THREE ESSAYS ON NORTH AMERICAN MONETARY UNION

BY

ROSMY JEAN LOUIS

A Thesis
Submitted to The Faculty of Graduate Studies
in Partial Fulfillment of The Requirements
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The University of Manitoba
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Dedication

To my parents for having shown me the way

To Paulo Di Rosmy and Paula

Thanks for your patience, support, and sacrifice

Challenge

My Dear son, Paulo
You always claim that you are smarter than I am, but
Can you beat this?

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ABSTRACT

This thesis has studied the issue of monetary union between the United States, Canada and Mexico and is the first of its kind in terms of scope in the literature. It has employed two econometric techniques: the Structural Vector Autoregression (SVAR) and the Markov switching framework to assess the feasibility of the common currency between the three countries. The SVAR technique is used in the two first essays and the Markov switching methodology is used in the third and last essay. The identification scheme adopted to identify each model is a combination of short- and long-run restrictions in the line of Gali (1992). Essay 1 has uncovered the nature of shocks that affect the United States and Canada by modeling each economy according to their relative degree of openness to international trade. Essay 2 has carried out a similar task for Mexico and Canada and for Mexico and the United States. On a pairwise comparison basis, these two first essays have shed light on how the three economies evolve over time as they are hit by a once-and-for-all shock, which is a prerequisite for any group of countries that envisage a monetary union in the spirit of Mundell (1961). The first two essays implicitly differentiate interaction between economies of relatively the same degree of economic development (United States and Canada) and between less developed and advanced nations (Mexico-U.S., Mexico-Canada). Based on Data taken from different sources that extends over the last four decades, these two essays have shown that shocks that affect Canada and the United States are symmetric in nature and therefore a monetary union is feasible between the two, if such a decision could solely be based on this criterion. As to the possibility of a monetary union between Mexico and Canada and Mexico and United States, there is no clear cut. The degree of shocks asymmetry or symmetry could not be established because the result depends on the order of integration of Mexico's money stock.

Essay 3 has explored the feasibility of monetary union between the three countries by relying on the Markov switching framework. This technique enables us to determine whether there is synchronicity in the dynamics of the economies as they are subjected to frequent shocks and whether the underlying data show signs of a common *North American* cycle. This essay has fulfilled two important tasks: a) it has brought robustness to the findings of Essays 1 and 2, and b) it has offered an alternative way to assess the feasibility of monetary union on the basis of business cycle symmetry or asymmetry. Using quarterly data on industrial production index for the period 1963:3-2002:4, and a classification of the probability regimes into recession, normal growth, and high growth, this essay has first provided evidence that there is synchronization of the business cycles in North America. In simple words, there is a high probability that the three economies go into and out of recession together over time. As to the common cycle feature, a set of pairwise comparison tests has demonstrated that Mexico and Canada share **each** a common cycle with the United States but not with each other. Therefore, this essay has found that a monetary union is most feasible between United States and Canada, thereby corroborating the previous results.

In few words, this thesis has demonstrated that independently of the technique used, the result is the same: Canada and the United States are most suitable for a monetary union. However, if we have to take into consideration the fact that Mexico's economy appears to be moving closer to fulfilling the optimum currency areas criteria, as found in Essay 3 and documented in Christ (2000), the three countries are suitable for a monetary union.

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There is one passage in the Bible that I cherish so much and for which I have no reference, unfortunately. It states: "...If the City is built and God is not the one who built it, whoever built it had built it in vain." I have no doubt in my mind that God is the sole architect of this thesis. The only things I have done thus far are just listen to him and take my dictation. I thank God for the wisdom, knowledge, and abundant life he has given me to complete this dissertation. As you all know, God is invisible but when he is pouring his blessings upon us he usually uses other human beings as intermediaries. The preparation of this thesis involved many individuals to whom I am greatly indebted. I would like to thank my advisory committee for their advice and insightful comments. I owe special thanks to Dr. Wayne Simpson, my principal advisor, for sharing his knowledge and for his invaluable guidance. In taking advanced Econometrics with Dr. Simpson, I have learnt the tools and the how to carry out an empirical investigation. These are assets that will never depreciate with time. Dr. Norman Cameron provided useful comments, theoretical, and technical advices. From the first day I met Dr. Cameron at the Bookstore, I knew that I would take advantage of his expertise. Dr. David Stangeland provided useful feedback. Without these, the thesis would not have reached the completion stage as scheduled. I really appreciate the speed at which you all have read, made corrections and suggestions to this thesis.

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him to enjoy a better future and search for a good purpose in life. May this thesis be a source of inspiration and motivation to him so that one day he could meet the challenge! The usual disclaimer applies.

GENERAL INTRODUCTION

THREE ESSAYS ON NORTH AMERICAN MONETARY UNION

The issue of monetary union between Canada, Mexico, and the United States (U.S.) is a subject that often resurfaces in Canada, usually at times when the Canadian currency is depreciating with respect to the U.S. currency. Yet it remains a relevant policy question of interest to academics, governments, policymakers, and society in general. To that end, there has been a continuous debate as to whether a monetary union between the three countries is a feasible option, a topic that has been discussed on two fronts: qualitative and empirical. The former regroups arguments of opposite views that are more in line with social values, patriotism, culture, and the cost and benefit of the current economic system in Canada. The latter tries to understand through econometric exercises how the dynamic of these economies make them suitable for such arrangement. Needless to say that, whether the approach is analytical or empirical, the motivation for such debate originates from the materialization of the European Union. Therefore, those in favor of such initiative contemplate that the North American Free Trade Agreement (NAFTA) currently in effect between the three countries could be, in the future, extended to what has already been termed the North American Monetary Union (NAMU). As important as this topic could be for Canada, Mexico, and the United States, there has not been a lot contributed on that issue in the economic literature. This thesis intends to fill the gap and is empirical in nature.

The empirical literature has mainly attempted to provide answer to a specific policy question: Is a monetary union between Canada, Mexico, and the United States feasible on the basis of either shock or business cycle asymmetry? The rationale behind the relationship between monetary union and the response of different economies to a similar shock is straightforward. If shocks that hit different countries are symmetric, then these countries have interest in undertaking a monetary union, provided that monetary policy has no real effects and flexible exchange rate does not perform its role as a shock absorber. Previous studies that have investigated this link have mostly made use of the structural vector autoregression (SVAR) technique to look at the impact of a once-and-for-all shock to some key economic variables either across countries, similar regions, or industries of different countries in order to determine whether their responses dictate symmetry or asymmetry. The main drawbacks to these studies, however, were 1) to assume that all economies follow the same dynamics by extracting the structural shocks from the same SVAR model; and 2) not to account for the degree of openness of the economies by leaving aside the real exchange rate. This thesis fills these gaps in two ways.

Firstly, the thesis employs the SVAR methodology to address the issue of monetary union for Canada, Mexico, and the United States by modeling each of these economies differently. That is, Canada and Mexico are modeled each as a small open economy whose policy and exchange rate shocks cannot influence the large neighboring country, which is the U.S.. By contrast, the U.S. is modeled as a relatively closed economy with a strong currency that cares much more about the oil price than the exchange rate and policy shocks that come from Canada or Mexico. This methodology is used in Essays 1 and 2.

Although the first two essays show how each of the North American economies responds to a once-and-for-all shock and how that shock continues to impact the key macroeconomic variables at different horizons, there is no way to account for other innovations that may concurrently perturbed these economies. This brings us to the second valuable contribution of this thesis, which also studies the feasibility of monetary union between the three countries by using a Markov-switching framework that captures the changing nature of the economies as they are subjected to different shocks over time. This technique is explored in Essay 3.

Taken separately, each essay contributes on its own right to the economic literature and taken together, these three essays complement each other and document empirically the monetary union issue between the North American countries. To the best of my knowledge, there are no other studies in the literature with such a scope. The rest of the thesis is organized as follows.

Essay 1 analyzes the feasibility of monetary union between United States and Canada based on the symmetry of macroeconomic shocks. The study covers the period 1961q1 – 2000q4 and uses the structural vector autoregression (SVAR) and the time-varying parameter state space model. The identification scheme considered to identify the structural shocks is a combination of short- and long-run restrictions in the line of Gali (1992). The results suggest that aggregate demand and aggregate supply shocks lean towards symmetry, while monetary shocks are asymmetric. Most importantly, monetary policy shocks in the United States have stronger effects on output than both domestic monetary policy and real exchange rate shocks. Two conclusions are then drawn: monetary policy is not as relevant as previous studies have emphasized, and the real exchange rate does not perform the role of shock absorber for the Canadian economy as many researchers believe. Hence, there is no great loss involved for Canada in losing its monetary policy independence by joining (at least) the United States in a monetary union, if such decision could solely be based on the behavior of shocks across the two countries.

Essay 2 is the first attempt at two pairwise comparisons to tackle the issue of monetary union between Mexico and the rest of the North American countries. It is also the first research to suggest that shocks between Mexico and the United States and between Mexico and Canada may not be asymmetric. To arrive at this finding, the paper has extended the work of Lalonde and St-Amant (1994) to a SVAR of five variables, with real exchange rate and foreign policy instrument being the two new variables. The models are identified by employing an extended combination of short- and long-run restrictions similar to Gali (1992). Based on data that spans the period 1960q1 – 2000q4, the study shows that the degree of shocks asymmetry Mexico and each of the two other countries depends on the order of integration of Mexico's money stock. This can be seen as a setback for previous studies that have uniformly emphasized that shocks between Mexico and the rest of the NAFTA partners were asymmetric.

Essay 3 is the first to have studied the business cycle linkages between Canada, Mexico, and the United States through the Markov-switching framework in order to determine to what extent these countries might be suitable to form a monetary union. The feasibility of the single currency arrangement is assessed on the basis of two criteria: 1) business cycle asymmetry; and 2) identification of a common cycle. Using quarterly data that extends over the period 1963:3 – 2002:4, the paper shows that a monetary union is feasible between the three countries. However, had the decision to enter such arrangement to be made on the grounds of a common cycle, only the U.S. and Canada would have qualified. To some extent these results confirm the findings of the two first essays and, most importantly, show that whether one relies upon structural vector autoregression or on Markov switching technique, Canada and the United States are most suitable for a monetary union.

On The Monetary Union Issue Between United States and Canada: An examination of Macroeconomic Shocks via Stuctural Vector Autoregression (SVAR) Analysis

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May 5, 2004

Abstract

This paper analyzes the feasibility of monetary union between United States and Canada based on the symmetry of macroeconomic shocks. The study covers the period 1961Q1 - 2000Q4 and uses the

structural vector autoregression (SVAR) and the Time-Varying State Space model. The identification scheme considered to identify the structural shocks is a combination of short- and long-run restrictions in the line of Gali (1992). The results suggests that aggregate demand and aggregate supply shocks lean towards symmetry, monetary shocks are asymmetric. Most importantly, monetary policy shocks in the United States have stronger effects on output than both domestic monetary policy and real exchange rate shocks. Two conclusions are then drawn: monetary policy is not as relevant as previous studies have emphasized, and the real exchange rate does not perform the role of shock absorber for the Canadian economy as many researchers believe. Hence, there is no great loss involved for Canada in losing its monetary policy independence by joining (at least) the United States in a monetary union, if such a decision could solely be based on the behavior of shocks across the two countries.

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1 Introduction

This paper is the first of three pairwise-comparisons between North American countries (United States, Canada, and Mexico) on the issue of monetary union. Its objective is to determine to what extent economic shocks between United States (U.S.) and Canada are asymmetric so as to argue whether monetary union is feasible, aside from other considerations such as culture and patriotism. Monetary union is an issue that has been highly debated over the years in Canada, following the publication of the original contribution of Mundell (1961). This debate even becomes overheated every time the Canadian dollar receives a great swing from the U.S. dollar in the foreign exchange market. With the materialization of the North American Free Trade Agreement (NAFTA), the focus of the discussion is whether Canada should take the next step towards pursuing a monetary union with United States and Mexico, a step that requires the abandonment of autonomous use of monetary policy so as to enjoy the benefits of the union. As in many economic decisions to be undertaken, the comparison of costs and benefits are paramount. Basic principles of economics dictate that decisions are favorable up to the point where marginal benefit is equal to marginal cost. An informed decision, in accordance with the optimum currency area, requires that: i) aggregate demand (AD) and aggregate supply (AS) shocks be symmetric, otherwise, production structures need to be homogenous; ii) factors of production to move freely; and iii) a set of fiscal instruments be in place in order to deal with the effects of asymmetric shocks across participating countries [see Kenen (1969), Meade (1957), Mundell (1961), Ingram (1973), and Sachs and Sala-i-Martin (1991)].

In line with most of the research on monetary union [see for example Kenen (1969), Bayoumi and Eichengreen (1993), Krugman (1993)], this paper concentrates on the first requirement. It intends to inform decision makers on whether there is a good reason to believe, on the basis of empirical economic evidence, that a monetary union between Canada and United States makes sense. This goal is pursued by employing both the Structural Vector Autoregression (SVAR) model and a Time-Varying Parameter State Space model. The former allows one to extract the structural innovations and to analyze the dynamic responses of the endogenous variables. The latter is used to determine the degree of symmetry between shocks of the two countries.

Previous studies by Shapiro and Watson (1988), Blanchard (1989), Blanchard and Quah (1989), Gali (1992), and Walsh (1993) have also used SVAR models to study the behavior of business cycle in the United States. Deserres and Lalonde (1994), Dupasquier et al. (1997), Cushman and Zha (1997), and Artis and Ehrmann (2000) extend these authors' work to examine how demand shocks (non-monetary, policy, and exchange rate shocks) and supply shocks affect business cycle behavior in Canada and how these shocks are related to those of the United States. Several identification schemes have been adopted: short-run restriction as in Sims (1986), long-run restrictions as first used by Blanchard and Quah (1989), and a combination of short- and long-run restrictions as originally imposed by Gali (1992). The findings are mixed for U.S. studies. For example, Blanchard and Quah found that AD shocks are the primary source of output fluctuation at all horizons after imposing the restriction that only supply shocks have a long-run effect on output, while Gali (1992) found that supply shocks account for most of the variation in output, around 70 percent. The general finding on monetary union research between U.S. and Canada points to AD and AS shocks being symmetric and monetary policy shocks having real effects on output. Hence, the common conclusion is that monetary union could involve great loss for Canada.

This paper, which covers the period 1961Q1 - 2000Q4, considers the identification scheme of Gali (1992). It identifies five (supply, demand, foreign policy, domestic policy, and real exchange rate) structural shocks for Canada and four (non-oil supply, oil supply, demand, and policy) for the U.S.. The impulse response functions and the forecast-error variance produced by the estimated model accord with the predictions of the underlying modified AD-AS model. Contrary to previous studies on Canada's business cycle, the findings about the U.S. are more pronounced but yet similar to previous studies. In assessing the degree of symmetry between shocks across the two countries, the empirical analysis suggests that : i) AD shocks are symmetric; ii) AS are inclined towards symmetry; iii) the effects of monetary policy as well as real exchange rate shocks on output are minuscule; iv) U.S. monetary policy shocks have more substantial effects on Canadian output than domestic monetary policy shocks, and v) monetary policy shocks are asymmetric. All these lead to the conclusion that monetary union between U.S. and Canada is feasible on the basis of the behavior of structural shocks for the period under analysis.

The remainder of the paper is organized as follows. Section 2 presents the background of the issues at stake. Section 3 contains the literature review. Section 4 discusses the underlying model along with the choice of policy instrument. Section 5 gives a detailed exposition of the SVAR methodology, which intends to enlighten any reader outside the field. Section 6 provides a brief discussion of the State Space model used to assess the nature of shocks across the two countries. Section 7 lays down the restrictions used the empirical phase to identify the structural model. Section 8 analyzes the data . Section 9 presents the main results of the empirical exercise. Section 10 concludes the paper.

2 Background

The backbone of the research on the feasibility of monetary union or any currency arrangement between nations is the theory of optimum currency areas (OCA) developed by Mundell (1961) and extended by McKinnon (1963) and Kenen (1969). These authors have identified conditions under which monetary unions work smoothly, namely, countries and/or regions must be subject to the same economic disturbances so that a common monetary policy can be effective. In the opposite case, each nation is better off by carrying out its independent monetary policy in order to deter or weaken the effects of asymmetric shocks.

In accordance with this theory, most of the subsequent research on Europe's economic and monetary union initiative had mainly focused on the identification of the types of shocks that affect each of the integrated members. The common findings pointed to the existence of substantial asymmetric shocks between nations and hence viewed the loss of monetary independence to be costly [see Chamie et al. (1994); Cohen and Wyplosz (1989); and Weber (1990)]. Although it is too early to question the validity of this research, the important controversy that emerges is whether the existence of asymmetric shocks constitute sufficient evidence against monetary arrangements. In his assessment of the costs of European Monetary Union (EMU) to individual member countries, Melitz (1996) sheds some light on the issue. He argues that when these shocks arise from the foreign exchange markets where trading takes place in different monetary units, a monetary union is the best solution since it rids the economies of the currency substitution problem by enacting a single currency. Melitz further distinguishes between asymmetric shocks that are microeconomic and those that are essentially macroeconomic in nature. In his view, although both originate from the commodity markets, monetary policy carried out either by national central bankers or a common entity (e.g., the European Central Bank) would not be an appropriate response to combat *microeconomic* shocks. As the argument goes, if one sector of the economy faces hardship, any attempt to help this sector to become more competitive, through currency depreciation induced by a reduction of interest rates, may eventually lead to the growth of some industries at the expense of other industries that heavily rely on imported inputs. However, when the dynamics of the economies are such that the shocks are mostly macroeconomic in nature, an independent monetary policy remedy may be superior to that of a common monetary authority, provided Central Bankers could commit to an optimal policy.[1] As Melitz explains, information problems related to the identification of shocks along with the lack of knowledge about the parametric structure of the economy and policy mistakes may make it impossible for monetary authorities to exploit opportunities to im-

[1] There is a large body of literature on this topic, starting from the seminal contribution of Kydland and Prescott (1977) and Calvo (1978) on time-inconsistency problems in the design of both monetary and fiscal policies. The focus is on the ability of central bank to renege once economic agents have committed to a specific level of inflation. For the marginal benefit in terms of output gain is greater than the marginal cost of positive average inflation. Other contributions in this field regroup include the work of Barro and Gordon (1983), Auernheimer (1974). Walsh (1998) chapter 8 provides an extensive treatment and recommends literature surveys by Persson and Tabellini (1990), Cukierman (1992), and Driffill (1988).

prove domestic welfare through independent policy. This discussion seems to be appealing, theoretically. For it shows that under some circumstances the setup of the monetary institution does not matter because the outcome is the same. But how substantiated is the whole argument at the empirical level?

The view that one should differentiate between microeconomic and macroeconomic related shocks appear to receive some support from the works of Bayoumi and Prasad (1995); Stockman (1988); and Bini-Smaghi and Vori (1992). These authors have decomposed output between regions and industries to distinguish between industry-specific shocks, region-specific shocks, and common shocks. In Melitz's assessment, it can be inferred from these authors' findings that a large portion, say 50 percent, is due to industry-specific shocks, a result which indicates that monetary policy in itself would not be an appropriate tool to combat asymmetric shocks. If one is willing to buy Melitz's argument, then it is a forgone conclusion that a common monetary policy is more beneficial for countries than separate policies. As evidenced by monetary unions in effect in Canada as well as in the United States, the Bank of Canada and the Federal Reserves handle all responses to shocks across provinces and states through policy actions, despite the fact that regions in these two countries are partly subject to asymmetric shocks. Research on this issue have not yet determined whether each province or state would be better off if it could carry out its own monetary policy. In this respect, the reality in these two countries may somehow undermine the importance of the research on idiosyncratic shocks.

Although there are disagreements among economists on how to approach the feasibility study of monetary union, the knowledge of how economic disturbances affect a nation and the interdependence of shocks between nations may be summarily important to decision makers before embarking in any negotiation. This may partly explain why studies of these sorts were so popular for the materialization of the European Union. In the case of North America, it seems that the existing literature has not yet flourished, which explains the need for this research in particular. With the exception of a few cases where United States and Canada are chosen for comparison with their European counterparts, there have only been few empirical papers mostly written by researchers at the Bank of Canada on possible monetary union between United States and Canada. These papers emerge as a response to those who have advocated a North American monetary union (NAMU).

Following the materialization of the European Union, the debate on NAMU usually becomes overheated in Canada anytime the Canadian dollar severely depreciates with respect to the U.S. dollar. The main question to which answers have been sought is whether Canada would not have been better off if it had opted for a monetary union with the U.S.. As can be inferred from the discussion above, there are two currents of thought. Proponents of the NAMU, with Courchene (1998) as the leading advocate, purport that such union carries benefits as well as costs for both countries, with obviously a net benefit for Canada on average. In his view, a larger market will be created to compete at the world level and will thereby strengthen the role of the U.S. dollar as a store of value and at the same time rid Canada of its weak dollar, which costs the Bank of Canada around $8 billion to maintain it during periods of turmoil in financial markets. It is also the case that since wages tend to equalize across the two countries, there will be no incentives for Canadian professionals to cross the border for the sake of better opportunities, putting a stop to the brain drain. The impact of a loose Canadian dollar, as Courchene further explains, has more negative impact on the economy than the loss of both monetary independence and seigniorage[around .02 percent of GDP, see Walsh (1998)] for the government. For although it is believed that a weak currency tends to promote exports and discourage imports, which finally gives rise to higher levels of domestic output (the beggar-thy-neighbor policy), he argues that such benefits could lead to competitive depreciation and could also destroy the productive capacity of the country as foreign-produced inputs may not be available due to the reduced purchasing power of the Canadian dollar.

Courchene's arguments are more in line with the predictions of international trade theory textbooks. When one considers the fact that foreigners own a large number of firms in Canadian soil, it becomes evident that a weak currency eventually imposes additional costs to both Canadians and investors who intend to repatriate part of their profits. To what extent are these costs important, so that a call for a monetary union is justifiable? It appears that empirical research, rather than qualitative statements, are needed.

The emphasis of those who oppose monetary union [see Murray, (1999)] is on the loss of Canadian culture, mainly public healthcare and other social programs actually financed by the tax gap between U.S. and Canada. In the monetary front, these authors contend that the loss of seigniorage along with the loss of monetary policy independence may restrain the ability of government to respond to shocks that are proper to Canada. Research done under this banner has centered around 1) the nature of shocks that hit regions in Canada, and 2) the similarities between shocks in Canada and shocks in the United States at the national as well as at the regional levels. Studies carried out by researchers at the Bank of Canada [see Duspasquier et al. (1997); Fenton and Murray (1993); and Kuszczak and Murray (1987)] fall under this category.

In sum, the feedback gathered from this discussion is that economists have not yet found a common ground on how to approach a feasibility study of monetary union between nations. There are two approaches that have been followed: one that looks at the nature of underlying shocks between similar regions or industries across countries, and the other that focuses on the relationship between shocks across borders. This paper uses the latter approach.

3 Literature Review

The research on monetary union mostly emphasizes the implications of asymmetric rather than symmetric shocks. For it is understood that symmetric shocks do not impose costs on potential countries as the policy implemented by a single country would have the same effects if it were implemented by a common authority. Several approaches to modelling asymmetric shocks have been taken over the years. The first line of research looks at how asymmetric shocks permeate the economy and partly suggests means by which their effects could be minimized. The focus is on the role of industry and product diversification, movement of factors of production, adjustments through financial markets, and fiscal redistribution as requirements of an optimum currency area. This may be termed the *"requirement-based approach."* The second approach, which one may call the *"liquidity approach,"* rather relies on price dynamics to investigate asymmetric shocks. The main variables are the real exchange rate and share prices. The third approach, the *"output - price approach,"* which is a combination of the two previous approaches, addresses the same issue by integrating movements in output and prices, and is the most popular under the structural vector autoregression methodology.

1. *The Requirement-based approach*

Kenen (1969) explains asymmetry of shocks by focusing on the degree of industry or product diversification. In his view, asymmetric shocks are likely to be important when countries have different industrial structures and produce different goods. This argument goes more in line with the Bank of Canada's position, which purports that monetary union is not appropriate for Canada because it is an industrial-based, while the U.S. is a consumption-based, economy. In the Bank's view, such arrangements may jeopardize the ability of Canada not only to respond to disturbances originating in the U.S. but in the rest of the world as well.

[Meade (1957), Mundell (1961), and Ingram (1973)] have instead explained the determinants of shocks by the degree of mobility of physical factors of production. Their argument is that the freer these factors move across countries, the lesser the effects of region specific shocks. Building upon the work of these pioneers, recent contributions by Eichengreen (1993), Barro and Sala-i-Martin (1991), Obstfeld and Peri (1998), and Asdrubali, Sorensen, and Yosha (1996) partly show that the speed at which labor mobility contributes to the smoothing of state and province specific shocks is faster in United States and Canada than in Europe. These findings explain why monetary union in these countries could be a success. However, it is not known if the movement of factors can lessen the effects of asymmetric disturbances between U.S. and Canada. As some authors have also recognized, adjustments to shocks through the labor and physical capital markets may take quite some time before the economy would see their effects.

It is perhaps in this vein that Atkeson and Bayoumi (1991) have explored the role of financial capital mobility as a substitute to physical capital mobility. Their model shows that agents can hedge against country-specific shocks by holding assets whose returns are uncorrelated with "region-specific sources of labor and capital income." Sachs and Sala-i-Martin (1991) have in turn emphasized the importance of the fiscal federal system to redistribute wealth across regions in order to reduce asymmetric shock effects.

2. *The Liquidity approach*

Several techniques have been used to capture the extent of asymmetric shocks. Poloz (1990) has computed the variability of the real exchange rate between regions in Canada and the four most important EC countries. His study reveals that real exchange rate varied more among Canadian provinces than among the European countries considered. Eichengreen (1990) focused on covariance analysis of real share prices across important cities, while Cohen and Wyplosz (1989) relied on time series of output to investigate asymmetric shocks.

The limitations of these approaches are that, as pointed out by Eichengreen (1990), and Bayoumi and Eichengreen (1993), observed movements in GDP and prices reflect combined effects of shocks and responses, which are difficult to separate out using the techniques mentioned above.

3. *The Output-Price approach*

In respect to the modeling of the joint movement in output and prices, the work of Bayoumi and Eichengreen (1993) (BE) represents an improvement upon previous studies. These authors argue that approaches taken in previous studies do not allow for a clear-cut distinction between disturbances and impulse responses. They estimate structural vector autoregressions (SVAR)[2] based by the aggregate demand (AD) - aggregate supply (AS) model and obtain the structural shocks after imposing long-run restrictions as proposed by Blanchard and Quah (1989) (BQ hereafter), and Bayoumi (1992). This identification technique allows the researchers to distinguish between shocks having permanent effects from those having temporary effects on output. The Bayoumi et al. (1992) study spans the period 1960-1988 and compares the nature of shocks associated with inflation (for AS dynamics) and output growth (for AD dynamics) in eleven OECD countries. In their examination of Canada and the Unites States (U.S.), they find that supply shocks in Canada and the U.S. are not highly correlated, a finding similar to this paper.

The BE method, nonetheless, has been criticized on the grounds that it only measures covariation between two countries at a time, and is therefore

[2]In the remainder of the paper, an SVAR of order p, SVAR(p), is used. Where p is the number of endogenous variables conforming the system.

not suitable to capture mutual dependency in a larger pool of countries [see Jansson (1997)]. Since the focus of this study is on two countries: U.S. and Canada, one can easily neglect this criticism. However, the main drawbacks of their study as signaled by Dupasquier et al. (1997) are that 1) it ignores monetary shocks, and 2) it hypothesizes that inflation follows a stationary process. In response to the first weakness, it appears that BE deliberately exclude monetary shocks in their model because their objective was to avoid their identified demand shocks being contaminated by policy shocks. The second flaw of the study seems to be more serious. Building upon the work of Phillips (1995), which shows that the use of a non-stationary and quasi-non-stationary variable in a VAR may lead to misleading forecasts, Dupasquier *et al.* in fact show in the appendix to their paper that core inflation (based on CPI excluding food and energy) is non-stationary.

In their study on economic interdependence between Canada, United States and the rest of the world, Kuszczak and Murray (1987) used a traditional VAR with five variables that includes: output, money, prices, interest rates, and exchange rates. Based on quarterly data for the period 1960: 1 to 1984:4 for Canada and the United States, they found that shocks affecting the U.S. economy are rapidly transmitted to the Canadian economy, and account for more than 50 percent of the variance in Canadian variables. Since the authors have used the traditional VAR where identification of shocks is based on the Cholesky decomposition, which has been reproached for its inconsistency with economic theory (see Cooley and Leroy (1985), there is not much sense that can be made of the impulse responses, even though the findings appear to be insightful.

Studies similar to that of Bayoumi et al. (1993) have been carried out by researchers at the Bank of Canada. To take into account the effect of monetary shocks, DeSerres and Lalonde (1994) use a three-variable VAR model, which is composed of inflation, the growth rates of output and the monetary aggregate (M1). The BQ decomposition was also used to identify the three types of shocks (monetary, non monetary AD shocks, and supply shocks) that affect Canada and the U.S. They then use estimates from a state-space model to determine whether shocks across regions in Canada have a common component and whether they have a component common to the American shocks. Their study, which is based on quarterly data and covers the period 1961:1-1992:1, reveals that shocks in Canadian regions are by and large correlated with each other, but the link between these shocks and common shocks in United States are relatively weak. This research also suggests that monetary union is not the best option for Canada.

The same flaw regarding the assumption that the inflation series is stationary was also detected in this study by Dupasquier *et al.* (1997). They also noted that the restriction that only monetary shocks have no long-run effect on real balances, imposed by DeSerres and Lalonde to identify monetary shocks, was somewhat questionable. For it is implied that transitory fiscal shocks might have a permanent effect on real balances, which, according to Dupasquier et al., weaken the analysis when too many shocks are being extracted.

Dupasquier, Lalonde, and St.-Amant (1997) examine the same question using a VAR model with three variables similar to Deserres and Lalonde (1994), except that the monetary aggregate is replaced by the real interest rate to capture the presence of monetary shocks. Their study, which is based on various sources of data and covers the period 1970:1-1995:4, was further extended to an SVAR(4) to looks at the response of nominal exchange rate to the different types of shocks being identified. In part, the impulse responses show that the nominal exchange rate appreciates in the wake of a positive real demand shock to output as domestic prices increase. This finding led them to conclude that the nominal exchange rate contributes in facilitating macroeconomic adjustments, and hence, by abandoning the current exchange rate system, Canada would bear a large burden. What appears to be surprising, however, is that the authors also found that when shock dynamics are taken into account, the correlations between AD and AS shocks in Canada and United States appear to be strong, which implies that (if not pure coincidence) one can predict the response of Canadian variables, say output, to a shock from the responses of U.S. variables to the same shock. This presupposes that there is a common link between the two countries, based on the high correlation of the disturbances, for which a common policy may find its applicability.

There are, however, two drawbacks to the studies reviewed so far. First, the structural shocks are usually extracted from models whose choice of variables reflect closed rather than open economies. Total exports as a share of real GDP clearly shows that Canada is better approximated as an open economy while the U.S. is best viewed as a relatively closed economy (see Carbaugh, 2002). Second, the papers ignore the influence of the Federal Reserve funds rate in the implementation of monetary policy in Canada. If there is irrefutable evidence in the estimation of Canadian monetary policy reaction function, it is that the Fed funds rate is always a significant variable [see Johnson and Siklos (1997), Jean Louis (2002)]. Therefore, the absence of these features in models that aim to recover structural shocks may lead to inferences that are quite misleading, since it is not clear whether these shocks emerge from the true dynamics of the economies. Cushman and Zha (1997) even argue that failure to properly account for the difference in modelling monetary policy between large, but relatively closed, and small, but open, economies may be at the origin of the price and exchange rate puzzles[3] endemic to traditional empirical models.

Two papers stand against these criticisms: Cushman and Zha (1997) and Artis and Ehrmann (2000). The former constructs a VAR model for Canada in which the monetary policy reaction function depends on both contemporaneous exchange rates and U.S. interest rates. They find that monetary policy shocks interpreted as contractionary monetary policy have little impact on Canadian output after a twelve-month period, but a lengthy real appreciation of the exchange rate. Although the United States serves the role of rest-of-the world to Canada in the Cushman and Zha study, there is no insight as to how economic innovations from the two countries are related.

Following a methodology similar to that of Gordon and Leeper (1994),

[3]Contractionary monetary policy that gives rise to an increase in the "home" price level and depreciation of the "home" currency, respectively.

Sims and Zha (1995), and Cushman and Zha (1997), Artis and Ehrmann estimate an SVAR(5) for four open economies (Sweden, Denmark, Canada, and United Kingdom) that builds around the assumption that the large neighboring country's central bank (U.S. taken for Canada) is not really concerned about changes in interest and exchange rates that occur in the small countries; therefore, it does not react to shocks associated with these variables coming from there. The small countries' central banks, on the contrary, are likely to respond quickly to foreign variables, thereby invalidating the assumptions that interest rate innovations are independent. Within this setup, the Fed funds rate and the nominal exchange rate ($C / $US) are explicitly modelled. To take into account exchange rate targeting practices, the exchange rate identification scheme enters in the form of the weight foreign exchange market disturbances have on monetary policy setting. Their results indicate that: 1) the Canadian and the United States economies are mainly hit by symmetric AD and AS shocks, 2) exchange rate is not very responsive to AD and AS shocks, and 3) the exchange rate shocks distort output and/or prices, which favor monetary union between the two countries if one relies on the five criteria relevant for the evaluation of monetary options. Yet, since they also found that 4) monetary policy in Canada has real effects on output, and 5) the exchange rate is largely driven by shocks in the exchange market, they conclude that "monetary union, or dollarization, could involve loss for Canada." How important these losses are compared to the benefits of monetary union in the future is still a mystery.

Although Artis and Ehrmann (2000) is among the most innovative papers on the issue of monetary union between U.S. and Canada, their finding that AD and AS shocks across the two countries are symmetric is solely based on the pure interpretation that both U.S. and Canada interest rates from Canada's SVAR estimation respond in the same way to a one-standard deviation innovation in AD and AS. They do not estimate any regression for the U.S. and therefore do not inform how the U.S. economy evolves over the years nor how it interacts with the Canadian economy. This paper attempts to fill this gap in its choice of variables by modelling the U.S. economy as a relatively closed economy and Canada as an open economy. The economic variables for each regression are then carefully chosen to reflect the relevant specificity of each economy. For example, since the U.S. dollar serves as an anchor for a major number of currencies, there is no reason for the Fed to worry about its fluctuations, therefore the exchange rate does not enter the U.S. SVAR system.

The key innovations in this paper are as follow. First, for the United States, the structural shocks are recovered from a separate SVAR model of four variables, including the oil price. This specification differs from existing analyses in that it separates out non-oil supply shocks from energy shocks to account for their respective impact on the U.S. economy, despite the fact that they do not enter the Fed's monetary policy reaction function explicitly. Second, for Canada, the paper not only uses the responses of foreign and domestic interest rates to assess the extent of symmetric shocks between the U.S. and Canada, it also employs the state space model in order to uncover a more robust result about the link between the shocks across the two countries. Contrary to the approach followed by Artis and Ehrmann (2000), no restrictions are imposed on the exchange rate shocks in order to let the data reveal the patterns of response and transmission.

4 The Model

The starting point of this paper is the popular downward sloping aggregate demand (AD) and the upward sloping aggregate supply (AS) model with a long-run vertical aggregate supply curve (LRAS) found in basic macroeconomic textbooks. Given a position of equilibrium, a positive demand shock gives rise to an increase in output and prices, with output being above full-employment level. It is understood that as pressures amount to increase nominal wages in order for worker to cope with increased output prices, the cost of production for firms will increase, thereby reducing AS. The end result is that output is gradually returned to its previous full employment level but accompanied by a permanent rise in prices.

The situation differs when a positive supply shock occurs. Both the short- and long-run AS curves shift to the right increasing output and decreasing prices on impact. As the AS curve becomes vertical over time, output further increases and prices fall even more. In sum, where as AD shocks affect output only temporarily, aggregate supply shocks have a permanent effect on output. However, this model is not devoid from any criticism.

The traditional IS-LM model from which AD is derived has long been under severe attack for its lack of microfoundations, its restrictive assumption of price stickiness, and the absence of any role for expectations. From the original contribution of Romer (1999, 2000), emphasis has been put on an alternative to the IS-LM-AS model whose variant has been found in textbooks such as Hall and Taylor (1997), and Taylor (1998). The main proposition is to replace the assumption that the central bank targets the money supply with the assumption that it follows a simple interest rate rule. There are at least two advantages in making this new assumption. First of all, it is a more realistic approach since it has been empirically found that central banks in developed countries target a short-term interest rate. The works of [Taylor (1993), Clarida and Gertler (1997), Von Hagen (1995), Bernanke and Mihov (1997), and Laubach and Posen (1997)] are among the most cited in the literature in this respect. However, in Romer's view, the nominal interest rate rule is a rule for the real interest rate. As a matter of fact, in the process of setting the nominal interest rate, the central bank takes into consideration the negative effect of expected inflation on real interest rate. As such, Romer argues that in the very short-run, a nominal rate rule seems to be a more appropriate description of the way central banks conduct policy. However, since the banks factor information about expected inflation into the target level of the nominal rate, which is reexamined frequently, they are implicitly setting the real rate.

The second advantage is derived from the first one. If one accepts the idea that a real interest rate rule is more realistic than a nominal rate rule, there is only a single rate, the real interest rate, which is consistent to both real and monetary sectors. It is thus easier to understand that the AD curve relates inflation and output as opposed to price level and output, eliminating altogether any confusion about the model's prediction. As Romer postulates, the real interest rate (r) can either be expressed as a function of inflation, simply, or as a function of both inflation (π) and output (Y). The former can be depicted as a horizontal line and referred to as the MP curve (for monetary policy) in a (Y, r) space whose purpose is to keep the model simple and easily tractable. The latter is rather more realistic in explaining the behavior of the central banks.

The choice of policy instrument in empirical analysis has always been a controversy. Sims (1980, 1992) showed that when the federal funds rate is added to a VAR of money, price, and output, the fraction of the forecasting error variance in US output that can be attributed to money stock innovations is lower. Not surprisingly, the most common identifying assumption in most of his work is that the monetary policy variable is unaffected by contemporaneous innovations in other variables. Bernanke and Blinder (1992) have argued in favor of the federal funds rate because in their view it produces better forecast of output, employment, and consumption than any other monetary aggregates and short-term or long-term bonds. Eichenbaum

(1992) has pointed out that some narrow money aggregate, say M0, is a better measure of monetary policy than the federal funds rate because it has a lower price puzzle,[4] a situation common to other studies on France, Germany, Japan and United Kingdom. The most commonly accepted explanation of the price puzzle is that it reflects the fact that monetary authorities do not usually possess perfect information and therefore do not respond promptly to prevent inflation. One way to get around this problem according to Sims (1992) is to include a commodity price index or other prices in the VAR. However, these price effects may be reduced but not completely eliminated. McCallum (1993) argues that since a short-term interest rate is the policy instrument used by Fed and the correct measure of monetary policy shocks is the residual in a reaction function for the same interest rate, the fact that the policy instrument only depends on lagged macroeconomic data offers the advantage that the residual not being a mixture of policy shock and other shocks, as it occurs when a monetary aggregate is the instrument of monetary policy.

