# A STUDY OF HYSTERESIS IN THE OPEN CANADIAN ECONOMY

By

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A Thesis
Submitted to the Faculty of Graduate Studies
in Partial Fulfilment of the Requirement
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Doctor of Philosophy

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

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***To my wife Mei and my son Victor.***

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# ABSTRACT

This dissertation analyzes the phenomena of hysteresis in the Canadian economy from an open economy approach which combines studies of hysteresis in the international trade and the domestic labour market. In the theoretical analysis, two models for a small open economy are developed: one for the aggregate demand side and one for the aggregate supply side. The first one presents a hysteretic *IS-LM-BP* model which shows that trade hysteresis could result in a vertical *IS* curve and bend the aggregate demand curve until it is infinitely inelastic. A very steep aggregate demand curve explains the demand side hysteresis in the domestic economy. The second model derives an open economy version of the Phillips curve by allowing the exchange rate to enter the right-hand-side of the equation, and provides a theoretical base for empirical testing. The empirical analysis of this study tests trade hysteresis and estimates the Phillips curve. Following the widely used approach of trade hysteresis testing, the unit root and the cointegration tests are performed on the series of net exports and the exchange rate for the data sets of the US, the OECD, and the rest of the world. The results show that both of net exports and the exchange rate followed random walk, and there is no cointegration between the two series which is consistent with trade hysteresis. The Phillips curve estimation includes two steps. Step one uses the causality test to show that changes in the exchange rate cause changes in the inflation rate, but not vice versa, which supports the open economy version of the Phillips curve. The next step is to estimate the Phillips curve, and the degree of hysteresis is calculated from the results of the estimation. In alternative estimations with different measurements of the unemployment rate, different data periods, and different data frequencies, the results suggest that hysteresis has been significant in the Canadian economy.

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**CHAPTER ONE**

# INTRODUCTION

The term "hysteresis" means that which "comes after" or "is behind", and comes from the Greek word for "to be behind". Today this terminology widely appears in natural science and it is used by scientists to describe the failure of a property that has been changed by an external agent to return to its original value when the cause of the change is removed[1].

Hysteresis is a property of dynamic systems. Hysteresis systems are path-dependent systems. The long-run solution of such a system not only depends on the long-run values of the exogenous variables, but also on the initial condition of each state variable. These systems have a long-lasting memory and are therefore "historical" systems.

Recently the concept of hysteresis has been adopted by economists to describe some economic phenomena which violate conventional economic theories. In these conventional theories, endogenous variables, such as unemployment and net exports, are functions of explanatory variables, such as the price level and exchange rate. However, much empirical

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[1] The phenomenon of hysteresis exists widely in the physical world. For example, in electromagnetism, a piece of ferrous metal can be permanently magnetized after a temporary electronic current shock. The relationship between changes of the intensity of magnetization in the metal and the intensity of magnetizing current can be described as a "hysteretic loop".

evidence suggests that these "functional relations" do not always hold. In some cases, when an exogenous shock occurs, the endogenous variables respond as described in conventional theories. The opposite, however, is not true; i.e., after the exogenous shock is withdrawn, its effect on the endogenous variables does not disappear, and the temporary exogenous shock may have a permanent effect on the endogenous variables. That is, a temporary shock could have a long-lasting effect on a system. This kind of phenomenon is defined as an economic version of hysteresis.

## 1.1 Hysteresis in Economics

The principle of hysteresis has been applied in two fields of economics. One is in labour economics with special reference to unemployment, and another is in international economics with special reference to international trade.

Beginning in the late 1980s, most theoretical and empirical studies on hysteresis have focused on the European labour market. As pioneers in this area, Blanchard and Summers (1986) discovered that the relationship between unemployment and inflation level suggested by the Phillips curve is not symmetric. In particular, when the inflation level increases (as the interest rate drops), the unemployment level does not respond to the change and return to its original trend, but stays at its previous level permanently. This phenomenon is called labour market hysteresis.

Studies on hysteresis in international trade are still in their infancy. From the late 1980's to the early 1990's, Baldwin (1988, 1990), Dixit (1989a, 1989b), and Krugman (1987) hypothesized that a temporary and sufficiently large rise in the exchange rate would induce permanent entries by foreign firms, thereby resulting in a permanent loss in trade balance. However, there are no convincing empirical reports to support the theory of trade hysteresis so far.

Studies of hysteresis in domestic labour markets and in international trade have been separately conducted in the existing literature. This dissertation examines linkages or possible relationships between trade hysteresis and domestic labour market hysteresis, or between the unemployment rate and the trade balance. For a small open economy, such as Canada, the evidence is supportive of linkages. Long before people drew attention to the phenomenon of hysteresis in economics, Turnovsky (1972) realized the special character of the Canadian economy when he studied the Phillips curve for industrialized countries. He pointed out that "the major difference between them (the Phillips curves in the Canadian and the US economies), of course, is that unlike the United States, Canada is heavily dependent on foreign trade. This tends to make the economy more competitive ...". Therefore, to conduct a study which combines trade hysteresis and domestic labour market hysteresis may enable us to understand the nature of hysteresis for a trade oriented small economy, and identify causes of hysteresis for the Canadian economy.

## 1.2 Motivation of This Study

The objective of this dissertation is to combine the studies on the domestic labour market and international trade and apply them to investigate the hysteresis hypothesis in the Canadian economy. The Canadian economy is well suited to this study, given its heavy international trade orientation. In fact, its domestic economic performance is largely dominated by net exports.

During the last four decades, Canadian economic performance has ranged widely. The average unemployment rate has steadily increased, from 4.0 percent in the 1950s, to 9.3 percent in the 1980s. Over the same time period the average inflation rate has fluctuated between 2.5 percent and 7.3 percent without displaying any clear trend. A Phillips curve explanation seems poorly suited to explain the joint behaviour of inflation and unemployment rates for the Canadian economy. It might be possible to use the hysteresis hypothesis to characterize this phenomenon.

In this dissertation, we examine the existence of hysteresis in the Canadian economy. Existing empirical analyses provide mixed results. Fortin (1991, 1993) support the concept of hysteresis; however, Cozier and Wilkinson (1991) and Poloz and Wilkinson (1992) reject hysteresis. All of these studies were isolated within a closed economy model. Given the dependence of the Canadian economy on international trade, it is important to study hysteresis in the context of an open economy model.

### 1.3 Possible Sources of Hysteresis for the Canadian Economy

Hysteresis describes an irregular relationship (asymmetric responses) between economic variables, e.g., the inflation and the unemployment rate, or the trade balance and the exchange rate. The irregular relationships could be "symptoms" of major changes and adjustments in the economic structure. Therefore, hysteresis phenomena in the Canadian economy (in both trade and labour markets) could be an indication of structural changes and adjustments in the economy. To list these changes and adjustments may help us to identify sources of hysteresis and understand the nature of hysteresis. If we consider the changes and adjustments as the sources of hysteresis in the Canadian economy, then these sources could be viewed as the external factors and the internal factors.

#### 1.3.1 External Causes of Canadian Hysteresis

External sources of international market pressure may affect the domestic economy through the channel of changes in the exchange rate and cause the Canadian hysteresis in trade and labour market. International market pressure includes: (1) strategic changes in the global economic structure; (2) dramatic shocks in the prices of oil and other primary commodities in the world market; and (3) unpredictable fluctuations in the international financial market.

## I. Structural Changes in A Global Economy

After the Second World War, a pyramid shaped economic hierarchy was formed in the global economy according to the differences in productivity and income level among nations. On the top of the pyramid, there is a small group of "developed countries" led by the United States. The middle of the pyramid is composed of "developing countries" which are transforming their economies from agricultural to industrial activities. On the bottom of the pyramid are many "underdeveloped countries" which remain traditional agricultural economies. The high income of the top group of countries is ensured through a large productivity gap relative to underdeveloped countries. From an international economics viewpoint, the productivity gap is determined by the capacity of innovation in new products[2].

Krugman (1979) assumed that innovation in new products takes place first in the developed countries[3]. The theory of international trade suggests that the huge income gap between the North and the South is caused by an asymmetric trade flow: the North exports high-valued "new products" to the South at monopolistic market prices, and the South exports low-valued primary commodities (agricultural, raw material, and labour

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[2] "New products" include strategic commodities, such as computers and aircraft, banking and insurance businesses, Hollywood entertainment and McDonald's franchises.

[3] We adopt Krugman's (1979) convention of denoting developed countries as being from the "North" and underdeveloped countries as being located in the "South".

intensive goods) to the North at competitive market prices.

This global economic structure, however, has been dramatically changed during last two decades. Success of the Japanese economy in the 1960's signalled that the existing global economic hierarchy is a dynamic system. Adjustment in the hierarchy occurs if the productivity gap changes among different economies. A major factor affecting change is technology mobility from the North to the South.

The first wave to shock the pyramid was the rise of the New Industrial Countries (NIC) in the 1970's, namely Taiwan, Korea, Singapore, and Hong Kong. Their success was based on Northern technology that enabled them to export capital intensive goods, rather than labour intensive goods.

In the 1980's, rapid economic growth in China and the other New Dragons, i.e., Thailand, Malaysia, Philippines, and Indonesia, formed another wave to shock the top of the pyramid. Their rapid growth was due to the acceleration of technology mobility from the North. The net result of these forces has been to mitigate the productivity gap between the Northern and Southern countries.

To maintain the productivity gap, the Northern countries required accelerated innovation in new products and services. The speed of innovation in the North, however, is not likely to be able to match the technology mobility from the North to the South.

Under this international challenge, the ability of the North to recover from each recession became weaker and weaker. The high paid jobs (comparing with the rest of the world) lost in the recessions of the 1970's and the 1980's became more and more difficult to regain. Due to global competitiveness, the domestic market mechanism in the North is weakening, which could be observed as an irregular movements in economic variables; i.e., change in the unemployment rate is not proportionate to the change in the inflation rate, and the balance of trade does not respond to the change in the exchange rate.

For the small and open Canadian economy, changes in international competitiveness could generate unexpected shocks to its domestic economy. As a result, the pressure from the rest of the world may appear as hysteresis. From this viewpoint, the asymmetric dependence between the Canadian and the US economies may cause trade hysteresis in Canada, and in addition, trade hysteresis may add to the labour market hysteresis in the Canadian domestic economy.

A strong linkage between the economies of Canada and the US determines that the Canadian economy is heavily dependent on US economic performance. The dependence is not only due to the large amount of trade flow between Canada and the US which dominates the Canadian economy, but also because the Canadian economy is "branch-plant oriented" in nature (i.e., many Canadian companies have their parent companies in the US). In addition, the relative size difference in the two economies results in an asymmetric dependence. The asymmetric pattern of dependence between the two economies could weaken the market mechanism in the smaller Canadian economy, because the unexpected shocks could be exported from the US to Canada through changes in the exchange rate between the two currencies, but not vice versa. As an indication of failure in market adjustment, the hysteresis phenomenon could be more significant in the Canadian economy than it appears in the US.

## II. Price Shocks from the Rest of the World

In addition to the dynamic adjustments in the world-wide income distribution, which appear as changes in the pattern of trade in the global economy, a change in the terms of trade which appears as price shocks from the world market may also add to Canadian hysteresis. From the theory of international trade (e.g., the Heckscher-Ohlin-Samuelson theorem), the price shocks to the industrialized economies could be viewed as a trend of price equalization in the global market, that is, a price decline in their exporting goods and a price increase in their importing.

The acceleration of technology transformation from the North to the South has been diminishing the monopolistic market power of the "new products" in the world market[4],

[4] For example, when the US and Japanese firms (such as GE, Motorola, Sony, or Toshiba) introduce new products to market, firms in Korea, Taiwan, and Southern China will quickly replicate their technology. The time lag between the first appearance of the products from the North and the followers from the South has shrank dramatically.

so the top group of economies finds it more and more difficult to maintain their high income status by selling their commodities to the rest of the world at monopolistic market prices.

At the same time, the price structure of the primary commodities has changed in the world market during the last two decades. As a result of the change, Northern economies are not able to pay low competitive market prices to the South. For example, the formation of the OPEC and the dramatic changes in oil prices generated drastic price shocks in the Canadian economy (and other industrialized economies) in the last two decades. The monopolistic power of the OPEC enabled it to raise oil prices from US$6 per barrel in 1972 to US$14 per barrel in 1974, and US$40 per barrel in 1981 (Gordon 1993). A temporary drop of the price (to US$17 per barrel) in 1986 did not last long, and one year later (in 1987) it rebounded to above the level of US$20 per barrel. The latest oil shock came from the Iraq-Kuwait War in 1990 and it stimulated the price to US$40 again. There is no indication that these kinds of shocks could be prevented or predicted in the future. Due to the inflexibility of price adjustments, all these shocks had permanent effects on the Canadian economy by adding extra production costs to the domestic economy.

For a large economy like the US, Gordon (1993) pointed out that "... (due to oil price shocks) in fact, the lowest nominal GDP growth of the decade was experienced in 1975, when the inflation rate was the fastest". This implies that the trade-off relationship suggested by the Phillips curve was weakened by the oil price shocks in the US economy. Increases in the costs of production has permanent effects on the domestic economy which may appear as hysteresis. For a small open economy like Canada, this phenomenon should be more significant than for the US.

## III. International Financial Market Fluctuations

The final external source of hysteresis stems from the shocks of unpredictable international financial market chaos. Because the US dollar is the major currency in the world financial market, fluctuations in the US dollar generate major shocks to the global financial market, and therefore the financial market pressure affects the Canadian economy through changes in exchange rates, especially the rate between the Canadian and the US dollars.

From the Bretton Woods Agreement of 1944 to the end of 1960's, the gold standard currencies and the fixed exchange rates among major industrial currencies played a major role in stabilizing the global financial market. Low interest rates prevented sudden drastic changes in exchange rates and capital movements and resulted in a stable global financial market. Since the 1970's, the situation has changed significantly. The flexible exchange rate system adopted by industrial economies implied that changes in the US dollar became more and more volatile during the last two decades. Cameron (1991) suggested that "...

as long as the US dollar is the main key currency, the United States is free to increase the world's money supply too rapidly without suffering all of the consequences (of expansionary monetary policy)". Due to the difference in relative sizes of and asymmetric dependence between the Canadian and US economies, fluctuations in the exchange rate between the two currencies generated tremendous unexpected shocks to the Canadian side.

During the last two decades, there were three major foreign exchange operations to change the US dollar supply in the global financial market: in the late 1970's, the US monetary authority intervened in the market to support its dollar; in 1985 it intervened in the money market again to counter the strong US dollar; and from 1987 to 1990, the purpose of the intervention was mixed but it caused fluctuation in the money market (Jacobson 1990). Consequently every large movement of the US dollar caused a financial market shock to the Canadian economy. Therefore, changes in the US dollar (and other major currencies) could cause shocks in the global financial market which will affect the Canadian economy. For instance, the unification of the two Germanies generated the highest domestic inflation in Germany since 1945 (*The Economist*, 2 May 1992). The domestic market pressure of Germany could be exported to other economies through exchange rate shocks[5]. As a small and open economy, Canada might be more sensitive to these international fluctuations than those large economies. If the domestic economy could not smoothly adjust to respond to the shocks, effects of the shocks will accumulate

[5] A theoretical model will be developed to show how changes in exchange rate affect a small open economy.

and result in a hysteresis in the Canadian economy.

### 1.3.2 Internal Causes of Canadian Hysteresis

The internal sources of hysteresis come from changes and adjustments in the domestic economic structure. These changes and adjustments generate domestic market pressure which deteriorates the market mechanism and causes an asymmetry effect in the relationship of the inflation-unemployment trade-off. The pressure may be generated from at least two sources: the rigid labour market and the government's social welfare programs.

#### I. Rigid Labour Market

For an industrialized economy like Canada, labour is the most important production input (wage and salary payments made up 70% of the national income) and the country's entire economic performance is largely affected by the structure of the labour market. The unions' monopolistic power over wage bargaining and labour supply[6] may harden the

[6] Even though only about 30% of all labour in Canada is unionized, the rest of the labour market has to, more or less, match the unionized wage level, because a visible wage gap between the unionized and non-union workers may cause employee shirking in the non-unionized sectors, as Akerlof and Yellen (1987), and Lawrence (1986) suggested.

market mechanism and cause hysteresis. Yellen (1984) described this effect in the "Insider-Outsider Theory". According to this theory, the insiders, those workers already employed by firms, typically try to keep their wage high. The outsiders, the unemployed, bear part of the cost of higher wages because at lower wage they might have been hired. When a recession comes, some of the insiders in the wage-setting process become outsiders as the unemployment rate rises. The insiders are able to demand higher real wages (the inflation rate during a recession is usually low) as the group of insiders is smaller. Then the recession may permanently push real wages further above the equilibrium level and result in a persistently high unemployment rate.

During the 1960's, the unemployment rates in Canada and the US were about the same on average since the two countries had similar labour markets. Since the mid-1970's, the unemployment rate in Canada has been about 2% or 3% higher than that of the US on average. Mankiw (1992) suggests that Canadian labour laws did more to foster unionization in Canada relative to the US since the 1970's. In 1991, 33% of the labour force in Canada were unionized, but the unionization of labour in the US at the same time was only 16% (Monthly Labour Review, December 1991). Since the 1970's, the real wage in Canada increased by 30% relative to the real wage in the USA. The comparison may suggest that labour unionization is a source of hysteresis in the Canadian economy[7].

[7] Adams (1989) studied the union density and bargaining coverage in selected industrialized countries (Canada, the USA, the UK, West Germany, Japan, and Sweden). His results suggest a direct linkage between labour unionization and hysteresis.

## II. Welfare Programs

Another possible source of hysteresis is the government's social welfare programs. Some social welfare programs provided by the government may discourage or reduce the efforts of unemployed people to search for jobs. By comparing differences in the unemployment insurance benefits between Canada and the United States, Moorthy (1989) suggested that the unemployment insurance (UI) system plays an important role in the Canadian economy. His study argued that UI is a critical feature of the Canadian system in that the provision of benefits, not only to those unemployed people who have lost their jobs, but also to some who have reentered the labour force or left jobs, has been largely responsible for the persistent high unemployment rate in Canada. This view is also shared by the Job-Searching-Separating model (Barro, 1988).

The above analysis suggests that the Canadian economy has experienced shocks from external (international) and internal (domestic labour market) sources, and these shocks caused structural changes and adjustments in the economy. Accordingly, the conventional market mechanism has deteriorated. The hypothesis of hysteresis can be used to detect the deterioration of the market mechanism[8] in the context of an open economy model of the Canadian economy.

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[8] Even though hysteresis and market mechanism deterioration are not the equivalent concepts, but we could consider the former as a possible signal of the latter.

An empirical investigation of Canadian hysteresis is equally important because it is directly related to Canadian industrial policy. As Krugman (1991) showed, trade hysteresis may cause de-industrialization for the smaller economy in trading. This consideration is particularly important for Canadian policy makers, given the consequences of losses in the manufacturing industry to the United States. If our empirical results show that the labour market hysteresis was caused by international fluctuations, policy makers should devote their efforts to further mitigating international shocks to improve Canadian global competitiveness.

## 1.4 Dissertation Layout

This dissertation consists of six chapters which are organized as follows.

Following the review of the background of hysteresis and motivation of this study in chapter one, chapter two reviews conventional theories on the trade balance determination and the Phillips curve hypothesis. The theories suggest that the relationships between the trade balance and the exchange rate, and between the inflation and the unemployment rate, are functional (a variable proportionally responds to changes of another).

Chapter three surveys the literature on trade hysteresis and labour market hysteresis. The survey finds existing studies follow the international trade literature or the domestic labour market literature without recognition of interdependencies. The conclusions of the studies are far from complete, in the measures of both theoretical analysis and empirical investigation. In addition, their applications to the Canadian economy are still in their early stage.

Chapter four forms the theoretical framework for this study. It starts from developing a trade hysteresis model at the macroeconomic level (all existing models in trade hysteresis are microeconomic analyses), and derives an explicit functional expression on trade hysteresis. The expression shows that with trade hysteresis, the net export, a component of the income identity in the IS-LM model, is a non-monotonic function of the exchange rate. A hysteretic net export could be introduced into the IS-LM model by applying the Interest Rate Parity (which maps the export-exchange rate space, X-E, to the output-interest rate space, Y-r). In this hysteretic IS-LM model, investment is an inverse function of interest rate, but net exports are a positive function of the interest rate. When the two opposite forces offset each other, we observe a vertical IS curve. A vertical IS curve implies that the aggregate demand curve is also vertical. This explains hysteresis due to exchange rate shocks -- output remains at a fixed level regardless of price level changes.

In addition, a small open economy version of the Phillips curve is developed in this chapter. In order to capture supply side shocks from the rest of the world, the open economy version of the Phillips curve allows the exchange rate to enter the equation. The equation provides a theoretical base for the empirical testing of hysteresis in this study.

Chapter five conducts empirical tests of hysteresis for the Canadian economy. The tests include two parts: trade hysteresis testing, and Phillips curve estimation.

Our theoretical model in Chapter four suggests a non-monotonic relationship between the trade balance and the exchange rate when trade hysteresis occurs (Proposition I). From the time series analysis point of view, the non-monotonic relationship can be interpreted as that the two time series are not cointegrated. Trade hysteresis described in Proposition I can be tested by examining whether the series of the trade balance and the exchange rate are cointegrated. In addition, since each series having a random walk (integration in degree one) is the necessary condition for them to be cointegrated, we use unit root test to test whether the two series follow a random walk. Therefore, the unit root test can be considered as a preliminary test for trade hysteresis.

Test of labour market hysteresis is based upon estimation of the open economy version of the Phillips curve, which is a result of previous chapter. The degree of hysteresis can be determined from the coefficients of estimation. The methods used to estimate the Phillips curve and determine the degree of hysteresis are quite comparable with those of Gordon (1989), and Fortin (1991, 1993).

Finally, Chapter six summarizes the study. The conclusion of this study indicates that hysteresis has been significant in the Canadian economy in the areas of both international trade and domestic labour market, especially since the middle of 1970's. In addition, the trade hysteresis did contribute to labour market hysteresis.

# CHAPTER TWO

# CONVENTIONAL THEORIES IN TRADE AND LABOUR MARKET

In order to study the special properties when hysteresis occurs in the international trade and labour market, it is necessary to summarize the development of the conventional theories in the two areas. Section one of this chapter summarizes the relationship between the trade balance and the exchange rate, and section two reviews the relationship between domestic inflation and output level.

## 2.1 The Exchange Rate in an Open Economy

The purpose of this section is to examine: (1) existing treatments of the relationship between the balance of trade and the exchange rate, theoretically and empirically; and (2) how the effects of changes in the exchange rate pass through other endogenous macro variables, such as the interest rate, the domestic price level, and the unemployment level.

### 2.1.1 Exchange Rate and Trade Balance

A key issue in contemporary international economics is to examine the effect of exchange rate changes on the balance of trade, via changes in prices. The traditional view of exchange rate movements typically assumed that a devaluation would reduce the foreign currency price of exports and increase the home currency price of imports with opposite effects for revaluation. The empirical debate centred on price elasticities of demand for those exports and imports. If the elasticities were sufficiently large, the devaluation would produce volume effects (higher exports, lower imports) that would outweigh the adverse movement in the terms of trade (cheaper exports, more expensive imports) and the trade balance would improve.

Analysis of the effects of changes in the exchange rate can be traced back as early as the 1920's, as Professor Frank Taussig suggested in his textbook (1927). Among that early literature, Williams (1920), Viner (1924), White (1933), and Taussig (1927) himself studied historical examples of the balance of payments. These studies defined the concept of adjustment in the balance of payments which is the sum of the current account and the capital account, under conditions of both fixed and flexible exchange rates.

It was not until the work of Laursen-Metzler (1950) that the connection between international monetary economics and macroeconomics became firmly established. Until then relative prices and devaluation had been primarily dealt with in partial equilibrium models. Laursen-Metzler (1950) approached the effects of exchange rate changes on the balance of trade from different perspectives. The main point to emerge was the recognition that the balance of trade equals the excess of income over spending. Accordingly, the analysis of various disturbances in their trade-balance effects could not bypass an explanation of the aggregate income-expenditure balance.

By the early 1960's, macroeconomics had become firmly established as an approach to open economy equations. The standard analysis was one of comparative statics in a model with income demand determined and with the exchange rate setting relative prices. The following years brought the highly influential work of Robert Mundell. He studied the role of the exchange rate in macroeconomic analysis and the theories of policy instruments under fixed and flexible exchange rates.

Based on previous work and his own contribution, Chacholiades (1978) provided a complete theoretical analysis to explain how changes in the exchange rate affect the trade balance. His analysis was based upon a standard open economy version of the Keynesian model. The model started from the income equation, a condition for the aggregate demand side equilibrium, which defines national income as equal to aggregate demand for the goods and services produced by the nation. Aggregate demand can then be partitioned into two parts: (i) the domestic demand which is a summation of consumption, investment, and government expenditure; and (ii) the demand from the rest of the world, namely, the balance of trade, which is defined as the difference between exports and imports. Combining the income equation with the investment equation, Chacholiades showed that the balance of trade is equal to the gap between the savings of a nation over its investment, or the excess of income of a nation over its total domestic spending. This result is indeed a macroeconomic interpretation of the balance of trade which bridges two fields of economics, international trade and macroeconomics, in one system of analysis. Therefore the balance of trade and its two components, exports and imports, are all macroeconomic variables.

Exports and imports are mainly determined by domestic and foreign income, the price level, and the exchange rate. From this multi-variable function, the effects of a change in exchange rate on the trade balance can be analyzed by deriving partial derivatives of the trade balance with respect to the exchange rate. As a result, the model shows that a change in the exchange rate will have two kinds of effects: a price effect which directly affects the volume of trade, due to change in the terms of trade (through a change in relative prices between the domestic and the foreign); and the income effect which measures changes in the welfare of the nation (through changes in the national income due to changes in the relative prices and the volume of trade). A general conclusion of Chacholiades' analysis is that there is a functional relationship between the balance of trade and the exchange rate.

In addition, if the price elasticities of the export and the import satisfy the stability condition (which is known as the Marshall - Lerner condition), a devaluation will be favourable for the balance of trade. Dornbusch (1980) gave the simplified expression,

$$\frac{\partial T}{\partial E} = M\,(m_1 + m_2 - 1) \tag{2-1}$$

where $T$ stands for the balance of trade, $E$ stands for the exchange rate, $m_1$ is the price elasticity of export, $m_2$ is the price elasticity of import, and $M$ is a positive coefficient. If the Marshall-Lerner condition is satisfied (the summation of the price elasticities is greater than unity), the functional relationship between the trade balance and the exchange rate is positive. This relationship is widely adopted by conventional literatures, for example, Baillie and McMahon (1989).

Since the 1970's, many studies in the field of international economics have focused on empirical analysis. Several papers appeared which tried to analyze empirically effects of devaluation on the trade balance and the balance of payments. All these studies used the exchange rate, the income level and some other exogenous variables, such as the price level or the money supply, to explain the balance of trade. There is a number of widely quoted studies which reported different results.

