each row represents a cointegrating vector with the variables indicated in the third column. The lack of cointegrating relationships in the large automobile sector may be due in part to its relative competitiveness. Manufacturers of large automobiles create their particular niches. Through reputation (and advertising) they are able to retain their clientele even during periods where markups might fluctuate. Since "market forces" do not push prices towards a constant markup over costs, unlike other automobile sectors, strict long-term cointegrating relationships need not exist.

There are cases where prices are cointegrated individually with exchange rates (e_{it}) and costs measured in foreign currency (C^*_{qit}), but not with costs expressed in Canadian dollars $(C^*_q/e)_{it}$. Adding an extra regressor to the cointegrating regression will not present any difficulties in modelling an ECM; however, as noted in Chapter 4, with two (or more) regressors, it is possible to have more than one cointegrating vector. Unfortunately, one of the shortcomings of the Engle-Granger two-stage procedure is the inability to recognize more than one cointegrating relationship.

The fourth column shows whether the data generating processes of the cointegrating regressions are trend stationary. Some tests accept the cointegrating relationships both with and without trends. The final column demonstrates which test accepts the cointegrating regressions. In comparison with PP tests, ADF tests only accept half of the regressions. This result is consistent with previous unit root tests where the low power of ADF tests lead to acceptance of false hypotheses (*i.e.*, H_0: no cointegration).

Given the cointegrating regressions in Table 5-3, the theoretically derived ECMs (equations *(4.29)*) are calculated using full information maximum likelihood (FIML) estimation. The results and associated tests are tabulated in Appendix F and the pass-through coefficients are briefly summarized in the following two tables.

TABLE 5-4

Pass-Through Coefficients from Original Model (Engle-Granger)

$$\Delta p_{it} = \gamma_0 \Delta(C_q^*/e)_{it} + \gamma_1[p_{it-1} - \kappa_0(C_q^*/e)_{it-1}] + \varepsilon_t$$

		Japan	Germany	U.S.
Subcompact				
	γ_0	-	35%	-
	κ_0	-	87%	-
Mid-size				
	γ_0	17%		75%
	κ_0	21%		124%

TABLE 5-5

Pass-Through Coefficients from Original Model (Engle-Granger,cost elasticity)

$$\Delta p_{it} = \gamma_0 \Delta(C_q^*)_{it} + \gamma_1 \Delta(e)_{it} + \gamma_2[p_{it-1} - \kappa_0(C_q^*)_{it-1} - \kappa_1(e)_{it-1}] + \varepsilon_t$$

		Japan	Germany	U.S.	Korea
Subcompact					
	γ_1	73%	43%	-	-
	κ_1	106%	76%	-	-
Mid-size					
	γ_1	14%	-	98%	105%
	κ_1	11%	-	143%	128%

where γ_i = short-run pass-through and κ_i = long run equilibrium pass-through.

Comparing the *dollar-cost* (C_q^*/e) pass-through, coefficients estimated using RLS and RALS (Table 5.1) are broadly consistent with the short-run ECM coefficients (γ_0) using the Engle-Granger approach (Table 5.4). In the long run (κ_0), German subcompacts and U.S. mid-size automobiles exhibit full pass-through, while Japanese mid-size remain at approximately 20%.

Rather than constraining the exchange rate pass-through to equate "foreign cost" pass-through, Table 5.5 presents the unrestricted exchange rate pass-through associated with the ECM estimation. A number of the previous results using RLS and RALS remain unchanged. For example, there are low Japanese and high U.S. pass-throughs in the mid-size/compact sector while the short-run/long-run coefficients for German subcompacts are relatively intact. However, there are two significant differences, namely a substantial increase in the pass-through coefficients of Japanese subcompacts and Korean mid-size/compacts. The full exchange rate pass-through of Korean mid-size cars (105%) can be reconciled with the *negative* 14% dollar cost pass-through once one accounts for the considerable *negative* pass-through of Korean production costs (Appendix F; Table F-2). Once again, there is evidence to substantiate the claim that Hyundai was dumping their automobiles on the Canadian market.

On the other hand, the discrepancy between the dollar-cost pass-through and the unconstrained exchange rate pass-through in the Japanese subcompact sector can be attributed to gains in productivity by Japanese automobile manufacturers during the latter part of the 1980's.[4] Over the data period, these productivity gains are reflected in (nominal) cost indexes which fall and/or increase at slower rates than competitors. Combining a higher exchange rate pass-through with reductions in cost parameters produces the observed low dollar-cost pass-through coefficients.

(ii) Extension to original model

The first step of the Engle-Granger procedure is to determine the cointegrating regressions. Unfortunately, one of the problems associated with SHAZAM cointegration tests is the interpretation of ADF and PP statistic given that the cointegrating regression coefficients are not provided. This presents considerable problems when there are greater than two cointegrating variables. For example, if one accepts a cointegrating vector of the form:

$$(5.2) \qquad P_{Japan} = f\left(C_q^*, e, P_{Germany}, P_{Korea}, P_{U.S.}, P_{Sweden}\right),$$

one cannot be certain that it is due to the fact that all variables are significant or a combination of some

[4] For Japanese productivity comparisons, see Fuss and Waverman [1990a,1990b] and Conrad [1989].

significant variables with others having zero coefficients; either case is possible. Consequently, dozens of cointegrating tests are performed in order to account for all possible combinations. Based upon the results of ADF and PP tests on the residuals, *sixteen* cointegrating equations are selected. The selection of each of these cointegrating regressions is based strictly upon theoretical considerations; they contain the maximum possible variables acceptable for each country under each automobile classification. The ECMs derived from these cointegrating regressions, along with the residual test statistics are presented in Appendix G. Given the theoretical specifications in equation *(4.30)* the following tables summarize the pass-through coefficients:

TABLE 5-6

Pass-Through Coefficients from Extension (Engle-Granger)

$$\Delta p_{it} = \gamma_0 \Delta (C_q^*/e)_{it} + \Sigma \gamma_{1j} \Delta p_{jt} + \gamma_2 [p_{it-1} - \kappa_0 (C_q^*/e)_{it-1} - \Sigma \kappa_{1j} p_{jt-1}] + \varepsilon_t$$

		Japan	Germany	U.S.	Sweden
Subcompact					
	γ_0	61%	-60%	-182%	-
	κ_0	78%	40%	-247%	-
Mid-size					
	γ_0	40%	99%	67%	-68%
	κ_0	33%	51%	72%	-1%
Large					
	γ_0	-	-	79%	-
	κ_0	-	-	94%	-

TABLE 5-7

Pass-Through Coefficients from Extension (Engle-Granger,cost elasticity)

$$\Delta p_{it} = \gamma_0 \Delta (C_q^*) + \gamma_1 \Delta (e)_{it} + \Sigma \gamma_{2j} \Delta p_{jt} + \gamma_2 [p_{it-1} - \kappa_0 (C_q^*)_{it-1} - \kappa_2 (e)_{it-1} - \Sigma \kappa_{3j} p_{jt-1}] + \varepsilon_t$$

		Japan	Germany	U.S.	Korea
Subcompact					
	γ_0	72%	4%	-71%	-
	κ_0	58%	38%	-194%	-
Mid-size					
	γ_0	40%	83%	140%	138%
	κ_0	30%	117%	120%	144%
Large					
	γ_0	-	-	64%	-
	κ_0	-	-	81%	-

Despite acceptance as cointegrating regressions, many of the variables - notably competitors' prices - are statistically insignificant suggesting that more parsimonious models might be more appropriate. However, as a competitor, the price of Korean automobiles is statistically significant in ***all*** mid-size regressions. Undoubtedly, the pricing strategy of Hyundai had an impact on other foreign importers' prices. The negative coefficient on Japanese and U.S. regressions imply a reduction on their prices following an increase in the Korean price. Such a strategy would make sense if:

(a) market forces reflect consumers' perception that all three are legitimate "substitutes"; or

(b) Japanese and U.S. exporters try to regain lost market shares.

Either way, the presence of Hyundai has increased the competitiveness in the mid-size/compact sector of automobiles and lowered the average pass-through rates.

There are also several pass-through coefficients in excess of 100%. Coefficients of this magnitude amplify rather than attenuate any changes in prices attributed to changes in exchange rates. For example, an appreciation of the U.S. dollar leads to an increase in Canadian dollar prices of U.S. automobile imports ***over and above*** increases associated with full pass-through. Static versions of the mark-up model (Knetter [1989,1993], Marston [1990]) show how mark-ups will increase as the seller's currency appreciates if the convexity of the demand schedules is greater than that of constant-elasticity schedules.

In the subcompact sector, the Japanese and German unconstrained long-run pass-through coefficients are 60% and 40% respectively, while that for the U.S is calculated at -194%. Negative rates imply a rejection of the traditional relationship between exchange rates and prices of traded goods. An appreciation of the Canadian currency, for example will lead to an increase in the Canadian price of foreign automobile imports. Under demand-induced PTM models, this outcome is consistent with U.S. markups in excess of 100% following an appreciation of the Canadian currency.

The extension to the original model produces a cointegrating regression in the large automobile sector. The long-run pass-through coefficient for the U.S. is 80%, while one also notices the importance of

Japanese competition. Specifically, a 10% change in the price of large Japanese automobiles will lead to a 3% change (in the same direction) in U.S. prices. The fact that a cointegrating relationship exists under the extension but not in the original model is testimony to the fragility of cointegrating tests as discussed by Muscatelli and Hurn [1992].

II. Johansen Procedure and VAR Estimation

In this section, the Johansen procedure replaces the Engle-Granger two-step procedure as the method for determining the number of potential cointegrating relationships in each of the three automobile classifications. In the case of subcompacts, inclusion of all four countries (Japan Germany, United States, and South Korea) restricts the data sample period from 1984:2 - 1987:4.[5] The lack of data for the given number of variables to be estimated results in a *singular matrix* for the vector of error terms. A singular matrix, by definition, implies a determinantal value of zero, an inverse which does not exist, and an inability to estimate the system of equations. To correct this problem, data from South Korean automobiles are omitted. This decision is based upon the previous E-G tests which do not find cointegrating relationships for Korean subcompacts, as well as the desire to increase the sample period. A somewhat similar problem arises in the case of compact/mid-size automobiles; vector calculations of test statistics leads to a singular matrix. However, previous E-G cointegration analysis precludes the omission of South Korean data. In fact, both E-G and traditional CLR analysis suggest that South Korean prices play a significant role in competitors' pricing decisions. Instead, Swedish data - typically representing the least significant contribution to Canadian automobile imports - are removed.

Accounting for these changes to subcompact and compact/mid-size systems of equations, the following three tables present the results of the Johansen rank tests:

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[5] South Korea entered the Canadian subcompact market in 1984:1 whereas German subcompacts were significantly affected by the reclassification of automobiles in 1988 (See Appendix B).

TABLE 5-8

Johansen Rank Tests for Subcompact Automobiles

	Maximum Eigenvalue Statistic			*Trace Statistic*		
	d.f. = T	d.f. = T-qk	95%‡	d.f. = T	d.f. = T-qk	95%‡
ρ ≤ 0	36.82**	32.21**	25.5	80.25**	70.23**	42.4
ρ ≤ 1	22.36*	19.56*	19.0	43.43**	38.00**	25.3
ρ ≤ 2	21.07**	18.44**	12.2	21.07**	18.44**	12.2

‡ See Osterwald-Lenum [1992; p. 469]

* Reject Null Hypothesis @ 1% level of significance.

**Reject Null Hypothesis @ 5% level of significance

TABLE 5-9

Johansen Rank Tests for Compact/Midsize Automobiles

	Maximum Eigenvalue Statistic			*Trace Statistic*		
	d.f. = T	d.f. = T-qk	95%‡	d.f. = T	d.f. = T-qk	95%‡
ρ ≤ 0	68.76**	56.80**	31.5	167.00**	138.00**	63.00
ρ ≤ 1	47.42**	39.17**	25.5	98.24**	81.16**	42.4
ρ ≤ 2	29.79**	24.61**	19.0	50.83**	41.99**	25.3
ρ ≤ 3	21.04**	17.38**	12.2	21.04**	17.38**	12.2

‡ See Osterwald-Lenum [1992; p. 469]

**Reject Null Hypothesis @ 5% level of significance

TABLE 5-10

Johansen Rank Tests for Large Automobiles

	Maximum Eigenvalue Statistic			*Trace Statistic*		
	d.f. = T	d.f. = T-qk	95%[‡]	d.f. = T	d.f. = T-qk	95%[‡]
$\rho \leq 0$	48.30**	42.00**	25.5	92.54**	80.47**	42.4
$\rho \leq 1$	33.44**	29.06**	19.0	44.24**	38.47**	25.3
$\rho \leq 2$	10.82	9.41	12.2	10.82	9.41	12.2

‡ See Osterwald-Lenum [1992; p. 469]

* Reject Null Hypothesis @ 1% level of significance.

**Reject Null Hypothesis @ 5% level of significance

In the subcompact classification, the maximum eigenvalue test statistic only rejects the null hypothesis of $H_0{:}\rho \leq 2$ at a 1% level of significance. However, proceeding to the null hypothesis of $H_0{:}\rho \leq 3$, this test statistic is rejected at the higher 5% level. Moreover, the tract test rejects all null hypotheses at a 5% level of significance. In a similar fashion, both tests reject all null hypotheses for the compact/mid-size sector.

The rejection of all null hypotheses for subcompacts and compact/mid-size automobiles implies that the Π matrix (equation (4.32)) is of full rank. Consequently, the entire system of equations is already stationary with all variables in the Y_t vector deemed integrated of the order zero such that the model can be estimated in levels rather than differences (see rank conditions for equation *(4.33)*). Although this conclusion contradicts earlier unit root and cointegration tests, it permits the researcher to estimate the system of equations as:

(5.3)
$$Y_t = \sum_{i=1}^{k} K_i Y_{t-i} + \sum_{j=0}^{k} \Gamma_j Z_{t-j} + \epsilon_t \ ,$$

where, Y_t = endogenous variables;

Z_t = exogenous variables; and

$\epsilon_t \sim IN(0,\Omega)$.

The results of the VAR estimation of equation (5.3), using the full information maximum likelihood estimator (FIML), are reported in Appendix H. The following table summarizes the pass-through coefficients:

TABLE 5-11

Pass-Through Coefficients from a VAR representation

	Japan	Germany	United States	South Korea
Subcompacts	110%	214%	3%	-
Compact/mid-size	130%	146%	375%	64%

With the exception of the U.S. subcompacts, the relative values remain consistent with previous results. For example, in the compact/mid-size sector, the U.S. has the highest pass-through coefficient, followed by Germany, Japan and South Korea. The high nominal values can be partially attributed to the fact that the results are based upon a model which is generated by theoretical considerations only, and do not reflect a parsimonious VAR representation.

On the other hand, rank tests for the large automobile sector (*TABLE 5-10*) indicate that the rank of Π is less than the q endogenous variables to be modelled. In particular, it establishes the existence of *two* cointegrating regressions. With the confirmation of cointegrating regressions, features of PC-FIML are employed to derive unique cointegrating regressions. The values of the α matrix from equation (4.33) are first systematically restricted to zero. These restrictions test whether a particular cointegrating relationship affects one of the equations to be estimated. Each time a restriction is implemented, a Likelihood Ration (LR) statistic, with a χ^2 distribution, tests whether these restrictions are readily acceptable. Once the α matrix is complete, a similar process is employed to determine unique values of the cointegrating matrix (β) matrix. Restrictions placed on β may be in the form of:

(i) zero restrictions (*i.e.*, competitors prices do not influence the long-run relationship of U.S. prices);
(ii) particular values (*i.e.*, U.S. pass-through coefficient is equal to 1); or
(iii) equality relationships (*i.e.*, U.S. exchange rate pass-through is equal to U.S. cost pass-through).

Applying this procedure, tests indicate that the two long-run cointegrating vectors are Japanese and U.S. prices. Cointegrating vectors for German prices always have exorbitant values in addition to wrong theoretical signs, regardless of the ordering of the variables. Once final versions of the cointegrating regressions are accepted, the next step is to determine a parsimonious VAR using the full information likelihood estimator. Similar to equation *(4.32)*, the system of equations is set up as:

$$\text{(5.4)} \qquad \Delta Y_t = \sum_{i=1}^{k} \mathrm{K}_i \Delta Y_{t-i} + \sum_{j=0}^{k} \Gamma_j \Delta Z_{t-j} + \Pi X_{t-k} + \epsilon_t ,$$

where, Y_t = endogenous variables;
Z_t = exogenous variables;
X_t = all variables; and
$\varepsilon_t \sim IN(0,\Omega)$.

The results of the VAR estimation of equation (5.4), using the full information maximum likelihood estimator (FIML), are reported in Appendix H. The following table summarizes the short-run and long-run exchange rate pass-through coefficients:

TABLE 5-12

Pass-Through Coefficients from a Johansen/VAR Representation

Large Automobiles

	Japan	*United States*
Short-run	-45%	120%
Long-run	31%	58%

The main feature of *TABLE 5-12* is that Japan and the United States have different exchange rate behaviour in *both* the short run and the long run. In the short run, the U.S. exchange rate pass-through is in excess of 100%: this is consistent with contracts denominated in U.S. currency, plus a premium if exchange rates are expected to continue in the same direction. On the other hand, the short-run "perverse" behaviour of large Japanese automobiles is replaced with a pass-through of 30% in the long run.

As a final note to the estimation section, the pass-through coefficients for each automobile classification - under all three methodologies - are tested in order to determine whether these coefficients are statistically different between competitors. Previous work is inconclusive: Knetter [1993] argues that there exists little evidence to suggest different pricing behaviour within common industries while Gross and Schmitt [1993] argue that the degree of pricing-to-market can vary across automobile sectors but remains constant within categories. This thesis adds to the debate by presenting evidence to suggest that, under certain circumstances, pass-through coefficients can also differ *within* automobile categories.

Under the Johansen\VAR methodology, only the large automobile classification produces long-run cointegrating vectors. Using the Johansen cointegrating restrictions tests on Japanese and U.S. pass-through coefficients, the likelihood ratio (LR) with a rank of two produces a χ^2 (9 d.f.) statistic = 16.069 [0.0655]. The null hypothesis (H_0: the coefficients are identical) is only just acceptable at a 5% level of significance and not acceptable at a 10% level of significance. At higher levels of significance the Japanese long-run pass-through coefficient of 31% is statistically different from the U.S. long-run pass-through of 58% (see page H-3).

The other case where there *potentially* exists statistically different pass-through coefficients between competitors within a common automobile category is in the Engle-Granger compact/mid-size classification. The Japanese long-run pass-through coefficient of 30% is considerably lower than German U.S. and South Korean competitors who each have long-run pass-through coefficients slightly in excess of 100%. Unfortunately, PcGIVE does not provide t-statistics or standard errors for coefficients in cointegrating regressions using the Engle-Granger approach. The absence of statistical data precludes any direct testing of the null hypothesis. Future research could be directed towards deriving restricted versus unrestricted regressions and making comparisons with F-tests. Another area of future research is identification of the underlying reason(s) why pass-through coefficients may differ (statistically) within automobile classifications - is it the dynamic nature of the model? assumptions concerning the market structure? econometric techniques?

5.5 Forecasting

Under the best-case scenario, the Johansen procedure will determine that *each* of the three systems of equations (subcompact, compact/mid-size and large automobiles) has at *least* one cointegrating vector.[6] Using the tests described in chapter 4, these individual systems are subsequently tested for model misspecification and/or parameter stability. Finally, in an effort to select the "better" econometric methodology, the forecasting results from the Johansen procedure are compared with those from the individual equations produced by the Engle-Grange two-step procedure.

Unfortunately, the Johansen procedure did not find any cointegrating relationships for either subcompact or compact/mid-size automobiles. Consequently, comparisons are restricted to the large automobile sector. Since the objective is to select the better methodology, an appropriate starting point, prior to comparisons of forecasting statistics, is to examine the actual versus fitted and the characteristics of the residuals under each methodology.[7]

< Insert Graphs I-1, I-2, ... , I-5 >

The actual versus fitted graphs (I-1, I-2, and I-3) indicate that the final models selected under both the Engle-Granger two-step procedure and the Johansen/VAR estimation are substantial representations of actual movements in prices of large automobiles. In fact, based upon comparisons of U.S.automobiles, one is unable to select the better of the two methodologies.

On the other hand, graphs of the residuals (I-4 and I-5) demonstrate that the Engle-Granger procedure has slightly more serial correlation than the Johansen/VAR representation. However, the distribution of the Engle-Granger residuals is more "normal" than the bimodal residuals generated under the

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[6] Otherwise the system has either no cointegrating vectors or it is already stationary in level form.

[7] Appendix I contains all graphs relating to this section

Johansen/VAR representation. Therefore, at this initial stage, there is little to suggest that one particular methodology dominates the other.

I. Static Forecasts

The next step is to examine the differences, if any, between static forecasts. The system of equations under the Johansen/VAR methodology and the single equation of the Engle-Granger approach are each estimated with 4 period and 6 period in-sample (ex-post) data points removed. Forecast analysis examines the possibility of parameter instability and misspecification. The results are presented in the following two tables:

TABLE 5-13

Static Forecast Tests Using a Johansen/VAR Representation

1-Step (ex-post) Forecast Analysis 1987(1) - 1987(4)

$\xi_1 \sim \chi^2(8) = 9.914$ [0.271] $\quad$ $\eta_1 \sim F(8,5) = 1.239$ [0.434]

$\xi_2 \sim \chi^2(8) = 4.578$ [0.802] $\quad$ $\eta_2 \sim F(8,5) = 0.572$ [0.770]

$\xi_3 \sim \chi^2(8) = 4.134$ [0.845] $\quad$ $\eta_3 \sim F(8,5) = 0.517$ [0.806]

1-Step (ex-post) Forecast Analysis 1986(3) - 1987(4)

$\xi_1 \sim \chi^2(12) = 69.431$ [0.000]** $\quad$ $\eta_1 \sim F(12,3) = 5.786$ [0.087]

$\xi_2 \sim \chi^2(12) = 17.605$ [0.128] $\quad$ $\eta_2 \sim F(12,3) = 1.467$ [0.420]

$\xi_3 \sim \chi^2(12) = 18.000$ [0.116] $\quad$ $\eta_3 \sim F(12,3) = 1.500$ [0.412]

** Reject null hypothesis at a 1% level of significance.

TABLE 5-14

Static Forecast Tests Using an Engle-Granger Two-Step Procedure

1-Step (ex-post) Forecast Analysis 1987(1) - 1987(4)

$\xi_1 \sim \chi^2(4) = 2.590$ [0.628] $\quad$ $\eta_1 \sim F(4,14) = 0.648$ [0.638]

$\xi_2 \sim \chi^2(4) = 2.145$ [0.709] $\quad$ $\eta_2 \sim F(4,14) = 0.536$ [0.712]

$\xi_3 \sim \chi^2(4) = 2.314$ [0.678] $\quad$ $\eta_3 \sim F(4,14) = 0.579$ [0.663]

1-Step (ex-post) Forecast Analysis 1986(3) - 1987(4)

$\xi_1 \sim \chi^2(6) = 26.485 \quad [0.000]^{**}$ $\qquad \eta_1 \sim F(6,12) = 4.414 \quad [0.014]^{*}$

$\xi_2 \sim \chi^2(6) = 12.596 \quad [0.050]^{*}$ $\qquad \eta_2 \sim F(6,12) = 2.010 \quad [0.129]$

$\xi_3 \sim \chi^2(6) = 9.543 \quad [0.145]$ $\qquad \eta_3 \sim F(6,12) = 1.590 \quad [0.232]$

* Reject null hypothesis at 5% level of significance.

** Reject null hypothesis at a 1% level of significance.

Both methodologies accept parameter stability and proper model specification at an in-sample forecast period of four. However, when the in-sample data period is extended to six forecast periods, both reject the parameter stability test (ξ_1) at a 1% level of significance while the Engle-Granger approach also reject the degrees-of-freedom corrected version (η_1) at a 5% level of significance. More importantly, one of the Engle-Granger tests for model misspecification (ξ_2) is rejected at a 5% level of significance.

In brief, there is evidence at the static forecast level to suggest that the Johansen/VAR representation has better parameter stability characteristics and generates the "better" model.

II. Dynamic Forecasts

While the 1-step static forecast tests are primarily designed to determine issues of parameter stability and model misspecification, dynamic forecasts analyses are strictly designed to measure the ability of an equation to generate accurate forecasts over the longest interval possible. The following graphs provide a visual representation of the dynamic forecasts:

< Insert Graphs I-6, I-7, and I-8 >

Each graph contains a forecast horizon of 16 quarters and includes a 95% forecast error bar for each observation.[8] The forecasts generated by the Johansen/VAR estimation for prices of large Japanese automobiles (*Graph I-6*) fall within the forecast error bars up until the seventh forecast period, at which point subsequent forecasts become erratic in comparison with actual price movements. The inconsistency of these later forecasts is undoubtedly due to significant fluctuations in actual prices starting in 1989. Since fluctuations of this order of magnitude are not recorded during the in-sample period, the distribution of forecast errors is not based upon this larger distribution of prices.