[4]The price puzzle is that in a VAR of output, prices, money, interest rate, contractionary shocks to monetary policy leads to persistent price increases, which are more pronounced when the policy instrument is the short-term interest rate rather than a money aggregate. It appears that although the price puzzle is not always significant, it is still important since it implies that the VAR might be misspecified [see Walsh (1998), pp. 26-28]

As evidenced by many empirical findings [Taylor (1993), Rudebusch (1995), and Fuhrer (1996)], and as the discussion seems to suggest, in short, for the United States the key policy instrument over most of the last 35 years has been the federal funds rate, or in some rare cases, some narrow money aggregate. In the case of Canada, a recent study by Jean Louis (2002) on Canadian monetary reaction function shows that the Bank of Canada has had a consistent monetary policy over the last three decades with the Bank rate (not a monetary aggregate) as the main policy instrument, a result that is independent of whether core CPI or CPI-all items has been used.

Although the choice of the real interest rate as a policy instrument is appealing theoretically for the reasons explained above, it does not however seem to be appropriate for empirical purposes, once it is evident that the bank rate is being used as the monetary policy instrument. In an SVAR framework, having both real interest rate and inflation in the system may be puzzling in that one would factor inflation twice. After all, it may be the case that there is not too much insight gained from this peculiar difference between real and nominal short-term interest rates. As Dupasquier et al. purport, their results do not change whether money rather than prices, or any other short-term interest rates are used instead. Nonetheless, this paper uses the

Central Bank rate as the instrument of monetary policy for both United States and Canada. In its most simplistic form, the theoretical model, as found in [Walsh (2000), pp.213-214], can be represented by a three equation system consisting of an AS, an AD, and a policy rule *a la* Taylor.[5]

$$y_t = E_{t-1}y_t + a(\pi_t - E_{t-1}\pi_t) + \varepsilon_t^s \tag{1}$$

$$y_t = E_t y_{t+1} - (i_t - E_t\pi_{t+1}) + \varepsilon_t^d \tag{2}$$

$$i_t = b_y y_t + b_\pi \pi_t + \varepsilon_t^p \tag{3}$$

Where E_{t-1} and E_t are expectation operators based on information available at different time periods to forecast the level of output. The rest of the variables are as defined above, except that ε_t^s, ε_t^d, and ε_t^p are the AS, AD, and policy shocks, respectively. This system can then be solved for the equilibrium inflation rate, interest rate,[6] and output, which are functions of

[5]The system can also be modified to incorporate the behavior of the foreign exchange market along with a term in the policy rule equation to capture the reaction of the Central Banker to exchange rate fluctuations. In the case of Canada, a policy rule within the line of Fuhrer and Moore (1995) makes more sense.

[6]As it is understood, interest rate as policy instrument is exogenously determined. The idea here is that the monetary authority will set the interest at a level to respond to the

the disturbances and the parameters of the model. It is, then, in this spirit that the empirical work is carried out. One tries to understand the dynamic response of the different variables to a shock in each of the driving forces, and should therefore (at least) expect the following predictions [see Gali (1992)].

i) Output and prices to move in opposite directions due to a supply shock and in the same direction due to a demand shock

ii) AD shocks to have short run effects on output and other real economic variables.

iii) Policy shocks are transmitted to the real sector through changes in the policy instrument.

The main issue with the solution of this model is that the structural disturbances are not observable. Hence, it is a priori difficult to assess the validity of its predictions. One way around this problem, as proposed in the literature, is to use an SVAR where the behavior of the variables is jointly modelled. In this respect, for Canada, the joint behavior of industrial production index, Fed funds rate, Bank of Canada's rate, CPI, and the real exchange rate are modelled, while for the U.S., the real GDP, Fed funds rate, GDP deflator, and the price of oil are analyzed. The Canadian variables

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effects of innovations, which is clear when one substitutes the equilibrium π and y back in the third equation. Hence, the context of equilibrium interest rate.

are assumed to be driven by the following shocks: supply, demand, foreign monetary policy, domestic monetary policy, and real exchange rate. Those of the U.S. are driven by: non-oil supply, oil supply, demand, and policy shocks. The next section lays down the SVAR methodology.

5 The Methodology

Following the seminal contribution of Sims (1980), the vector autoregression (VAR) methodology has been widely employed to carry out empirical work in macroeconomics. It has been profiled as the tool that brings consensus among economists on the debate that centers around the true underlying structure of the economy, in that it addresses the concerns raised by Lucas regarding the inability of large-scale macroeconometric models as tools of forecasting to account for changes in policy. In a traditional VAR model, all variables are considered endogenous and there are no identifying restrictions, which leaves no room for "data mining". Moreover, each variable is treated symmetrically and is regressed on the lagged values of the other variables. This framework simplifies the role of economic theory, which resorts to only specifying the variables to be included in the model. However, the VAR approach has come under attack by Cooley and LeRoy (1985) who demonstrate that the Choleski decomposition proposed as identification restriction is based on a type of recursive contemporaneous structure for the economy that is not in fact atheoretical but inconsistent with economic theory. They also argue that the shocks estimated under these restrictions are not "pure shocks but rather linear combinations of the structural disturbances".

In order to address the issues raised by Cooley and Leroy (1985), a number of authors starting with Sims(1986), Bernanke (1986), and Blanchard and Watson (1986) have amended the traditional VAR by factoring in identification schemes that are based on economic theory. They thus impose short-run restrictions on the variance-covariance matrix of the residuals obtained from the estimation of their reduced-form models to recover the structural shocks. As they have established, these restrictions are classified short-run because the shocks are considered to have temporary effects on the endogenous variables. Further extensions of the VAR approach to incorporate long-run constraint to identify shocks include the contributions of Shapiro and Watson (1988), Blanchard and Quah (1989), and Blanchard (1989). This approach is often referred to as "structural VAR (SVAR) methodology" and is a widely known and acceptable technique to interpret business cycle issues and to identify the effects of different economic policies.

Although this paper employs an SVAR model with 5 and 4 variables for Canada and the United States, respectively, for ease of theoretical exposition, a trivariate model illustrates the details of the technique being used: real GDP (y) is expressed in logarithm, inflation (π) is measured by consumer price index (CPI - all items) and the Central Bank rate (i_t) [(i_t^c) for Canada, and (i_t^f) for the United States] represents the instruments of monetary policy.[7] Upon determination of optimal lag length and testing for stationarity in the variables, the structural model can be represented as follows:[8]

$$\pi_t + b_{12} y_t + b_{13} i_t = a_{10} + \sum_{j=1}^{N} a_{11}(j) y_{t-j} + \sum_{j=1}^{N} a_{12}(j) \pi_{t-j} + \sum_{j=1}^{N} a_{13}(j) i_{t-j} + \varepsilon_t^p \quad (4)$$

$$b_{21} \pi_t + y_t + b_{23} i_t = a_{20} + \sum_{j=1}^{N} a_{21}(j) y_{t-j} + \sum_{j=1}^{N} a_{22}(j) \pi_{t-j} + \sum_{j=1}^{N} a_{23}(j) i_{t-j} + \varepsilon_t^s \quad (5)$$

[7] The other reason for relying on a trivariate model to expose the theory is that at the stage of the determination of the degree of symmetry between the structural shocks across the two countries one will only pick the three most relevant shocks: supply, demand, and policy.

[8] The details about the SVAR are provided here in order to familiarize the interested reader with the concept. In a final presentation, one would normally put these equation systems in the appendix.

$$b_{31}y_t+b_{32}\pi_t+i_t = a_{30}+\sum_{j=1}^{N} a_{31}(j)y_{t-j}+\sum_{j=1}^{N} a_{32}(j)\pi_{t-j}+\sum_{j=1}^{N} a_{33}(j)i_{t-j}+\varepsilon_t^d \quad (6)$$

Where ε_t^d is aggregate demand shock, ε_t^s is aggregate supply shock, and ε_t^p is policy shock. Using polynomial lag operator, the equation system can be represented in matrix form as:

$$\begin{bmatrix} 1 & b_{12} & b_{13} \\ b_{21} & 1 & b_{23} \\ b_{31} & b_{32} & 1 \end{bmatrix} \begin{bmatrix} \pi_t \\ y_t \\ i_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \\ a_{30} \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{12}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ y_{t-1} \\ i_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^s \\ \varepsilon_t^d \end{bmatrix} \quad (7)$$

Let B be the matrix of contemporaneous variables, A(L), the polynomial lag matrix, Z_t the vector of endogenous variables and Z_{t-1} its lagged values, and ε_t the vector of disturbances. Hence, the system can be written as:

$$BZ_t = A_0 + A(L)Z_{t-1} + \varepsilon_t \quad (8)$$

The infinite Wold moving average[9] may be represented by the following set

[9]According to Wold (1938), every stationary process Z_t can be written as the sum

of equations as:

$$\pi_t = \overline{\pi} + \sum_{k=0}^{\infty} r_{11}(k)\varepsilon^p_{t-k} + \sum_{k=0}^{\infty} r_{12}(k)\varepsilon^s_{t-k} + \sum_{k=0}^{\infty} r_{13}(k)\varepsilon^d_{t-k} \tag{9}$$

$$y_t = \overline{y} + \sum_{k=0}^{\infty} r_{21}(k)\varepsilon^p_{t-k} + \sum_{k=0}^{\infty} r_{22}(k)\varepsilon^s_{t-k} + \sum_{k=0}^{\infty} r_{23}(k)\varepsilon^d_{t-k} \tag{10}$$

$$i_t = \overline{i} + \sum_{k=0}^{\infty} r_{31}(k)\varepsilon^p_{t-k} + \sum_{k=0}^{\infty} r_{32}(k)\varepsilon^s_{t-k} + \sum_{k=0}^{\infty} r_{33}(k)\varepsilon^d_{t-k} \tag{11}$$

or

$$\begin{bmatrix} \pi_t \\ y_t \\ i_t \end{bmatrix} = \begin{bmatrix} \overline{\pi} \\ \overline{y} \\ \overline{i} \end{bmatrix} + \begin{bmatrix} R_{11}(L) & R_{12}(L) & R_{13}(L) \\ R_{21}(L) & R_{22}(L) & R_{23}(L) \\ R_{31}(L) & R_{32}(L) & R_{33}(L) \end{bmatrix} \begin{bmatrix} \varepsilon^p_t \\ \varepsilon^s_t \\ \varepsilon^d_t \end{bmatrix} \tag{12}$$

All the shocks in these equations are structural shocks. The sets of coefficients $r_{ij}(k)$ are called the impulse response functions. For example for k=0, the coefficient $r_{21}(0)$ is the instantaneous impact of one-unit change in ε^p_t on y_t, while $r_{21}(1)$ and $r_{22}(1)$ are the one period responses of unit changes

of two uncorrelated processes μ_t and x_t, $Z_t = \mu_t + x_t$ where μ_t (the mean term) is a deterministic process that can be forecast perfectly from its own past and x_t is a process with MA representation; $x_t = R(L)\varepsilon_t$ with ε_t being a white noise process. See Lutkepohl, H. 1991. *Introduction to Multiple Time Series Analysis.* Springer-Verlag. pp. 20-21 in ε^{p}_{t-1} *and* ε^{s}_{t-1} on y_t, respectively.

In a condensed form, with μ being the mean vector of endogenous variables, the Wold moving average can be written as:

$$Z_t = \mu + R(L)\varepsilon_t \tag{13}$$

The variables are as defined above except that R(L) is the matrix of the polynomial in the lag operators with r_{kn}being the individual coefficients of $R_{kn}(L)$.For example, the coefficients of $R_{23}(L)$ represent the impulse responses of a demand shock on output. Since it is assumed that the AD, AS, and policy shocks are pure shocks and therefore uncorrelated, one can thus proceed to their normalization, with Σ being the variance-covariance matrix of the structural disturbances, var $(\varepsilon^d_t) = var(\varepsilon^s_t) = var(\varepsilon^p_t) = var(\varepsilon) = 1$, and cov $(\varepsilon_t \varepsilon'_t) = 0$, it is straightforward that:

$$\Sigma = E(\varepsilon_t \varepsilon'_t) = \begin{bmatrix} var(\varepsilon^p_t) & cov(\varepsilon^p_t \varepsilon^s_t) & cov(\varepsilon^p_t \varepsilon^d_t) \\ cov(\varepsilon^s_t \varepsilon^p_t) & var(\varepsilon^s_t) & cov(\varepsilon^s_t \varepsilon^d_t) \\ cov(\varepsilon^d_t \varepsilon^p_t) & cov(\varepsilon^d_t \varepsilon^s_t) & var(\varepsilon^d_t) \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} = I \tag{14}$$

Since the structural equations cannot be estimated because the endogenous variables have contemporaneous effects on each other, it is recommended that one transform the system of equations into a more usable form. The reduced form equations obtained are:

$$\begin{bmatrix} \pi_t \\ y_t \\ i_t \end{bmatrix} = \begin{bmatrix} 1 & b_{12} & b_{13} \\ b_{21} & 1 & b_{23} \\ b_{31} & b_{32} & 1 \end{bmatrix}^{-1} \begin{bmatrix} a_{10} \\ a_{20} \\ a_{30} \end{bmatrix} + \begin{bmatrix} 1 & b_{12} & b_{13} \\ b_{21} & 1 & b_{23} \\ b_{31} & b_{32} & 1 \end{bmatrix}^{-1} \begin{bmatrix} A_{11}(L) & A_{12}(L) & A_{12}(L) \\ A_{21}(L) & A_{22}(L) & A_{23}(L) \\ A_{31}(L) & A_{32}(L) & A_{33}(L) \end{bmatrix} \begin{bmatrix} \pi_{t-1} \\ y_{t-1} \\ i_{t-1} \end{bmatrix} + \begin{bmatrix} 1 & b_{12} & b_{13} \\ b_{21} & 1 & b_{23} \\ b_{31} & b_{32} & 1 \end{bmatrix}^{-1} \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^s \\ \varepsilon_t^d \end{bmatrix} \tag{15}$$

or

$$\begin{bmatrix} y_t \\ \pi_t \\ i_t \end{bmatrix} = \begin{bmatrix} \psi_{10} \\ \psi_{20} \\ \psi_{30} \end{bmatrix} + \begin{bmatrix} \psi_{11}(L) & \psi_{12}(L) & \psi_{13}(L) \\ \psi_{21}(L) & \psi_{22}(L) & \psi_{23}(L) \\ \psi_{31}(L) & \psi_{32}(L) & \psi_{33}(L) \end{bmatrix} \begin{bmatrix} y_{t-1} \\ \pi_{t-1} \\ i_{t-1} \end{bmatrix} + \begin{bmatrix} e_t^d \\ e_t^s \\ e_t^p \end{bmatrix} \tag{16}$$

In a more compact form, the system can be expressed as:

$$Z_t = \psi_0 + \psi(L) Z_{t-1} + e_t \tag{17}$$

where $\psi_0 = B^{-1}A_0 = \psi_{k0}$; $\psi(L) = B^{-1}A(L) = \psi_{kn}$; *with* k = 1, 2, 3 and n = 1, 2, 3 and $e_t = B^{-1}\varepsilon_t$.

The estimation of the reduced-form model boils down to applying ordinary least squares (OLS) to each equation separately once the optimal lag length has been determined to get rid of autocorrelation. There are a number of techniques available to arrive at the number of lags: Akaike or Schwartz information criteria, top-down approach, etc. The latter is used in this paper because it has been recognized that the information criteria tests tend to select too few lags and therefore fail to capture the actual error process. For ease of explanation, the constant terms are dropped from the previous equation. It can thus be shown that:

$Z_t = \psi(L)LZ_t + e_t \Longrightarrow Z_t - \psi(L)LZ_t = e_t \Longrightarrow Z_t(I - \psi(L)L) = e_t \Longrightarrow$ $Z_t = (I - \psi(L)L)^{-1}e_t$. By letting C(L) $= (I - \psi(L)L)^{-1}$, it follows that:

$$Z_t = C(L)e_t \tag{18}$$

is the Wold moving average representation of the estimated unrestricted model. or

$$\begin{bmatrix} \pi_t \\ y_t \\ i_t \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \\ C_{31}(L) & C_{32}(L) & C_{33}(L) \end{bmatrix} \begin{bmatrix} e_t^p \\ e_t^s \\ e_t^d \end{bmatrix} \tag{19}$$

In line with Blanchard and Quah, the shocks obtained from the estimation of the reduced-form equations can be expressed as linear combinations of the structural disturbances. By correspondence between equation (19), the MA representation of the reduced-form model, and equation (13), the MA representation of the structural model, it can be established that $C(L)e_t = R(L)\varepsilon_t$, excluding the means. As $C(0) = I$ and this relationship must hold for all t:

$$\begin{bmatrix} e_t^p \\ e_t^s \\ e_t^d \end{bmatrix} = \begin{bmatrix} r_{11}(0) & r_{12}(0) & r_{13}(0) \\ r_{21}(0) & r_{22}(0) & r_{23}(0) \\ r_{31}(0) & r_{32}(0) & r_{33}(0) \end{bmatrix} \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^s \\ \varepsilon_t^d \end{bmatrix} \tag{20}$$

or

$$e_t = R(0)\varepsilon_t \tag{21}$$

From equation (18 or 19) it is clear that ε_t could be recovered if the matrix R(0) were known. Let Ω be the variance-covariance matrix of the reduced form innovations.

$$\Omega = E(e_t e_t') = R(0)E(\varepsilon_t \varepsilon_t')R'(0) \tag{22}$$

Since the Ω matrix is symmetric, it contains m elements along the principal diagonal and m-j elements along the jth off-diagonal (with j= 1,2,3) and one corner element, which total (m$^2 + m)/2$ free elements.[10] That is, six free elements in our trivariate models. B&Q argue that knowledge about Ω and the three long-run restrictions provide the exact number of restrictions

[10]Since one uses five and four variables for the Canadian and U.S. SVARs, ten and six restrictions are imposed on R(0), respectively.

needed to identify the coefficients of R(0). For instance, based on the assumption that the structural shocks are white noise $[E(\varepsilon_t \varepsilon_t') = I]$ it can be shown from the Ω equation that:

$$\Omega = \begin{bmatrix} var(e_t^p) & cov(e_t^p e_t^s) & cov(e_t^p e_t^d) \\ cov(e_t^s e_t^p) & var(e_t^s) & cov(e_t^s e_t^d) \\ cov(e_t^d e_t^p) & cov(e_t^d e_t^s) & var(e_t^d) \end{bmatrix} =$$

$$\begin{bmatrix} r_{11}(0) & r_{12}(0) & r_{13}(0) \\ r_{21}(0) & r_{22}(0) & r_{23}(0) \\ r_{31}(0) & r_{32}(0) & r_{33}(0) \end{bmatrix} \begin{bmatrix} r_{11}(0) & r_{21}(0) & r_{23}(0) \\ r_{12}(0) & r_{22}(0) & r_{32}(0) \\ r_{13}(0) & r_{23}(0) & r_{33}(0) \end{bmatrix} =$$

$$\begin{bmatrix} r_{11}^2(0) + r_{12}^2(0) + r_{13}^2(0) & \begin{matrix} r_{11}(0)r_{21}(0)+ \\ r_{12}(0)r_{22}(0)+ \\ r_{13}(0)r_{23}(0) \end{matrix} & \begin{matrix} r_{11}(0)r_{23}(0)+ \\ r_{12}(0)r_{32}(0)+ \\ r_{13}(0)r_{33}(0) \end{matrix} \\ \begin{matrix} r_{11}(0)r_{21}(0)+ \\ r_{12}(0)r_{22}(0)+ \\ r_{13}(0)r_{23}(0) \end{matrix} & r_{21}^2(0) + r_{22}^2(0) + r_{23}^2(0) & \begin{matrix} r_{21}(0)r_{23}(0)+ \\ r_{22}(0)r_{32}(0)+ \\ r_{23}(0)r_{33}(0) \end{matrix} \\ \begin{matrix} r_{31}(0)r_{11}(0)+ \\ r_{12}(0)r_{32}(0)+ \\ r_{13}(0)r_{33}(0) \end{matrix} & \begin{matrix} r_{31}(0)r_{21}(0) \\ +r_{22}(0)r_{32}(0)+ \\ r_{23}(0)r_{33}(0) \end{matrix} & r_{31}(0)r_{23}(0) + r_{32}^2(0) + r_{33}^2(0) \end{bmatrix}$$

The other three coefficients of $R(0)$ could be found when equations (13), (19), and (21) are combined and when matrix $R(L)$ is made lower triangular. This can be accomplished by either imposing short- or long-run restrictions, or a combination of both. Let us assume for the sake of this theoretical exposition that only long-run restrictions are imposed in order to properly identify the model. The most common assumption are: 1) only policy shocks can affect the trend of inflation (meaning that supply and demand shocks have no effect on inflation in the long-run, which implicitly provides two restrictions) and 2) demand shocks have no long run effects on output. In other words, the cumulative effects of demand shocks on output are zero, thereby producing three additional equations..

$Z_t = R(L)\ \varepsilon_t; \quad Z_t = C(L)e_t; \quad and\ e_t = R(0)\ \varepsilon_t \Longrightarrow Z_t = C(L)R(0)\varepsilon_t \equiv R(L)\ \varepsilon_t$

or

$$\begin{bmatrix} R_{11}(L) & R_{12}(L) & R_{13}(L) \\ R_{21}(L) & R_{22}(L) & R_{23}(L) \\ R_{31}(L) & R_{32}(L) & R_{33}(L) \end{bmatrix} = \begin{bmatrix} C_{11}(L) & C_{12}(L) & C_{13}(L) \\ C_{21}(L) & C_{22}(L) & C_{23}(L) \\ C_{31}(L) & C_{32}(L) & C_{33}(L) \end{bmatrix} \begin{bmatrix} r_{11}(0) & r_{12}(0) & r_{13}(0) \\ r_{21}(0) & r_{22}(0) & r_{23}(0) \\ r_{31}(0) & r_{32}(0) & r_{33}(0) \end{bmatrix} =$$

$$\begin{bmatrix} C_{11}(L)r_{11}(0)+ & C_{11}(L)r_{12}(0)+ & C_{11}(L)r_{13}(0)+ \\ C_{12}(L)r_{21}(0)+ & C_{12}(L)r_{22}(0)+ & C_{12}(L)r_{23}(0)+ \\ C_{13}(L)r_{31}(0) & C_{13}(L)r_{32}(0) & C_{13}(L)r_{33}(0) \\ C_{21}(L)r_{11}(0)+ & C_{21}(L)r_{12}(0)+ & C_{21}(L)r_{13}(0)+ \\ C_{22}(L)r_{21}(0)+ & C_{22}(L)r_{22}(0)+ & C_{22}(L)r_{23}(0)+ \\ C_{23}(L)r_{31}(0) & C_{23}(L)r_{32}(0) & C_{23}(L)r_{33}(0) \\ C_{31}(L)r_{11}(0)+ & C_{31}(L)r_{12}(0)+ & C_{31}(L)r_{13}(0)+ \\ C_{32}(L)r_{21}(0)+ & C_{32}(L)r_{22}(0)+ & C_{32}(L)r_{23}(0)+ \\ C_{33}(L)r_{31}(0) & C_{33}(L)r_{32}(0) & C_{33}(L)r_{33}(0) \end{bmatrix}$$

$$C_{11}(L)r_{12}(0) + C_{12}(L)r_{22}(0) + C_{13}(L)r_{32}(0) = 0 \tag{23}$$

$$C_{11}(L)r_{13}(0) + C_{12}(L)r_{23}(0) + C_{13}(L)r_{33}(0) = 0 \tag{24}$$

$$-+ \tag{25}$$

$$C_{21}(L)r_{13}(0) + C_{22}(L)r_{23}(0) + C_{23}(L)r_{33}(0) \quad = \quad 0 \tag{26}$$

Since $C(L)$ is known from the estimation of the MA representation of the reduced form model, once the contemporaneous coefficients matrix of structural shocks, $[R(0)]$, has been identified, it is then straightforward to obtain 1) the structural shocks $\{e_t = R(0)\ \varepsilon_t \Longrightarrow \varepsilon_t = R(0)^{-1}e_t\}$ and 2) $R(L)$, the coefficients matrix of the MA representation of the structural model. For $R(L) = C(L)R(0)$. The knowledge of $R(L)$ and the structural innovations then allow to compute the impulse responses from equations (9), (10), and (11), as explained above. Moreover, one can take the variance of each equation of the system in order to determine the contribution of each shock to the variance of each left-hand side variable, which is termed variance decomposition. For example, if one takes the variance of output in equation (10), it will be possible to demonstrate what percentage is due to policy shock, supply shock (own shock), and demand shock.

In line with previous studies, the state space model is employed in order to determine to what extent that shocks affecting Canada are symmetric to those of the United States. In addition, this paper attempts to advance the methodology by testing for causality in the Granger sense between shocks across the two countries. It would have been a good exercise to test for cointegration between structural shocks across the two countries by using the method proposed by Johansen and Juselius (1990). However, this is not possible since these variables are found to be stationary, a situation that is consistent with the assumption of white noise. Then, the only room left is to use standard time-series method for further analysis. In this respect, the impulse responses of Canadian endogenous variables to U.S. structural shocks are explored. The state space model is explained in the subsection below.

6 Analysis of Shock Symmetry Between U.S. and Canada

The state space model[11], originally developed by control engineers, has found a wide range of application in econometrics, partly due to the fact that estimation of state space form dynamic models can be carried out by the Kalman filter and partly because such models allow for unobserved variables to be accommodated with observables. The class of unobserved variables accounted for are: "(rational) expectations, missing observations, unobserved components (cycles and trends), and measurement errors." Generally speaking, the state space representation of the dynamics of an $n \times 1$ observed variable is

[11] For more details regarding this model, see Harvey (1981, 1989).

given by a *measurement equation* as follows.

$$\begin{bmatrix} \varepsilon_t^{d-can} \\ \varepsilon_t^{s-can} \\ \varepsilon_t^{p-can} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha_{1t} \\ \alpha_{2t} \\ \alpha_{3t} \end{bmatrix} + \begin{bmatrix} \beta_{1t} & 0 & 0 \\ 0 & \beta_{2t} & 0 \\ 0 & 0 & \beta_{3t} \end{bmatrix} \begin{bmatrix} \varepsilon_t^{d-us} \\ \varepsilon_t^{s-us} \\ \varepsilon_t^{p-us} \end{bmatrix} + \begin{matrix} \xi_{1t} \\ \xi_{2t} \\ \xi_{3t} \end{matrix} \tag{27}$$

where the state vector $\alpha_t = (\alpha_{1t}, \alpha_{2t}, \alpha_{3t})'$ is not directly observable and is assumed to be the component of shocks specific to Canada. This variable is generated via the Kalman filter. β_{it} captures the relationship between shocks across the two countries, and ξ_t is vector of disturbances with mean zero and covariance matrix, G_t. Normally, $\xi_t = (\xi_{1t}, \xi_{2t}, \xi_{3t})'$ contains all other shocks that originate from the rest of the world. Although α_t is unobserved, its movement is assumed to follow an AR(1) process as defined by the following *transition equation*:

$$\alpha_t = T_t \alpha_{t-1} + \eta_t \tag{28}$$

where η_t is $g \times 1$ vector of disturbances with mean zero and covariance matrix, Q_t. ξ_t and η_t are assumed to be uncorrelated with each other at any period of time. The initial value of the state vector, α_0, and the error terms are taken to be uncorrelated. Hence,

$$\begin{pmatrix} \xi_t \\ \eta_t \end{pmatrix} \sim WN\left[0, \begin{pmatrix} G_t & 0 \\ 0 & \eta_t \end{pmatrix}\right], \qquad t = 1,..,T$$

and

$$E[\alpha_0 \eta_t'] = 0, \qquad E(\alpha_0 \xi_t') = 0 \qquad t = 1, ..., T$$

The model is estimated by using the method of maximum likelihood (ML). Following Deserres and Lalonde (1994), positive (negative) values of the parameter estimates $\tilde{\beta}_{it}[= \frac{\partial \varepsilon_t^{can}}{\partial \varepsilon_t^{us}}]$ can be interpreted as the existence of symmetric (asymmetric) shocks. Let $H_{jk}(j = 1,2,3; k = 1,2,3)$ be the variance-covariance matrix of α_t, and M_{jk} be the variance-covariance matrix of $\varepsilon_t^{us} \sim N(0,1)$. and be The variance proportion of Canadian shocks explained by U.S. shocks is given by:

$$\frac{\tilde{\beta}_{it}^2}{\tilde{\beta}_{it}^2 + H_{jk}}, with\ j = k \tag{29}$$

To summarize the methodology so far, the SVAR is only a means to an end. It is used to extract the structural shocks for each country, which are then later analyzed through state space model to uncover their degree of symmetry. As can be understood from this methodology, the identification of the system is crucial to recover the structural disturbances. What restrictions to impose in order to achieve just-identification and to have impulse responses that are in line with the theoretical predictions is the main dilemma that econometricians have to go through. The identification process is discussed next.

7 Identifying Restrictions

The main issue that a researcher faces in applying SVAR methodology is the identification problem.[12] This may be due to the fact that there has not been a consensus in the literature as to what particular set of assumptions is appropriate for identifying the effects of shocks. There are actually two competing set of identifying assumptions: short-run restrictions in the line of Sims (1992), Bernanke and Blinder (1992), and Christiano-Eichenbaum (1992), or long-run restrictions as originally applied by Blanchard and Quah (1989). Building upon the work of Gali (1992), this paper adopts a combi-

[12]There are actually three concerns regarding the SVAR methodology. The first is whether the policy shocks extracted really originate from the true policy reaction function of the Central Bank. The second is the belief that researchers may impose restrictions that allow them to show results they want the data to support, the so-called data mining. The third one is the orthogonality restriction needed for the model to work properly. (For a detailed overview of the SVAR methodology, see Gottschalk, Jan (2001) " An Introduction into the SVAR Methodology: Idendification, Interpretation, and Limitations of SVAR models." Working Paper No. 1072. Kiel Institute of World Economics.

nation of short- and long-term restrictions.

Since the paper partly aims at differentiating between non-monetary and monetary demand shocks, and having made a case for the Central Bank rate as the policy instrument; one therefore needs to shed light on the choice of identifying assumption for the monetary policy shock. The literature, in this respect, contains a wide variety to choose from. The typical identifying assumption in Sims (1980) work is that monetary policy variable is unaffected by contemporaneous innovations in other variables. In later work by Sims and others, monetary policy is assumed to not affect contemporaneous macroeconomic variables. In Bernanke and Blinder (1992)'s work, monetary policy is considered to be predetermined and therefore does not depend on other contemporaneous shock. In some Canadian studies on monetary union, Lalonde and St.-Amant (1993) and DeSerres and Lalonde (1994) have imposed the restriction that in the long-run monetary policy has no effect on real variables. Dupasquier et al. (1997) in turn have borrowed from Bullard and Keating (1995) the identifying assumption that only the policy variable can affect the trend of inflation. Since the present study is closest to that of Artis and Ehrmann (2000), similar restrictions are imposed: domestic monetary policy shocks have no contemporaneous effect on either output or the foreign policy variable. The rest of the restrictions are as follows.

For Canada, the paper allows 1) long-term effects of supply shocks on output; 2) instantaneous effects of only supply and demand shocks on output, 3) no contemporaneous impact of the exchange rate shocks (ε_t^e) on the Fed funds rate, and 4) no immediate effects of exchange rate shocks on consumer prices.[13] In the case of the United States, since supply shocks are split between non-oil and energy shocks and the exchange rate variable is deliberately excluded from the regression, the following assumptions are made. Whereas only non-oil supply shocks (ε_t^s) are entitled to have long-run effects on U.S. output, both energy (ε_t^{oil}) and non-oil shocks are expected to instantaneously impact output, a Real Business Cycle (as opposed to Keynesian) theory feature.[14] The last restriction is that policy shocks are unable to impact the price of oil in the short-un.

[13]The first set of long-term restrictions requires that all but the first term of the first row of the infinite moving average matrix, R(1), be zero. The second set of restrictions impose zeros from the third to the fifth element of the first row of R(0). The rest of the zero- restrictions are imposed on the fourth and fifth elements, and on the fifth element of row 2 and 3 of R(0), respectively.

[14]There are a number of shocks that can originate from the supply side, which could give rise to significant changes in productivity. They include *natural disasters, oil price 'hikes', war, political upheaval, strikes, government regulations such as import quotas, and technological change.* Among all, the latter is considered as the driving-force of random changes in output over the long-term for advanced economies. [See Snowdon, Vane, and Wynarczyck (1998)]

8 Data and Data Analysis

The data for the study cover the period 1961-2000 for Canada and 1961:1 -1999:2 for the United States, and are quarterly. Canadian and U.S. data were taken from Statistics Canada's CANSIM data base, IMF's International Financial Statistics (IFS), Federal Reserves Bank of Saint Louis (FRBSL), and RATS database. They include industrial production (y), seasonally adjusted (IFS), consumer price index (p) '(CPI)' (IFS), the nominal Bank rate of Canada (i_t^c) - series B14006 (CANSIM), the Federal Reserves funds rate (i_t^f) - series B54408 (CANSIM), real exchange rate (q) computed from related IFS series, and oil price per barrel (P_{oil}) '(West Texas intermediate - Dow Jones)' (FRBSL), GDP deflator (p^*)– (RATS), and Real GDP (y^*) (RATS). Since the data taken from the IFS inherit different base years, they were all converted to a common base, which is 1995. All variables are expressed in logarithmic form except for the nominal interest rates and real exchange rate. With the exception of the real exchange rate, the Canadian data have been deseasonalized through the TRAMO/SEAT procedure proposed by Gomez and Maravall (1992), which is also a subroutine in Eviews 4.0. The entire US data set were also deseasonalized. Figure 1 shows the graphical representation of the modified data.

Figure 1 about here

To determine whether the data are stationary, two popular unit root tests[15] are carried out on the series as presented on Tables 1 and 2. These include the Augmented Dickey Fuller (ADF), and the Phillips-Perron tests. With the exception of real exchange rate that is stationary (at level), I(0), and CPI that is integrated of order 2, I(2), on average, all other variables reveal that, independently that one consider stationarity around a linear trend, or a constant, or a constant and linear trend, or neither, they are integrated of order 1, I(1), at the 1% level of significance. The U.S. variables are I(1) with the exception of GDP deflator, which is unambiguously I(2). In very few cases where doubts existed about the proper order of integration of the variables since different tests give different results, had the correlogram been used as a determining criterion. It also confirms the order of integration of the variables.

Table 1 about here

Table 2 about here

Given the findings that the variables are integrated of different orders,

[15]For more details about these tests, the advised reader is referred to the Eviews manual for Eviews 4.1 and the original papers by these authors.

a cointegration test based on Johansen and Juselius (1990) maximum likelihood estimation for the variables that are integrated of the same order was carried out for each country. The test shows no evidence of cointegration in either country, which confirms the unit root tests results. This ensures that there is no long-run relationship between the variables for which extra long-run restrictions are needed besides the ones considered. Moreover, the problem that differencing may lead to distortions in the relationship between the original variables, a situation endemic to VAR models with cointegrated variables, is no longer of concerns (for more details, see Lutkepohl, 1991, pp. 350-375). Thus, this makes it possible to employ the VAR approach after taking the first differences of the variables. Tables 3 and 4 report the results of the cointegration test.

Table 3 about here

Table 4 about here

The determination of the lag length of the reduced form models is specified on the basis of the VAR Lag Order Selection Criteria found in Eviews 4.0, which indicates the lag order selected by each criterion. Tables 5 and 6 display the optimal lag length. For the Canadian data $(y_t, i_t^f, i_t^c, p, and\ q)$, when a maximum number of 12 lags is chosen, the Likelihood Ratio (LR) test selects 12 lags, the final prediction error (FPE) and the Akaike information criterion (AIC) select each 5 lags, while the Schwarz information criterion (SC) and the Hannan-Quinn information criterion select 4 lags. When the maximum number of lags is reduced to 6, the LR, FPE, and AIC all chose a lag length of 6 while the last two criteria suggest 4 lags. A similar pattern is observed in the U.S. data, when a maximum number of 12 lags is set, The LR and AIC select 10, FPE select 5, while SC and HQ suggest only 2 lags. When a maximum of 6 lags is chosen, the LR, FPE, and AIC indicate an optimum of 6, while the SC selects zero lag and HQ gears toward 1. Among all these tests, the LR is the most recommended and is seemed to be biased toward choosing the largest number of lags, which in fact can be seen as an advantage since the objective of the researcher is not to leave out important information. However, in order to avoid losing degrees of freedom and in accordance with previous studies, a lag length of 6 is adopted for Canada and a lag length of 5 is chosen for the U.S. in the estimation phase.

Table 5 about here

Table 6 about here

9 Empirical Results

This section presents the empirical estimation of the structural model in accordance with the procedure described above. For Canada, the model is specified as a system and is ordered as follows: $(\Delta y_t, \Delta i_t^f, \Delta i_t^c, (\Delta p_t),\ q)$.[16] Each variable is assumed to be driven by supply, demand, foreign policy, domestic policy, and exchange rate shocks, namely, $(\varepsilon_t^s, \varepsilon_t^d, \varepsilon_t^{p*}, \varepsilon_t^p, \varepsilon_t^e)$. For the United States, the vector of endogenous variables $(\Delta y_t^*, \Delta P_{oil}, \Delta i_t^f, \Delta(\Delta p_t^*))$ are also assumed to be driven by the structural innovations $(\varepsilon_t^s, \varepsilon_t^{oil}, \varepsilon_t^d, \varepsilon_t^p)$. In the first stage, the associated reduced form of the SVAR system is estimated and residual tests are carried out in order to ensure that it is stable and well fit for good predictions (see Tables 7 and 8). In the second stage, identifying restrictions are imposed in order to obtain the impulse responses, variance decomposition of structural forecast errors, and the structural innovations. Each of these is discussed in more detail.

Table 7 about here

[16] Although Dupasquier *et al.* *(1997)* had made a strong case against inflation being stationary and this paper indeed finds such evidence, Figure 1 has demonstrated that there is no substantial loss of information whether one works with the first or the second difference of CPI. Yet if one had to take into consideration that CPI is I(2), the variable that would enter the SVAR of Canada is $\Delta\Delta p_t$ instead of Δp_t.

Table 8 about here

9.1 Impulse Response Analysis

The impulse response functions, which illustrate the qualitative effect of a one standard deviation shock to each of the endogenous variables, are given in figures 2 and 3. The graphs include confidence bands of 5% generated with a bootstrapping procedure. The results for the Canadian system are by and large consistent with the predictions of the underpinning theoretical model. The time path is shown in figure 3, where the vertical axis measures the quarterly impact on each endogenous variable and the horixontal axis the quarters (time horizon) following the shock. After a supply shock, output increases, domestic interest rate remains low for several quarters and declines permanently, prices fall and real exchange rate slightly fluctuates around the baseline. However, in response to demand shock, output and prices move in the same direction, interest rates rise and real exchange rate appreciates. A foreign monetary policy shock interpreted as a contractionary monetary policy shows an instant increase in domestic interest rate that lasts several quarters, which confirms part of the assumption that Canada (the small country) reacts without lag to economic events originated from the U.S.