Cooper's (1971) study showed that the impact effect of 15 of 24 devaluation cases (for developing countries) was to improve the trade balance. To continue Cooper's study, Connolly and Taylor (1972) tried to analyze the relationship between the balance of payments (defined as net change in reserves) and the domestic output, and their results also suggested that devaluation improved the balance of payments.

Later, Laffer (1976) examined the time path of the trade balance over 7 years (for the US), from 3 years before devaluation until 3 years after. He found that although the trade balance improved in the year following devaluation for 8 of 15 cases, in one half of those cases the trade deficit was still worse than the average balance of the 3 years prior to devaluation. A similar study was reported by Salant (1976), who examined the relationship between the exchange rate and the balance of payments based on 101 cases from the US data, and found that in about three quarters of the cases (75 of 101) the balance of payments improved as a result of devaluations. In contrast, the devaluation resulted in improvement in the trade balance only in less than one half the cases (46 of 101).

Miles (1979) studied the statistical relationship between the exchange rate and both the trade balance and the balance of payments for 14 countries with 1960's data. The study tested the effect of devaluation while standarizing for other variables that may affect the foreign accounts. His report shows that the balance of payments does seem to improve following devaluation, but empirical evidence is not strong to support the hypothesis that devaluation improves the trade balance[1].

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[1] In his empirical equations, he used the exchange rate and other variables, such as the growth rate and money supply, to explain the trade balance. The regression results show that the coefficient of exchange rate is significant (at the 5%

Another empirical analysis on the exchange rate - trade balance relationship was reported by Feldman (1982). The study analyzed the US data for the period of 1975 - 1982 and concluded that 20% appreciation in the US dollar caused 18% increase in imports (excluding petroleum). The report suggested that a change in the exchange rate did affect the trade balance for the US.

From the 1980's to the early 1990's, empirical studies on the exchange rate - trade balance continued, but the findings were still inconclusive. For example, Rose (1991) examined the data of five major OECD countries, including Canada, Germany, Japan, the UK, and the USA, for the period of 1976 - 1986, and found there is little evidence that the exchange rate significantly affects the trade balance.

In conclusion, the relationship between the trade balance and the exchange rate is clearly established in theoretical analysis, but the hypothetical relationships have not been clearly tested in empirical analysis.

### 2.1.2 Exchange Rate and Macroeconomics

How does a change in the exchange rate affect other macroeconomic variables? Since Cassel (1919, 1922) introduced the hypothesis of the Purchasing Power Parity, the

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level) for only 3 of 14 countries.

exchange rate has been related with macroeconomic analysis in a large range of contexts by various authors, including Dornbusch (1971, 1973, 1986, and 1988), who studied the relationship between the exchange rate and inflation (price level); Sargent (1985, 1987), who used the exchange rate as an exogenous variable in the Cash-in-Advance model to analyze policy optimization; and Blanchard and Fischer (1989), who used the exchange rate to model asset pricing. Research commonly focuses on studying the behaviour of the exchange rate itself, as in Baillie and McMahon (1989), rather than using the exchange rate as an important variable in a broad model.

Ueda (1983) modeled a small open economy based on the Mundell - Fleming model to demonstrate the role of the exchange rate in macroeconomics[2]. The model shows that the exchange rate plays an important role in the domestic economy, by affecting both the money and the goods markets. According to this model, a change in the exchange rate will be responded by a change in the domestic interest rate. The change in the interest rate will affect money demand in the domestic monetary market and generate a market pressure to change the price level. In the goods market, the change in the interest rate will causes a change in investment, and the change in the exchange rate will cause a change in net exports. As the result, the output will be changed.

In order to examine the relationships between the exchange rate and other

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[2] Similar analysis can be seen in many advanced macroeconomic texts. For example, Turnovsky (1977) and Scarth (1988).

macroeconomic variables, Robinson, Webb and Townsend (1979) tested the influences of the exchange rate changes on prices based on the data of 18 industrial countries for various time periods. Their report hows that the deviations of domestic price levels (from their trends) in these economies can be explained by changes in the exchange rates.

## 2.2 The Phillips Curve and its Developments

This section surveys literature on the labour market which includes the original Phillips curve relationship, the expectation-augmented Phillips curve, the concept of the natural rate of unemployment, empirical studies on the relationship, and their applications to the Canadian economy.

### 2.2.1 Original Phillips Curve

Unemployment and inflation have been the focus of macroeconomics since its birth. Unlike many other dimensions of economic achievement and failure, unemployment and inflation are readily measurable, painful to experience, and therefore of direct and immediate concern to participants in all markets. It is hardly surprising that the Phillips curve which relates these two variables has attracted more attention than any other macroeconomic hypothesis. Economists had started to investigate the relationship between the two variables before Phillips and his remarkable paper in 1958. Fischer (1926) had identified "a statistical relation between unemployment and price changes", though he viewed causation as running from high inflation to low unemployment, rather than in the opposite direction. Tinbergen (1933) was apparently the first to estimate a Phillips curve of a conventional form for the Netherlands data. Later he contemplated applying the same relationship in his study of the British trade cycle in the nineteenth century (1951), though he eventually settled on the rate of change of coal prices as the determinant of wage inflation. Klein and Goldberger (1955) included a Phillips curve in their econometric model of US data. Brown (1955) illustrated the relation between wage change and unemployment graphically. Indeed, the dependence of wage inflation on unemployment had been rejected by Dunlop (1938) long before Phillips' article had been written. However, none of those studies explicitly revealed the trade-off relationship between unemployment and inflation, as Phillips did in 1958.

The theoretical foundation of the Phillips curve is simply the hypothesis that the price of a commodity changes at a rate determined by excess demand for it. The labour market was selected for analysis because the unemployment rate is a readily observable proxy for excess demand. Lipsey (1960) set this relationship into a standard version, as we can see in most literatures today:

$$w = f(U); \qquad f' < 0 \tag{2-2}$$

where $w$ is the wage inflation, and $U$ is the unemployment rate. Phillips estimated the relationship between unemployment and the rate of change of wages. The data were used for fitting the curve related to the period 1861-1913. When that curve was superimposed on a scatter diagram showing the post-Second World War observations for 1948-1957, they were found to lie very close to the curve. This is a remarkable result and it exhibits unchanged parameters over a period of almost a century. Since then, many empirical studies have been conducted to verify the trade-off relationship between the two variables.

The most well-known reports include Samuelson and Solow (1960), Lipsey (1960), Griffin (1962), Wallis (1971), Rowley and Wilton (1973), and Gilbert (1976).

### 2.2.2 The Expectations-Augmented Phillips Curve

Based upon Phillips' work, Friedman (1966, 1968) and Phelps (1967, 1968) modified the Phillips curve allowing for the orientation of wage setting towards the future. Equation 2-5 became:

$$w = f(U) + P^{e} \qquad (2\text{-}3)$$

where $P^{e}$ denotes the expected rate of price change. The unit coefficient on this variable is the crucial feature of the equation.

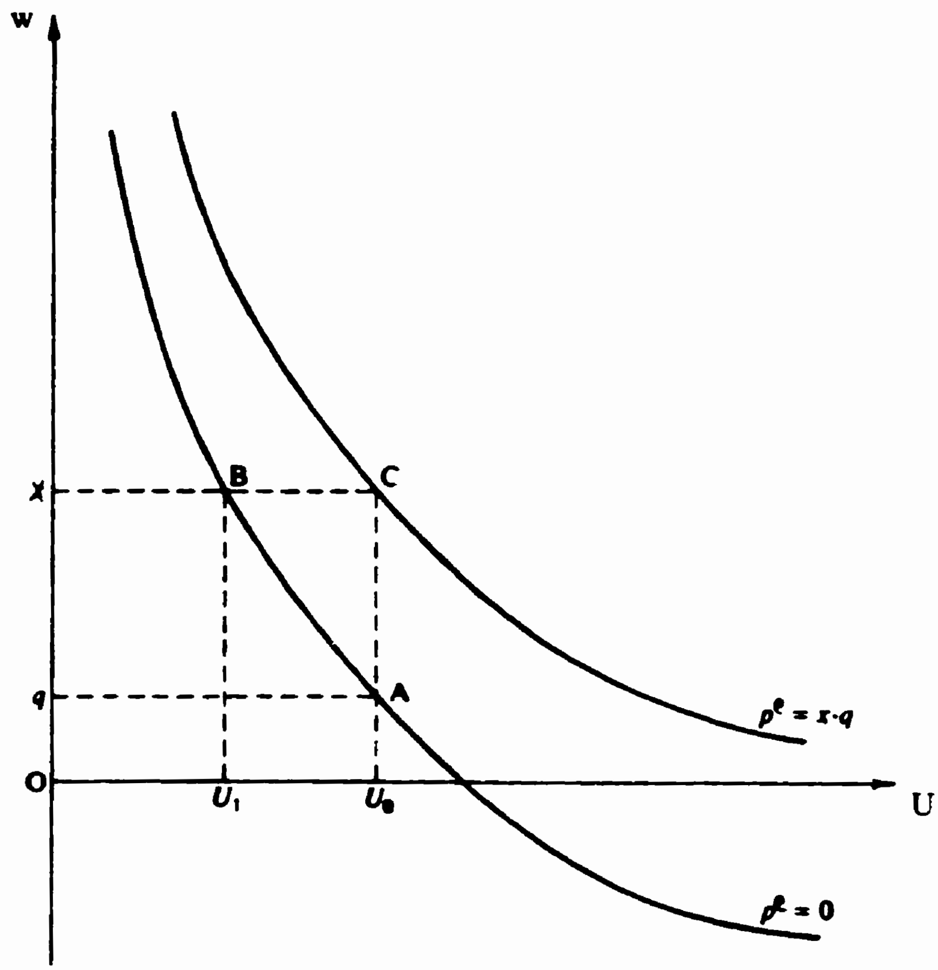


Figure 2-1 Expectation-Augmented Phillips Curves

Different Phillips curves for each value of the expected rate of price change are shown in Figure 2-1. Assume for simplicity that firms set their prices as a mark-up on unit labour cost, and suppose there exists an initial equilibrium at point *A*: the unemployment rate is $U_0$, the actual and expected rates of price change are zero, unit labour costs are constant, and nominal and real wages are increasing at the rate of productivity growth $q$. There is then a demand for labour expansion which reduces unemployment and increases the rate of wage inflation, so that the economy moves from point *A* to point *B* along the curve labelled $P^e = 0$. Wages are now rising at $x$ percent per period, unit labour costs are no longer constant, and so prices will start to rise at a rate of $x - q$ per period. With prices rising, the expectation of price stability embodied in the short-run Phillips curve must be revised. When expectations have adjusted fully to this experience of inflation, the relevant Phillips curve will be that labelled $P^e = x - q$, which is derived by displacing the original curve vertically upwards by the change in the expected inflation rate. At any unemployment rate level below $U_0$, however, wages will rise at a rate in excess of $x$ percent, and the process of adjustment to the experience of change will be repeated. The Phillips curve will continue to shift vertically upwards as long as unemployment remains below $U_0$, and the actual inflation rate will continue to increase, dragging the anticipated rate upwards with it. The process will be terminated only when unemployment has returned to $U_0$, at which point the acceleration of inflation ceases because the actual and anticipated rates of price change are again equal, e.g. at point *C*. Therefore $U_0$ is the equilibrium or "**natural**" rate of unemployment, because only at that rate are expectations consistent with experience. Once reattained it will be maintained, in the absence of further disturbances, with inflation continuing at whatever level was reached while unemployment was below the natural rate. To bring the inflation rate down, unemployment must be held above $U_0$, so that the above process operates in the reverse direction. Friedman and Phelps' modification suggests there is a whole family of Phillips curves, each associated with a particular anticipated inflation rate and vertically displaced from any other by the difference between those anticipated inflation rates.

### 2.2.3 The Natural Rate of Unemployment and its Interpretations

The status of the natural rate of unemployment is closely related to the alternative interpretations of the expectation-augmented Phillips curve. The curve could also be interpreted as the inverted supply curve interpretation. Then the natural rate of unemployment represents the outcome of voluntary choices of aggregate supply (along the curve). The magnitude of the natural rate can represent a cause for concern only if those choices are conditioned by inefficient institutions. Attention is then directed towards reform of those institutions rather than the natural rate itself. Under the interpretation which treats the Phillips curve as the (inverted) supply curve, the natural rate "seems to be synonymous with the Keynesian concept of the minimum feasible unemployment rate" (Laidler 1981). There is nothing intrinsically "natural" about the concept when it is denied the legitimacy conferred by voluntary choice, hence the alternative label is adopted by some economists, the "Non-Accelerating Inflation Rate of Unemployment", NAIRU. The semantic difference reflects their conviction that the unemployment associated with stable equilibrium inflation is largely involuntary. The NAIRU may be affected by social policy expressed in the replacement ratio, which relates unemployment compensation to potential earnings; but this voluntary component is regarded as quantitatively unimportant. How to interpret the Phillips curve distinguishes the Neo-Classical and Keynesian understandings of the long-run relationship between wage inflation and the unemployment level. In the short run, both schools believe the inverse relationship suggested by the curve.

### 2.2.4 Empirical Studies and the Canadian Case

During the last three and half decades, economists have made many attempts to estimate the original Phillips curve relationship. When people tried to use the original Phillips curve to predict economic performances for the period of 1960s to 1970s, they found that forecasting errors were bigger and bigger as time went on, as Marin (1972) reported. The data fitting problems encouraged studies to modify the original Phillips curve and resulted in the development of the expectation-augmented variation of the curve. Then testing the expectation-augmented Phillips curve rapidly became a very active field of research. In order to model the expectation, many studies used adaptive methods as an econometric expression of the curve. A typical econometric form of the price expectation can be modeled as:

$$p^{*} = \lambda p - (1-\lambda)p^{*}_{-1} \qquad (2\text{-}4)$$

where the coefficient λ is greater than 0 and less than 1.

Combining Equations 2-3 and 2-4, the expectation-augmented Phillips curve can be expressed as:

$$w = f(U) - (1-\lambda)\ f(U_{-1}) + \alpha p + (1-\lambda)w_{-1} \qquad (2\text{-}5)$$

This expression is known as the Koyck transformation[1] model. The coefficient $\alpha$ in Equation 2-5 measures the weight of expected price level in the wage settlement. The natural rate hypothesis requires $\alpha = 1$ (i.e., the unit coefficient in Equation 2-3).

Earlier studies, including Lipsey (1960), Solow (1969), and Sumner (1972), all reported that the curve is consistent with the empirical evidence. These studies support the concept of the natural rate of unemployment because the empirical results were not able to reject the hypothesis of $\alpha = 1$. However, many studies such as Gordon (1971) and Parkin (1970) showed that empirical results were inconsistent with the US and the UK data because their estimated $\alpha$ is significantly below unity. Gordon (1976) suggested the inconsistent result was an empirical disturbance rather than a theoretical inconsistency.

[1] The Koyck transformation enables us to eliminate the unobservable expectation variable.

He states "... the gradual acceleration of inflation during 1966-70 caused the computer to yield ever higher value of $\alpha$ as the passage of time provided additional observations until finally ... tests with a sample period including early 1971 were unable to reject statistically the hypothesis that $\alpha = 1$". Therefore an existence of the natural rate was a common concept shared by many economists at that time.

Turnovsky (1970, 1972) studied the US data and the Canadian data separately, and found mixed results. His reports showed that the expectation-augmented Phillips curve seems fit the Canadian data better than those of the US. To explain the difference between the two economies, he conjectured "the major difference between them, of course, is that unlike the United States, Canada is heavily dependent on foreign trade. This tends to make the economy more competitive and hence to make it conform more closely to the Neo-Classical assumptions".

Strong policy implications of the Phillips curve, especially those disinflation related policies in the Canadian economy, encouraged more detailed empirical analyses to discover the nature of the inflation-unemployment relationship. Studies in the 1980's show that a great deal of uncertainty is involved in the Phillips curve relationship.

A Phillips curve can be fully described in the inflation-output space, or alternatively in the wage growth rate-unemployment rate space, by two factors: (i) its shape (slope); and (ii) its position (shift). The shape of the Phillips curve is largely dependent on the data set, such as what variables are used to represent inflation and unemployment (or output), what time period is under consideration, and the frequencies of the data. However, as long as the curve is downward sloping in the inflation-unemployment space or upward sloping in the inflation-output space, one should believe that the relationship suggested by the curve is correct. The shape and the position of the curve are of limited interest from a theoretical perspective.

A policy maker needs not only to recognize the trade-off relationship suggested by the Phillips curve, but also to determine the specific curve of interest from the entire Phillips curve family. Therefore to determine the position of the curve is important. This problem involves the NAIRU determination and many studies on this have were conducted in the 1980s. Theoretically, the Non-Accelerating Inflation Rate of Unemployment (NAIRU) is determined by the labour market equilibrium, but it is practically unobservable. In order to estimate the NAIRU, some presumed relationships, namely, the Phillips curve and Okun's law, have to be used. Their dependencies cause a logical deadlock (or, a vicious circle): An NAIRU is needed to describe a Phillips curve and a Phillips curve relationship is necessary to estimate the NAIRU. The following form of the expectations-augmented Phillips curve is prevalent in the 1980's empirical studies:

$$w = p^e + g - \delta(u - u^*) - \chi\beta + \varepsilon \qquad (2\text{-}6)$$

where $w$ is the wage growth rate, $p^e$ is expected inflation, $g$ is expected productivity, $u$

is the actual unemployment rate, $u^*$ is the NAIRU, $\chi$ is a set of other influences on the wage growth, $\varepsilon$ is a disturbance, and $\delta$ and $\beta$ are coefficients. Obviously different specification of the right-hand-side variables in Equation 2-4 could result in different values of the NAIRU and the coefficients. Fortin and Prud'homme (1992) reported that the Canadian NAIRU in the 1980's should be in the range of 6.2% - 7%. The estimation by the Bank of Canada (Rose 1990) shows the NAIRU could be as high as 10.4% in Canada. Rose (1990) suggested some theoretical reasons for the uncertainty of the estimation, such as how to specify the fractional unemployment, demographic imbalance in the Canadian labour market, and the effects of labour unionization. Studies on the nature of the Phillips curve and its related concepts (i.e., the NAIRU) are far from completion. Further investigation in this area includes studies of hysteresis.

# CHAPTER THREE

# LITERATURE SURVEY ON HYSTERESIS

This chapter surveys developments within hysteresis studies. It includes three parts: trade hysteresis, labour market hysteresis, and hysteresis in Canada.

## 3.1 Trade Hysteresis

It seems that the earliest appearance of hysteresis in relation to international trade was in the study of Kemp and Wan (1974), even though the study itself did not discuss trade hysteresis. The study analyzed the relationship between firm cost and labour force adjustment within a closed economy model, but the authors conjectured that their model could be modified to account for hysteresis in trade patterns due to international labour migration.

Studies on international trade hysteresis did not really start until the late 1980s. The motivation of these studies was based on the trade practice between the US and Japan. In the early 1980s, the US dollar appreciated against the Japanese yen and its trade deficits increased significantly during this period. Some American economists, including Richard Baldwin of Columbia, Avinash Dixit of Princeton, and Paul Krugman of MIT, were concerned that due to hysteresis, the terms of trade might not improve after the US dollar depreciated to its initial levels. In these studies, trade hysteresis has been analyzed from both the supply and the demand sides.

### 3.1.1 The Supply Side Hysteresis

Krugman (1986) considered the implication of hysteresis in the trade balance for the Purchasing Power Parity level of the dollar. In his paper, he did not model hysteresis explicitly, but offered dynamic economies of scale as a possible explanation for the existence of hysteresis in international trade. In the meantime, Baldwin (1986) discovered that foreign firms can enter a domestic market only by incurring once-and-for-all sunk costs. A temporary and sufficiently large rise in the exchange rate would induce permanent entries by foreign firms. Due to these sunk costs, firms will find it profitable to stay in the domestic market even when the exchange rate returns to former levels, which is known as "the beachhead effect". Thus, the economy faces quite a different trade pattern even after the exchange rate has fallen to its previous value. In this case, trade hysteresis is identified with the notion that the exchange rate at which entry (of foreign firms) occurs is not the same exchange rate at which exit occurs. Later, Baldwin and Krugman (1989) extended these considerations in several ways. Among other aspects, the behaviour of aggregated imports is examined when there are many industries subject to potential foreign entry. This aspect is important in order to ensure that the results of the single-industry case do not get smoothed away in the aggregate. Moreover, they explicitly dealt with the feedbacks from entry and exit decisions to the exchange rate itself.

Franz (1990) edited a special issue on hysteresis in *Empirical Economics* (15[2] 1990) to publish the latest developments in this area. In this journal, Baldwin (1990) summarized all trade hysteresis analyses in the supply side as following two models. The two are partial equilibrium models in nature and share a common theoretical framework based on the Cournot-Nash quantity-taking game between domestic producers and foreign exporters, all of whom are endowed with perfect foresight. The domestic firms are assumed to be the incumbents at the beginning or initial stage of the game, whereas the foreign firms are the potential entrants.

In Baldwin's first model, foreign firms must undertake a fixed-cost investment in order to enter the domestic market. This investment is both sunk and durable (i.e., it lasts longer than a single period). It is meant to reflect firm-specific and market-specific costs such as those incurred to establish sales, distribution and service networks, to create brand recognition through advertising, and to redesign the product to meet local regulations. In the benchmark case, it is assumed that if the exchange rate were to remain at its initial level, then foreign firms would not enter the domestic market because the initial fixed cost exceeds the present discounted value of profits from expected domestic sales. However, if the domestic exchange rate were to appreciate temporarily by a sufficient amount at the beginning of the second stage of the game, then foreign firms would enter the domestic market because an appreciation of the exchange rate reduces their constant average (and marginal) production costs, measured in domestic currency. The key result is that once these foreign firms are in the domestic market, their decision to exit depends only on whether they can cover the variable selling costs, and the sunk cost for entry is no longer relevant. Hence, it is likely that they would remain in the market even if the exchange rate were to return to its initial level. In other words, the foreign firms' entry and exit decisions are asymmetric with respect to the level of the exchange rate because of the existence of the sunk cost for entry. Therefore, a temporary appreciation of the exchange rate causes trade hysteresis by permanently changing the structure of the domestic market (i.e., foreign firms are now present) and increasing the level of imports. Thus, the existence of a sunk cost for entry produces a non-linear relationship between the level of imports and the exchange rate.

In his second model, Baldwin assumed that instead of a one-time fixed cost to enter the domestic market, a fixed per-period cost must be paid by all firms, both domestic and foreign, incumbents and potential entrants, operating in the domestic market. In other words, the required investment is no longer durable; it lasts but a single period. In the benchmark case, it is assumed once again that the domestic firms are the incumbents. However, at the beginning of the second stage, the domestic exchange rate appreciates and, as a result, foreign firms enter because their unit production costs are now lower. This entry could potentially force all of the domestic producers out of the market. The likelihood of this outcome depends on the cost structures of the domestic firms and the elasticity of the demand curve. Therefore, in the third stage, when the exchange rate returns to its initial level, the foreign firms would be incumbents. The basic intuition behind this model is that there are two equilibria -- one in which only domestic firms are in the market and in the other, only foreign firms. A temporary and sufficiently large exchange rate movement shifts the market from one equilibria to the other. Essentially, this model can only determine the number of firms in the market, not their countries of origin; consequently, there are multiple equilibria -- a result typical of trade models that incorporate increasing return to scale. In this case, the non-linear relationship between the level of imports and the exchange rate is caused by the presence of increasing return to scale that gives incumbents a cost advantage.

The models of Baldwin and Krugman form the basis for trade hysteresis literature and were extended significantly by Dixit (1989a, b). Dixit assumed that the exchange rate follows a Brownian motion, price is competitively determined but foreign firms' revenues in their currency (yen) are uncertain, since revenues are in domestic currency (US dollar) and the exchange rate is random. In the presence of sunk costs to entry and exit, foreign firms facing a random revenue stream will choose to enter or exit at different levels of the exchange rate because of the fixed sunk cost to getting in or out of a market. With this consideration, price must get well above average variable cost for entry, and fall below average variable cost to exit. The width of this entry/exit band is highly sensitive to the underlying variance of the price responsible for the randomness in revenues or costs, the degree to which any exchange rate shock is expected to be permanent, and the ratio of operating costs to sunk costs. In Dixit's models, this entry/exit band is described as a "trigger area". Within the trigger area foreign firms do not withdraw from domestic market regardless of changes in the exchange rate. These analyses are applied to foreign (Japanese) firms producing in their home country (Japan) but selling in the domestic (US) market. The choice facing foreign firms is whether or not to enter the domestic market.

In addition to analysing foreign firms' behaviour, Baldwin (1988) and Dixit (1989) drew special attention to hysteretic effects on import price. They argued that pricing behaviour was affected by the presence of additional foreign firms.

Besides the sunk cost models, Krugman and Richard (1987) presented another supply side theory of trade hysteresis which is known as the learning curve model of industrial organization and comparative advantage. The basic idea of the learning curve model is that firm-specific unit costs of production are a decreasing function of cumulative output within the plant or firm, reflecting acquired skills and knowledge of the workforce involved. The theory is particularly relevant to advanced technological products such as aircraft and electronics with a fairly short product cycle. At the level of the individual firm, the presence of a learning curve effect implies that there is a strong advantage to being first in the market with a product in order to raise sales and thus to gain permanent cost advantages. As applied to exchange rates, the learning curve gives rise to hysteresis in a fairly straightforward way. The basic scenario goes like this. An appreciating domestic currency allowed foreign firms to keep prices low and to sell volume at the expense of domestic firms at the same point in the product-development cycle. Increased sales by foreign firms relative to domestic firms allowed the foreign firms to get a permanent cost-productivity advantage relative to the competing domestic firms. When domestic currency returned to its previous level, the foreign firms had secured a permanent comparative advantage in these higher-technology products.

### 3.1.2 The Demand Side Hysteresis

The causes of trade hysteresis could come from the demand side if a temporary exchange rate appreciation leads to a permanent shift in the demand curve for foreign imports. The demand side hysteresis is based on imperfect competition theory and the notion of product differentiation. Schmalensee (1982) explained the structural shift in demand. The idea is that incumbents fill up niches in product space to prevent entry, and advertisement-created product loyalty can reduce flexibility in customers' buying behaviour when there are switching costs to consumers. Uncertainty about product quality in consumers' minds can also lead them to stick with what they know. Therefore in a product differentiated world with sunk costs to entry, an increase in the share of imports will not be relinquished easily by foreign competitors who use foresight and strategies. Strong international linkages in demand can be exploited by firms maximizing the present value of profits, and such behaviour can lead to what appears to be market-share competition. The transmission mechanism in this theory runs from exchange rates to prices to increased market share that tends to become permanent; that is, a permanent shift in the demand curve for imports occurs that does not subsequently reverse in response to an exchange rate depreciation.