On the other hand, dynamic forecasts of large U.S. automobiles under the Johansen/VAR estimation are quite impressive. With the exception of one forecast point (1989(4)), all forecasts fall within the forecast error bars. This contrasts significantly with the dynamic forecasts of large U.S. automobiles under the Engle-Granger two-step procedure; only the first year of forecasts fall within forecast error bars, while ten of the remaining twelve forecasts lie outside forecast error bars. In spite of the assumption of parameter constancy and invariance, forecasts generated by the Engle-Granger methodology deteriorate at a rapid pace in the latter years of the forecast horizon.

Combining results from both static and dynamic forecast analysis, the statistical evidence demonstrates that ECMs developed under a VAR representation - and assuming that the Johansen procedure identifies r (<q) cointegrating vectors - are "better" models than those ECMs developed through an Engle-Granger two-step procedure. The Johansen/VAR methodology produces ECMs with greater parameter stability, lower probability of model misspecification and finally, better forecast ability.

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[8] Dynamic forecasts are based on a sequential process (e.g., 1, 2, ..., 16-step forecasts) and ignore parameter uncertainty problems. As a result, the dynamic process assumes that the parameters calculated in the sample period are constant and invariant over any possible regime changes outside of the sample. This ensures that the forecast errors come from the identical distribution as the in-sample period. Despite this assumption of parameter certainty and invariance, the variance of forecast errors typically increase with the forecast horizon (h), to the point where the forecast error may become heteroscedastic and/or serially correlated.

CHAPTER 6

CONCLUSION

6.1 Summary

This thesis measures the effect of changes in exchange rates on prices of automobiles imported into Canada during the 1980s. The theoretical model of exchange rate pass-through is motivated by :

(a) the desire to derive a general model which is capable of synthesizing existing models, which only identify portions of pass-through.

(b) the desire to forge stronger links between theoretical foundations and empirical estimation by providing a natural framework for recent econometric developments.

The model takes the form of a rational expectations, dynamic optimization problem where firms maximize profits with respect to price, subject to linear demand curves and quadratic adjustment costs. Solving for the system of Euler equations, one derives a partial adjustment model, which can also be respecified as an error correction model (ECM) capable of separating short-run dynamics from long-run equilibrium relationships. By including competitors' prices in the demand curve, an extension to the model, which "nests" the original, accounts for the possibility of strategic price interaction between competitors.

Each of the three individual automobile classifications (subcompact, compact/midsize, and large) is estimated using three different econometric methodologies: recursive least squares (RLS); the Engle-Granger two-step procedure; and the Johansen/VAR approach. Overall, the results indicate that, regardless of which econometric methodology is employed, U.S. firms pass-through the largest amount of a change in exchange rates, followed in order by Germany and Japan. These results corroborate Knetter's [1989] earlier study on manufactured goods and recent study (Gagnon and Knetter [1995]) on automobile exports. However, Knetter [1993] argues that there is little evidence to indicate differences in behaviour within common industries. Gross and Schmitt [1993], on the other hand, contend that the degree of pricing-to-market varies across automobile sectors but remains similar within a given category. This thesis goes one step further and argues that pricing behaviour is different, not only across but also within automobile categories.

On average, the results from the extension duplicate the ordinal rankings of the original model, although the pass-through coefficients change substantially in certain cases. Under the Engle-Granger procedure, all countries producing compact/midsize automobiles take into consideration the pricing strategy of the Korean automobile manufacturer (Hyundai). Finally, the Engle-Granger two-step procedure and the Johansen/VAR approach are ranked, in terms of producing the 'best' ECM, by parameter stability, model misspecification tests and forecast ability. Under the assumption that the Johansen procedure identifies r (<q) cointegrating vectors, the Johansen/VAR methodology produces ECMs with greater parameter stability, lower probability of model misspecification and better forecasting ability.

6.2 Areas of Future Research

Differences in exchange rate pass-through estimates obtained by different researcher, using identical countries, commodities and time periods can be traced to two factors: data and methodology. If there are to be substantial improvements in the future, one should address these categories.

I. Data

Firstly, if possible, unit value price indices should be replaced with true price indices. Equally, one should endeavour to use exact cost indices for *each* of the automobile categories rather than one cost index for all categories. Secondly, the commodity-composition problem of price indices can be reduced if monthly and quarterly data are replaced with annual data. Unfortunately, the trade-off is less data points leading to a reduction in the number of lags available for each variable. In the long run, as data become available, this trade-off is minimized. However, in the case of Canadian data, if one extends the sample into the 1990s, one would have to consider the structural break of 1990-91 when the manufacturer's tax of 13.5% was replace by a 7% goods and services tax. Not all automobiles prices were reduced by the same amount; some actually increased.

II. Methodology

One option available for future research is examining the possibility of time-varying parameters. Using the Kalman filtering technique and maximum likelihood estimation, Wong and Manzur [1993] test whether cointegrating parameters of a purchasing power parity (PPP) model vary over time. This approach could be used to test time-varying parameters in exchange rate pass-through models. Caution must be exercised to ensure that constantly-changing long-run relationships are not confused with short-run dynamics of the model.

Another potential area of research is the inclusion of the role of competition policy as a factor determining exchange rate pass-through. Levinsohn [1994] has started research in this area. He argues that trade theorists have neglected the importance of competition policy and offers a number of ways in which trade in inextricably linked to competition policy. Differences in competition policies across countries may account for another potential source of PTM.

Finally, all future research must take into account the time-series properties of the data. Without some knowledge of the data generating processess one faces the possibility of developing spurious relationships and forming incorrect statistical inferences.

REFERENCES

Acheson, Keith,[1989]. "Power Steering the Canadian Automotive Industry: The 1965 Canada-USA Auto Pact and Political Exchange", *Journal of Economic Behaviour and Organization*, 11, 237-251.

Aliber, Robert Z.,[1976]. "The Firm Under Pegged and Floating Exchange Rates", *Scandinavian Journal of Economics*, 78, 309-326.

Artus, Jacques R.,[1974]. "The Behaviour of Export Prices for Manufactures", *IMF Staff Papers*, 21, 583-603.

Artus, Jacques R., and John H. Young,[1979]. "Fixed and Flexible Exchange Rates: A Renewal of the Debate", *IMF Staff Papers*, 26, 654-698.

Athukorala, Premachandra,[1991]. "Exchange Rate Pass-Through: The Case of Korean Exports of Manufactures", *Economics Letters*, 35, 79-84.

Athukorala, Premachandra, and Jayant Menon,[1994]. "Pricing to Market Behaviour and Exchange Rate Pass-Through in Japanese Exports", *Economic Journal*, 104, 271-281.

Aukrust, Odd,[1977]. "Inflation in the Open Economy", *Artikler 96*, Statistisk Sentralbyra, Oslo.

Balassa, Bela,[1964]. "The Purchasing-Power Parity Doctrine: A Reappraisal", *Journal of Political Economy*, 72, 584-596.

Baldwin, Richard E.,[1988]. "Hysteresis in Import Prices: The Beachhead Effect", *American Economic Review*, 78, 773-785.

Baldwin, Richard E., and Paul R. Krugman,[1986]. "Persistent Trade Effects of Large Exchange Rate Shocks", Working Paper #2017, National Bureau of Economic Research, Cambridge, Mass.

Banerjee, Anindya, Juan J. Dolado, John W. Galbraith, and David F. Hendry,[1993]. *Co-integration, Error Correction and the Econometric Analysis of Non-Stationary Data.* Oxford University Press, Oxford, U.K.

Banerjee, Anindya, Juan J. Dolado, David F Hendry, and G.W. Smith,[1986]. "Exploring Equilibrium Relationships in Econometrics Through Static Models: Some Monte Carlo Evidence", *Oxford Bulletin of Economics and Statistics*, 48, 2553-277.

Bhagwati, Jagdish N.,[1988]. "The Pass-Through Puzzle: The Misssing Prince from Hamlet", unpublished manuscript, Department of Economics, Columbia University, New York, N.Y.

Blaug, M.,[1992]. *The Methodology of Economics: Or How Economists Explain.* Cambridge University Press, Cambridge, U.K.

Branson, William H.,[1972]. "The Trade Effects of the 1971 Currency Realignment", *Brookings Papers on Economic Activity*, 1, 15-58.

Branson, William H., and Richard C. Marston,[1989]. "Price and Output Adjustment in Japanese Manufacturing", Working Paper #2879, National Bureau of Economic Research, Cambridge, Mass.

Brett, George,[1987]. "Hyundai May Face Charges for Dumping", *Toronto Star*, 15 August, p.C1.

Cassel, Gustav,[1916]. "The Present Situation of the Foreign Exchanges", *Economic Journal*, 26, 62-65.

Charemza, Wojciech W., and Derek F. Deadman,[1993]. *New Directions in Econometric Practice: General to Specific Modelling, Cointegration and Vector Autoregresion.* Edward Elgar Publishing Ltd., Brookfield, Vermont.

Chow, Gregory, C.,[1960]. "Tests of Equality Between Sets of Coefficients in Two Linear Regressions", *Econometrica*, 28, 591-605.

Conrad,Klaus,[1989]. "Productivity and Cost Gaps in Manufacturing Industries in U.S., Japan and Germany", *European Economic Review*, 33,1135-1159.

Cooley, T.F., and S.F. LeRoy,[1985]. "Atheoretical Macroeconometrics: A Critique", *Journal of Monetary Economics*, 16, 283-308.

Cross, Rod,[1993]. "On the Foundations of Hysteresis in Economic Systems", *Economics and Philosophy*, 9, 53-74.

Darnell, A.C., and J.L. Evans,[1990]. *The Limits of Econometrics.* Edwar Elgar Publishers, Aldershot, U.K.

Davidson, Russell, and James G. Davidson,[1993]. *Estimation and Inference in Econometrics.* Oxford University Press, New York, N.Y.

Daw, James,[1987]. "Giants Claim Hyundai Cars Are Dumped", *Toronto Star*, 16 July, p.E1.

Dickey, D.A. and W.A. Fuller,[1979]. "Distribution of the Estimators for Autoregressive Time-Series with a Unit Root", *Journal of the American Statistical Association*, 74, 427-431.

Dickey, David A., and Wayne A. Fuller,[1981]. "Likelihood Ratio Statistics for Autoregressive Time Series with Unit Roots", *Econometrica*, 49, 1057-1072.

Dickey, David A., Dennis Jansen, and Daniel L. Thorton,[1991]. "A Primer on Cointegration with an Application to Money and Income", *Federal Reserve Bank of St. Louis*, 73, 58-78.

Dickey, David A., and Robert J. Rossana,[1994]. "Cointegrated Time Series: A Guide to Estimation and Hypothesis Testing", *Oxford Bulletin of Economics and Statistics*, 56, 325-353.

Dixit, Avinash,[1989]. "Hysteresis, Import Penetration, and Exchange Rate Pass-Through", *Quarterly Journal of Economics*, 104, 205-228.

Dixit, Avinash,[1988]. "Optimal Trade and Industrial Policy of the US Automobile Industry", in R. Feenstra (ed.), *Empirical Methods in International Trade*, MIT Press, Cambridge. Mass.

Dockner, Engelbert J.,[1992]. "A Dynamic Theory of Conjectural Variations", *Journal of Industrial Economics*, 40, 377-395.

Dolado, Juan J., and Tim Jenkson,[1987]. "Cointegration: A Survey of Recent Developments", Department of Applied Economics, University of Oxford, Discussion Paper no. 39, Oxford, U.K.

Dolado, Juan J., Tim Jenkinson, and Simon Sosvilla-Rivero,[1990]. "Cointegration and Unit Roots", *Journal of Economic Surveys*, 4, 249-273.

Doornik, Jurgen A., and David F. Hendry,[1992]. *PcGIVE: An Interactive Econometric Modelling System*. University of Oxford, U.K.

Doornik, Jurgen A., and David F. Hendry,[1994]. *PcGIVE Professional 8.0: An Interactive Econometric Modelling System*. University of Oxford, U.K.

Dunn, James A.,[1987]. "Automobiles in International Trade: Regime Change or Persistence?", *International Organization*, 41, 225-252.

Dunn, Robert M., Jr.,[1970]. "Flexible Exchange Rates and Oligopoly Pricing: A Study of Canadian Markets", *Journal of Political Economy*, 78, 140-151.

Eaton, Jonathan, and Gene M. Grossman,[1986]. "Optimal Trade and Industrial Policy Under Oligopoly", *Quarterly Journal of Economics*, 101, 383-406.

Elster, Jon,[1976]. "A Note on Hysteresis in the Social Sciences", *Synthese*, 33, 371-391.

Engle, Robert F., and C.W.J. Granger,[1987]. "Co-integration and Error Correction: Representation, Estimation, and Testing", *Econometrica*, 55, 251- 276.

Engle, Robert F., and C.W.J. Granger,[1991]. "Cointegrated Economic Time Series: An Overview with New Results", in R.F. Engle and C.W.J. Granger (eds.), *Long-Run Economic Relationships*, Oxford University Press, Oxford, U.K.

Engle, Robert F., and Byung Sam Yoo,[1987]. "Forecasting and Testing in Cointegrated Systems", *Journal of Econometrics*, 35, 145-159.

Ewing, J.A.,[1881]. "On the Production of Transient Electric Currents in Iron and Steel Conductors by Twisting them when Magnetized or by Magnetizing them when Twisted". *Proceedings of the Royal Society of London*, 33, 21-23.

Favero, C. and David F. Hendry,[1992]. "Testing the Lucas Critique: A Review", *Econometric Reviews*, 11, 265-306.

Feenstra, Robert,[1989]. "Symmetric Pass-Through of Tariffs and Exchange Rates under Imperfect Competition: An Empirical Test", *Journal of International Economics*, 26, 25-45.

Feenstra, Robert C., Joseph E. Gagnon, and Michael M. Knetter,[1993]. "Market Share and Exchange Rate Pass-Through in World Automobile Trade", Working Paper #4399, National Bureau of Economic Research, Cambridge, Mass.

Fienberg, Robert M.,[1986]. "The Interaction of Foreign Exchange and Market Power Effects on German Domestic Prices", *Journal of Industrial Economics*, 35, 61-70.

Fisher, Eric,[1989]. "A Model of Exchange Rate Pass-Through", *Journal of International Economics*, 26, 119-137.

Franz, Wolfgang,[1990]. "Hysteresis in Economic Relationships: An Overview", *Empirical Economics*, 15, 109-125.

Friedman, J.W.,[1983]. *Oligopoly Theory*. Cambridge University Press, Cambridge, Mass.

Froot, Kenneth A., and Paul D. Klemperer,[1989]. "Exchange Rate Pass-Through When Market Share Matters", *American Economic Review*, 79, 637-654.

Fuller, W.,[1976]. *Introduction to Statistical Time Series*. John Wiley and Sons, New York, N.Y.

Fuss, Melvyn and Leonard Waverman,[1990a]. "The Extent and Sources of Cost and Efficiency Differences between U.S. and Japanese Motor Vehicle Producers", *Journal of the Japanese and International Economies*, 4, 219-256.

Fuss, Melvyn and Leonard Waverman,[1990b]. "Productivity Growth in the Motor Vechicle Industry, 1970-1984: A Comparison of Canada, Japan and the United States", in Charles R. Hulten (ed.), *Productivity Growth in Japan and the United States*, National Bureau of Economic Research, University of Chicago Press, Chicago, Ill.

Gagnon, Joseph E.,[1989]. "Adjustment Costs and International Trade Dynamics," *Journal of International Economics*, 26, 327-344.

Gagnon, Joseph E., and Michael Knetter,[1995]. "Markup Adjustment and Exchange Rate Fluctuations: Evidence from Panel Data on Automobile Exports", *Journal of International Money and Finance*, 14, 289-310.

Genberg, Hans,[1978]. "Purchasing Power Parity Under Fixed and Flexible Exchange Rates", *Journal of International Economics*, 8, 247-276.

Georgescu-Roegen, N.,[1971]. *The Entropy Law and the Economic Process*. Harvard University Press, Cambridge, Mass.

Gerrard, Bill,[1995]. "The Scientific Basis of Economics: A Review of the Methodological Debates in Economics and Econometrics", *Scottish Journal of Political Economy*, 42, 221-235.

Geweke, J., R. Meese, and W. Dent,[1983]. "Comparing Alternative Tests of Causality in Temporal Systems", *Journal of Econometrics*, 21, 161-194.

Giavazzi, F. and C. Wyplosz,[1985]. "The Zero Root Problem: A Note on the Dynamic Determination of the Stationary Equilibrium in Linear Models", *Review of Economic Studies*, 52, 353-357.

Gilbert, C.L.,[1986]. "Professor Hendry's Econometric Methodology", *Oxford Bulletin of Economics and Statistics*, 48, 283-307.

Giovannini, Alberto,[1988]. "Exchange Rates and Traded Goods Prices", *Journal of International Economics*, 24, 45-68

Goldstein, Morris, and Mohsin S. Khan,[1976]. "Large Versus Small Price Changes and the Demand for Imports", *IMF Staff Papers*, 23, 200-225.

Granger, C.W.J.,[1969]. "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods", *Econometrica*, 37, 213-228.

Granger, C.W.J.,[1986]. "Developments in the Study of Cointegrated Economic Variables", *Oxford Bulletin of Economics and Statistics*, 48, 213-228.

Granger, C.W.J., and P. Newbold,[1974]. "Spurious Regressions in Econometrics", *Journal of Econometrics*, 35, 143-159.

Gross, Dominique M., and Nicolas Schmitt,[1993]. "Pricing-to-Market and Rivalry in the Automobile Market", Department of Economics, Simon Fraser University, Discussion Paper no. 93-14. Burnaby, B.C.

Guilkey, D.K. and P. Schmidt,[1989]. "Extended Tabulations for Dickey-Fuller Tests", *Economics Letters*, 31, 355-357

Haberler, G.,[1949]. "The Market for Foreign Exchange and the Stability of the Balance of Payments: A Theoretical Analysis", *Kyklos*, 3, 193-218.

Hansen, Lars P., and Thomas J. Sargent,[1980]. "Formulating and Estimating Dynamic Linear Rational Expectations Models," *Journal of Economic Dynamics and Control*, 2, 7-46.

Hansen, Lars P., and Thomas J. Sargent,[1981]. "A Note on Wiener-Kolmogorov Prediction Formulas for Rational Expectation Models", *Economics Letters*, 8, 255-260.

Harvey, Andrew C.,[1991]. *The Econometric Analysis of Time Series*. MIT Press, Cambridge, Mass.

Hay, Donald A., and Derek J. Morris,[1991]. *Industrial Economics and Organization: Theory and Evidence*. Oxford University Press, Oxford, U.K.

Hendry, David F.,[1993]. *Econometrics: Alchemy or Science? Essays in Econometric Methodology*. Blackwell Publishers, Oxford, U.K.

Hendry, David F.,[1987]. "Econometric Methodology: A Personal Perspective", in T.F. Bewley (ed.), *Advances in Econometrics: Fifth World Congress*, Volume 2, Cambridge University Press, Cambridge, U.K.

Herguera, Iñigo,[1994]. "Exchange Rate Uncertainty, Market Structure and the Pass-through Relationship", *Economic Notes by Monte dei Paschii di Siena*, 23, 292-307.

Holden, Kenneth, and John Thompson,[1992]. "Co-integration: An Introductory Survey", *British Review of Economic Issues*, 14, 1-55.

Holmes, John,[1992]. "The Continential Integration of the North Automobile Industry: From the Auto Pact to the FTA and Beyond", *Environment and Planning*, 24, 95-119.

Hooper, Peter, and Catherine L. Mann,[1989]. "Exchange Rate Pass-Through in the 1980s: The Case of U.S. Imports of Manufactures", *Brookings Papers on Economic Activity*, 297-337.

Isard, Peter,[1977]. "How Far Can We Push the 'Law of One Price'", *American Economic Review*, 67, 942-948.

Ito, Takahashi,[1992]. *The Japanese Economy*. MIT Press, Cambridge, Mass.

Jarque, C.M., and A.K. Bera,[1980]. "Efficient Tests for Normality, Homoscedasticity and Serial Independence of Regression Residuals", *Economics Letters*, 6, 255-259.

Johansen, Soren,[1988]. "Statistical Analysis of Cointegration Vectors", *Journal of Economic Dynamics and Control*, 12, 231-254.

Johansen, Soren,[1991]. "Estimation and Hypothesis Testing of Cointegrated Vectors in Gaussian Vector Autoregressive Models", *Econometrica*, 59, 1551-1580

Johansen, Soren, and Katerina Juselius,[1990]. "Maximum Likelihood Estimation and Inference on Cointegration - With Applications to the Demand for Money", *Oxford Bulletin of Economics and Statistics*, 52, 169-210.

Johansen, Soren, and Katerina Juselius,[1992]. "Testing Structural Hypothesis in a Multivatiate Cointegration Analysis of the PPP and the UIP for UK", *Journal of Econometrics*, 20, 325-333.

Junz, Helen B., and Rudolf R. Rhomberg,[1973]. "Price Competitiveness in Export Trade Among Industrial Countries", *American Economic Review*, 63, 412-418.

Kalter, Eliot R.J.,[1978]. "The Effect of Exchange Rate Changes Upon International Price Discrimination", International Financial Discussion Papers #122, Board of Govenors of the Federal Reserve, Washington, D.C.

Kasa, Kenneth,[1992]. "Adjustment Costs and Pricing-to-Market: Theory and Evidence," *Journal of Internationad Economics*, 31, 1-28.

Keely, James F.,[1983]. "Cast in Concrete for All Time? The Negotiation of the Auto Pact", *Canadian Journal of Political Science*, 16, 281-298.

Kennan, John,[1979]. "The Estimation of Partial Adjustment Models with Rational Expectations," *Econometrica*, 47, 1441-1455.

Kennedy, Peter,[1992]. *A Guide to Econometrics*. MIT Press (Third Edit on), Cambridge, Mass.

Khosla, Anil,[1991]. "Exchange Rate Pass-Through and Export Pricing Evidence from the Japanese Economy," *Journal of the Japanese and International Economies*, 5, 41-49.

Kiviet, J.F.,[1986]. "On the Rigor of Some Mis-specification Tests for Modelling Dynamic Relationships", *Review of Economic Studies*, 53, 241-261.

Knetter, Michael M.,[1989]. "Price Discrimination by U.S. and German Exporters", *American Economic Review*, 79, 198-910.

Knetter, Michael M.,[1993]. "International Comparisons of Pricing-to-Market Behaviour", *American Economic Review*, 83, 473-486.

Knetter, Michael M.,[1994]. "Is Export Price Adjustment Asymmetric? Evaluating the Market Share and Marketing Bottlenecks Hypotheses", *Journal of International Money and Finance*, 13, 55-70.

Krasnosel'skii, M.A., and A.V. Pokrovskii,[1989]. *Systems with Hysteresis*. translated by Marek Niezgōdka, Springer-Verlag, Berlin.

Kravis, Irving B., and Robert E. Lipsey,[1974]. "International Trade Prices and Price Proxies", in Nancy D. Ruggles (ed.), *The Role of the Computer in Economic and Social Research in Latin American*. New York, N.Y.

Kravis, Irving B., and Robert E. Lipsey,[1977]. "Export Prices and the Transmission of Inflation", *American Economic Review*, 67, 155-163.

Kreinin, Mordechai E.,[1977]. "The Effect of Exchange Rate Changes on the Prices and Volume of Foreign Trade", *IMF Staff Papers*, 23, 297-329.

Kremers, Jeroen J.M., Neil R. Ericsson, and Juan J. Dolado,[1992]. "The Power of Cointegration Tests", *Oxford Bulletin of Economics and Statistics*, 54, 325-348.

Krugman, Paul R.,[1987]. "Pricing to Market when the Exchange Rate Changes", in S.W. Arndt, and J.D. Richardson (eds.) *Real-Financial Linkages Among Open Economies*, MIT Press, Cambridge, Mass.

Krugman, Paul R., and Richard E. Baldwin,[1987]. "The Persistence of the U.S. Trade Deficit", *Brookings Papers on Economic Activity*, 1, 1-56.

Laffer, Arthur B.,[1973]. "Do Devaluations Really Help Trade?", *The Wall Street Journal*, February 5, p.10.

Laffer, Arthur B.,[1974]. "The Bitter Fruits of Devaluation", *The Wall Street Journal*, January 10, p.14.

Leamer, Edward E., and Robert M. Stern,[1970]. *Quantitative International Economics*. Allyn and Bacon, Boston, Mass.

Lerner, A.P.,[1944]. *The Economics of Control*. Macmillan Company, New York, N.Y.

Levinsohn, James,[1994]. "Competition Policy and International Trade", Working Paper #4972, National Bureau of Economic Research, Cambridge, Mass.

Liu, Ta-Chung,[1954]. "The Elasticity of Import Demand: A Theoretical and Empirical Reappraisal", *IMF Staff Papers*, 3, 416-441.

Lucas, Robert E. Jr.,[1976]. "Econometric Policy Evaluation: A Critique", in Karl Brunner and Allen Meltzer (eds.), *The Phillips Curve and Labour Markets*. Vol. 1, Carnegie-Rochester Conference Series on Public Policy. North-Holland, Amsterdam.

MacDonald, Ronald, and Mark P. Taylor,[1992]. "Exchange Rate Economics: A Survey", *IMF Staff Papers*, 39, 1-57.