The effects on the rest of the variables, as Artis and Ehrmann (2000) also argued, depends on the Bank's of Canada reaction function. There is no clear pattern to be expected, they may go either way. As to the response to a domestic monetary policy shock, output displays a hump-shaped pattern for several quarters, real exchange rate appreciates, and prices drop below the reference line and rebounds after the second quarter. In the long-run, domestic interest rate and prices move in opposite directions. The response of the foreign policy instrument is not surprising, the Fed does not react to Canada's monetary policy until after several quarters. The response to a real exchange rate shock, say an appreciation, could be interpreted along the same line. It appears to be in accordance with the predictions that a short rise must occur in output, domestic interest rate, and prices.

Figure 2 about here

Figure 3 about here

Within reasonable doubt, the results found from this exercise approximate the patterns uncovered by Artis and Ehrmann, which covers a smaller time horizon. These authors have interpreted the nature of supply and demand shocks on the basis of the responses of both foreign and domestic interest rates. It is their view that if both variables move in opposite directions, then the shocks are predominantly asymmetric. In the opposite case, they are symmetric. One of their key findings was that U.S. and Canada are hit by symmetric AD and AS shocks, which is common to previous studies by Kuszczak and Murray (1987); Deserres and Lalonde (1994), and Dupasquier et al. (1997).[17] This paper confirms the findings that both demand and supply shocks are symmetric across the two countries if one has to pass judgement on the basis of the same criterion. How robust this result is and what implications it entails definitely depends on the light shed by the state space model exercise. Before this, the impulse responses for the U.S. are examined based on figures 4 and 5.

Figure 4 about here

Figure 5 about here

Yet again, the impulse responses show that output and prices are inversely related in the presence of a non-oil supply shock. At impact, the price of oil declines and shortly rises to reach a peak in the fifth quarter. After then it sharply converges to its long-run path. The Fed funds rate seems

[17] All these studies are based on a smaller sample size.

to follow a similar pattern but a faster speed. As could be expected, in response to an oil shock output abruptly decline and prices rise (a typical supply shock effect). The price of oil increases and fluctuate above its long run level for a while. It sharply declines to reach its lowest point in the fifth quarter and quickly rebounds back to a level higher than the original impact. The oil price seems to stabilize after ten quarters. The interest rate in turn declines and later on fluctuates around its trend. In response to a demand shock, prices and output move in the same directions, with some unexpected features in the first two quarters, interest rate increases, the price of oil reaches a peak at impact and sharply declines. Policy shocks lead to an immediate jump in interest rate, output quickly falls, prices decline and the price of oil temporarily declines in the first quarter and quickly reverts to reach a peak in the fourth quarter. With the exception of some of the initial responses, which are direct implications of the restrictions imposed, the impulse responses seem reasonable. Aggregating all 28 quarters, the overall result shows that technological change has permanent effects on output, an oil shock has long-run effects on the nominal variables, and a policy shock can alter the trend of inflation.

9.2 Variance Decomposition Analysis

While the impulse responses provide information on the effect of a structural shock, they do not indicate the extent to which this shock contributes to the fluctuations observed in the endogenous variables. The variance decomposition serves this purpose. It assesses the relative importance of each structural disturbance to each variable. The forecast-error variance decompositions for both countries are given in Tables 9 and 10 and in Figures (6 & 7) and (8 & 9) for Canada and the United States, respectively.

Table 9 about here

Table 10 about here

Figure 6 about here

Figure 7 about here

Figure 8 about here

Figure 9 about here

For Canada, supply and demand shocks account for much of the variability in output with domestic monetary policy shocks being negligible in comparison to the remaining shocks. The most striking result is that domestic monetary policy shocks account for 1.79 percent or less of output variance at all reported horizons, a finding that is at odds with previous studies by Deserres and Lalonde (1994) - 17 percent, Dupasquier *et al.* (1997) - 49 percent , and Artis and Ehrmann (2000) - 5.12 percent. The implication is that one cannot solely rely on monetary policy to reject the idea of a monetary union. In few words, this result sends a strong message that monetary policy is not as important as one might think to mitigate the effects of shocks for the period considered. As it become evident, U.S. monetary policy shocks are more important than Canada's domestic policy shocks in terms of their contribution to the variance of output. Table 9 also shows that AD and foreign policy shocks are important in accounting for variability in the Fed funds rate. As could be predicted from the assumption about the U.S. as a large country, Canada's policy shocks start having considerable effects on the Fed fund rate in the eighth quarter while the exchange rate shocks continue to produce no significant impacts even after 28 quarters. As for the Bank of Canada's rate, all the structural shocks are important in explaining its variability at various horizons. However, it is worth emphasizing that U.S. and domestic policy shocks carry more weigths. In the long-run, AD, Real exchange rate, and supply shocks dominate the picture in an orderly fashion. Most of the variation in the price level is due to supply and demand shocks, with foreign policy shocks being more relevant than domestic policy shocks.

In the case of the United States, Table 10 shows that oil shocks largely contributes to output variation and the effects of policy shocks are even more important than those of demand shocks. Technological (or non-oil) shocks play a major role in the forecast error variance of all the variables. Demand shocks explain most of the variability in the price of oil but little of the Fed funds rate and the price level. Supply shocks (technological and oil) in general and policy shocks are the main driving forces behind the behavior of these two series. In sum, the results demonstrate that, contrary to the identification assumption, oil shocks do have permanent effects not only on output but on the entire variables explaining the working of the U.S. economy. As opposed to Canada, U.S. monetary policy shocks have real effects on output and these effects become more important at a longer forecast horizon. The surprising facts, however, are that 1) demand shocks seem to be almost irrelevant for output, the price level, and the monetary policy instrument; and 2) the long-lasting effects of policy shocks on the price level, which economists refer to as *price puzzle*. This may be due to the inability of the model to fully capture the dynamics of the GDP deflator over time.

9.3 State Space Analysis

The state space model was estimated in order to determine the degree of symmetry between the two countries. For this purpose, the shocks (supply, demand, and monetary) common to each SVAR estimation were chosen. Figures 10 and 11 show the behavior of these shocks over time. As expected, all are stationary with mean zero and variance more or less equal to one. However, when one adequately implements the state space technique, the output obtained proved to be useless for any inference, standard errors were extremely large. To get around this problem, the single exponential smoothing method[18] was applied to the disturbances. This method seemed to be appropriate because it is a simple method of adaptive forecasting, which is useful when the series move randomly in the neighborhood of a constant mean with no trend nor seasonal patterns as depicted in Figures 10 and 11. The smoothed disturbances are presented in Figure 12. Four state space model estimations were carried out (AD_Canada. vs AD_US; AS_Canada vs AS_US(oil), AS_Canada vs AS_US(non-oil), Policy_Canada vs Policy_US). The results are shown in Table 11. As stated above, a positive

[18]For more details on smoothing methods, please consult Eviews manual pp. 182-193.

(negative) sign of the slope coefficients dictate that the two shocks are symmetric(asymmetric). Since a Time-Varying Parameter Model[19] within the State Space models family is the one that best suits the data at hand, the slope coefficient as well as the intercept are a composite of two terms: a fixed coefficient and a state variable. In each case, the sign is determined when these two terms are added. In sum, this exercise reveals that symmetry between the AD shocks and between the AS shocks only exist after a one-lag period but not contemporaneously as explained above. The decisions about whether AS_Canada and AS_US(oil) shocks or policy shocks are symmetric or asymmetric are inconclusive because the state space model does not converge even after 1000 iterations. In other words, the state space exercise indicate that nonmonetary AD as well as AS shocks take up to a quarter before their effects could be felt in Canada.

Table 11 about here

Given the difficulties that emerge fromt the state space analysis, other statistical techniques have also been used in order to assess the degree asym-

[19]In order to run this model, one has to choose a structure for the state equation that may either be random walk, or constant mean, or AR(1) and constant mean. The last option should be selected when "one believes that shocks to the random coefficients have some persistence, but that the coefficients eventually return to their mean values." (Eviews manual, pp. 526)

metry of the shocks. A summary is provided in Table 12. The contingency coefficient[20] reveals that the nonmonetary AD shocks (61.47 percent) as well as the AS shocks (55 percent on average) are highly associated across countries, while policy shocks are not, when a 1/2 rule is used as a benchmark. The cross correlation at different leads or lags clearly indicates that the AD shocks and the AS shocks are positively correlated, whereas the policy shocks are negatively correlated. These exercises irrefutably confirm the SVAR results. Further information is provided through the Ganger causality test, which demonstrates among other results that AD shocks in the U.S. Granger causes AD Shocks in Canada.

Table 12 about here

Given these results, one can now try to answer the question that is at the center of this research and that has been at the forefront of the debate on monetary union between United States and Canada. Do the behavior of macroeconomic shocks favor monetary union between the two countries? When a monetary union arrangement between countries of similar size is being investigated, one should carry out the analysis in both directions. This

[20]The interpretation of the contingency coefficient is similar to that of the simple correlation. It is now a standard procedure in Eviews 4.0, which the interested reader could easily consult any time. Nonetheless, all the details are provided in Essay 3 where this concept is most relevant.

would mean, in this context, that one should consider whether monetary union is a good move for Canada and for the United States as well. However, when one country is large and the other is small, the large country has almost nothing in jeopardy, which may explain why the literature does not really focus on the risks involved for the U.S.. The present study goes in line with this belief, and attention is only paid to Canada (the small country).

It is common to find in the literature that the real exchange rate serves as a shock absorber and has been proven to be important in the conduct of monetary policy in Canada. However, the fact that after 28 quarters only 2 percent of real exchange rate variance is due to supply shocks, while 78.79 percent of the variability in output is explained by supply shocks, points to the real exchange rate not performing its role as a shock absorber for the Canadian economy that the optimal currency literature has advocated. In this respect, this paper agrees with Melitz (1996) that, if exchange rate fluctuations are the main concern, a common currency is, within reasonable doubts, the appropriate cure. This research, however, still leaves room for one to combat the idea of monetary union by relying on the asymmetry of supply shocks implied by the impulse responses (see Figures 2 the last quarters). But the most important point is, since supply shocks explain not much of the variations in the domestic policy instrument, it does not really matter whether these shocks at the end of the forecast horizon are symmetric or asymmetric because little can be done about them under either a common or independent monetary authority. Moreover, US policy shocks account for a large portion of the Bank of Canada's rate (49.95 percent or less at all horizons) and have more effects on output and the price level than Canadian monetary policy shocks. All these seem to suggest that the loss of monetary policy independence along with the loss of the exchange rate as a shock absorber may have been exaggerated by previous studies. There is no great loss involved for Canada in pursuing monetary union with the United States. In summary, the findings of this research support monetary union between the two countries.

10 Conclusion

This paper has studied the behavior of macroeconomic shocks between United States and Canada in order to determine whether these shocks favor monetary union between the two countries. In accordance with the literature, the paper has focused on the relevance of shocks symmetry. It employs two econometric techniques to have a thorough understanding of the issue at hand. One is the Structural Vector Autoregression (SVAR) approach, which is used to extract the structural innovations affect each country, and the other is the State Space model that enables the researcher to identify these shocks as symmetric or asymmetric. The variables were carefully chosen to reflect the dynamics of each economy. The U.S. economy is modeled as a large but relatively closed economy while Canada is considered as an open economy. The paper has used an SVAR(5) for Canada to trace out the responses to structural supply, demand, U.S. monetary policy, domestic policy, and real exchange rate shocks for the period 1961Q1 - 2000Q4. However, an SVAR(4) for the United States traces out the responses to structural non-oil, oil supply, demand, and policy shocks and covers the period of 1961Q1 - 1999Q2. The identification of the models is achieved by imposing both short- and long-run restrictions. The observed dynamic adjustments of the variables of each model are by and large consistent with the underpinning theoretical model. Among other results, for the United States, monetary policy is relevant for economic adjustments. For policy shocks even play a greater role than AD in the variance of output. As for Canada, the forecast-error variance indicates that domestic monetary policy and exchange rate shocks in Canada have no significant impact on output and are pretty much less relevant than U.S. monetary policy shocks. AD shocks are found to be symmetric but AS shocks are not. This result is confirmed by the State Space model estimation. Therefore, there is ample ground to believe that the loss of monetary independence along with the flexible exchange rate system will not impose substantial loss on the Canadian economy as other studies predict. In sum, this paper argues that if the decision to enter a monetary union arrangement with the United States could solely be based on shocks symmetry and the relevance of domestic monetary policy, Canada is free to pursue such a goal.

A word of caution is always necessary in any empirical analysis. Although this paper is based on a sample period larger than any other studies from the literature reviewed, it is not known whether the choice of different identification assumptions could substantially alter the results and lead to different conclusions. From the few that have been tried, the results seem to be robust. Since the SVAR technique in itself is not free from any weaknesses and is a controversial tool, this paper could not definitely be immume.

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Table 1. Unit Root Tests – Canadian Variables

	ADF			PP			
Variables	Level	Difference	Order	Level	Difference	Order	Decision
Ycan	-2.32	-5.92	I(1)	-2.20	-9.81	I(1)	I(1)
Frate	-2.48	-10.35	I(1)	-2.62	-11.38	I(1)	I(1)
Brate	-2.42	-9.94	I(1)	-2.10	-9.71	I(1)	I(1)
CPI	-1.90	-3.06 † -11.16 ††	I(2)	-2.43	-4.29	I(1)	I(2)
Real Exc. Rate	-3.46		I(0)	-8.34		I(0)	I(0)

A constant, a time trend and a maximum lag of 13 are included in the OLS regressions for all variables. Sample period covers 1961:1 – 2000:4. Critical values are based on McKinnon (1996) : 1% = 4.017, 5% = 3.44, 10% = 3.14. Keys: †, first difference; † †, second difference.

Table 2. Unit Root Tests – USA Variables

	ADF			PP			
Variables	Level	Difference	Order	Level	Difference	Order	Decision
Frate	-2.47	-10.11	I(1)	-2.60	-11.30	I(1)	I(1)
Oil Price	-2.13	-10.56	I(1)	-2.06	-10.51	I(1)	I(1)
GDP Deflator	-2.66	-1.65 † -13.31 ††	I(2)	-2.92	-2.88 † -18.35 ††	I(2)	I(2)
Real GDP	-0.81	-9.01	I(1)	-0.92	-9.20	I(1)	I(1)

A constant, a time trend and a maximum lag of 13 are included in the OLS regressions for all variables. Sample period covers 1961:1 – 2000:4. Critical values are based on McKinnon (1996 : 1% = 4.017, 5% = 3.44, 10% = 3.14. Keys: †, first difference; † †, second difference.

Table 3. Cointegration Test – Canada's Variables
Date: 09/26/03 Time: 13:50
Sample(adjusted): 1962:4 2001:4
Included observations: 157 after adjusting endpoints
Trend assumption: Linear deterministic trend (restricted)
Series: YCAN_SA FRATE_SA BRATE_SA
Lags interval (in first differences): 1 to 6

Unrestricted Cointegration Rank Test				
Hypothesized		Trace	5 Percent	1 Percent
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Critical Value
None	0.107569	36.14916	42.44	48.45
At most 1	0.074961	18.28153	25.32	30.45
At most 2	0.037791	6.048131	12.25	16.26
*(**) denotes rejection of the hypothesis at the 5%(1%) level				
Trace test indicates no cointegration at both 5% and 1% levels				
Hypothesized		Max-Eigen	5 Percent	1 Percent
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Critical Value
None	0.107569	17.86762	25.54	30.34
At most 1	0.074961	12.23340	18.96	23.65
At most 2	0.037791	6.048131	12.25	16.26
*(**) denotes rejection of the hypothesis at the 5%(1%) level				
Max-eigenvalue test indicates no cointegration at both 5% and 1% levels				

Table 4. Cointegration Test – USA Variables

Date: 11/08/02 Time: 18:18
Sample(adjusted): 1962:3 2000:4
Included observations: 154 after adjusting endpoints
Trend assumption: Linear deterministic trend
Series: YUS POIL FRATE
Lags interval (in first differences): 1 to 5

Unrestricted Cointegration Rank Test

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None	0.089587	25.50247	29.68	35.65
At most 1	0.058460	11.04855	15.41	20.04
At most 2	0.011440	1.771873	3.76	6.65

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Trace test indicates no cointegration at both 5% and 1% levels

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None	0.089587	14.45392	20.97	25.52
At most 1	0.058460	9.276677	14.07	18.63
At most 2	0.011440	1.771873	3.76	6.65

*(**) denotes rejection of the hypothesis at the 5%(1%) level
Max-eigenvalue test indicates no cointegration at both 5% and 1% levels

Table 5 Lag Length Determination -- Canada

VAR Lag Order Selection Criteria
Endogenous variables: D(YCAN_SA) D(FRATE_SA) D(BRATE_SA) D(D(CANCPISAB)) D(Q_SA)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-738.3091	NA	0.009469	9.529604	9.627356	9.569307
1	-664.8789	141.2119	0.005090	8.908704	9.495215*	9.146920*
2	-635.7212	54.20342	0.004830	8.855400	9.930670	9.292128
3	-601.1507	62.04960	0.004283	8.732702	10.29673	9.367943
4	-573.9524	47.07413	0.004183	8.704517	10.75731	9.538271
5	-543.6700	50.47063*	0.003939*	8.636795*	11.17834	9.669061
6	-520.6766	36.84834	0.004086	8.662521	11.69283	9.893300

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 6. Lag Length Determination United States

VAR Lag Order Selection Criteria

Endogenous variables: D(USARGDPS) D(OILPRICE) D(FRATE) D(D(USADEFLS))						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-1246.830	NA	289.0474	17.01810	17.09947*	17.05116
1	-1216.884	57.85596	239.1152	16.82835	17.23521	16.99366*
2	-1196.832	37.64736	226.4070	16.77323	17.50558	17.07079
3	-1172.584	44.20754	202.6244	16.66101	17.71885	17.09082
4	-1148.582	42.45224	182.1426	16.55214	17.93547	17.11420
5	-1130.856	30.38826	178.5759	16.52865	18.23747	17.22296
6	-1108.651	36.85748*	165.0203*	16.44423*	18.47854	17.27079

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

Table 7　　　Stability Test - Canada

Roots of Characteristic Polynomial
Endogenous variables: D(YCAN_SA) D(FRATE_SA) D(BRATE_SA) D(D(CANCPISAB)) D(Q_SA)
Exogenous variables: C
Lag specification: 1 6
Date: 09/26/03 Time: 13:27

Root	Modulus
-0.919860	0.919860
-0.110765 - 0.848786i	0.855983
-0.110765 + 0.848786i	0.855983
0.472871 + 0.700186i	0.844907
0.472871 - 0.700186i	0.844907
-0.530423 + 0.631486i	0.824695
-0.530423 - 0.631486i	0.824695
0.227793 + 0.788721i	0.820957
0.227793 - 0.788721i	0.820957
-0.676180 - 0.441303i	0.807445
-0.676180 + 0.441303i	0.807445
0.756523 - 0.277413i	0.805783
0.756523 + 0.277413i	0.805783
0.585839 + 0.512541i	0.778399
0.585839 - 0.512541i	0.778399
-0.394230 - 0.665393i	0.773411
-0.394230 + 0.665393i	0.773411
0.719446 - 0.274136i	0.769905
0.719446 + 0.274136i	0.769905
-0.742885 + 0.157061i	0.759307
-0.742885 - 0.157061i	0.759307
0.052006 + 0.742443i	0.744263
0.052006 - 0.742443i	0.744263
-0.184159 + 0.709073i	0.732598
-0.184159 - 0.709073i	0.732598
0.351874 - 0.434731i	0.559291
0.351874 + 0.434731i	0.559291
-0.481397	0.481397
-0.227696 + 0.349223i	0.416896
-0.227696 - 0.349223i	0.416896

No root lies outside the unit circle.
VAR satisfies the stability condition.

Inverse Roots of AR Characteristic Polynomial

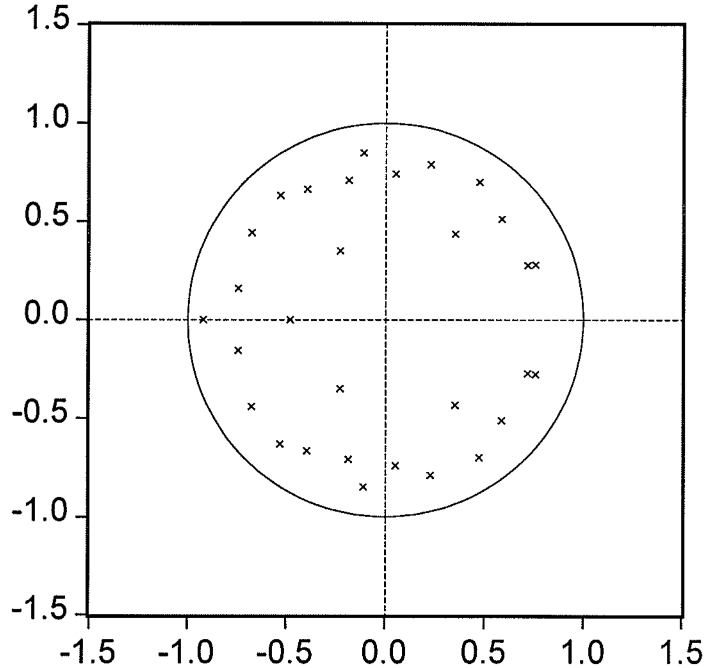


Table 8. AR Roots - USA

Roots of Characteristic Polynomial
Endogenous variables: D(USARGDPS) D(OILPRICE) D(FRATE) D(USADEFLS)
Exogenous variables: C
Lag specification: 1 5
Date: 11/08/02 Time: 16:53

Root	Modulus
0.929833	0.929833
-0.799965	0.799965
-0.411001 + 0.681531i	0.795868
-0.411001 - 0.681531i	0.795868
0.708442 - 0.349842i	0.790114
0.708442 + 0.349842i	0.790114
-0.099836 - 0.756031i	0.762595
-0.099836 + 0.756031i	0.762595
0.109283 - 0.721487i	0.729717
0.109283 + 0.721487i	0.729717
0.676061	0.676061
0.314719 - 0.581974i	0.661621
0.314719 + 0.581974i	0.661621
-0.487860 - 0.400667i	0.631302
-0.487860 + 0.400667i	0.631302
-0.304198 - 0.501495i	0.586544
-0.304198 + 0.501495i	0.586544
0.444430 - 0.312430i	0.543259
0.444430 + 0.312430i	0.543259
-0.535753	0.535753

No root lies outside the unit circle.
VAR satisfies the stability condition.

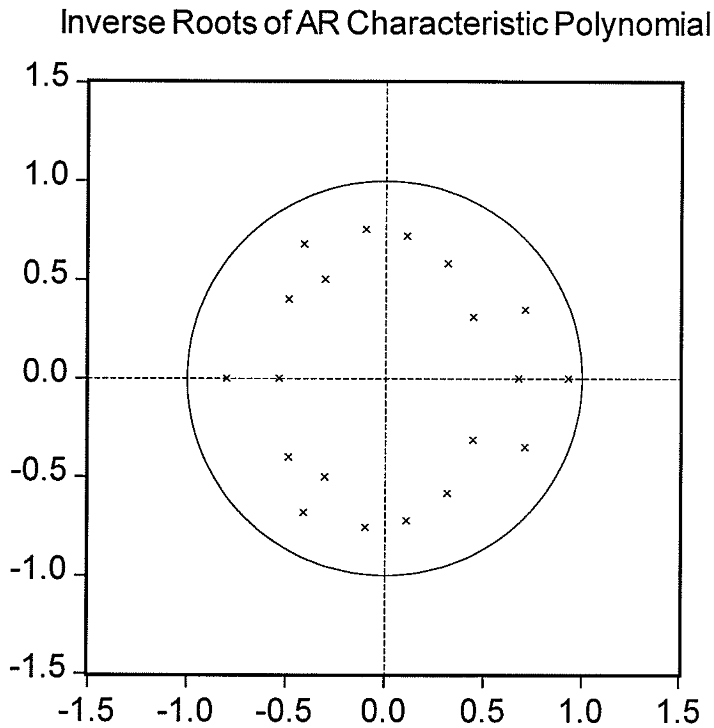


Table 9. Canada - Variance Decomposition

Canada					
Variance decomposition for output					
Quarter	Supply Shock	Demand Shock	U.S. Monetary Policy Shock	Home Monetary Policy Shock	Real Exchange Rate Shock
1	10.02	89.98	0.00	0.00	0.00
4	9.36	80.57	9.67	0.18	0.20
8	14.84	65.86	18.28	0.77	0.23
12	35.06	48.43	14.38	1.79	0.35
28	78.79	15.80	4.32	0.76	0.32
Variance decomposition for Fed Funds rate					
1	7.67	3.47	88.85	0.00	0.00
4	9.98	11.00	78.31	0.68	0.03
8	8.07	8.39	79.75	3.65	0.14
12	6.16	6.80	80.36	6.56	0.13
28	3.38	4.88	81.24	10.41	0.09
Variance decomposition for Bank of Canada's rate					
1	2.29	1.17	20.85	50.79	24.91
4	9.01	5.67	30.09	36.65	18.58
8	12.65	4.42	44.00	24.36	14.57
12	12.71	4.33	47.66	20.14	15.66
28	9.93	5.09	49.95	14.35	20.68
Variance decomposition for CPI					
1	77.09	21.15	0.95	0.79	0.01
4	79.39	20.06	0.23	0.06	0.25
8	74.79	23.17	1.93	0.03	0.09
12	71.87	24.61	3.08	0.16	0.19
28	61.71	30.64	3.41	1.86	2.37
Variance decomposition for Real Exchange rate					
1	0.00	0.00	0.00	46.95	53.04
4	0.15	2.61	3.85	29.77	63.62
8	0.18	13.02	4.39	23.06	59.34
12	0.07	20.18	2.77	19.81	57.16
28	0.02	27.57	1.41	17.51	53.48
Note: The numbers across each row may not sum to 100.0 due to rounding errors.					

Table 10. United States – Variance Decomposition

U.S.A.				
Variance decomposition for output				
Quarter	Technological Shock	Oil Shock	Demand Shock	Policy Shock
1	8.84	91.16	0.00	0.00
4	19.03	76.83	0.17	3.97
8	41.76	50.74	0.90	6.60
12	58.22	34.87	0.74	6.16
28	80.63	16.02	0.34	3.01
Variance decomposition for Price of oil				
1	4.76	0.72	94.5	0.01
4	17.43	4.77	77.05	0.75
8	23.19	14.43	61.70	0.68
12	22.64	21.84	53.74	1.77
28	23.03	29.56	42.55	4.87
Variance decomposition for Fed funds rate				
1	38.76	22.84	1.73	36.67
4	26.36	58.79	0.65	14.19
8	17.40	74.80	0.75	7.04
12	12.96	81.20	0.94	4.89
28	8.39	86.93	0.91	3.77
Variance decomposition for GDP deflator				
1	52.89	4.39	1.83	40.88
4	63.61	9.92	0.32	26.15
8	55.33	23.18	0.11	21.37
12	47.07	31.25	0.21	21.45
28	36.20	38.55	0.53	24.71
Note: The numbers across each row may not sum to 100.0 due to rounding errors.				

Table 11. State Space Results

$AD\_Shock\_Canada_t = (SV1+C(1)) + (SV2+C(2))*AD\_Shock\_US_{t-1} + e_t$ $AD\_Shock\_Canada_t = (-1.85 + 1.17) + (24.61 - 15.86)*AD\_Shock\_US_{t-1}$	Convergence: After 358 iterations
$AS\_Shock\_Canada = (SV1+C(1)) + (SV2+C(2))*AS\_Shock\_US_{t-1} + u_t$ $AS\_Shock\_Canada = (-0.03) + (1.69 - 0.86)*AS\_Shock\_US_{t-1}$	Convergence: After 62 iterations
Note: *1) SV = Final value of the state variable, C = fixed coefficient component, AS_Shock_US refers to technological shocks.* *2) The state space estimation for the policy shocks, and for oil shock variables failed to converge even after 1000 iterations. The results are not reported here.*	*3) all the coefficients are significant at the 5% level.*

Table 12. Overall Results

State Space Models		Corrected Contingency Table				
Shocks	**Symmetry**	**Shocks**	**AD_US**	**AS_US(1)**	**AS_US(2)**	**Policy US**
AD	YES	AD_Canada	61.47			
AS – AS(non-oil =1)	YES	AS_Canada		59.27	49.00	
AS – AS(oil=2)	NC	Policy _Canada				46.49
Policy	NC					

Cross Correlations

Lag / Lead	**AD_Shock_US**	**AS_Shock_US(non-oil)**	**AS_Shock_US(oil)**	**Policy_Shock_US**
AD_Canada				
Lag (Lead) 0	59.91 (59.91)			
Lag (Lead) 2	61.98 (54.71)			
Lag (Lead) 4	63.56 (48.86)			
Lag (Lead) 6	64.46 (43.46)			
AS_Canada				
Lag (Lead) 0		68.81 (68.81)	27.57 (27.57)	
Lag (Lead) 2		62.75 (67.84)	29.99 (23.80)	
Lag (Lead) 4		56.23 (59.47)	32.96 (21.44)	
Lag (Lead) 6		50.38 (50.43)	36.63 (18.50)	
Policy_Canada				
Lag (Lead) 0				-28.07 (-28.07)
Lag (Lead) 2				-27.97 (-31.26)
Lag (Lead) 4				-27.57 (-32.72)
Lag (Lead) 6				-24.51 (-31.39)

Granger Causality Test

1)AD_US Granger causes a) AD Canada *** b) Policy Canada *** 2) AD Canada Granger causes AS_US(1)** 3)AS_US(2) Granger causes a) AD Canada * b) AS_US(1)***	4)AS_Canada Granger causes a) AD_US*** b) AS-US** c) Policy_US** ***Overall Notes**: Significance Levels are 1% = *; 5% = **; 10% = **** *NC = No Convergence*

Figure 1. Deseasonalized Data - Canada

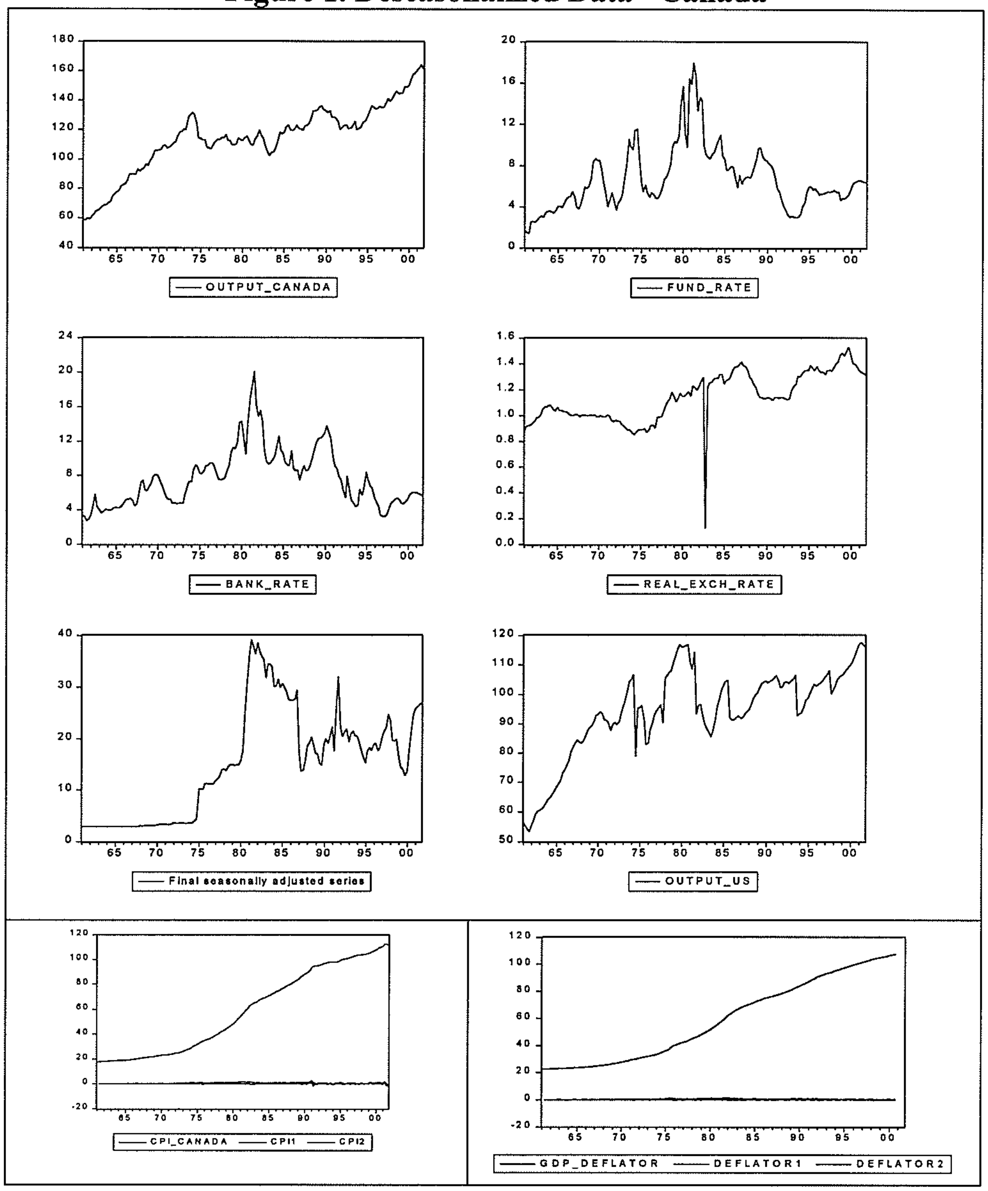
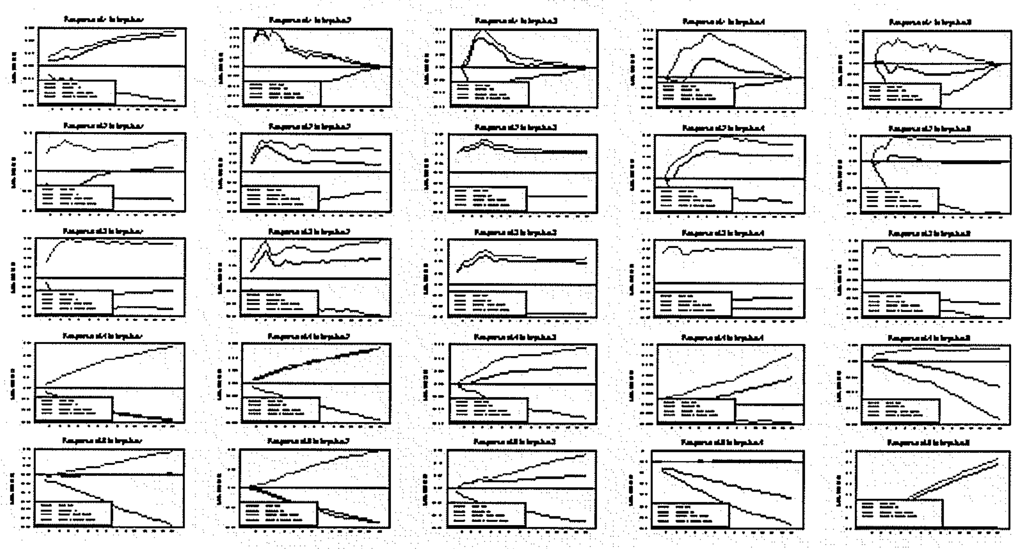


Figure 2. Cumulated Impulse Responses – Canada

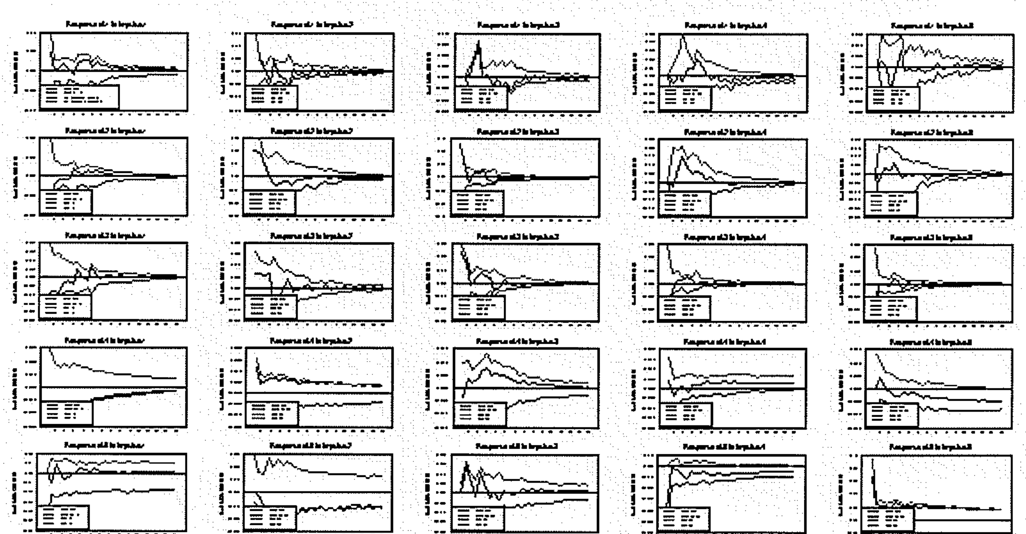
Shocks: AS(1) AD(2) Foreign MP(3) Domestic MP(4) Exch. Rate (5)



Note: the variables are from top to bottom: Output – Fed Fund Rate – Bank of Canada's Rate – CPI – Real Exchange Rate. MP = Monetary Policy.

Figure 3. Non-Cumulated Impulse Responses -- Canada

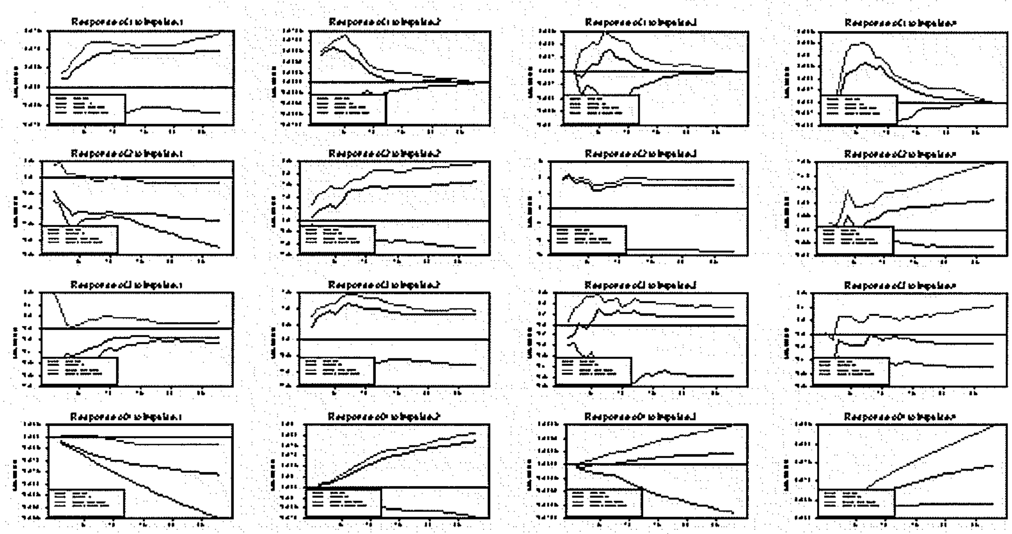
Shocks: AS(1) AD(2) Foreign MP(3) Domestic MP(4) Exch. Rate (5)



Note: the variables are from top to bottom: Output – Fed Fund Rate – Bank of Canada's Rate – CPI – Real Exchange Rate. MP = Monetary Policy.