From a welfare point of view, demand hysteresis is a potentially serious matter. It implies that the terms of trade of the country experiencing a temporary exchange rate overvaluation could permanently deteriorate. At least with supply hysteresis, consumers get lower prices of imports. Supply side hysteresis has the positive prediction that an exchange rate appreciation today implies, at a normal exchange rate, a higher level of imports and lower prices in the future. Demand side hysteresis implies a combination of higher prices[1] and possibly a higher level of imports.

### 3.2. Labour Market Hysteresis

Research on labour market hysteresis has been drawing a lot of attention since the late 1980s. These studies were focused on the persistence of high unemployment in Europe during the 1980s which posed some puzzles for theoretical and empirical macroeconomics. The analytical problems are evidenced by estimates of the Natural Rate

[1] As the result of hysteresis, foreign firms occupy domestic market shares permanently and even imported goods are relatively expensive compared to those domestically produced. For example, the relatively high prices of Toyota pushed up general prices of automobiles.

of Unemployment, or in terms of dynamics, the Non Accelerating Inflation Rate of Unemployment (NAIRU), which follows the actual path of unemployment rather closely.

Friedman proposed his hypothesis of the Natural Rate of Unemployment in 1968, and this theory plays a key role in today's macroeconomic theories. According to this theory, after a high unemployment recession, an economy should tend towards its natural rate as the inflation rate rises. Tobin (1972) summarized the dynamics of aggregate supply by using two equations: the price markup equation which describes the wage-price mechanism, and the Phillips curve equation which describes the wage-unemployment relationship. The dynamic solution of the two equations yields a long-run equilibrium value which is known as the NAIRU. In Friedman's words (1968), the NAIRU is a *"level that would be ground out by the Walrasian system of general equilibrium equation"*. The New Classical school believes that there is a NAIRU for an economy and it is determined by the structure of the economy. Barro (1988) showed that NAIRU is governed by the ratio of the "job separation rate" and the sum of "job separation rate" and "job finding rate". The NAIRU hypothesis allows macroeconomists to study separately short-run and long-run development in the economy, and it can be summarized as follows: *"fluctuations in aggregate demand affect output and employment only in the short run. In the long run, the economy returns to the level of output, employment, and unemployment described by the classical model"* (Mankiw 1992).

However, this theory could not explain the experience in the European labour market, especially in the United Kingdom. In the 1970s, UK unemployment averaged 3.4 percent, whereas in the 1980s it averaged 9.4 percent. There was no trade-off relationship between the inflation level and the unemployment level; the unemployment rates had been persistently high during the 1980s regardless of changes in inflation rates.

By analysing this hysteretic phenomenon, New Keynesians began to question the existence of NAIRU and argue that the aggregate demand side may affect output and employment even in the long run. As Solow (1986) pointed out, a natural rate that hops around from one triennium to another under the influence of unspecified forces, including past unemployment rates, is not "natural" at all. Therefore, recessions in the short run might leave permanent scars on the economy by altering the NAIRU. In other words, does the trade-off relationship suggested by the Phillips curve exist in today's industrialized economies? Or is the relationship true in only one direction (disinflation is always associated with high unemployment), but not vice versa? For example, when the inflation rate rises (due to falling interest rate, generating rising demand and therefore rising inflation), we may not see a significant drop in the unemployment rate. This is the centre of the debate on hysteresis.

Blanchard and Summers (1986, 1987, 1988), and Summers (1990) discovered that the relation between the unemployment and inflation level which is described by the Phillips curve does not hold in reverse; i. e., when the inflation rate increases (and the interest rate drops), the unemployment level does not respond to these changes and return to its original trend (NAIRU), but stays at its new level permanently. They believe that unions play an important role in Europe which causes a persistent by high unemployment level via price (wage) stickiness. The rationale of labour market hysteresis can be explained by three different theories.

The most dominant explanation of labour market hysteresis is the insider-outsider theory developed by Lindbeck and Snower (1987). This model hypothesizes that employed union members (insiders) always set wages so as to maintain just their own employment rather than so as to care for the unemployed (outsiders), because of the monopoly market power of the insiders to hold up wages. Why don't firms fire insiders? There are two reasons: the first is the cost of hiring and training outsiders, and the second is the threat of strike action by insiders. Adverse shocks which raise unemployment reduce the number of insiders. The new, smaller group of insiders then forms the basis of the next wage negotiations. The new, larger group of outsiders has no influence on the bargaining process. Rather, wages are set so as to maintain the new, lower level of employment. The shocks may be temporary but the new, higher level of unemployment is permanent with no tendency to return to its previous, lower level; i.e., unemployment exhibits hysteresis.

The final explanation of hysteresis is that the economy's capacity falls during a period of high unemployment, reducing the level of capacity to the level of actual output. By comparing the cases of Europe and the US, Europe and Japan, and Germany and the US, the empirical studies of Graafland (1989), Brunello (1990), and Jaeger and Parkinson (1990), respectively, support the hysteresis hypothesis for the European labour market. Graafland (1989) used a wage-employment equation (an empirical version of the Phillips curve) to examine labour markets in European economies, including Belgium, France, Germany, Italy, the Netherlands, the UK, and the US for the period of 1970-1985. His results showed that the hysteresis phenomenon is more relevant in Europe than in the US. Brunello (1990) used time series techniques (the Dickey-Fuller unit root test) to test European and Japanese data for the period of 1955-1987 and reported that labour market persistency (another term for hysteresis) is significant in Europe but not in Japan. In addition, Jaeger and Parkinson (1990) developed a modified version of the Phillips curve (which decomposes the unemployment rate into two components) to test the USA data for the period of 1954-1989 and German data for 1962-1989, and their results confirmed the suggestion of significant hysteresis in Europe but not in the US.

According to Franz (1990), another mechanism besides wage bargaining which can possibly generate labour market hysteresis stems from the search process seen both from the employer's and the job applicant's viewpoints. In a screening process the firm has to identify the unknown productivity of the applicant for the job in question. If firms use unemployment experience itself as a screening device, the unemployed persons with a long duration of unemployment are viewed as the less promising candidates due to their potential depreciation of human capital during the long unemployment spell. In an economic study about the recruitment behaviour of firms, Ebmer (1989) found evidence that hiring chances are largely reduced by long-term unemployment as well as by "unfavourable" characteristics such as age, physical disabilities, and the like. Some of the long-term unemployed with unfavourable characteristics may have had these attributes already when being unemployed. However, firms may have been reluctant to fire them bowing to social norms and because their fellow workers did the work of these persons in order to help them. In the case of bankruptcy, or large dismissals, these persons find themselves in the unemployment pool with virtually no chance to escape from unemployment. On the other side of the search process, the long-term unemployed people may reduce their searching intensity due to their discouragement as a consequence of being so often rejected by employers. Moreover, if skills are acquired not only through on-the-job-training but also through changing jobs, then high unemployment supports a deterioration in skills because it reduces job mobility.

The third major channel through which hysteresis may affect the economy stresses the role of the capital stock. Burda (1988) pointed out that reductions in the capital stock affect labour demand in the same way as adverse supply shocks do. In those neoclassical models demand shocks have no impact on employment unless they influence the real exchange rate. But in a world characterized by price rigidities, demand shocks may have a more direct effect on the supply-side capacity. Klundert and Van Schaik (1989) have shown that an adverse demand shock leads to a reduction in the capital stock if large firms close plants and/or scrap capital. This decrease of the capital stock gives rise to unemployment which may turn out to be persistent because firms cannot suddenly be reopened and begin production even if product demand increases; i.e., the model exhibits hysteresis. This argument provides an obvious channel through which hysteresis may affect the NAIRU. The basic idea is that the NAIRU depends on the capital stock. The evolution of the capital stock depends not only on factor prices but also on aggregate demand in the market. Running the economy, however, at an unemployment rate higher than the NAIRU implies a reduction of investment. This will, in turn, increase the NAIRU[2].

From a macroeconomic viewpoint, the hysteresis phenomenon reflects a property of multi-equilibria theory: if there are many possible NAIRU points, then an economy has no tendency to stay at or approach any particular (desirable) point (NAIRU = 7%, for example). From a policy application point of view, this theory provides a rationale for the government to play an active role to intervene in the economy by implementing supply-side policies, because those policies would change or interfere with the normal mechanisms behind the Phillips curve. On the other hand, some of those economists who fail to recognize this phenomenon believe that traditional demand-side policies are sufficient to manage an economy and there is no particular reason to emphasize supply-side policies. Because the trade-off relationship of the Phillips curve is "normal", there is no reason to worry about the permanent harm caused by a conventional policy, for example, a disinflationary monetary policy.

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[2] This argument is probably true in micro-analysis; however, it seems less convincing at a macro-analysis level if the assumptions of price flexibility and homogeneity of all agents are not applied in aggregation.

### 3.3. Hysteresis in Canada

The first study of Canadian hysteresis was conducted by Fortin (1991, 1993). His studies focused on empirical analysis and reported the existence of labour market hysteresis in the Canadian economy.

The theoretical basis of Fortin's studies is the original Phillips curve equation (Equation 2-2), and the equation was modified into an econometric version as the following:

$$\begin{aligned} \pi &= \alpha\pi_{-1} - \beta[u - hu_{-1}] \\ &= \alpha\pi_{-1} - \beta[(1 - h)u + h\Delta u] \end{aligned} \qquad (3\text{-}1)$$

where $\Delta u$ stands for the change of unemployment (first order difference). This equation says that the current inflation level $\pi$ is jointly determined by the last period's inflation level $\pi_{-1}$ and the market pressure which is a function of the unemployment rate. The weights of the two parts are measured by the coefficients $\alpha$ and $\beta$. If the value of the coefficient $h$ is close to zero (insignificant), this implies that the market pressure is simply captured by the (current) level of unemployment $u$; therefore, the equation is the conventional Phillips curve. If the value of $h$ is close to unity (significant), it means that the level of inflation is not determined by the current level of unemployment but by the

**change** in unemployment $\Delta u$ which describes the history of unemployment. Therefore, the labour market hysteresis implies that a change in the inflation rate has no effect on the level of unemployment. The degree of hysteresis therefore is measured by the value of the coefficient $h$. Thus, to test hysteresis is to test the null hypothesis of $h = 1$. In his empirical analysis, Fortin used a log change of the CPI to represent inflation. The right hand side of the regression equation included unemployment rate for males, the first difference of the unemployment rate and its lagged value, the lagged value of the log change CPI, and other price indices. By estimating the annual data for the period of 1957 - 1990, Fortin reported that the degree of unemployment hysteresis in the Canadian economy is significantly high for the period of 1973 - 1990 ($h$ = 0.865). The direct implication of this study is that the Bank of Canada's disinflation policy during 1980s is the main cause of the seriousness of the 1990 recession (which resulted in a high unemployment rate), and it is also the key factor in the slow recovery (of the unemployment rate, especially) from the recession. With strong labour market hysteresis, Fortin argued, "(Canadian) unemployment would essentially follow a random walk driven by the history of supply-side influences". In other words, the current high unemployment rate may last for a long period regardless of changes in inflation.

In contrast, the studies conducted by the Bank of Canada deny the existence of Canadian hysteresis. Cozier and Wilkinson (1991) reported that disinflation caused only temporary output loss, at an one-to-two percentage ratio. Therefore, there is no evidence of hysteresis in Canada. Later, by comparing the differences in how to measure inflation and how to treat the unemployment rate and potential output data between the estimations of Fortin (1991) and Cozier and Wilkinson (1991), Poloz and Wilkinson (1992) argued that evidence against Canadian hysteresis is more compelling than evidence in its favour. In response to this argument, Fortin (1993) re-estimated the Canadian data for the period of 1973 - 1990, and concluded that there is a strong degree of hysteresis in the Canadian economy.

Investigations into Canadian labour market hysteresis leave many issues unresolved. The study of Canadian trade hysteresis is even in its early infancy. To date, there have been no theoretical analyses on this topic reported and only one empirical study has been conducted by Amano, Beaulieu, and Schembri (1993).

By examining the share of export-oriented manufacturing industries relative to other manufacturing industries over the period of the Canadian dollar appreciation since 1986, Amano, et al (1993) show that the performance of exported-oriented industries has been relatively strong throughout the post-1986 period. This result may be interpreted as suggesting that "the functional relation between exports and the exchange rate does not hold".

To test trade hysteresis, their study used the methods of time series analysis. First, they conducted unit root tests, cointegration tests, and error-correction tests[3] to test the relationship among the export volumes, export commodity prices, and the exchange rate for the period of 1973 to 1991. Then, they analyzed the structural stability in the Canadian export sector by sequential Chow tests and examining the cumulative sum of squares of the regression residuals. According to their conclusions, there is an existence of structural instability in the Canadian export sector and some evidence of trade hysteresis in the export volumes, even though the evidence was relatively weak.

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[3]Generally speaking, a hysteretic variable exhibits random-walk if it is a time series. The unit-root method is a statistical test developed by Dickey and Fuller (1981). The cointegration and the error-correction methods are used to test the long-run relationship between two time series and structural change of a system. More details will be discussed in Chapter 5.

## CHAPTER FOUR

# TWO THEORETICAL MODELS OF HYSTERESIS FOR A SMALL OPEN ECONOMY

This chapter is the theoretical part of the dissertation, and it develops two models of hysteresis for a small open economy: one for the aggregate demand side and one for the aggregate supply side. Section one presents a hysteretic IS-LM-BP model. The model shows that trade hysteresis could result in a vertical IS curve and bend the aggregate demand curve up to vertical. A vertical aggregate demand curve explains hysteresis in the domestic economy. Section two develops an open economy version of the Phillips curve by allowing the exchange rate to enter the right-hand-side of the equation, and provides a theoretical base for empirical testing.

Macroeconomics analyzes the two major forces which determine macroeconomic performance: aggregate demand and aggregate supply. Among alternative models of different schools, the IS-LM model (the IS-LM model for a closed economy and the IS-LM-BP model for an open economy) of the Keynesian doctrine is a theoretically mature and empirically reliable model to deal with the aggregate demand side relationships. The aggregate supply side relationships are summarized by the Phillips curve. In order to analyze the inherent relationship between trade hysteresis and the domestic labour market hysteresis, this chapter tries to incorporate trade hysteresis with conventional macroeconomic analysis from both the aggregate demand and the aggregate supply sides. In the demand side analyses, it starts from aggregating the hysteretic trade volume into net export behaviour (a component of the aggregate demand). Then it constructs a hysteretic IS-LM-BP model by allowing net exports to exhibit hysteresis. This IS-LM-BP model allows us to examine how trade hysteresis affects the domestic economy. To model the aggregate supply side hysteresis, i.e., labour market hysteresis, the exchange rate is used to capture the external shocks (international market pressure) to the domestic economy in the Phillips curve. The open economy version of the Phillips curve provides a theoretical base for empirical tests.

## 4.1 An Hysteretic IS-LM-BP Model

### 4.1.1 The Trigger Model

After the US dollar had fallen from its peak level in 1985, the US trade balance had been slow to improve and foreign firms had been reluctant to raise their prices in the US market. In order to explain this hysteretic trade phenomenon, Baldwin, Dixit, and Krugman had developed a number of partial equilibrium models of trade hysteresis during the late 1980s. Among these analyses, the Trigger Model of Dixit (1989a, 1989b) provided a useful theoretical basis for a description of trade hysteresis.

Dixit's Trigger Model is based on the following two assumptions. First, exporting firms are assumed to maximize their expected present discounted value in infinite time horizon. This assumption means that in order to maximize their profits in the long-run, exporting firms may be willing to take current losses due to a change in exchange rate, and choose to stay in a foreign market they already occupy (the trade hysteresis therefore occurs). Second, the exchange rate between the currencies of domestic and exporting countries is assumed to follow a Brownian motion. This assumption implies that the exchange rate exhibits a random walk in continuous time[1], and it is consistent with the empirical evidence. By setting a corresponding objective function (the expected value of profits in infinite periods) and using dynamic programming methods (solving the Bellman equation), Dixit generated a hysteretic loop to describe the trade hysteresis; the loop can be interpreted as in Figure 4-1.

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[1] The random walk can be tested by the Dickey-Fuller test which is similar to the F test. More details will be discussed in the next chapter.

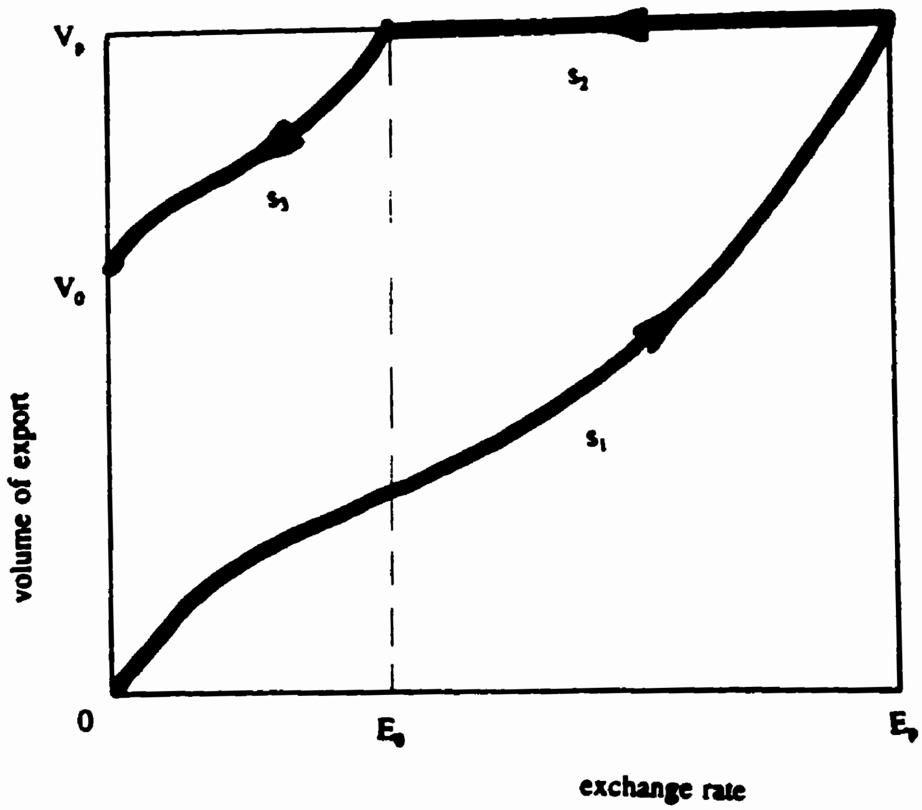


Figure 4-1 Hysteresis Loop

A general hysteresis loop is shown in Figure 4-1, where *E* stands for the nominal exchange rate (price of foreign currency in terms of domestic currency)[2], and *V* stands for the volume of export (real goods). If a temporary positive exchange rate shock occurs (domestic currency depreciation), the conventional theory suggested that the volume of exports should increase as the nominal exchange rate rises. This process is represented as the path $s_1$ in Figure 4-1. When *E* reaches peak value of the shock, $E_p$, it starts to change its direction. The volume of export, *V*, however, does not decrease as *E* drops, because firms have already invested "sunk costs" to exporting. For that reason, to stay in the foreign market makes them better off. Therefore trade hysteresis occurs ($V = V_p$ as $E$ drops) and this is the path $s_2$. Later, after *E* drops below a certain point $E_0$, firms start to withdraw from the foreign market because the exporting costs become higher and higher (due to domestic currency appreciation), and this withdrawing process is shown as the path $s_3$. Finally as *E* moves back to its original level 0[3], and *V* ends at $V_0$ which measures the accumulated effect of the volume of trade caused by an exchange rate shock (if a shock comes from the opposite direction, the analysis will be held by adding a negative sign). The paths $s_1$, $s_2$, and $s_3$ form a "hysteretic loop", and the degree of trade hysteresis is represented by the length of $s_2$. The hysteretic loop describes how the domestic firms

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[2] In the following analysis we will use the same notation for the real exchange rate (which is the nominal exchange rate times the domestic and the foreign price ratio), since the domestic price can be normalized as the unit and the foreign price level can be treated as an exogenous.

[3] We can set the original point ($E = 0$) at the exchange rate level before the shock occurs, so this point does not mean that the exchange rate is zero.

occupy the f[illegible] ncy (or foreign firm [illegible] es) and what the per[illegible]ent eff[illegible] n some realities in t[illegible] s eco[illegible] rica or American fir[illegible] stay in[illegible]

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occupy the foreign market due to a temporary depreciation of the domestic currency (or foreign firms invade the domestic market when the domestic currency appreciates) and what the permanent effect is after the exchange rate shock. This theory may explain some realities in today's economy, such as why those Japanese firms stay in North America or American firms stay in Canada regardless of changes in the exchange rates.

However, Dixit's elegant analysis is microeconomic in nature and there is no explicit form to describe hysteretic exports as a function of the exchange rate in the model. One is not able to aggregate this microeconomic model into macroeconomic analysis due to the lack of such a function[4]. In order to overcome this difficulty, we use the Trigger model as the microeconomic foundation and develop an explicit expression to characterize exports as a function of the level of exchange rate, the magnitude of the exchange rate shock, and the degree of hysteresis.

The derivation of this functional form has both theoretical and empirical implications. First, it allows one to develop a macroeconomic model which incorporates trade hysteresis. Second, it allows for improved empirical research on trade hysteresis. As Amano, et al (1993) concluded in their recent survey, "Although the theoretical concept of trade hysteresis is intuitively plausible, it has so far failed to stand up to empirical

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[4] Macroeconomic analysis needs microeconomic foundations. For example, the consumption function, a component of aggregate expenditure, requires the existence of a microeconomic model in which the consumption of a typical consumer can be expressed as an explicit function of his/her income.

testing". The results of this paper suggest a more general empirical specification than those of previous studies.

### 4.1.2 A Functional Expression of Trade Hysteresis

A hysteretic loop in *E-V* space can be denoted as a real set s:

$$\{(E,V) \mid E \in \mathbf{R},\ V \in \mathbf{R},\ (E,V) \in s = s_1 \cup s_2 \cup s_3\}$$

where $E$ is the exchange rate and $V$ is the (physical) volume of exports. The set $s$ describes a hysteretic relationship between $E$ and $V$. In general, $s$ is a *correspondence*[5], and it cannot be expressed as a *single-valued function*[6]. In other words, there is no *explicit function f*, such that, $f\colon E \rightarrow V$.

The export, $X$, in terms of domestic currency, is defined as: $X = V^{*}P_f$ E, where $P_f$ is

[5] A correspondence is a general mathematical relationship between ordered pairs (variables). If $x$ and $y$ have a correspondence relationship in a given set, then for each value of $x$, there are certain values of $y$ to correspond it. A correspondence may or may not be expressed as a functional form.

[6] For detailed discussion of correspondences and functions, see Klein and Thompson 1984.

the foreign price level[7]. If $V$ could be explicitly written as a function of $E$: $V = V(E)$, then $X$ could be calculated as[8]:

$$X = \int_{0}^{E} P_{f}\, V(E)\, dE \qquad (4\text{-}1)$$

However, this definite integral does not exist because $V$ cannot be explicitly written as a function of $E$[9]. In order to get $X$, we need to find a meaningful integral which can calculate $X$ on set $s$. We may apply the method of vector operation which is widely used by physicists to solve this problem.

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[7] Converting $V$ into $X$ is essential for constructing a macroeconomic model, because $X$ is a component of the goods market equilibrium (IS curve) and the balance of payments (BP curve).

[8] $X$ should really be $X_t$:

$$X_{t} = \int_{t_0}^{t} \int_{0}^{E} P_{f}\, V(E)\, dE dt$$

but for the static equilibrium analysis, we do not emphasize the time dimension.

[9] A similar example is that the points on the unit circle can be defined by a correspondence on x-y space:

$$\{(x,y): x \in \mathbf{R},\ y \in \mathbf{R},\ x^2 + y^2 = 1\}$$

but y cannot be expressed as an explicit function of x, because lack of one-to-one representation between y and x. Therefore, the (global) integral $A = \int_{-1}^{1} y\, dx$ does not exist. However, "A" does have meaning (area of the circle), we can get it by calculating a local integral (one quarter of the circle) then times 4, or by calculating a global integral in the polar coordinate space $\rho$-$\varphi$.

When a horse pulls a wagon to move along a path, the "result" of the process is measured by the *work*, the product of the magnitude of the horse's *force* times the *length* of path the wagon moved. Similarly, the result of trading goods and services is measured by the *export*, the product of the *volume* of exports (quantity) times its *dollar value* (price times exchange rate). In Newtonian mechanics, the work, $W$, is defined as the *inner-product* of two vectors, force $F$ and its path $L$ (that is, $W = F \bullet L$). Mathematically, this can be calculated as a *line-integral*: $W = \int_L F dL$. Similarly, we can consider that export $X$ (in terms of dollars) is the "work" -- the inner-product of "force" $V$ and "path" $E$, that is, $X = V \bullet E$. By its definition, $X$ should be the absolute value of the inner-product of $V$ and $E$, which is equivalent to Equation 4-1.

Since we have mathematical difficulty to directly calculate Equation 4-1, we may try to find an indirect way to do it. Let us start from defining another inner-product, $U = V \bullet s$, which is related to Equation 4-1 and can be calculated. Where $V$ is the volume of export, $s$ is the path of the hysteresis loop, and $U$ can be considered as an intermediate variable, or a "shadow"[10] of $X$. Comparing the two inner-products, $X$ and $U$, we can see that both of them represent the cumulative effects of $V$, but measured by different "scales": $X$ is measured by the axis $E$, and $U$ is measured by the axis $s$[11]. Therefore we

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[10] In terms of topology, $U$ is a projection of $X$ which transforms the vector from $V$-$E$ space to $V$-$s$ space.

[11] If we continue to borrow physicists' terminology, we may say that work $X$ represents the result of force $V$ moved along path $E$, and work $U$ represents the result of the same force but along another path $s$.

may first calculate $U$, then convert $U$ into $X$. We know that $U$ is:

$$U = \left| \int_s P_f \, V \, ds \right| \tag{4-2}$$

Now we need to explain the meaning of line-integral $U$, and to work out the relationship between $U$ and $X$.

In the absence of hysteresis (in which case an explicit function $V = V(E)$ exists), $X$ can simply be calculated as the area under the curve $V$. In a linearized case (which is described by $s_1$ in Figure 4-2), $V = aE$. Export $X$ can be geometrically measured by the triangle area under $s_1$ times the price: $X = (aP_fE^2)/2$. The geometric meaning of $U$ is a similar measurement along $s$, instead of along the horizontal axis $E$. So $U$ can also be considered as an "absolute value of work" which is done by a "force", $V$, along the loop path $s$. Because $U$ and $X$ have a similar interpretation (they are both inner-products of $V$), the *projection* of $U$ on axis $E$ is just $X$.