MacKinnon, James G.,[1991]. "Critical Values of Cointegration Tests", in R.F. Engle, and C.W.J. Granger (eds.), *Long-Run Economic Relationships*. Oxford University Press, Oxford, U.K.

Magee, Steven P.,[1973]. "Currency Contracts, Pass-Through and Devaluation", *Brookings Papers on Economic Activity*, 303-323.

Magee, Steven P.,[1974]. "U.S. Import Prices in the Currency-Contract Period", *Brookings Papers on Economic Activity*, 117-164.

Mann, Catherine L.,[1986]. "Prices, Profit Margins, and Exchange Rates", *Federal Reserve Bulletin*, 72, 366-369.

Marshall, A.,[1923]. *Money, Credit and Commerce*. Sentry Press, New York, N.Y.

Marston, Richard C.,[1990]. "Pricing to Market in Japanese Manufacturing", *Journal of International Economics*, 29, 217-236.

Marston, Richard C.,[1991]. "Price Behaviour in Japanese and U.S. Manufacturing", in Paul R. Krugman (ed.), *Trade With Japan: Has the Door Opened Wider?*, National Bureau of Economic Research, University of Chicago Press, Chicago.

McKinnon, Ronald I.,[1963]. "Optimum Currency Areas", *American Economic Review*, 57, 717-725.

Melick, William R.,[1990]. "Estimating Pass-Through: Structure and Stability", International Finance Discussion Paper #387, Board of Govenors of the Federal Reserve, Washington, D.C.

Menon, Jayant,[1992]. "Exchange Rates and Prices of Australian Manufactured Exports", *Weltwirtschaftliches Archiv*, 128, 695-710.

Menon, Jayant,[1993a]. "The Pass-Through Puzzle: A Tale of Two Missing Princes?", *Atlantic Economic Journal*, 21, 88.

Menon, Jayant,[1993b]. "Exchange Rate Pass-Through: Australian Imports of Motor Vehicles", *International Economic Journal*, 7, 93-109.

Menon, Jayant,[1995]. "Exchange Rate Pass-Through", *Journal of Economic Surveys*, 9, 197-231.

Mill, John Stuart,[1836]. "On the Definition of Political Economy and the Method of Investigation Proper to it", in J.M. Robson (ed.), *Collected Works of John Stuart Mill, Vol 4*. University of Toronto Press, Toronto, 1967.

Mills, Terrence, C.,[1991]. *Time Series Techniques for Economists*. Cambridge University Press, New York, N.Y.

Milner, Brian,[1987]. "GM, Ford Complaints Trigger Hyundai Probe", *Globe & Mail*, 16 July, p.B1.

Muscatelli, Vito A., and Stan Hurn,[1992]. "Cointegration and Dynamic Time Series Models", *Journal of Economic Surveys*, 6, 1-41.

Muscatelli, Vito A., and L. Papi,[1990]. "Cointegration, Financial Innovation and Modelling the Demand for Money in Italy", *The Manchester School*, 58, 242-259.

Nelson, C. and C. Plosser,[1982]. "Trends and Random Walks in Macroeconomic Time Series", *Journal of Monetary Economics*, 10, 139-162

Newey, W. and K. West,[1987]. " A Simple, Positive Semi-Definite Heteroskedasticity and Autocorrelation Consistent Covariance Matrix", *Econometrica*, 55, 703-708.

Nickell, Stephen,[1985]. "Error Correction, Partial Adjustment and All That: An Expository Note," *Oxford Bulletin of Economics and Statistics*, 47, 119-129.

Officer, Lawrence H.,[1976]. "The Purchasing-Power-Parity Theory of Exchange Rates: A Review Article", *IMF Staff Papers*, 23, 1-60.

Officer, Lawrence H.,[1978]. "The Relationship Between Absolute and Relative Purchasing Power Parity", *Review of Economics and Statistics*, 60, 562-568.

Officer, Lawrence H.,[1980]. "Effective Exchange Rates and Price Ratios Over the Long Run: A Test of the Purchasing-Power-Parity Theory, *Canadian Journal of Economics*, 13, 206-230.

Ohno, Kenichi,[1989]. "Export Pricing Behaviour of Manufacturing: A U.S. - Japan Comparison", *IMF Staff Papers*, 36, 550-579.

Ohno, Kenichi,[1990]. "Exchange Rate Fluctuations, Pass-Through, and Market Share", *IMF Staff Papers*, 37, 294-310.

Orcutt, Guy H.,[1950]. "Measurement of Price Elasticities in International Trade", *Review of Economics and Statistics*, 32, 117-132.

Osterwald-Lenum, Michael,[1992]. "A Note with Quantiles of the Asymptotic Distribution of the ML Cointegration Rank Test Statistics", *Oxford Bulletin of Economics and Statistics*, 54, 461-472.

Pagan, A.R.,[1987]. "Three Econometric Methodologies: A Critical Appraisal", *Journal of Economic Surveys*, 1, 3-24.

Pagan, A.R., and M.R. Wickens,[1989]. "A Survey of Some Recent Econometric Methods", *Economic Journal*, 99, 962-1025.

Parsley, David,[1993]. "Exchange Rate Pass-Through: Evidence from Aggregate Japanese Exports", *Southern Economic Journal*, 60, 454-462.

Perman, Roger,[1991]. "Cointegration: An Introduction to the Literature", *Journal of Economic Studies*, 18, 3-30.

Perron, Pierre,[1988]. "Trends and Random Walks in Macroeconomic Time Series: Further Evidence from a New Approach", *Journal of Economic Dynamics and Control*, 12, 297-332.

Phillips, P.C.B.,[1987]. "Time Series Regression with a Unit Root", *Econometrica*, 55, 277-301.

Phillips, Peter C. B., and Mico Loretan,[1991]. "Estimating Long-run Economic Equilibria", *Review of Economic Studies*, 58, 407-436.

Ramsey, J.B.,[1969]. "Tests for Specification Errors in Clasical Linear Least Squares Regression Analysis", *Journal of the Royal Statistical Society*, 31, 350-371.

Rangan, Subramanian and Robert Z. Lawrence,[1993]. "The Responses of U.S. Firms to Exchange Rate Fluctuations: Piercing the Corporate Veil", *Brookings Papers on Economic Activity*, 341-379.

Price Surveillance Authority [1989]. "Inquiry Into Effects of Exchange Rate Appreciation on Prices of Consumer Goods", Report no. 21, Australian Government Publishing Service, Canberra, Australia.

Reimers, H.-E.,[1992]. "Comparisons of Tests for Multivariate Cointegration", *Statistical Papers*, 33, 335-359.

Reinhart, Carmen M.,[1995]. "Devaluation, Relative Prices, and International Trade", *IMF Staff Papers*, 42, 290-312.

Richardson, J. David,[1978]. "Some Empirical Evidence on Commodity Arbitrage and the Law of One Price", *Journal of International Economics*, 8, 341-351.

Robinson, W., T.R. Webb, and M.A. Townsend,[1979]. "The Influence of Exchange Rate Changes on Prices: A Study of 18 Industrial Countries", *Economica*, 46, 27-50.

Rosse, James,[1970]. "Estimating Cost Function Parameters Without Cost Data", *Econometrica*, 38, 256-275.

Runkle, D.E.,[1987]. "Vector Autoregression and Reality", *Journal of Business and Economic Statistics*, 5, 437-454.

Sargan, John D.,[1961]. "The Maximum Likelihood Estimation of Economic Relationships with Autoregressive Residuals", *Econometrica*, 29, 414-426.

Sargan, John D.,[1964]. "Wages and Prices in the United Kingdom: A Study in Econometric Methodology", in P.E. Hart, G. Mills, and J.K. Whitaker (eds.), *Econometric Analysis for National Economic Planning*, Butterworths, London, U.K.

Sargan, John D.,[1980]. "Some Tests of Dynamic Specification for a Single Equation", *Econometrica*, 48, 879-897.

Sargan, John D.,[1983]. "Identification inModels with Autoregressive Errors", in S. Karlin, T. Amemiya, and L.A. Goodman (eds.), *Studies in Econometrics, Time Series and Multivariate Statistics*, Academic Press, New York, N.Y.

Sargent, Thomas J.,[1976]. "A Classical Macroeconomic Model for the United States", *Journal of Political Economy*, 84, 207-238.

Sargent, Thomas J.,[1979]. "Causality, Exogeneity, and Natural Rate Models: Reply to C.R. Nelson and B.T. McCallum", *Journal of Political Economy*, 87, 403-409.

Sargent, Thomas J.,[1987]. *Macroeconomic Theory*. Academic Press (Second Edition), New York, N.Y.

Schembri, Lawrence,[1988]. "Export Prices and Exchange Rates: An Industry Approach", in Robert Feenstra (ed.), *Trade Policies for International Competitiveness*, University of Chicago Press, Chicago, Illinois.

Setterfield, Mark,[1993]. "Adjustment Asymmetries and Hysteresis in Linear Models", unpublished manuscript, Trinity College.

Shinjo, Koji,[1993]. "Exchange Rate Changes and Pricing Behavior of Japanese Firms: A Cross-Section Analysis", *Journal of the Japanese and International Economies*, 7, 157-174.

Sims, C.A.,[1972]. "Money Income and Causality", *American Economic Review*, 62, 182-191.

Sims, C.A.,[1980]. "Macroeconomics and Reality", *Econometrica*, 48, 1-48.

Spencer, David E.,[1989]. "Does Money Matter? The Robustness of Evidence from Vector Autoregressions", *Journal of Money, Credit, and Banking*, 21, 442-454.

Spitäller, Erich,[1980]. "Short-Run Effects of Exchange Rate Changes on Terms of Trade and Trade Balance", *IMF Staff Papers*, 27, 320-348.

Stock, James H.,[1987]. "Asymptotic Properties of Least Squares Estimators of Co-integrating Vectors", *Econometrica*, 55, 1035-1056.

Stock, James H. and Mark Watson,[1988]. "Testing for Common Trends", *Journal of the American Statistical Association*, 83, 1094-1107.

Summers, Lawrence H.,[1991]. "The Scientific Illusion in Empirical Macroeconomics," *Scandinavian Journal of Economics*, 93, 129-148.

Thompson, Arthur A. amd John P. Formby,[1993]. *Economics of the Firm: Theory and Practice*. Prentice Hall, Englewood Cliffs, N.J.

Tichy, Gunther,[1976]. "Theoretical and Empirical Difficulties Involved in Estimating Exchange Rate Effects", *German Economic Review*, 14, 112-125.

Vanek, Jaroslav,[1962]. *International Trade: Theory and Economic Policy*. Homewood Publishers, Homewood, Illinois.

Viner, Jacob,[1937]. *Studies in the Theory of International Trade*. New York, N.Y.

Wanniski, Jude,[1975]. "The Mundell-Laffer Hypothesis - A New View of the World Economy", *Public Interest*, 39, 31-52.

White, H.,[1980]. "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity", *Econometrica*, 48, 817-838.

Wilson, John F., and Wendy E. Takacs,[1979]. "Differential Responses to Price and Exchange Rate Influences in the Foreign Trade of Selected Industrial Countries", *Review of Economics and Statistics*, 61, 267-279.

Wong, Wing-Keung, and Meher Manzur,[1993]. "Cointegrated Variables with Time-Varing Cointegration Parameter: Purchasing Power Revisited", School of Economics and Finance, Curtin University of Technology, Working Paper 93-12, Perth, Australia.

Wyplosz, C.,[1987]. "Comments", in R. Laylard and L. Calmfors (eds.), *The Fight Against Unemployment*. MIT Press, Cambridge, Mass.

Yang, Yung Y., and Min Hwang,[1994]. "Price Behaviour in Korean Manufacturing", *Review of Economics and Statistics*, 76, 461-470.

Zellner, A.,[1962]. "An Efficient Method of Estimating Seemingly Unrelated Regressions and Testing for Aggregation Bias", *Journal of the American Statistical Association*, 57, 348-368.

APPENDIX A

MATHEMATICAL DERIVATION OF THE EXTENSION TO THE ORIGINAL MODEL

Firms with differentiated products facing linear demand curves and quadratic adjustment costs will solve the following rational-expectations dynamic optimization problem:

$$\text{(A.1)} \qquad \underset{(p_{it+\tau})}{Max}\ V_t = E_{t-1}\sum_{\tau=0}^{\infty} b^{\tau}\left[p_{it+\tau}q_{it+\tau} - \left(\frac{C^{*}(q_{it+\tau})}{e_{it+\tau}}\right) - \frac{f}{2}(q_{it+\tau} - q_{it+\tau-1})^2\right]$$

where,

E_{t-1} = mathematical expectations operator,

b = discount factor ($0 < b < 1$),

p_i = price of i[th] country's automobile, denominated in Canadian dollars/unit,

q_i = quantity of i[th] country's automobile,

$C^{*}(q_i)$ = cost of i[th] country's automobile, denominated in foreign currency/unit,

e_i = bilateral exchange rate expressed as i[th] currency/Canadian dollar, and

f = adjustment cost parameter.

Substituting quantities with:

$$\text{(A.2)} \qquad q_{it+\tau} = a_i - \alpha_i p_{it+\tau} + \sum_{j\neq i}\beta_j p_{jt+\tau}$$

equation (A.1) becomes

$$\text{(A.3)} \qquad \underset{(p_{it+\tau})}{Max}\ V_t = E_{t-1}\sum_{\tau=0}^{\infty} b^{\tau}\Bigg[p_{it+\tau}(a_i - \alpha_i p_{it+\tau} + \sum_{j\neq i}\beta_j p_{jt+\tau}) - \left(\frac{C^{*}(a_i - \alpha_i p_{it+\tau} + \sum_{j\neq i}\beta_j p_{jt+\tau})}{e_{it+\tau}}\right)$$
$$- \frac{f}{2}(-\alpha_i p_{it+\tau} + \sum_{j\neq i}\beta_j p_{jt+\tau} + \alpha_i p_{it+\tau-1} - \sum_{j\neq i}\beta_j p_{jt+\tau-1})^2\Bigg]$$

Maximizing equation (A.3) produces the following system of Euler equations:

$$(A.4) \qquad (a_i - \alpha_i p_{it+\tau} + \sum \beta_j p_{jt+\tau}) + p_{it+\tau}\phi_{it+\tau} - \left[\frac{C_q^*}{e}\right]_{it+\tau} \phi_{it+\tau} - f\Pi_{it+\tau}\phi_{it+\tau} + bf\Pi_{it+\tau+1}\phi_{it+\tau} = 0$$

where,

$$\phi_{it+\tau} = \frac{\partial q_{it+\tau}}{\partial p_{it+\tau}} = -\alpha_i + \sum \beta_j \theta_{it+\tau} ,$$

$$\theta_{it+\tau} = \frac{\partial p_{jt+\tau}}{\partial p_{it+\tau}} ,$$

$$C_q^* = \frac{\partial C^*(q)}{\partial q} , \textit{ and}$$

$$\Pi_{it+\tau} = -\alpha_i \, p_{it+\tau} + \sum \beta_j p_{jt+\tau} + p_{it+\tau-1} - \sum \beta_j p_{jt+\tau-1} .$$

Dividing equation (A.4) by $\phi_{it+\tau}$ and rearranging to isolate the price of the ith country's automobile, $p_{it+\tau}$, on the left-hand side (L.H.S.) and all other variables on the right-hand side (R.H.S.) :

(A.5)

$$\underline{L.H.S.} = \frac{-\alpha_i p_{it+\tau}}{\phi_{it+\tau}} + p_{it+\tau} + f\alpha_i p_{it+\tau} - f\alpha_i p_{it+\tau-1} - bf\alpha_i p_{it+\tau+1} + bf\alpha_i p_{it+\tau}$$

$$\underline{R.H.S.} = -\frac{a_i}{\phi_{it+\tau}} - \frac{\sum \beta_j p_{jt+\tau}}{\phi_{it+\tau}} + \left[\frac{C_q^*}{e}\right]_{it+\tau} + f\sum \beta_j p_{jt+\tau} - f\sum \beta_j p_{jt+\tau-1} - bf\sum \beta_j p_{jt+\tau+1} + bf\sum \beta_j p_{jt+\tau} .$$

L.H.S.

Concerntrating on the left hand side of the system of Euler equations, if one:

(a) multiplies by -1; and
(b) divides by $f\alpha_i$.

one derives the following expression from (a):

(A.6) $$\underline{L.H.S.}: \quad = \quad bf\alpha_i p_{it+\tau+1} + \left[\frac{\alpha_i}{\phi_{t+\tau}} - 1 - f\alpha_i - bf\alpha_i\right]p_{it+\tau} + f\alpha_i\, p_{it+\tau-1}\ ,$$

and the following expression combining (b) with (a):

(A.7) $$bp_{it+\tau+1} + \left[\frac{1}{f\phi_{t+\tau}} - \frac{1}{f\alpha_i} - 1 - b\right]p_{it+\tau} + p_{it+\tau-1}\ ,$$

or alternatively,

(A.8) $$\underline{L.H.S.}: \quad = \quad b\left(1 + \frac{\Gamma}{b}L + \frac{1}{b}L^2\right)p_{it+\tau+1}\ ,$$

where

(A.9) $$\Gamma = \left[\frac{1}{f}\left(\frac{1}{\phi_{t+\tau}} - \frac{1}{\alpha_i}\right) - (1+b)\right].$$

In order to calculate the roots of the system of equations (λ_1, λ_2), one needs to factor the term in brackets in equation **(A.8)** in the following manner:

(A.10) $$1 + \frac{\Gamma}{b}L + \frac{1}{b}L^2 = (1 - \bar{\lambda}_1 L)(1 - \bar{\lambda}_2 L) = 1 - (\bar{\lambda}_1 + \bar{\lambda}_2)L + \bar{\lambda}_1\bar{\lambda}_2 L^2 ,$$

such that,

(A.11) $$(i)\ \frac{\Gamma}{b} = -(\bar{\lambda}_1 + \bar{\lambda}_2) ,$$
$$(ii)\ \frac{1}{b} = \bar{\lambda}_1\bar{\lambda}_2 \rightarrow \bar{\lambda}_2 = \frac{1}{\bar{\lambda}_1 b} .$$

Using the results from equation **(A.11)**:

(A.12) $$-\Gamma = b\bar{\lambda}_1 + \frac{1}{\bar{\lambda}_1} .$$

Substituting **(A.12)** into **(A.9)**:

(A.13) $$\left[\frac{1}{f}\left(\frac{1}{\alpha_t} - \frac{1}{\phi_{t+\tau}}\right) + (1+b)\right] = b\bar{\lambda}_1 + \frac{1}{\bar{\lambda}_1} .$$

The expression in equation **(A.13)** is *positive* since $\alpha_t > 0$, $\phi_{t+\tau} < 0$, and $0 < b < 1$.

Calculation of λ_1 and λ_2

The minimum point of the u-shaped function, $b\lambda + \lambda^{-1}$ occurs when $\lambda = 1/\sqrt{b}$ and the associated value is $2/\sqrt{b}$. Given that $0 < b < 1$, it is the case that $1 + b \geq 2/\sqrt{b}$ with an equality at $b = 1$. Consequently, for relatively large values of α_i and $\phi_{it+\tau}$ where $-\Gamma \approx (1 + b)$, it is also the case that $-\Gamma \geq 2/\sqrt{b}$. Therefore, the solutions for λ_1 and λ_2 are both distinct and real. Suppose λ_1 is the smaller root, then $\lambda_1 < 1/\sqrt{b} < \lambda_2$. Moreover, if the function $b\lambda + \lambda^{-1}$ equals $(1 + b)$ then $\lambda_1 = 1$ and $\lambda_2 = 1/b$ are the two roots. However, since $-\Gamma > (1 + b)$, unity represents the upper bound for λ_1 while $1/b$ represents the lower bound for λ_2.

<u>R.H.S.</u>

Operations performed on the left-hand side of the equation must also be performed on the right-hand side. Therefore, multiplying the R.H.S. from equation (A.5) by -1:

(A.14)
$$\underline{R.H.S.} = \frac{a_i}{\phi_{it+\tau}} + \frac{\sum \beta_j p_{jt+\tau}}{\phi_{it+\tau}} - \left[\frac{C_q^*}{e}\right]_{it+\tau} - f\sum \beta_j p_{jt+\tau} + f\sum \beta_j p_{jt+\tau-1} + bf\sum \beta_j p_{jt+\tau+1} - bf\sum \beta_j p_{jt+\tau}$$

and dividing by $f\alpha_i$:

(A.15)
$$\frac{a_i}{f\alpha_i\phi_{it+\tau}} + \frac{\sum \beta_j p_{jt+\tau}}{f\alpha_i\phi_{it+\tau}} - \frac{1}{f\alpha_i}\left[\frac{C_q^*}{e}\right]_{it+\tau} - \frac{\sum \beta_j p_{jt+\tau}}{\alpha_i} + \frac{\sum \beta_j p_{jt+\tau-1}}{\alpha_i} + \frac{b\sum \beta_j p_{jt+\tau+1}}{\alpha_i} - \frac{b\sum \beta_j p_{jt+\tau}}{\alpha_i}.$$

Equation (A.15) can be rearranged as:

(A.16)
$$\frac{a_i}{f\alpha_i\phi_{it+\tau}} - \frac{1}{f\alpha_i}\left[\frac{C_q^*}{e}\right]_{it+\tau} + \frac{1}{\alpha_i}\left[b\sum \beta_j p_{jt+\tau+1} + \left(\frac{1}{f\phi_{t+\tau}} - (1 + b)\right)\sum \beta_j p_{jt+\tau} + \sum \beta_j p_{jt+\tau-1}\right].$$

Adding and subtracting:

(A.17)
$$\frac{1}{f\alpha_i^2}\sum \beta_j \, p_{jt+\tau} \,,$$

will produce:

(A.18)
$$\frac{a_i}{f\alpha_i\phi_{it+\tau}} - \frac{1}{f\alpha_i}\left[\frac{C_q^*}{e}\right]_{it+\tau} + \frac{1}{\alpha_i}\left[b\sum \beta_j p_{jt+\tau+1} + \left(\frac{1}{f}\left(\frac{1}{\phi_{t+\tau}} - \frac{1}{\alpha_i}\right) - (1+b)\right)\sum \beta_j p_{jt+\tau} + \sum \beta_j p_{jt+\tau-1}\right] + \frac{1}{f\alpha_i^2}\sum \beta_j p_{jt+\tau} \,,$$

or alternatively,

(A.19)
$$\frac{a_i}{f\alpha_i\phi_{it+\tau}} - \frac{1}{f\alpha_i}\left[\frac{C_q^*}{e}\right]_{it+\tau} + \frac{1}{\alpha_i}\left[b\left(1 + \frac{\Gamma}{b}L + \frac{1}{b}L^2\right)\sum \beta_j p_{jt+\tau+1}\right] + \frac{1}{f\alpha_i^2}\sum \beta_j p_{jt+\tau} \,.$$

Plugging in the expression from equation (A.10), the right-hand side becomes:

(A.20)
$$\underline{R.H.S.}: \; = \frac{a_i}{f\alpha_i\phi_{it+\tau}} - \frac{1}{f\alpha_i}\left[\frac{C_q^*}{e}\right]_{it+\tau} + \frac{1}{\alpha_i}\left[b(1 - \tilde{\lambda}_1 L)(1 - \tilde{\lambda}_2 L)\sum \beta_j p_{jt+\tau+1}\right] + \frac{1}{f\alpha_i^2}\sum \beta_j p_{jt+\tau} \,.$$

Equating both sides:

$$
\text{(A.21)} \quad b(1 - \bar{\lambda}_1 L)(1 - \bar{\lambda}_2 L)p_{it+\tau+1} = \frac{a_i}{f\alpha_i\phi_{it+\tau}} - \frac{1}{f\alpha_i}\left[\frac{C_q^*}{e}\right]_{it+\tau} + \frac{1}{\alpha_i}\left[b(1 - \bar{\lambda}_1 L)(1 - \bar{\lambda}_2 L)\sum \beta_j p_{jt+\tau+1}\right] + \frac{1}{f\alpha_i^2}\sum \beta_j p_{jt+\tau} .
$$

To satisfy the transversality condition, one operates (*i.e.*, divides) using the forward inverse of $(1 - \bar{\lambda}_2 L)$ and the discount factor, b. That is, one uses the "unstable root", $\bar{\lambda}_2$, to solve in the forward direction.[1] This produces the following equality:

$$
\text{(A.22)} \quad (1 - \bar{\lambda}_1 L)p_{it+\tau+1} = \frac{-(b\bar{\lambda}_2)^{-1}L^{-1}a_i}{f\alpha_i\phi_{it+\tau}(1 - \bar{\lambda}_2^{-1}L^{-1})} + \frac{-(b\bar{\lambda}_2)^{-1}L^{-1}}{f\alpha_i(1 - \bar{\lambda}_2^{-1}L^{-1})}\left[\frac{C_q^*}{e}\right]_{it+\tau} + \frac{1}{\alpha_i}\left[(1 - \bar{\lambda}_1 L)\sum \beta_j p_{jt+\tau+1}\right] + \frac{-(b\bar{\lambda}_2)^{-1}L^{-1}}{f\alpha_i^2(1 - \bar{\lambda}_2^{-1}L^{-1})}\sum \beta_j p_{jt+\tau} .
$$

Substituing for expression *(ii)* in equation (A.11):

1

$$
\frac{1}{1 - \lambda L}x_t = -\sum_{i=1}^{\infty}\left(\frac{1}{\lambda}\right)x_{t+i}
$$

(A.23)

$$(1 - \tilde{\lambda}_1 L)p_{it+\tau+1} = \frac{-\tilde{\lambda}_1 a_i}{f\alpha_i \Phi_{it+\tau}\left(1 - \frac{1}{\tilde{\lambda}_2}\right)} + \frac{\tilde{\lambda}_1}{f\alpha_i}\sum_{k=0}^{\infty}\left(\frac{1}{\tilde{\lambda}_2}\right)^k \left[\frac{C_q^*}{e}\right]_{it+\tau+1+k} + \frac{1}{\alpha_i}\left[(1 - \tilde{\lambda}_1 L)\sum \beta_j p_{jt+\tau+1}\right]$$

$$+ \frac{\tilde{\lambda}_1}{f\alpha_i^2}\sum_{k=0}^{\infty}\left(\frac{1}{\tilde{\lambda}_2}\right)^k \sum \beta_j p_{jt+\tau+k} \, .$$

Finally, rearranging to isolate $p_{it+\tau+1}$ on the left-hand side,and reinserting the mathematical expectations operator, one derives equation *(3.12)* in chapter 3:

(A.24)

$$p_{it+\tau+1} = \left[-\frac{\lambda_1 a}{f\alpha_i \Phi_{it+\tau}\left(1-\frac{1}{\lambda_2}\right)} + \frac{\lambda_1}{f\alpha_i}\sum_{k=0}^{\infty}\left(\frac{1}{\lambda_2}\right)^k E_{t+\tau}\left(\frac{C_q^*}{e}\right)_{it+\tau+1+k} + \lambda_1 p_{it+\tau}\right]$$

$$+ \frac{1}{\alpha_i}\sum_{j\neq i} \beta_j p_{jt+\tau+1} - \frac{\lambda_1}{\alpha_i}\sum_{j\neq i} \beta_j p_{jt+\tau} - \frac{\lambda_1}{f\alpha_i^2}\sum_{k=0}^{\infty}\left(\frac{1}{\lambda_2}\right)^k E_{t+\tau}\left(\sum_{j\neq i} \beta_j p_{jt+\tau+1+k}\right)$$

APPENDIX B

DATA: SOURCES, PROBLEMS AND REMEDIES

The following data appendix discusses the sources of data, problems encountered and remedies implemented. The sample consists of *quarterly data* obtained for the period 1980:1 to 1990:4. The selection of this particular sample period is based upon :

(a) the desire to capture large movements in explanatory variables, particularly exchange rates;
(b) the desire to model pricing behaviour over one (or more) complete business cycle(s); and
(c) data availability.