Figure 4. Cumulated Impulse Responses – United States

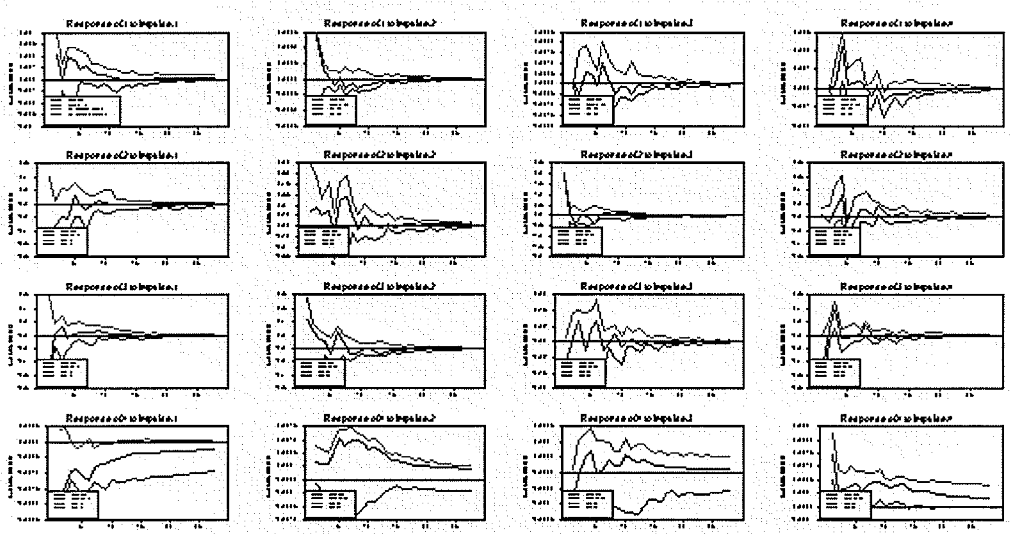
Shocks: Non-oil AS Oil -AS AD MP



Note: the variables are from top to bottom: Output – Oil Prices – Fed Fund Rate – CPI. MP = Monetary Policy

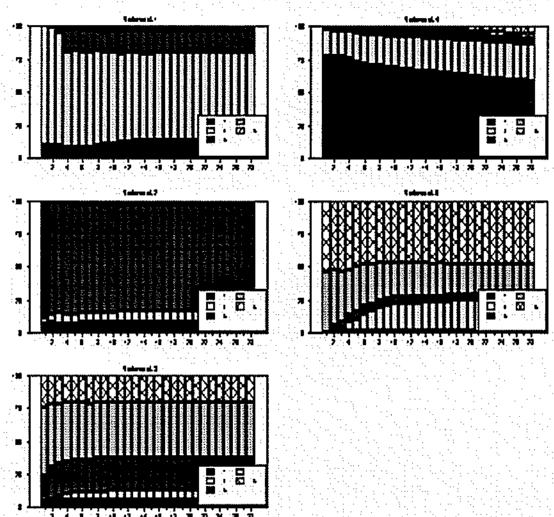
Figure 5. Non-Cumulated Impulse Responses – United States

Shocks: Non-oil AS Oil -AS AD MP



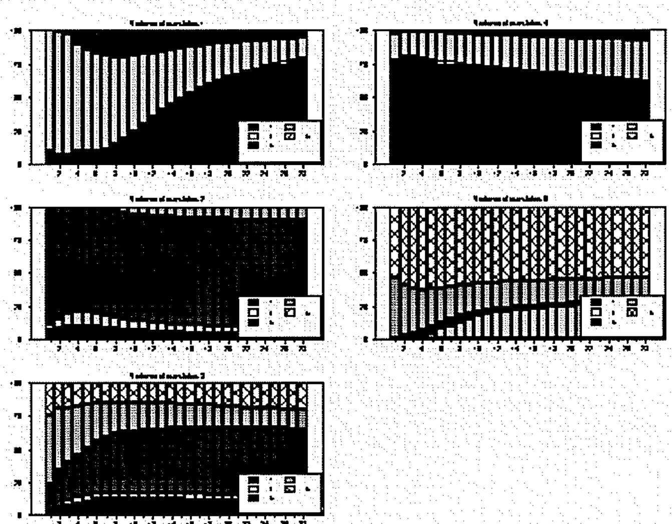
Note: the variables are from top to bottom: Output – Oil Prices – Fed Fund Rate – CPI. MP = Monetary Policy

Figure 6. Variance Decomposition – Not Cumulated – Canada



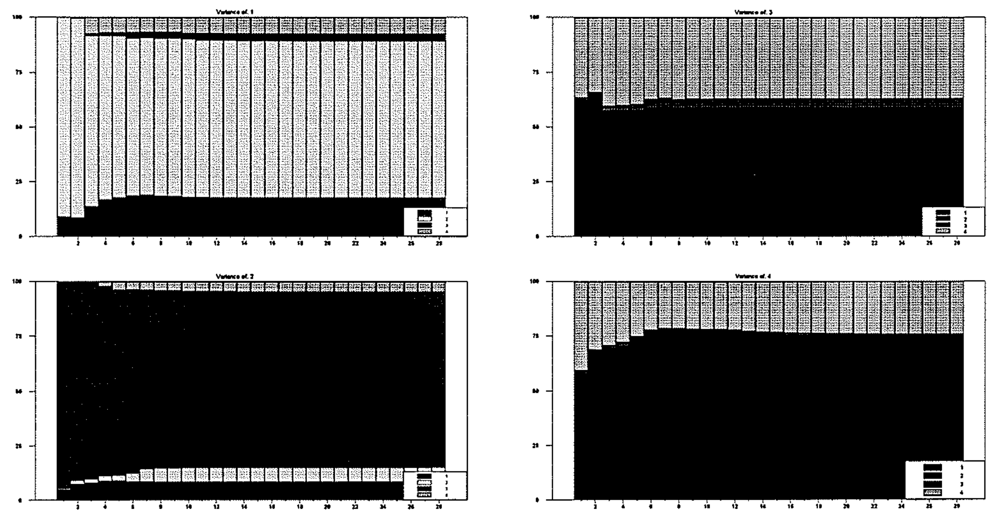
Note: Column 1: *output, fund rate, bank rate;* **Column 2**: *CPI, real exchange rate* **Shocks are ordered as**: *supply (1), demand (2), foreign policy (3); domestic policy (4), and real exchange rate (5).*

Figure 7. Variance Decomposition – Cumulated - Canada



Note: Column 1: *output, fund rate, bank rate;* **Column 2**: *CPI, real exchange rate* **Shocks are ordered as**: *supply (1), demand (2), foreign policy (3); domestic policy (4), and real exchange rate (5).*

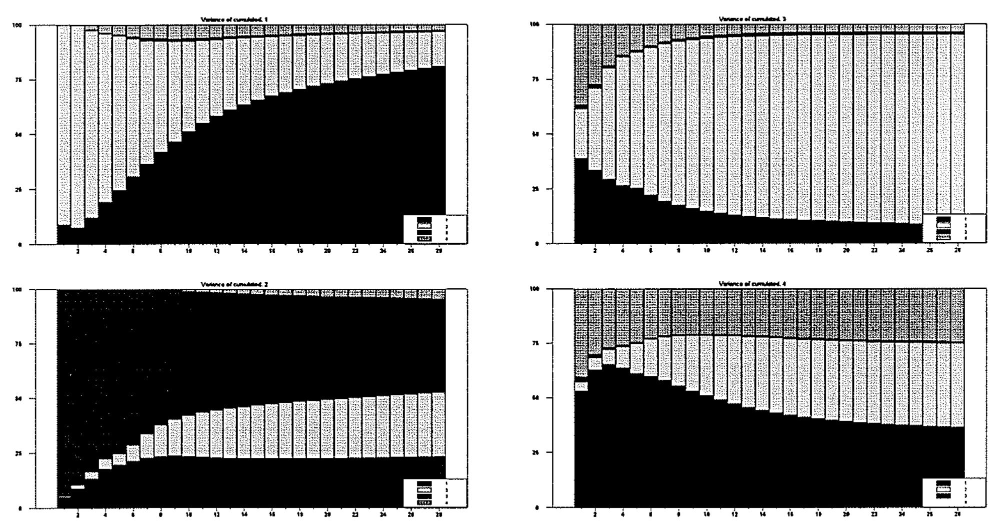
Figure 8. Variance Decomposition – Not Cumulated – United States



Note: Column 1: *output, oil price;* **Column 2**: *fund rate, CPI*
Shocks are ordered as: *Technological (1), oil (2) demand (3), domestic policy (4).*

Figure 9. Variance Decomposition – Cumulated United States

Note: Column 1: *output, oil price;* **Column 2**: *fund rate, CPI.*



Shocks are ordered as: *Technological (1), oil (2), demand (3); domestic policy(4).*

Figure 10. Structural Innovations – Canada

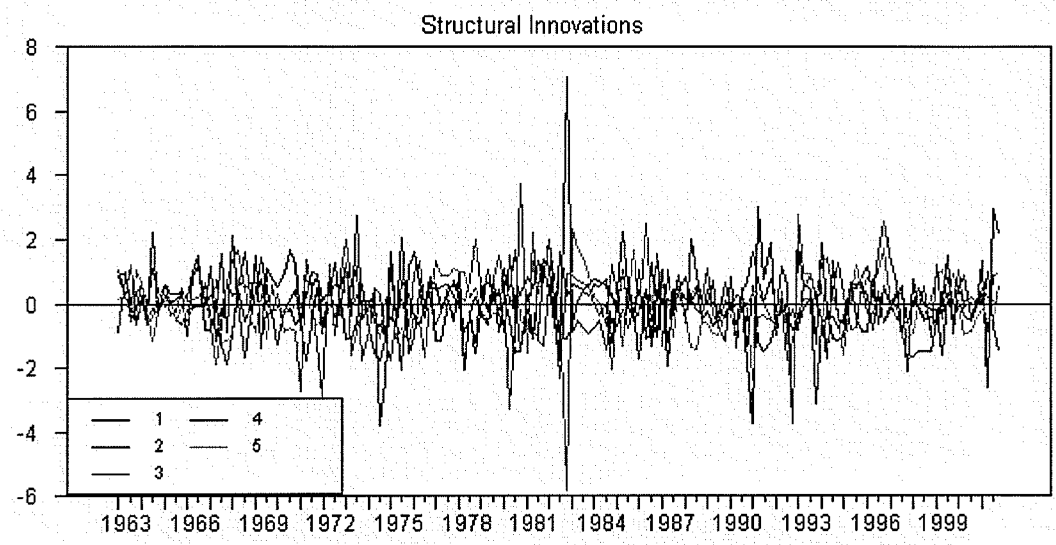


Figure 11. Structural Innovations – U.S.

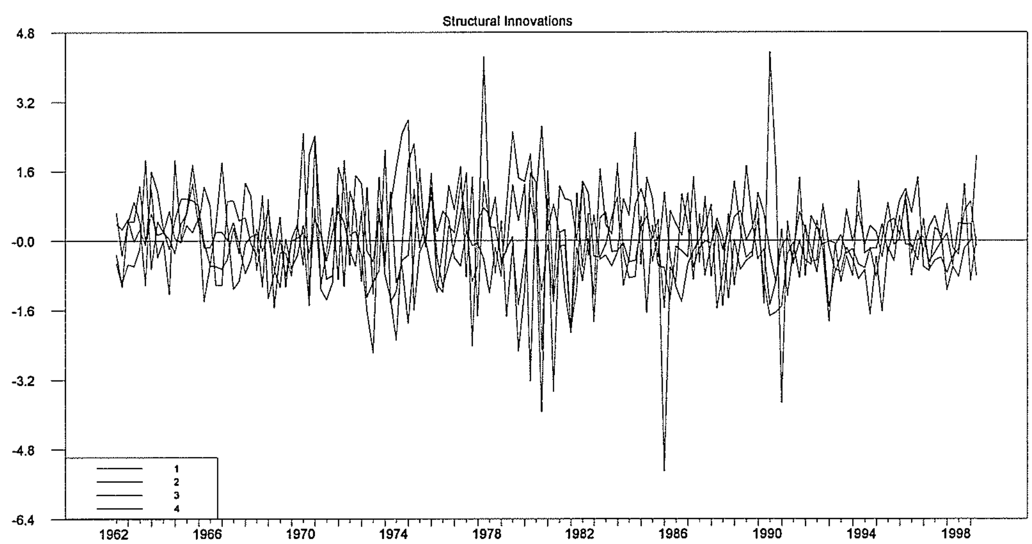
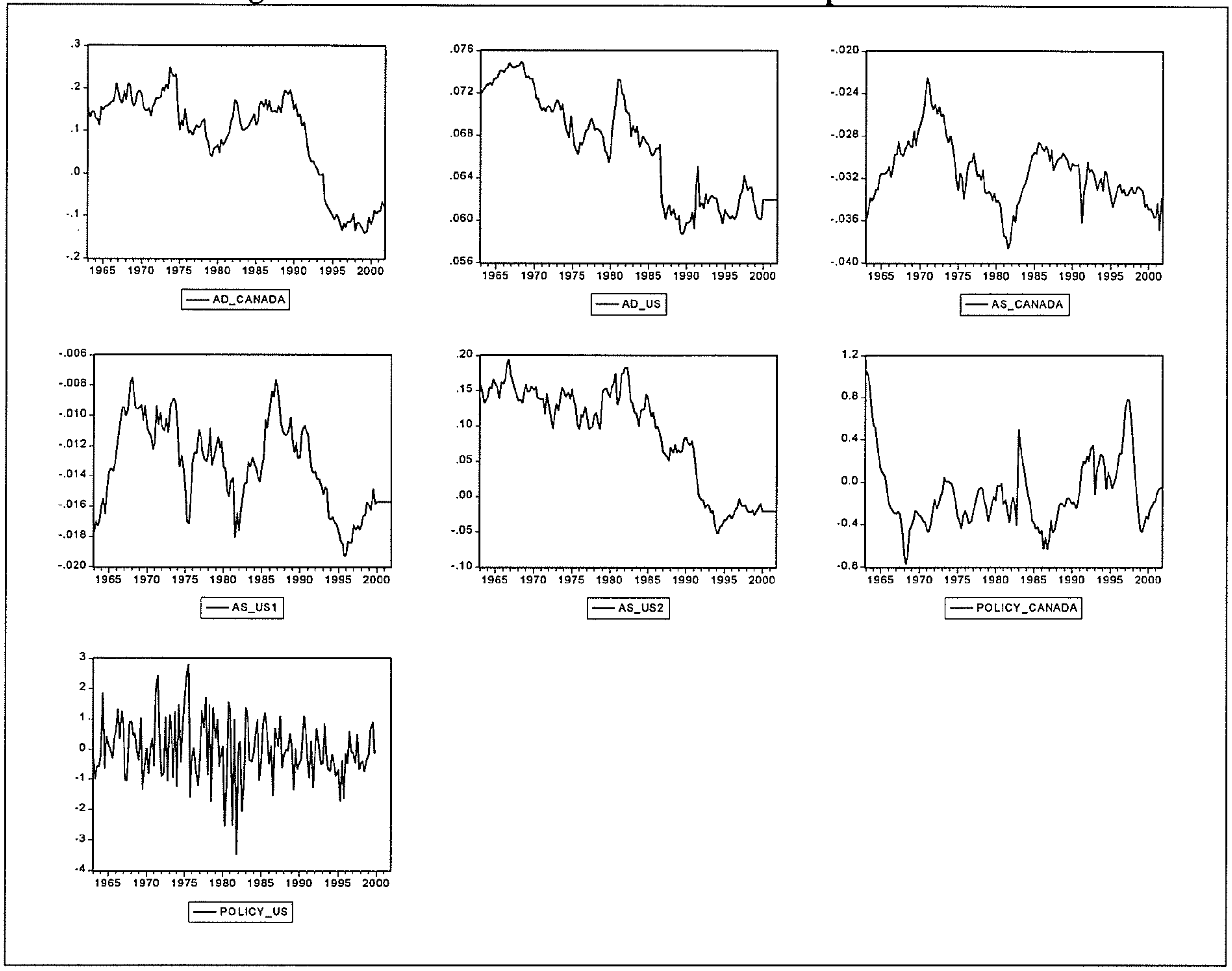


Figure 12. Structural Shocks Series for State Space Exercises



On the North American Monetary Union Issue: A Study of Macroeconomic Shocks Between Mexico and Its North American Free Trade Agreement (NAFTA) Partners via Structural Vector Autoregression (SVAR) Methodology

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CANADA

May 9, 2004

Abstract

This paper is the first attempt at two pairwise comparisons in order to tackle the issue of monetary union for Mexico with its NAFTA partners in the literature. It is also the first research to suggest that shocks between Mexico and the United States and between Mexico and Canada may not be asymmetric. To arrive at this finding, the paper has extended the work of Lalonde and St-Amant (1994) (an SVAR of output, monetary base, and CPI) to an SVAR of 5 variables, with real exchange rate and foreign policy instrument being the two new variables. The models are identified by employing an extended combination of short- and long-run restrictions in the line of Galí (1992). Based on data that spans the period 1960Q1 - 2000Q4, the study shows that the degree of shocks asymmetry between Mexico and the United States and between Mexico and Canada depends on the order of integration of Mexico's money stock. This can be seen as a setback for previous studies that have uniformly emphasized that shocks between Mexico and the rest of the NAFTA partners were asymmetric.

1 Introduction

The objective of this study is to understand how macroeconomic shocks between Mexico and its NAFTA partners are related in order to determine whether monetary union is a feasible option between them, ceteris paribus. The optimum currency area (OCA) literature provides the means by which countries could be assessed in terms of suitability to such arrangement. They include measurements such as the size of the economies, degree of openness, trade concentration and similarity of shocks as emphasized by [Mundell (1961) and Tower and Willet (1976)]. The determination of the degree of symmetry between shocks across countries has been so far the most popular criterion used in empirical works to evaluate optimum currency areas.

Researchers have also used various methodologies to uncover the nature of shocks. Specifically, cointegration analysis and structural vector autoregression methodology aided by either contemporaneous cross correlation or state space space analyses are the most frequently employed techniques in studies that focus on the relationship between Mexico and the rest of the North American countries. For example, Michelis (2002) uses the [Johansen and Juselius (1990)] cointegration technique and a .5 rule on the cross correlation coefficient of regional and national GDP growth rates across the three countries to show that a common currency is feasible between Canada and the United States, but not between Mexico and the other two countries. Del Negro and Obiols-Homs (2001) estimate a structural vector autoregression (SVAR) with block exogeneity restrictions to demonstrate among other facts that disturbances originating in the United States economy have been the main driving forces behind shocks affecting Mexico. A study by Bayoumi and Eichengreen (1993), which is based on a combination of SVAR with long-run restrictions and contemporaneous cross-correlation of structural shocks, attempts to gauge the degree of shock asymmetry between Mexico and industrial regions in the United States. They observe that supply shocks are the most important disturbances in Mexico and that those shocks are negatively correlated with shocks affecting the United States. Therefore, they conclude that it is not in the advantage of Mexico to fix its currency in any form to the U.S. dollar. Finally, Lalonde and St-Amant (1995) extend the work of Bayoumi and Eichengreen by using a trivariate SVAR to extract the structural shocks, which are then fitted into a state space model to uncover the degree of shock asymmetry across the countries. They then arrive at a conclusion similar to Bayoumi and Eichengreen that a monetary union with the United States would involve substantial adjustment costs for both Mexico and Canada. What can be inferred from these studies is that although there is a mixed feeling about the feasibility of monetary union between Canada and the United States, all seem to agree that Mexico does not fulfill the OCA criteria and therefore must not even contemplate such a union.

The present paper represents an improvement upon the work of Lalonde and St-Amant (1995) and Bayoumi and Eichengreen (1993) among others in that it introduces two extra variables: real exchange rate and foreign monetary policy instrument in the SVAR procedure to account for the interaction of the Mexican economy with the rest of the North American countries. Part of the contributions of this essay is that it provides answers to two questions: 1) What type of shocks are most important for the Mexican economy when foreign monetary policy and real exchange rate shocks are explicitly modelled in addition to the usual demand, supply, and policy shocks identified by Lalonde and St-Amant? and 2) Is it possible to arrive at the same conclusion about the Mexican economy vis-à-vis United States and Canada in regard to the feasibility of monetary union?

To tackle these issues, the paper estimates two SVARs with five endogenous variables each, namely, industrial production index, foreign monetary policy instrument,[1] domestic monetary policy instrument (money stock),

[1] The Bank of Canada's rate is used in the Mexico - Canada SVAR when Canada is modelled as the large country while the Fed fund rate plays the same role in the Mexico -

consumer price index, and real exchange rate. The structural shocks obtained from each SVAR along with those previously determined from a similar exercise for United States and Canada enter the estimation of a Time-Varying state space model. This version of the SVAR methodology, which is borrowed from Artis and Ehrmann (2000), entails at least two advantages that make it superior to previous work that has used the same technique. First, it enables the researcher to directly model the influence of foreign policy on the domestic economy in order to uncover the degree of shock asymmetry, which renders the use of auxiliary techniques such as cross correlation and state space useless.[2] In few words, if foreign and domestic policy instruments follow the same path when the economy is hit by supply and demand shocks, then each of these shocks is symmetric across countries. Second, it allows the researcher to factor in the weight that the central bank is assumed to attach to real exchange rate in setting monetary policy.

Based on data taken from the International Financial Statistics (IFS) of the International Monetary Fund (IMF) for the period 1960 - 2000 and a combination of short- and long- run restrictions *a la* Galí (1992) to identify

United States SVAR.

[2]Yet, to confirm the SVAR findings, this paper uses the state space model in the second stage of the empirical exercise.

the structural model, this paper is the first attempt at two pairwise comparisons (Mexico vs. U.S.; and Mexico vs. Canada) to have found that the nature of shocks that affect Mexico in relation to Canada and the United States is sensitive to the order of integration attributed to the money stock (M1) in the estimation. This result may be a setback for all the studies that have found Mexico not suitable for monetary union on the basis that shocks affecting its economy are categorically asymmetric in relation to the other two countries under consideration. Nonetheless, in accordance with previous studies, the paper does find evidence of a supply shock dominance in the dynamics of the Mexican economy. However, foreign monetary policy shocks were found to be more important than domestic policy shocks but less than real exchange rate shocks in their contribution to the variance of output, another result that undermines the claims that countries must reject the idea of monetary union on the basis that monetary policy has real effects on output.

The rest of the paper is organized as follows. Section 2 presents the background of the study. Section 3 reviews the literature and illustrates the model and the methodology. Section 4 describes and analyzes the data. Section 5 analyzes the empirical results. Finally, section 6 concludes the paper.

2 Background

The arguments against monetary union as related to Canada mainly rest on the "*effectiveness*" of independent monetary policy and the flexible exchange rate system, which are believed to have served the economy as an insulator and a shock absorber, respectively. This view is partly justifiable because the Bank of Canada is seen as being successful in keeping inflation relatively low during the 1990s and in designing mechanisms towards preventing currency crises over the years. However, if the Bank of Mexico had to be judged upon the same criteria, it would have been evident that its track records have not withstood the test of time and are therefore not that impressive. Inflation has always been high and the economy has been subject to deep debt, financial, and foreign exchange crises.

Contrary to Canada, Mexico has tried several exchange rate regimes following the official demise of the Bretton Woods system in 1973. It indeed followed some sort of fixed exchange rate policies to the U.S. dollar in the 1970s until 1982 and again during the Salinas period (1989-1994). During both periods, inflation approximates 20 percent on average, a very low rate when one considers that it was above 100 percent in the early and mid 1980s, most precisely before the announcement of a stabilization program *"Pacto de Solidaridad Economica"* sponsored by the then presidential candidate Salinas in 1988. As evidenced by Figure 1, the growth of output is accompanied by a steady inflation rate during these periods. This would suggest that Mexico's economy does better under the fixed than under the floating regime. Nevertheless, in both times, the fixed exchange rate regime had to be abruptly abandoned at tremendous costs if the following economic instability and performance are taken into consideration. In light of this situation, many analysts are led to believe that recent international financial crises were partly caused by prevailing dirty fixed regimes and therefore argue that floating regimes were a better option [See Sachs and Larrain (1999); Roubini, Corsetti, and Pesenti (1998)]. This reasoning echoes Friedman's (1988) arguments for flexible exchange rates that there is no need to require adjustments in nominal prices when the nominal exchange rate can fulfill the same task with less distortions in real economic activity.

Figure 1 about here

The debate on whether fixed regimes are better than floating regimes or vice-versa is a very old one. However, what might be understood from Mexico's economic debacle is that despite fixing the exchange rate to the US dollar, the respective monetary and fiscal authorities had used contra-productive macroeconomic policies such as massive monetary expansion, and particularly in 1982, loose fiscal policies, a behavior that goes against the very basic principles of currency arrangements [see Rivera-Batiz and Rivera-Batiz (1994)]. Without being side tracked off the issue at hand, it is also important to note that Mexico had also paid a high price for its careless policy. The debt crisis that partly arose as a consequence of this mismanagement had a long-lasting negative repercussion on the productive capacity of the economy. Even seven years after, Mexico had to constantly struggle to return to the pre-crisis levels of industrial production and inflation rates (see Figure 1). Given this environment, it appears very difficult to assess the merits of any alternative exchange rate regime.

Needless to say that Mexico has also experienced two episodes of forced dirty flexible exchange rate regimes: 1982 - 1988 and December 1994 to Present. The first episode originated in 1982 with the debt crisis, specifically when the government made it public that it could no longer service its obligations. In the face of a huge depreciation, the tasks of the monetary authorities partly reduced to pegging the rate of depreciation of the peso, which were proven deficient in containing inflation. The second episode started in December 1994 when the depletion of international reserves had reached an alarming level thereby making it impossible for the Bank of Mexico to maintain the parity of the peso to the U.S. dollar. At that point in time, the only choice left to the monetary authority was to let the peso freely float, a situation that still prevails today. However, the Bank had thereafter on many occasions intervened in the market to maintain the value of the peso above a certain critical level.

In the early phase of the economic turmoil, as inflation was rising above 20 percent, the government had to offer a higher risk premium in order to attract foreign investment. Interest rate reached a peak of 63 percent, which could not move investors as they perceived a greater sovereign risk associated with doing business in Mexico (see Figure 2). It was not until the concretization of the bailouts by the International Monetary Fund (IMF) and the US government that investors' confidence was then reestablished and since then the state of the economy has improved continuously. Both interest and exchange rates seem to have stabilized and inflation has settled around 10 percent [see ECLAC (2001)]. Growth of gross domestic product averaged 5% in 1999 and reached 8% in the first quarter of 2000 [see Barro (2000)]. However, as Barro also emphasizes, the improvement of the economy is mainly driven by export-led-growth strategies that stem from slashed tariffs under NAFTA and a strong U.S. economy, but not by increases in factor productivity or technological progress. Therefore, for the short-period of time that Mexico has experienced the floating regime, there is no strong arguments that can be made in favor of this exchange rate system. Crudely speaking, by reading behind Barro's lines, it can be argued that the success of the Mexican economy during the late 1990s and early 2000s is partly a matter of luck.

Figure 2 about here

Summarizing the discussion so far, it appears that when quasi-fixed systems (as in Mexico, 1982-1988) are proven to be so disastrous, the merits of the system are put into doubt. There is uncertainty about how long the 'positive' effects of the floating regimes could last since the costs associated to doing business in Mexico is rising as the currency constantly loses value. Understandably, it becomes legitimate to try other alternatives. It is perhaps within this context that the actual Mexican government presided by Vicente Fox is motivated to either dollarize the economy or to enter a monetary union with United States and Canada, despite strong Mexican nationalism sentiments [see Barro (2000); Skousen (2001), and Francis (2000)]. An eventual move to either of these arrangements is justified by the repeated economic instability that the Mexican economy has been subjected to over the years. As the business sector in Mexico contemplates, converting NAFTA into a North American Monetary Union would create the largest market in the world, and would alleviate Mexico's economic situation by any standard as a developing country. The question, however, is whether there is an equal advantage for Canada in signing such arrangement.

Putting the debate into perspective, by the year 2004, NAFTA will enter a maturity phase in that the 10-year probationary period awarded to each country to make proper adjustments in some industries (e.g. automobile industry in Mexico) would reach an end. As a consequence, these industries will be opened to full competition. [3] Nonetheless, the pattern of trade between member countries has not substantially changed during this period. The United States remains the most important trading partner of both Canada and Mexico. More than 80% of each country's total exports accrue to the

[3]For example, the automobile industry sector in Mexico, which has been protected since its creation in 1920s will be opened to competition from both partners. Similar industries in Canada such as the film sector will be subject to the same treatment.

United States (U.S.). Canada does not seem to have had so far any substantial gain from trading with Mexico, though optimistic observers have pointed to a tendency of increasing trade [see Chriszt (2000)]. Since this agreement was signed in order to provide each member nation better access to the others' markets, expertise and technology, it is economically justifiable to expect a higher volume of trade between the two countries, even when this could be translated into a decrease of their U.S. market share under the assumption of a constant productive capacity. There again, one may still argue that it would not have been in Canada and Mexico's best interests because they would have left room for other competitors. From a different perspective, it can be understood that a broader trade between Mexico and Canada could possibly lessen their losses against potential economic downturns in the U.S..

In a few words, it can be argued that the expansion of trade between the two countries carries a cost as well as a benefit. Which one is greater seems to be a forgone conclusion. The benefit for going for the big market appears to outweigh the costs associated to a well diversified trade patterns as the U.S. serves as a pole of attraction for both Mexico and Canada, a behavior that is well understood within the context of International Trade Theory. Commonly accepted arguments in the economics literature to explain preferential trading tendencies among countries include similar manufactured goods, geographic location, differential labour cost, inflation, and product quality [see Krugman and Obstfeld (1997)]. Since a lot of ink has already been spilled on these subjects, this paper does not contemplate further elaboration. Nonetheless, it is worth mentioning that the geographic proximity, i.e., U.S. being closer to both countries than they are to each other, may be a reasonable explanation for the lack of trade between the Canada and Mexico.

Is it perhaps fair to reason that, if the existing prevailing trade patterns were to continue even under a monetary union arrangement, there would be no incentive for Canada to join with Mexico as a partner. Put differently, had Mexico and the U.S. decided to form a monetary union, would Canada have stepped aside? Answers to these questions are likely to be found if one looks in retrospect to the factors that have motivated Canada to sign NAFTA besides the fact that it had already signed a free trade area (FTA) with the United States in 1989. It is believed that Canada made such a move not because it expected to gain so much from trading with Mexico but rather because it was eager not to lose its U.S. market share as the most important trading partner of the United States. Building a case for monetary union along the same line, ceteris paribus, seems to suggest that Canada may eventually enter a monetary union with the sole objective to protect its interest in the U.S. market. If it is true that a monetary union between U.S. and Mexico would eventually displace Canada in the U.S. market, then it is rational to believe that Canada would be compelled to protect its interest, even when this means signing a monetary union. Therefore, the answer to the question is a simple no. Moreover, it is unrealistic to believe that Mexico does not represent an economic threat to Canada. The fact that Mexico is a developing country with very cheap labor does constitute an impediment for the Canadian economy as some established firms on Canadian soil may be tempted to move their plants to Mexico in the sake of higher profits. Then, if one believes in factor price equalization, a monetary union will have the advantage of stabilizing employment across member countries as factors of production will move freely to this end. In this respect, Canada might expect to gain from common currency arrangement with Mexico.

At this point, it is also important to note that research on whether shocks that hit each NAFTA member country are symmetric or asymmetric for the feasibility of monetary union are mostly relevant for the Canadian economy only. On the one hand, the United States is already a major player with a very strong currency that serves as a store of value and that facilitates transactions at the world level. On the other hand, Mexico's economy is the most problematic. Its economy is characterized by low purchasing power for the average worker, slow productivity growth, and a lack of confidence from international investors due to the risk associated with the peso. It may still be argued that these features of the economy are not that relevant due to the fact that investors have ways to overcome these barriers. For example, at the national level, traders and investors may be able to hedge exchange-rate risk by either quoting their goods in U.S. or Canadian dollars, or by dealing in the derivatives market. However, menu costs and the cost of hedging in most cases are extremely high. At the world level, if one puts aside, for the sake of argument, the constant threat that Brazil, Argentina, and Chile represent for Mexico in competing for foreign investment, many small competitors in Latin America such as: Panama (since 1904), Ecuador (in 2000), and El Salvador (January 2001) have already adopted the U.S. dollar as their legal currency, thereby making their markets a more stable environment in which to carry out business. When all these factors are taken into account there may be some legitimacy in profiling Mexico as a country in need of an anchor. To the extent that this is true, then the degree of shock asymmetry may be relegated to a secondary role, not to say it becomes irrelevant. Canada, however, is the only country that has so far been reluctant in pronouncing in favor of the monetary union between the three countries because it still adheres to the notion that an independent monetary policy along with a flexible exchange rate regime is a better shock absorber for the economy. It is therefore in this idea that this paper is written. It seeks to understand whether shocks between Canada and Mexico and United States and Mexico are symmetric. Since the SVAR methodology used enables one to recover the structural shocks for the Mexican economy, the paper also looks at the relationship between the shocks by using the Time Varying Parameter of the State Space models as a means to confirm the SVAR results. The next section gives a brief overview of the literature and presents the underlying model that one believes capture the dynamics of the Mexican economy.

3 Literature Review

This section reviews the literature on monetary union between Mexico and the rest of the NAFTA partners. Not surprisingly, even though contributions on debt and currency crises abound the literature [see Lustig (1992), Larrain and Selowsky (1991), Alesina and Tabellini (1988), and Dornbusch (1989), Baig and Goldfajn (1998), Warner (1998), Flood and Marion (1998)], few papers with different approaches have been written on the subject of monetary union. There is a qualitative stance mostly taken by columnists such as Francis (2000), Barro (2000), and Skousen (2001), which mostly deals with the issue of dollarization as opposed to monetary union. Since the objective of this paper is to understand how shocks in Mexico are related to those of Canada and the United States, and given the fact that the views expressed in these articles are more of personal value judgments, there is not much that can be inferred from these contributions. As can be understood from their context, these opinions seems to have emerged in response to the calamities of the Mexican economy.

A very eclectic paper by Chriszt (2000) stands above these criticisms in that it is a thorough and objective analysis of the issue of currency arrangement for the North American countries which shed lights on the merits of both dollarization and monetary union for each integrating member. Chriszt determines whether dollarization or monetary union is appropriate to Mexico and Canada by applying the criteria of the optimum currency areas (OCA) to their case. As stressed by Mundell (1961), OCAs regroup countries or regions that are linked by the trade of goods and services and by financial and labor mobility, which make them suitable to join in a single currency arrangement. Citing the work of Tower and Willet (1976), the author also noted that it was until later that economists had envisaged to develop a set of criteria for measuring OCAs, which includes i) the size of the economy computed as ratio of domestic to foreign output; ii) the degree of openness measured as the ratio of total trade (imports plus exports) to domestic output; iii) the trade concentration; and iv) the similarity of shocks. On the basis of these criteria and following Williamson (2000), Chriszt uncovers the following facts : i) Canada's economy equals 7 percent of total U.S. GDP while Mexico's economy is just over 5 percent of the same; ii) Canada is more open than Mexico with total trade accounting for 70 and 58 percent of GDP, respectively; iii) Canada and Mexico mostly trade with the United States, around 80 and 81 percent, respectively;[4] and iv) Canada and the United States respond similarly to economic shocks while Mexico and the U.S. respond differently to shocks. However, the main difference between the two economies in their relationship with the United States stems from

[4]Though very minuscule, this small difference in trading would indicate that Mexico is getting more ground in the U.S. market than Canada. It is within this context that the paper argues above that Canada may be compelled to enter a monetary union if it feels that it is being displaced by Mexico or other competitors.

factor mobility. The author further observes that although capital flows relatively freely across the three countries, labor is yet immobile mostly between Mexico and the United States, a situation that can be explained by the large disparity in economic development between the two countries. By taking into consideration the OCAs criteria, Chriszt agrees with Williamson (2000) that *Canada appears to be much more suited for joining the United States in a single currency arrangement than does Mexico.* But he also recognizes that *Mexico appears to be moving closer to fulfilling OCAs criteria.* This is approximately the kind of conclusion that one would expect just by pure observation.

Fulfilling the OCAs criteria is just a step towards qualifying a country for a single currency area or a multicurrency area with fixed exchange rates, which Mundell (1961) refer to as OCA. The question that arises, however, is if a country had to decide for a single currency, should it opt for dollarization or monetary union? This is where Chriszt (2000) contribution is most interesting. In fact, he goes about assessing each option on the basis of seigniorage, U.S. interest premium, lender-of-last resort, and monetary policy issue. In terms of seigniorage, he shows that under dollarization countries adopting the U.S. dollar entirely forgo these revenues while under monetary union they would receive a share based on an upon agreed formula. With respect to U.S. interest premium, which he demonstrates to be higher for Mexico than for Canada, he contends that both options, dollarization and monetary union, can reduce its size considerably but the sovereign risk, that is risk associated to a country's solvency track record, is likely to remain higher under dollarization. In regard to the role of lender-of-last resort that incumbs to the monetary authority, Chriszt notes that the central bank would no longer be able to issue currency under dollarization but would definitely survive under monetary union since the newly created banking institution would fulfill a role similar to that of the European Central Bank (ECB). In terms of monetary policy, the author argues that it would be imported from the United States under dollarization while its development and implementation would be shared with the members under a monetary union. This cost-benefit analysis leads Chriszt (2000) to conclude that monetary union represents a better option than dollarization for all the countries, including United States since it may now be forced to return 85 percent of net seigniorage gain to countries that dollarize in accordance to a legislation introduced in the U.S. Senate in 1999.

Although Chriszt's paper is very useful in addressing the relevant issues to monetary union, it only scratches on the surface the most relevant question, which is whether shocks between Mexico and each of the remaining NAFTA partners are symmetric or asymmetric. Chriszt argues that Mexico and the United States respond differently to shocks (which would imply that shocks are asymmetric between the two) partly because Mexico is a major oil-exporting country that is frequently subjected to financial market disturbances and the U.S. is a major oil-importing country that plays a pivotal role in setting international interest rates. What can be understood from his argument is that since the two countries operate in different sides of the market, they are affected by different shocks. But the answer to this issue can only come about through an empirical estimation.

At the empirical level, there are mainly three strands of the literature. The first one consists in estimating single equations in the line of [Calvo and Mendoza (1996); and Kamin and Rogers (1996)], the second one focuses on correlation and cointegration analyses while the third one makes use of structural vector autoregression (SVAR) technique. Attention is paid to the last two lines of research in this literature review.