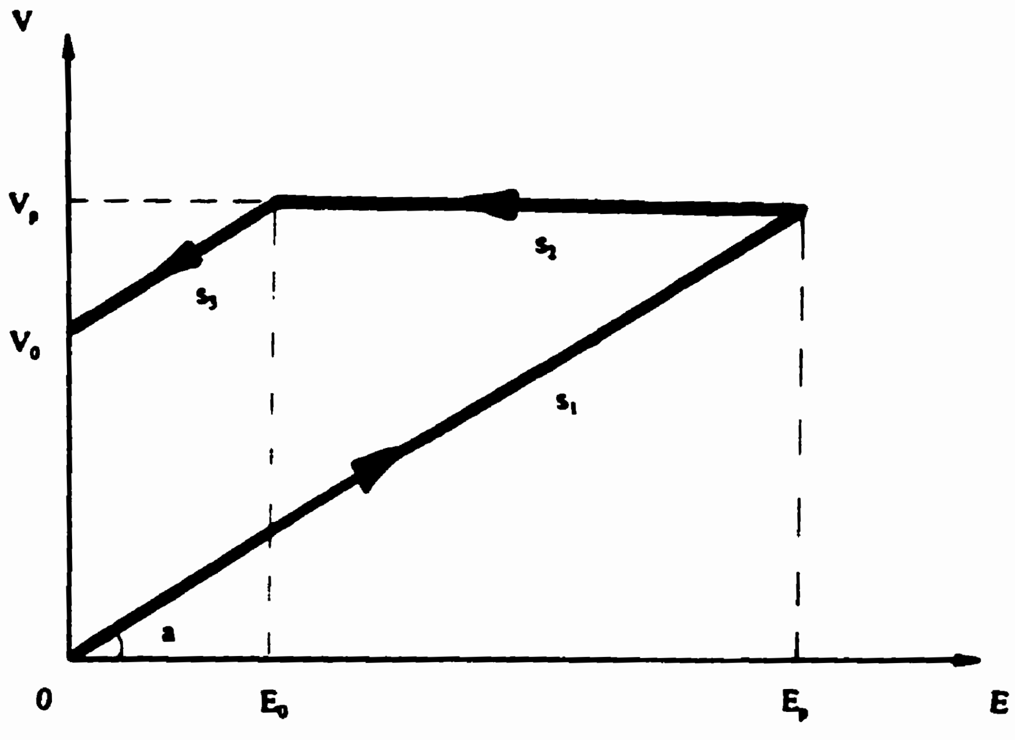


Figure 4-2 Linearized Hysteresis Loop

For simplicity, let's linearize the curves which formed the hysteresis loop and assume that each of them has a constant slope: $a$, $0$, $a$, for $s_1$, $s_2$, and $s_3$, respectively, as shown in Figure 4-2. Next, we can write $V$ as a step function of $E$:

$$V = \begin{bmatrix} aE, & s \in s_1; \\ aE_p, & s \in s_2; \\ aE - V_0, & s \in s_3. \end{bmatrix} \quad (4\text{-}3)$$

The line-integral, $U$, along the hysteretic loop which is characterized by Equation 4-3, can be calculated. Since $X$ is the projection of $U$ on axis $E$, in the linear case, we can rotate the coordinate system and get the following relationship between $U$ and $X$[12]:

$$X = \frac{1}{\sqrt{1+a}}\, U \quad (4\text{-}4)$$

Therefore the hysteretic export, $X$, can be expressed as:

[12] A proof is given in Appendix 4-1.
For a general non-linear case, theoretically, there is a Jacobian transformation to link U and X. In this linearized case, the Jacobian is simply $(1+a)^{-1/2}$.

$$X = X(E) = \frac{1}{\sqrt{1-a}} \mid \int_s P_f\ V\ ds \mid \qquad (4-5)$$

For a small open economy, the world market price should be exogenously given; therefore $P_f$ is not a function of $E$. The hysteretic function between $X$ and $E$ (that is, $s \in s_2$) can be calculated from Equations 4-3 and 4-5[13]:

***RESULT I***

$$X = X(E, E_p) = aP_f E_p (\frac{3}{2} E_p - E);$$
$$X_E = \frac{\partial X}{\partial E} = -aP_f E_p < 0, \qquad s \in s_2 \qquad (4-6)$$

where $E_p$ is the peak value of an exchange rate shock which is shown in Figure 4-2. Let $E_0 = hE_p$, $h \in (0, 1)$, and $V_0 = a(1-h)E_p = a\theta E_p$. The parameter $\theta = 1-h$ measures the degree of hysteresis.

The cumulative effect on the export, $X$, caused by this process of hysteresis (that is, when hysteresis is over, $s \in s_3$) can also be calculated according to Equations 4-3 and 4-5:

[13] for detailed calculation, see Appendix 4-2.

***RESULT II***

$$X = X(E, E_p, h)$$
$$= aP_f[\frac{3-h^2}{2}E_p^2 - (1-h)E_pE - \frac{E^2}{2}]; \qquad (4\text{-}7)$$
$$X_E = \frac{\partial X}{\partial E} = -aP_f[(1-h)E_p - E] < 0,$$
$$s \in s_3$$

Results 1 and 2 are the explicit functional forms of the hysteretic export X, during the hysteresis process (Equation 4-6) and the cumulated effects caused by an exchange shock (Equation 4-7). From the two results we can see that the export, *X* (which determines the balance of payments and aggregate demand in the goods market), is an inverse (non-linear) function[14] of the level of the exchange rate, *E*, which is opposite to the conventional theory of international economics[15]. In the conventional theory as we reviewed in Chapter 2, the Marshall-Lerner condition suggests that there is a monotonic (positive) functional relationship between X and E (e.g., devaluation improves exports and vice versa, if the Harberger condition is satisfied). In the case of trade hysteresis, however, this relationship works for one direction only: when an exchange shock comes

[14] Because the exporting firms have already occupied foreign markets and do not give up their market share when their domestic currency appreciates. Without change in the volume of exporting (number of the physical items), the value of export decreases as the domestic currency appreciates.

[15] If the exchange shock comes from the opposite direction, i.e., an appreciation in domestic currency, then a negative sign should be added to the results.

($s \in s_1$), $X$ is a positive function of $E$ (as the Marshall-Lerner condition suggested, $X_E = \partial X / \partial E > 0$). But when the shock withdraws ($s \in s_2 \cup s_3$), as Results 1 and 2 show, $X$ becomes a negative function of $E$ ($X_E = -aP_f E_P < 0$, $s \in s_2$; and $X_E = -aP_f[(1-h)E_P - E]$, $s \in s_3$). Obviously, the Marshall-Lerner condition is not valid anymore as hysteresis occurs. Therefore we can immediately obtain the following:

***PROPOSITION I***

***If trade hysteresis occurs, the relationship between export and exchange rate is non-monotonic.***

This proposition can also be extended to a general nonlinear case, because a nonlinear hysteretic loop, as shown in Figure 4-1, can be linearized by the linear approximation method[16].

Moreover, we can see that the magnitude of the exchange rate shock, $E_p$, determines the slopes and positions of $X$ curves (on $X$-$E$ space). The degree of hysteresis, $h$ ($=1-\theta$), only affects $X$ in the long run (Equation 4-7). After an exchange rate shock has totally disappeared (that is, when the exchange rate resumes its pre-shock level, $E = 0$), the shock's net effect permanently left on export is:

[16] Many mathematics books provide this method, for example, A. C. Chiang (1984).

$$X_p = aP_f \frac{3-h^2}{2} E_p^2 \qquad (4\text{-}8)$$

Equation 4-8 shows that the permanent result caused by an exchange rate shock is not a function of the level of the exchange rate $E$ itself[17], but the degree of trade hysteresis $h$, the magnitude of the shock $E_p$, the world price $P_f$, and the parameter $a$. Theoretically, the parameter $a$ describes the openness of the economy (the structure of the international sector in the economy). $E_p$ measures the heaviness of the international disturbance. For a small economy, the world price $P_f$ is exogenously given[18]. As the name suggested, the degree of trade hysteresis $h$ describes how serious the trade hysteresis is.

Exports are explicitly expressed as a function of the exchange rate, as well as the magnitude of exchange rate shock. Therefore, hysteretic export caused by an exchange rate shock can be fully characterized by a functional form.

The methodology of this section contrasts the typical approaches of economists and physicists. Economists of use partial derivatives to examine relationships among economic variables. In contrast, physicists often use derivatives to examine the velocities or

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[17] As the permanent (or, long lasting) result of trade hysteresis, exporting firms stay in foreign markets, say, Toyota stays in North America, regardless of the level of the exchange rate (between the Japanese yen and the US dollars).

[18] If we implicitly assume that the domestic price is one, then $P_f$ should be considered as the price ratio between foreign and domestic.

accelerations among different moving objects (dynamic variables). Similarly, if we have difficulty describing the "velocities" of variables, we can analyze their relationships by tracing the orbits they passed, that is, to calculate an integral. In the case of trade hysteresis analysis, if we know the orbit of hysteretic trade (the path characterized by the hysteretic loop), then the behaviour of trade hysteresis (cumulative effects of trade hysteresis) can be described by taking a line integral.

### 4.1.3 The IS-LM-BP Model

As a core theory of Keynesian analysis, the IS-LM-BP model has dominated mainstream applied macroeconomics for decades. This model is theoretically mature and empirically reliable. This section incorporates the hysteretic export X into this model. Under an assumption that a small open economy produces a single homogeneous good, then a standard IS-LM-BP model with trade hysteresis can be specified as the following:

$$Y = C + I + G + X; \qquad (4\text{-}9)$$

$$L = \frac{M + R}{P}; \qquad (4\text{-}10)$$

$$B = X + K; \qquad (4\text{-}11)$$

$$C = C(Y, E); \quad C_Y > 0, \quad C_E > 0; \qquad (4\text{-}12)$$

$$I = I(Y, r); \quad I_Y > 0, \quad I_r < 0; \qquad (4\text{-}13)$$

$$X = X(E); \quad X_E < 0 \quad (\textit{hysteresis occurs}); \qquad (4\text{-}14)$$

$$L = L(Y, r); \quad L_Y > 0, \quad L_r < 0; \qquad (4\text{-}15)$$

$$K = K(Y, r, E^{*}); \quad K_Y > 0, \quad K_r > 0, \quad K_{E^{*}} < 0; \qquad (4\text{-}16)$$

$$B = \dot{R}. \tag{4-17}$$

where

$Y$ = the aggregate demand which is equal to the output (GDP) at equilibrium;

$C$ = consumption;

$I$ = investment;

$G$ = government spending;

$X$ = export, or current account;

$L$ = money demand;

$P$ = domestic price level;

$r$ = domestic interest rate;

$E$ = foreign exchange rate, price of foreign currency in terms of domestic currency;

$M$ = domestic money stock;

$B$ = balance of payments;

$R$ = official stock of foreign exchange reserves;

$K$ = capital flow, or capital account balance.

The first three equations specify the structure of the model. Equation 4-9 is the income identity which defines the IS curve and describes the goods market equilibrium. Equation 4-10 is the open economy version of LM curve which describes the money market equilibrium. Equation 4-11 defines the balance of payments equilibrium (the BP curve).

The next six equations are the behavioural functions. Equation 4-12 is a consumption function. For a small open economy, the domestic consumption includes both domestic and imported goods and services. Therefore, the consumption, *C*, is not only a function of income, *Y*, but is also affected by the exchange rate, because a large proportion of consumption goods consists of imports, and a change in the exchange rate will directly cause a price fluctuation in imports[1]. Equation 4-13 is a standard investment function which says that investment behaviour is mainly determined by income level and domestic interest rate.

Equation 4-14, the net export function, is the key relationship which characterizes our hysteretic model. Some explanation of the equation may be needed. First, the definition of "net export" is the difference of export and import. In this model, the import could be considered as having two parts: the endogenous part (which refers to those goods and services which are sensitive to changes in the exchange rate, such as the tourist industry) and the exogenous part (which refers to those goods and services which are insensitive to changes in the exchange rate, such as food from the south, labour intensive goods from developing countries, and so on). Since the exogenous part is very likely to dominate the endogenous part, we may say that the import is insensitive to changes in the exchange rate, but the export is sensitive to them. Therefore the net export function mainly emphasizes behaviour of the export. In other words, Equation 4-14 describes how exports respond to changes in the exchange rate. Second, the crucial point of Equation 4-14 is

[1] A similar argument can be seen in Turnovsky (1977).

that it is not a normal "function" (between the export and the exchange rate) in the sense of mathematics. The hysteretic export behaviour is described as ***Proposition I***: when the trade hysteresis occurs, the export, $X$, is a non-monotonic function of the exchange rate $E$. A temporary exchange rate shock (or, a disturbance) causes an immediate change in export (which is described as the path $s_1$ in Figures 4-1 and 4-2), and this disturbance will generate a long lasting effect, as shown by Equation 4-8[2]. In addition, during and after the shock, the normal functional relationship between export and exchange rate is reversed, i.e., as the exchange rate drops, the export continuously increases (***Results I and II***). Therefore $X_E$ ($= \partial X/\partial E$) is negative because the Marshall-Lerner condition does not hold due to trade hysteresis.

Equation 4-15 is a standard money demand function which says that the money demand $L$ is positively related to the income level $Y$, and negatively related to the interest rate $r$. Equation 4-16 specifies the motivation of capital flow. In most literature the capital flow is specified as a function of the interest rate: $K = K(r)$, which says that the capital flow depends mainly on the yield differential between domestic and foreign bonds, and the value of $K_r$ describes the degree of capital mobility. A very interesting phenomenon is quite common in today's international economy: many developed economies are more

[2] For example, an exchange rate shock (due to economic or non-economic reasons) causes the Canadian dollar to depreciate, say, 15% within one week (against the US dollar or other currencies of Canada's major trading partners). An immediate change in trade caused by the shock is described by the path $s_1$ (in Figures 4-1 and 4-2), and we define this as a "temporary" reaction. The long lasting hysteretic phenomenon starts as the exchange shock disappears, as shown in the paths $s_2$ and $s_3$. The negative sign of $X_E$ came from these two parts.

likely to attract foreign investments than are many developing economies[3], which could not be explained by the conventional theory of international economics (according to the principle of the factor price equalization suggested by the Heckscher-Ohlin-Samuelson theorem, movement of capital flow should be from the developed economies (high income countries) to the developing ones (low income countries)). This reality is particularly true for the Canadian economy. In order to describe this phenomenon, we use $K = K(Y, r, E^e)$, and $K_Y > 0$ to specify the capital flow. This specification says the higher the domestic income, the easier it is to attract investment from the rest of the world. In addition, the capital flow is also affected by people's expectations of the future exchange rate, $E^e$ (where the superscript $e$ means expected value)[4]. We use $\partial K/\partial E^e < 0$ to describe investment caused by the expectation.

Finally, Equations 4-11 and 4-17 introduce some intrinsic dynamics into the system. The two equations say that the change in the official holdings of foreign exchange reserves must equal the excess of the sources over the uses of foreign exchange that flow in and out of the economy during each market period. This change in reserve holding is the balance of payments.

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[3] The explanations could be non-economic, such as considerations of political stability or risk.

[4] A particular set of expectations of the future exchange rate can be specified as $E^e = f({}_t\Delta E_{t+1})$, which means that people make predictions on the exchange rate at period $t$ for the next period $t+1$.

To see the intrinsic relationships of the system, we reduce the model to a reduced form with three equations and take a total differential of each one:

$$dY = C_Y dY + C_E dE + I_Y dY + I_r dr + dG + X_E dE; \tag{4-18}$$

$$L_Y dY + L_r dr = dM + dR; \tag{4-19}$$

$$dB = X_E dE + K_Y dY + K_r dr. \tag{4-20}$$

These three relationships allow us to solve for an aggregate demand side dynamic equilibrium[5] and to determine three endogenous variables: d$Y$, d$r$, and d$B$. This system can be expressed as a matrix form:

$$\begin{bmatrix} (1-C_Y-I_Y) & -I_r & 0 \\ L_Y & L_r & 0 \\ -K_Y & -K_r & 1 \end{bmatrix} \begin{bmatrix} dY \\ dr \\ dB \end{bmatrix} = \begin{bmatrix} (C_E+X_E)\,dE + dG \\ dM + dR \\ X_E dE \end{bmatrix} \tag{4-21}$$

---

[5] The dynamic motivation comes from the open economy adjustment, Equation 4-17. However, since our endogenous variables do not include $dR$ (due to lack of independent relationships), we are implicitly treating the foreign reserve $R$ as a constant. The solution yielded from this model is a temporary equilibrium path rather than a long run equilibrium path. We use the term "dynamic" to emphasize the feedback process within the system, rather than to describe a time horizon.

The first equation in the matrix is the IS curve, the second one is the LM equation and the last one is the BP curve. From the right-hand-side of the matrix form we can see that the hysteretic item $X_E$ could affect the system via two channels: the goods market equilibrium (IS curve) and the balance of payments (BP curve). The rationale of the effects caused by the hysteretic trade could be analyzed as the following.

If all items in the right-hand-side of Equation 4-21 are treated as exogenous, the system is a standard IS-LM-BP model (except for our special specification on the capital flow). The inverse of the IS curve's slope is simply:

$$\frac{dY}{dr} = \frac{I_r}{1 - (C_Y + I_Y)} \qquad (4\text{-}22a)$$

The reduced form of the model (Equations 4-18, 4-19, and 4-20) offers us three independent relationships -- equilibria in the goods market, the (domestic) money market, and the balance of payments -- which allow us to solve for three endogenous variables. The three variables, $dY$, $dr$, and $dB$, are all essential to the system because the first two define the dimension of the analysis (the $Y$ - $r$ space), and $dB$ is the key variable for an open economy. In order to incorporate trade hysteresis into the system, we must also consider the exchange rate, $dE$, as an endogenous variable that characterizes hysteretic trade. Therefore an additional (independent) relationship is needed to determine $dE$. A possible way to do so is to bridge d$E$ with d$r$ (i.e., d$E$ = $f$(d$r$) ), other than using the

Interest Rate Parity. In the standard IS-LM-BP model, the Interest Rate Parity and the capital flow specification are not independent conditions because they can be substituted for each other. The standard capital flow is motivated by the interest rate gap between the domestic and the rest of the world (i.e., $K = K(r)$, $K_r > 0$). $K_r$ is the degree of capital mobility which describes the maturity of the capital market. Today's advanced communication technology has made the degree of capital mobility extremely large ($K_r >> 0$), therefore the BP curve is very flat. As a result, there is very little room for the adjustment between the domestic interest rate and the foreign exchange rate. In other words, a flat BP curve implicitly includes the condition of the Interest Rate Parity. However, with our specification of the capital flow, the two relationships could be independent. Equation 4-16 says that the capital flow is not only motivated by the interest rate gap between the domestic and the rest of the world, but also by international investors' arbitrage behaviour (expectation of future exchange rate), as well as the income level of the domestic economy (e.g., Canada and the US are more likely to attract foreign investment than Mexico and Argentina). A relationship between interest rate $r$ and the exchange rate $E$ can be derived from the specification on the expected exchange rate $E^e$ in Equation 4-16:

$$E^{e} = \xi_1 (r_f - r_{t-1}) + \xi_2 E_{t-1} \qquad (4\text{-}23a)$$

Equation 4-23a says that the expected exchange rate is a function of the interest rate gap between foreign and domestic, and last period's exchange rate. This relationship is a modified version of the Interest Rate Parity Theorem which allows the domestic interest rate and the exchange rate to adjust separately. If we adopt the static expectation condition ($dE^* = 0$) and treat the foreign interest rate as exogenous, taking a derivative on Equation 4-23a results in the following:

$$dE^* = -\xi_1 dr + \xi_2 dE = 0;$$
$$dr = \eta dE; \quad where \ \eta = \frac{\xi_2}{\xi_1} \tag{4-23b}$$

where $\eta$ is a positive coefficient which is determined by the nature of the financial market, as well as size of the economy. After combining the first equation in 4-21 and Equation 4-23b, the inverse of the IS curve's slope can be obtained as the following:

$$\frac{dY}{dr} = \frac{I_r + \frac{1}{\eta}(C_E+X_E)}{1 - (C_Y+I_Y)} \tag{4-22b}$$

The denominator describes a temporary multiplier mechanism which can be read as (*1 - feedback ratio*) where the feedback ratio is the sum of the marginal propensity to consume and the marginal propensity to invest. The system stability condition requires the feedback ratio to be greater than zero but less than unity[6]. Therefore the denominator

[6] Scarth (1988) offered a theoretical explanation of this condition.

is positive since the system is presumed stable. Scarth (1988) summarized the convergence conditions for the IS-LM system and argued that a "normal" IS curve (without hysteresis) could be downward sloped or upward sloped, as long as the value of its slope is smaller than that of the LM curve.

In the case of a standard IS-LM model, the slope of the IS curve is determined by the marginal propensity to invest (domestically) $I_r$, because the nature of the IS curve is to describe the domestic goods market equilibrium. If the investment function is "normal" ($I$ is negatively related to $r$), the IS appears as a downward sloping curve, as it is shown in most literature. Now, in this study, we have three items in the numerator: $I_r$ (negative), $C_E$ (positive), and $X_E$ (positive, without trade hysteresis; and negative, with trade hysteresis). The latter two items, $C_E$ and $X_E$, are brought into the model to emphasize the open economy. When $X_E$ is positive (no trade hysteresis) and in the same magnitude as that of $C_E$, the two items offset each other. The slope of the IS curve is still dominated by $I_r$ (probably this is why most studies did not include them in their models). However, when trade hysteresis occurs, it changes the sign of $X_E$ from positive to negative which means a steeper IS curve ($X_E$ and $C_E$ are all negative and added into $I_r$). As the degree of trade hysteresis increases (the absolute value of $X_E$ increases), the IS curve is pushed clock-wise to vertical. When it reaches an extreme, the magnitude of $X_E$ dominates the slope of the IS curve ($I_r$ and $C_E$ become relatively small compared with $X_E$), and then the IS curve could be pushed up to vertical.

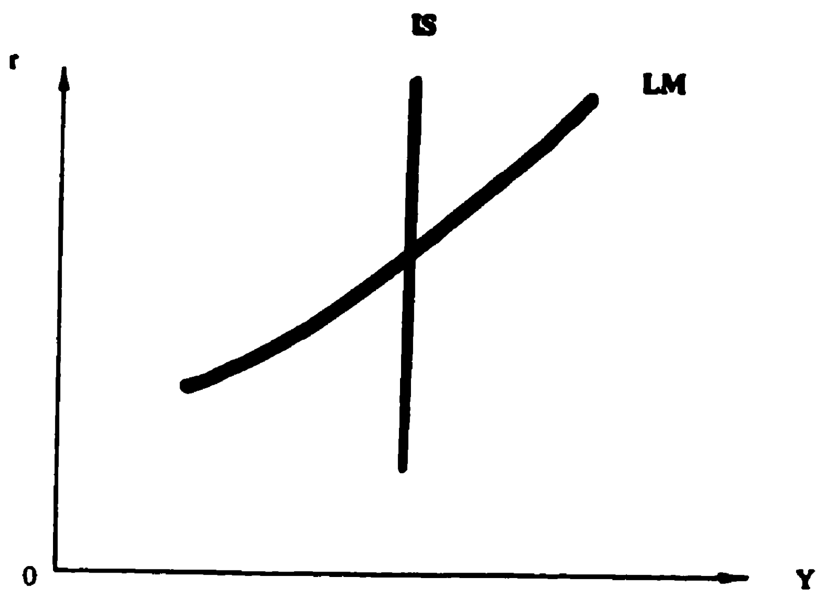


Figure 4-3 Hysteretic IS-LM Model

The hysteretic IS-LM curve in Figure 4-3 shows this process: without trade hysteresis, the IS curve is in a normal downward sloped shape. As the trade hysteresis occurs, the curve becomes steeper. The IS curve approaches vertical when the trade hysteresis reaches its extreme[7]. This phenomenon could be explained as follows. In a normal case, the slope of an IS curve is dominated by the domestic financial market signal, i.e., the investment response to the interest rate ($I_r < 0$); therefore, the IS curve is downward sloped. Since the trade hysteresis causes an opposite direction of the movement between $Y$ and $r$ (negative $X_E$ via the Interest Rate Parity) and this reduces the sensitivity of the aggregate demand responding to the interest rate, the IS curve becomes steeper. A more intuitive interpretation of this adjustment process could be explained as follows. The investment $I$ falls as the domestic interest rate $r$ rises; consequently, $Y$ decreases, other things being equal (i.e., without changes in other components of $Y$, namely $C$, $G$, and $X$). This is what is meant by "downward sloping IS curve (on the $Y$ - $r$ space)". Now with existence of the trade hysteresis, a rise in the interest rate is associated with an appreciation in the exchange rate (Equation 4-23), but the hysteretic export causes an increase in $X$ (higher price of export and the same volume of export) which offsets the loss of $Y$ by the investment. Therefore $Y$ becomes less sensitive to changes in $r$, i.e., the downward sloping

---

[7] The extreme means full hysteresis $h = 1$ in *Result II* (Equation 4-7). In the case of full hysteresis, the hysteretic loop (Figure 4-2) has two parts only, $s_1$ and $s_2$. The downward sloping part, $s_3$, becomes horizontal (same as $s_2$). Note that $h$ is only a theoretical description of the degree of hysteresis; it cannot be directly tested by empirical analysis.

IS curve approaches a vertical position. For a small economy, if its economic structure largely relies on the international trade sector (the export-import component largely dominates the aggregate demand of the economy which is true for the Canadian economy), the trade hysteresis could be a dominant force in determining the entire goods market equilibrium. When this happens, the domestic interest rate level is irrelevant to the goods market equilibrium, which appears as a vertical IS curve.

An immediate implication of the vertical IS curve is that it generates a vertical aggregate demand curve. In the output-interest space (*Y-r*) where the IS-LM-BP model is constructed, the position of the LM curve changes as the price level changes, that is, the higher the price level, the flatter the LM curve. The aggregate demand curve is a result of *mapping*[8] the price changes from the Y-r space to the output-price space, *Y-P*, as shown in Figure 4-4.

[8] A mapping is a transformation which connotes the action of association of one set with another. In most cases, the concept of "mapping" is similar to that of "function", but the former emphasizes more geometric domains and the latter emphasizes descriptive relationships among variables.