The countries in question are Japan, South Korea, (West) Germany, Sweden, and the United States. Selection of these countries is based upon their relative importance, over the sample period, in terms of the total Canadian dollar value of foreign automobile imports into Canada.[1]

(i) Prices

Price data for all countries are quarterly unit values as reported in Statistics Canada's *Imports, Merchandise Trade*. Although import unit values are readily obtainable, they are not the preferred choice for price data (Kravis and Lipsey [1974]). The main problem is that unit-value indexes can change if the composition of imports change, while prices remain constant. One manner to avoid this problem is to differentiate the product as best possible. By segregating the automobile industry into three separate categories - subcompacts, mid-size, and large - one can minimize the problem of commodity composition. Another method of minimizing the problems associated with inconsistent unit-value indexes is to select a larger frequency for the data. For example, by selecting quarterly

[1] Raw data for prices, costs and exchange rates are plotted for each country and automobile classification on pages B-4 to B-15. All data is in logarithmic form.

data, as opposed to monthly, one can spread the distortionary effects of one month of "unusual imports".[2]

(ii) Exchange rates

Nominal exchange rates for Japan, (West) Germany, Sweden and the United States come from the Bank of Canada's *ETS Data Management System*. The Korean won data come from the Bank of Korea's *Monthly Statistical Bulletin.*

(iii) Costs

There are numerous methods to derive production costs: some studies use indirect cost proxies such as the foreign price of similar goods while others infer costs changes from a common component in export prices across different destination markets. In an effort to acquire better *direct* measures, the U.S. costs, published by the U.S. Bureau of Labor Statistics, are *Producer Price Indexes* for the net output of passenger cars. Germany has a similar statistic called the *Index der Erzeugerpreise Gewerblicher Produkte* published by the Statistics Bundesamt. Japanese costs are measured by the output price index of the transportation equipment sector in the *Economic Statistics Monthly* from the Bank of Japan. South Korean costs are an indirect proxy: the wholesale price (in won) for a "typical" Korean automobile.[3] This statistic is constructed by the Economic Planning Board and published in the *Economic Statistics Yearbook.* Due to the lack of Swedish data, the choice of cost statistics is limited to the Domestic Supply statistic published in the IMF's International Financial Statistics. This index measures the price development in the producer and import stages for

---

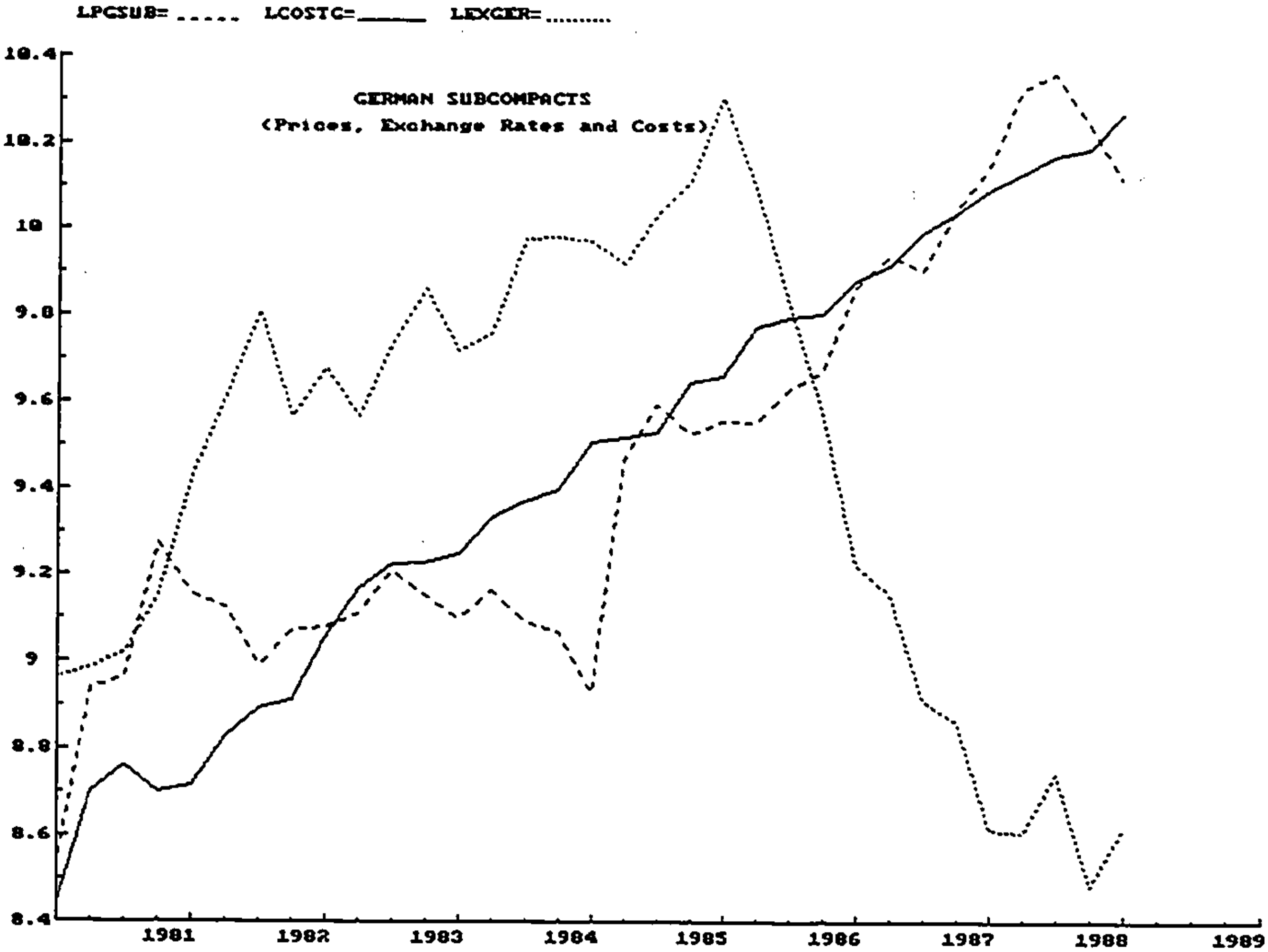
[2] For example, exports may decide to ship three months worth of accumulated "customized" orders in the span of one month.

[3] "Typical" Korean cars range from a Hyundai Pony in 1985 to a Hyundai Excel in later years.

industrial goods consumed in the country.

Finally, during the sample period there is one important structural change in the automobile industry. As of the first quarter in 1988, Statistics Canada redefined the classification of automobiles. Prior to 1988, automobiles are categorized according to the size of their interior, measured in cubic feet. Under this classification, a compact/mid-size automobile ranges from 100 to 120 cubic feet (SIC categories 581-05 and 581-07). In the first quarter of 1988, all automobiles are re-classified according to their engine size, measured in litres. Consequently, compact/mid-size automobiles range from 1.5 to 3.0 litres. Given this change, certain models jump from one category to another. For example, the average price of a large German automobile in 1987 is $26,000 whereas in 1988, the price jumps to $45,000 (see page B-13) and remains at this higher level to the end of the sample period. This is the typical case where the average German stationwagon (relatively large interior) is replaced with the high performance sports car (relatively large engine).

The fact that there is a structural break at 1988:1 can have significant importance when one is examining the stationary properties of variables. Perron [1988] demonstrates that if a variable has a constant mean and variance over the period prior to a structural break, and a constant but higher or lower mean and variance over the period subsequent to a structural break, DF and ADF tests will interpret the structural break as evidence of nonstationarity. Clearly, this is a false interpretation since the data are stationary; there is simply a once-and-for-all jump in the first and second moments. To avoid the problem of accepting nonstationarity when it is false, separate unit root tests are performed over the two sample periods. Secondly, if one estimates regressions on the basis of the complete sample period, the structural break will have considerable effect on the values of the estimates. Therefore, to avoid the problem of tenuous estimates associated with structural breaks, some of the estimation results exclude the post-1987:4 data.