In his study of a monetary union in North America, Michelis (2002) carries out a regional analysis in the line of Bayoumi and Eichengreen (1994) that covers eight U.S. regions, four Canadian regions, and Mexico. He focuses on correlations of real GDP growth rates across the regions as well as cointegration analysis on variables that are relevant for convergence criteria, similar to the ones adopted by the Maastricht Treaty. In few words, the author looks at the long-run co-movements of a) regional GDP growth rates, b) short- and long-term interest rates, c) nominal exchange rates, and d) inflation rates. Based on data that spans the period 1950-1999, Michelis found that the cross correlation coefficient of regional and national GDP growth rates between Canada and the U.S. surpasses by a large margin a 50 percent cut-off point that would be required to either accept or reject the idea of optimum currency area (OCA). However, he noted that the same could not be argued for Mexico. This led him to conclude that a common currency may be feasible between the two countries but it is less likely that such arrangement would include Mexico. The main drawback of this study is that it does not inform how shocks between the countries are related. In addition, there also exists the risk of spurious correlation as Canadian and U.S. data may have the same underlying trend and Mexican data may have a powerful inflationary component that causes nominal variables to appear to be correlated even if they are not [see Ramanathan (2001), and Studenmund

(2000)].

A study by Del Negro and Obiols-Homs (2001), which borrows Cushman and Zha's (1997) small open economy model framework, investigates the usefulness of monetary policy for Mexico by estimating a vector autoregression that is composed of two blocks. The first block includes domestic variables such as exchange rate, money supply, interest rate, price level, and output while the second block includes foreign variables from the United States (a proxy for the rest of the world), namely, index of international commodity prices, output, general price level, and interest rate. In order to identify their VAR, they impose a block exogeneity restriction, which implies that none of the domestic variables have either contemporaneous or long-run effects on any of the foreign variables (the small vs. big country assumption). The authors used monthly data from the period of 1976 - 1997, which they divided into four sub-periods to take into account the sudden stops of exchange rate regimes. Their research reveals that: *i) exogenous shocks to monetary policy have had no impact on output and prices; ii) most of the shocks originated in the foreign sector; iii) disturbances originating in the U.S. economy have been a more important source of fluctuations for Mexico than shocks to oil prices.* This study however does not inform one about the nature of shocks between Mexico and the U.S. and is completely silent as to the relationship between Mexico and Canada in this respect.

Early studies by Bayoumi and Eichengreen (1993) and Lalonde and St-Amant (1993) seem to have addressed the criticisms raised in this paper with respect to the works of [Chriszt (2000), Michelis (2002), Del Negro and Obiols-Homs (2001)]. In fact, Bayoumi and Eichengreen examine the correlation of structural shocks between Mexico and nine regions of the United States by using a bivariate SVAR where endogenous variables such as output and prices are assumed to be each driven by supply and demand innovations. In order to identify their model, they employed the decomposition method that only supply shocks have long-run effects on output, as proposed by Blanchard and Quah (1989). The results of their study reveal that supply shocks are considerably more important than demand shocks for Mexico and these shocks are negatively correlated with structural disturbances originated from industrial regions in the U.S.. Bayoumi and Eichengreen then arrive at the conclusion that dollarization or any form of fixed exchange rates or monetary union would impose substantial costs to the Mexican economy. This study has been criticized by Lalonde and St-Amant on the grounds that the identification method used by Bayoumi and Eichengreen along with the contemporaneous correlation is not suitable to determine the degree of shocks asymmetry that would exist in any form of fixed regime because i) monetary shocks are not extracted from the demand shocks, and ii) it is difficult to interpret the results when some cross-correlations are constrained to be the common component by choosing a region as an anchor.

Lalonde and St-Amant (1993) remedy the weaknesses they have noted from Bayoumi and Eichengreen's work by incorporating a monetary base [$M(0)$] as a third variable and a policy shock as a third disturbance, which enables them to dissociate monetary from non-monetary demand shocks. They also identify their model by using the decomposition method proposed by Blanchard and Quah (1989) that can be summarized by the following restrictions: i) only supply shocks have long-run effect on output, which impose two zeros on the second to third element of the first row of their long-run effects matrix; and ii) the neutrality of money in the long-run that implies that policy shocks have the same effects on both the growth rate of money and the growth rate of prices but no effect on output, a restriction equivalent to constraining the third elements of rows 2 and 3 of their matrix of long-run effects to be the same. In order to determine the degree of symmetry of the structural shocks and their relative importance, the authors then incorporate

Canada into their state space analysis for comparison purposes. They reach a conclusion similar to that of Bayoumi and Eichengreen in that Mexico would incur significant adjustment costs if it had adopted a fixed exchange rate with either Canada or the United States.

Although Lalonde and St-Amant study does represent an improvement upon the work of Bayoumi and Eichengreen, there are several drawbacks to their contributions. The first one is related to modeling Mexico's economy as a closed economy when there is evidence that it is even more open than the United States as documented by Chriszt (2000). The second weakness resides in the failure to account for the influence of either the United States or Canada as a large country on the dynamics of the Mexican economy, the smallest of the three in economic size. As Cushman and Zha (1997) have emphasized, this distinction may be crucial for statistical inference. The last flaw concerns the conclusion that Mexico would incur significant adjustment costs under any system of fixed exchange rate or monetary union. As the authors themselves argue in their section: "Political History of the Exchange Rate Regime in Mexico," the debt crisis of 1982 put an end to four decades of constant economic growth and low inflation, which without any doubt was a period dominated by fixed exchange rate regime. Moreover, one could appreciate from Figure 1, which is similar to the one found in Lalonde and St-Amant, that Mexico's economy does much better under fixed exchange rate than under flexible exchange rate over a long sample. For example, the year 1989 witnessed a sharp decrease in inflation and a recovery of output growth as a new stabilization program and a fixed exchange rate regime were introduced by the government. Their graph also shows that for the period 1989-1993 output growth in relation to inflation were at levels similar to those prevailing during the Golden years of the 1970s.

The question that arises then is given these irrefutable evidences, would the costs predicted by empirical studies be greater than the benefits that fixed exchange rate regimes had brought about to Mexico over the years? Definitely, one would agree that there is no easy answer to such difficult question. It may also be the case that one may find herself deepening further in the interminable debate of fixed versus flexible regimes in every attempt to provide an answer. This paper stays away from that controversy. Nonetheless, it seeks to understand whether it is possible to reach the same conclusion if one makes provision in a model for the weaknesses detected in the work of Lalonde and St-Amant (1993). In few words, this paper uses a five variable SVAR in the vein or Artis and Ehrmann (2000) to study the degree of shock asymmetry between Mexico and the rest of the NAFTA partners. It introduces a real exchange rate variable and a foreign policy instrument to account for the interaction of the domestic economy with the rest of the world (proxied by the U.S. or Canada) and two extra structural shocks, namely foreign monetary policy and exchange rate shocks. The paper also employs a Time-Varying Parameter model of the class of State Space models, which enables the researcher to confirm the results derived from the SVAR procedure. The next section presents the underpinning theoretical model.

3.1 Model

The underlying theoretical model of this paper is the small open economy model as outlined by [Walsh (1998)], which is a version of the AS-IS-LM model. In accordance with Walsh, this model is proven to be useful in two ways. First, it is a good approximation of a model consistent with the behavior of optimizing agents and one does not lose any information in conducting policy analysis. Second, it is most suitable to analyze interactions between countries when disturbances in one country is unlikely to have substantial effects on other large economies. As established above, since Mexico is the smallest in economic size of the three North American countries, these two features of the model fit its economy perfectly well. Hence, the Mexican economy can be best approximated by the following set of equations:

$$y_t = -b_1\rho_t + E_{t-1}y_t + b_2(p_t - E_{t-1}p_t) + \varepsilon_t^s \tag{1}$$

$$y_t = a_1\rho_t + E_t y_{t+1} - a_2 r_t + a_3 y_t^* + \varepsilon_t^d \tag{2}$$

$$m_t - q_t = y_t - c_1 i_t + \varepsilon_t^p \tag{3}$$

$$i_t = r_t + (E_t p_{t+1} - p_t) \tag{4}$$

$$\rho_t = r_t^* - r_t + E_t\rho_{t+1} + \varepsilon_t^\rho \tag{5}$$

Equations (1), (2), (3), (4), and (5) are aggregate supply, IS, money demand, Fisher equation, and a variant of the interest rate parity condition, respectively. Where y_t denotes the log of industrial production index, i_t is the nominal interest rate, s_t is the nominal exchange rate, $q_t[= hp_t+(1-h)(s_t+p_t^*]$ is the log of consumer prices, which is a weighted average of domestic and foreign influences, $0 < h < 1$ is the weight, p_t and p_t^* are the log of domestic and foreign output prices, m_t is the log of money stock (*or* M_1), r_t is the real interest rate, and ρ_t $[= s_t + p_t^* - p_t]$ is the real exchange rate. ε_t^s, ε_t^d, ε_t^p,and ε_t^ρ are assumed to be the structural shocks that drive supply, demand, money, and the financial sector of the economy. E_t is the expectation operator and $*$ denotes foreign variables. A rise in ρ_t interpreted as a real domestic depreciation has a negative effect on output supply but a positive effect on demand. The former arises due to the fact both the prices of imported inputs and the ratio of consumer prices to producer prices rise while the latter originates as a result of domestically produced goods becoming less expensive in relation to foreignly produced goods.

It can be inferred from the structure of the economy postulated above that the equilibrium levels of the endogenous variables depend on the shocks that hit the economy. Since the effects of shocks on macroeconomic variables are best analyzed through empirical estimation, the SVAR methodology is used in this respect. As a prelude to the estimation phase, it is important to highlight the basic predictions of the theoretical model, which can be summarized as follows. Output and prices are expected to move in opposite direction in the presence of a supply shock but in the same direction in the presence of a demand shock. Foreign interest rate is expected to rise as a result of contractionary foreign monetary policy shock. Contractionary domestic monetary policy shock must lead to decrease in output, prices, money, and an increase in real exchange[5]. Most importantly, if AD and AS shocks from Mexico and the United States are symmetric, then the foreign interest rate and money are both expected to move in the same direction as a response of each to these shocks. The methodology that enables the researcher to study the impact of the structural shocks on the endogenous variables are explained in the next section.

3.2 Methodology

This paper uses the structural vector autoregression technique to uncover the dynamics of the Mexican economy as related to those of Canada and the

[5]The response of real exchange rate ($\rho_t = \frac{ep_t*}{p_t}$) to any shock is not a clear-cut. Real exchange rate may increase or decrease depending on how one defines the nominal exchange rate (s_t) and the assumption made about the prices (p_t). For example, if s_t is defined as $\$C$ / $\$US$ and prices are assumed to be relatively fixed within the Keynesian framework, a contractionary monetary policy shock brings about an increase in nominal interest rate. In a Mundell-Fleming open economy, if this interest rate is above the foreign interest rate and there is perfect capital mobility (based on the well-known assumptions), one should expect massive capital inflow to the domestic economy, which leads to a decrease in the nominal exchange rate (interpreted as an appreciation), hence a decrease in ρ_t. Simply put, a contractionary domestic monetary policy shock leads to a decrease in ρ_t. However, if prices are allowed to fluctuate, the movement in ρ_t depends on the relative changes in s_t and p_t. Based on the same example, $s_t \downarrow \Longrightarrow \rho_t \downarrow$, $p_t \downarrow \Longrightarrow \rho_t \uparrow$.

United States. This methodology has been used intensively in the economic profession after [Sims (1986) and Bernanke (1986)] have used short-run restrictions and [Blanchard and Quah (1989)] have used long-run restrictions as a way to model the innovations using economic analysis in response to Cooley and Leroy's (1985) critique of Sims's (1980) unidentified VAR. Further improvement in the SVAR technique was brought about with the work of Gali (1992) that combines short- and long-run restriction to identify their model.[6]

Assuming Z_t is a vector containing the so-ordered variables $(y_t, i_t^f, m_t, p_t, \rho_t)$ that are driven by the so-ordered structural innovations $\varepsilon_t = (\varepsilon_t^s, \varepsilon_t^d, \varepsilon_t^{p*}, \varepsilon_t^p, \varepsilon_t^\rho)$,which are assumed to follow a normal distribution with covariance matrix equal to the identity matrix, I. Simply put, $E(\varepsilon_t \varepsilon_t^{'}) = I$. Let $B(L)$ be the polynomial lag matrix. Hence, by ignoring the mean values, the system can be written as:

$$B(L)Z_t = \varepsilon_t \tag{6}$$

If $B(L)$ is invertible, a condition that holds if and only if the polynomial

[6]Since all the details regarding this methodology have already been provided in Essay # 1, this section is only a summary.

lag matrix of the reduced form model is invertible, then one can write the infinite Wold moving average $[MA(\infty)]$ of the structural system as:

$$Z_t = R(L)\varepsilon_t \tag{7}$$

Where $R(L) = B(L)^{-1}$.However, since the structural model cannot be estimated because ε_t is not observable, one has to first estimate the reduced-form model and transform its residuals in order to obtain ε_t. The reduced-form VAR representation is as follows:

$$\psi(L)Z_t = e_t \tag{8}$$

where $\psi(L) = \psi_0 + \psi_1 L + \psi_2 L^2 + ... + \psi_p L^p; L$ is the lag-operator with $L^i Z_t = Z_{t-i}$, and ψ_0 is the identity matrix. e_t is the reduced-form residuals set with covariance matrix, Ω, being symmetric. In few words, $E(e_t e_t^{'}) = \Omega$. Assuming $\psi(L)$ is invertible, one can write the reduced-form $MA(\infty)$ representation as:

$$Z_t = C(L)e_t \tag{9}$$

Where $C(L) = \psi(L)^{-1}$. Following Blanchard and Quah (1989), the relationship between the structural shocks and the reduced form shocks can be established by equating (7) and (9), the $MA(\infty)$ of both systems. It follows that:

$$R(L)\varepsilon_t = C(L)e_t \tag{10}$$

Since $C(0)$ is equal to I and this equation holds for all t, it is straightforward that:

$$R(0)\varepsilon_t = e_t \tag{11}$$

By squaring both sides and taking expectations, one finds that:

$$R(0)R(0)' = \Omega \tag{12}$$

and by substituting (11) in (10):

$$R(L)\varepsilon_t = C(L)R(0)\varepsilon_t \tag{13}$$

and by dividing both side of (13) by ε_t :

$$R(L) = C(L)R(0) \tag{14}$$

Since Ω is symmetric, Equation (12) places $n(n+1)/2[= 5(5+1)/2 = 15]$ restrictions on the elements of $R(0)$, the additional $n(n-1)/2[= 10]$ restrictions needed are taken from economic theory in order to fully identify $R(0)$. Knowledge of this matrix enables one to recover i) $R(L)$ given that $C(L)$ is already known from (9); and ii) ε_t from (11). Finally, the variance decomposition and the impulse responses analyses follow from (7).

3.2.1 Time-Varying-Parameter State Space models

The estimation of the SVAR model above supplies the structural innovations needed to determine the degree of symmetry between shocks across countries. Only supply, demand, and domestic monetary policy shocks are chosen because they are the only shocks common to the three SVARs. This exercise employs a time-varying parameter class of the state space models, which are estimated via the method of maximum likelihood (ML). One peculiarity of this paper, however, is that it tries to carry out two pairwise comparisons (Mexico vs. US; and Mexico vs. Canada). This becomes possible due to the fact that the structural shocks from both United States and Canada had already been estimated from Essay # 1. These shocks are assumed to follow a standardized normal distribution. As usual, there are two equations to the state space representation of any dynamic $n \times 1$ observed variables: 1) a *measurement equation:*

$$\begin{bmatrix} \varepsilon_t^{d-mex} \\ \varepsilon_t^{s-mex} \\ \varepsilon_t^{p-mex} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \alpha_{1t}(j) \\ \alpha_{2t}(j) \\ \alpha_{3t}(j) \end{bmatrix} + \begin{bmatrix} \beta_{1t}(j) & 0 & 0 \\ 0 & \beta_{2t}(j) & 0 \\ 0 & 0 & \beta_{3t}(j) \end{bmatrix} \begin{bmatrix} \varepsilon_t^{d-j} \\ \varepsilon_t^{s-j} \\ \varepsilon_t^{p-j} \end{bmatrix} + \begin{matrix} \xi_{1t}(j) \\ \xi_{2t}(j) \\ \xi_{3t}(j) \end{matrix} \tag{15}$$

where the state vector $\beta_{it}(j)$ $(i = 1, 2, 3; j = U.S., Canada)$ is a time-varying slope coefficient that captures the relationship between shocks across Mexico and either U.S. or Canada, $\alpha_t = (\alpha_{1t}(j), \alpha_{2t}(j), \alpha_{3t}(j))'$ is a time-varying intercept that is assumed to be the component of shocks specific to Mexico. Both α_t and $\beta_{it}(j)$ are not directly observable but are generated via the Kalman filter while , and ξ_t is vector of disturbances with mean zero and covariance matrix, G_t. Normally, a positive (negative) sign of $\beta_{it}(j)$ indicates that the two shocks are symmetric (asymmetric). $\xi_t = (\xi_{1t}(j), \xi_{2t}(j), \xi_{3t}(j))'$ are assumed to contain all other shocks originated from the rest of the world.

2) a *transition equation*:

$$\beta_{it}(j) = T_t \beta_{it}(j)_{t-1} + \eta_t \tag{16}$$

that describes the dynamics of the coefficients $\beta_{it}(j)$, which are assumed to follow a first-order Markov process. Where η_t is $g \times 1$ vector of disturbances with mean zero and covariance matrix, Q_t. ξ_t and η_t are assumed to be uncorrelated with each other at any period of time. The initial value of the state vector, α_0, and the error terms are taken to be uncorrelated. Hence,

$$\begin{pmatrix} \xi_t \\ \eta_t \end{pmatrix} \sim WN \left[0, \begin{pmatrix} G_t & 0 \\ 0 & \eta_t \end{pmatrix} \right], \qquad t = 1, .., T$$

and

$$E[\beta_{i0}(j)\eta_t'] = 0, \qquad E(\beta_{i0}(j)\xi_t') = 0 \qquad t = 1, ..., T$$

3.3 Identifying Restrictions

This paper applies a combination of short-run and long-run restrictions in the vein of Gali (1992), which is a mixture of the contributions of [Sims (1986, 1992), Blanchard and Quah (1989), and Blanchard and Watson (1992)]. It assumes that 1) only supply shocks have long-term effects on output; 2) only supply and demand shocks can affect output contemporaneously; 3) the Fed funds rate does not react in the short-run (if it reacts at all) to monetary policy and exchange rate shocks originating in Mexico; and 4) the monetary authority attaches a weight to the exchange rate in setting monetary policy. Further details on the fourth restriction will be provided below. The first set of restrictions is in accordance with the long-run Phillips curve. The second set of restriction may be understood in the context that firms react to news in the financial sector with lags because they face menu and adjustment costs from goods and labor markets. The third restriction is in line with the arguments put forward by [Cushman and Zha (1997), Sims and Zha (1998), Leeper, Sims, and Zha (1996), and Artis and Ehrmann (2000)] that the large country does not take into consideration disturbances occurring in small countries when setting its policy instrument. As in Artis and Ehrmann, the fourth restriction is borrowed from Smets (1997) who provides a mechanism that enables researchers to disentangle monetary policy from exchange rate shocks when there is evidence that the central bank has been constantly targeting the exchange rate. This paper tries to adapt this technique when the central bank is assumed to follow a money rule as opposed to an interest rate rule in the case of Smets.

The idea is that once the reduced-form of the structural model has been estimated and the effects of supply and demand shocks have been accounted for, the remaining residuals are composed of a contribution from monetary policy shock and a contribution from exchange rate shock :

$$e_t^m = \alpha_1 \varepsilon_t^p + \alpha_2 \varepsilon_t^e \tag{17}$$

$$e_t^e = \beta_1 \varepsilon_t^p + \beta_2 \varepsilon_t^e \tag{18}$$

In the vein of Smets (1997), the money stock as well as the exchange rate are linear combinations of domestic monetary policy and exchange rate innovations, as expressed in equations (17) and (18). Given the fact that the reduced form residuals (e_t^m, e_t^e) are known, then the solution to the system that allows one to recover the structural monetary policy shock is a trivial one:

$$\varepsilon_t^p = \frac{\beta_2}{\alpha_1\beta_2 - \alpha_2\beta_1} e_t^m + \frac{\alpha_2}{\alpha_1\beta_2 - \alpha_2\beta_1} e_t^e \tag{19}$$

Equation (19) states that the central bank sets its monetary policy on the basis of the weight that it attaches to the money stock and the exchange rate. By normalization of the sum of the weights on the two residuals, it can be shown that

$$\varepsilon_t^p = (1-\varpi)e_t^m + \varpi e_t^e \tag{20}$$

Then, it is clear that $\varpi\, \epsilon [0, 1]$ and by expressing equation (20) in a suitable form to be estimated one obtains

$$e_t^m = \frac{\varpi}{1-\varpi} e_t^e + \frac{1}{1-\varpi} \varepsilon_t^p \tag{21}$$

As is evident from equation (21), one is in the presence of a non-linear regression where the regressor and the disturbance are correlated. The estimation method suggested, as reported in Artis and Ehrmann, follows Hansen (1982) Generalized Method of Moments, which contains the 2SLS-IV estimator as a special case. Since this paper inherited the same codes that Artis and Ehrmann borrowed from Smets (1997), the same instruments as well as the exact specification of the estimation from the original contribution is used to arrive at ϖ, which solves the identification problem.[7]

[7] One simple way to understand all this is to recall that R(1) is the matrix of long-run effects and R(0) is that of the contemporaneous effects. The first set of restrictions impose zero on the second to the fifth element of the first row of R(1), a total of four zeros. The second set of restrictions implies that the third to the fifth element of the first row of R(0) is zero, a total of three zeros. The third set of restrictions assumes that the fourth to the fifth element of the second row of R(0) is zero, a total of 2 zeros. To complete the identification scheme, one extra restriction is needed since one already has nine (of the 10) restrictions that are equal to nine zeros. Instead of imposing a zero on the fifth element of the third row of R(0), which would imply that real exchange rate shocks have

4 Data and Data Analysis

The data set used for the empirical analysis covers the period 1960Q1 - 2000Q4. The series include industrial production index (y), which is a narrow measure of economic activity; money stock ($M1$); consumer price index (CPI); real exchange rate (q); and the Fed fund rate (i_t^f). All but the fund rate were taken from the International Financial Statistics (IFS) of the International Monetary Fund (IMF). The fund rate was taken from Statistics Canada's CANSIM database. Since the data from the IFS are constructed on different base periods, they were all converted to the latest base, which is 1995. They were then deseasonalized, filtered using Hodrick Prescott method, and demeaned. Variables such as $M1, y, and\ CPI$ were log transformed. Figure (3) shows the processed data. However, it is worth noting that there is one drawback in working with data of this sort. It does not allow the researcher to observe the initial response of the variables to shocks

no contemporaneous effects on the money stock, a not too realistic assumption when the central bank supposedly follows a money rule, one has decided to opt for the weight that the monetary authority is attached to domestic monetary policy and real exchange rate shocks. If the real exchange rate is given a 10 percent percent weight, then one should expect the fifth element of the third row to be .10 while the fourth element is .90. However, what is peculiar here is that these weights cannot be found by trial and error, one has to go through a lengthy estimation to arrive at that percentage. Nonetheless, what will be shown at the end is that the impulse responses as well as the variance decomposition are not sensitive to the weight, for a very large range of weights leads to the same pictures.

because all the impulse responses start at the baseline (mean zero). In order to have a feedback about such responses, which may be important, an estimation is also carried out with the unprocessed data. Due to the fact that the sample period contains about thirteen years of data points in which the fixed exchange rate regime was in effect (1960 - 1973, officially), the nominal exchange rate was not considered as a good candidate since it does not allow for any variation during these years. The real exchange rate computed as the product of the nominal exchange rate and the relative prices of imports and exports was instead adopted.[8] Finally, all nominal variables for Mexico, with the exception of the indices, were modified to take into account the introduction of a new currency (namely, the *new peso* that is equivalent to 1,000 *old pesos*) on January 1, 1993.

Figure 3 about here

As part of the requirements of the SVAR methodology, the variables entering the system must be stationary. The Augmented Dickey-Fuller (ADF) test and the Phillips Perron (PP) tests with a trend and an intercept were used to uncover the order of integration of the variables. The results from

[8] It may appear strange to compute the real exchange rate in this fashion. However, the objective here is to only concentrate on the tradables. The CPI is not used because it includes both tradables and nontradables.

both tests suggest that CPI, y, q, and i_t^f are each integrated of order 1, $I(1)$. However, some confusion arises as to M_1. ADF shows that this variables is $I(2)$ while PP indicates it is $I(1)$. As usual, when such a situation occurs, the researcher has to make the appropriate decision of whether to go along with either $I(1)$ or $I(2)$ or both. This paper tries both orders of integration for M_1 in the estimation phase and determines which one is more suitable for inferences. Table 1 displays the unit roots.

Table 1 about here

A cointegration test of the variables that are integrated of the same order was also carried out in order to determine whether there is any long-run relationship between the variables that needs to be explicitly taken into consideration. The Johansen and Juselius (1991) maximum likelihood estimation method was performed under five scenarios. The trace statistic as well as the maximum eigenvalue statistic reveals that there is no cointegration between the variables at the 5 percent significance level. Table 2 presents the summary of the cointegration test

Table 2 about here

The optimal lag length reported in Table 3 is determined according to the information criteria. The Final Prediction Error (FPE), the Likelihood

Ratio test, the Akaike information criterion (AIC), the Hannan-Quinn (HQ), and the Schwarz (SC) information criteria converge to 2 lags as the optimal lag length to incorporate in the VAR. The regression is then estimated with these 2 lags.

Table 3 about here

One of the main concerns that researchers usually address in time series analysis is whether the parameter estimates are stable over time. The Chow test and the Cusum squared test have been used to test for structural breaks in the literature. These tests require that one impose a date at which one suspects the break might have occurred, which in many cases lead to the estimation of several subsample regressions, provided the number of data points are enough. Otherwise, the regression must be estimated over the longest period. In the case of Canada, several studies [citation on Kusczack p. 78 here] found no structural break in the data as the exchange rate system shifted from fixed to flexible. In studies on United States economy, there is still some ongoing debate as to whether a break has occurred, but the general view seems to suggest no structural breaks have occurred at all [see Sims (1999); Bernanke and Mihov (1998); and Cushman and Zha (1997)].

At first glance, the picture of the Mexican economy purports that several remarkable breaks have occurred over the years. First, the shift of the exchange regime from fixed to flexible took place in 1973. Second, the period 1976 - 1982 marks a return to the old fixed regime. Third, the debt crisis and a huge devaluation followed in 1982. Fourth, a dual exchange system was in place between 1982 and 1991. Fifth, from November 1991 to December 1994, a crawling target zone regime was implemented and allowed the new peso to be exchanged at any rate between 3 and 4 (but strictly less than 4) to 1 in parity with the U.S. dollars. Sixth, since the foreign exchange crisis in December 1994, the peso was allowed to float "freely." Other major events include the oil shocks of 1973 and 1979 and the participation in the North American Free Trade Agreement (NAFTA). All these events call for estimating the model for different regimes as in Del Negro and Obiols-Homs (2001).[9] However, in comments on these authors' paper, Crucini (2001) observes that the numbers from their variance decomposition tables *do not reveal significant differences across exchange rate regimes* when the standard deviation (a measure of volatility) of industrial production growth is taken into consideration. The same critique stands against the study of Cushman and Zha

[9]The sample used by these authors are from 1976 to 1997. They subdivide their sample in four subperiods based on the foreign exchange regime: i) peg (09/76 - 01/82); ii) flexible (02/82 - 03/88); iii) crawling peg (03/88 - 11/94); iv) flexible (12/94 -).

(1997) that is based on Canadian data and on which the paper of Del Negro is built upon. This leads to the conclusion that although apparently the events dictate that structural breaks have occurred, the data shows no such evidence. Since the impulse responses and standard errors are not valid if the reduced-form VAR is not stable, in this paper, stability of the parameters are tested using the autoregressive roots (AR Roots). The results are presented in Table 4 and show that all roots are contained in the unit circle. Therefore, the VAR satisfies the stability condition.

Table 4 about here

5 Empirical Results

This section presents the empirical results based on 1) the estimation of the SVAR model and 2) the estimation of the Time-Varying State Space model. As stated above, the former enables the researcher to extract the structural shocks characterizing the Mexican economy, which are then used in the latter to confirm the degree of symmetry or asymmetry with those of the United States and Canada, previously obtained from similar procedures in Essay # 1. In the first stage of the econometric exercise, the weight that the central bank assigns to the exchange rate in setting monetary policy is computed and it turns out to be 40 percent. In addition, the endogenous variables as well as the structural shocks are ordered as $(\Delta y_t, \Delta i_t^f, \Delta m_t, \Delta p_t, \Delta \rho_t)$ and $(\varepsilon_t^s, \varepsilon_t^d, \varepsilon_t^{p*}, \varepsilon_t^p, \varepsilon_t^\rho)$, respectively. Two issues, however, emerge as to the choice of the variables.

The first one is related to the choice of the domestic policy instrument. The money stock ($M1$) instead of a short-term interest rate is chosen because there is no evidence in the literature [see Torres-Garcia (1998), (1999)] that the Bank of Mexico has used the overnight loan rate for a long period to carry out its objectives. In fact, the Bank of Mexico starts targeting inflation aggressively after the exchange rate crisis in December 1994. Even then, as Yacamán (1999) and Días (1999) reported, and the paper quotes Yacamán: *the Bank decided to set quantitative targets consistent with its inflation objective for the annual growth of the monetary base and uses the observed behavior of the monetary base as guidelines for its actions in the money market.* In his view, the monetary authority in Mexico was then compelled to use the monetary base instead of interest rates as operational target because it was almost impossible to find adequate levels since the crisis brought about chaos. Exchange rate depreciated by more than 100%, inflation rose above 20%, one-month T-bill rate skyrocketed to 65 percent, and real GDP plunged. Then the strategy followed by the bank to be able to send signals to the market without setting any specific level of interest rate was to implement monetary policy through a zero-average reserve requirement system.[10]

The second issue is related to the choice of foreign monetary policy instrument. The dilemma is since Mexico is the smallest (in economic size) of the three countries and one needs the structural innovations for pairwise comparison with the U.S. and Canada, should two estimations be carried out? Which are, 1) Mexico - U.S. with the Fed fund rate in the Mexico's SVAR as the large country's policy instrument, and 2) Mexico - Canada with the Bank of Canada's rate as the large country's policy instrument. This strategy may seem a priori more tedious and enlightening, however, it carries the drawback of supplying two sets of structural shocks, which amount to asking which set

[10]The zero-average reserve requirement or "reserve averaging around zero" is a system that allows the central bank to monitor the activities of commercial banks in order to control money creation. Since each chartered bank holds a current account at the central bank, the accumulated balance of this account over a 28-calendar-day period must sum zero. If this balance is negative, a case of overdraft, the commercial bank is charged an interest rate equivalent to twice that of the market determined rate on those balances. Commercial banks with positive accumulated balance incur an opportunity cost in that the money sitting at the vault of the central bank could have earned them interest. Hence, given this situation, the optimal decision for each chartered bank is to neither have a negative balance in order to avoid penalty, nor to have a positive balance in order to avoid losing money. In few words, they must maintain a zero balance.

really reflects the true nature of the Mexican economy (the dilemma of having too much in general). To sort this problem out, the paper carries out two estimations: one in which the U.S. is considered as the country whose economic states primarily affect Mexico, a claim that can easily be ascertained, and the other in which Canada is chosen as the large country, leaving the U.S. aside (definitely, not too realistic). This enables one to determine whether there is substantial differences in the results.

In the second stage of the estimation, the reduced-form model is estimated and the identifying restrictions, which include the weight computed in the first stage, are imposed to extract the structural shocks. The impulse responses as well as the variance decompositions obtained through the same process are analyzed below in more details.

5.1 Impulse Response Analysis

Figure 4 shows the responses of each endogenous variable to each of the structural innovations. In particular, it shows that output and prices move in opposite directions when the economy is hit by a supply shock but in the same direction under the influence of an AD shock. The key and most important finding of this paper is that AD and AS shocks are symmetric between United States and Mexico. The same results continue to hold when the Fed fund rate is replaced with the Bank of Canada's rate as the foreign monetary policy instrument [see Figure 5], which also suggest that AD and AS shocks are symmetric between Mexico and Canada. A triangular relationship that leads to the conclusion that the North American countries are subject to common shocks, a finding contrary to Lalonde and St-Amant (1995). The criterion to arrive at this conclusion is the same as the one used by Artis and Ehrmann (2000) who purport that in this context if money and foreign interest move in the same directions in response to AD and AS shocks, then the two are symmetric across the two countries. A copy of the impulse responses from these authors' work is attached for comparison purposes [see Figure 6].

Figure 4 about here

Figure 5 about here

Figure 6 about here

Further analysis of the impulse responses reveals that a domestic monetary policy shock causes output to increase, money stock to decrease, inflation to decrease continuously and real exchange rate to increase and die out after the fortieth quarter. If the policy shock is interpreted as contractionary, it is clear that there is an output puzzle that emerges from the process, otherwise, it is a price puzzle. Although one has imposed the restriction that only supply shocks have long-run effects on output, the Mexican data show that the remaining shocks have quite a persistent effect on output. Real exchange rate follows a hump-shaped pattern before a money shock. In sum, the predictions of the theoretical model are materialized within reasonable doubts. Since the impulse responses can only inform about the pattern of the endogenous variables in response to the structural innovations but not the contribution of each shock to the variation of these variables, the variance decomposition analysis follows.

5.2 Variance Decomposition Analysis

Table 5 reports estimates of the relative contribution of each structural shock to each endogenous variable. It shows that 91.20 percent or less of the variability of output over a 60-quarter period are due to changes in aggregate supply, while demand shocks account for 33.87 percent or less at all reported horizons. In few words, shocks to Mexico's output are essentially supply driven, a finding similar to Bayoumi and Eichengreen (1993) and Lalonde and St-Amant (1993). U.S. monetary policy shocks have more effects (up to

24 quarters) on output than domestic monetary policy but fewer than real exchange rate, a result that is partly consistent with the findings of Del Negro and Obiols-Homs (2001) that disturbances originating in the U.S. economy have been a more important source of fluctuations for Mexico than shocks to oil prices. In the very short-run, the contribution of real exchange shock to the variance of output is substantial in comparison to those of domestic and foreign policy shocks, a peak of 1.5 percent after 12 quarters. Given these results, it is unlikely that one would argue that independent monetary and exchange rate policies have served the Mexican economy for the period considered and therefore Mexico should not contemplate abandoning its current systems for a monetary union. But this would be inappropriate, if the objective of the central bank of any country is to maintain price stability, the variance decomposition of the price level reveals that the monetary authority in Mexico has not had a great performance so far. As a matter of fact, 85.71 percent of the fluctuations in prices originate from monetary policy shocks in the first quarter. This proportion remains significantly high after non-monetary demand shocks become the dominant factor after 48 quarters. The unfold story of the real exchange rate dictates that both aggregate demand and domestic monetary policy shocks are equally responsible for the vari-

ance in output, but at a longer horizon demand shocks are the main driving forces, around 93.74 percent after 48 quarters. The variance decomposition analysis also reveals that demand shocks and real exchange rate shocks are the main factors that lead to variations in the stock of money, with the latter relatively dominating the picture up to the eighth quarter. This confirms the fact that the Bank of Mexico had to either frequently respond to the depreciation of the peso even under floating regimes or to sustain the value of the currency under fixed regimes. The results also demonstrate that foreign monetary policy has had greater impact on the stock of money than supply shocks up to 12 quarters. Finally, and as expected, monetary policy shocks proper to the U.S. explain 95.50 percent of the variations in the fund rate in a 4-quarter horizon. The Fed considerably reacts to supply shocks originated from Mexico after 4 quarters and to demand shocks after 8 quarters.

Table 5 about here

The variance decomposition analysis with Canada as the large country in Mexico's SVAR does not differ in a great deal from that with the U.S. as the large country explained above. Table 6 displays the results. In particular, it shows that i) demand and supply shocks are equally important for the variance of output; ii) foreign monetary policy is more important than domestic policy shocks but less than exchange rate shocks in the contribution to disturbances in output; iii) Canada's monetary policy shock explain 92.73 percent or less of the variations in the Bank of Canada's rate; iv) Variations in money stock are explained mostly by innovations in real exchange rate and aggregate demand; v) domestic monetary policy shock contributes 91.62 percent or less to the variation of the price level at all reported horizons; and vi) domestic policy, demand, and supply shocks are the main disturbances that drive the real exchange rate, with demand shocks playing a dominant role after 4 quarters.

Table 6 about here

What are the possible drawbacks of these results? The first one to note is that the findings are sensitive to the order of integration of the money stock, $M1$. That is, if one considers $M1$ as $I(2)$, AD and AS shocks are then found to be symmetric across the two countries. However, when $M1$ is considered as $I(1)$, there is asymmetry between the shocks. This holds independently that one uses the Bank of Canada's rate or the fund rate as the instrument of foreign monetary policy. Figure 7 and Table 7 respectively show the impulse responses and the variance decomposition when the Fund rate is the policy instrument and M1 is I(1). It is clear from the impulse responses that the fund rate and the money stock move in opposite direction in the presence of supply and demand shocks. One may also argue that by processing the data to some extent may be responsible for the sensitivity of the results. Figure 8 shows the impulse responses of the unprocessed data. It can be inferred that there is not much insight that can be gained from those responses.

Figure 7 about here

Table 7 about here

Figure 8 about here

The second drawback is that the symmetries of AD and AS shocks across Mexico and the rest of the North American countries are suspect despite the fact that the results do not change that much as different foreign policy instruments are being used. But one must also take into account that there is a high correlation between fund rate and Bank of Canada's rate, around 87% according to Table 8. This means that any interest rate that is highly correlated with that of the U.S. is likely to show that AD and AS shocks between that country and Mexico are symmetric even though there may not be any link whatsoever between the two countries. The results from this paper are robust in the first instance only if one could prove that 1) the autocorrelation between U.S. and Canada interest rates is unique and 2) all unit root tests give the same order of integration. In both grounds, it is nearly impossible to arrive at such consensus. Then the only venue left to board is whether the State Space model confirm the results.

Table 8 about here

Another issue that is of relevance is the weight that one assumes the Bank of Mexico attaches to real exchange rate in setting monetary policy. It could be argued that the results are sensitive to the weight because the data were constrained not to reveal the *true* relationship between the variables and the related exchange rate and policy shocks. In order to answer this claim, the paper estimates several regressions with weights of 0, 35, 50, and 80 percent for Mexico and each of the remaining NAFTA partners.[11] As can be seen in Figures 9, 10, and 11, the pattern of the impulse responses in the Mexico - U.S. exercise remains the same. The only exception occurs when a weight of zero is imposed, a situation where the exchange is completely absent in the monetary policy reaction function of the Central Bank. Yet, AD and AS shocks continue to be symmetric across countries even when monetary policy and exchange rate shocks revert the pattern of the endogenous variables (see Figure 12). A similar pattern is also observed in Mexico - Canada's

[11] Please note for $\varpi \geqslant .80$, the program returns an invertible matrix. The author deliberately decides not to carry out the same exercise when $M(1)$ is $I(1)$.

regression (see Figures 13 and 14). In few words, this simulation indicates that the findings of this paper do not crucially depend on the choice of the weight. Particularly, AD and AS shocks remain symmetric independently of the weights.