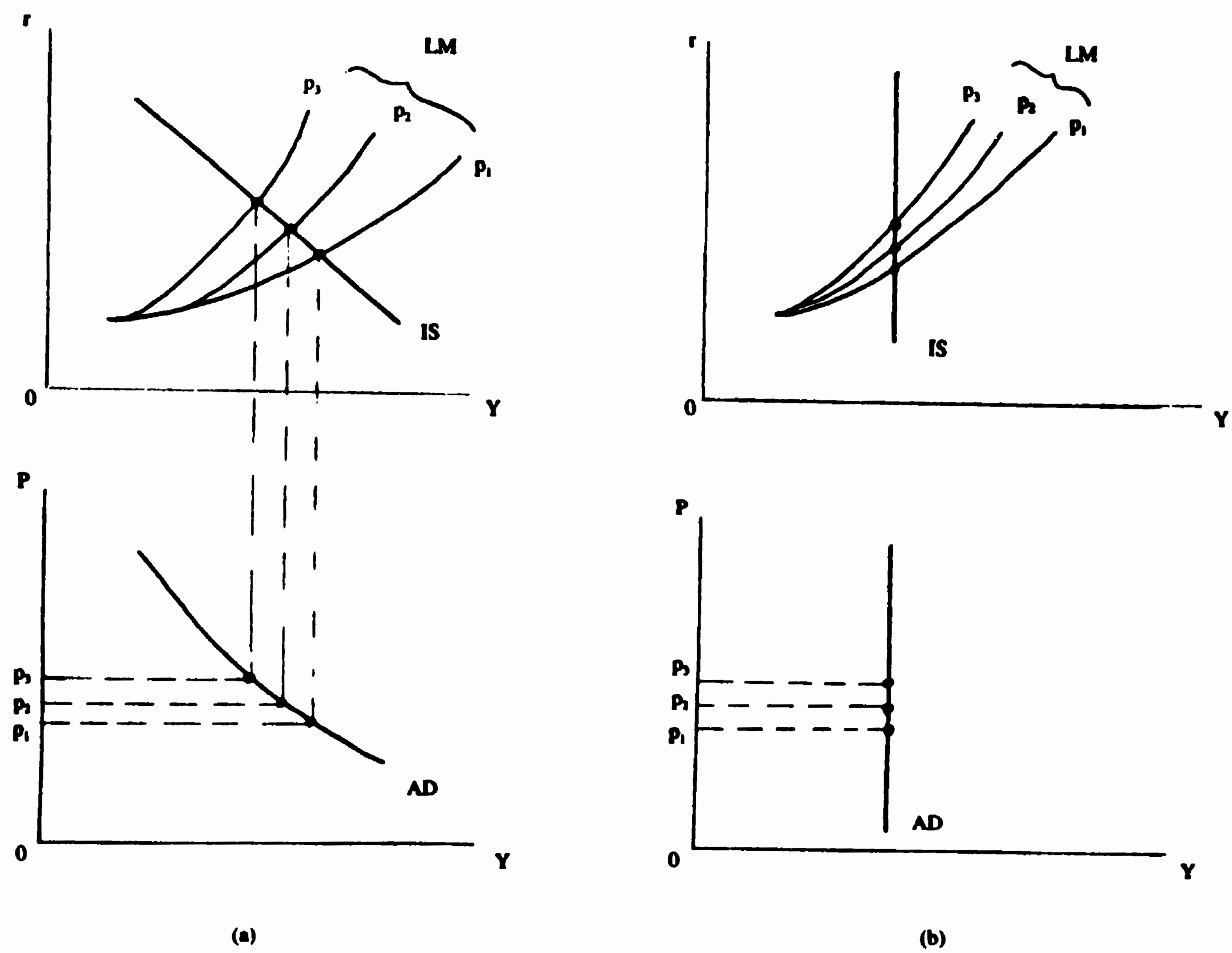


Figure 4-4 IS-LM and AD Curves

In a normal case, the IS curve is downward sloped: the mapping generates a downward sloped aggregate curve, as shown in Figure 4-4a. When the trade hysteresis occurs and the IS curve becomes vertical, the mapping results in a vertical aggregate curve. This result shows that the trade-off relationship between the aggregate demand and the price level disappears as the hysteretic trade sector dominates the economy. Therefore, the real variables (the output and the unemployment rate) do not show any functional relationship with the domestic price signals, that is, the labour market hysteresis.

***PROPOSITION II***

***For a small open economy, trade hysteresis results in a very steep IS curve (up to vertical), which generates a steep aggregate demand curve. The steeper the aggregate demand curve, the weaker the relationship between domestic output and the price level (or inflation rate). As the degree of trade hysteresis increases, the aggregate demand curve steepens and explains the domestic labour market hysteresis[9].***

[9] This model explains the demand side hysteresis only, so we could assume that the aggregate supply curve is upward sloped. As price level rises, the output drops along the downward sloped AD curve. At the same time the AD curve bends steeper and steeper (due to trade hysteresis), so the output level will not be able to resume its original level when the price shock is removed. The supply side hysteresis will be discussed in the next section.

## 4.2 A Modified Version of the Phillips Curve

An intuitive interpretation of the Phillips curve equation is that all market pressures of the aggregate supply side (on the right hand side of the equation) appear as one market signal -- the inflation rate (on the left hand side of the equation). For a small open economy, the market pressure is closely linked with international economic fluctuations. The most direct channel of this linkage is through changes in the exchange rate which affect the comparative costs in production between domestic and foreign firms.

As Scarth (1988) pointed out, the two biggest macroeconomic shocks which occurred in the global economy since the 1970's were the drastic changes in the world prices of primary commodities and the fluctuations in the level of US interest rates. The effects of these shocks on a small open economy like Canada could go through the channel of the change in exchange rates which causes an immediate change in import prices and production costs, and in turn shifts the aggregate supply curve.

In order to capture the effects of changes in exchange rates from the aggregate supply side, this section starts from a partial equilibrium model which links the exchange rate with the price level, then uses this price-exchange rate relationship to construct an open economy version of the Phillips curve.

### 4.2.1 A Cournot-Nash Equilibrium Model for an Open Economy

Dornbusch (1987) suggested that the interaction of the movements in the nominal exchange rate and the less-than-fully flexible (sticky) wage adjustments produces cost shocks for some firms in an industry -- foreign firms at home and domestic firms abroad -- and thus brings about the need for an industry-wide adjustment in prices. For a small export-import oriented economy like Canada, the price adjustments may be observed as changes in general price level (which is the inflation rate). A standard Cournot-Nash equilibrium model can be used to describe this process.

In a one-good-only world, assume that all firms (domestic and foreign) have the same technology which uses one input (labour) to produce the identical good. This assumption implies perfect substitution between alternative suppliers and places of production. $P$ is the price of the good (it is also the domestic price level in a one-good-only world), and $w$ and $w^*$ are unit labour costs which are given in domestic and foreign currencies, respectively. The mechanism of exchange rate-price adjustment is simply this: the exchange rate, $E$, changes, say a Canadian dollar appreciation, lower foreign unit labour costs in Canadian dollars. As a result the market equilibrium is disturbed in the industry, and price and output adjustments must occur.

If a demand function is given as:

$$Q_d = a - bP \tag{4-25}$$

where all non-price determinants are captured in the constant $a$, there are $n$ domestic firms (say, located in southern Ontario) and $n^*$ foreign firms (probably located in Michigan) with respective sales of $q$ and $q^*$ per firm. Aggregate sales of all firms have to sum up to market demand:

$$Q = nq + n^*q^* \tag{4-26}$$

The equilibrium price level can be determined as:

$$P = \frac{a - nq - n^*q^*}{b} \tag{4-27}$$

Profits for $i$th domestic firm and $j$th foreign firm are defined as their revenue minus their total (labour) cost:

$$(a) \quad \pi_i = Pq - wq$$
$$= (P - w)[a - bP - (n-1)q - n^* q^*]; \tag{4-28}$$
$$(b) \quad \pi^*_j = Pq^* - w^* q^*$$
$$= (\frac{P}{E} - w^*)[a - bP - nq - (n^*-1)q^*]$$

For a Cournot-Nash equilibrium, each firm maximizes its own profits taking the sales of other firms as given. The domestic firm's reaction function can be derived by taking the first order condition of the two profit function[1]:

$$\frac{d\pi_i}{dq_i} = 0: \quad (\textit{with Cournot-Nash condition: } \frac{dq^*}{dq} = 0) \tag{4-29}$$
$$q = \frac{a-bw}{2n} - \frac{n^*}{2n} q^*$$

Similarly the foreign firm's reaction function can be derived as:

$$\frac{d\pi^*_j}{dq^*} = 0: \quad (\textit{with Cournot-Nash Condition: } \frac{dq}{dq^*} = 0) \tag{4-30}$$
$$q^* = \frac{a-bEw^*}{2n^*} - \frac{n}{2n^*} q$$

---

[1] Varian (1984) presented a "Conjectural Variations" model to demonstrate general oligopolistic behaviours, and the Cournot-Nash case is one of them which assumes that each firm believes that the other firms will not change their output decisions, so that a change in its own output of 1 unit will lead to a change in industry output of 1 unit.

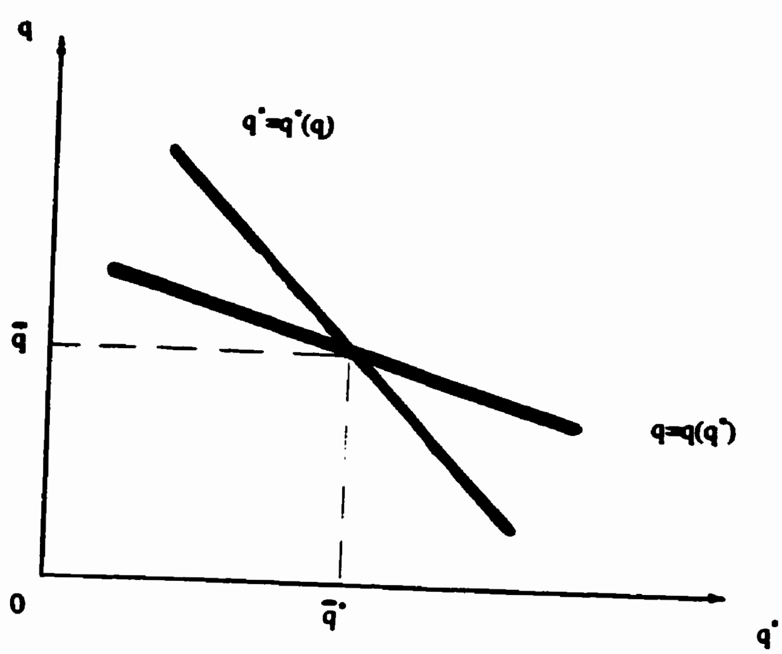


Figure 4-5 Cournot-Nash Equilibrium

The two reaction functions are straight lines, as shown in Figure 4-5. The equilibrium sales of domestic and foreign firms are determined by intersection of the two reaction lines:

$$
\begin{aligned}
&(a) \qquad \bar{q} = \frac{a+b(Ew^{*}-2w)}{3n}; \\
&(b) \qquad \bar{q}^{*} = \frac{a+b(w-2Ew^{*})}{3n^{*}}
\end{aligned}
\qquad (4\text{-}31)
$$

Substitute the equilibrium sales into Equation 4-27, and we can get the equilibrium price:

$$
\begin{aligned}
&\bar{P} = \varphi_0 + \varphi_1 E; \\
&\varphi_0 = \frac{a+bw}{3b}, \quad \varphi_1 = \frac{w^{*}}{3}
\end{aligned}
\qquad (4\text{-}32)
$$

This result explains how changes in the exchange rate affect domestic price level[2],

[2] This result slightly differs from that of Dornbusch (1987). He reported the following equation:

$$\bar{P} = \frac{nw+n^{*}Ew^{*}}{n+n^{*}+1} + \frac{a}{b(n+n^{*}+1)}$$

the difference between the two results, however, does not affect our main conclusion: a direct (positive) relationship between *P* and *E*.

and it provides a theoretical base which allows us to build a direct connection between exchange rate and domestic inflation.

### 4.2.2 The Phillips Curve in an Open Economy Version

In today's macroeconomic analysis, the Phillips curve is used to summarize aggregate supply side relationships. On the left-hand-side of the Phillips curve equation, the actual inflation rate represents a "market signal" which indicates the direction of departure of the economy from its potential trend line position (fluctuations). For example, a change in inflation rate could be an indication of a gap between the levels of actual and potential output. On the right-hand-side of the equation, we put all "market pressure" related items: GDP gap, expected inflation rate which is people's response to changes in the market signal, and zero-mean residuals. For a small open economy, the aggregate supply side relationships can be specified as the following:

$$\pi = \gamma \pi^d + (1-\gamma)\pi^o \tag{4-33}$$

$$\pi^d = f\left(\frac{Y_{-1} - Y^*}{Y^*}\right) + \pi^e \tag{4-34}$$

$$\pi^o = \frac{P^o - P^o_{-1}}{P^o_{-1}} \tag{4-35}$$

$$P^o = \varphi_0 + \varphi_1 E = \phi(E) \tag{4-36}$$

Equation 4-33 says that the actual inflation rate, $\pi$, is a weighted sum of the internal inflation, $\pi^d$, and the external inflation, $\pi^o$. The weight, $\gamma$, describes the importance of the trade oriented sector for an economy. The internal inflation captures the domestic market pressure and it is well defined by the conventional expectation-augmented Phillips curve, i.e., Equation 4-34. Equation 4-34 shows that domestic market pressure is a function of output gap of the last period in terms of percentage (where $Y^*$ stands for the potential output level), and the expected inflation rate, $\pi^e$, is also directly responsible for actual domestic inflation. Equation 4-35 defines external inflation which is the change in price of tradable goods, $P^o$. Equation 4-36 is the same as Equation 4-32 which states that changes in price of tradable goods are caused by exchange rate shocks. Since price of tradable goods is a linear (positive) function of exchange rate, $\varphi(E)$, the external inflation should also be a positive function of exchange rate:

$$\pi^o = \frac{\phi(E) - \phi(E_{-1})}{\phi(E_{-1})}$$

$$= g\left(\frac{E - E_{-1}}{E_{-1}}\right); \quad g'(\cdot)>0 \tag{4-37}$$

Combine Equations 4-33, 4-34, and 4-37, and all of the aggregate supply side relationships now can be summarized as:

$$\pi = \pi^e + \gamma f\left(\frac{Y_{-1} - Y^*}{Y^*}\right) + (1-\gamma)g\left(\frac{E - E_{-1}}{E_{-1}}\right) \tag{4-38}$$

where $f(\cdot)$ and $g(\cdot)$ are positive functions. We may call this equation the open economy version of the Phillips curve.

How does this model compare to the reality, especially the treatment of $g(\cdot)$? For a large economy, such as the United States, a number of studies have reported how changes in the exchange rates cause domestic inflation, including Hooper and Lowrey (1979), and Woo (1984), for example. These reports show that a depreciation of the US dollar has always been accompanied by a higher inflation rate; and an exchange rate appreciation invariably has been linked with a lower inflation rate. The external sector has been an important factor in explaining US inflation. In addition, Dornbusch (1987) reported that the impact of a 10% (US) dollar appreciation on the domestic price level ranged between 1 to 2 points for the US economy. For the small open Canadian economy, this effect should be more significant.

In the case of a small open economy, the movements of domestic inflation should be more significantly affected by changes in exchange rates and other external factors. To analyze supply side effects, Ryan, Kumar and Osberg (1986) studied how the changes in exchange rate affect the domestic structure of price and wages in the UK. The study summarized the Norwegian model as the following two-sector interacting model. First, competitive pressure sets the domestic price of tradeable goods equal to the world price, given the exchange rate, as required for the PPP. Then, given the tradeable prices, wages in the export sector are determined residually with a view to material costs and the return required by a competitive capital market. Next, wages in the sheltered sector involve a fixed wage-wage relationship, resulting from the clearing of the inter-sectoral labour market. Last, prices of non-tradeable goods are given by the mark-up over unit labour costs required to earn the same rate of return on capital as in the export sector.

Since the open economy version of the Phillips curve summarizes all relationships in the aggregate supply side, so it is indeed the aggregate supply curve. This aggregate supply equation enables us to conduct empirical tests on the Canadian hysteresis.

# CHAPTER FIVE

# TESTING HYSTERESIS FOR THE OPEN CANADIAN ECONOMY

Based on the two theoretical models developed in the previous chapter, the empirical testing in this study can be divided into two parts: the aggregate demand side study which involves testing trade hysteresis, the core of the hysteretic IS-LM-BP model, and the aggregate supply side study which deals with testing labour market hysteresis. The first test applies time series analysis, and the second test focuses on the Phillips curve estimation.

## 5.1 Testing Trade Hysteresis

As we have shown in the hysteretic IS-LM-BP model, trade hysteresis could result in the demand side hysteresis. Testing trade hysteresis, therefore, is the key issue in empirical studies of the aggregate demand side hysteresis. From a theoretical viewpoint, the nature of trade hysteresis can be characterized as the non-monotonic relationship between the exchange rate and export, as in *Proposition I.* From a time series analysis viewpoint, the property of the non-monotonic relationship between the exchange rate and export could be interpreted as meaning that the two series are not cointegrated, so the residual of a cointegrating regression follows a random walk.

If the series of export and the exchange rate are not cointegrated, it means that a normal linear relationship between the movements of the two does not exist, and this is an econometric expression of trade hysteresis. Burda (1990) further showed that a hysteretic variable can be described by a Koyck distribution and that the series follows a random walk. As a prevailing method, testing trade hysteresis follows two steps: first, the unit root test is used as a preliminary test to examine the stationarity for the series of export and the exchange rate separately[1], and then, the cointegration test is employed to detect a hysteretic relationship between the non-stationary (random walk) variables.

### 5.1.1 Time Series and Testing Hysteresis

Recent studies (for example, Nelson and Plosser (1982), Stock and Watson (1988), Maddala (1992), etc.) reported that many macroeconomic variables are not stationary. Nelson and Plosser (1982) studied two fundamental classes of time series which are

[1] In addition, the assumption of random walk is the necessary condition for the trigger model of Dixit (1989), which provides the microeconomic foundation of the hysteretic IS-LM-BP model; therefore, using the unit root test to test trade hysteresis is methodologically consistent with our theoretical analysis.

commonly used in macroeconomic analysis: (i) Trend-Stationary Processes (TS), which can be expressed as a deterministic function of time *t*, called trend, plus a stationary process with mean zero; (ii) Difference Stationary Processes (DS), for which a first or higher order difference of the series is a stationary and invertible ARMA process. For a DS process, a temporary exogenous shock will have some impact even in the long run, which can be considered as a necessary condition for variables exhibiting a hysteretic relationship.

**(1) Unit Root Test**

As a typical DS process, a random walk series has a special property: if a shock breaks the series equilibrium and brings it to a new position, the series has no tendency to resume its original position and stays in the new position forever after the shock is removed. This path-dependence property (the current position depends on its previous position only) is a kind of "memory" ability which "memorizes" where it came from. Testing whether macroeconomic series follow random walk is testing the memory ability of these variables. The memory ability is, indeed, a capacity to accumulate the effects of a transitory shock. Therefore, if two series have a hysteretic relationship, each of them should follow a random walk[2]. A random walk can tested by the unit root test.

[2] Recall that the hysteretic IS-LM-BP model in Chapter 4 relies on the assumption of random walk (Brownian Motion).

The random walk test is based on the following model:

$$Y_t = \alpha + \rho Y_{t-1} + e_t \tag{5-1}$$

where $Y_t$ is a time series variable, $\alpha$ and $\rho$ are coefficients and $e_t$ is an error series. From the equation we can see that the current value of $Y_t$ entirely depends on its previous ones.

Testing a random walk is testing the hypothesis of $\rho = 1$ in Equation 5-1, which is known as the "unit root test".

The null hypothesis for testing random walk is

$H_0$: $\rho = 1$; against its alternative $H_1$: $\rho < 1$.

In the theory of testing, the null hypothesis and its alternative are not on the same footing. The null hypothesis is on a pedestal and it is rejected only if there is overwhelming evidence against it. Therefore the null hypothesis of unit root, $H_0$, is not easily rejected[3]. Since the probability of rejecting the null hypothesis is very low, we may think that the test only allows us to reject (or fail to reject) the hypothesis if a series

[3] As Maddala (1992) pointed out, if $H_0$ and $H_1$ are in the same footing, testing results should be symmetric when they are switched to the opposite (i.e., treat $H_1$ as the null hypothesis, and $H_0$ as its alternative). But the studies of Kahn and Ogaki (1990), et al, reported contrary results which suggest that $H_0$ and $H_1$ are asymmetric.

does not follow random walk. A failure to reject is only weak evidence in favour of the random walk hypothesis, especially at a high significance level. In this sense, we say that the power of the test for random walk is limited.

Presently, there are two popular tests available for testing the random walk hypothesis: the Dickey-Fuller Test and the Augmented Dickey-Fuller Test.

The Dickey-Fuller Test is a "seemly $F$ test", which jointly tests the null hypothesis of $(\beta, \rho) = (0, 1)$ in the following model[4]:

$$\begin{aligned} Y_t &= \alpha + \beta t + \rho Y_{t-1} + \lambda \Delta Y_{t-1} + e_t; \\ \Delta Y_{t-1} &= Y_{t-1} - Y_{t-2} \end{aligned} \tag{5-2}$$

where $\beta$ is the time trend parameter, $\rho$ is the unit root coefficient, and the error series $e_t$ is assumed to be white noise. The statistic of the test is constructed by an $F$ ratio of the unrestricted regression:

$$Y_t - Y_{t-1} = \alpha + \beta t + (\rho - 1) Y_{t-1} + \lambda \Delta Y_{t-1} \tag{5-3}$$

---

[4] The simplest Dickey-Fuller test is that $\rho = 1$, which is based on a t-statistic and modified critical values. This is where the spurious regression problem lies.

and the restricted regression (with restriction $\beta = 0$ and $\rho - 1=0$)[5]:

$$Y_t - Y_{t-1} = \alpha + \lambda \Delta Y_{t-1} \tag{5-4}$$

This statistic is distributed as an *F* distribution with special critical values provided by the Dickey-Fuller Table. This test only allows us to reject the hypothesis that a variable is not a random walk. A failure to reject is only weak evidence in support of the random walk hypothesis; therefore, the power of the Dickey-Fuller Test is limited.

In the Dickey-Fuller Test, the error series is assumed to be white noise, which satisfies the conditions of independence and homoscedasticity. Those are rather strong assumptions to make about the error item in most econometric work. In comparison with the Dickey-Fuller Test, the power of test in the Augmented Dickey-Fuller Test (ADF) is improved. The ADF uses the least square regression estimator and the associated *t* statistic to test randomness in a general ARIMA model:

$$Y_t = \alpha + \beta t + \rho Y_{t-1} + \sum_{j=1}^{k} \lambda_j \Delta Y_{t-j} + e_t \tag{5-5}$$

---

[5] Hypothesis $\rho = 1$ tests the unit root, and hypothesis $\beta = 0$ tests whether the series has a time trend. A single restriction regression on $\beta$ enables us to construct a "*t*"-like test, and the joint restriction regression enables us to construct an "F" like test.

The purpose in adding the items $\Delta Y_{t-j}$ is to allow for ARMA error processes. By estimating Equation 5-5 we can get a "$t$ test": $t(1) = (\rho-1)/SSE(\rho)$, and an "$F$ test" which jointly tests $(\beta, \rho) = (0, 1)$[6]. These test statistics have asymptotically the same distribution as Dickey-Fuller statistics and hence the same significance table can be used. This model does not need the identical independent normal distribution (iid) assumption on error series $e_t$, which the Dickey-Fuller Test is based upon. Therefore, the scope of its application is more general. The critical values of ADF are given by Mackinnon (1991). In this study, the ADF will be applied to test the series of trade flows and foreign exchange rate.

A random walk series is a path dependent variable based on its previous value which can be used to characterize a variable's hysteretic behaviour. As a Markov process, random walk series can be used to describe a variable's short-run dynamics. Therefore the unit root test can (only) be considered as a necessary condition for hysteresis testing. In order to verify further whether a temporary shock from one variable (e.g., the exchange rate) could result in a permanent effect on another (e.g., net exports), a long-run relationship between them can be examined by asking whether the two series are cointegrated.

[6] The restricted regression uses the same restriction as the original Dickey-Fuller test: $\beta = 0$ and $\rho-1 = 0$.

**(2) Cointegration Test and Long-run Relationship**

Chinn (1991) suggested that the long-run relationship between two series could exist even if both of them follow random walks, and the long-run relationship can be examined by testing whether they are cointegrated. If the relationship between net exports and the exchange rate is non-monotonic, as suggested by ***Proposition I***, then the two series should drift apart and without a tendency to move together in the long-run. Therefore, the cointegration test can be used as a sufficient condition for testing trade hysteresis. The test can be described as the following.

If two random walk series, $Y_t$ and $X_t$, are both integrated of order $n$, i.e., $Y_t \sim I(n)$ and $X_t \sim I(n)$, then $Y_t$ and $X_t$ are said to be cointegrated if there exists a coefficient "$b$" such that the residual series $Y_t - bX_t$ is $I(0)$. This is denoted by saying $Y_t$ and $X_t$ are $CI(n, n)$. It means that the regression of equation:

$$Y_t = bX_t + u_t \qquad (5\text{-}6)$$

will produce a true estimation because $Y_t$ and $bX_t$ do not drift too far apart from each other over time. Thus there is a long-run equilibrium relationship between them. If $Y_t$ and $X_t$ are not cointegrated, i.e., $Y_t - bX_t = u_t$ is also $I(n)$, they can drift apart from each other more and more as time goes on. Thus there is no linear long-run equilibrium relationship between the two series. According to Maddala (1992), by asking the question of whether

$Y_t$ and $X_t$ are cointegrated, we are asking whether there is a long-run relationship between the trends in the two series. If they are cointegrated, $u_t$ is I(*0*). Since unit root tests will be applied to $u_t$, the null hypothesis is $u_t$ having a unit root. Thus the null hypothesis and the alternative in cointegration tests are:

$H_0$: $u_t$ has a unit root, or, $Y_t$ and $X_t$ are not cointegrated;

$H_1$: $Y_t$ and $X_t$ are cointegrated[7].

In the case of trade hysteresis, if both the net export $X_t$ and exchange rate $E_t$ follow random walk, but their first order differences, $\Delta X_t$ and $\Delta E_t$ are stationary, they are both I(1).

Engle and Granger (1987) developed a method to test cointegration CI(1,1) by running an OLS regression:

$$X_t = \alpha + \beta E_t + u_t \tag{5-7}$$

and then testing whether the residual series, $u_t$, from this regression are stationary. Therefore the cointegration test can be done by two regressions. First, we run an OLS regression on Equation 5-7. Then we use the residual series, $u_t$, generated by the

[7] Again, $H_0$ and $H_1$ here are asymmetric and $H_0$ has the pedestal, so the test power is also limited.

regression to run another regression:

$$\Delta\hat{u}_t = T + \beta_0\hat{u}_{t-1} + \sum_{i=1}^{n}\beta_i\Delta\hat{u}_{t-i} \tag{5-8}$$

where the trend item, $T$, is optional. The Engle-Granger (EG) test compares the Dickey-Fuller $t$ statistic of $\beta_0$ with the Mackinnon critical values to determine whether or not to reject the hypothesis of $u_t$ having an unit root. In an EG test, the null hypothesis is that *the series are NOT cointegrated and there is a unit root in the residual series*. If the null hypothesis is rejected, we know that $u_t = X_t - \alpha - \beta E_t$ is a stationary series and conclude that the series of the net export and the exchange rate are cointegrated. If the hypothesis cannot be rejected ($u_t$ having an unit root), it means the linear combination of $X_t$ and $E_t$ is non-stationary, and they have no tendency to move together in the long-run, i.e., the net export and the exchange rate series are not cointegrated.

Pindyck and Rubinfeld (1991) suggested that both the Dickey-Fuller test and the Durbin-Watson test can be used to test whether $u_t$ is stationary. In practice, the Dickey-Fuller test is much more popular than the Durbin-Watson test because of greater test power.