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GERMAN SUBCOMPACTS
(Prices, Exchange Rates and Costs)
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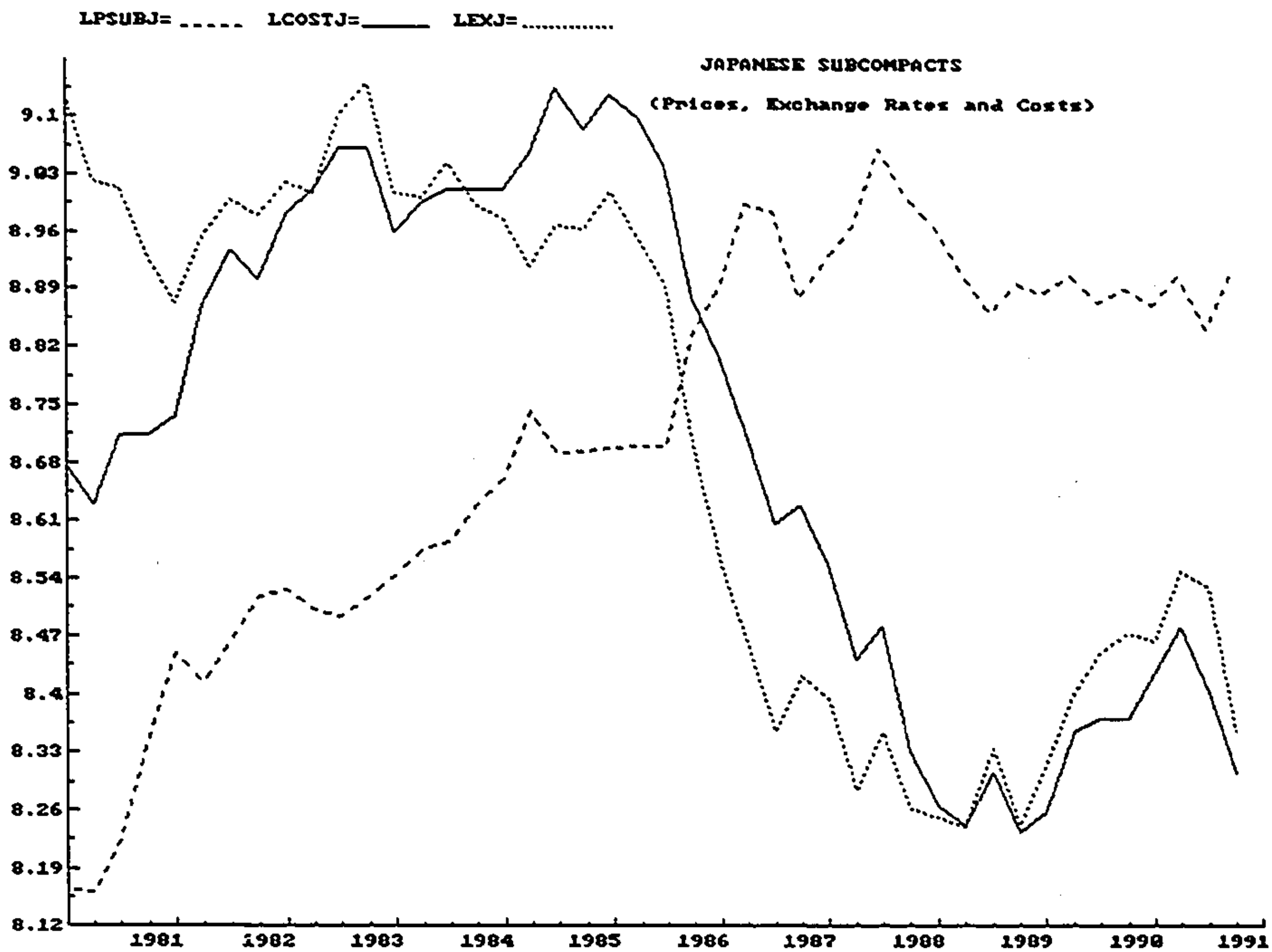
10.2
10
9.8
9.6
9.4
9.2
9
8.8
8.6
8.4
1981
1982
1983
1984
1985
1986
1987
1988
1989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LCOSTJ= _____
LEXJ= ....
JAPANESE SUBCOMPACTS
(Prices, Exchange Rates and Costs)
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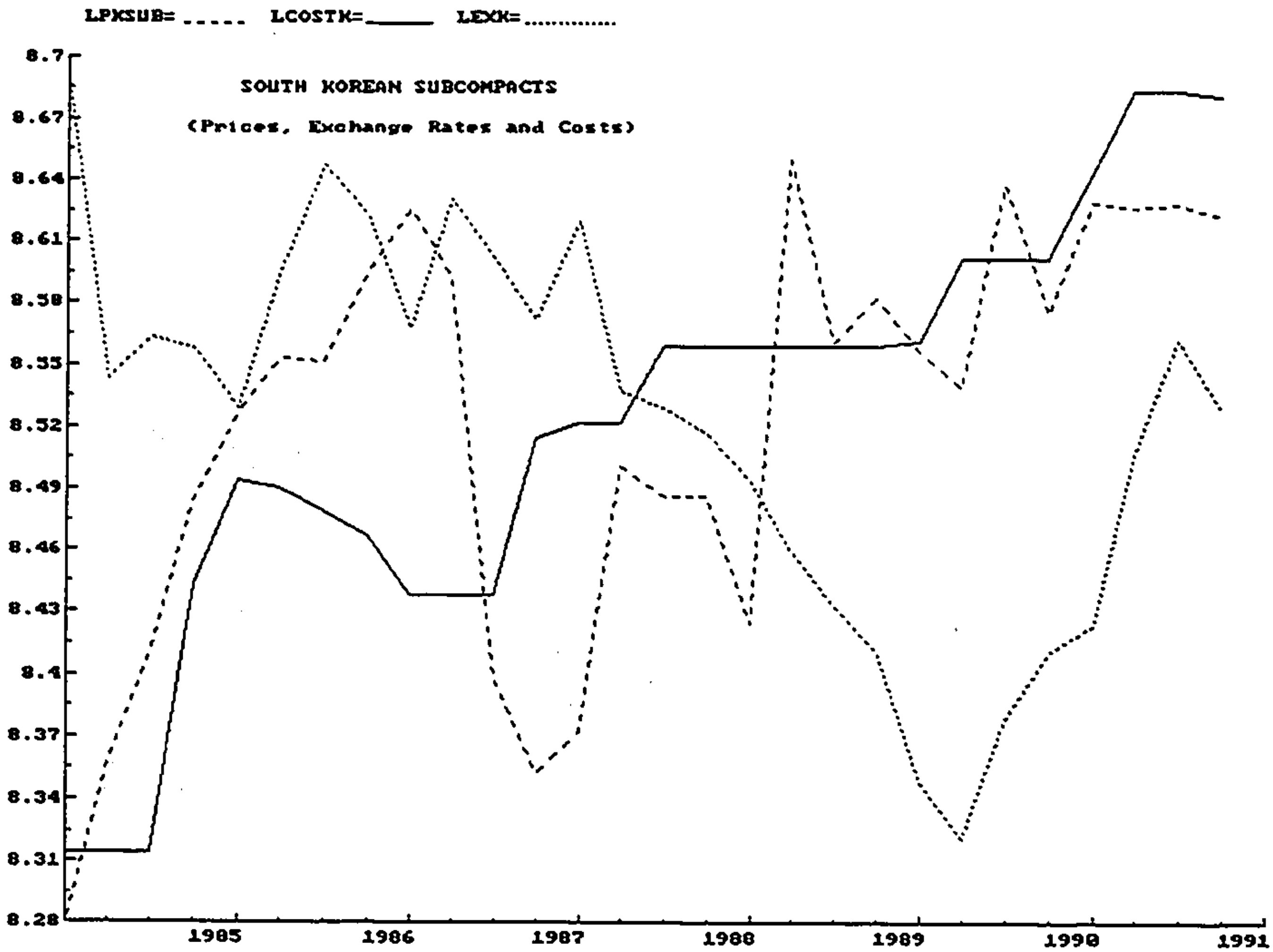
9.03
8.96
8.89
8.82
8.75
8.68
8.61
8.54
8.47
8.4
8.33
8.26
8.19
8.12
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991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SOUTH KOREAN SUBCOMPACTS
(Prices, Exchange Rates and Costs)
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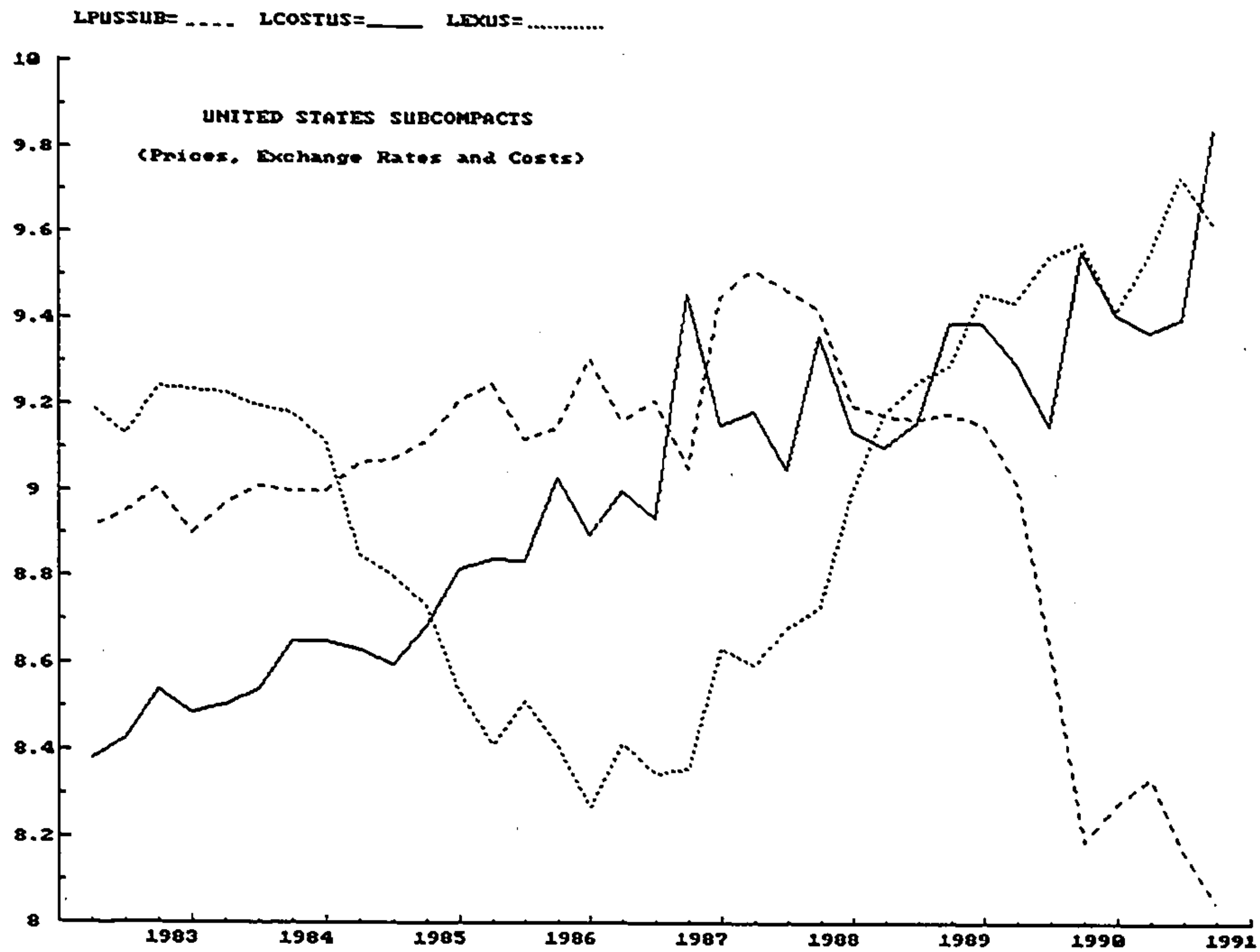
8.64
8.61
8.58
8.55
8.52
8.49
8.46
8.43
8.4
8.37
8.34
8.31
8.28
1985
1986
1987
1988
1989
1990
1991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LCOSTUS=____
LEXUS=..........
UNITED STATES SUBCOMPACTS
(Prices, Exchange Rates and Costs)
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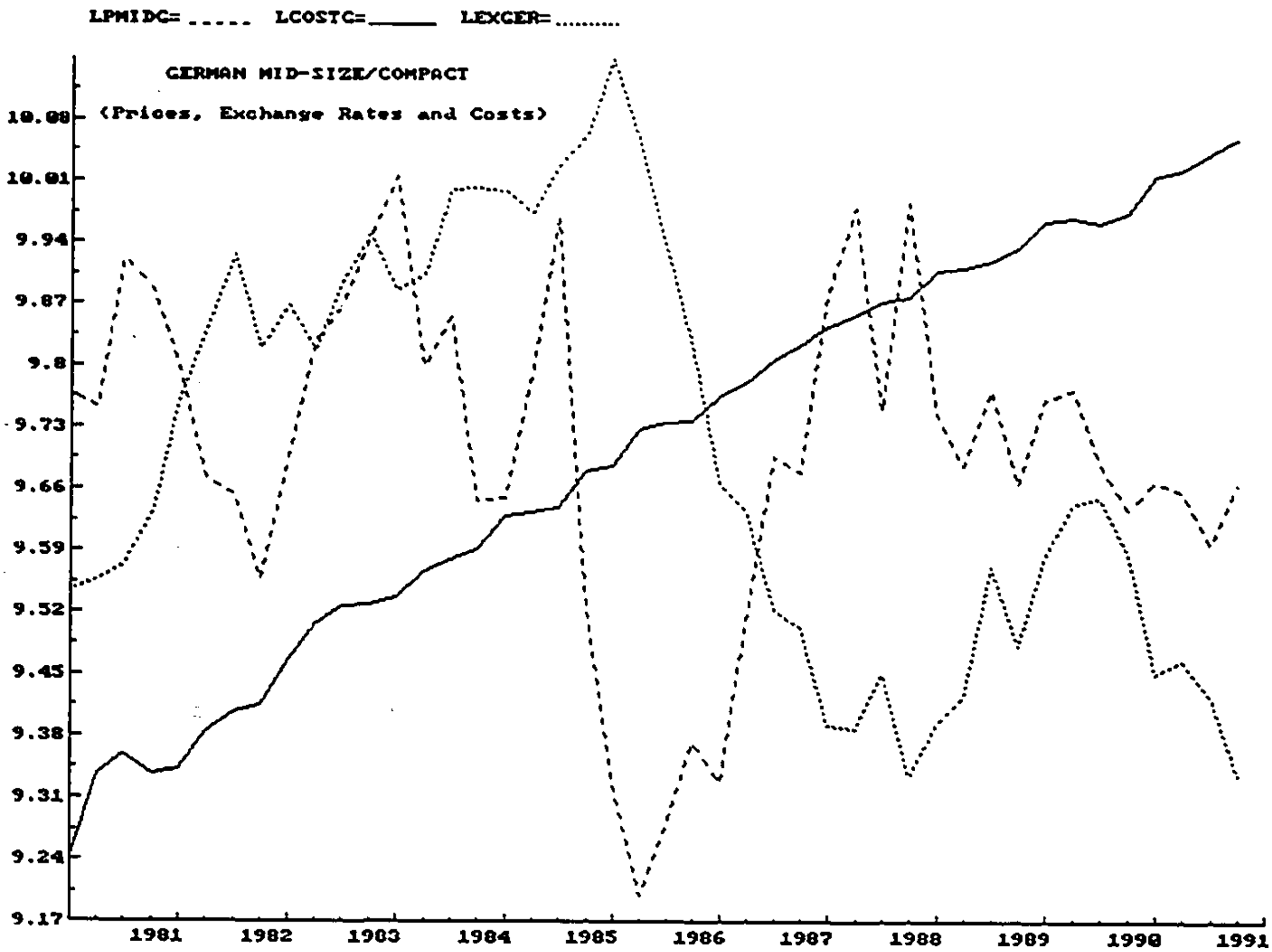
9.8
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
8
1983
1984
1985
1986
1987
1988
1989
1990
1991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GERMAN MID-SIZE/COMPACT
(Prices, Exchange Rates and Costs)
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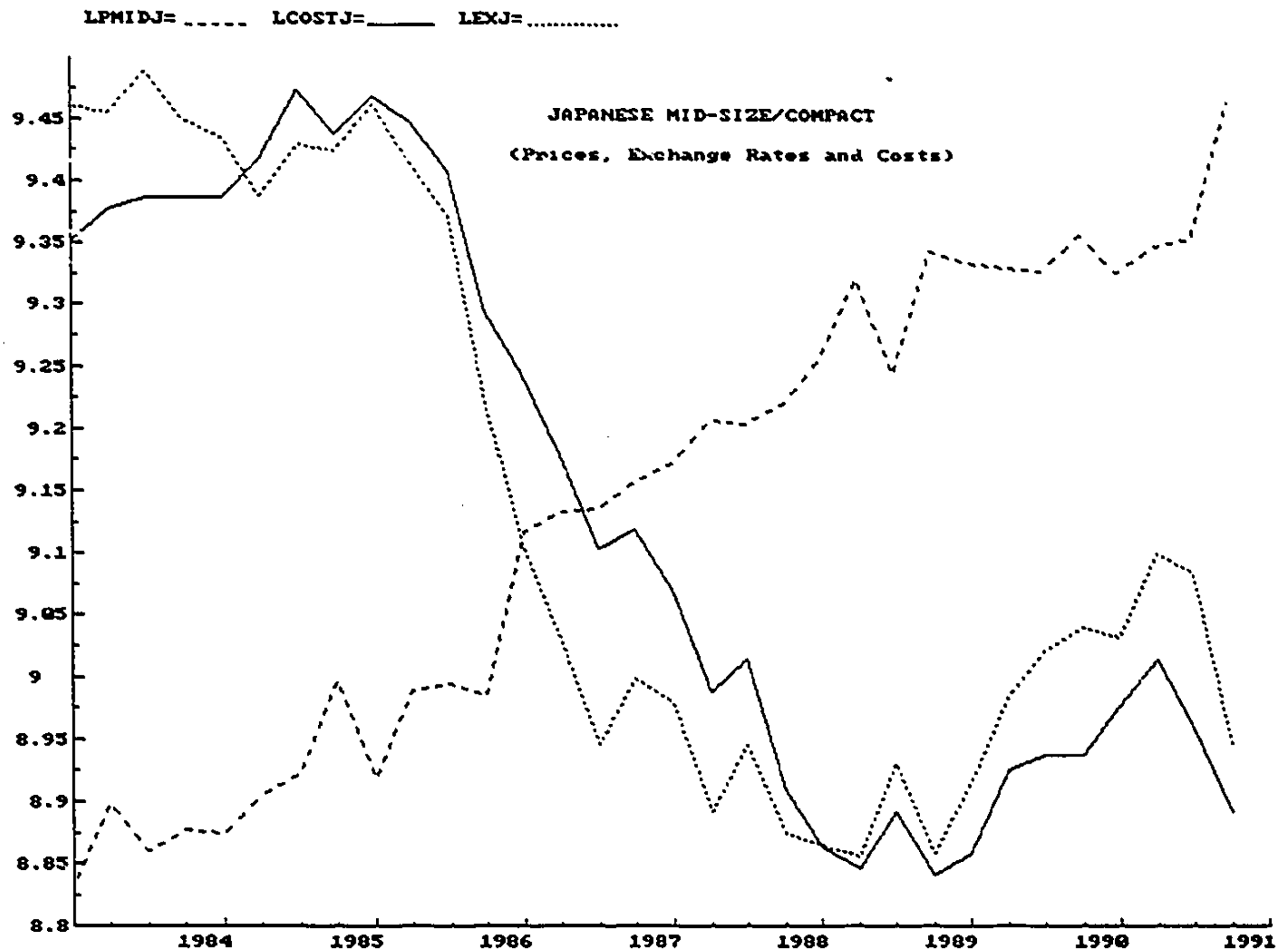
10.01
9.94
9.87
9.8
9.73
9.66
9.59
9.52
9.45
9.38
9.31
9.24
9.17
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991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JAPANESE MID-SIZE/COMPACT
(Prices, Exchange Rates and Costs)
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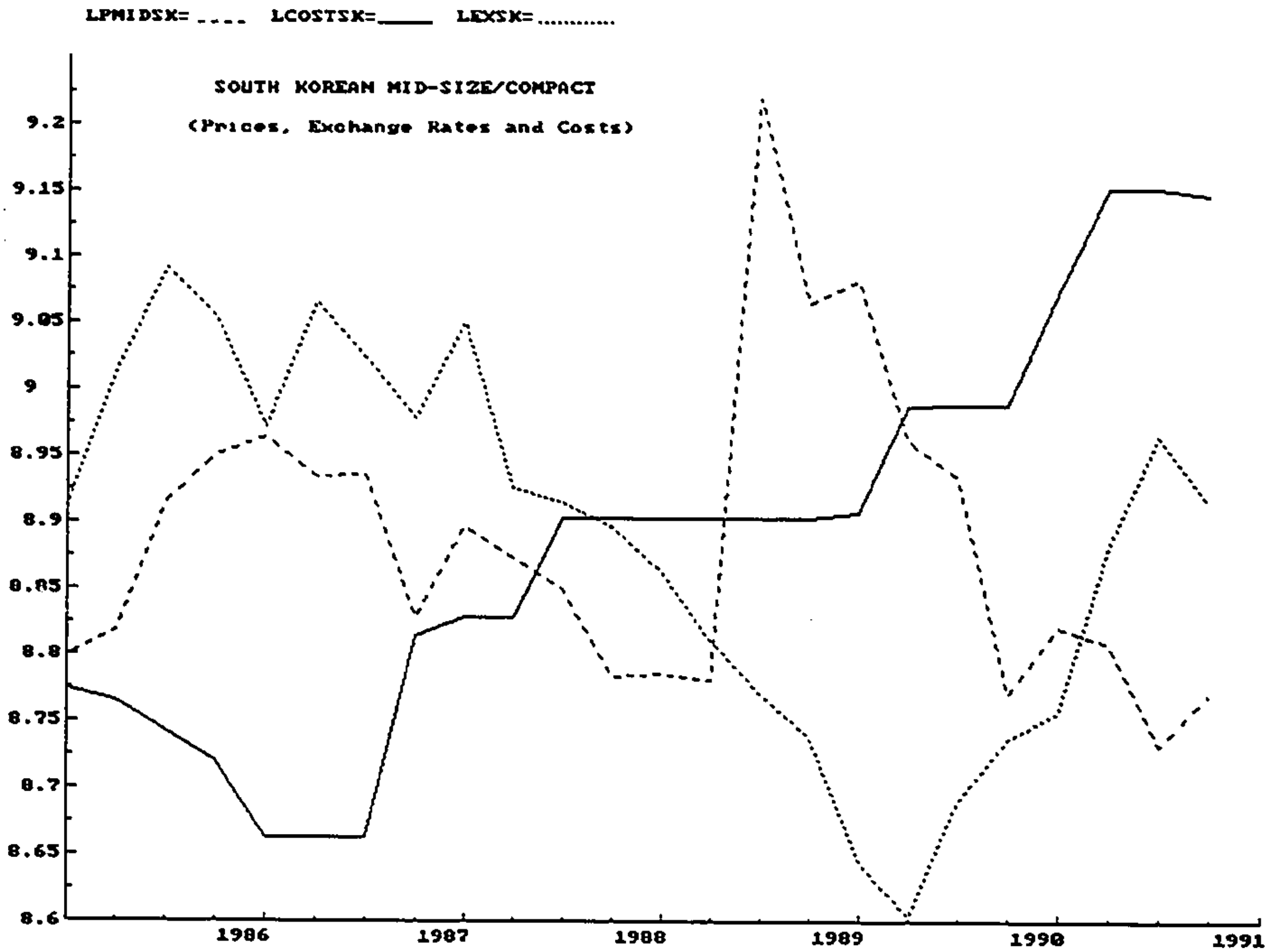
9.4
9.35
9.3
9.25
9.2
9.15
9.1
9.05
9
8.95
8.9
8.85
8.8
1984
1985
1986
1987
1988
1989
1990
1991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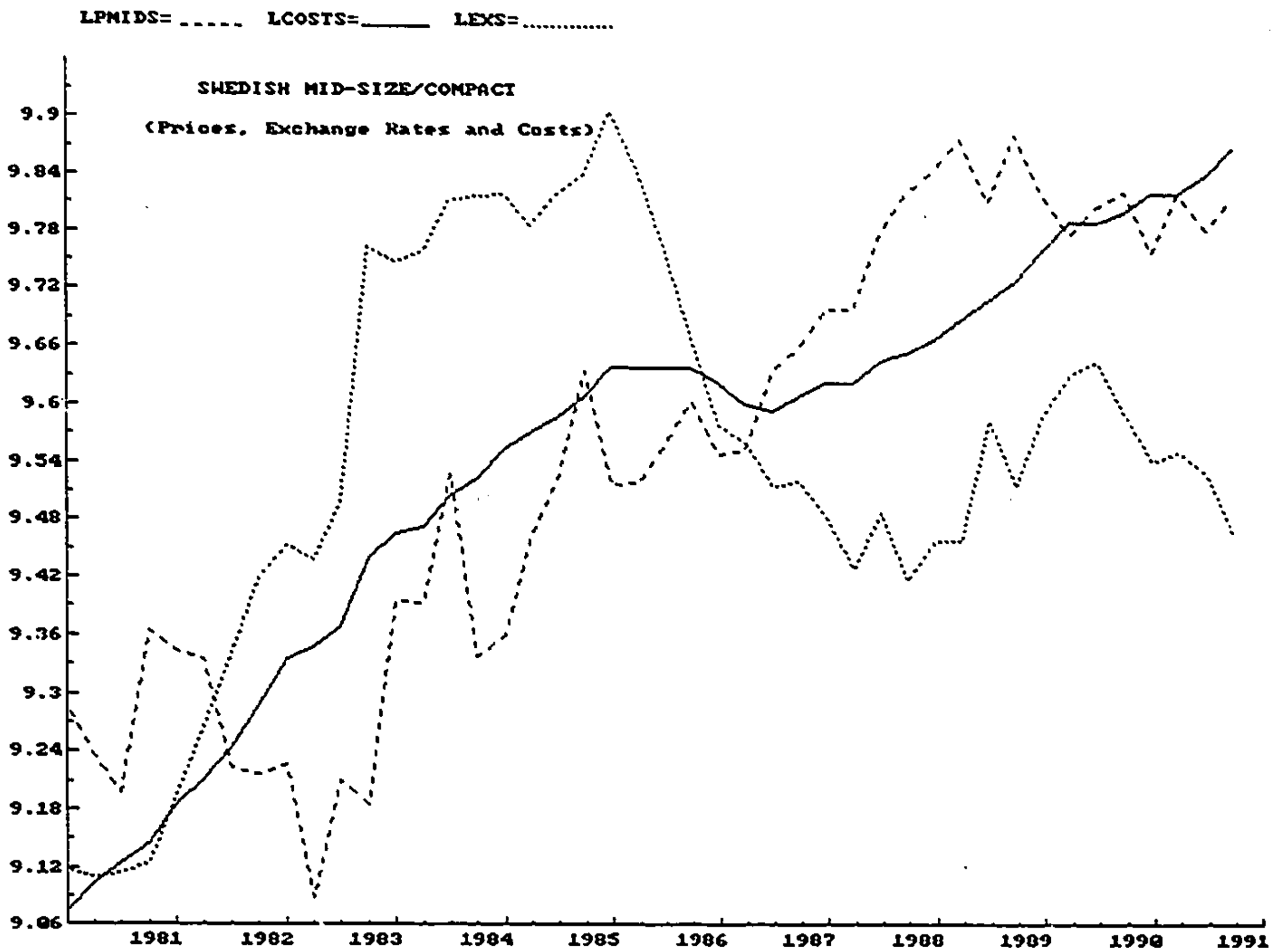
SOUTH KOREAN MID-SIZE/COMPACT
(Prices, Exchange Rates and Costs)
9.2
9.15
9.1
9.05
9
8.95
8.9
8.85
8.8
8.75
8.7
8.65
8.6
1986
1987
1988
1989
1990
1991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(Prices, Exchange Rates and Costs)
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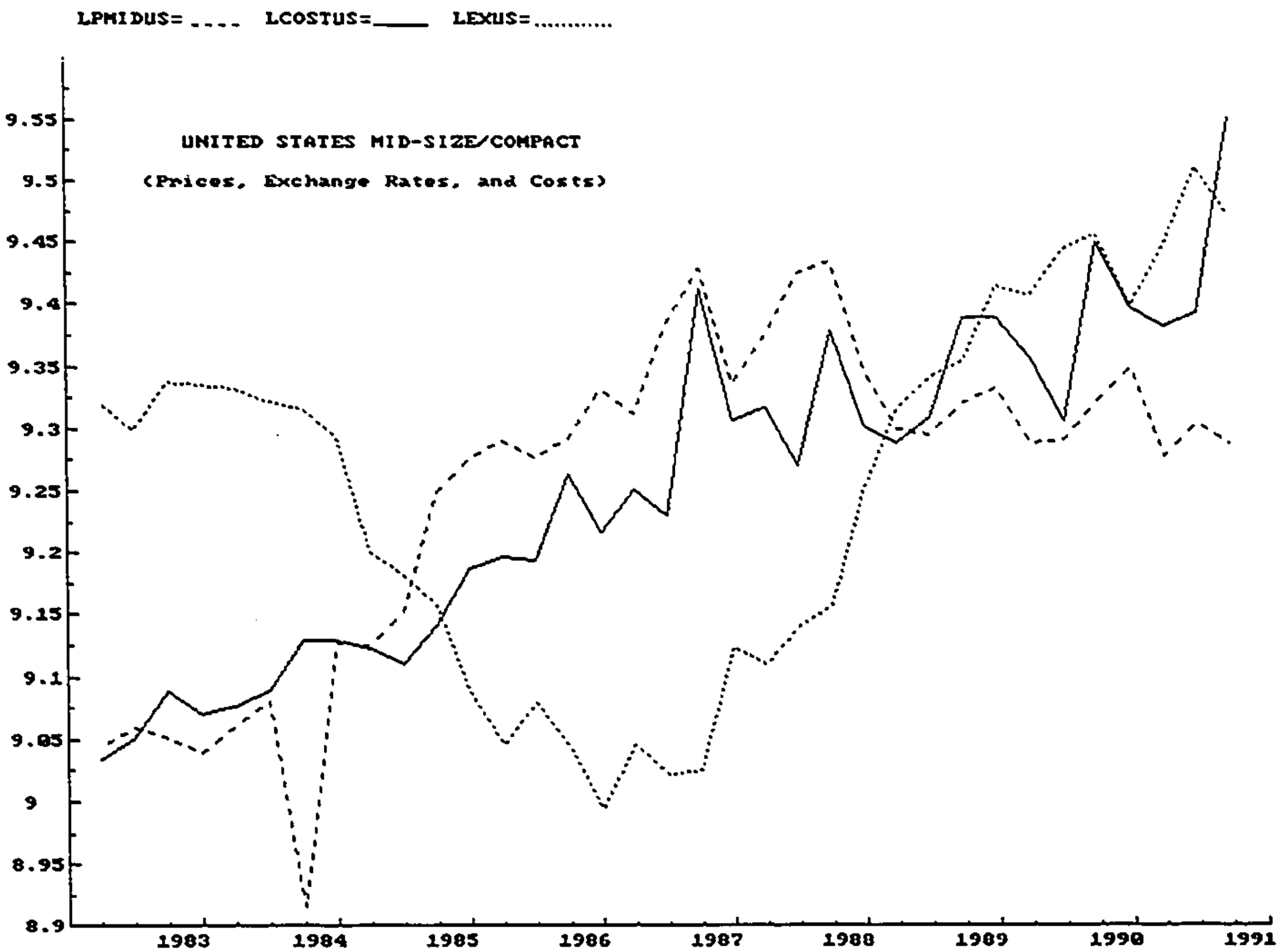
9.84
9.78
9.72
9.66
9.6
9.54
9.48
9.42
9.36
9.3
9.24
9.18
9.12
9.06
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991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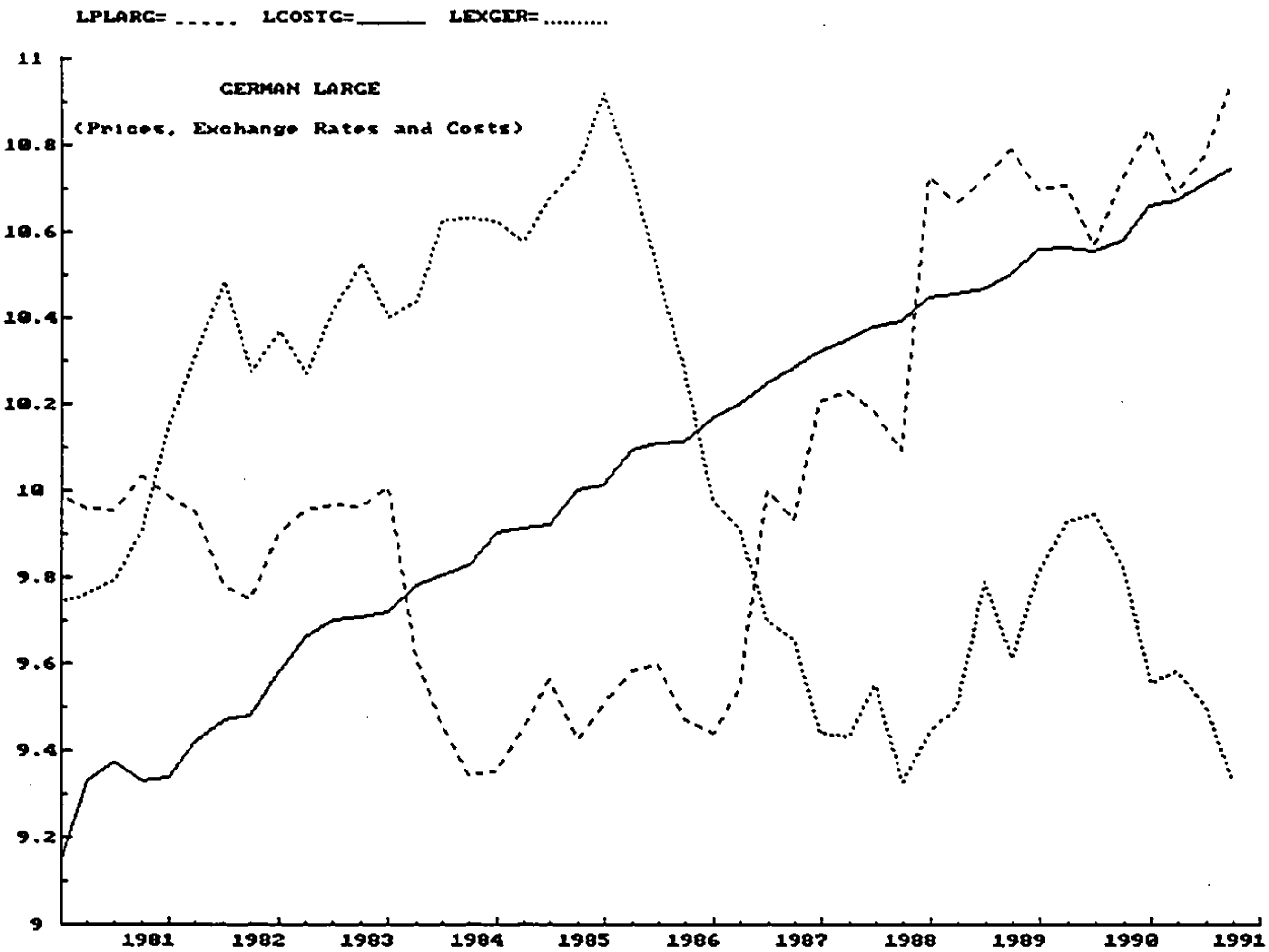
UNITED STATES MID-SIZE/COMPACT
(Prices, Exchange Rates, and Costs)
9.55
9.5
9.45
9.4
9.35
9.3
9.25
9.2
9.15
9.1
9.05
9
8.95
8.9
1983
1984
1985
1986
1987
1988
1989
1990
1991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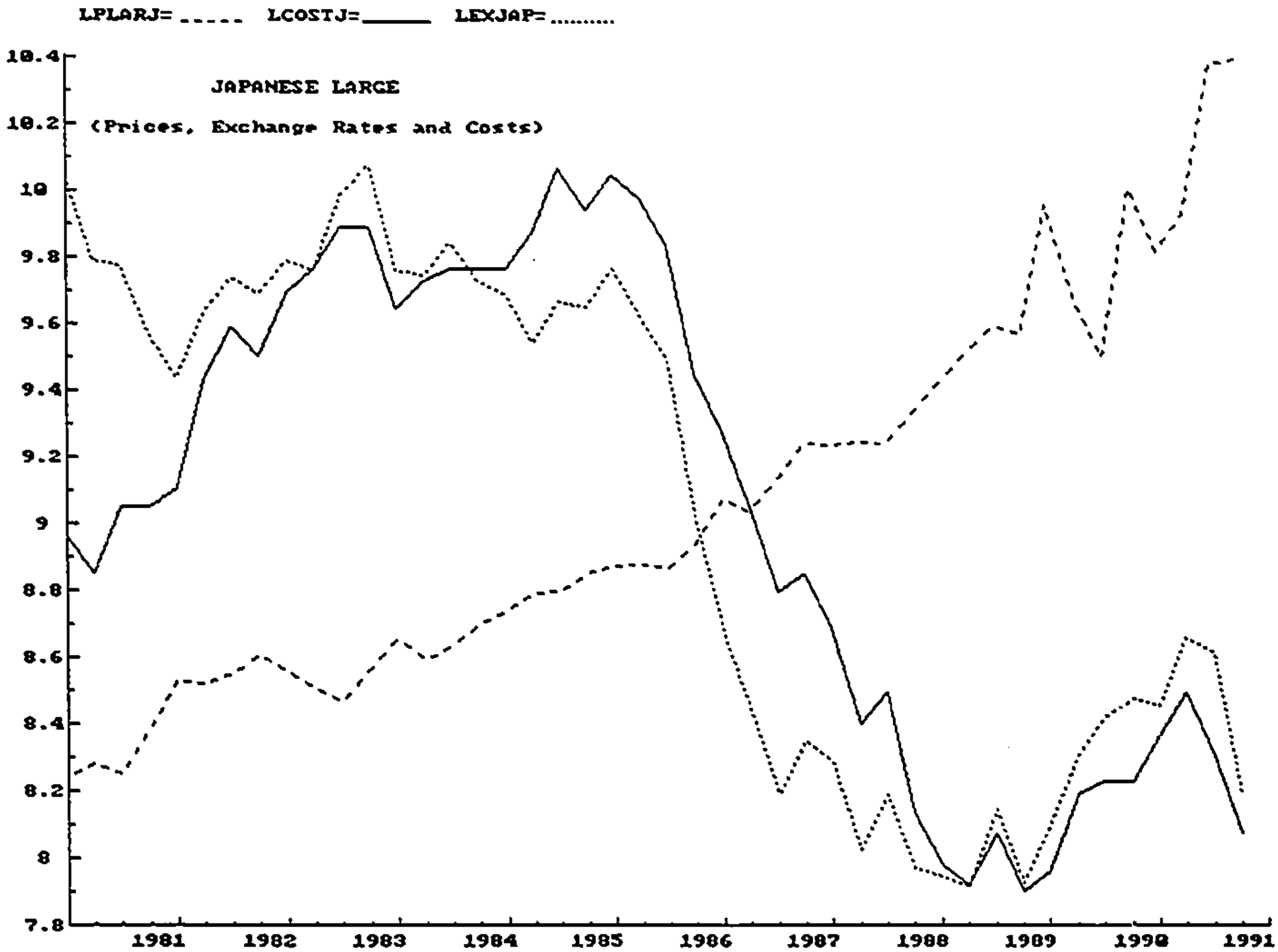
GERMAN LARGE
(Prices, Exchange Rates and Costs)
11
10.8
10.6
10.4
10.2
10
9.8
9.6
9.4
9.2
9
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991