Figure 9 about here

Figure 10 about here

Figure 11 about here

Figure 12 about here

Figure 13 about here

Figure 14 about here

5.3 State Space Analysis

Given the structural shocks extracted from the structural vector autoregression, a Time-Varying State Space model is employed to uncover the degree of asymmetry between supply, demand, and monetary policy shocks across Mexico - Canada, and Mexico - United States. This has been possible because structural shocks Canada and U.S. economies were previously recovered in Essay 1. Figure 15 shows the structural shocks that enter the State Space phase of the estimation. As the paper argues above, since there are two sets of structural shocks for Mexico, it might have been difficult to determine which one reflect the dynamics of that economy. But, as it becomes evident, there is no reason to expect the structural shocks to be too dissimilar since the variance decomposition as well as the impulse response functions that emanate from them are not. Nonetheless, as a cautious measure, each set of Mexico's structural shocks is run against that of Canada and the United States.

Figure 9 about here

Unfortunately, the results of the state space estimation are found to be inconclusive. As one would expect, the sign of the time-varying slope coefficient must be positive so that one could confirm the SVAR results that the shocks are symmetric. But, these coefficients were found to be insignificant at all conventional levels as their p-values exceeded the 10 percent critical value. Several other specifications such as Recursive Coefficient Models and Autoregressive Moving Average (ARMA) models were also estimated without any success. These results are not reported in this paper. The other alternatives that the paper has explored is the computation of the Pearson Corrected Contingency Coefficient (CC_{corr}) and the cross correlation between the structural shocks at different leads and lags, with lag $0 =$ lead 0

reflecting the contemporeaneity of the series. These statistical procedures demonstrate that (see Table 9) AD shocks between Mexico and Canada and between Mexico and the U.S. are symmetric but AS shocks as well as policy shocks are asymmetric. In all cases, there is a low association between the variables as evidenced by a CC_{corr} below 50 percent, with Mexico's and US policy shocks being the exception.

Table 9 about here

6 Conclusion

This paper has studied the issue of monetary union as related to the symmetry of macroeconomic shocks between Mexico - United States and Mexico - Canada. It employs two techniques: a structural vector autoregression and a Time-Varying State Space model. The structural vector autoregression methodology was used in order to recover the structural shocks, the impulse responses and the variance decompositions as well. It also dictates whether the shocks are symmetric or asymmetric by relying on the responses of the domestic and the foreign monetary policy instruments to demand and supply shocks. The state space model enables the researcher to confirm the results obtained from the SVAR exercise.

In the first approach, a combination of short- and long-run restrictions in the line of Gali (1992) has been used to just identify the model. Under the assumptions of 1) a long-run Phillips curve; 2) only supply and nonmonetary demand shocks having contemporaneous effect on output; 3) large countries not reacting to disturbances originated from small countries; and 4) a weight attached to exchange rate by the Bank of Mexico in setting monetary policy, the paper could demonstrate that AD and AS shocks are symmetric across the countries. This result holds independently of the weight chosen.

In the second approach, the structural shocks from this paper along with those from a comparison between United States and Canada (computed in Essay 1) are used to determine whether shocks between the countries are symmetric. The results are found to be inconclusive.

To the extent that one does not need the state space results to back up those of the SVAR, the finding that AD and AS shocks are symmetric is still robust within the context that M1 is I(2). For it is invariant of the weight attached to the real exchange rate. The main controversy of this paper perhaps resides in the fact M1 can either be I(1) or I(2). As explained above, the symmetry between AD and AS only holds when M1 is

I(2) not I(1). If one considers I(1) as a better approximation for M1 than I(2), then the results of this paper are similar to Lalonde and St-Amant (1993). But the researcher does not believe there is a strong argument for taking such a stance. As Lalonde and St-Amant themselves acknowledge and the paper translates: "*For Mexico, we chose the monetary base [M0] instead of the money stock M1 because the latter has been subjected to several structural changes, which makes its use very difficult.*" What they probably meant is that: "since our result partly holds under M1, we prefer to use M0 as a safer ground." The next question that arises is whether one should have followed their path. First of all, it is worth noting that their study covers the post Bretton Wood era 1973:1 - 1991:4 for which data on M0 are available. However such data are partly missing in the IMF - IFS for Mexico for the 1960s. Secondly, this paper already takes into consideration the structural changes that have occurred by accounting for changes in base year and money denomination. Thirdly, suppose for the sake of argument that one had tried M0, in what ways would have that helped? It would only lead to the misleading impression that the two shocks are asymmetric while in fact there are conditions under which they are not. Having made these points, it is wise to conclude that, depending on the measure of money chosen, AD and AS shocks as related to Mexico - United States and Mexico - Canada may be symmetric or asymmetric. Where does that conclusion lead in terms of adopting monetary union or not? It is important to remember that both Mexico and the United States governments have emphasized the need for a monetary union and Canada is the only country being reluctant so far. The paper has argued that, in this respect, the issue of whether shocks are symmetric or asymmetric only matters for Canada. Since the data only provides an ambiguous direction, the only plausible factors that would push Canada into a monetary union particularly with Mexico is if 1) U.S. continues to levy high tariffs on Canadian goods, and 2) Mexico threaten to displace Canada in the U.S. market by first signing such arrangement with the United States. Leaving economics aside for a moment, it is likely that the position of Canada on this issue will change as a new Liberal leader will be in power by February 2004 and it appears that the major opposition party is in favor of a closer ties to the United States.

7 References

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Table 1. Unit Root Tests – Mexico Variables

	ADF			PP			
Variables	Level	Difference	Order	Level	Difference	Order	Decision
CPI	-2.59	-6.67	I(1)	-3.06	-13.51	I(1)	I(1)
Fund rate	-2.47	-10.11	I(1)	-2.60	-11.30	I(1)	I(1)
Y	-2.24	-5.57	I(1)	-2.35	-13.36	I(1)	I(1)
M1	-1.05	-3.28 † -6.65 ††	I(2)	-7.94	16.51	I(1)	I(2)
Q	-1.09	-6.56	I(1)	-1.34	-14.25	I(1)	I(1)

A constant, a time trend and a maximum lag of 13 are included in the OLS regressions for all variables. Sample period covers 1961:1 – 2000:4. Critical values are based on McKinnon (1996) : 1% = 4.017, 5% = 3.44, 10% = 3.14. Keys: †, first difference; ††, second difference.

Table 2 Cointegration Analysis

Sample: 1960:1 2000:4
Included observations: 157
Series: FRATE YMEX Q CPI
Lags interval: 1 to 6

Data Trend:	None	None	Linear	Linear	Quadratic
Rank or No. of CEs	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Selected (5% level) Number of Cointegrating Relations by Model (columns)					
Trace	0	0	0	0	0
Max-Eig	0	0	0	0	0
Log Likelihood by Rank (rows) and Model (columns)					
0	-1868.613	-1868.613	-1866.297	-1866.297	-1863.619
1	-1862.605	-1861.078	-1859.405	-1851.596	-1849.192
2	-1859.050	-1855.445	-1853.777	-1845.529	-1843.126
3	-1857.435	-1851.904	-1851.428	-1841.017	-1839.169
4	-1857.147	-1851.408	-1851.408	-1838.670	-1838.670
Akaike Information Criteria by Rank (rows) and Model (columns)					
0	25.02692	25.02692	25.04837	25.04837	25.06521
1	25.05230	25.04558	25.06249	24.97575*	24.98334
2	25.10892	25.08848	25.09270	25.01311	25.00797
3	25.19025	25.15801	25.16469	25.07028	25.05948
4	25.28850	25.26634	25.26634	25.15504	25.15504
Schwarz Criteria by Rank (rows) and Model (columns)					
0	26.89570*	26.89570*	26.99502	26.99502	27.08973
1	27.07682	27.08956	27.16488	27.09760	27.16359
2	27.28917	27.30766	27.35082	27.31016	27.34396
3	27.52623	27.55240	27.57854	27.54253	27.55120
4	27.78021	27.83593	27.83593	27.80249	27.80249

Table 3 Lag Length Determination					
VAR Lag Order Selection Criteria					
Endogenous variables: D(YDM) D(FRATEDM) D(D(M1DM)) D(PIDM) D(QDM)					
Exogenous variables: C					
Date: 01/14/03 Time: 14:26					
Sample: 1960:1 2000:4					
Included observations: 160					
Lag	LogL	LR	FPE	AIC	SC
0	1920.729	NA	2.74E-17	-23.94662	-23.85052
1	3980.967	3965.957	2.45E-28	-49.38709	-48.81049
2	5446.967	2730.424*	3.69E-36*	-67.39958*	-66.34249*

* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion

Table 4. Stability Test with 2 lags

Roots of Characteristic Polynomial
Endogenous variables: D(YDM) D(FRATEDM) D(D(M1DM)) D(PIDM) D(QDM)
Exogenous variables: C P_OIL P_OIL(-1) P_OIL(-2)
Lag specification: 1 2
Date: 01/14/03 Time: 14:40

Root	Modulus
0.989810 - 0.116958i	0.996696
0.989810 + 0.116958i	0.996696
0.968616 + 0.218245i	0.992899
0.968616 - 0.218245i	0.992899
0.985249 - 0.069353i	0.987687
0.985249 + 0.069353i	0.987687
0.967175 - 0.198303i	0.987295
0.967175 + 0.198303i	0.987295
0.974308 - 0.082064i	0.977757
0.974308 + 0.082064i	0.977757

No root lies outside the unit circle.
VAR satisfies the stability condition.

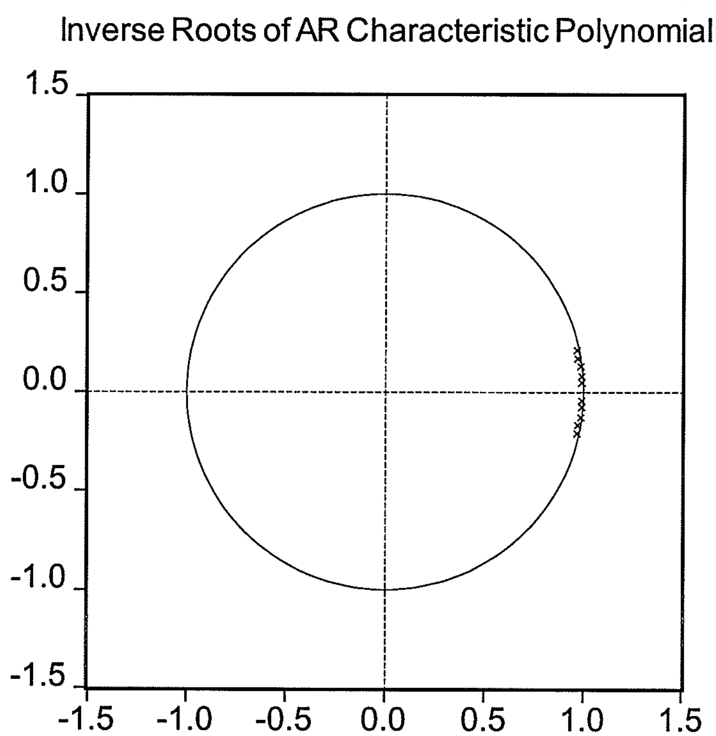


Table 5. Variance Decomposition for Mexico with U.S. as a Large Country When M(1) is I(2)

Quarter	Supply Shock	Demand Shock	U.S. Monetary Policy Shock	Home Monetary Policy Shock	Real Exchange Rate Shock
Mexico					
Variance decomposition for output					
1	69.87	30.13	0.00	0.00	0.00
4	67.79	31.86	0.15	0.001	0.21
8	65.14	33.36	0.61	0.007	0.88
12	63.54	33.87	1.08	0.02	1.5
24	68.29	29.66	1.04	0.17	0.85
48	88.41	9.98	0.17	1.09	0.36
60	91.20	7.78	0.10	0.70	0.22
Variance decomposition for Fed Funds rate					
1	0.16	0.38	99.46	0.00	0.00
4	0.65	3.02	95.50	0.29	0.55
8	0.73	23.08	72.67	0.44	3.08
12	0.49	52.53	41.27	0.26	5.41
24	22.91	55.70	13.07	5.74	2.59
48	36.60	34.31	12.78	5.33	10.98
60	34.34	31.53	12.79	5.77	15.85
Variance decomposition for M1					
1	2.67	11.41	3.09	2.38	80.46
4	1.33	19.17	2.58	4.28	72.65
8	0.38	34.48	1.93	6.77	56.44
12	0.68	54.13	1.34	7.52	36.33
24	1.67	64.02	0.55	7.15	26.62
48	25.41	42.00	1.85	11.50	19.24
60	24.47	40.33	2.74	11.52	20.95
Variance decomposition for CPI					
1	0.12	3.67	10.42	85.71	0.08
4	0.22	4.13	10.64	84.71	0.31
8	1.69	3.58	11.12	83.50	0.12
12	3.99	1.70	11.37	82.18	0.76
24	9.00	21.75	5.87	51.33	12.05
48	4.21	85.61	0.63	6.27	3.28
60	15.87	75.87	0.42	4.15	3.69
Variance decomposition for Real Exchange rate					
1	12.18	34.14	5.75	46.85	1.09
4	7.36	40.02	5.09	47.04	0.50
8	3.25	49.92	4.19	42.35	0.29
12	1.17	61.36	3.31	33.73	0.44
24	0.08	87.80	1.23	9.86	1.03
48	2.25	93.74	0.13	1.76	2.12
60	7.29	87.22	0.11	2.47	2.92

Note: The numbers across each row may not sum to 100.0 due to rounding errors.

Table 6. Variance Decomposition for Mexico with Canada as a Large Country when M(1) is I(2)

Mexico Variance decomposition for output					
Quarter	Supply Shock	Demand Shock	Canada Monetary Policy Shock	Home Monetary Policy Shock	Real Exchange Rate Shock
1	52.55	47.45	0.00	0.00	0.00
4	49.71	49.97	0.15	0.002	0.16
8	46.42	52.22	0.60	0.006	0.77
12	44.26	53.38	0.96	0.01	1.39
24	46.23	52.07	0.65	0.27	0.79
48	66.27	28.72	0.27	3.85	0.89
60	76.88	18.88	0.23	3.22	0.80
Variance decomposition for Fed Funds rate					
1	4.67	5.91	89.42	0.00	0.00
4	4.19	2.66	91.89	0.009	1.24
8	2.11	0.91	92.73	0.004	4.25
12	3.24	7.39	84.78	0.008	4.59
24	26.88	46.72	17.08	0.60	8.73
48	30.83	34.83	10.47	10.23	13.64
60	30.11	34.04	10.71	10.68	14.46
Variance decomposition for M1					
1	1.03	6.80	6.23	4.33	81.61
4	0.34	11.89	4.21	7.51	76.05
8	0.11	22.94	2.35	12.11	62.49
12	0.30	39.58	1.34	14.67	44.11
24	3.12	60.82	0.53	11.00	24.54
48	25.67	37.51	4.91	15.91	16.00
60	24.10	31.86	7.83	18.00	18.23
Variance decomposition for CPI					
1	0.65	0.93	5.65	91.55	1.22
4	0.04	0.94	5.65	91.62	1.76
8	0.82	0.52	6.12	91.49	1.06
12	2.77	0.20	6.56	90.07	0.40
24	7.20	19.37	3.29	59.41	10.73
48	6.48	79.19	0.59	10.96	2.78
60	22.74	67.11	1.14	6.83	2.17
Variance decomposition for Real Exchange rate					
1	18.96	34.26	1.32	44.40	1.06
4	12.72	39.33	0.75	46.54	0.66
8	6.92	47.93	0.34	44.23	0.59
12	3.48	57.95	0.15	37.38	1.04
24	0.61	82.32	0.02	13.672	3.82
48	5.95	90.65	0.47	2.15	0.77
60	13.40	81.39	0.94	3.25	1.02
Note: The numbers across each row may not sum to 100.0 due to rounding errors.					

Table 6. Variance Decomposition for Mexico with United States as a Large Country when M(1) is I(1)

Mexico					
Variance decomposition for output					
Quarter	Supply Shock	Demand Shock	U.S. Monetary Policy Shock	Home Monetary Policy Shock	Real Exchange Rate Shock
1	16.60	83.00	0.00	0.00	0.00
4	16.07	83.69	0.10	0.14	0.06
8	14.58	84.31	0.28	0.74	0.10
12	12.16	85.31	0.27	1.74	0.51
24	3.87	85.58	0.69	4.81	6.05
48	8.22	67.90	4.46	5.60	13.83
60	19.51	57.18	4.85	5.22	13.77
Variance decomposition for Fed Funds rate					
1	0.15	3.54	96.31	0.00	0.00
4	5.25	1.61	92.51	0.57	0.06
8	22.01	0.45	74.77	2.56	0.22
12	45.51	0.49	49.31	4.44	0.27
24	59.70	5.27	31.35	3.31	0.39
48	57.29	15.48	20.82	3.39	3.02
60	58.76	13.20	20.14	3.81	4.09
Variance decomposition for M1					
1	35.05	10.74	15.67	11.61	26.93
4	19.91	11.00	22.15	7.19	39.76
8	8.61	10.41	26.67	3.38	50.93
12	4.13	10.19	27.26	1.77	56.65
24	2.67	16.82	22.47	3.89	54.15
48	19.20	44.24	8.73	5.70	22.15
60	9.22	64.54	5.69	6.19	14.35
Variance decomposition for CPI					
1	1.46	0.10	1.56	84.28	12.60
4	0.66	0.51	2.39	87.50	9.00
8	0.53	3.58	4.68	87.53	3.68
12	1.34	8.35	8.20	81.19	0.92
24	18.11	18.16	12.08	44.57	7.10
48	61.28	11.20	2.68	22.60	2.25
60	69.90	9.78	1.73	16.90	1.68
Variance decomposition for Real Exchange rate					
1	36.30	5.68	8.14	46.53	3.36
4	38.07	2.40	7.50	48.75	3.30
8	41.60	0.37	7.19	46.96	3.89
12	46.50	0.54	7.14	40.90	4.91
24	65.61	4.91	5.15	19.13	5.20
48	86.58	6.24	0.81	5.19	1.20
60	91.17	4.26	0.50	3.09	1.00

Note: The numbers across each row may not sum to 100.0 due to rounding errors.

Table 8. Correlation Matrix		
	Canada's Bank Rate	Fed Fund Rate
Canada's Bank Rate	1.000000	0.865506
Fed Fund Rate	0.865506	1.000000

Table 9 Cross Correlation Between Mexico and its NAFTA Partners' Structural Shocks

	Lag (Lead) 0	Lag (Lead) 2	Lag (Lead) 4	Lag (Lead) 6	Contingency Coefficient
Canada as Large Country					
AD_Mex – AD_Canada	6.49	3.30 (3.92)	-2.46 (-0.04)	-5.06 (-0.77)	36.9
AD_Mex – AD_US	21.30	15.21 (19.02)	7.04 (9.27)	2.23 (3.84)	36.28
AS_Mex – AS_Canada	-11.64	-16.07 (-4.32)	-15.14 (-0.33)	-11.88 (-0.42)	32.95
AS_Mex – AS(1)_US	-13.17	-16.87 (-1.22)	-13.88 (-2.55)	-6.30 (-4.84)	21.37^
AS_Mex – AS(2)_US	-9.99	-7.45 (-8.84)	-4.85 (-6.69)	-4.91 (-9.45)	30.55
MP_Mex – MP_Canada	-11.34	-3.34 (-2.18)	9.47 (8.17)	14.91 (16.70)	41.73
MP_Mex – MP_US	-22.15	-16.91 (-24.07)	-10.44 (-26.93)	-4.77 (-29.21)	41.27
US as Large Country					
AD_Mex – AD_Canada	2.96	1.04 (0.11)	-3.75 (-3.47)	-7.19 (-3.11)	32.38
AD_Mex – AD_US	20.65	15.93 (17.50)	9.19 (8.47)	5.18 (4.68)	39.43
AS_Mex – AS_Canada	-16.13	-19.64 (-8.91)	-17.80 (-2.65)	-13.67 (-1.71)	26.69
AS_Mex – AS(1)_US	-15.03	-19.11 (-3.13)	-16.00 (1.01)	-8.47 (-5.34)	21.08
AS_Mex – AS(2)_US	-10.55	-9.92 (-8.77)	-9.18 (-6.85)	-10.25 (-9.93)	34.20
MP_Mex – MP_Canada	-11.34	-3.34 (-2.18)	9.47 (8.17)	14.91 (16.70)	44.06
MP_Mex – MP_US	-22.58	-18.57 (-24.12)	-12.07 (-26.07)	-5.38 (-27.94)	56.33

Note: *AS(1) = Technological Shock; AS(2) = Oil Supply shock; ^ = not significant. The variables in parentheses represent the correlations at different leads. Since for Mexico we have two sets of disturbances, and having collected the structural innovations for Canada and for the United States from Essay 1, we have computed the correlation between each of the latter countries structural shocks with those of Mexico. This explains why we have the two subtitles. For example, under '**Canada as Large Country**' AS_Mex –AS(1)_US is the correlation between the supply shock extracted from Mexico's estimation with Canada as the large country and the technological shock obtained from the US 's estimation. In few words, this Table shows that AD shocks are weakly but positively correlated between Mexico and Canada and between Mexico and the US, whereas the AS shocks as well as the policy shocks are negatively correlated. With the exception of Mexico and US policy shocks, there is low degree of association between Mexico and its NAFTA partners' structural shocks.*

Figure 1. Inflation and Output Growth Performances Under Different Exchange Rate Regimes 1960 - 1997

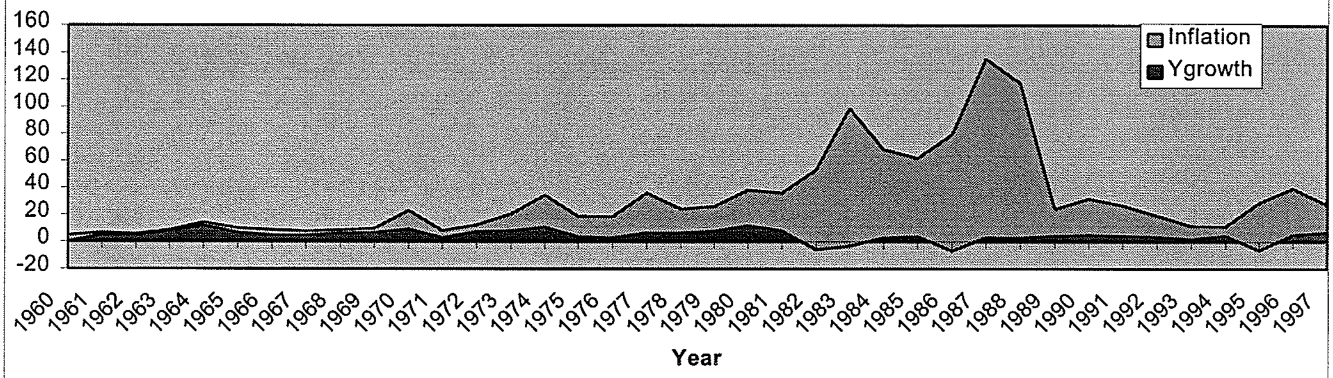


Figure 2 Interest Rates and Premium

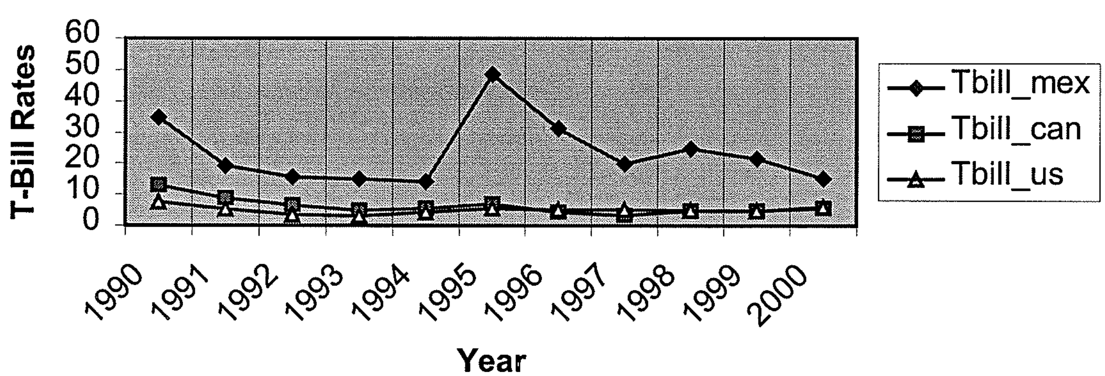


Figure 3. Processed Data

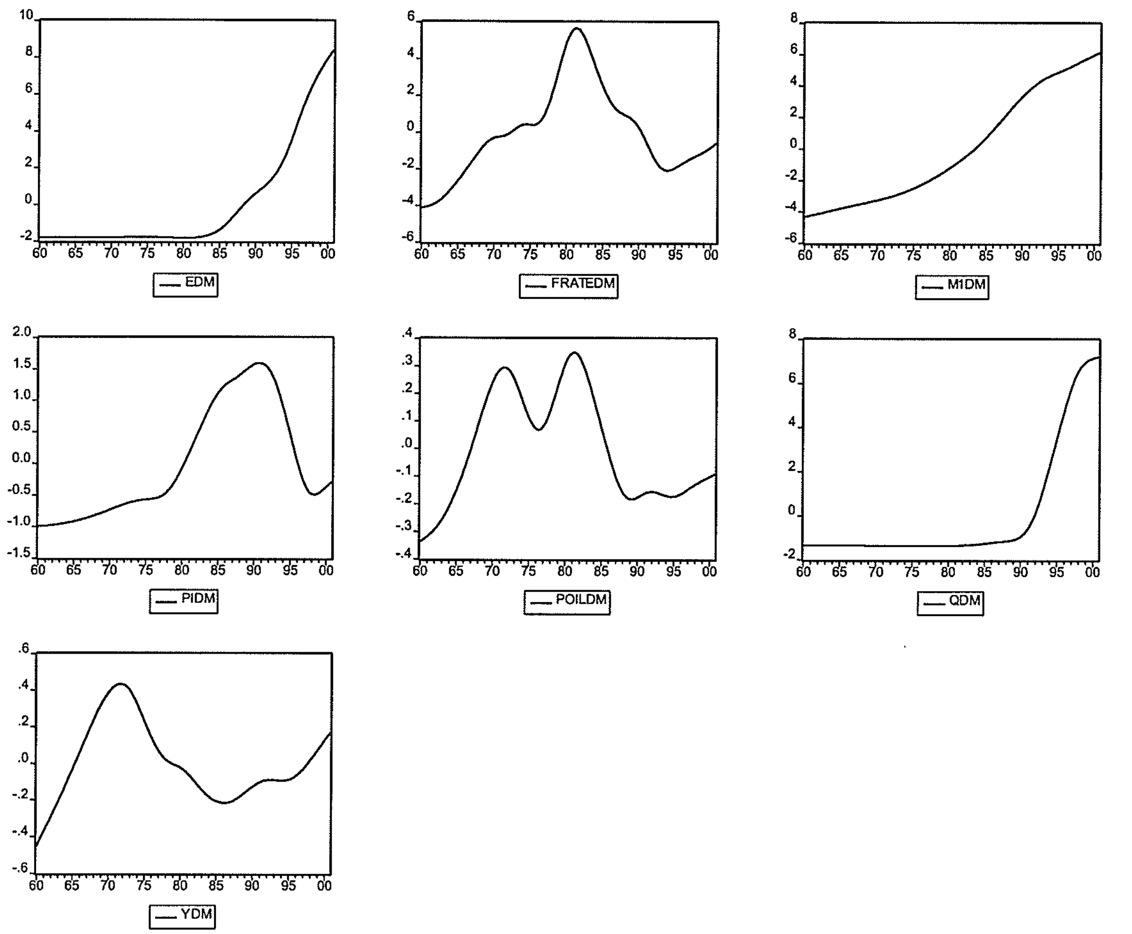


Figure 4. Mexico's Impulse Responses With U.S. Being the Large Country
Exchange Rate Weight = .40 and M1 is I(2)

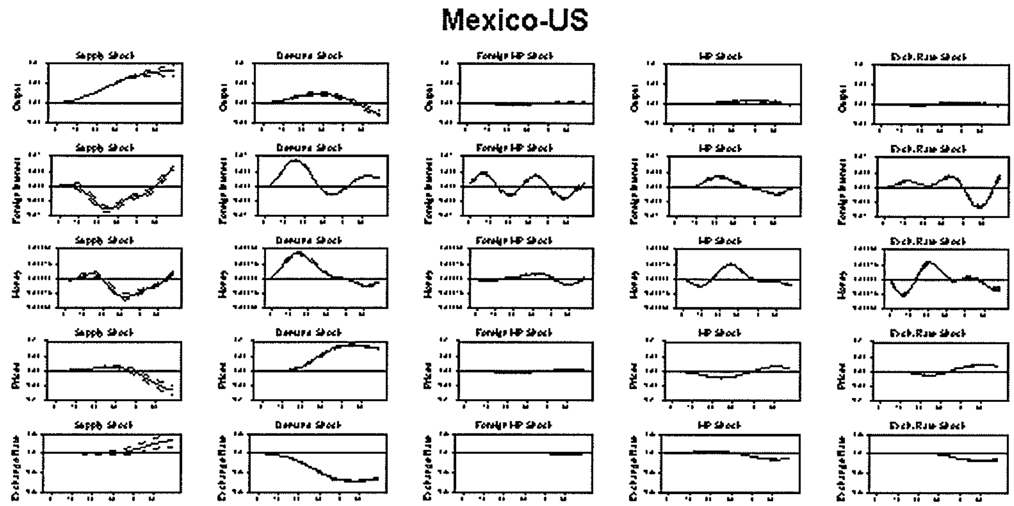


Figure 5. Mexico's Impulse Responses With Canada Being the Large Country
Exchange Rate Weight = .40 and M1 is I(2)

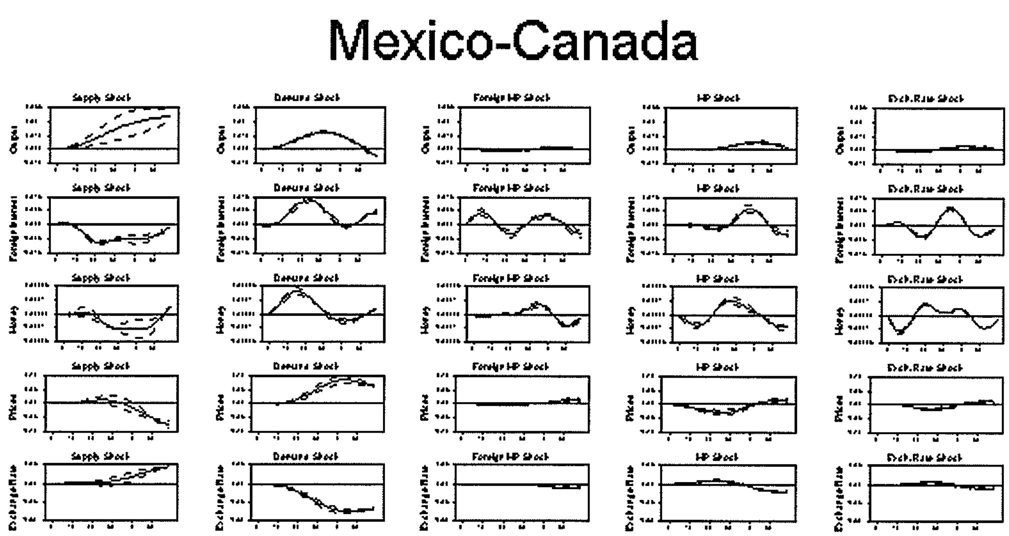


Fig. 6 Taken From Artis et al. (2000) **Canada**

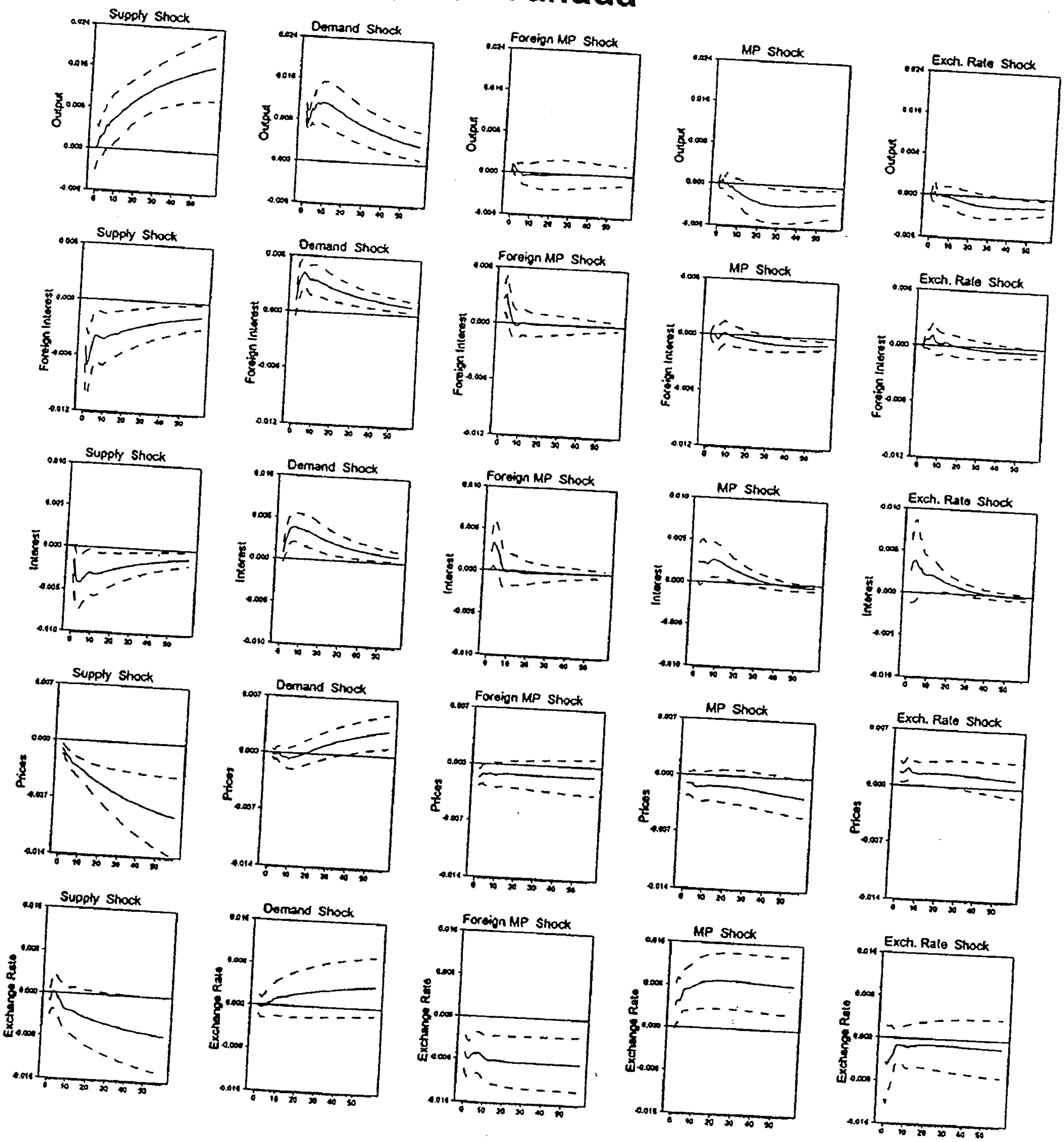


Figure 7. Mexico's Impulse Responses With U.S. Being the Large Country
Exchange Rate Weight = .40 and M1 is I(1)

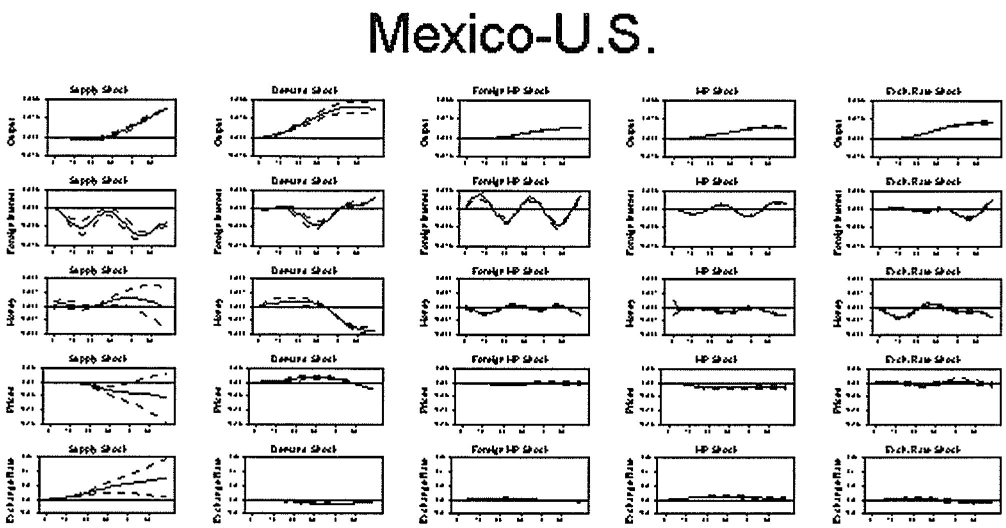


Figure 8. Mexico's Impulse Responses From Unprocessed Data

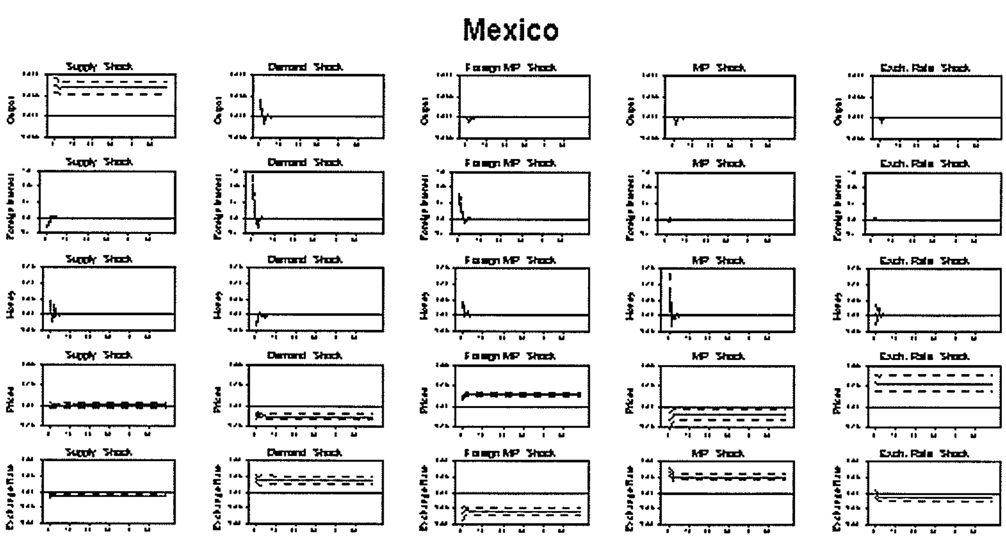


Figure 9. Mexico's Impulse Responses With U.S. Being the Large Country
Exchange Rate Weight = .35 and M1 is I(2)