The EG test uses a single equation to test cointegration between two random walk variables. In order to examine possible cointegration among a group of random walk series[8], Johansen (1991) developed a multi-variable test to determine simultaneously the number of cointegration relationships among these variables, called the rank of cointegration.

The Johansen test expresses each integrated variable in an autoregressive form, called a Vector Autoregression (VAR) model. In the VAR model, the first differences of the first order integrated variables (i.e., random walk series) are written as functions of lagged linear combination of the variables, which are residuals of possible cointegrating regressions. This autoregressive expression is called the Vector Error Correction (VEC) form, because it relates the current changes in the variables to their past period's disequilibrium (i.e., the cointegrating regression residual). As time goes on, the changes in the variables should approach to stationary if the variables do not drift apart, that is, the variables are cointegrated in the long-run[9]. Therefore, the Johansen test examines how significantly changes in the variables can be explained by the lagged residuals. The test estimates the restricted and the unrestricted likelihood functions of the VEC model. By comparing the likelihood ratio with its *chi*-square distributed critical value, the test accepts or rejects the hypothesis of cointegration at given level of significance.

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[8] For example, among variables $C$ (consumption), $Y$ (income), $M$ (money supply), and $r$ (interest rate), two of them, three of them, or all of them, could be cointegrated. Therefore, there could be a multi-cointegration among them, and the number of the cointegration relationships is called the rank of cointegration.

[9] Intriligator, et. al (1996) provide a detailed discussion on the VEC model and Maddala (1992) presents a two-variable example of the model to demonstrate its rationale.

In our two-variable case, the cointegrated function of net exports and the exchange rate (Equations 5-7 and 5-8) can be expressed as a two-equation VEC model:

$$\begin{aligned} \Delta E_t &= \delta_1 + T + \gamma_1 u_{t-1} + \varepsilon_{1,t} \\ \Delta X_t &= \delta_2 + T + \gamma_2 u_{t-1} + \varepsilon_{2,t} \end{aligned} \tag{5-9}$$

where $u$'s are the OLS residuals from Equation 5-7; therefore, the VEC model can also be expressed as:

$$\begin{aligned} \Delta E_t &= \delta_1 + T + \gamma_1(X_{t-1} - \alpha - \beta E_{t-1}) + \varepsilon_{1,t} \\ \Delta X_t &= \delta_2 + T + \gamma_2(X_{t-1} - \alpha - \beta E_{t-1}) + \varepsilon_{1,t} \end{aligned} \tag{5-9'}$$

where the intercepts $\delta_i$ $(i = 1, 2)$ and the linear deterministic trend $T$ are optional in the test, and $\varepsilon_i$ $(i = 1, 2)$ are white noises. The null hypothesis in this test is:

$H_0$: $(\gamma_1, \gamma_2) = (0, 0)$, or, $X$ and $E$ are not cointegrated;

against $H_1$: $(\gamma_1, \gamma_2) \neq (0, 0)$, or, $X$ and $E$ are cointegrated.

The Johansen test estimates the likelihood ratio of the VEC model, which is the ratio of the restricted and the unrestricted values of the maximum likelihood functions with the restriction $H_0$. If the likelihood ratio is greater than its critical value at a certain significance level, we reject the null hypothesis and conclude the variables are integrated in order one.

In this study, we will use both the Engle-Granger test and the Johansen test to examine cointegration between net export and the exchange rate, if both of the series follow random walk.

### 5.1.2 The Data Set

All data used in this study are extracted from the CANSIM, an electronic data bank of Statistics Canada. Net exports are computed as the sum of the merchandise and service balance. The exchange rates are the average of the daily spot rates. The price levels (domestic and the foreign) are the consumer price indices. The domestic GDP is in 1986 dollar terms. Detailed variable specifications and the CANSIM series numbers are given in Appendix 5-1.

### 5.1.3 Empirical Analysis

The empirical analysis for trade hysteresis in this study includes two steps. First, we perform the unit root tests on the series of net exports and foreign exchange rate. Second, we test for cointegration between the two series, if both series have unit roots which indicate net exports and the exchange rate follows a random walk.

In order to see whether the two series behave as random walks in a long time horizon, we would like to test the two series in long periods. The available data periods are from 1950:4 to 1994:2 for the US and the rest of the world (ROW) data, and from 1978:4 to 1994:2 for the OECD data. During such a long period, the absolute values of the series changed significantly, as did their variances. Consequently, heteroscedasticity may be a problem in our tests. Thompson and Tiao (1971) reported that the variance of a time series has a trend to grow over the long run. To avoid the problem of heteroscedasticity, we express the net export as the relative share of the GDP (the net export-GDP ratio times 100), and use the real exchange rates, which are the products of the nominal exchange rates and the domestic-foreign price ratios, instead of the nominal exchange rates. In addition, transforming the series into logarithm form is a common method recommended by many studies (Maddala 1992, for example) to avoid the heteroscedasticity problem. The series of net exports and the exchange rate are transformed into logarithm form for testing.

## I. Unit Root Test

The US is the largest trade partner of Canada and the trade flows between the two countries dominate the Canadian economy. Therefore, the unit root test starts from the US data. In order to see the trade activities between Canada and other industrial economies, next we test the OECD data. In addition, we extend the test to the data of the rest of the world.

### (1) Tests on the US Data

This section reports the results of the unit root tests on the series of net export and the exchange rate. The regressions are based on the Augmented Dickey-Fuller model (ADF in Equation 5-5).

Figure 5-1 plots the series of net export from Canada to the US, and its two component series: merchandise export and service export. In this equation, *MT* stands for the merchandise trade balance, *SV* for the services trade balance, *NX* for the net exports, and they are all measured in percent of the GDP. The series of the net export and current account are plotted in Figure 5-2, where *CU* stands for the current account and it is also in terms of the GDP ratio (%). The figure shows that fluctuations of the net export determine the pattern of change in the current account[1].

[1] The current account also includes payments and receipts arising from interest and dividends that are earned by capital owned in domestic country and invested in the rest of the world, and transfer payments. Since these parts are usually small compared with the net export, many studies have treated the net export as the current account.

Figure 5-1 Trade in Merchandise (MT), Service (SV), and Net Export (NX) Canada/USA (in percent of GDP) 1950:4 - 1994:2

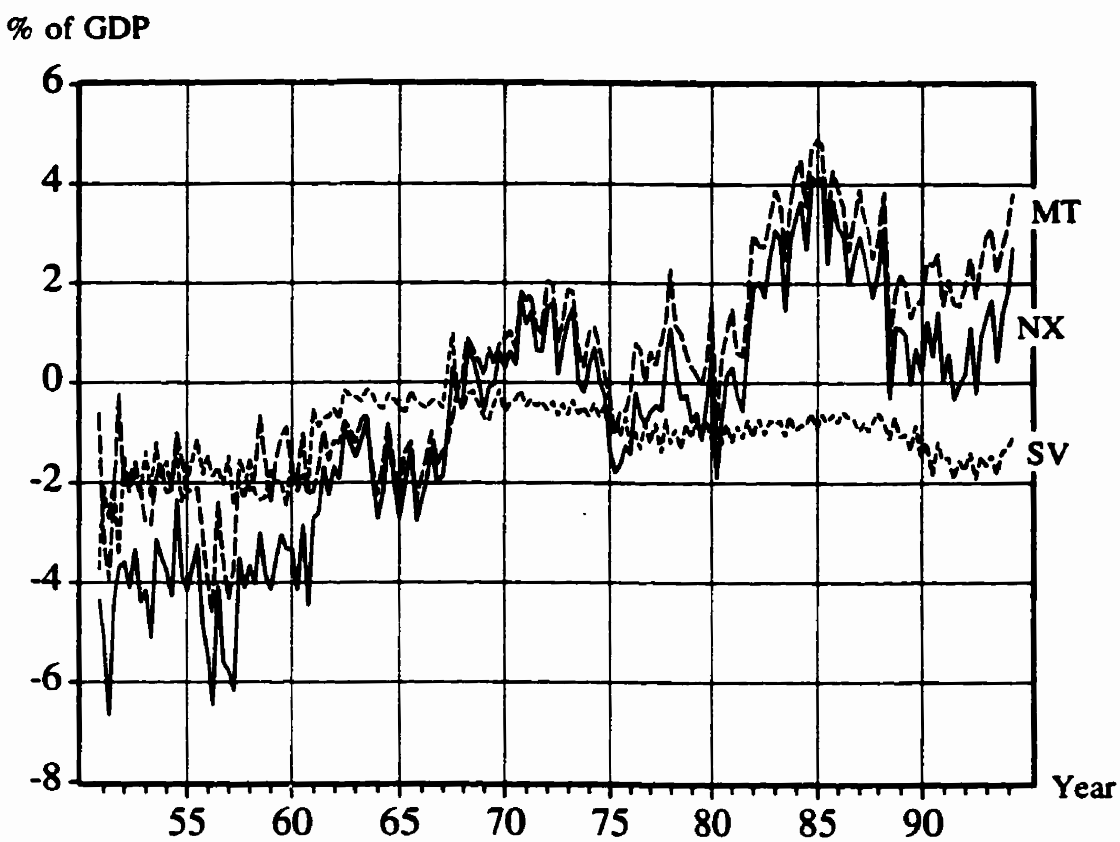


Figure 5-2 Net Export (NX) and Current Account (CU), Canada/USA
(in percent of GDP) 1950:4 - 1994:2

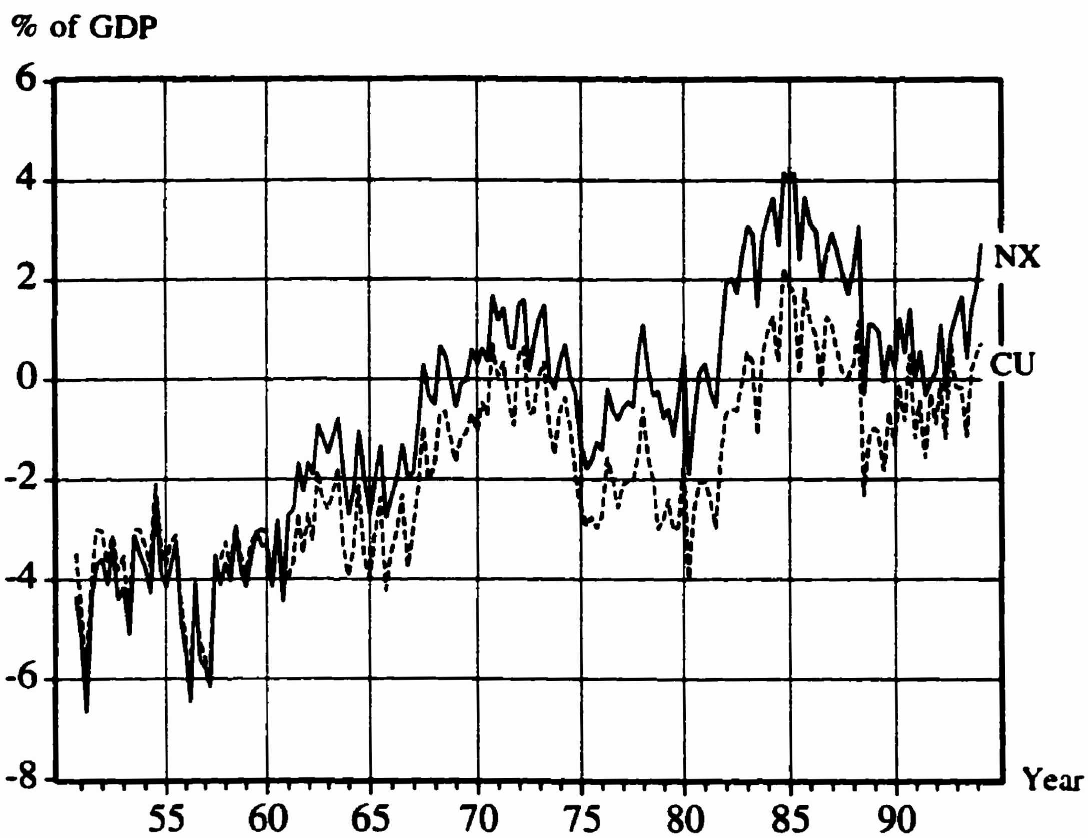
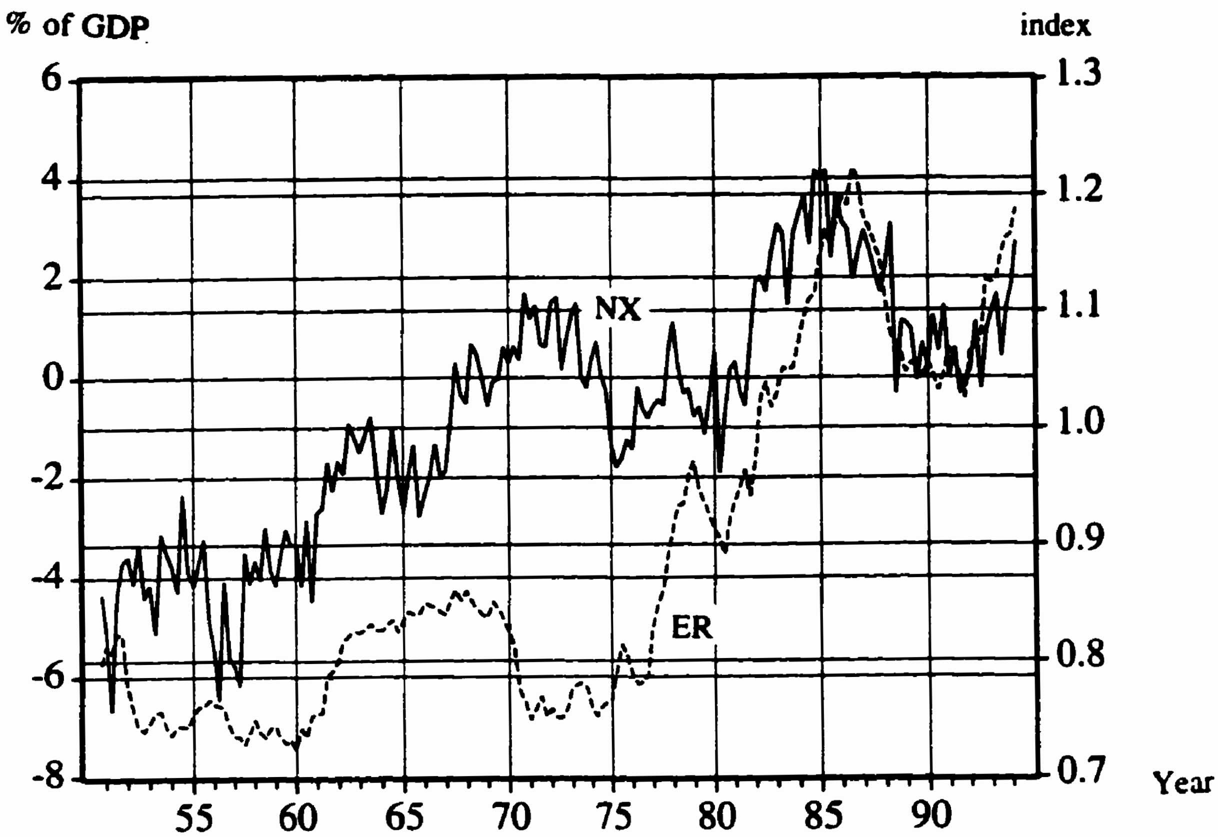


Figure 5-3 Net Export-GDP Ratio (NX) and Real Exchange Rate (ER)
Canada/USA 1950:4 - 1994:2



From the figures we can see that the merchandise trade dominates the changes in net exports, and net exports dominate the changes in the current account. Therefore, we have reason to believe that the trade model in Chapter 4 is able to explain the behaviours of the net export (which is a component of the IS curve) and the current account (which is a component of the BP curve).

In order to see the relationship between the net export and the exchange rate, Figure 5-3 plots the two series, where *ER* is the real exchange rate between the two currencies, i.e., the nominal exchange rate (the price of foreign currency in terms of the Canadian dollar) times the price ratio of the two countries.

Table 5-1 summarizes the unit root tests on the series of net exports between Canada and the US, *NX*, its first difference, $\Delta NX$, the exchange rate between the two currencies, *ER*, and its first difference, $\Delta ER$, for the period mentioned above. We examine whether a series has a unit root by comparing its ADF test value and corresponding critical value.

**Table 5-1: Unit Root Tests for US Data**
**1950:4 - 1994:2**

| | Variables | | | |
|---|---|---|---|---|
| | NX | ΔNX | ER | ΔER |
| ADF test | -2.14 | -4.86 | -2.30 | -3.73 |
| 5% C.V. | -3.44 | -3.44 | -3.44 | -3.44 |
| *k* | 12 | 8 | 8 | 8 |
| S.E. | .070 | .404 | .017 | .157 |
| Coeff. | -.149 | -1.96 | -.038 | -.586 |
| Constant | .215 | .027 | -.014 | -- |
| Trend | .001 | -- | 1E-4 | -- |
| Adj. $R^2$ | .707 | .883 | .176 | .396 |

The Augmented Dickey-Fuller test (ADF) statistics are the $t$ test statistic of the coefficient of the lagged series. The absolute values of the test are compared with their corresponding absolute critical values at 5% significance level (noted as "5% C.V.") provided by Mackinnon (1991). If the absolute value of the ADF test statistic is greater than the absolute critical value, it indicates that the coefficient of the lagged series is greater than zero at 5% significance level and we should reject the hypothesis of the series in question having a unit root, i.e., it does not follow a random walk. Otherwise, if the ADF test statistic is less than its critical value, we should accept the hypothesis of the series having a unit root.

The third row of the table indicates the effective lengths of lag (which is $k$ in Equation 5-5). Since the right-hand-side items of regression in the Augmented Dickey-Fuller test are lagged values of the left-hand-side variable[2], the estimation quality of $\rho$ depends on the lag length $k$ in the regression, i.e., the value of $R^2$ changes as $k$ changes. Therefore, the power of the test depends on the lag length. The error item fits an ARMA process as $k$ increases and explanatory power improves[3].

---

[2] Whether to include the constant $\alpha$ and the time trend $\beta$ in a regression, depends on the nature of the series under test. For example, for those series like GDP or net export, the two items should be included in the regression. For series like the exchange rate which is unlikely to have intercept and time trend (because the Canadian dollar has no long-run tendency to appreciate or depreciate against the US dollar), including $\alpha$ and $\beta$ in the regression will waste two degrees of freedom.

[3] Theoretically, a sufficient length of lag should be included to capture whatever short run dynamic patterns there may be in the series. Empirically, we may leave in all lag

The rest of the table reports the standard errors (S.E.), the coefficient values (Coeff.) of the lagged series (which is ρ in Equation 5-5), the constant and trend items of the regressions (α and β in Equation 5-5). The last row reports adjusted $R^2$.

The first two columns of the variables show the testing results for net export and its first difference. Since the ADF test statistic for *NX*, -2.14, is smaller than its 5% critical value, -3.44, in terms of absolute value (when $k$ = 12), we accept the null hypothesis of *NX* having a unit root. The result also shows that *NX* has a (very small) long-run trend (0.001) which is a secular drift process as time goes on. For the first difference of net export, Δ*NX*, the absolute value of its ADF test statistic (4.86) is greater than the 5% critical value (3.44), so we reject the null hypothesis of Δ*NX* having a unit root.

The next two columns report the results of the tests on the exchange rate and its first difference. Similarly, we accept the null hypothesis of *ER* having a unit root because its ADF test statistic (-2.30, when $k$ = 8) is smaller than the 5% critical value 3.44 in terms of absolute value, and reject the null hypothesis of Δ*ER* having a unit root, as the absolute value of its ADF test statistic (3.73) is greater than the 5% critical value of 3.44. In addition, the small constant (-0.14) and the near zero coefficient for the trend item (1E-4) indicate that there is no long run tendency of real appreciation or depreciation between Canadian and the US dollars.

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terms up to the length at which the last lag term has a significant coefficient, and drop all lag terms longer than that, as suggested by Phillips, P. (1987).

From the test results we conclude that the series of net exports and the exchange rate may have unit roots, i.e., they are non-stationary. Since their first differences are stationary, we conclude that the two series are integrated of order one, I(1). Therefore, the necessary conditions for both cointegration tests on the two series are satisfied.

**(2) Test on the OECD and the ROW Data**

This section reports the unit root test on the OECD and the rest of the ROW data[4]. The exchange rates, *ER*, are calculated as a weighted sum of the exchange rate indices of Canada's major trading countries which are available in the CANSIM (as listed in Appendix 5-1). The test results are summarized in Tables 5-2 and 5-3.

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[4] Since more than half of Canadian international trade is between Canada and the US, the US trade data is the major component of the OECD and the ROW data sets. Consequently, our tests on the OECD and the ROW will be dominated by the behaviour of the US data. In order to examine the trade activities between Canada and other countries, we isolate the US data from the OECD and the ROW data sets. The non-US data can be obtained by subtracting the US data from the OECD and the ROW data respectively.

**Table 5-2: Unit Root Tests for (non-US) OECD Data**
**1978:4 - 1994:2**

| | Variables | | | | | |
|---|---|---|---|---|---|---|
| | NX | ΔNX | Δ2NX | ER | ΔER | Δ2ER |
| ADF test | -2.77 | -1.77 | -4.39 | -.928 | -2.22 | -2.96 |
| 5% C.V. | -3.51 | -3.50 | -1.95 | -3.50 | -3.50 | -1.95 |
| *k* | 15 | 8 | 5 | 10 | 8 | 6 |
| S.E. | .223 | .697 | 1.14 | .075 | .239 | .735 |
| Coeff. | -.617 | -1.24 | -4.99 | -.070 | -.529 | -2.18 |
| Constant | -2.39 | -.060 | -- | -.021 | .011 | -- |
| Trend | .0049 | -- | -- | 6E-4 | -- | -- |
| Adj. $R^2$ | .415 | .736 | .905 | .456 | .367 | .749 |

**Table 5-3: Unit Root Tests for (non-US) ROW Data**
**1950:4 - 1994:2**

| | Variables | | | |
|---|---|---|---|---|
| | NX | ΔNX | ER | ΔER |
| ADF test | -2.06 | -5.05 | -.055 | -5.10 |
| 5% C.V. | -3.44 | -2.88 | -3.44 | -2.88 |
| *k* | 13 | 9 | 16 | 9 |
| S.E. | .105 | .598 | .039 | .240 |
| Coeff. | -.217 | -3.02 | .002 | -.123 |
| Constant | -.556 | -.039 | .024 | -.013 |
| Trend | -.002 | -- | -5E-4 | -- |
| Adj. $R^2$ | .527 | .838 | .388 | .504 |

The test results for the OECD data are summarized in Table 5-2. From the first column of the results we can see that the test statistic for net export (-2.77, when $k = 15$) is smaller than the 5% critical values (-3.51) in terms of absolute values, so we accept the null hypothesis of *NX* having a unit root. The estimated trend is 0.0049, which is about 5 times bigger than the trend in the US data (where the trend is 0.001). Since the first difference series, $\Delta NX$, in the next column, also follows a random walk (the absolute value of the test statistic, 1.77 (when $k = 8$), is smaller than the 5% critical value, 3.50), we continue to test its second difference, $\Delta 2NX$. The result in the third column shows that $\Delta 2NX$ is a stationary series, because the absolute test statistic, 4.39 (when $k = 5$), is greater than its corresponding 5% critical value, 1.95. Therefore we know that net export may be integrated in order two: $NX \sim I(2)$.

The next three columns report the test results for the exchange rate, *ER*, and its differences, $\Delta ER$ and $\Delta 2ER$ (at effective lag length $k = 10, 8, 6$, respectively). Since the absolute values of the test statistics for *ER* and $\Delta ER$ (0.928 and 2.22, respectively) are smaller than the corresponding 5% critical value (3.50), and the statistic for $\Delta 2ER$ (2.96) is greater than its 5% critical value (1.95), for the same reason, we conclude that the exchange rate is $ER \sim I(2)$.

Table 5-3 reports the test results for the ROW. The absolute values of the test statistics for *NX* and *ER* are 2.06 and 0.55 (at effective lag length $k = 13, 16$, respectively), which are smaller than the 5% critical value, 3.44. The statistics for the first difference of the two series are (5.05 and 5.10, at $k = 9$), which are greater than the 5% critical value, 2.88. Therefore, we conclude that both net export and the exchange rate have unit roots, and they are integrated of order one: $NX \sim I(1)$, $ER \sim I(1)$.

The results of the unit root tests in Tables 5-1, 5-2 and 5-3 suggest that both net export and the exchange rate follow random walk. In addition, the tests on their difference show that each of the two series is integrated in order one (the only exception is for the OECD data which suggested the series are integrated in the second order). So we conclude that the two series have unit root and, therefore, we use cointegration tests to examine the possibility of a hysteretic relationship between them.

## II Cointegration Tests

Two different tests are performed to test cointegration between net export and the exchange rate: the Engle-Granger (EG) test and the Johansen test. The EG tests a single equation by examining whether a linear combination of *NX* and *ER* (the residual *u* of their regression) has a unit root. If the residual is a stationary series, *NX* and *ER* are cointegrated. Therefore, the EG method is similar to the ADF unit root test. The Johansen test is a VAR matrix test which estimates the ratio of a restricted likelihood function (in our two variable case, the restriction is the unit root $\rho = 1$) and unrestricted likelihood function, and compares the ratio with its *chi* distributed critical values. We accept the null hypothesis that *NX* and *ER* are not cointegrated if the likelihood ratio is smaller than the critical value.

The results of the two tests are reported in Tables 5-4 and 5-5.

**Table 5-4: Summary of Engle-Granger Tests on Net Export and Exchange Rate**

| | Data Sets | | |
|---|---|---|---|
| | US | OECD | ROW |
| EG test | -2.27 | -2.86 | -2.47 |
| 5% C.V. | -3.84 | -3.94 | -3.84 |
| *i* | 20 | 12 | 11 |
| S.E. | .075 | .121 | .116 |
| Coeff. | -.170 | -3.47 | -.278 |
| Trend | -.008 | -.010 | .005 |
| Adj. $R^2$ | .749 | .410 | .551 |

**Table 5-5: Summary of Johansen Test on Net Export and Exchange Rate**

| | Data Sets | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | US | | | (non-US) OECD | | | (non-US) ROW | | |
| | I | II | III | I | II | III | I | II | III |
| LL. Ratio | 3.46 | 2.08 | 5.27 | 10.83 | 5.72 | 12.23 | 16.83 | 7.07 | 19.04 |
| 5% C.V. | 15.41 | 12.53 | 19.96 | 15.41 | 12.53 | 19.96 | 15.41 | 12.53 | 19.96 |
| 1% C.V. | 20.04 | 16.31 | 24.60 | 20.04 | 26.31 | 24.60 | 20.04 | 16.31 | 24.60 |

Table 5-4 summarizes the EG tests between the series of net exports and the exchange rates. The EG test compares the $t$ statistics of the lagged residual, $\Delta u_t$ (in Equation 5-8), with their corresponding critical values at 5% significance level (noted as "5% C.V."). If the absolute value of the EG test statistic is smaller than the critical value, it indicates that the coefficient of the lagged series is greater than zero at 5% significance level and we should accept the hypothesis of the series in question having a unit root, i.e., *NX* and *ER* are not cointegrated. Otherwise, if the EG test statistic is greater than its critical value, we should reject the hypothesis of the series having a unit root.