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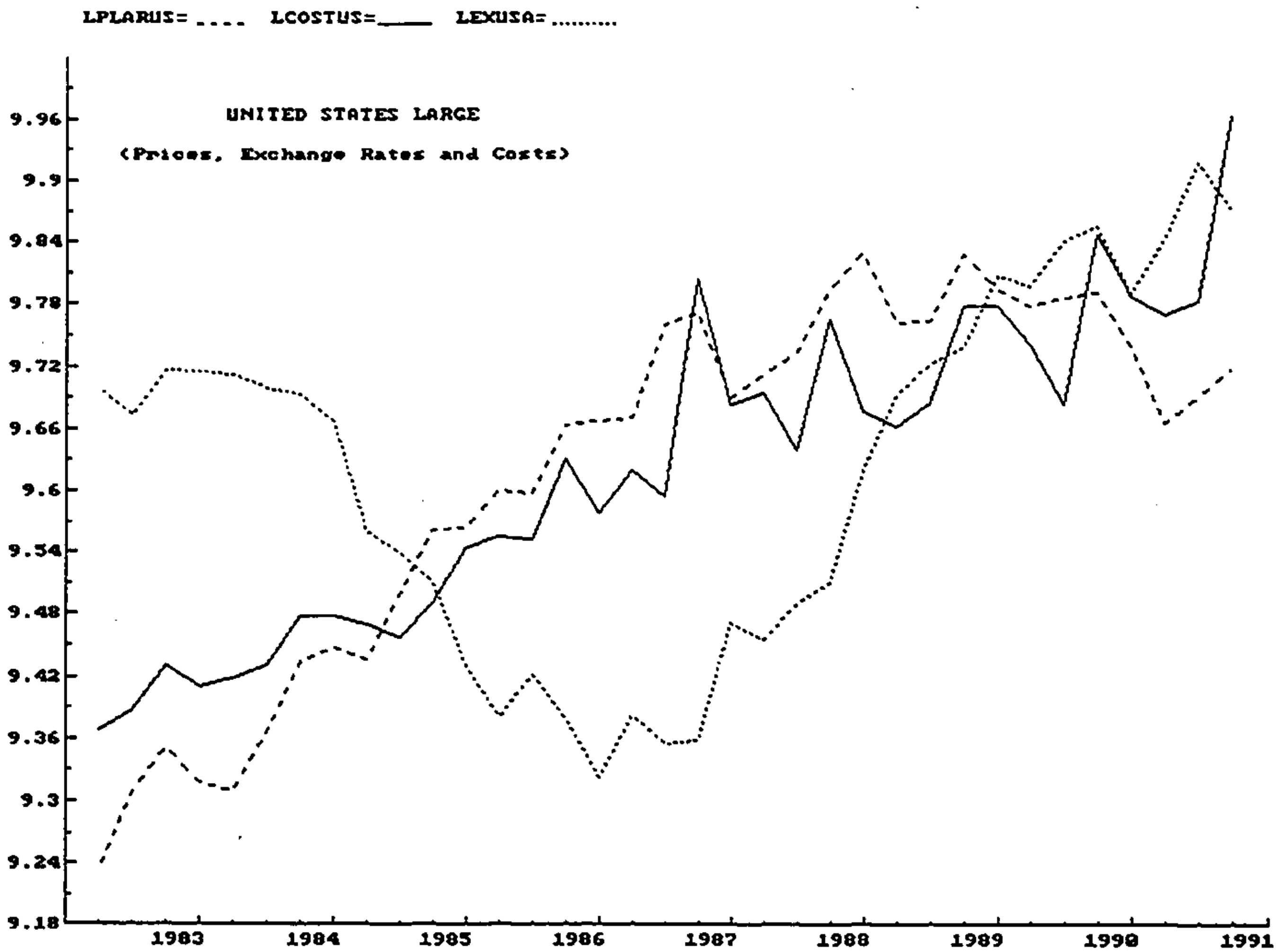
JAPANESE LARGE
(Prices, Exchange Rates and Costs)
10.4
10.2
10
9.8
9.6
9.4
9.2
9
8.8
8.6
8.4
8.2
8
7.8
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991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UNITED STATES LARGE
(Prices, Exchange Rates and Costs)
9.96
9.9
9.84
9.78
9.72
9.66
9.6
9.54
9.48
9.42
9.36
9.3
9.24
9.18
1983
1984
1985
1986
1987
1988
1989
1990
1991

APPENDIX C

INITIAL MODEL REGRESSIONS

The following tables summarize regression results and diagnostic tests using PC-GIVE 7.0.

TABLE C-1

SUBCOMPACT AUTOMOBILES

	Japan 1980(2)-1990(4)	*United States* 1982(2)-1987(4)	*Germany* 1980(2)-1988(1)	*Korea* 1984(2)-1990(4)
Constant	1.715 (0.566)†	0.606 (1.386)	0.720 (0.523)	2.772 (0.782)
p_{t-1}	0.811 (0.063)	0.589 (0.265)	0.740 (0.086)	0.500 (0.188)
$(C^*_q/c)_t$	0.133 (0.054)	0.641 (0.666)	0.448 (0.170	0.169 (0.125)
R^2	0.95	0.68	0.92	0.53
D.W.	1.77	2.36	1.81	1.99
Hansen Test:	0.150	0.546*	0.093	0.191
LM [$X^2(3)$]:	2.48	5.97	1.03	2.10
ARCH [$X^2(3)$]:	2.68	4.87	2.07	2.56
Bera-Jarque [$X^2(2)$]:	0.16	4.2	5.73	0.95
White Test:	5.97	8.87	2.81	3.10
Wald Test for Rβ=r: ($C^*_{qt} = c_t$)	10.96*	15.59	5.61*	0.003

*Reject Null Hypothesis at a 5% level of significance.

† (s.e.)

TABLE C-2

MID-SIZE/COMPACT AUTOMOBILES

	<u>*Japan*</u> 1983(2)-1990(4)	<u>*United States*</u> 1982(2)-1990(4)	<u>*Sweden*</u> 1980(2)-1990(4)	<u>*Germany*</u> 1980(2)-1990(4)	<u>*Korea*</u> 1985(2)-1990(4)
Constant	9.260	0.436	0.776	2.346	5.689
	(0.631)[†]	(0.771)	(0.664)	(1.170)	(1.566)
p_{t-1}	0.015	0.606	0.889	0.723	0.500
	(0.006)	(0.138)	(0.101)	(0.108)	(0.180)
$(C^*_q/e)_t$	0.738	0.651	0.103	0.083	-0.140
	(0.09[illegible])	(0.173)	(0.141)	(0.083)	(0.098)
R^2	0.73	0.85	0.89	0.54	0.27
D.W.	0.21	2.54	2.38	1.93	2.05
Hansen Test:	1.336**	0.187	0.832**	0.278	0.115
LM $[X^2(3)]$:	26.27**	4.49	4.95	1.51	1.61
ARCH $[X^2(3)]$:	19.43**	2.38	18.00**	13.33**	0.14
Bera-Jarque$[X^2(2)]$	2.77	26.14	0.17	0.83	70.06
White Test:	15.186**	5.04	9.92	9.10	2.50
Wald Test for $R\beta=r$: $(C^*_{qt} = e_t)$		3.49	7.69*	5.72*	5.02*

*Reject Null Hypothesis at a 5% level of significance,

**Reject Null Hypothesis at a 1% level of significance.

† (s.e.)

TABLE C-3

LARGE AUTOMOBILES

	Japan 1980(2) -1988(4)	United States 1982(2) - 1990(4)	Germany 1980(2) - 1987(4)
Constant	1.362 (0.572)[†]	0.126 (0.484)	1.150 (0.743)
p_{t-1}	0.863 (0.060)	0.846 (0.043)	0.764 (0.108)
$(C_q^*/e)_t$	0.247 (0.091)	0.277 (0.114)	0.293 (0.152)
R^2	0.98	0.95	0.78
D.W.	1.96	2.03	1.80
Hansen Test:	0.171	0.087	0.17
LM $[X^2(3)]$:	5.34	10.77*	1.80
ARCH $[X^2(3)]$:	2.82	2.43	0.05
Bera-Jarque$[X^2(2)]$	2.38	0.84	0.12
White Test:	2.23	1.27	4.91
Wald Test for $R\beta=r$: $(C_{qt}^* = e_t)$	0.003	1.16	2.52

* Reject Null Hypothesis at a 5% level of significance

† (s.e.)

APPENDIX D

EXTENSION TO INITIAL MODEL REGRESSIONS

The following tables summarize regression results and diagnostic tests using PC-GIVE 7.0

TABLE D-1

SUBCOMPACT AUTOMOBILES

	Japan 1984(2) - 1988(1)	United States 1984(2) - 1988(1)	Germany 1984(2) - 1988(1)	Korea 1984(2) - 1988(1)
Constant	5.932	8.497	-1.010	4.232
	(2.781)†	(5.252)	(4.167)	(3.175)
$PJapan_t$		-0.118	0.532	0.510
		(0.723)	(0.448)	(0.447)
$PJapan_{t-1}$	-0.050	-0.553	0.191	-0.450
	(0.345)	(0.687)	(0.568)	(0.366)
$PU.S._t$	0.081		0.219	0.173
	(0.156)		(0.205)	(0.153)
$PU.S._{t-1}$	0.053	-0.293	0.208	0.317
	(0.132)	(0.289)	(0.185)	(0.102)
$PGermany_t$	0.186	0.731		-0.030
	(0.284)	(0.478)		(0.229)
$PGermany_{t-1}$	-0.110	0.103	0.197	-0.301
	(0.093)	(0.208)	(0.130)	(0.218)
$PKorea_t$	-0.182	0.590	0.349	
	(0.366)	(0.680)	(0.436)	
$PKorea_{t-1}$	0.363	-0.087	-0.700	0.329
	(0.361)	(0.694)	(0.337)	(0.255)
$(C_q^*/e)_t$	0.463	-0.623	0.383	0.176
	(0.240)	(1.128)	(0.247)	(0.205)
R^2	0.95	0.80	0.98	0.86
D.W.	2.08	1.98	2.38	2.31
Hansen Test	0.153	0.261	0.352	0.161
LM $[X^2(3)]$	0.46	0.79	0.97	0.18
ARCH $[X^2(3)]$	0.27	0.79	0.11	0.08
Bera-Jarque $[X^2(2)]$	0.22	12.66	0.42	0.10

† (s.e.)

TABLE D-2

MID-SIZE/COMPACT

	Japan 1985(2) - 1990(4)	United States 1985(2) - 1990(4)	Sweden 1985(2) - 1990(4)	Germany 1985(2) - 1990(4)	Korea 1985(2) - 1990(4)
Constant	9.449 (3.773)[†]	4.731 (2.372)	3.528 (5.614)	-7.569 (17.080)	10.550 (6.132)
$PJapan_t$		-0.322 (0.221)	-0.004 (0.372)	-0.951 (0.656)	-0.892 (0.599)
$PJapan_{t-1}$	0.695 (0.167)	0.299 (0.209)	-0.004 (0.362)	0.930 (0.456)	0.654 (0.557)
$PU.S._t$	-0.393 (0.180)		-0.295 (0.342)	0.202 (0.936)	-0.828 (0.431)
$PU.S._{t-1}$	-0.208 (0.234)	-0.096 (0.228)	0.161 (0.367)	0.840 (0.896)	-0.633 (0.604)
$PSweden_t$	0.041 (0.253)	-0.035 (0.214)		-0.038 (0.701)	-0.208 (0.456)
$PSweden_{t-1}$	0.118 (0.231)	0.116 (0.203)	0.545 (0.213)	-0.142 (0.553)	0.994 (0.544)
$PGermany_t$	-0.105 (0.084)	0.001 (0.098)	-0.014 (0.156)		0.175 (0.197)
$PGermany_{t-1}$	0.003 (0.063)	0.132 (0.087)	0.152 (0.099)	0.287 (0.381)	-0.024 (0.164)
$PKorea_t$	-0.291 (0.064)	-0.107 (0.072)	-0.041 (0.138)	0.275 (0.200)	
$PKorea_{t-1}$	0.116 (0.080)	0.066 (0.069)	0.075 (0.125)	0.162 (0.202)	0.461 (0.199)
$(C^*_q/e)_t$	0.334 (0.168)	0.860 (0.211)	0.191 (0.286)	0.695 (0.423)	-0.764 (0.442)
R^2	0.95	0.80	0.90	0.87	0.68
D.W.	2.29	2.66	2.33	2.70	2.66
Hansen Test	0.153	0.262	0.061	0.220	0.374
LM $[X^2(3)]$	1.27	2.00	5.16*	2.94	3.14
ARCH $[X^2(3)]$	0.35	0.22	1.03	0.92	0.40
Bera-Jarque	0.45	0.45	0.83	0.43	0.02

* Reject Null Hypothesis at a 5% level of significance

† (s.e.)

TABLE D-3

LARGE AUTOMOBILES

	Japan 1982(2) - 1990(4)	*United States* 1982(2) - 1990(4)	*Germany* 1982(2) - 1990(4)
Constant	-1.755	0.270	0.522
	(0.607)†	(0.558)	(1.921)
$PJapan_t$		0.276	0.779
		(0.034)	(0.118)
$PJapan_{t-1}$	0.514	-0.014	0.040
	(0.114)	(0.034)	(0.133)
$PU.S._t$	0.310		0.328
	(0.170)		(0.772)
$PU.S._{t-1}$	0.242	0.775	-0.408
	(0.178)	(0.077)	(0.667)
$PGermany_t$	0.028	0.034	
	(0.046)	(0.048)	
$PGermany_{t-1}$	0.066	-0.325	0.747
	(0.047)	(0.045)	(0.080)
$(C_q^*/e)_t$	0.164	0.346	0.422
	(0.100)	(0.156)	(0.249)
R^2	0.98	0.95	0.92
D.W.	1.64	1.91	2.24
Hansen Test	0.053	0.053	0.093
LM $[X^2(3)]$	1.68	3.20*	1.12
ARCH $[X^2(3)]$	1.35	1.3	0.23
White Test	3.76	0.24	1.18
Bera-Jarque $[X^2(2)]$	1.54	0.56	2.6

* Reject Null Hypothesis at a 5% level of significance

† (s.e.)

APPENDIX E

UNIT ROOT TESTS

The following tables summarize unit root tests performed using the COINT command from Shazam 7.0

Table E-1

Unit Root Tests for Subcompact Prices

[Levels]

	Germany	Japan	Korea	U.S.
	1980.1-1987.4	1980.1-1990.4	1984.1-1990.4	1980.1-1987.4
ADF				
τ_c	0.23	-2.44	-2.86**	-1.09
τ_{ct}	-2.66	-1.82	-3.02	-2.36
PP				
τ_c	-0.88	-2.44	-2.85*	-1.08
τ_{ct}	-4.39*	-1.86	-3.03	-2.43

[First Differences]

	Germany	Japan	Korea	U.S.
	1980.1-1987.4	1980.1-1990.4	1984.1-1990.4	1980.1-1987.4
ADF				
τ_c	-3.60*	-3.74*	-2.10	-3.84*
τ_{ct}	-3.51*	-4.00*	-2.04	-3.86*
PP				
τ_c	-8.88*	-5.63*	-6.02*	-6.32*
τ_{ct}	-8.65*	-6.05*	-5.90*	-6.28*

* Reject null hypothesis of unit root @ 5% significance level.
** Reject null hypothesis of unit root @ 10% significance level.

τ_c Test statistic (tau) with constant.
τ_{ct} Test statistic (tau) with constant and trend.

Table E-2

Unit Root Tests for Compact/Midsize Prices

[Levels]

	Germany	*Japan*	*Korea*	*Sweden*	*U.S.*
	1980.1-1990.4	1983.1-1990.4	1985.1-1990.4	1980.1-1990.4	1980.1-1990.4
ADF					
τ_c	-2.57**	-0.14	-2.60**	-0.92	-2.44
τ_{ct}	-2.57	-2.49	-2.61	-2.35	-1.56
PP					
τ_c	-2.63**	-0.29	-2.59**	-0.90	-2.32
τ_{ct}	-2.64	-3.93*	-2.58	-3.17**	-1.93

[First Differences]

	Germany	*Japan*	*Korea*	*Sweden*	*U.S.*
	1980.1-1990.4	1983.1-1990.4	1985.1-1990.4	1980.1-1990.4	1980.1-1990.4
ADF					
τ_c	-3.60*	-5.09*	-3.11*	-2.71**	-2.95*
τ_{ct}	-3.56*	-4.97*	-3.06	-2.67	-3.33**
PP					
τ_c	-6.74*	-9.26*	-5.87*	-9.16*	-6.74*
τ_{ct}	-6.65*	-9.03*	-5.89*	-9.04*	-6.65*

* Reject null hypothesis of unit root @ 5% significance level.
** Reject null hypothesis of unit root @ 10% significance level.

τ_c Test statistic (tau) with constant.
τ_{ct} Test statistic (tau) with constant and trend.

Table E-3

Unit Root Tests for Large Prices

[Levels]

	Germany 1980.1-1987.4	*Japan* 1980.1-1988.4	*Sweden* 1984.2-1988.4	*U.S.* 1980.1-1990.4
ADF				
τ_c	-1.59	0.18	-2.21	-1.94
τ_{ct}	-1.45	-1.89	-2.80	2.20
PP				
τ_c	-1.60	0.18	-2.22	-2.74
τ_{ct}	-1.43	-2.02	-2.72	-0.63

[First Differences]

	Germany 1980.1-1987.4	*Japan* 1980.1-1990.4	*Sweden* 1984.1-1990.4	*U.S.* 1980.1-1987.4
ADF				
τ_c	-3.35*	-3.37*	-3.19**	-2.28*
τ_{ct}	-3.46*	-3.54*	-2.97	-3.62*
PP				
τ_c	-5.73*	-5.44*	-3.17**	-6.37*
τ_{ct}	-5.83*	-5.41*	-2.94**	-8.03*

* Reject null hypothesis of unit root @ 5% significance level.

** Reject null hypothesis of unit root @ 10% significance level.

τ_c Test statistic (tau) with constant.

τ_{ct} Test statistic (tau) with constant and trend.

Table E-4

Unit Root Tests for Cost Data

[Levels]

	<u>*Germany*</u> 1980.1-1990.4	<u>*Japan*</u> 1980.1-1990.4	<u>*Korea*</u> 1984.1-1990.4	<u>*Sweden*</u> 1980.1-1990.4	<u>*U.S.*</u> 1982.2-1990.4
<u>ADF</u>					
τ_c	-1.37	-1.00	-1.39	-1.73	-0.39
τ_{ct}	-1.10	-2.85	-2.62	-3.02	-1.94
<u>PP</u>					
τ_c	-1.82	-0.52	-1.41	-2.44	-0.26
τ_{ct}	-3.04	-1.93	-2.75	-1.90	-5.41*

[First Differences]

	<u>*Germany*</u> 1980.1-1990.4	<u>*Japan*</u> 1980.1-1990.4	<u>*Korea*</u> 1984.1-1990.4	<u>*Sweden*</u> 1980.1-1990.4	<u>*U.S.*</u> 1982.2-1990.4
<u>ADF</u>					
τ_c	-4.68*	-1.96	-4.22*	-1.64	-2.46
τ_{ct}	-5.12*	-2.15	-4.19*	-1.78	-2.36
<u>PP</u>					
τ_c	-8.09*	-5.00*	-4.23*	-3.83*	-4.23*
τ_{ct}	-8.02*	-5.36*	-4.20*	-4.08*	-4.20*

* Reject null hypothesis of unit root @ 5% significance level.
** Reject null hypothesis of unit root @ 10% significance level.

τ_c Test statistic (tau) with constant.
τ_{ct} Test statistic (tau) with constant and trend.

Table E-5

Unit Root Tests for (Dollar) Cost Data

[Levels]

	Germany	***Japan***	***Korea***	***Sweden***	***U.S.***
	1980.1-1990.4	1980.1-1990.4	1984.1-1990.4	1980.1-1990.4	1982.2-1990.4
ADF					
τ_c	0.20	-1.18	-1.54	0.35	-2.68**
τ_{ct}	-1.88	-1.45	-2.64	-1.37	-2.49
PP					
τ_c	0.07	-1.21	-1.54	0.32	-1.89
τ_{ct}	-1.92	-1.57	-2.78	-1.37	-1.70

[First Differences]

	Germany	***Japan***	***Korea***	***Sweden***	***U.S.***
	1980.1-1990.4	1980.1-1990.4	1984.1-1990.4	1980.1-1990.4	1982.2-1990.4
ADF					
τ_c	-3.05*	-3.63*	-3.53*	-2.00	-1.14
τ_{ct}	-3.31**	-3.51*	-3.28**	-2.59	-1.36
PP					
τ_c	-5.27*	-5.34*	-4.59*	-5.98*	-6.91*
τ_{ct}	-5.57*	-5.20*	-4.59*	-6.42*	-7.03*

* Reject null hypothesis of unit root @ 5% significance level.
** Reject null hypothesis of unit root @ 10% significance level.

τ_c Test statistic (tau) with constant.
τ_{ct} Test statistic (tau) with constant and trend.

Table E-6

Unit Root Tests for Exchange Rates

[Levels]

	Germany	*Japan*	*Korea*	*Sweden*	*U.S.*
	1980.1-1990.4	1980.1-1990.4	1980.1-1990.4	1980.1-1990.4	1980.1-1990.4
ADF					
τ_c	-0.63	-0.92	-1.46	-2.04	-1.38
τ_{ct}	-1.93	-1.43	-1.31	-1.43	-1.14
PP					
τ_c	-0.76	-0.96	-1.51	-2.04	-1.22
τ_{ct}	-1.96	-1.55	-1.43	-1.46	-0.78

[First Differences]

	Germany	*Japan*	*Korea*	*Sweden*	*U.S.*
	1980.1-1990.4	1980.1-1990.4	1980.1-1990.4	1980.1-1990.4	1980.1-1990.4
ADF					
τ_c	-2.94*	-3.57*	-1.56	-1.77	-2.03
τ_{ct}	-3.22*	-3.47*	-1.57	-2.23	-2.50
PP					
τ_c	-5.27*	-5.36*	-4.82*	-5.30*	-6.01*
τ_{ct}	-5.61*	-5.23*	-4.69*	-5.78*	-6.71*

* Reject null hypothesis of unit root @ 5% significance level.
** Reject null hypothesis of unit root @ 10% significance level.

τ_c Test statistic (tau) with constant.
τ_{ct} Test statistic (tau) with constant and trend.

APPENDIX F

The following tables summarize regression results and diagnostic tests using PC-GIVE 7.0

TABLE F-1

Engle-Granger Error Correction Models

Subcompact Automobiles

	Japan	Germany	
κ	-1.06	0.87	-0.76
$\Delta(C_q^*/c)_t$		0.35	
$\Delta(C_q^*)_t$	2.87		-5.14
Δc_t	-0.73		-0.43
ECM_{t-1}	-0.70[a]	-0.58[b]	-0.68[c]
R^2	0.57	0.40	0.44
D.W.	1.83	1.62	1.40
LM $[\chi^2(3)]$	1.22 [0.31][‡]	0.55 [0.65]	1.55 [0.23]
ARCH $[\chi^2(3)]$	2.30 [0.10]	3.20* [0.04]	4.14* [0.02]
Normality $[\chi^2(3)]$	4.61 [0.10]	2.06 [0.35]	1.62 [0.45]
White Test	0.63 [0.71]	2.10 [0.11]	1.93 [0.12]
RESET	0.47 [0.50]	3.54 [0.07]	9.27** [0.005]
Wald Test			

[a] ECM: $p_t = -8.122 + 0.008t + 4.797(C_q^*)_t - 1.059c_t + \varepsilon_t$

[b] ECM: $p_t = +5.574 + 0.279t + 0.872(C_q^*/c)_t + \varepsilon_t$

[c] ECM: $p_t = +32.95 + 0.088t - 5.388(C_q^*)_t - 0.766c_t + \varepsilon_t$

† (s.e.)

‡ [Probability under null hypothesis]

*Reject Null Hypothesis at a 5% level of significance.