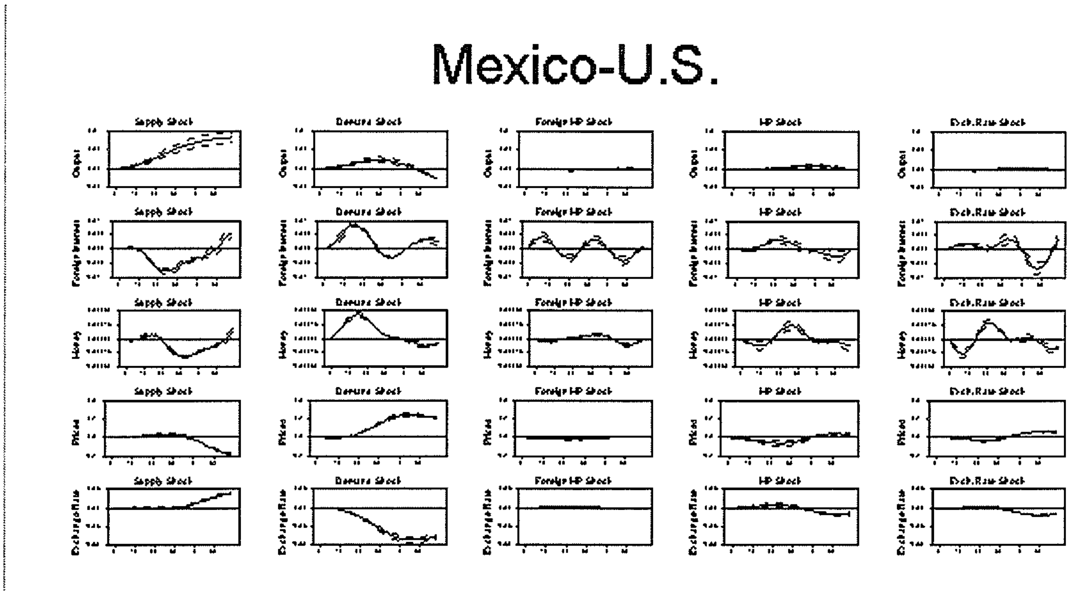


Figure 10. Mexico's Impulse Responses With U.S. Being the Large Country
Exchange Rate Weight = .50 and M1 is I(2)

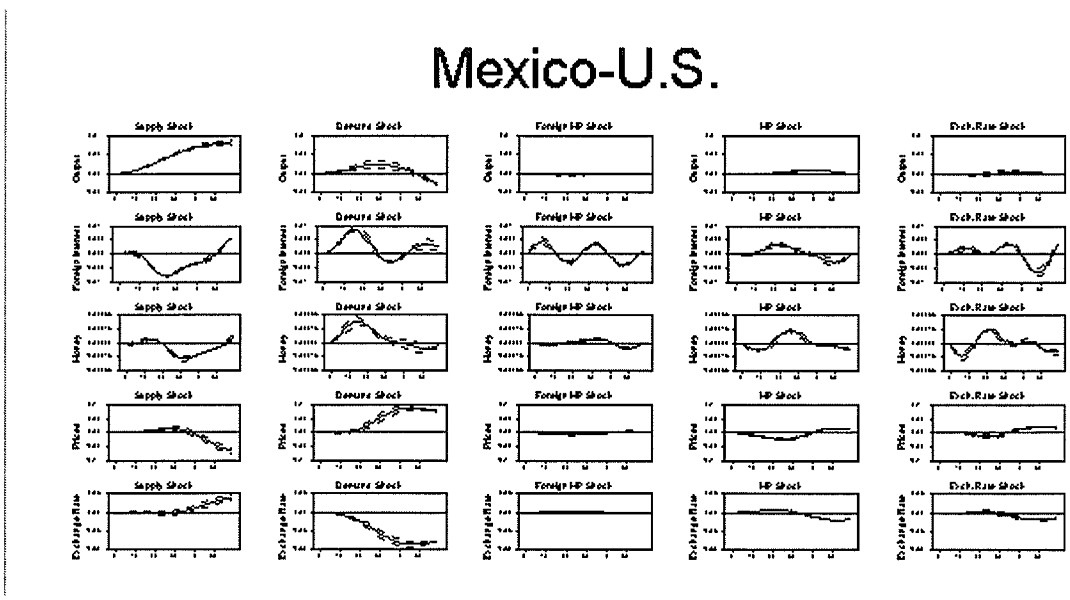


Figure 11. Mexico's Impulse Responses With U.S. Being the Large Country
Exchange Rate Weight = .80 and M1 is I(2)

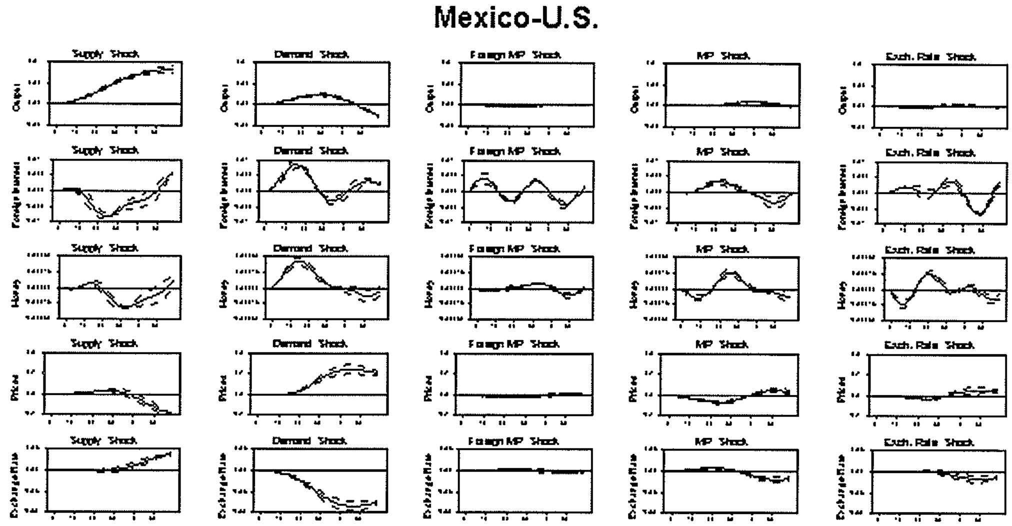


Figure 12. Mexico's Impulse Responses With U.S. Being the Large Country
Exchange Rate Weight = .00 and M1 is I(2)

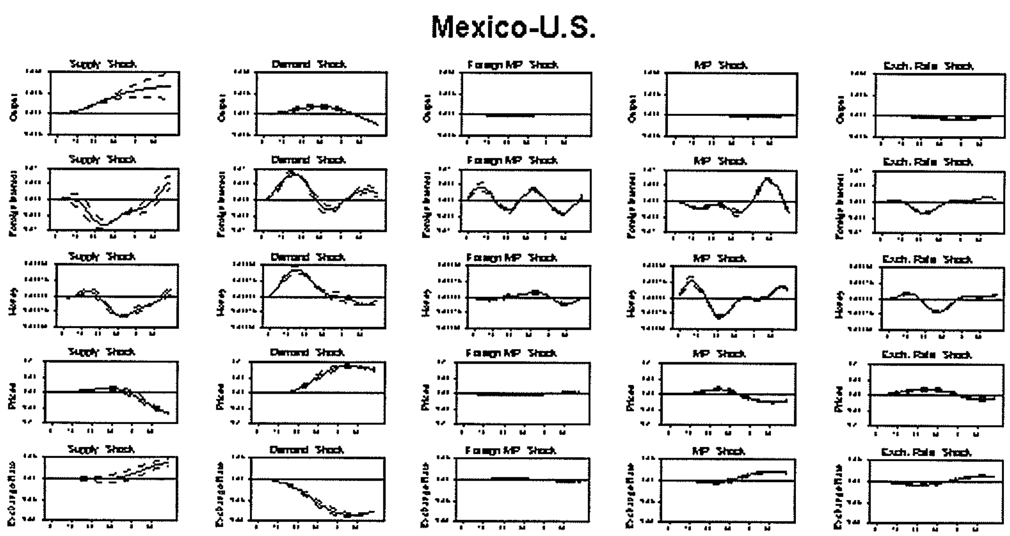


Figure 13. Mexico's Impulse Responses With Canada Being the Large Country
Exchange Rate Weight = .00 and M1 is I(2)

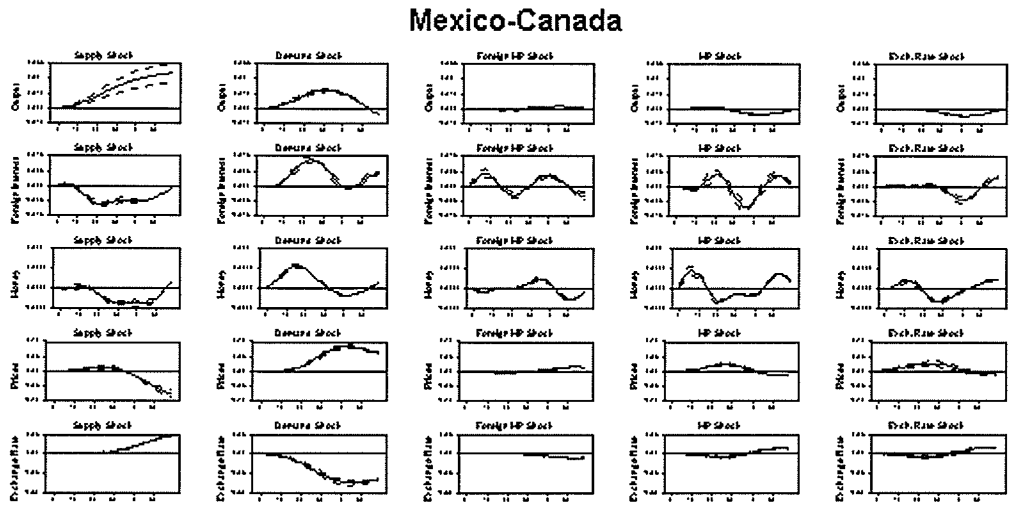


Figure 14. Mexico's Impulse Responses With Canada Being the Large Country
Exchange Rate Weight = .80 and M1 is I(2)

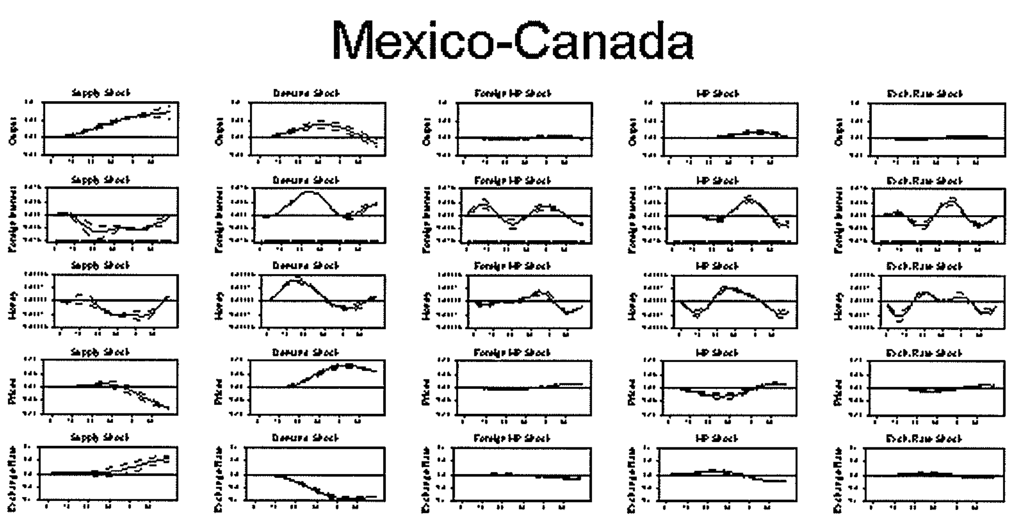
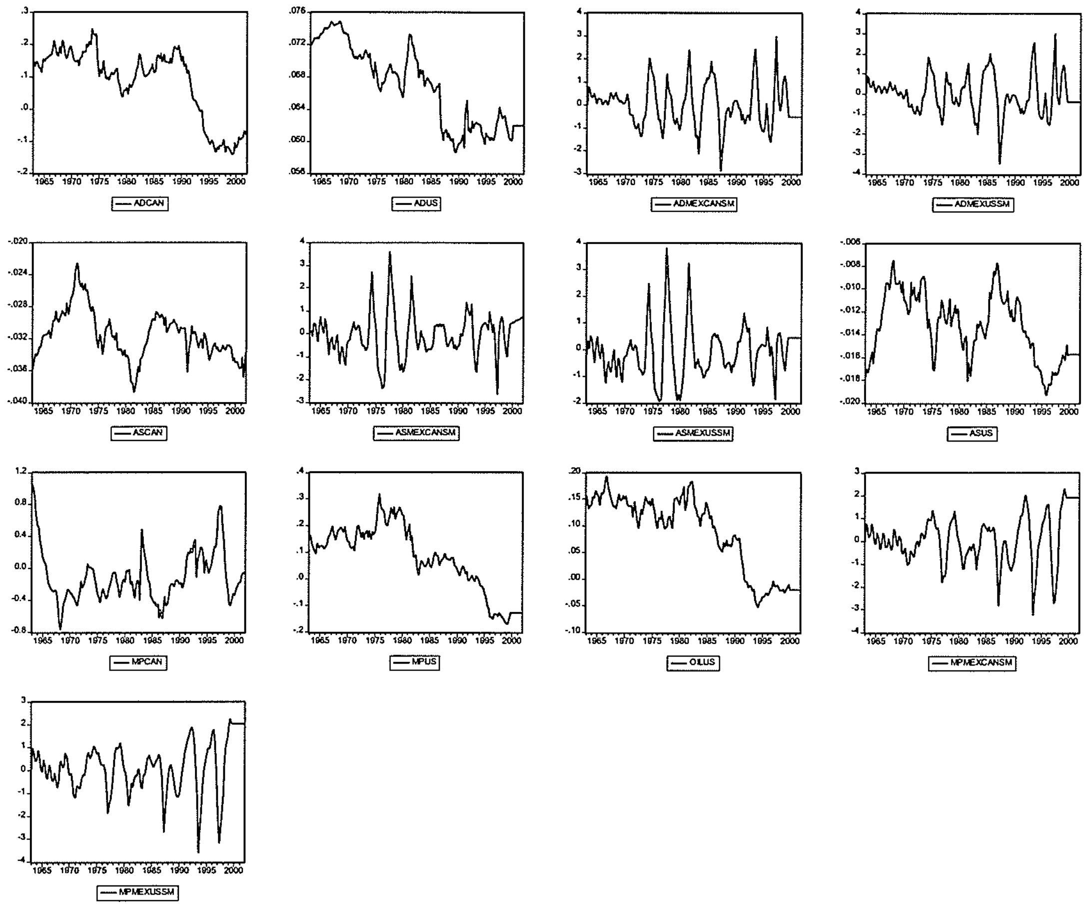


Figure 15 Structural Shocks



On The North American Monetary Union: A Study of The Business Cycle Behavior Between Canada, Mexico, and The United States.

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May 9, 2004

Abstract

This paper is the first to have studied the business cycle linkages between Canada, Mexico and the United States through the Markov-switching framework in order to determine to what extent these countries might be suitable to form a monetary union. The feasibility of the single currency arrangement is assessed on the basis of two criteria: 1) business cycle asymmetry; and 2) identification of a common cycle. Using quarterly data that extends over the period 1963:3-2002:4, the paper shows that a monetary union is feasible between the three countries if decisions are to be made on the basis of business cycle symmetry. However, had the decision to enter such arrangement to be made on the grounds of a common cycle, only the U.S. and Canada would have qualified. To some extent these results confirm the findings of the two first essays and, most importantly, show that whether one relies upon structural vector autoregression or on Markov-switching technique, Canada and the United States are most suitable for a monetary union.

1 Introduction

The purpose of this paper is to understand how the business cycles of Canada, United States, and Mexico are linked to each other in order to determine to what extent a monetary union between the three countries is feasible. The relationship between business cycle and a single currency arrangement is easy to qualify but difficult to quantify. Common sense would dictate that, in a two-country world, if when one economy is in recession, the other is in expansion, or vice versa then there is no synchronization of the business cycle, and therefore there is no ground for a monetary union. In other words, each country is better off alone since it can use domestic policy tools to counter shocks that provoke those cycles. It is also the case that if when one country is in recession (expansion) the other is also in recession (expansion), and most importantly, if one country drives the business cycle of the group, then there is ground to believe policy designed in the pivotal country is also good for the rest. Put differently, a monetary union between these countries is feasible. Having said all these, how can one assess quantitatively the feasibility of a common currency for the North American Countries?

Following the footsteps of Krolzig (1997a), Artis, Krolzig, and Toro (1999), and Hamilton (1989), this paper has used the Markov-switching vector autoregression (MS-VAR) technique to tackle the issue of monetary union in North America by investigating the business cycle linkages between the three countries. To the best of my knowledge, this paper represents the first application of Markov-switching in a multivariate framework to the North American business cycle, and is also the first of its kind on North America. The task is carried out in two phases. In the first phase, a generalization of the original Hamilton (1989) univariate Markov-switching model is applied to each country in order to find out whether there is certain degree of commonality between the individual cycles and whether these cycles are symmetric. In the second stage, the MS-VAR is estimated in order to test for a common cycle.

Using quarterly data on industrial production index for the period 1963:3 - 2002:4 and a classification of the probability regimes into: recession, normal growth, and high growth, this paper first provides evidence that there is synchronization of the business cycles in North America, a finding that holds whether one considers the multivariate model or the aggregate picture of the univariate processes. As to the common cycle, a set of pairwise comparison tests demonstrates that Mexico and Canada share each a common cycle with the United States but not with each other. The multivariate analysis not only confirms the univariate tests, but it also informs that (a) Canada shares a common cycle with U.S. and Mexico combined; (b) U.S. shares a common cycle with Canada and Mexico combined; however, (c) Mexico **does not** share a common cycle with U.S. and Canada combined. This last result seems to have brought essence to what was suspected in the way that studies were carried out in the literature, in that countries of the same degree of economic development tend to move according to the same wavelength and therefore were modeled according to such criterion. It is not known whether previous studies had been able to show the same.

Other relevant findings are that (a) the North American cycle affects the three countries in a similar fashion after the debt crisis in 1982; and (b) the United States business cycle drives the North American cycle, from which one can infer that any time the U.S. is in recession there is a high probability that Canada and Mexico will also be in recession concurrently and an even higher probability that they will be in recession in the next quarter. However, though easy to demonstrate, this paper has not investigated whether normal growth or high growth in the U.S. necessarily matches the same regimes in Canada and in Mexico, a fact that casual observation would definitely dismiss on the basis of recent past economic events. For when the Mexican economy crashed in 1994-1995, the U.S. was booming and Canada was in normal growth mode. By the same token, in early 2000s, the U.S. was experiencing recession while Canada could technically avoid a recession.

Simply put, the contributions are that 1) on the basis of business cycle asymmetry criterion, there is synchronization between the three countries, which dictates that a monetary union is feasible; and 2) on the basis of common cycle, monetary union is most feasible between Canada and the United States. The rest of the paper is organized as follows. Section 2 provides the background and the justification for the study. Section 3 briefly reviews the literature. Section 4 highlights the underlying models and associated issues and exposes the relevant aspects of the Markov-switching methodology. Section 5 analyzes the data. Section 6 interprets the results. Finally, Section 7 concludes the paper.

2 Background

This paper is believed to be the first research to have taken into consideration the relationship between business cycles across North America. Despite the fact that studies on this topic abound in the economic literature for Europe, it was not known at the time of writing this paper of any attempt to model Canada, United States, and Mexico's linkages in terms of business cycles jointly. The contributions to business cycle research, in general, that one has come across can be regrouped into two categories. The first category, whose focus is on the dynamics of single independent countries [see Diebold and Rudebusch (1996); Krolzig, Marcellino, and Mizon (2002); Marcellino and Mizon (2000)], seeks to explain how single or joint behavior of some macroeconomic variables over time have the ability to capture the features of the economic cycles for a specific country. In this setup, financial as well as labour market variables are often used in order to investigate the existence of a common cyclical component between output, employment, labour supply, and real earnings. This line of research is mostly related to dating turning points in order to determine whether the regime classification outlined by the data is closely related to traditional business cycle datings issued by agencies such as the National Bureau of Economic Research (NBER) and the Economic Cycle Research Institute (ECRI).

The second strand of the literature shows interest in groups of countries that share a similar characteristic. These countries may be, approximately, of the same degree of economic development [see Mills and Holmes (1999); Lumsdaine and Prasad (2002); Backus and Kehoe (1992)] or share a common geographic location, or are involved in some sort of economic arrangements [see Artis, Krolzig, and Toro (1999); Girardin (2002)]. This line of research looks at co-movement of macroeconomic time series in order to investigate the possibilities of common components and cycles across countries.

Needless to say that this paper falls under the second category since it embraces 3 countries -Canada, Mexico and the United States-, which belong to the same sub-continent and are linked by the North American Free Trade Agreement (NAFTA) that may possibly extend to a monetary union in the future. What is peculiar, however, is that Canada and the United States are well-developed countries while Mexico is a developing country. There are two issues related to this distinction: 1) the literature is, to be cautious, very scarce or simply non-existent, which leaves no grounds for comparison of findings; and 2) the research might a priori gives the impression that Canada and the United States share a common business cycle with each other but not with Mexico.

The last point may explain discrepancies found in the whole literature in that studies on international business cycles that include Canada and the United States usually incorporate them within a broader group of developed countries, either as members of the G7, partners of western European countries, or OECD [see Artis et al. (1999); Backus and Kehoe (1992); and Lumsdaine and Prasad (2002)]. By contrast, the few that include Mexico usually model it within the context of Latin America with the United States irregularly serving as a reference [see Mejía-Reyes (1999); Engel and Issler (1993)]. In few words, this classification gives the impression that developed and developing countries are likely to evolve according to their own wavelength. Therefore this paper is the first one that breaks with the common approach by facing the challenges of combining countries of different levels of economic development, namely, Canada, Mexico, and the U.S., in an international business cycle study. It takes this path in order to determine to what extent their economic interdependence, which has been largely documented in the literature, is subjected to what is termed a common "North American Business Cycle."

The interesting question, however, is why bother with a study on business cycle when the two first essays [see Jean Louis (2003a,b)][1] have found that shocks that affect the three countries are symmetric? Is not it true that the business cycle originates because of shocks? Do not symmetric shocks mean symmetric business cycle? Though all these questions are sound at the theoretical forefront, there are many reasons for pursuing research on

[1] These papers are referred to as Essay1 and Essay 2 respectively hereafter because they are part of a three-essay dissertation, with this one being the third.

business cycle for Canada, Mexico, and the United States. [Artis et al. (1999)] provides the first justification in a similar study for Europe. They in fact stressed that "*...findings of business cycle synchronicity (or not) are an important indicator of the optimality of monetary union (or not) and hence deserve careful screening.*" Since the first two essays are already embarked in the feasibility of monetary union between the three countries, this essay represents the last important and necessary step towards this goal.

Secondly, in their recent literature review on optimal currency areas, [Lafrance and St-Amant (1999)] note that researchers have come up with different conclusion about the feasibility of monetary union when they have used the structural vector autoregression (SVAR) methodology to focus on either shocks asymmetry or business cycle asymmetry across regions and/or countries. As related to Canada and the United States and as suggested by some empirical evidence, the authors observe that "*a monetary union between the two countries appears more costly from the point of view of shock asymmetry than that of business-cycle asymmetry*", which means that studies that have relied on business cycles correlation are more likely to conclude that monetary union is feasible between the two countries than those that have relied on contemporaneous correlation of shocks. Based on this observation, Lafrance and St-Amant call for further research to discriminate between the two explanations. In this sense, this paper can be viewed as a step towards ascertaining the claim made by these authors in that, since Essays 1 and 2 have established that shocks that hit the North American countries are symmetric, it is then left to show whether their business-cycles are symmetric or asymmetric. Hence, this research has a clear raison d'être.

Yet, one could still argue that this paper leaves the question raised by Lafrance and St-Amant unanswered, and that would be absolutely right. For it is not the topic of interest. Nonetheless, for the sake of scientific curiosity and since an attempt to clarify the fact that symmetry of shocks does not necessarily mean symmetry of business cycles (the question that has been raised above) may eventually shed some lights on the issue, a brief explanation may help scratch the surface and thereby bring closure to the debate.

There are actually two types of shocks that affect any economy: Aggregate demand (AD) and aggregate supply (AS). From AD shocks it is possible to purge monetary policy, exchange rate, and non-monetary demand shocks, whereas oil, labor market, and technological shocks among others can be extracted from AS shocks. The symmetry of shocks could simply mean that on average non-monetary AD and AS shocks have the same effect on the economies. That is, in the business cycle context, they have the same effect on actual output around its potential level or trend. But what about monetary policy shocks?

Studies that have differentiated between the components of AD shocks [see Dupasquier et al. (1997); Lalonde and St-Amant (1994); Artis and Ehrmann (2000)] do not address the issue of shocks asymmetry across countries as related to monetary policy. Essay 1 has taken that step and has found that there is no symmetry between policy shocks across the countries. Following the same line of reasoning, this would dictate that business cycles are asymmetric. This way of thinking would concur with the definition that the business cycle is the result of the many different types of shocks and disturbances (symmetric or asymmetric) that affect the economy, which consist, according to [Fischer, Dornbusch, and Smachlensee (1988)], the basis for the irregular pattern observed in the cycles because the shocks themselves are irregular.

Given the fact that what is called monetary shocks is partly 1) the ability of Central Bankers to alter the course of the economy either by rule or by discretion, 2) changes in the velocity of money as related to the volume of transactions, and 3) changes in income among other determinants, then there is no reason to expect monetary shocks that hit the United States economy be symmetric with those that affect Canada or Mexico, or vice-versa. For these countries do not have the same level of economic activity. Since it is not known with certainty which portion of AD shocks is accounted for by monetary shocks[2], it makes sense to argue, to the extent that the information about asymmetric monetary policy shocks is fully reflected in the path of the business cycle, it is unlikely that the business cycles across countries exhibit either symmetry or asymmetry in harmony with the structural innovations. In summary, discrepancies exist between business-cycle- and structural-shocks-based research or between business cycle paths and structural shocks pattern because not all shocks are symmetric. This discussion brings one to the consideration of a third justification for the paper.

A good reason for a study on business cycle could also be found in the weaknesses of the SVAR methodology emphasized by [Cochrane (1997)] and

[2]The point here is that if the different components of AD shocks were known or measurable, one could possibly arrive at the fraction that monetary policy shocks account for. But this would not be possible if one had a single component for AD shocks as in [Blanchard and Quah (1989)], for disaggregation is not a recommended procedure..

nicely summarized by [Krolzig (2002)]. The criticisms are of three sorts: 1) time invariance or constancy of parameters and covariance matrix; 2) linearity in the models, which makes it impossible for researchers to account for changes in the dynamic multipliers over time; 3) Gaussianity or zero-mean-white-noise assumptions about the structural innovations. In light of these issues, there have been renewed attention by scholars to explore nonlinearity in economic time series by modelling regime shifts. Hence, by allowing switches in regime, this paper may be seen as a way to cover ground left by the two previous essays that are based on SVAR.

Before attacking the topic of interest, it is necessary to refresh our understanding about some basic concepts. The business cycle can be understood as the fluctuations of real or actual output around its potential level or growth path over time. These movements are best understood in terms of the labels that economists have used for their classifications. For example [Fischer et al. (1988)] distinguish two phases of the business cycle: a peak and a trough and further define the transition from peak to trough as recession and that from trough to peak as recovery, or simply, turning points in accordance with [Boldin (1994)]. Most recent basic macroeconomic textbooks, however, outline four phases [see McConnell, Brue and Barbiero (2002)]. A peak is a situation where business activity reaches a local maximum as real output is at or in the neighborhood of capacity output while a recession is a period of decline in real output for at least two consecutive quarters. A trough is considered as the lowest level of actual output below its trend while in the recovery phase output starts to rise towards full-employment.

The connection between business cycle and the feasibility of monetary union is very straightforward. If the ups and downs of the U.S. economy are synchronized with those of Canada and Mexico and vice versa, then it is in the best interest of the three countries to form a monetary union. By contrast, If ups (downs) in the United States correspond to downs (ups) in any of the two remaining countries for most of the periods considered, then there is no need for the countries to consider the monetary union option. What is interesting, however, is that despite the close ties between the three countries in terms of international trade and the dominance of the U.S. economy, casual observation cannot really dictate a priori whether or not the three economies evolve around the same growth pattern. For during the oil shocks in 1973 and 1979, U.S. was the most affected of the 3 countries. In the early 1980s, all three countries went into recession but the Mexican economy was the most devastated due to the debt crisis that started in 1982. In the 1990s, after facing some hardship, as the U.S. and Canada economies were booming, Mexico experienced a severe setback in 1994-1995. Historical events also tell us that the duration as well as the intensities of the business cycle phases are not even across the three countries. The growth rate of output in Mexico during the late 1990s and early 2000s were at least equal to the combined growth rates of U.S. and Canadian output, but the trough seems to have lasted longer as output struggles to rebound to its potential level.

There are actually two views of the business cycle. The first one is the so called *classical business cycles* whose focus is on the patterns of expansion and recession in the *level* of macroeconomic activity. However, it has been recognized that this approach fails to capture much of the short-term volatility that the economy is subjected to because the occurrence of recessions are rare compared to expansions that are considered as the normal state of the economy [see Parkin and Bade (2003)]. The second approach, known as *growth cycles*, which is an alternative to the first one, examines short-term fluctuations in the growth rate of aggregate economic activity. As the authors also pointed out, the procedure to identify the different phases (business cycle turning points or peaks and troughs) remains the same under both methods. Nonetheless, this paper uses the second approach.

What are the issues at stake in terms of business cycle? In other words, being at a peak, how fast does the economy reach a trough or vice versa? Is the speed the same? How long does a recession or a boom last? Part of the answers to these questions can be found in the contributions of Mitchell (1927, p. 290) who claimed that '*the most violent declines exceed the most considerable advances ... Business contractions appear to be a briefer and more violent process than business expansions.*' However, as [Diebold and Rudebusch (1996)] have pointed out, the consensus that seems to have emerged among researchers as to the proper characterization of the dynamics of business cycle is the need to model the passage from expansion to recession as regime switching from "good" to "bad" states, and vice versa.

Modern literature, in that respect, has broadened those concepts to incorporate all the aspects of the business cycles in order to determine whether 1) probabilistic models can be used to date and forecast turning points [see Neftci (1984) and Diebold and Rudebusch (1989)]; and 2) there is asymmetry in the phases. For example, [Sichel (1993)] has developed the concepts of '*steepness*' and '*deepness*' while [McQueen and Thorley (1993)] have developed the concept of '*sharpness*' *or turning point asymmetry.* Steepness asks whether the speed of contraction is faster than that of recovery while deepness asks whether the amplitude or duration of troughs differs from that of peaks. Sharpness relates to whether troughs are sharp or peaks are more rounded, or vice-versa. The formal tests are explained in the section reserved for the methodology.

In their survey, Diebold and Rudebusch (1996) have stressed that business-cycle asymmetry is only one of the two elements of Burns and Mitchell (1946)'s definition of business cycles, with the other being co-movement of macroeconomic variables [see Backus and Kehoe (1992), and Stock and Watson (1989, 1991, 1993) for studies using this framework]. However, what they have also noted is that contributions to the literature have concentrated on either one or the other aspect of the business cycle. They then advance the literature by proposing a methodology that allows for the extraction of a common component that characterizes the business cycle from a group of macroeconomic variables. Artis, Krolzig, and Toro (1999) have taken a similar path to uncover a common European cycle. This paper studies the North American business cycle by following closely the methodology used by these authors. The next section presents the literature review.

3 Literature Review

This section briefly reviews the few contributions on business cycle linkages as related to the North American countries. On the basis of earlier observations, it can be noted that there are two categories of studies: 1) those that examine Canada jointly with the United States along with other developed countries and 2) those that match Mexico with other Latin American countries and the U.S. taken as a country of reference. This classification of the studies may make sense due to the disparity in the state of development between the three countries.

The sensitivity of the Canadian economy to business cycles in the United States has long been a subject of investigation. Early contributions by [Rosenbluth (1957), Chambers (1958), and Hay (1966)] relied on spectral techniques to analyze macroeconomic variables in order to determine whether there are any similarities between the phases of the business cycles across the two countries. As Bonomo and Tanner (1972) also reported, by simply comparing peaks and trough between U.S. and Canada, these studies left all the relevant aspects of economic dependence 'over cycles of all length' out . These authors instead combined the spectral method with a comparison of the relationship between the two countries over all the cycles. Their study that is based on monthly data of industrial production indexes and covers the period 1919-1967 shows that the two economies are subject to similar cycles but the duration of Canadian cycles is smaller than that of the United States. Most importantly, these authors also found that 1) Canadian cycles tend to lag by less than one month behind those of the U.S. for cycles less than 50 months long; 2) the sensitivity of Canada's economy to economic cycles in the U.S. has not been changed in a systematic way, despite the adoption of the flexible exchange rate by Canada in the 1950s.[3]

A study by Phillips (1991) partly confirms the findings of Bonomo and Tanner (1972). In fact, Phillips evaluates the transmission of business cycles for the period 1961:1-1989:3 between United States and Canada, Germany, and the United Kingdom by using a two-country business cycle model, which is considered by many as the first attempt at a generalization of the univariate two-regime Markov-switching model of Hamilton (1989) [see Filardo and Gordon (1994) and Krolzig (1997a)]. Based on seasonally adjusted data on industrial production taken from the IMF's International Financial Statistics

[3]The point here is that if the flexible exchange rate regime has served as a shock absorber for the domestic economy, there is no reason to expect ups and downs in the U.S. to be transmitted to Canada. Therefore, the business cycle patterns across the two countries must be dissimilar.

for Canada and the United States, Phillips arrives at the conclusion that both countries 'move into and out recessions simultaneously' with either having to lead the other. He agrees with Bonomo and Tanner that shocks to U.S. growth rates are transmitted to Canada after a one-lag period but does not believe that the autocorrelation (0.34) of the innovations is too small to be portrayed as the main factor behind the international transmission of business cycles across the two countries. The author instead discovers that world wide recessions that have occurred in 1974, 1979-1980 with the oil shocks, and early 1980s are the major factors that can explain the synchronization of the business cycles across countries. As Phillips clearly emphasized, his study does not take into consideration any transmission of cycles that might occur between large industrial nations and less developed countries [such as Mexico-U.S. and Canada-Mexico] and further asserts that the transmission of cycles across developed countries is negligible. Krolzig (1997a, b) has reached a similar conclusion in his international business cycle analysis of developed nations. He found that the synchronization of these economies' cycles are mostly due to common world-wide shocks that have occured since the first oil shock in 1973.

Backus and Kehoe (1992) have also looked at evidence of an international business cycle by analyzing national accounting annual data for a set of ten countries, including Canada and the United States. Their study extends over a period of 100 years and contrasts properties of GNP, investment, government purchases, net exports, inflation and money stock by using generalized-method-of-moments. Of relevance for this paper is their finding that contemporaneous correlation of output fluctuations (a feature of the business cycle) between the two countries was 0.49, 0.91, and 0.64 during the Prewar, Interwar, and Postwar periods, respectively. This finding led them to conclude that Canada and the United States are subject to common external shocks that give rise to a certain conformity of the cycles.

Further research by [Gregory, Head, and Raynault (1997)] seems to have brought new controversy to the issue of business cycles in developed nations. In fact, these authors 'have measured the part of the fluctuations in GDP growth in the then G-7 countries (now G-8 with Russia) that could be explained by the world business cycle.' They have found, in respect to both Canada and the United States, that little of these countries' fluctuation in GDP can be accounted for by the world business cycle. This led them to conclude that internal shocks to these economies are the main sources of their business cycles. In [Abel, Bernanke, and Smith (1999)] words, the Canadian and U.S. business cycles are mostly made at home.

Thus far, the literature has sent a mixed signal as to the relationship between business cycles across the two countries. What about Mexico? As stated above, at this point, nothing can be said about the association of its business cycle regimes with Canada and little vis-a-vis the United States. For the only study that deals with this issue is Mejía-Reyes (1999), using the classical business cycles approach. In fact, this author relies on yearly data on real GDP per capita for the period 1950-1995 to date turning points across major economies in Latin America and the United States. He used a methodology proposed by Artis, Kontolemis, and Osborn (1997) that is based on Pearson's corrected contingency coefficient (CC_{corr}), which is a measure of correlation. In Mejía-Reyes's view, a CC_{corr} greater than 60% is an indication of "strong" correlation, between 40 and 60% is considered "mild", and less than 40% is portrayed as a clear sign of "low" association of the cycles. Having found a CC_{corr} around 20% for Mexico and the United States, he then concludes that the business cycles of the two countries are idiosyncratic. In other words, the turning points are mostly dissimilar.

In summary, it can be noted that different studies have used different techniques such as spectral analysis, cross-correlation, and Markov switching vector autoregression (MSVAR) among others to tackle the issue of international business cycles. As [Diebold and Rudebusch (1996)] have emphasized, these studies have either concentrated on one or the other aspects of the business cycles as found in [Mitchell (1946)]. That is, their focuses are either on co-movement of economic variables or asymmetry of the business cycles but not on both. [Artis et al. (1999)] have taken into consideration Diebold and Rudebusch's view in their study of the 'European business Cycle' by analyzing both aspects of the business cycles through a variety of techniques that include (a) the univariate MS-AR model proposed by [Hamilton (1989)]; (b) the CC_{corr} as a preliminary step towards common cycle investigation; and (c) the two-step procedure proposed by [Krolzig (1997a)] that consists in estimating a Markov-switching vector error correction model (MS-VECM). This paper applies among others[4] a similar set of techniques in its analysis of the 'North American business cycle' but follows closely the foot prints of [Krolzig (1997a,b)] for its valuable contribution to the regime switching literature. Further details are provided in the section below.

[4]Here one refers to the works of Sichel (1993) and McQueen and Thorley (1993) on business cycle asymmetries.

4 Model and Methodology

4.1 Models of the Business Cycle Within an AD-AS Framework

This section presents the underlying theoretical foundation of the business cycle and is followed by the methodology adopted to estimate the model. There are actually two principal business cycle theories: The Classical, and the Keynesian whose proposition can easily be analyzed within the framework of aggregate demand-aggregate supply (AD-AS) model [see Abel et al.(1997), McConnell et al. (2000) among others]. AD is assumed to be downward sloping due to wealth and substitution effects, AS is assumed to be vertical in the long-run but horizontal in the very short-run and full-employment equilibrium occurs when the three curves intersect each other. According to the Classical school, since prices are perfectly flexible, adverse aggregate demand shocks have no effects on output. Therefore, the short-run AS curve becomes irrelevant because the economy is always at full-employment. However, they view adverse AS shocks as disturbances that can decrease the potential level of output and increase the price level. In other words, Classical economists believe that the business cycle originates because of AS shocks not shocks in

AD, since AD shocks are short-lived and thereby have little or no effects on real output.