In order to capture the entire dynamic pattern of $\Delta u_t$, we estimated all possible lag terms up to the length at which the last lag term has a significant coefficient. The effective lag interval $i$ is reported for each set of data.

The results show that the absolute values of the EG test, 2.27, 2.86, and 2.47, for the US, the (non-US) OECD, and (non-US) ROW, are all smaller than their corresponding 5% critical values, 3.84, 3.94, and 3.84, respectively. Therefore, we accept the null hypothesis of the residual series $u_t$ having a unit root, i.e., the linear combination of *NX* and *ER* is not stationary, and the two series are not cointegrated.

In addition to the EG tests, we used the Johansen test to examine further a possible cointegration between the series of net exports and the exchange rate, and the results are summarized in Table 5-5.

The Johansen Test is performed according to different assumptions on the possible cointegration relationship between *NX* and *ER*. In table 5-5, "I" stands for the assumption of a linear deterministic trend between the two series and an intercept in the regression; "II" stands for the assumption of no deterministic trend but with an intercept; and "III" means no deterministic trend and no intercept. Since estimated coefficients in VAR models have no explicit meaning to be interpreted[5], we only report the log-likelihood ratio (L.L. Ratio) of the $H_0$ (which is, no cointegration between the series) in each regression, and compare it with its corresponding critical values with given level of significance (5% and 1%, respectively).

Because all of the values of L.L. ratios are smaller than their corresponding critical values (except for the ROW data under assumption I), we conclude that the null hypothesis should be accepted, i.e., *NX* and *ER* are not cointegrated.

The Engle-Granger test and the Johansen test examine stationarity of the linear combination of two series, which tells whether or not the two series move in the same direction in the long-run. The results in Tables 5-4 and 5-5 suggest that *NX* and *ER* do not move together, i.e., they are not cointegrated for the three data sets during the periods

[5] Hall, et. al (1994) pointed this out, and explanation is given by Griffiths (1993) and Intriligator, et. al. (1996).

of time mentioned above.

Since both of the series of net exports and the exchange rate follow random walk, to examine a cointegration relationship of the two series is to find a long-run relationship between them. Our testing of the US, the OECD, and the ROW data suggests that such a relationship does not exist. The results verify Chinn's (1991) study, which concluded that "the difficulty in finding cointegration is consistent with the hypothesis of hysteresis in trade". Intuitively speaking, no cointegration means lack of a tendency for the two series to move together, i.e., a functional relationship between the net export and the exchange rate could not be found. Therefore the results support the hypothesis of trade hysteresis.

We have performed the unit root test and the cointegration tests on three data sets: the US, the (non-US) OECD, and the ROW, for different lag lengths and time periods. The test results could be summarized as the following points:

---- Both net export *NX* and the exchange rate *ER* have unit roots, i.e., the series follow random walks, but their difference series are stationary.

---- There is no convincing evidence to show that *NX* and *ER* are cointegrated.

The existence of unit roots in the two series serves as a preliminary condition for the hypothesis of trade hysteresis. Our cointegration tests suggested that the two series are not cointegrated, which verifies the hypothesis (as it was discussed by Chinn 1991). Therefore, our test results are in favour of trade hysteresis.

## 5.2. ESTIMATION OF THE PHILLIPS CURVE

### 5.2.1 Estimation Equation

The focus of studies in labour market hysteresis is to test for the existence of the Non Accelerating Inflation Rate of Unemployment (NAIRU). The NAIRU can be determined through estimating the Phillips curve. An empirical version of the Phillips curve is commonly expressed as the following[1]:

$$\pi_t = \alpha\pi_{t-1} + \beta(u_t - u^*) + \varepsilon_t \qquad (5\text{-}10a)$$

where $\pi_t$ is inflation rate, and the lagged inflation rate $\pi_{t-1}$ in the right hand side is used to model the expected inflation. $u^*$ is the NAIRU, and $\varepsilon_t$ is residual. Since the NAIRU is not observable, to specify $u^*$ become the problem of empirical analysis. Gordon (1989) suggested that $u^*$ is determined by the previous unemployment rate, $u_{t-1}$, and a vector of exogenous variables, $Z_t$:

$$u_t^* = \eta u_{t-1} + \gamma Z_t \qquad (5\text{-}10b)$$

[1] Its theoretical rationale corresponds to Equation 2-6.

Equations 5-10 could be read as a summary of the aggregate supply side analysis. As the major indicator of economic performance, inflation, $\pi_t$, reflects general market pressure (on the right-hand-side of the equation), which is defined as the unemployment gap (or equivalently, the GDP gap), and the gap is explained by shock factors, $Z_t$. The model developed in Chapter 4 suggests that for a small open economy, the domestic inflation is not only determined by the domestic factor (i.e., GDP gap), but is also affected by shocks from the rest of the world (i.e., shocks of the foreign exchange rate). According to Equation 4-36, $Z_t$ can be specified as:

$$Z_t = (1-\gamma)g\left(\frac{E_t - E_{t-1}}{E_{t-1}}\right) \tag{5-11}$$

Therefore, the empirical form of the Phillips curve can be written as:

$$\begin{aligned} \pi_t &= \alpha\pi_{t-1} + \beta(u_t - (\eta u_{t-1} + \delta e_t)) + \varepsilon_t \\ &= \alpha\pi_{t-1} + \beta u_t - (\beta\eta)u_{t-1} - (\beta\delta)e_t + \varepsilon_t \\ &\textit{where} \\ e_t &= \left(\frac{E_t - E_{t-1}}{E_{t-1}}\right), \qquad \delta = \frac{(1-\gamma)g}{\gamma} \end{aligned} \tag{5-12}$$

In this small open economy version of the Phillips curve, if $\alpha = 1$ (and there is no external shock), then the NAIRU corresponds to a steady state situation where the inflation level entirely depends on its history. Some New Classical theories[2] treated the NAIRU hypothesis as consistent with a value of $\alpha$ below unity, since with some time series processes for the price level, rational agents will form expectation with a weight which is less than unity on lagged inflation. The most important parameter for this study is the value of $\eta$, because hysteresis arises when the NAIRU depends on lagged unemployment significantly. Full hysteresis is defined as $\eta = 1$. In order to test hysteresis, the right hand side of the above equation can be written in terms of $u_t$ and its first difference:

$$\begin{aligned} \pi_t &= \alpha\pi_{t-1} + \beta[(1-\eta)u_t + \eta(u_t-u_{t-1}) - \delta e_t] + \varepsilon_t \\ &= \alpha\pi_{t-1} + \beta(1-\eta)u_t + \beta\eta(\Delta u_t) - \beta\delta e_t + \varepsilon_t \end{aligned} \tag{5-13}$$

From Equation 5-10 we can tell that the parameter $\beta$ should be negative. Since the exchange rate shock item, $e_t$, can be transformed into a logarithmic form[3], so the Phillips curve can be estimated as:

[2] For example, Sargent (1971) pointed out that Friedman's Natural Rate Hypothesis (1968) should be consistent with $\alpha < 1$.

[3] Since the series of exchange rate $E_t$ is a function of time $t$, so:

$$e_t = \frac{E_t - E_{t-1}}{E_{t-1}} \approx \frac{\frac{dE}{dt}}{E} = d(logE_t) \approx \Delta(logE_t)$$

where "log" stands for the natural logarithm.
From now on, $e_t = \Delta(\log E_t)$.

$$\pi_t = a_0 + a_1\pi_{t-1} + a_2u_t + a_3\Delta u_t + b_1(\Delta \log E_t) + \varepsilon_t \qquad (5\text{-}14)$$
$$= a_0 + a_1\pi_{t-1} + a_2u_t + a_3\Delta u_t + b_1e_t + \varepsilon_t$$

The parameters, $\alpha$, $\beta$, $\eta$, and $\delta$, can all be identified from regression coefficients $a_i$ (i = 1, 2, and 3) and $b_1$:

$\alpha = a_1$; $\beta = a_2+a_3$; $\eta = a_3/(a_2+a_3)$; and $\delta = -b_1/(a_2+a_3)$.

The degree of hysteresis is measured as:

$$\eta = a_3/(a_2+a_3) \qquad (5\text{-}14')$$

The expression (5-4') can be considered a definition of labour market hysteresis which says that the degree of hysteresis, $\eta$, is determined by the relative ratio[4] of the coefficients of previous unemployment rate, $u_{t-1}$ and the change in current unemployment rate, $u_t$.

How does the external shock, which is measured by $b_1$, affect domestic hysteresis? Even though the expression (5-14') does not directly involve $b_1$, since the four theoretical

[4] This relative ratio measures the weight of $\Delta u_t/(\Delta u_t+u_t)$. The ratio can be read as "how important is the change in $u$ compared with its cumulative (since last period) value", and this ratio emphasizes more cumulative effect than the regular ratio of $u_{t-1}/u_t$.

parameters, $\alpha$, $\beta$, $\eta$, and $\delta$ in Equation 5-13, are simultaneously determined by the four regression coefficients $a_1$, $a_2$, $a_3$, and $b_1$ in Equation 5-14, therefore the exchange shock systematically affects hysteresis $\eta$ through the process of the Phillips curve estimation. According to the theoretical model developed in the previous chapter, including measures of external exchange shocks makes the Phillips curve equation properly specified for a small open economy, and so removes some specification errors from estimates of $a_2$ and $a_3$, thereby affecting domestic hysteresis $\eta$. Intuitively speaking, if the exchange rate shocks are responsible for changes in domestic inflation rate, then the total deviation of $\pi_t$ should be partially explained by $e_t$ (i.e., $b_1$, significantly differs from 0). As a result, estimates of $a_2$ and $a_3$ should be closer to their true values[5].

Equations 5-13 and 5-14 suggest that domestic inflation is affected by a change in the exchange rate, which is a result of theoretical analysis in Chapter Four. However, the Purchasing Power Parity (PPP) implies a contrary view of causation, i.e., changes in inflation cause changes in the exchange rate. A Granger causality test is employed to empirically verify our hypothesis against the PPP.

The available period for the data set is from the first quarter of 1966 to the third quarter of 1994. The inflation rate, $\pi_t$, is computed from CPI, and the exchange rate

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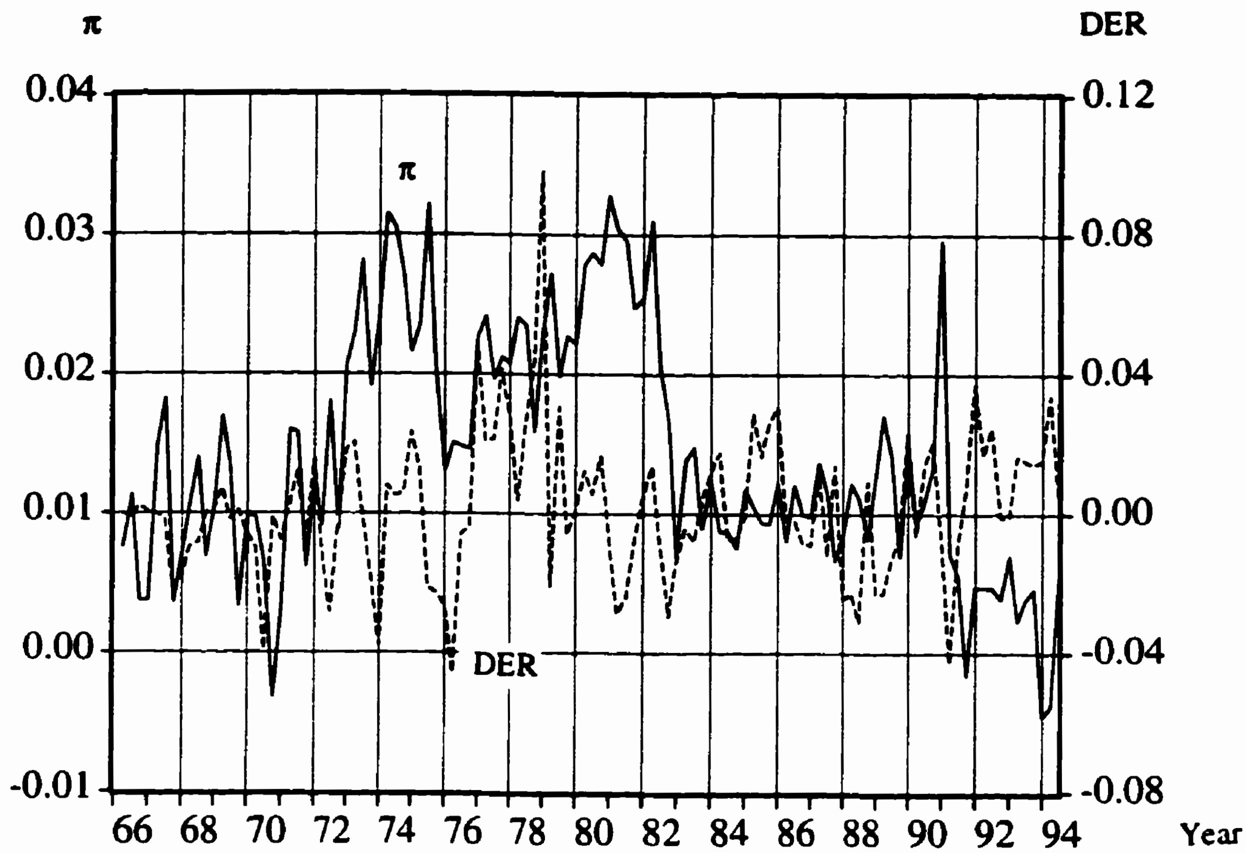
[5] Comparatively, Fortin (1991, 1993) estimated the Phillips curve with the same data but without considering the external shocks, and his results are significantly different from other similar studies, e.g., Poloz and Wilkinson (1992). The differences among them could be due to bigger estimating errors involved in their model specifications.

index, $E_t$, is the trade-weighted sum of exchange rates. Figure 5-4 plots the series of the inflation rate and the change in the log exchange rate.

Figure 5-4 Inflation Rate ($\pi$) and Exchange Rate (ER)
Canada/ROW 1966:1 - 1994:3



### 5.2.2 Causality Test

The causality test developed by Granger (1969) addresses the question of whether the change in the (log) exchange rate, $e_t$, is a cause of the change in the domestic inflation rate, $\pi_t$, or vice versa. The Granger test examines how much of the current fluctuations in $\pi_t$ can be explained by its past values, $\pi_{t-i}$ ($i$ = 1, 2, 3 ...), and then tests whether adding lagged values of $e_t$ can improve the explanation. Inflation, $\pi_t$, is said to be Granger-caused by the change in the (log) exchange rate $e_t$ if $e_{t-i}$ ($i$ = 1, 2, 3 ...) helps in the prediction of $\pi_t$, or, equivalently, if the coefficients of $e_{t-i}$ are statistically significant; in addition, $\pi_t$ and $\pi_{t-i}$ should **NOT** help to explain $e_t$. Therefore, the Granger test involves the following two steps.

First, test the null hypothesis "**$e_t$ does not cause $\pi_t$**" by running two regressions:

***Unrestricted:***

$$\pi_t = \sum_{i=1}^{n} \gamma_i \pi_{t-i} + \sum_{i=1}^{n} \xi_i e_{t-i} + \varepsilon_t \qquad (5\text{-}15)$$

***Restricted:***

$$\pi_t = \sum_{i=1}^{n} \gamma_i \pi_{t-i} + \varepsilon_t$$

Then use the sum of squared residuals from each regression to calculate an $F$ statistic and test whether the group of coefficients $\xi_i$ ($i$ = 1, 2, 3...) is different from zero at a given significant level. If it is, we can reject the null hypothesis.

Second, test the null hypothesis "$\pi_t$ **does not cause** $e_t$" by running the same regression as above, but switching the positions of $e_t$ and $\pi_t$, and testing whether lagged values of $\pi_t$ are different from zero at a given significant level.

To conclude that changes in the exchange rate cause fluctuations in the domestic inflation rate we need to reject the hypothesis that "$e_t$ does not cause $\pi_t$" **and** not reject the hypothesis that "$\pi_t$ does not cause $e_t$"[6]. Since the theory of the Granger test is couched in terms of the relevance of all past information, so the number of lags, $n$, in the regressions is important for the test and different numbers of lags may produce different test results. In order to get a robust result, we have chosen 10 different lag lengths to run the test: $n$ = 2, 4, 6, ... 20. The lag length of twenty enables us to consider the last five years of information.

The results of the Granger test are summarized in Table 5-6.

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[6] In order to conclude $e_t$ causes $\pi_t$ (and not vice versa), Pindyck and Rubinfeld (1991) suggested that to reject the first hypothesis **and** not reject the second hypothesis are both necessary. Because rejecting the former is not exactly equivalent to "$e_t$ causes $\pi_t$" (just as a verdict of "not guilty" could not be really interpreted as "innocent"), the second step provides additional information on the relationship of the two variables.

**Table 5-6 Causality Tests Between $e_t$ and $\pi_t$ (1966:1-1994:3)**

| n | Obs. # | A: $e_t$ does not cause $\pi_t$ | | B: $\pi_t$ does not cause $e_t$ | |
|---|---|---|---|---|---|
| | | $F_{obs}$ | p-value % | $F_{obs}$ | p-value % |
| 2 | 112 | 3.31 | 4.00 | 1.64 | 19.86 |
| 4 | 110 | 2.41 | 5.39 | 0.98 | 42.26 |
| 6 | 108 | 2.04 | 6.75 | 1.04 | 40.69 |
| 8 | 106 | 1.73 | 10.19 | 0.74 | 65.52 |
| 10 | 104 | 1.26 | 26.93 | 0.33 | 96.98 |
| 12 | 102 | 1.51 | 12.99 | 0.48 | 92.02 |
| 14 | 100 | 1.68 | 8.78 | 0.95 | 51.39 |
| 16 | 98 | 1.84 | 4.40 | 1.20 | 28.86 |
| 18 | 96 | 1.76 | 5.29 | 0.93 | 54.52 |
| 20 | 94 | 1.64 | 7.76 | 0.81 | 69.11 |

where:

Hypothesis A is "$e_t$ does not cause $\pi_t$";

Hypothesis B is "$\pi_t$ does not cause $e_t$".

The results in columns 5 and 6 in Table 5-6 show that values of the $F$ statistic are not significantly different from zero. In other words, the results do not reject Hypothesis B (with probabilities far above 5% or 10% significance level). Therefore, we may believe that the data set does not fit the PPP theory.

The test results for Hypothesis A (in columns 3 and 4) vary as the length of lag changes. The values of the $F$ statistic decrease[7] as the length of lag increases.

When the lengths are short, $n$ = 2, 4, or 6, the values of the $F$ statistic are significantly greater than zero (3.31, 2.41, and 2.04, respectively), which allows us to reject Hypothesis A at the 10% significance level (the probability values for Hypothesis A to be accepted are small: 4%, 5.39%, and 6.75%, respectively).

As the lag length increases, the $F$ values drop faster than their critical values, therefore, the probability of Hypothesis A exceeds the 10% level. We are not able to reject the null hypothesis at 10% significance level when $n$ = 8, 10, and 12 ($F$ = 1.73, 1.26, and 1.51, corresponding to the probabilities for Hypothesis A to be accepted of

[7] As the length of lag inreases, the number of observations decreases, and the degrees of freedom are changed as well.

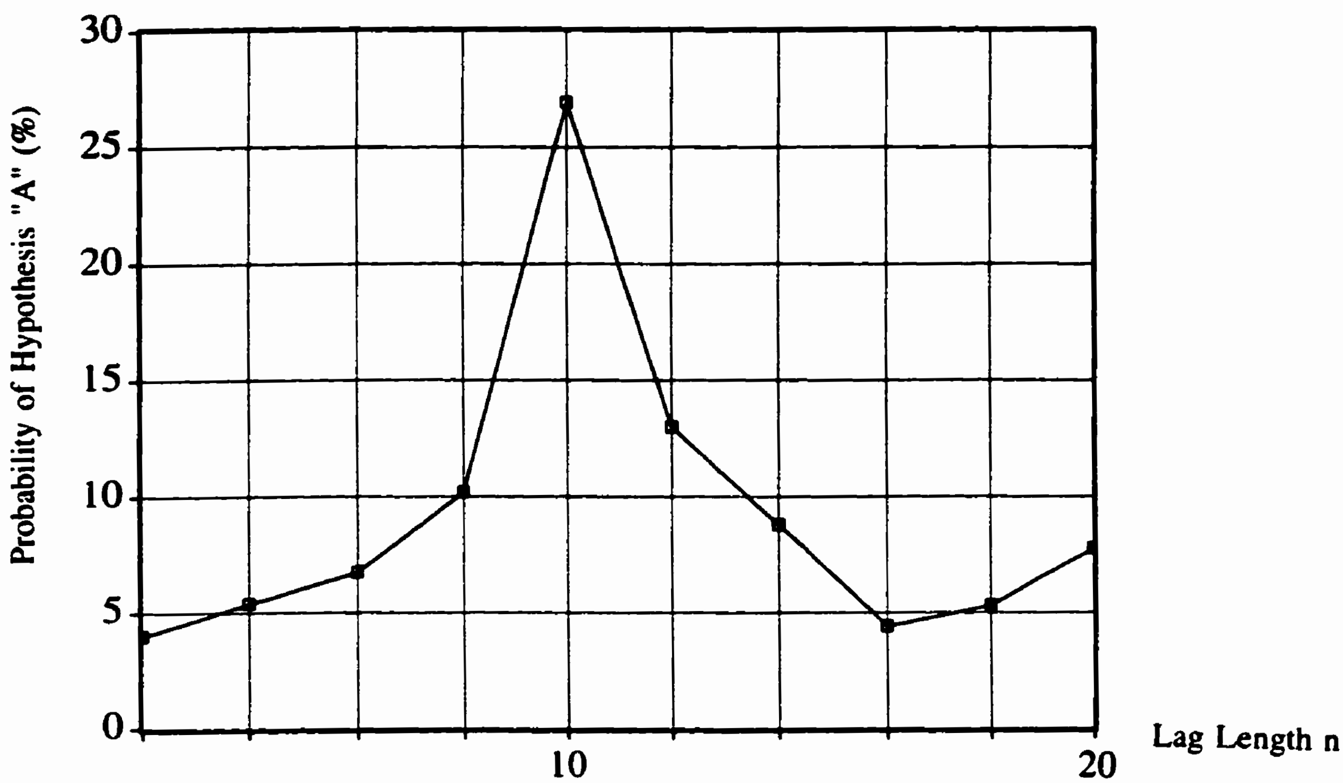
10.19%, 26.93%, and 12.99%, respectively).

Then, as the length of lag increases beyond 12 ($n$ = 14, 16...), the $F$ values stay at a stable range (below 2); therefore, we are able to reject Hypothesis A at 10% significance level. Figure 5-5 shows the relationship between the length of lag and probability of Hypothesis A.

Combining the above analyses (reject A and do not reject B), we conclude that change in the (log) exchange rate causes changes in the domestic inflation rate[8]. Therefore, we proceed to estimate the Phillips curve of the small open economy version.

[8] It may be worthwhile to note at this point that Granger causality could always reflect, not causation between the two variables tested, but both of the variables being jointly caused by some omitted third variable (or, other variables), with different lag lengths. As a result, Granger causality addresses the question of causality, but can not answer it for sure.

Figure 5-5 Relationship Between Probability of A and Lag Length n



### 5.2.3 Phillips Curve Estimation and Hysteresis Test

This section reports estimations on the open economy version of the Phillips curve equation which was a result of Chapter Four. In addition to Equation 5-14, many empirical studies[1] have suggested that the inflation rate is also closely affected by the prices of food and energy. Even though information contained in the inflation rate and the prices of food and energy overlap, the quality of the estimation (biasedness of the estimators) is not affected by adopting the latter as extra explanatory variables to explain the former[2].

Theoretically, these factors could be classified as "shocks" to the inflation rate because food and energy prices are more likely determined by the markets of the rest of the world (exogenous) rather than by the domestic economy. They are important in the sense of being empirically significant (i.e., they could help to improve the quality of regressions, $R^2$, if they are included in the right hand side of the Phillips curve equation). In order to enlarge the variety of dynamic paths in the regression, we add some lagged values for the explanatory variables in the equation. Therefore the Phillips curve (Equation 5-14) can

[1] For example, Fortin 1991, 1993, and Poloz, et al, 1992.

[2] Adding inflation in food price and energy price is more or less equivalent to adding the dependent variable to the list of explanatory variables. Econometric explanation of this treatment can be seen in Kennedy's (1985) Ballentine diagrams.

be specified as the following[3]:

$$\pi_t = a_0 + a_1\pi_{t-1} + a_2 u_t + a_3\Delta u_t + a_4(\Delta u)_{t-1} + b_1 e_t + b_2 e_{t-1} + c_1(p_f)_t + c_2(p_f)_{t-1} + c_3(p_e)_t + c_4(p_e)_{t-1} + \varepsilon_t \quad (5\text{-}16)$$

where $\pi$ is the inflation rate (change in the CPI), $u$ is the unemployment rate, $\Delta u$ is the first difference of $u$, $e$ is change in the exchange rate (first difference), $p_f$ is change in the food price (inflation in food price), and $p_e$ is change in the energy price (inflation in energy price).

In order to see whether any distortion is generated by demographic and policy changes[4], this study uses two unemployment rates separately. One is the aggregate rate for both sexes aged twenty-five and over, and the other is the rate for males aged twenty-five and over. The estimating period is from the first quarter of 1966 to the third quarter of 1994. The estimations include different unemployment rates, whole time period and

[3] Since many macroeconomic variables are likely to have unit roots, as Nelson and Plosser (1982) pointed out, a regression on non-stationary series may produce spurious outputs. In order to avoid possibly biased results of OLS regression, the Johansen test is used to ensure that $\pi$, $u$, $e$, $p_f$ and $p_e$ are cointegrated.

[4] As Fortin (1991) suggested, for example.

its sub-period of 1975-1994[5]. The results are summarized in the following table.

[5] Some studies, e.g. Fortin (1991, 1993), reported that a significant hysteresis occurred in the Canadian economy since the mid 1970's, but other studies, e.g. Poloz and Wilkinson (1992), reported the opposite. So we estimate this sub-period to re-examine the debate from an open economy approach.