**Reject Null Hypothesis at a 1% level of significance

TABLE F-2

Engle-Granger Error Correction Models

Mid-size/Compact Automobiles

	Korea	Japan		United States	
κ	-1.28	0.21	-0.11	1.24	-1.43
$\Delta(C_q^*/c)_t$		0.17		0.75	
$\Delta(C_q^*)_t$	-1.48		-0.41		0.25
Δc_t	-1.05		-0.14		-0.98
ECM_{t-1}	-0.85^a	-1.22^b	-1.35^c	-0.94^d	-0.94^e
R^2	0.44	0.66	0.72	0.52	0.55
D.W.	1.96	1.85	1.95	2.04	2.05
LM $[\chi^2(3)]$	0.75 [0.54]‡	1.41 [0.26]	0.65 [0.59]	0.39 [0.76]	0.54 [0.66]
ARCH $[\chi^2(3)]$	0.03 [0.99]	0.30 [0.83]	0.33 [0.80]	0.14 [0.93]	0.08 [0.97]
Normality $[\chi^2(3)]$	12.15** [0.00]	0.81 [0.66]	0.52 [0.77]	15.75** [0.0004]	13.46** [0.001]
White Test	1.01 [0.46]	1.92 [0.14]	1.24 [0.33]	0.06 [0.99]	0.22 [0.97]
RESET	2.48 [0.13]	0.18 [0.67]	0.17 [0.68]	0.68 [0.41]	1.44 [0.24]
Wald Test					

[a] ECM: $p_t = 23.04 + 0.007t - 1.33C_q^* - 1.276\ c_t + \varepsilon_t$

[b] ECM: $p_t = 8.746 + 0.016t + 0.21(C_q^*/c)_t + \varepsilon_t$

[c] ECM: $p_t = 12.27 + 0.015t - 0.66C_q^* - 0.110\ c_t + \varepsilon$

[d] ECM: $p_t = 2.99 + 0.006t + 1.24\ (C_q^*/c)_t + \varepsilon_t$

[e] ECM: $p_t = 7.534 + 0.007t + 0.23C_q^* - 1.433\ c_t + \varepsilon$

† (s.e.)

‡ [Probability under null hypothesis]

* Reject Null Hypothesis at a 5% level of significance,

** Reject Null Hypothesis at a 1% level of significance

ENGLE-GRANGER ERROR CORRECTION MODELS (EXTENSION)

The following tables summarize regression results and diagnostic tests using PC-GIVE 7.0

Table G-1

Error Correction Models (Extension) for Subcompact Automobiles

	Japan		Germany		U.S.A.	
	1982(2)-1987(4)		1982(2)-1987(4)		1982(2)-1987(4)	
κ	0.778	-0.584	0.399	-0.375	-1.824	1.941
$\Delta(C_q^*/c)_t$	0.61		-0.60		-2.47	
$\Delta(C_q^*)_t$		1.36		-3.81		-2.32
Δc_t		-0.72		-0.04		0.71
ECM_{t-1}	-1.30^a	-1.39^b	-0.71^c	-0.70^d	-1.32^e	-0.97^f
$\Delta PJapan_t$			0.12	0.50	-0.35	-0.12
$\Delta PGermany_t$	0.03	0.07			0.19	0.16
$\Delta PU.S.A._t$	0.05	0.02	0.40	0.45		
$\Delta PKorea_t$	0.02	0.04			0.80	0.69
R^2	0.80	0.88	0.41	0.47	0.78	0.77
D.W.	1.85	1.99	1.68	1.61	2.18	1.56
LM $[\chi^2(1)]$	0.06 [0.80]	1.26 [0.30]	0.64 [0.54]	0.55 [0.59]	0.46 [0.51]	3.55 [0.10]
ARCH $[\chi^2(1)]$	0.01 [0.94]	0.01 [0.93]	1.87 [0.19]	2.29 [0.14]	1.25 [0.30]	0.01 [0.94]
Normality	0.12 [0.99]	0.57 [0.93]	5.65 [0.06]	3.40 [0.18]	0.83 [0.66]	0.93 [0.63]
White Test	N/A	N/A	0.99 [0.50]	0.99 [0.53]	N/A	N/A
RESET	0.15 [0.71]	0.28 [0.61]	3.46 [0.08]	5.46^* [0.03]	0.20 [0.67]	6.02^* [0.04]

Table G-1 cont'd,

[a] ECM_t: $p_t = 6.621 - 0.011t + 0.778(C_q^*/e)_t + 0.030PGermany_t + 0.979PU.S.A._t + 0.187PKorea_t + \varepsilon_t$

[b] ECM_t: $p_t = 12.43 - 0.018t - 0.888(C_q^*)_t - 0.584e_t + 0.114PGermany_t + 0.028U.S.A._t + 0.290Korea_t + \varepsilon_t$

[c] ECM_t: $p_t = -2.419 - 0.024t + 0.399(C_q^*/e)_t + 0.542PJapan_t + 0.570PU.S.A._t + \varepsilon_t$

[d] ECM_t: $p_t = -13.71 + 2.669(C_q^*)_t - 0.375e_t + 0.684PJapan_t + 0.583U.S.A._t + \varepsilon_t$

[e] ECM_t: $p_t = 15.23 + 0.044t - 1.824(C_q^*/e)_t + 0.102PGermany_t - 0.338PJapan_t + 0.470PKorea_t + \varepsilon_t$

[f] ECM_t: $p_t = 2.29 - 0.210(C_q^*)_t + 1.941e_t + 0.377PGermany_t + 0.054Japan_t + 0.510Korea_t + \varepsilon_t$

[1] (s.e.)

[2] [Probability under null hypothesis]

[*] Reject Null Hypothesis at a 5% level of significance

Table G-2a

Engle-Granger Error Correction Model (Extension) for Compact/Midsize Automobiles

	Japan 1985.2 - 1990.4	Germany 1985.2 -1990.4	U.S.A. 1985.2 - 1990.4	Sweden 1982.2 - 1990.4
κ	0.396 (0.105)	0.991 (0.540)	0.673 (0.262)	-0.676 (0.340)
$\Delta(C^*_q/e)_t$	0.33 (0.09)	0.51 (0.32)	0.72 (0.15)	-0.013 (0.208)
ECM_{t-1}	-1.22[a] (0.27)	-0.67[b] (0.17)	-1.29[c] (0.26)	-0.73[d] (0.13)
$\Delta PJapan_t$			-0.32 (0.14)	
$\Delta PGermany_t$	-0.06 (0.04)		0.05 (0.05)	0.05 (0.06)
$\Delta PU.S.A._t$	-0.21 (0.11)	0.19 (0.49)		0.40 (0.16)
$\Delta PKorea_t$	-0.12 (0.05)	0.42 (0.19)	-0.14 (0.06)	
$\Delta PSweden_t$	-0.05 (0.11)	-0.09 (0.49)	0.06 (0.13)	
R^2	0.83	0.58	0.74	0.55
D.W.	1.85	2.49	2.21	1.90
LM $[\chi^2(1)]$	0.36 [0.70]‡	1.12 [0.35]	0.51 [0.61]	1.03 [0.40]
ARCH $[\chi^2(1)]$	0.50 [0.62]	0.13 [0.88]	0.34 [0.72]	0.27 [0.85]
Normality $[\chi^2(2)]$	1.87 [0.39]	0.93 [0.63]	0.77 [0.68]	1.22 [0.54]
White Test	0.38 [0.90]	0.34 [0.94]	0.45 [0.86]	0.48 [0.85]
RESET	2.64 [0.12]	0.25 [0.63]	4.9* [0.04]	0.76 [0.39]

[a] ECM_t: $p_t = 11.80 - 0.016t + 0.40(C^*_q/e)_t - 0.08PGermany_t - 0.20PU.S.A._t - 0.05PKorea_t + 0.002PSweden_t + \varepsilon_t$

[b] ECM_t: $p_t = -8.16 + 0.99(C^*_q/e)_t + 1.20PU.S.A._t + 0.67PKorea_t - 0.37PSweden_t + \varepsilon$

[c] ECM_t: $p_t = 4.74 - 0.0004t + 0.67(C^*_q/e)_t - 0.07PJapan_t + 0.11PGermany_t - 0.05PKorea_t + 0.13PSweden_t + \varepsilon$

[d] ECM_t: $p_t = 0.07 + 0.02t - 0.68(C^*_q/e)_t + 0.28PGermany_t + 0.89PU.S.A._t + \varepsilon$

† (s.e.) ‡ [Probability under null hypothesis] * Reject Null Hypothesis at a 5% level of significance

Table G-2b

Engle-Granger Error Correction Model (Extension) for Compact/Midxize Automobiles

	Japan	Germany	U.S.A.	Korea
	1985(1)-1990(4)	1985(1)-1990(4)	1985(1)-1990(4)	1985(1)-1990(4)
κ	-0.303	-1.169	-1.201	-1.438
	(0.196)[†]	(0.645)	(0.364)	(0.886)
$\Delta(C_q^*)_t$	1.05	-5.77	0.27	-0.92
	(1.14)	(3.76)	(0.18)	(0.74)
Δe_t	-0.39	-0.83	-1.42	-1.38
	(0.15)	(0.34)	(0.32)	(0.88)
ECM_{t-1}	-1.32[a]	-0.62[b]	-1.21[c]	-0.69[d]
	(0.27)	(0.16)	(0.24)	(0.23)
$\Delta PJapan_t$			-0.36	-0.82
			(0.13)	(0.49)
$\Delta PGermany_t$	-0.04		0.03	0.26
	(0.04)		(0.05)	(0.17)
$\Delta PU.S.A._t$	-0.19	0.09		-0.78
	(0.11)	(0.47)		(0.44)
$\Delta PKorea_t$	-0.12	0.36	-0.15	
	(0.04)	(0.18)	(0.05)	
$\Delta PSweden_t$	-0.04	-0.38	0.07	-0.25
	(0.11)	(0.48)	(0.11)	(0.41)
R^2	0.86	0.64	0.80	0.64
D.W.	1.76	2.14	2.27	1.95
LM [$\chi^2(1)$]	0.75 [0.49][‡]	0.15 [0.86]	0.95 [0.41]	0.01 [0.99]
ARCH [$\chi^2(1)$]	0.20 [0.82]	0.18 [0.84]	1.36 [0.30]	0.03 [0.97]
Normality [$\chi^2(2)$]	1.46 [0.48]	0.82 [0.66]	0.12 [0.94]	2.15 [0.34]
White Test	N/A	0.39 [0.89]	N/A	N/A
RESET	2.77 [0.12]	0.85 [0.37]	1.25 [0.28]	11.06[**] [0.004]

Table G-2b cont'd

[a] ECM$_t$: $p_t = 15.43 + 0.02t - 0.38(C_q^*)_t - 0.30e_t - 0.08PGermany_t - 0.17PU.S.A_t - 0.05PKorea_t + 0.08PSweden_t + \varepsilon_t$

[b] ECM$_t$: $p_t = -0.50 - 0.11(C_q^*)_t - 1.17e_t + 0.73PU.S.A_t + 0.62PKorea_t - 0.12PSweden_t + \varepsilon$

[c] ECM$_t$: $p_t = 6.56 + 0.007t + 0.19(C_q^*)_t - 1.20e_t - 0.13PJapan_t + 0.08PGermany_t - 0.05PKorea_t + 0.22PSweden_t + \varepsilon$

[d] ECM$_t$: $p_t = 36.44 - 0.88(C_q^*)_t - 1.44e_t - 0.35PJapan + 0.29PGermany_t - 1.50PU.S.A_t + 0.02PSweden + \varepsilon$

† (s.e.)

‡ [Probability under null hypothesis]

* Reject Null Hypothesis at a 5% level of significanc

** Reject Null Hypothesis at a 1% level of significance

Table G-3

Engle-Granger Error Correction Models (Extension) for Large Automobiles

U.S.A.

1982.2 - 1987.4

κ	0.787 (0.192)[†]	-0.81 (0.23)
$\Delta(C_q^*/c)_t$	0.939 (0.205)	
$\Delta(C_q^*)_t$		1.06 (0.26)
Δc_t		-0.64 (0.32)
$\Delta PJapan_t$	0.287 (0.117)	0.32 (0.12)
$\Delta PGermany_t$	0.014 (0.035)	0.02 (0.03)
ECM_{t-1}	-1.322[a] (0.236)	-1.382[b] (0.240)
R^2	0.73	0.75
D.W.	1.96	1.88
LM $[\chi^2(2)]$	2.97 [0.08][‡]	0.82 [0.46]
ARCH $[\chi^2(2)]$	0.69 [0.52]	0.14 [0.87]
Normality $[\chi^2(2)]$	0.34 [0.84]	0.59 [0.75]
White Test	0.31 [0.94]	0.10 [0.99]
RESET	1.11 [0.31]	0.98 [0.34]
Wald Test for $R\beta=r$ $\{\Delta C_q^* = \Delta c_t\}$		0.978 [0.34]

[a]ECM: $p_t = 5.09 + 0.014t + 0.78\,(C_q^*/c)_t + 0.06\ PJapan_t - 0.02PGermany_t + \varepsilon_t$

[b]ECM: $p_t = 5.41 + 0.014t + 0.67C_q^* - 0.81c_t + 0.08\ PJapan_t - 0.02PGermany_t + \varepsilon_t$

[†] (s.e.)

[‡][Probability under null hypothesis]

APPENDIX H

JOHANSEN PROCEDURE AND VAR ESTIMATION

The following tables summarize VAR regression results based upon the Johansen Procedure using PCFIML 8.0

Table H-1

Subcompact Automobiles

	Japan	Germany	U.S.
	(1982:2-1988:1)	(1982:2-1988:1)	(1982:2-1988:1)
Constant	10.905 (15.712)	-19.744 (47.199)	2.858 (44.913)
Trend	0.026 (0.020)	-0.098 (0.060)	0.044 (0.058)
P (Japan)$_{-1}$	-0.068 (0.215)	0.049 (0.646)	0.665 (0.615)
P (Germany)$_{-1}$	0.002 (0.080)	0.330 (0.236)	0.169 (0.224)
P (U.S.)$_{-1}$	0.083 (0.105)	0.395 (0.316)	0.086 (6.301)
e (Japan)	-1.096 (0.446)	0.128 (1.340)	0.138 (1.275)
C_q^* (Japan)	3.011 (2.492)	11.905 (7.487)	4.060 (7.124)
e (Germany)	0.217 (0.256)	-2.14 (0.768)	-0.770 (0.731)
C_q^* (Germany)	-1.880 (1.975)	-6.075 (5.932)	-0.401 (5.644)
e (U.S.)	0.325 (0.755)	-0.105 (2.268)	-0.032 (2.158)
C_q^* (U.S.)	-0.55 (0.641)	-1.319 (1.925)	-1.781 (1.832)
LM F[1,12]	2.427 [0.145]	0.538 [0.477]	0.211 [0.654]
Normality χ^2[2]	0.560 [0.756]	3.250 [0.197]	0.666 [0.717]
ARCH F[1,11]	0.008 [0.930]	0.506 [0.492]	0.001 [0.971]

Vector Statistics:

Portmenteau:	34.146	*AR (1) F[9.19]*:	2.868 [0.025]*
R^2:	0.9964	*Normality χ^2[6]*:[1]	4.430 [0.618]

[1] Based on the test statistic proposed by Doornik and Hendry [1994].

* Reject Null Hypthesis at a 5% level of significance.

Table H-2

Compact/Midsize Automobiles

	Japan	Germany	United States	Korea
	1985(2)-1990(4)	1985(2)-1990(4)	1985(2)-1990(4)	1985(2)-1990(4)
Constant	-10.557	1.276	28.184	-7.010
	(10.542)	(46.021	(0.150)	(50.697)
Trend:.	0.010	-0.037	-0.002	-0.051
	(0.012)	(0.050)	(0.011)	(0.055)
P (Japan)$_{-1}$	-0.515	2.217	0.401	1.162
	(0.198)	(0.867)	(0.191)	(0.955)
P (Germany)$_{-1}$	0.059	0.126	0.065	-0.312
	(0.070)	(0.306)	(0.067)	(0.337)
P (U.S)$_{-1}$	0.114	-0.140	-0.146	-0.915
	(0.207)	(0.902)	(0.199)	(0.994)
P (Korea)$_{-1}$	-0.074	0.156	0.107	0.265
	(0.071)	(0.311)	(0.069)	(0.342)
e (Japan)	-1.310	0.624	1.474	-0.653
	(0.439)	(1.914)	(0.422)	(2.109)
C_q^* (Japan)	6.659	-0.971	-7.931	0.959
	(2.699)	(11.783)	(2.599)	(12.980)
e (Germany)	0.014	-1.458	-0.133	0.123
	(0.257)	(1.121)	(0.247)	(1.234)
C_q^* (Germany)	0.476	-4.175	2.234	1.487
	(1.593)	(6.952)	(1.534)	(7.659)
e (U.S.)	2.475	0.031	-3.744	0.592
	(1.013)	(4.423)	(0.976)	(4.872)
C_q^* (U.S.)	0.420	0.654	0.269	-0.698
	(0.310)	(1.354)	(0.299)	(1.492)
e (Korea)	-0.397	-1.316	0.078	-0.635
	(0.419)	(1.829)	(0.403)	(2.015)
C_q^* (Korea)	-0.122	0.970	-0.442	1.002
	(0.408)	(1.783)	(0.393)	(1.964)
LM F[1,8]	6.452 [0.035]*	4.120 [0.077]	4.497 [0.067]	4.338 [0.071]
Normality χ^2[2]	6.121 [0.047]*	0.127 [0.938]	0.230 [0.891]	8.592 [0.014]*
ARCH F[1,7]	0.000 [0.995]	1.385 [0.278]	0.341 [0.578]	1.201 [0.309]

Vector Statistics:

Portmenteau:	67.418	*AR (1) F[6,16]:*	6.763 [0.069]
R^2:	0.9999	*Normality χ^2[8]:*[1]	17.152 [0.028]*

[1] Based on the test statistic proposed by Doornik and Hendry [1994]

* Reject Null Hypthesis at a 5% level of significance.

Table H-3

Large Automobiles

	Japan	***United States***
	1982(2) - 1988(4)	1982(2) - 1988(4)
Constant	-	11.853 (2.713)
ΔP (Japan)$_{-1}$	0.406 (0.116)	0.270 (0.212)
ΔP (Germany)$_{-1}$	0.087 (0.031)	-
ΔP (U.S.)$_{-1}$	-	0.174 (0.127)
ΔP (Germany)	-	0.086 (0.033)
Δc (Japan)	0.447 (0.197)	0.463 (0.271)
Δc (U.S.)	-1.040 (0.401)	-1.202 (0.525)
Δc (Germany)$_{-1}$	0.204 (0.089)	-
ΔC^*_q (Japan)	-[illegible] 903 (1.312)	-2.560 (1.770)
ΔC^*_q (U.S.)	-	1.050 (0.254)
ECM (Japan)$_{-1}$	-1.349[a] (0.148)	-
ECM (U.S.)$_{-1}$	-0.254 (0.028)	1.503[b] (0.345)
LM F[1,8]	4.309 0.079]	4.388 [0.070]
Normality χ^2[2]	0.723 [0.697]	2.548 [0.228]
ARCH F[1,7]	0.055 [0.821]	0.017 [0.901]

Vector Statistics:

Portmenteau:	15.787	*AR (1) F[4,20]*:	4.002 [0.015]*
R^2:	0.9999	*Normality χ^2[4]*:[1]	4.426 [0.351]

[a]ECM: $\Delta P_{Japan} = 0.018 + 1.000\Delta P_{Japan\,-1} + 0.533\Delta P_{U.S.} - 0.309\Delta c_{Japan} + 0.811\Delta C^*_{q\ Japan} + 0.864\Delta c_{U.S.} + 0.639\Delta C^*_{q\ U.S.}$

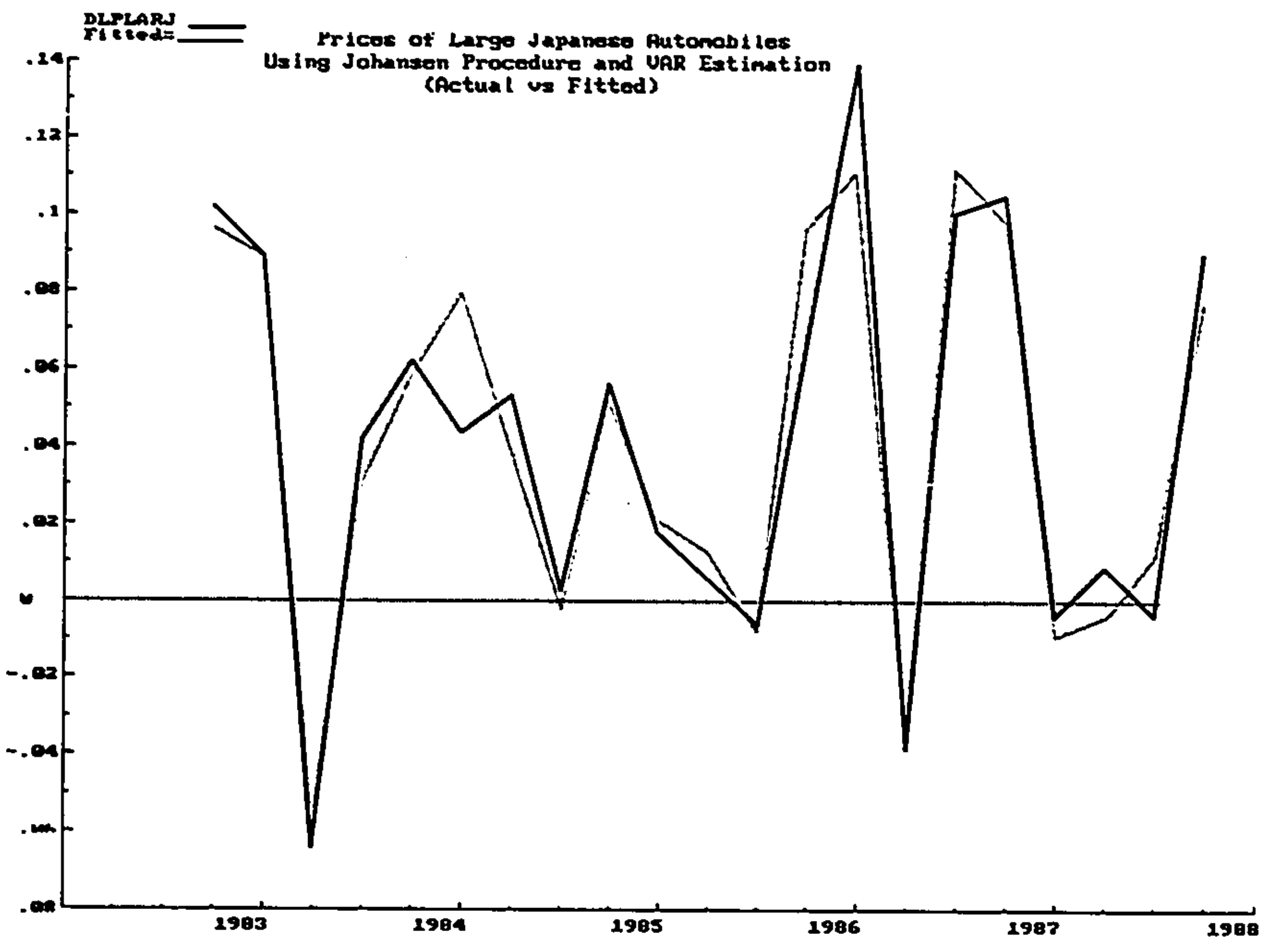
[b]ECM: $\Delta P_{U.S.} = 0.029 + 1.000\Delta P_{U.S.\,-1} - 0.367\Delta P_{Japan} - 0.581\Delta c_{U.S.} + 0.888\Delta C^*_{q\ U.S.}$

[1] Based on the test statistic proposed by Doornik and Hendry [1994].