**Table 5-7 Phillips Curve Estimation (1966:1-1994:3)**

| Explanatory Variables | Estimations with Different $u$ and Sub-Periods | | | | | |
|---|---|---|---|---|---|---|
| | $I_{66\text{-}94}$ | $II_{66\text{-}94}$ | $III_{75\text{-}94}$ | $IV_{75\text{-}94}$ | $V_{66\text{-}94}$ | $VI_{75\text{-}94}$ |
| $a_0$ (constant) | **-1.95** | **-1.34** | -1.08 | **-1.51** | -.355 | 1.45 |
| | (.633) | (.627) | (.737) | (.687) | (.437) | (1.27) |
| $\pi_{-1}$ | **.489** | **.416** | **.283** | **.274** | **.869** | .104 |
| | (.067) | (.068) | (.097) | (.099) | (.120) | (.089) |
| $u$ | -.298 | **-.445** | **-.988** | **-.684** | -.251 | **-.837** |
| | (.193) | (.236) | (.387) | (.334) | (.158) | (.165) |
| $\Delta u$ | **-.161** | **-.351** | -.495 | **-.561** | **-.325** | **-.972** |
| | (.024) | (.068) | (.395) | (.252) | (.155) | (.163) |
| $(\Delta u)_{-1}$ | **.054** | **.296** | .220 | **.523** | **.464** | -.348 |
| | (.023) | (.069) | (.395) | (.302) | (.144) | (.288) |
| $e$ | **-1.33** | **-1.23** | **-1.87** | -1.43 | .141 | **.311** |
| | (.233) | (.227) | (.442) | (1.42) | (.101) | (.062) |
| $e_{-1}$ | **-.880** | .551 | **1.31** | .713 | .060 | **-.350** |
| | (.225) | (.266) | (.444) | (1.41) | (.139) | (.066) |
| $p_f$ | **.273** | **.271** | **.191** | **.173** | **.103** | **.094** |
| | (.042) | (.040) | (.043) | (.042) | (.012) | (.011) |
| $(p_f)_{-1}$ | **-.279** | **-.280** | **-.216** | **-.198** | **-.129** | **-1.23** |
| | (.043) | (.040) | (.042) | (.043) | (.011) | (.011) |
| $p_e$ | **.041** | **.040** | **.031** | **.033** | **.008** | **.009** |
| | (.011) | (.011) | (.010) | (.010) | (.003) | (.003) |
| $(p_e)_{-1}$ | **-.032** | **-.030** | -.014 | -.015 | .005 | **.008** |
| | (.011) | (.010) | (.012) | (.011) | (.003) | (.004) |
| $\eta$ | **.351** | **.441** | **.334** | **.451** | **.564** | **.537** |
| adj. $R^2$ | .602 | .641 | .720 | .701 | .789 | .882 |
| SER | .430 | .413 | .394 | .404 | .286 | .652 |
| D-W | 1.96 | 1.97 | 1.83 | 1.85 | 2.47 | 2.50 |

* The numbers in the brackets are standard errors.
** The significant (5%, one tail) coefficients are marked in bold type.

The six estimations are specified as the following:

Estimation I uses the aggregate unemployment rate for the whole period (1966:1 - 1994:3);

Estimation II uses the male unemployment rate for the whole period (1966:1 - 1994:3);

Estimation III estimates a sub-period of Estimation I (1975:1 - 1994:3);

Estimation IV repeats Estimation II with its sub-period (1975:1 - 1994:3);

Estimation V uses the aggregate unemployment rate and annual data (1966 - 1994);

Estimation VI estimates a sub-period of Estimation V (1975 - 1994).

From Estimation I we can see that for the entire period (1966:1 - 1994:3), the level of unemployment plays a more important role in explaining the inflation rate than that of the change in the unemployment rate ($a_2$ =-0.298 and $a_3$ = -0.161). The negative signs of the two coefficients verify the negative relationship between inflation rate and unemployment rate. The degree of hysteresis can be determined from the coefficients: $\eta$ = (-0.161)/(-0.298 -0.161) = 0.351 (or 35.1%). Since the degree of hysteresis is fairly small in this period, we may believe that the Phillips curve relationship is quite "normal" on average. In addition, the natural rate of unemployment (for the three decades on average) can be calculated as $a_0/a_2$ (%) = (-1.95)/(-0.298) = 6.54%.

Estimation II considers a different measurement of unemployment rate. When the aggregate unemployment rate is replaced by the male unemployment rate, the relative importance of the **level** of unemployment rate ($a_2$) drops **and the change** of unemployment rate ($a_3$) increases. As a result, the degree of hysteresis rises to 44.1% ($\eta$ = 0.441). Even though the natural rate of unemployment for males ($a_0/a_2$ = 3.01%) is lower than that of the aggregate data set (which is 6.54%), the higher degree of hysteresis for the male data indicates that the unemployment rate for males rose at a higher rate than the aggregate rate. In other words, the series of male unemployment rate experienced a greater deviation from its potential level (the natural rate) during this period than that of the aggregate rate.

The difference between the two estimations could be due to the demographic distortion in the aggregate rate. Fortin (1991) reported that the aggregate unemployment rate had no change on average during the 1980s (at 7.5% level); the male unemployment rate, however, rose by 25% during this period, from 4.8% in 1981 to 6.1% in 1989. The demographic distortion could be caused by the fluctuations of part-time and seasonal employment.

The two estimations show that different measurements of domestic market pressure could result in different significant levels of hysteresis. This discovery helps us to understand the debate between Fortin and the economists of the Bank of Canada: their investigations of the Canadian hysteresis were all focused on the domestic factors, and their different results may have been caused by different measurements of the domestic market pressure. Our study enlarged the investigation scope from the closed economy to the open economy. When the external market pressure (the exchange rate shock) is considered, the Phillips curve is more accurately estimated and the estimated hysteresis should be closer to its true value. The level of hysteresis should not be entirely affected by the measurement of the domestic market pressure. Therefore, we have reason to believe that the results of the open economy approach should be more robust and reliable than that of the closed economy approach.

Economic interdependence became more important for the Canadian economy during the last two decades. Consequently, international market pressure (the external shocks) significantly affected the domestic economic performances in Canada, especially after the first oil shock in the early 1970s, so we conduct estimations for the period of 1975 - 1994 to see whether the international market pressure causes the domestic hysteresis[6].

Estimation III re-estimates the aggregate unemployment rate for the period of the first quarter 1975 to the third quarter of 1994. The result shows that the degree of hysteresis remains unchanged in the two estimations ($\eta$ = 33.4% in Estimation III, and $\eta$ = 35.1% in Estimation I). This is due to the relative ratio of the level of unemployment rate and

[6] The Chow test can be used to check whether the estimates are robust when data sets change, but our focus of re-estimating the sub-set is to see possible changes in significance of hysteresis since the middle of 1970's, and to compare our results with other studies.

the **change** of unemployment rate (or, the importance of the shares of the level and the change to explain change in inflation rate) which remains unchanged ($a_2$ changed from -0.298 to -0.988 and $a_3$ changed from -0.161 to -0.495 in Estimations I and III, respectively).

Estimation IV considers the same time period as Estimation III with the male unemployment rate. There is no significant difference from the levels of hysteresis estimated in IV and II ($\eta_{IV} = 0.451$ and $\eta_{II} = 0.441$). The hysteresis of 45.1% was caused by both domestic and international market pressures.

From Estimations I, II, III, and IV, we can see that the hysteresis phenomenon is quite recognizable, but far from severe in the Canadian economy, as the degree of hysteresis $\eta$ significantly differs from zero but is not close to unity. In other words, we may say that the **change** and the **level** of unemployment rate are both important to explain the changes in inflation because the estimated coefficients $a_3$ and $a_2$ are in the same magnitudes in all of the regressions. The sources of the Canadian hysteresis were found in both the domestic and international market pressure. In addition, a higher degree of hysteresis appeared in the estimations for the male data than in the aggregate data. This is probably because the aggregate data may partially smooth out the significance of existing hysteresis.

The study of Poloz and Wilkinson (1992) suggested that different frequencies of data could also result in different significant levels of hysteresis. An annual data set is more likely to result in hysteresis than a quarterly data set, because hysteresis could be offset by seasonal fluctuations in a quarterly data set[7]. In order to see whether or not the data frequencies affect the result, we use the annual data to repeat the above estimations.

Estimation V repeats Estimation I with the annual data set. The estimation shows that when the data frequency changed from quarterly to annually, the **level** of unemployment rate became relatively less significant ($a_2$ changed from -0.298 to -0251) and the **change** in the rate became much more significant ($a_3$ rose from 0.161 to 0.325 in absolute values). As a result, the degree of hysteresis $\eta$ rose from 35.1% to 56.4%.

When the annual data are used to estimate the period of 1975 - 1994 in Estimation VI, the results are indeed in favour of the hysteresis hypothesis: $a_2$ = -0.837, $a_3$ = -0.972, and $\eta$ = 53.7%. Why does the annual data set result in a higher degree of hysteresis? The reason could be that the seasonal fluctuations in the inflation rate and the unemployment rate may (partially) offset each other and produce a less significant level of hysteresis. Therefore, we suspect that 53.7% (from Estimation VI) should be the level of hysteresis for the Caadian economy, which takes into account both the seasonal fluctuations and the demographic distortions.

[7] The hysteresis test examines whether the change in unemployment rate (the first difference) is important to explain the inflation rate and whether the seasonal fluctuations in unemployment rate could disturb the true values of the first difference. Annual data sets should be more appropriate for the purpose of measuring the first difference.

Comparing the results in Estimations V and VI with those in the previous four estimations, we can see that the data frequency makes a difference in the significance of hysteresis. The annual data results in a level of hysteresis about 20% higher than that of the quarterly data.

In conclusion, our empirical analyses suggest that hysteresis in the Canadian economy is recognizable. However, the level of hysteresis is only around the 50% range, and it is far from its theoretical definition of unity (100%). In addition, our findings suggest that international shocks affect the domestic economy via the exchange rate, and these shocks are largely responsible for the domestic hysteresis.

## CHAPTER SIX

# CONCLUSION

This dissertation investigated hysteresis from the open economy approach, which focused on discovering how the changes in the exchange rates affect both Canadian exports and domestic economic performance. Our theoretical analysis explained the mechanism of hysteresis for a small open economy, and our empirical investigation found that hysteresis was significant in the Canadian economy during the last two decades.

The relationships between the exchange rate and the balance of trade, and between the inflation rate and the unemployment rate (or output level) suggested by the conventional theories, are all functional. Thus, one variable (e.g., the balance of payments) should respond to a change in another variable (e.g., the exchange rate) in a unique pattern which can usually be described by a well-specified (linear or non-linear) function. These theories were briefly reviewed in Chapter Two.

Chapter Three surveyed the literature on hysteresis. The survey found that the existing studies followed two separate lines: trade hysteresis and domestic labour market hysteresis. In addition, most of these studies -- theoretical research and empirical analysis -- concentrated on the European labour hysteresis. Studies on other labour markets and hysteresis in trade were rather in their early stage. This dissertation attempted to combine the two separate lines to study hysteresis in the Canadian economy.

As the theoretical part of this study, Chapter four developed two models of hysteresis for a small open economy which could be applied to the Canadian case: one for the aggregate demand side and one for the aggregate supply side.

The first one presented a hysteretic IS-LM-BP model which showed that trade hysteresis could result in a vertical IS curve and bend the aggregate demand curve up to vertical. A vertical aggregate demand curve explained hysteresis in the domestic economy. The demand-side model discovered that hysteresis could be caused by a hysteretic export component which dominates the entire aggregate demand and bends the aggregate demand curve up to vertical. For a small open economy, when its net exports dominate the aggregate demand and a severe trade hysteresis occurs, a functional relationship between the output level (or unemployment rate) and change in price level disappears (i.e., $\eta = 1$). The vertical aggregate demand curve explained why the trade-off relationship between price and output disappeared.

The second model developed an open economy version of the Phillips curve by allowing the exchange rate to enter the right-hand-side of the equation (which suggests that a change in the exchange rate directly affects domestic inflation rate). The model enlarged the market pressure from the domestic to international and provided a theoretical base for empirical testing, allowing us to determine whether the domestic hysteresis is caused by international market pressure.

Chapter Five conducted empirical tests on hysteresis for the open Canadian economy. The empirical analyses were divided into two parts: trade hysteresis testing and Phillips curve estimation.

The results of the unit root test and the cointegration test were reported in part one. Trade hysteresis was tested by examining whether net exports and the exchange rate are cointegrated in the long-run. The necessary condition of both series being integrated of order one, $I(1)$, was established on ADF unit root tests. The test was based on three groups of data: the US data for the period of 1950:4 - 1994:2; the OECD data for the period of 1978:4 - 1994:2; and the Rest of the Wold (ROW) data for the period of 1950:4 - 1994:2. All of the test results suggested that the series of net exports and exchange rates have unit roots with given levels of significance (5%). The test results also showed that the non-stationary series of net export and exchange rate could be stabilized by taking their first or second order differences.

Both the Engle-Granger and the Johansen tests were performed to examine relationship between net export series and the exchange rate series for the three sets of data. The former uses the $t$ test to examine a single equation model and the latter uses the maximum-likelihood method to test a vector error correction VAR model. All results of the tests show that net export and the exchange rate are not cointegrated, which indicates an existence of trade hysteresis in the open Canadian economy. In other words, there was no statistical evidence to show that changes in net exports could be explained by changes in the exchange rates.

The second part of the empirical analysis estimated the open economy version of the Phillips curve based on the theoretical models developed in Chapter four.

Step one of the estimation performed the causality test between changes in the inflation rate and the exchange rate (i.e., their first differences) with quarterly data for the period of 1966:1 - 1994:3. The results showed that changes in the exchange rate did Granger cause changes in the domestic inflation rate. Therefore, the open economy version of the Phillips curve was verified by the empirical evidence.

The next step was to estimate the Phillips curve, and the degree of hysteresis was calculated from the results of the estimation. In alternative estimations with different measurements of the unemployment rate (the aggregate unemployment rate and the male unemployment rate), different data periods (1966:1 - 1994:3, and 1975:1 - 1994:3), and different data frequencies (quarterly and annually), the results suggested that hysteresis has been significant in the Canadian economy, especially since the middle of the 1970's.

The hysteresis phenomenon is an indication of market imperfections, since a hysteretic relationship between variables suggests that interaction between the forces of demand and supply does not follow well-specified rules in the conventional theories. Theoretically, the hysteresis phenomenon is consistent with the multi-equilibria theory. As a new development of the New Keynesian School, the multi-equilibria theory suggests that possible equilibrium point in an economic system is not unique, and as a result of dynamic adjustment between the forces of demand and supply, the actual equilibrium may end up at an undesirable point (i.e., a high unemployment level) and stay there without a tendency to move back to its previous (desirable) position[1]. The empirical results in this study supported the hysteresis hypothesis for the Canadian economy, and suggested that the sources for domestic labour market hysteresis are found in both the domestic market pressure and that of the rest of the world.

The policy implication of this study is that governments may be called upon to respond necessary shock results, i.e., purposely use policies to help the economy to reach a desirable equilibrium, i.e., a low unemployment rate situation.

Finally, a possible extension of this may be addressed. The theoretical analysis in this study developed two propositions in Chapter Four. The non-monotonic relationship between net exports and the exchange rate (Proposition I) was tested by examining whether the two series were cointegrated, but the vertical aggregate demand curve, as a

[1] Cooper and John (1988), Ball and Romer (1992), and Mankiw (1992) discussed the multi-equilibria theory and concluded that it could result in a coordination failure, i.e., a failure of the market adjustment mechanism.

result of trade hysteresis (Proposition II), remains without empirical verification. Testing whether an aggregate demand curve is vertical, under the condition of trade hysteresis, could be a consideration in future studies. A vertical aggregate demand curve could be tested from alternative approaches. One possible approach is that, from a time series viewpoint, a vertical aggregate demand curve implies that movements of change in the output and change in price drift apart in the long-run, i.e., they are not cointegrated. Therefore, we may simultaneously test integration among series of the output, inflation rate, net export and the exchange rate, to verify the relationship suggested by Proposition II.

## APPENDIX 4-1: RELATIONSHIP BETWEEN U AND X

To show the relationship between line-integral U and integral X (refer to Figure A):

Draw an anxilairy line $S_0G$, such that:

(1) $S_0G \perp OS$; and (2) $S_0G = E_0S_0 = V_0$.

From Figure A we can see that the line-integral, U, measures triangle $OS_0G$, and the integral X measures triangle $OE_0S_0$:

$$X = \int_0^E V\, dE = \frac{1}{2}\ (OE_0)\ (E_0S_0) = \frac{1}{2} V_0 (OE_0)$$

$$U = \int_S V\, ds = \frac{1}{2} (OS_0)\ \ (GS_0) = \frac{1}{2} V_0 (OS_0)$$

Therefore, the relationship between $OE_0$ and $OS_0$ can be seen:

$\because\ OE_0 / OS_0 = \cos\alpha$;
$\therefore\ OS_0 = (1 / \cos\alpha)\ OE_0$.

$\because$ (1) $(\cos\alpha)(\sec\alpha) = 1$; (2) $\sec^2\alpha - \tan^2\alpha = 1$; and (3) $\tan\alpha = a$

$$\therefore\ OS_0 = (\sec\alpha)\ (OE_0) = \sqrt{1+\tan^2\alpha}\,(OE_0) = \sqrt{1+a^2}\,(OE_0)$$

$$so,\ \ U = \frac{1}{2} V_0 \sqrt{1+a^2}\,(OE_0) = \sqrt{1+a^2}\ X$$

$$that\ is,\ \ X = \frac{1}{\sqrt{1+a^2}}\ U \qquad Q.E.D.$$

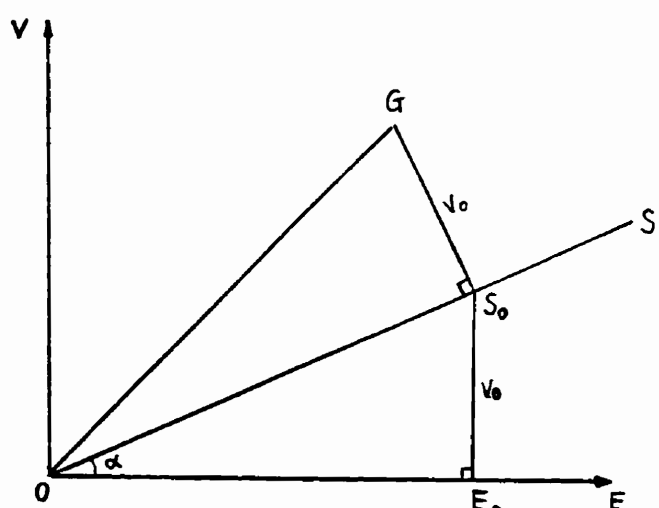



Figure A

## APPENDIX 4-2: LINE-INTEGRAL CALCULATION

The line-integral Calculation (refer to Figure 4-2)

Because the linearized loop (Equation 3) $s = \sum s_i$, $i = 1, 2, 3$, so U can be calculated as:

$$U = \sum_{i=1}^{3} U_i$$

$$\textit{where} \quad U = \int_s P_f\, V\, ds; \quad U_i = \int_{s_i} P_f\, V\, ds, \quad i = 1,2,3.$$

$$\textit{since} \quad ds = \sqrt{(dV)^2 + (dE)^2} = \sqrt{1 + \left(\frac{dv}{dE}\right)^2}\, dE = \sqrt{1+a^2}\, dE,$$

$$\textit{so,} \quad \int_s P_*\, V\, ds = \int_0^E P_*\, V\sqrt{1+a^2}\, dE$$

Now we can calculate $U_i$ one by one.

(a) $s \in s_1$ (exchange rate shock comes):

$$U = U_1$$

$$U_1 = \int_0^E a\, P_f\, E\sqrt{1+a^2}\, dE = \frac{aP_f\sqrt{1+a^2}}{2} E^2$$

$$\textit{by Equation 4-5:} \quad X = \frac{aP_f}{2} E^2$$

(b) $s \in s_2$ (during hysteresis process, the short run):

$$U = U_1(E_p) + |\, U_2\, |$$

$$|\, U_2\, | = \left|\int_{E_p}^{E} aP_f E_p\sqrt{1+a^2}\, dE\,\right| = \int_E^{E_p} aP_f E_p\sqrt{1+a^2}\, dE = aP_f\sqrt{1+a^2}\, E_p(E_p - E)$$

$$\textit{by Equation 4-5:} \quad X = aP_f E_p\left(\frac{3}{2}E_p - E\right)$$

(c) $s \in s_3$ (cumulative effects caused by the shock, the long run):

$$U = U_1(E_p) + |\, U_2(E_0)\, | + |\, U_3\, |,$$

$$|\, U_3\, | = \left|\int_{E_0}^{E} P_f(aE + V_0)\sqrt{1+a^2}\, dE\,\right| = \int_E^{E_0} P_f(aE + V_0)\sqrt{1+a^2}\, dE$$

$$\because \quad E_0 = hE_p; \quad V_0 = a(1-h)E_p$$

$$\therefore \quad |\, U_3\, | = aP_f\sqrt{1+a^2}\left[\frac{1}{2}(h^2E_p^2 - E^2) + (1-h)E_p(hE_p - E)\right]$$

$$\textit{by Equation 4-5:} \quad X = aP_f\left[\frac{3-h^2}{2}E_p^2 - (1-h)E_pE - \frac{E^2}{2}\right]$$

## APPENDIX 4-2: LINE-INTEGRAL CALCULATION

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Because the linearized loop (Equation 3) $s = \sum s_i$, i = 1, 2, 3, so U can be calculated as:

$$U = \sum_{i=1}^{3} U_i$$

$$\text{where} \quad U = \int_s P_f \, V \, ds; \quad U_i = \int_{s_i} P_f \, V \, ds, \quad i = 1,2,3.$$

$$\text{since} \quad ds = \sqrt{(dV)^2 + (dE)^2} = \sqrt{1 + (\frac{dV}{dE})^2} \, dE = \sqrt{1+a^2} \, dE,$$

$$\text{so,} \quad \int_s P_* \, V \, ds = \int_0^E P_* \, V \sqrt{1+a^2} \, dE$$

Now we can calculate $U_i$ one by one.
(a) $s \in s_1$ (exchange rate shock comes):

$$U = U_1$$

$$U_1 = \int_0^E a \, P_f \, E \sqrt{1+a^2} \, dE = \frac{aP_f\sqrt{1+a^2}}{2} E^2$$

$$\text{by Equation 4-5:} \quad X = \frac{aP_f}{2} E^2$$

(b) $s \in s_2$ (during hysteresis process, the short run):

$$U = U_1(E_p) + | U_2 |$$

$$| U_2 | = | \int_{E_p}^{E} aP_f E_p \sqrt{1+a^2} \, dE | = \int_{E}^{E_p} aP_f E_p \sqrt{1+a^2} \, dE = aP_f\sqrt{1+a^2} \, E_p(E_p - E)$$

$$\text{by Equation 4-5:} \quad X = aP_f E_p(\frac{3}{2}E_p - E)$$

(c) $s \in s_3$ (cumulative effects caused by the shock, the long run):

$$U = U_1(E_p) + | U_2(E_0) | + | U_3 |,$$

$$| U_3 | = | \int_{E_0}^{E} P_f(aE + V_0)\sqrt{1+a^2} \, dE | = \int_{E}^{E_0} P_f(aE + V_0)\sqrt{1+a^2} \, dE$$

$$\because \quad E_0 = hE_p; \quad V_0 = a(1-h)E_p$$

$$\therefore \quad | U_3 | = aP_f\sqrt{1+a^2}[\frac{1}{2}(h^2E_p^2 - E^2) + (1-h)E_p(hE_p - E)]$$

$$\text{by Equation 4-5:} \quad X = aP_f[\frac{3-h^2}{2}E_p^2 - (1-h)E_pE - \frac{E^2}{2}]$$

## APPENDIX 5-1: DATA SOURCES

The variables in Chapter 5 are specified as following (with CANSIM series numbers):

### (A) Trade Flow Series (in $million)

| | |
|---|---|
| $BOP_{US}$: | Balance of payments, Canada/US, (D71669) |
| $CU_{US}$: | Current account, Canada/US, (D71102) |
| $MT_{US}$: | Merchandise trade account, Canada/US, (D71103) |
| $CP_{US}$: | Capital account, Canada/US, (D71145) |
| $BOP_{UK}$: | Balance of payments, Canada/UK, (D71201) |
| $CU_{UK}$: | Current account, Canada/UK, (D71202) |
| $MT_{UK}$: | Merchandise trade account, Canada/UK, (D71203) |
| $CP_{UK}$: | Capital account, Canada/UK, (D71245) |
| $BOP_{EC}$: | Balance of payments, Canada/EC, (D71301) |
| $CU_{EC}$: | Current account, Canada/EC, (D71302) |
| $MT_{EC}$: | Merchandise trade account, Canada/EC, (D71303) |
| $CP_{EC}$: | Capital account, Canada/EC, (D71345) |
| $BOP_{OECD}$: | Balance of payments, Canada/OECD, (D71501) |
| $CU_{OECD}$: | Current account, Canada/OECD, (D71502) |
| $MT_{OECD}$: | Merchandise trade account, Canada/OECD, (D71503) |
| $CP_{OECD}$: | Capital account, Canada/OECD, (D71545) |
| $BOP_{ROW}$: | Balance of payments, Canada/Rest of world, (D71001) |
| $CU_{ROW}$: | Current account, Canada/Rest of world, (D71002) |
| $MT_{ROW}$: | Merchandise trade account, Canada/Rest of world, (D71003) |
| $CP_{ROW}$: | Capital account, Canada/Rest of world, (D71045) |

### (B) Price and Exchange Rate Series

| | |
|---|---|
| CPI: | Consumer price index for all items, 1986=100, (P484000) |
| IPP: | Industrial product price index, 1986=100, (D613420) |

| | |
|---|---|
| $P_{IMP}$: | Paasche import price index, all countries' total major goods, 1986=100, (D750000) |
| $P_{EXP}$: | Paasche export price index, all countries's total major goods, 1986=100, (D751020) |
| $P_{US}$: | US consumer price index, all items, 1984=100, (D139105) |
| $ER_{US}$: | Canada/US spot exchange rate, (B3400) |
| $ER_{FR}$: | Canada/France spot exchange rate, (B3404) |
| $ER_{GER}$: | Canada/Germany spot exchange rate, (B3405) |
| $ER_{ITL}$: | Canada/Italy spot exchange rate, (B3406) |
| $ER_{JAP}$: | Canada/Japan spot exchange rate, (B3407) |
| $ER_{UK}$: | Canada/UK spot exchange rate, (B3412) |
| $ER_{AUS}$: | Canada/Australia exchange rate, (B3425) |
| $ER_{HK}$: | Canada/Hong Kong exchange rate, (B3428) |
| $ER_{MXC}$: | Canada/Mexico exchange rate, (B3430) |
| $ER_{G10}$: | Canada/G-10 exchange rate, (B3418) |
| $ER_{AVG}$: | Average exchange rate, weighted by trade volume between Canada and its trading countries. |

**(C) Output and Unemployment Series**

| | |
|---|---|
| $Y_P$: | Output, GDP in market price ($million), (D10057) |
| $Y_d$: | Income based GDP ($million), (D11000) |
| $U_{25}$: | Unemployment rate for both sex, 25 years old and over (%), (D767262) |
| $U_M$: | Unemployment rate for male, 25 years old and over (%), (D767657) |
| $U_F$: | Unemployment rate for female, 25 years old and over (%), (D767731) |
| $U_{15}$: | Unemployment rate for both sex, 15 years old and over (%), (D767289) |

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