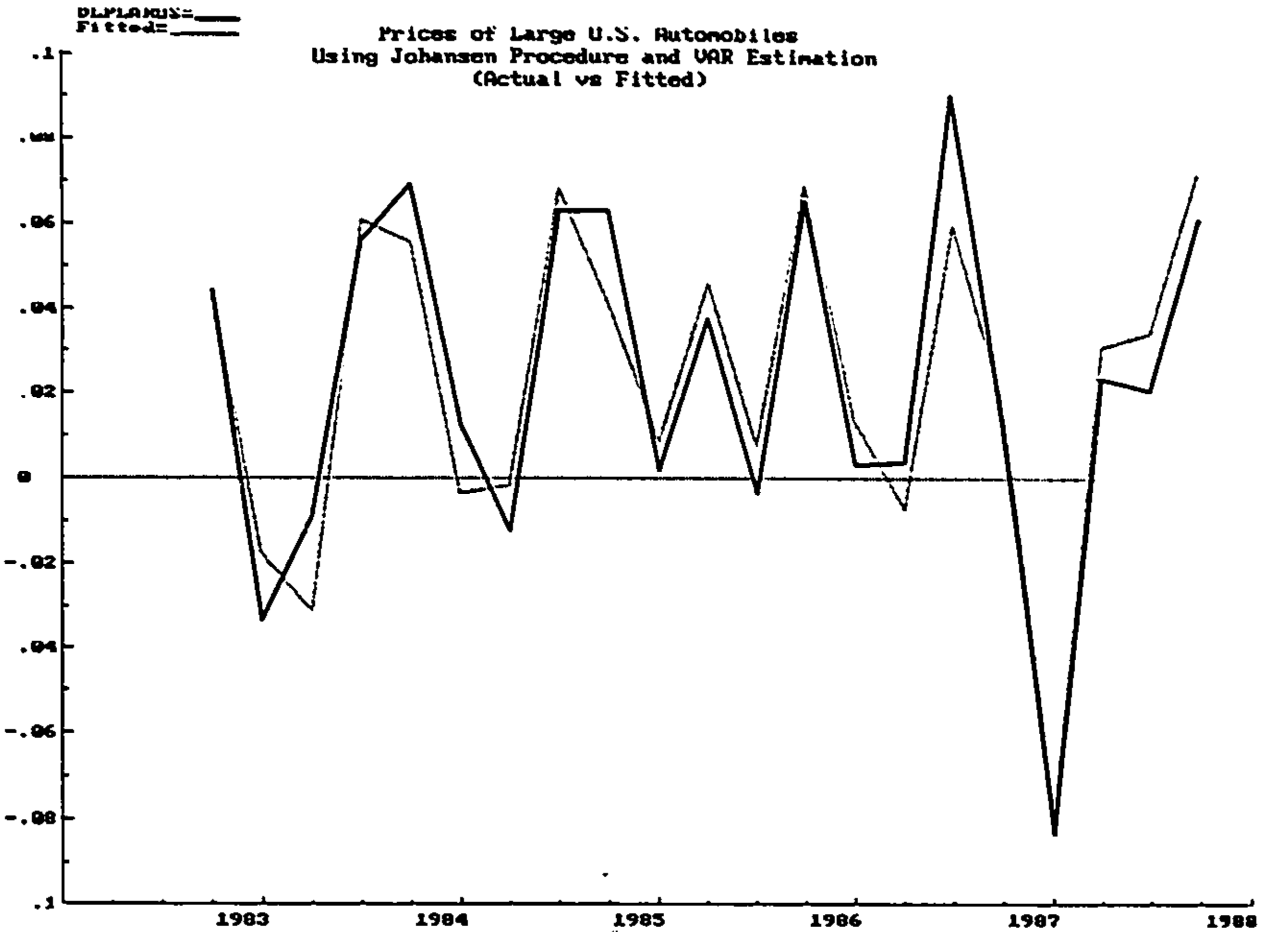
* Reject Null Hypthesis at a 5% level of significance.

This appendix contains all graphs generated by the dynamic forecasting techniques.

Graph I-1

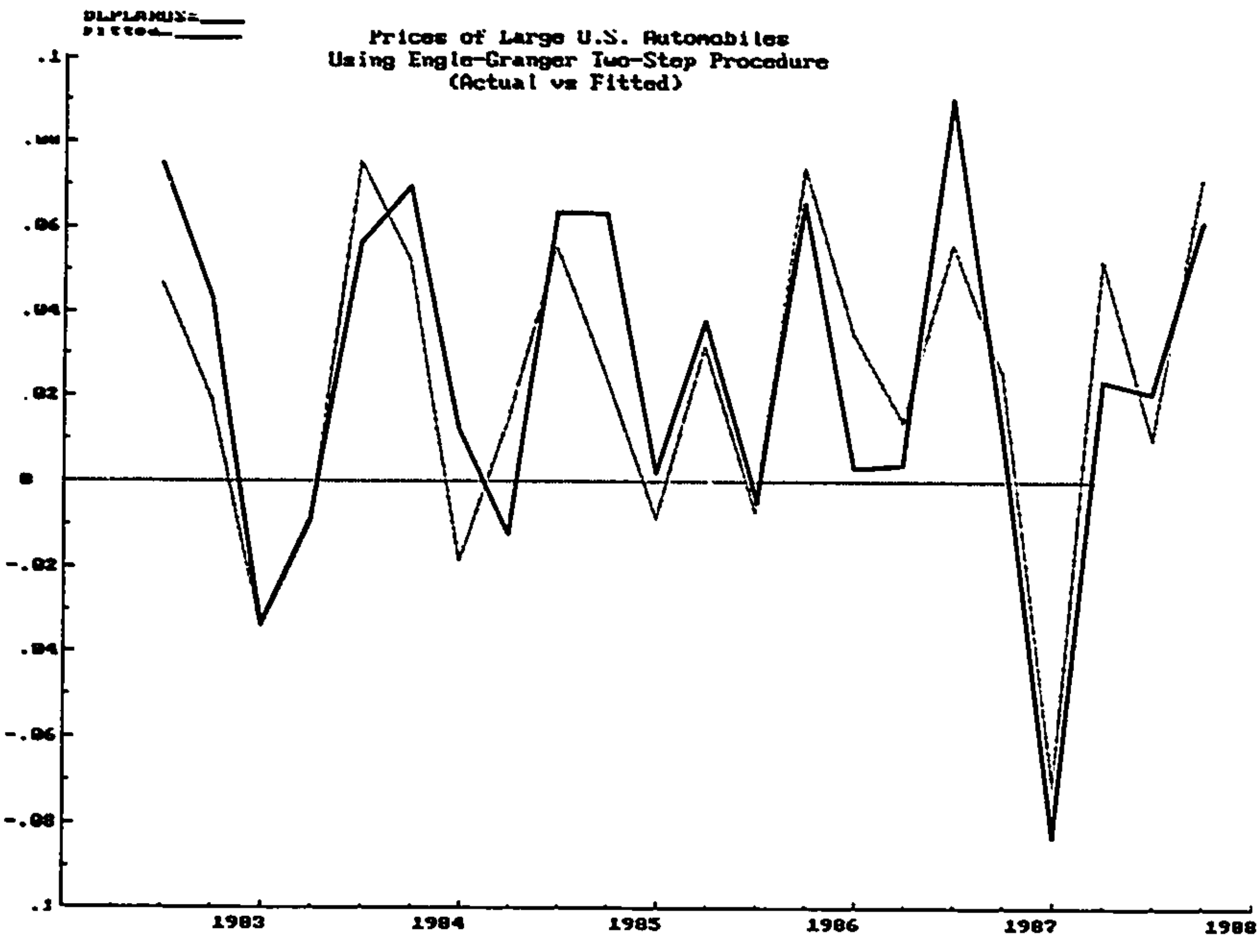


Graph I-2

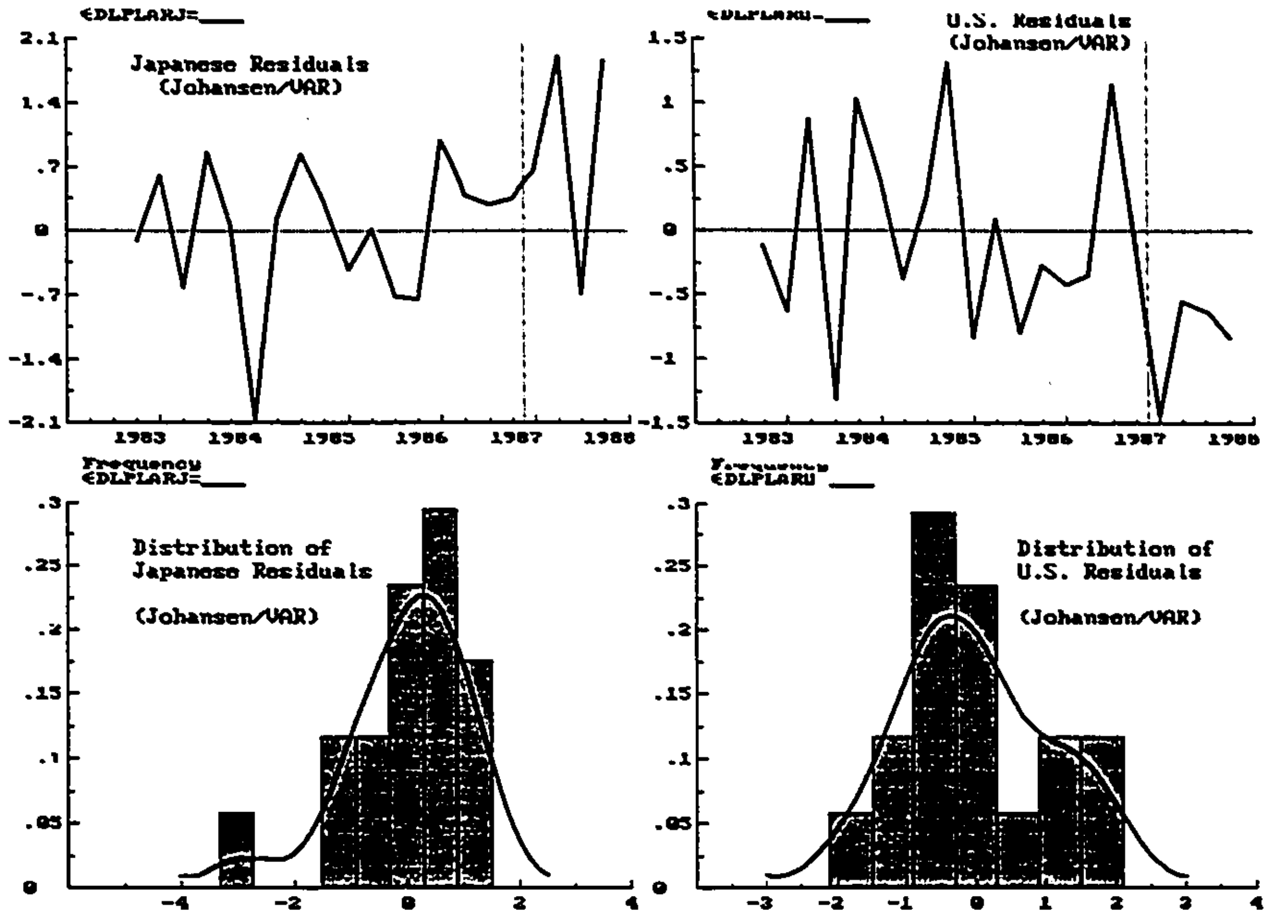


DLPLARUS=
Fitted=
Prices of Large U.S. Automobiles
Using Johansen Procedure and VAR Estimation
(Actual vs Fitted)
.1
.06
.04
.02
0
-.02
-.06
-.08
.1
1983
1984
1985
1986
1987
1988

Graph I-3

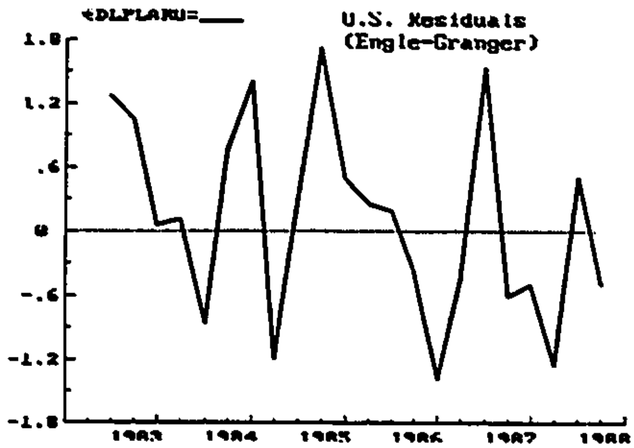

Prices of Large U.S. Automobiles
Using Engle-Granger Two-Step Procedure
(Actual vs Fitted)
.1
.06
.04
.02
0
-.02
-.06
-.08
1983
1984
1985
1986
1987
1988

Graph I-4

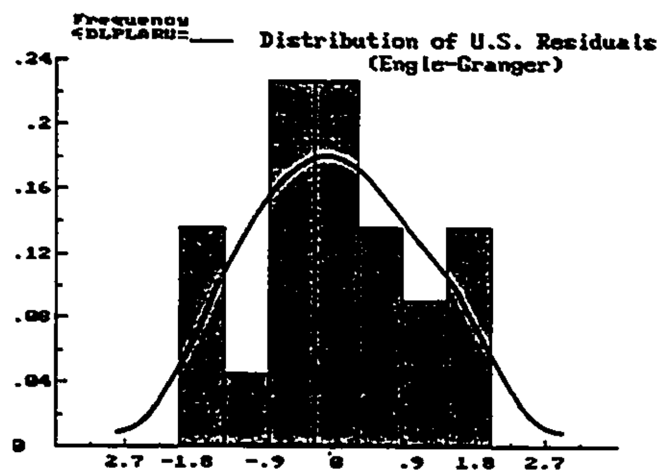


EDLPLARJ=
Japanese Residuals
(Johansen/VAR)
2.1
1.4
.7
0
-.7
-1.4
-2.1
1983
1984
1985
1986
1987
1988
U.S. Residuals
(Johansen/VAR)
1.5
1
.5
0
-.5
-1
-1.5
Frequency
EDLPLARJ=
Distribution of
Japanese Residuals
(Johansen/VAR)
.3
.25
.2
.15
.1
.05
0
-4
-2
0
2
4
EDLPLARU
Distribution of
U.S. Residuals
(Johansen/VAR)
-3
-2
-1
0
1
2
3
4

Graph I-5

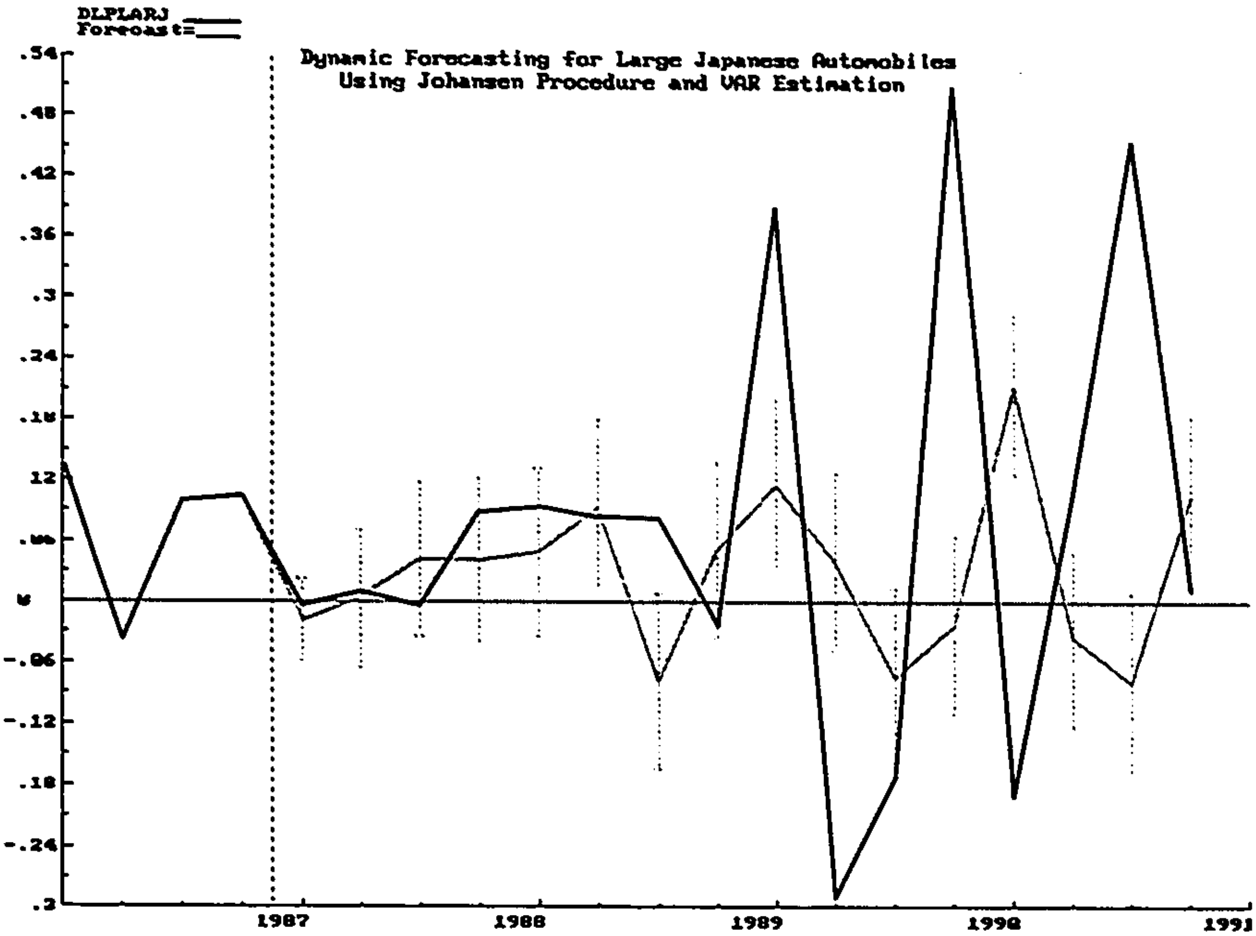


<DLPLARU=
U.S. Residuals
(Engle-Granger)
1.8
1.2
.6
0
-.6
-1.2
-1.8



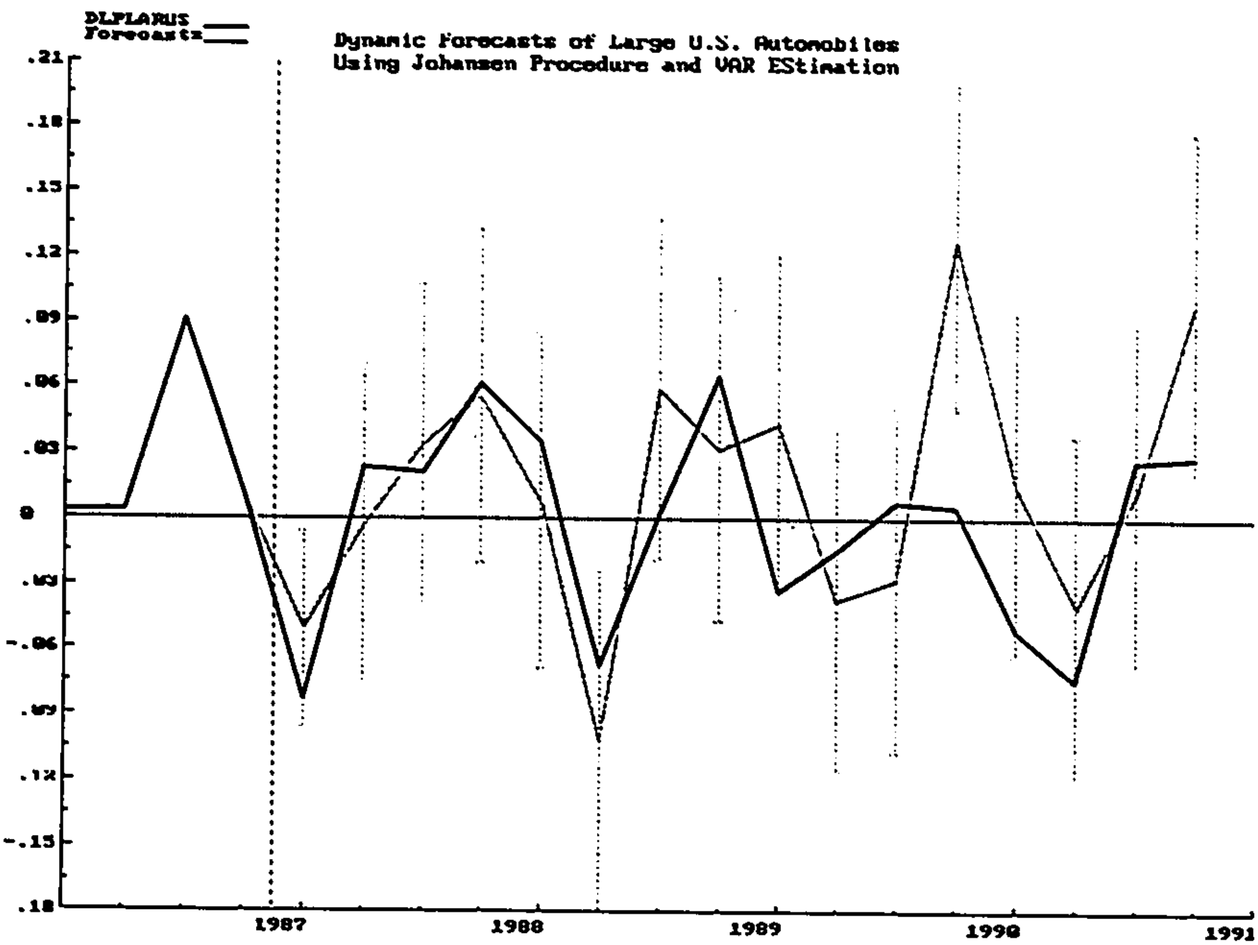
Frequency
<DLPLARU=
Distribution of U.S. Residuals
(Engle-Granger)
.24
.2
.16
.12
.08
.04
0
2.7
-1.8
-.9
0
.9
1.8
2.7

Graph I-6

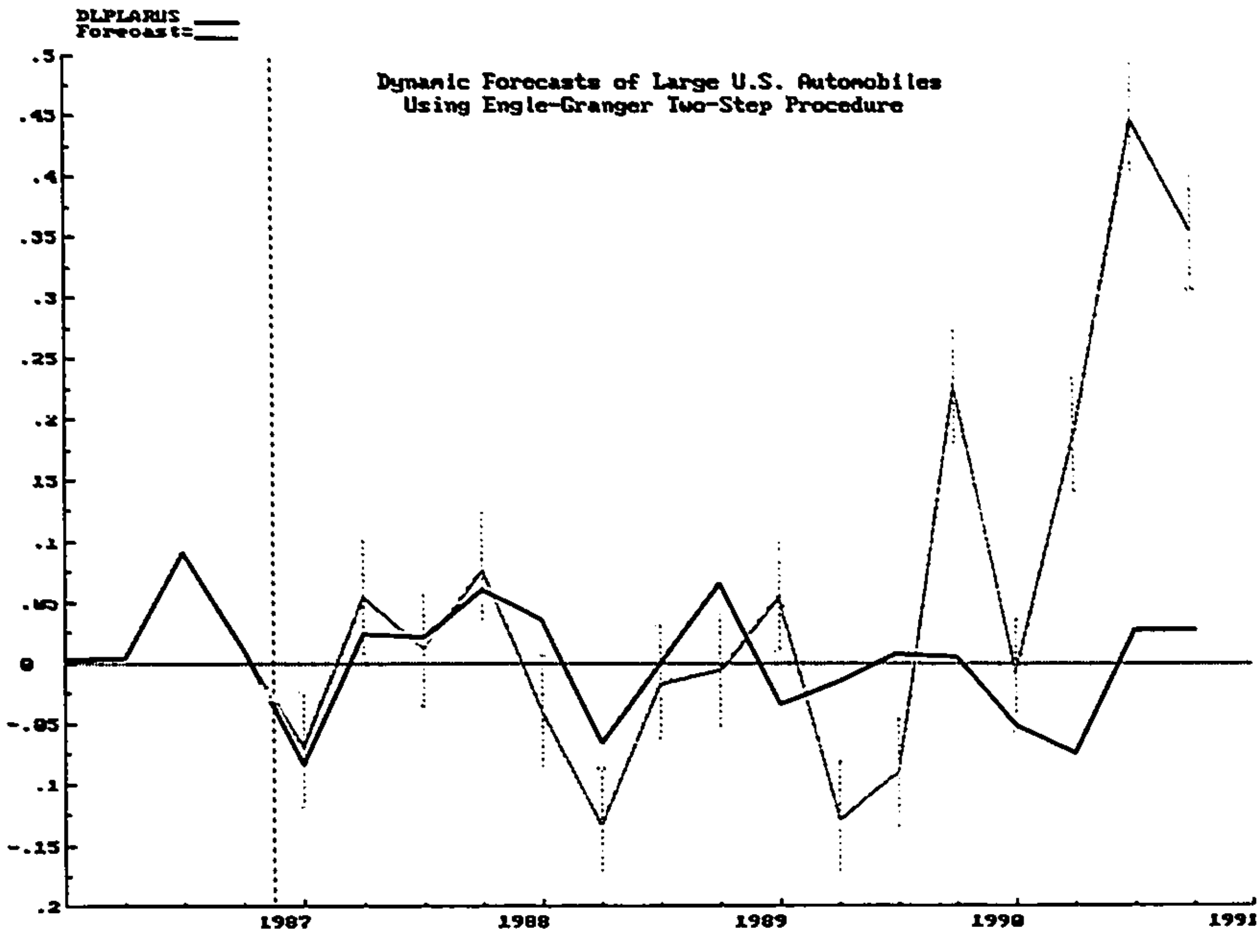


DLPLARJ
Forecast=
Dynamic Forecasting for Large Japanese Automobiles
Using Johansen Procedure and VAR Estimation
.54
.48
.42
.36
.3
.24
.18
.12
.06
0
-.06
-.12
-.18
-.24
-.3
1987
1988
1989
1990
1991

Graph I-7


DLPLARUS
Forecasts
Dynamic Forecasts of Large U.S. Automobiles
Using Johansen Procedure and VAR EStimation
.21
.18
.15
.12
.09
.06
.03
0
-.06
-.15
1987
1988
1989
1990
1991

Graph I-8



DLPLARUS
Forecast=
Dynamic Forecasts of Large U.S. Automobiles
Using Engle-Granger Two-Step Procedure
.5
.45
.4
.35
.3
.25
.2
.15
.1
.05
0
-.05
-.1
-.15
.2
1987
1988
1989
1990
1991