Although the Keynesian school agrees with the Classical school on the effects of adverse AS shocks on the economy, they strongly reject their postulation on adverse AD shocks. In Keynesian economists' view, since prices do not adjust automatically because of, say, long-term contracts in the labor market, AD shocks may give rise to a decline in output that may eventually take a long-time to return (if ever) to its previous level. In this respect, Keynesians believe that both AD and AS shocks are the sources of the business cycle.

An extension of the classical thought is the real business cycle theory (RBC) developed by Kydland and Prescott (1982) that adopts the traditional assumptions of market clearing and super-neutrality of money. This theory explains the causes of the business cycle in a broader spectrum by differentiating between real shocks (that is, *shocks that affect the real side of the economy as related to output, labor force, real quantity of government purchases, spending and saving decisions by consumers*) and nominal shocks (e.g. shocks to money supply or demand). In the RBC view, among these two types of disturbances, innovations to productivity (negative or positive) are mostly (not totally) responsible for the fluctuations in output. Despite the extreme assumption this theory is built upon, it has been argued in the literature [see Abel et al. (1999), Snowdon, Vane, and Wynarczyk (1994), and Romer (2001)] that this approach is consistent with some of the basic business cycle facts regarding the procyclical nature of aggregate output, employment, real wages, and labor productivity [see Table 1 taken from Abel *et al.* (1999) for a complete picture]. At the international level, this theory seems to have also been able to explain international business cycles through the synchronization of productivity shocks, and through the similarities in movements in consumption and output across countries [see Feldstein and Horioka (1980), and Backus, Kehoe, and Kydland (1992)]. However, it fails on its prediction that inflation is countercyclical [see Abel *et al.* (1999)].

Table 1 about here

The discussion thus far suggests that there is no uniform theory of business cycles. Independently of the view that one adheres to, however, the AD-AS model can be used as a tool to analyze the contention of the competing theories. Nevertheless, the conventional empirical estimation of such model can by no means bring light to the features of business cycles (asymmetry and co-movement) that are of interest to this paper. Although [Kydland and Prescott (1982), Plosser (1989), and Abel and Bernanke (1992)] have developed a method known as calibration (a comparison between simulated and observed data) to examine the quantitative implications of the RBC model, this paper follows the approach proposed by Krolzig (1997a), which is *a data-driven model specification* that suits its purpose. The next subsection exposes the details of this approach.

4.2 Methodology

The point of departure of this methodology is the original contribution of Hamilton (1989) that considers a univariate Markov-Switching autoregression (MS-AR) with two regimes. This model captures the changing nature of economic time series over time that occurs due to extraordinary events such as wars, financial panics, natural disasters, and drastic changes in government policies. Hamilton reasons that if these events have occurred in the past, there is no reason to believe that they will not repeat in the future. Therefore, he suggests that we model time series processes in a manner that accounts for the changes in their mean values by incorporating the probability of a possible state. The original example used by Hamilton is presented here in order to facilitate the exposition.[5]

In fact, Hamilton considers a fourth-order autoregressive Markov-switching-mean model $[MS-AR(4)]$ of quarterly real GNP growth (Δy_t) for the U.S. that extends over the period 1953 - 1984:

$$\Delta y_t-\mu(s_t)=\alpha_1[\Delta y_{t-1}-\mu(s_{t-1})]+\alpha_2[\Delta y_{t-2}-\mu(s_{t-2})]+...+\alpha_4[\Delta y_{t-4}-\mu(s_{t-4})]+u_t \tag{1}$$

where $u_t \backsim N(0,\sigma^2)$ and $\mu(s_t)$ is the conditional mean that is driven by the latent state s_t.

$$\mu(s_t)=\begin{Bmatrix} \mu_1>0 \text{ if } \mathrm{s}_t=1 \text{ ('}\textit{expansion}\text{ or }\textit{boom'}) \\ \mu_2<0 \text{ if } \mathrm{s}_t=2 \text{ ('}\textit{contraction}\text{ or }\textit{recession'}) \end{Bmatrix} \tag{2}$$

The regime generating process is an irreducible ergodic Markov chain with a finite number of states $s_t=1,...,M(=2)$ that is governed by the transition probability $p_{ij}[=P\{s_t=j|s_{t-1}=i,s_{t-2}=k,...\}=P\{s_t=j|s_{t-1}=i\}]$ collected in a square matrix, namely a *transition matrix*, indicating that

[5] Proper treatments to the data available for this study such as unit roots testing, lag length determination, smoothing in order to remove outliers, and seasonality will be considered in the data analysis section.

state i precedes state j:

$$P = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \tag{3}$$

p_{ij} with $i = j$ is the probability of being in a given state, say recession or boom while p_{ij} with $i \neq j$ is the transition probability from state i to state j or vice versa. For example, p_{12} $[= 1 - p_{11}]$ is the probability of being in expansion and switching to recession while $p_{21}[= 1 - p_{22}]$ is the opposite. The horizontal sums of the probabilities equal unity. That is, $\sum\limits_{j=1}^{M} p_{ij} = 1 \forall i, j \in \{1, ...M\}$. It is also the case that knowledge of the P matrix enables the researcher to determine the duration of a state as given by $[1/(1 - p_{ij})]$, with $i = j$.

Hamilton has demonstrated that the patterns of recession and expansion that his Markov-switching-mean model is able to display are fairly closely related to the business cycle dates proposed by the NBER for the U.S., which are normally determined after the occurrences of events. Put differently, Hamilton has established that, given the information available, his model has the capability of leading to probability inferences about the unobserved regimes that enables researchers to reconstruct the regimes and thereby produce better forecasts. Several authors seem to have agreed with these contentions. They have exploited these properties as a prelude to multivariate analysis.

For example, [Krolzig (1997b)] carried out a business cycle analysis for individual countries that include U.S.A, Japan, West-Germany, United Kingdom (UK), Canada, and Australia by relying on the methodology proposed by Hamilton. He then compared his results with turning points dates provided by ECRI, NBER, and Artis et al.(1997), and discovered that these countries tend to experience booms and contractions simultaneously. With the exceptions of Spain and France, this contemporaneity of the regime shifts across countries has also been found in a similar study by Artis *et al.* (1999) on nine European countries, which, in their view, opens the way to investigate an underlying common cycle (*namely, the European Business Cycle*) that calls for a system approach. They supplement their univariate analysis with an examination of the cross-correlation of the smoothed probability of being in a recession at different leads and lags along with the Pearson's contingency coefficient, a non-parametric procedure that uncovers the comovement of the regimes across countries. Their results reveal that, with the exception of UK, there is a high degree of concordance among the business cycle of the remaining countries.

Nonetheless, one of the features of Hamilton's work is that if the probability of being in a given state is unity (say $p_{11} = 1$) there is no possibility of *ever returning* to another state, say state 2. In which case, state 1 is considered as an *absorbing state* and the Markov chain is said to be *reducible.* This has been regarded as an extreme or remote case where an economy will experience either expansion or contraction permanently and clearly reflects the existence of a structural break or a one-time jump in the series. A more realistic case is one that is characterized by an irreducible ergodic Markov chain where the probability of being in a given state is less than unity, in which case the shifts are temporary.

Although [Hamilton (1989)] and subsequent contributions have had some successes with the two-regime MS-AR specification, several authors [Kim and Piger (2000), Krolzig (2000), and Sichel (1994)] have challenged its prediction of the business cycle patterns. These authors have instead suggested to model a three-regime MS-AR that takes into consideration episodes of recession, rapid growth and slow growth in accordance with Friedman (1993) and Kim-Nelson's (1999) *plucking* model, which purport that, following a transitory adverse shock, output experiences a high growth and subsequently slows down as it approaches its trend.

The original model has also been subjected to a number of refinements in order to accommodate regime shifts in (1) intercepts (I); (2) autoregressive parameters (A); and (3) covariance matrix (H). Moreover, it has been generalized to multivariate analysis, namely MS-VAR or MS-VECM [see Krolzig (1998)]. In its broadest form, a Markov switching mean vector autoregression of order p and M regimes $[MSM(M) - VAR(p)]$ is given by:

$$y_t - \mu(s_t) = A_1(s_t)(y_{t-1} - \mu(s_{t-1})) + ... + A_p(s_t)(y_{t-p} - \mu(s_{t-p})) + u_t \quad (4)$$

where $u_t \backsim NID(0, \Sigma(s_t))$ and $\mu(s_t)$ is $K \times 1$ dimensional mean of the *k-th* dimensional time series vector y_t, $A_1(s_t), ..., A_p(s_t)$ are slope coefficients, u_t is a disturbance term whose covariance matrix $\Sigma(s_t)$ along with all parameters of the model is dependent on the regime, s_t. For example, in a three-regime set up:

$\mu(s_t) = \mu_1 < 0,$ if $s_t = 1$ ('recession') with $\sigma^2(s_t) = \sigma_1^2$

$\mu(s_t) = \mu_2 > 0$ if $s_t = 2$ ('rapid growth') with $\sigma^2(s_t) = \sigma_2^2$

$\mu(s_t) = \mu_3 > 0$ if $s_t = 3$ ('slow growth') with $\sigma^2(s_t) = \sigma_3^2$

It is also expected that $\sigma_2^2 > \sigma_1^2 > \sigma_3^2$ because episodes of rapid growth are normally more volatile than periods of recession, which in turn is more volatile than period of slow growth (in the vicinity of the steady state). One characteristic of this modelling device, however, is that it allows for an immediate one-time jump in the mean following a shift in regime, which, according to Krolzig, does not account for the possibility that the mean may smoothly approach a new level after the transition from one state to another. In order to factor in this feature, Krolzig therefore suggests a regime-dependent intercept $\nu(s_t)$ that can take into account the smooth transition of the mean:

$$y_t = \nu(s_t) + A_1(s_t)y_{t-1} + ... + A_p(s_t)y_{t-p} + u_t \tag{5}$$

As [Krolzig (1997a, Ch.3; 1998)] has demonstrated, the $[MSM(M) - VAR(p)]$ and the Markov switching intercept vector autoregression of order p with M states $[MSI(M) - VAR(p)]$ are two different models that imply two different dynamic adjustments of the observed variables in response to a change in regime. The former implies that a permanent regime shift leads to an immediate jump in the mean growth rate of the process to its new level. For the latter, Krolzig purports that a once-and-for-all regime shift in the intercept gives rise to a dynamic response of the growth rate of the observed variable that is *identical to an equivalent shock in the white noise series u_t.*

Given the variety of models[6] that one can choose from, the dilemma is to determine which one is appropriate for the data at hand. What Krolzig however has suggested is that one does not need to have all the parameters in the model to be regime-dependent. A plausible specification for empirical applications is to allow the autoregressive parameters, the mean *or* the intercepts to be regime dependent, and the error term to be either hetero or homoskedastic. In the context of this research, which involves the three North American countries, [Krolzig (1997a, Ch. 12)] has opened the way by estimating Hamilton's $MSM(2) - AR(4)$ univariate model that has proven to be a good representation of the business cycle dynamics in both Canada and the United States. With respect to the multivariate generalization, the author has tested different model specifications in his search for a global business cycle and arrived at the conclusion that a Markov switching intercept heteroskedasticity vector autoregression in difference with 3 states and 4 lags [$MSIH(3) - DVAR(4)$] has the best fit of all estimated models. Since one cannot estimate these models blindly, it remains to come up with the

[6]Markov-switching (MS)- mean (M); intercept (I); Autoregressive parameters (A); heteroskedasticity (H). That is, MSM, MSI, MSA, and MSH among others.

appropriate specification along with the usual determination of the optimal lag length for Canada, United States, and Mexico's growth rates of industrial production. The information criteria for model selection will be used in this process.

The choice of the proper model is a necessary step towards the two milestones of this paper, which are (1) asymmetry of the business cycles across countries; and (2) common cycles in order to address the feasibility of monetary union. The former can be analyzed within a univariate framework where the turning points of the cycles across countries are compared while the latter is best understood within an MSVAR or MSVECM setup. The discussion below addresses these issues in their order of presentation.

4.2.1 Business Cycle Asymmetry

As mentioned earlier, there are three aspects of the business cycle, namely, *steepness, deepness, and sharpness*, that are investigated when the purpose is to detect asymmetry. In order to understand these three facets, it is necessary, given the observable time series y_t, to define a detrended component (x_t) such that $x_t = y_t - \tau_t$, where τ_t is a non-stationary trend component and x_t is stationary possibly consisting of cycle and noise components [see

Clements and Krolzig (1998)]. Customarily, non-stationarity is assumed to be eliminated via differencing, $x_t = \Delta y_t$. These variables will help bring to light the features of the business cycles as outlined in the definitions.

Definition 1. *Deepness. Sichel (1993). The process $\{x_t\}$ is said to be non-deep (non-tall) iff x_t is not skewed:*

$$E[(x_t - \mu_x)^3] = 0.$$

where μ_x is the mean of the detrended process.

Definition 2. Steepness. Sichel *(1993). The process $\{x_t\}$ is said to be non-steep iff Δx_t is not skewed:*

$$E[(\Delta x_t)^3] = 0.$$

These two definitions establish that positive skewness of the processes x_t and Δx_t implies tall and steep expansion and negative skewness implies steep and deep contractions. In other words, deepness dictates whether troughs have a longer duration than peaks while steepness indicates whether the speed at which the economy reaches the trough is faster than that at which it reaches the peak.

Definition 3. *McQueen and Thorley (1993). The process $\{x_t\}$ is said to be non-sharp if the transition probabilities to and from the two outer regimes are identical:*

$$p_{m1} = p_{mM} \text{ and } p_{1m} = p_{Mm,} \text{ for all } m \neq 1,\ M; \text{ and } p_{1M} = p_{M1},$$

where M is the number of regimes as defined before. In the case of a two-regime model, non-sharpness requires that the transition matrix be symmetric, e.g., $p_{12} = p_{21}$, while in a three-regime model, $p_{13} = p_{31}, p_{12} = p_{32}$, and $p_{21} = p_{23}$.

Sharpness addresses the question of whether troughs are sharper than peaks. These characteristics of the business cycle are investigated for each of the North American countries. The rejection or acceptance of the null hypothesis of business cycle asymmetry across countries will be based on the Wald tests suggested by [Clements and Krolzig (2001)], and will also dictate whether there is synchronization of the business cycle across countries that justifies monetary union

4.2.2 Common Cycle Between North American Countries

The investigation of a common cycle between Canada, Mexico, and the United States is carried out according to the two-step procedure recommended by Krolzig (1996). In the first step, the Johansen maximum likelihood procedure for testing for cointegration (long-run relationship) between the observables is implemented in order to obtain the cointegrated matrix. In the second step, in case a long-run relationship is confirmed, an MS-VECM [i.e. an MS-VAR with the cointegrating vector incorporated] is estimated with the expectation maximization (EM) algorithm in order to capture short-run dynamics. Otherwise, a pure MS-VAR is estimated via the same technique.[7]

The test used to uncover whether the three countries share a common cycle follows Hamilton and Perez-Quiros's (1996) original contribution. The idea put forward by Hamilton and Perez-Quiros is that, given two difference-stationary series $(\Delta y_t, \Delta x_\tau)$ independent of each other for all t and τ, and whose dynamics are driven by the unobserved states (s_t, s_τ) of the business cycle, the log likelihood for each series can be expressed as: $\ell(\theta_y) = \sum_{t=1}^{T} \log f(\Delta y_t | s_t = j, z_t; \theta_y)$ and $\ell(\theta_x) = \sum_{\tau=1}^{T} \log f(\Delta x_t | s_\tau = i, z_\tau; \theta_x)$. θ is a vector of population parameters that contains, among other elements, the transition probabilities and the means or intercepts, z_t is a vector of ex-

[7]In either case, MS-VAR or MS-VECM, shifts in some of the parameters (intercept and variance) are introduced and since the Johansen procedure becomes standard in most time series textbooks, its details are regurgitated in the empirical section of this paper.

ogenous variables, and $f(*)$ is the conditional density function. It is not difficult to realize that the maximization of each log likelihood function subject to the constraints that the sum of the probabilities be equal to 1 and positive each will produce the $\theta_{\max}$, and hence, the $\ell(\theta_{\max})$. Using the independence assumption for two random variables $[f_{x,y}(x,y) = f_x(x) \times f_y(y) \; or \; p_{x,y}(x,y) = p_x(x) \times p_y(y)]$, it becomes clear that the log of the joint density function is equal to the sum of the logs of the marginal density functions and its maximum level could be obtained through the same maximization process. The key in all these is that the joint density function assumes that the states are the same for both series while the univariate estimations assume they are different, the same holds for the remaining parameters of the models. Hence, by comparing the log likelihood of the joint model with the sum of the log likelihoods of the univariate models, one can form a decision as to whether the two series share a common cycle. As Peersman and Smets (2001) nicely put, in an $n - country$ model partitioned into two submodels, one with $n-1$ countries and the other with the n^{th} country, if the sum of the log likelihoods that results from the estimations of those two models is greater than the log likelihood of a model with the full sample of n countries, then the null hypothesis that the n^{th} country shares a the same business cycle as the remaining $n-1$ countries is rejected $[(LR_{n-1} + LR_{n-th}) > LR_n]$. It is also the case that one could rely on Akaike and Schwarz information criteria (i.e, the likelihood corrected for the number of parameters in the model) in order to rule whether to reject the null hypothesis of a common cycle.

5 Data and Data Analysis

The quarterly data used in this study are the seasonally adjusted industrial production indexes for Canada, United States, and Mexico. They were taken from the CD-ROM of the International Financial Statistics of the International Monetary Fund (IFS - IMF) and cover the period 1963:3 - 2002:4. The growth rate as well as the levels of the variables are relevant for this econometric exercise. As a matter of fact, the growth rate of industrial production index is needed for the univariate Hamilton's model while the levels are needed for its generalized version, which requires a cointegration test in order to determine whether one has to go with MSVAR or MSVECM.[8]

A preliminary analysis of the rough data [see Figure 1] shows the pres-

[8]As will become clear latter, the growth rates of the variables are not suitable for cointegration test because each one is stationary. That is, integrated of order 0, I(0) [see Johansen and Juselius (1992)].

ence of outliers in the series of each country, which might render statistical inferences about the model a bit weak. In order to get around this problem, a software developed by [Gomez and Maravall (1992)], namely, the TRAMO/SEATS programme, which is also a subroutine in EViews 4.1, was used to purge the data from the effects of outliers.[9] The series were then tested for a unit root by using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Table 2 shows the results consistent with a trend and an intercept term underlying the data. Only for the levels of the variables had the first differences to be taken in order to achieve stationarity. In few words, Both tests concur that the growth rate variables are I(0) and the levels of the variables are I(1) at the 1% level of significance.

Figure 1 about here

Table 2 about here

Further analysis of the data displays facts that are summarily important in a preliminary assessment of business cycle linkages between Canada, Mexico, and the United States. As can be seen from Table 3, the descriptive

[9]TRAMO stands for "Time Series Regression with ARIMA Noise, Missing Observations, and Outliers" and SEATS stands for "Signal Extraction in ARIMA Time Series." For details regarding how these programmes work, the interested reader is referred to the Eviews 4.1 and the authors webpages for free downloads and other information.

statistics of a quarter to quarter growth rate over different subperiods reveal some quite interesting features. Firstly, all three countries have consistently experienced a positive average growth rate in each of the last four decades, despite major historical economic events such as oil shocks, debt crisis, and international conflicts. Secondly, each country achieved its highest mean growth rate in the 1960s, which confirms the last decade of the Golden Era. Finally, both U.S. and Mexico have recorded their lowest performances in the 1980s (0.50 and 0.690 percent, respectively) while Canada has seen its worse in the 1990s by averaging 0.51 percent. These statistics suggests that the three countries tend to move together over time, however, caution must be exercised here because the table does not supply any information about the recession phases of the business cycles.

Table 3 about here

For the overall sample [1963:3 - 2002:4] in Table 3, even though the U.S. has recorded the lowest mean quarterly growth rate, it has been the least volatile economy of all three countries, as measured by a standard deviation of 0.805. This pattern slightly changes when the focus is shifted towards the subsamples. Nonetheless, Mexico is, as many observers would expect, the most volatile over the four decades and the full sample. As to the link between the three economies measured by the contemporaneous correlation coefficient, Table 4 dictates that, given a 1/2 rule, there is a strong positive correlation of the growth rate of output between Canada and the United States over all the periods but the 1960s. The correlations between Mexico - Canada and Mexico - United States are weak and positive for all periods, except for the 1960s where they are weak and negative. However, when the levels of output are used instead [see Table 5], a strong (close to perfect) positive correlation is uncovered between the three countries.

Table 4 about here

Table 5 about here

6 Empirical Results

This section presents the empirical results of the model estimation and stresses the two components of the business cycle research advanced by Diebold and Rudebusch (1996), asymmetry and co-movement of economic variables. As such, the analysis is carried out in different stages. The first stage consists in estimating a univariate Hamilton-type model for each country in order to determine whether such model has the ability to capture the business cycle dates proposed by the NBER and the Economic Cycle Research Institute (ECRI). At this stage, features of the business cycle such as steepness, deepness, and sharpness[10] that are possible to analyze within the univariate framework are given full consideration. In addition, the smoothed probability of being in a recession (regime 1) extracted from the Hamilton model is used in a cross-correlation and contingency coefficient (a non-parametric approach) analysis in order to inform whether there is any similarity between the business cycles of the three countries that opens the way to study the co-movement of the variables in a system approach.

In the second stage, the Johansen maximum likelihood estimation is used in order to uncover long-run relationship between the three series. Upon findings that there is no cointegration between the variables, a MSVAR instead of a MSVECM is employed in the last stage in the investigation of common cycle.

6.1 The Univariate MS-AR Models

[10]These are the three pillars on the investigation of asymmetry of the business cycle as outlined in the methodology.

The estimation results of this section are all computed via the MSVAR1.31e package for Ox 3.2 by Krolzig (2003). The generalized Hamilton model used for each country is based on the Akaike, Hannan-Quinn, and Schwartz information criteria, abbreviated as AIC, HQ, and SC, respectively. Table 6 shows that a Markov-switching- intercept-heteroschedastic model with 3 regimes and 4 lags [MSIH(3)-AR(4)] is the best representation for the Canadian business cycle, whereas a Markov-switching-mean heteroschedastic model with 3 regimes and 3 (4) lags [MSMH(3)-AR(3), -AR(4)] is proven to be a good approximation for the Mexican (U.S.) business cycle.[11] The three regimes considered are recession, normal growth, and high growth and are classified as regime 1, regime 2, and regime 3 respectively.[12] The features of the business cycle of Canada, United States, and Mexico are given in Figures 2, 3, and 4, respectively. In each quadrant, there are four panels. The first panel shows how well the mean value of the dependent variable generated by the Markov-switching process approximate the true data series. The resulting

[11] In the case of the United States, SC prefers MSMH(3)-AR(3) to MSMH(3)-AR(4). Since the difference between the two is really small, the MSMH(3)-AR(4) was chosen as it is also the model indicated by AIC and HQ.

[12] The choice of 3 instead of 2 states is based on a top-down testing. It does not make sense to test from 2 states to 1 state because the rejection of the null hypothesis of two states would mean the countries have either experienced boom or recession over such a long period. Such conclusion would be erroneous when there periods of disturbances that are well marked. The details are not reported in this paper.

regime probabilities are shown in the lower three panels. Each of these panels contains the filtered, smoothed, and predicted probabilities of the regime in question. The filtered probability $[Pr(s_t = m|Y_t);\ m \in M]$ is considered as the optimal inference on the state variable that results when each observation is assigned to a particular state and that only information available up to that time is taken into consideration. The smoothed probability by contrast is based on the full sample information whereas the predicted probability uses all available information at time $t-1$ [see Clements and Krolzig (2000); and Hamilton (1994)]. These figures show that the models adopted are capable of not only capturing most of the recession and expansion periods established by NBER and ECRI but also those contractions that have occurred in the early 2000s.[13]

Table 6 about here

Figure 2 about here

Figure 3 about here

Figure 4 about here

[13]The best way to understand these figures is to look at the origin at the first panel. Ups (normal or high growth) and downs (recession) in the mean are reproduced in the lower panels as areas that correspond to the different regimes. For example, a high spot in the recession diagram corresponds to a flat spot in the normal and high growth diagrams.

Table 7 summarizes the results of the univariate exercises. It shows that each country's model clearly differentiates between the different phases of the business cycle. Regime 1 depicts recessions with a negative average growth rate. Regime 2 represents normal growth with a positive average growth rate, and with a higher mean, regime 3 characterizes high growth episodes after recessions. The table also reports the duration of each phase of the business cycle that partly confirms [Bonomo and Tanner (1972)]'s contention that the duration of Canadian cycles is shorter than that of the United States. In Canada and in the United States normal growth prevails for approximately 16 and 11 quarters respectively while in Mexico recession prevails for 4 quarters. The shortest duration is for high growth in both Canada and Mexico and for recession in the United States. In respect to the frequency of the state, the probability of being in Regime 2 is 57.4% for the U.S., 88% for Canada, and 46% for Mexico. This fact confirms that Mexico is the least likely to experience sustained economic growth among the three North American economies. Moreover, as indicated by the standard error of the regimes, Mexico's economy is more volatile than the U.S. but less volatile than Canada in periods of normal growth. However, the most volatile regime is recession for the United states, high growth for Mexico, and normal growth for Canada with a standard error of 1.58, 2.04, and 1.09, accordingly.

Table 7 about here

In order to uncover the link between the business cycles of the three countries, the paper compares the recession dates inferred by the smoothed probabilities. Table 8 displays the results. It shows that the three countries have experienced recession concurrently during three episodes: after the first oil shock in the mid 1970s, after the second oil shock and with the emergence of the debt crisis in the early 1980s, and in the early 2000s. This finding confirms Krolzig (1997a,b) that worldwide shocks are partly responsible for the co-movement of output growth at the international level. In addition, it could also be observed that Canada and the United States share most of the recession periods. Most importantly, the double dip recessions in the 1980s in the U.S. and the two strong contractions in 1981/1982 and in 1990/1991 documented in [Krolzig (1997b)] are also captured in the table. Figure 5 sheds more lights by showing graphically the smoothed probability of Regime 1. It becomes clear that Canada and the U.S. are more closely related to each other than they are related to Mexico.

Table 8 about here

Figure 5 about here

Further analysis of the link between the countries leads to consider the pattern of the transition probabilities. That is, the probability that regime j will materialize in period t+1 given the fact that regime i prevails in period t. The regimes can also be the same in both periods, in which case their probability will indicate the persistence of that episode. Table 9 presents the matrix of transition probabilities. On the basis of a 1/2 rule, the tables demonstrates that the probability that a contraction (normal growth) will be followed by another quarter of contraction (normal growth) is relatively persistent in all three countries.[14] However, only in the United States where the high growth regime is highly persistent with a probability (p_{33}) of 84%. The probability of falling from high growth mode to normal growth is only high for Canada (almost 100%) and Mexico (58%). There is not too much difference across the three countries in the transition from high growth regime to recession, the probability is very close to zero in each case. In reference to the shift from normal growth to recession, Mexico has the highest probability of all, around 13%. Whereas, being in recession, Canada has the highest

[14]By relative persistence, it is understood that for some regimes the probability is above 70 percent while for others it is between 50 and 60 percent.

probability (around 34 percent) of all of moving into expansion. In sum, the insight gathered from the matrix of the smoothed transition probabilities is that the turning points of the business cycles are more inclined towards symmetry than asymmetry.

Table 9 about here

Testing for asymmetry is one of the features of the business cycle that the univariate models enable researchers to explore and is one of the two milestones (with co-movement being the other) of this paper. This test is carried out in three facets as described in the methodology. The null hypotheses are non-sharpness, -deepness; and -steepness. Table 10 presents the information on those tests. Sharpness determines whether troughs are sharp or peaks are rounded or vice versa. In other words, it sheds light on whether the turning points of the business cycles are asymmetric. For all three countries, the test fails to reject the null hypothesis of non-sharpness and one therefore concludes that the turning points of the business cycle in each country are symmetric.

Table 10 about here

A similar analysis is done for deepness, which dictates whether troughs have a longer duration than peaks. Again, for all the three countries, the null hypothesis of non-deepness could not be rejected, thereby leading to the conclusion that troughs have shorter duration than peaks. This finding agrees with [Burns and Mitchell (1946)] well-known claim that business contractions are briefer and more violent than expansions. The null hypothesis of non-steepness is rejected at the 1% significance level for United States and Canada but failed to be rejected even at the 10 percent significance level for Mexico, which indicates that the speed at which the U.S. and the Canadian economies reach the trough is faster than that at which they reach the peak. The converse is true for Mexico. In sum, these three criteria indicate that business cycle within each country is symmetric and, taken together, the three countries follow the same cycle patterns.

The synchronous nature of the business cycle across the three countries is further examined by focusing on the cross-correlation matrix of the smooth probability of being in a recession at different leads and lags. Table 11 contains the results. It demonstrates that there is a positive contemporaneous correlation of the recession regime across the three countries on a pairwise comparison basis. With the exception of Mexico-Canada [(Mexico-U.S.) and (Canada-U.S.)], up to lag (lead) 4, one could still observe that positive relationship of the smooth probabilities. In fact, the light shed by this exercise is that there is ground to explore whether the three North American countries share a common cycle, which is the second milestone of this paper and which necessitates a system approach.

Table 11 about here

What [Artis et al. (1999)] have also argued is that one may first wish to explore a non-parametric procedure in order to uncover the cycle regime co-movement across countries, before boarding the MS-VAR venue. This procedure consists in defining a binary time series variable for each country that takes the value of 1 if the smoothed probability of being in a recession is 0.5 or above and zero otherwise. In other words, recession periods are assigned 1 and growth and high growth are assigned 0. For each pair of countries (i, j), one obtains a 2×2 contingency table that records expansions and recessions frequencies as seen in Table 12. The next step boils down to computing via Eviews 4.1 the Pearson's contingency coefficient that is corrected to take values between 0 and 100:

$$CC_{corr} = \frac{CC}{\sqrt{0.5}}100 \tag{6}$$

where CC $= \sqrt{\frac{\hat{\chi}^2}{N+\hat{\chi}^2}}$ and $\hat{\chi}^2 = \sum_{i=0}^{1}\sum_{j=0}^{1} \frac{(n_{ij} - \frac{ni.n.j}{N})^2}{\frac{ni.n.j}{N}}$

In addition, n_{ij}, for $i, j = \{0, 1\}$ is the number of periods for which the two countries are either in the same or in different states and N is the total number of observations. The interpretation of the CC_{corr} is analogous to the correlation coefficient in that the larger the measure the larger the association between the two series [see Eviews 4.1 manual, pp 210-213]. A CC_{corr} of 100 indicates that the countries always experience expansion and contractions at the same time and thereby have the same business cycle turning point dates. A CC_{corr} of zero implies absence of commonality. These normally are extreme cases. However, it is customary to base decisions on some types of rule. For example, [Mejia-Reyes (1999)] used an arbitrary classification[15] in his classical business cycle analysis on Latin America, whereas [Artis et al. (1999)] relied on a threshold level of 50 percent in their study on European business cycle. Using a similar rule (see Table 13), this paper reaches a partial conclusion that there is a high commonality of expansion and recessions between Canada and the United States, as evidenced by a CC$_{corr}$ of 57.4 percent. For the other two pairs of countries, Canada-Mexico (37.0 percent)

[15] CC$_{corr}$ > 60% $\Longrightarrow$ "strong" association
40% $\leqq$ CC$_{corr}$ $\leqq$ 60 $\Longrightarrow$ "*mild*" association, and below 40% $\Longrightarrow$ "weak" association.

and U.S.-Mexico (38.07 percent), a low association was found over the full sample period.

Table 12 about here

Table 13 about here

Although the result on U.S.-Mexico reported here is far above Mejía-Reyes's 20 percent association, it remains a surprise to observe that the business cycle linkages between the two advanced nations in North America and Mexico are almost the same despite the fact that Mexico is far more closely related to the U.S. than it is to Canada in terms of international trade. The findings from the CC_{corr} seem to have confirmed the belief that countries with the same degree of economic development are likely to be subjected to the same business cycle.

However, before heading to the common cycle study, the paper checks whether the inferences from the models are reliable by analyzing the structures of the estimated errors, despite the insight gathered from the information criteria about the suitability of these models. Figures 6, 7, and 8 show the paths of the errors associated with the [MSIH-AR(4); MSMH-AR(4); MSMH-AR(3)] models for Canada, United States, and Mexico, respectively. The left-hand side of each graph reports the one-step predicted and the smoothed errors whereas the right-hand side displays the smoothed standardized residuals that are corrected for regime shifts. According to [Krolzig (1997a) Ch. 7, Krolzig and Toro (2000)], one should expect the standardized residuals to be Gaussian and the predicted errors to be non-normal. The statistical properties of these innovations plotted in Figures 9, 10, and 11 clearly demonstrate these facts. The density functions[16] and the Quantile-to-Quantile (QQ) plots reveal that the standardized residuals are closer to the normal distribution. Most importantly and as shown by the correlograms, there is little or no autocorrelation left in the errors.

Figure 6 about here

Figure 7 about here

Figure 8 about here

Figure 9 about here

Figure 10 about here

Figure 11 about here

Having established that the models used fit the data fairly and that there

[16] Attention must be given to the scale and the standard deviation in case there is any confusion as to which innovations (predicted or standardized) are closer to the normal distribution.

is a high degree of synchronization of the business cycle of the three countries, the $MSVAR$ is used in the next section in order to investigate the existence of a common cycle in North America by focusing on the stochastic process of the industrial production indexes.

6.2 Common Cycle

The investigation of a common cycle in North America is carried out according to the two-stage procedure proposed by [Krolzig (1997a)]. The first stage consists in testing for long-run relationship between the level of industrial production indexes by using the Johansen's maximum likelihood procedure. Upon detection of cointegration, the estimated cointegrated matrix is incorporated into the system in order to give rise to the estimation of a Markov-switching vector equilibrium correction model (MS-VECM), or a MS-VAR in the second stage, if there is no cointegration. The expectation maximum likelihood procedure (EM algorithm) is used at this stage.

6.2.1 Cointegration Analysis

The basic model for the multivariate cointegration analysis[17] is a k-dimensional vector autoregression (VAR) of the non-stationary endogenous variables y_t with p lags and white-noise innovations. This model may be augmented to incorporate, a trend, an intercept, a vector of exogenous variables, seasonal and intervention dummies. In order to keep the representation simple, it is expressed as:

$$y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + \in_t \tag{7}$$

where A_i is a polynomial lag coefficient. After some manipulation, this expression can be rewritten in a more usable form as:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \in_t \tag{8}$$

where $\Pi = \sum_{i=1}^{p} A_i - I$ and $\Gamma_i = -\sum_{j=i+1}^{p} A_j$. However, the key feature to note as asserted by the Granger theorem is that if the rank r of the matrix Π is

[17]The theoretical aspects of cointegration analysis can be found in any popular times series textbook and software manuals. The exposition in this paper follows closely Enders (1995), and Eviews manual 4.1. It is intended to make matter easier for the reader.

less than or equal to the k dimensional vector of endogenous variables, then there are multiple cointegrating vectors. Precisely, there exist k$\times r$ matrices α and β, each with rank r such that $\Pi = \alpha\beta'$. α is the coefficient matrix that captures the speed of adjustment (short-run relationship) in the vector error correction model and β the matrix of cointegrating parameters. The possibility to order the k characteristic roots λ of the matrix Π in a manner such that $\lambda_1 > \lambda_2 > ... > \lambda_k$ leads one to consider several cases. For example, using the generalization $ln(1\text{-}\lambda_i)$ and given that $ln(1) = 0$ if there is no cointegration between the variables the λ_s will be zero since the rank of Π is zero, λ_1 will fall between 0 and 1 when rank $(\Pi) = 1$ as $\ln(1\text{-}\lambda_1) < 0$ and $\ln(1\text{-}\lambda_2) = ... = \ln(1-\lambda_k) = 0$. Since the rank of a matrix equals the number of its characteristic roots that are nonzero, only these roots can be retrieved from the process. Johansen used the maximum likelihood procedure to obtain the Π matrix and employed the following two statistical tests (the Trace and the Maximum Eigenvalue) to rule whether to reject the null hypothesis of cointegration:

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \tag{9}$$

$$\lambda_{\max}(r, r+1) = -T \ln(1 - \hat{\lambda}_{r+1}) \tag{10}$$

where $\hat{\lambda}_i$ are the estimated values of the characteristic roots extracted from the Π matrix and T is the sample size.

The trace statistic tests whether the number of cointegrating vectors are less than or equal to r while the maximum eigenvalue test the null hypothesis of r against $r+1$ cointegrating vectors. The decision rule is that one must reject the null hypothesis whenever the computed statistic is greater than the critical value, in this case, obtained by Johansen and Juselius (1990) through Monte Carlo simulation.

The cointegration test for uncovering long-run relationships between the level of industrial production indexes of Canada, Mexico and the United States was carried out with four lags, a trend, and an intercept term. As shown in Table 14, the Trace and Maximum-eigenvalue tests reject the null hypothesis of cointegration at both the 5 and 1 percent levels. Therefore, the model under consideration is of MS-VAR type instead of MS-VECM.

Table 14 about here

6.2.2 The Multivariate MS-VAR

A multivariate generalization of the MS-VAR model is carried out in the second stage in order to determine to what extent one could extract and date a North American business cycle. For this purpose, a Markov switching vector autoregression with regime-dependent intercept and covariances is chosen on the basis of information criteria. AIC, HQ, and SC reveal that MSIH(3)-VARX(1) is a better suited model for the data on industrial production index of the three countries. The model also contains an exogenous dummy variable, namely X, that captures the shift from the Gold Standard era to a period of dirty regimes in North America. It takes the value of 1 from 1963:3 to 1972:4 and 0 over the rest of the sample. The optimal lag length of 1 was chosen on the basis of the bottom-up procedure recommended by Krolzig (1997). Also worth mentioning is the use of a three-regime model in order to pick up recession, normal growth, and rapid growth.[18]

The estimated parameters of the model using quarterly data for the period 1963:3-2002:4 are shown in Table 15. The different regimes are well marked by the direction and the magnitude of the intercept terms. Regime 1

[18] A two regime-model has been criticized on the grounds that it is too restrictive to capture both recessions and rapid growth episodes. A four-regime model in contrast bears computational burden and is therefore not recommended.

depicting recession appears with a negative value. Regime 2 reflecting periods of normal growth is captured by a positive intercept value that is smaller than Regime 3 of rapid growth episodes. The transition probability matrix reveals that the regimes are persistent when a 1/2 rule is chosen as a benchmark and that there is an equal probability (16%) of moving from normal and from high growth to recession. However, the converse is not true, the probability of going from normal growth to recession (12.23%) is three times higher than going from high growth to recession. The duration of the regimes confirms that recessions are briefer than expansions in North America. A recession lasts less than a year, normal growth about 2 years and rapid growth a little more than a year. Partly, these are stylized facts that established the predictions of the model fall within certain range of expectations about the regimes and the normal state of the economy as being reckoned in the literature.

Table 15 about here

The contemporaneous correlation matrix of growth shocks presented in Table 16 shows that periods of recessions in United States are highly (above 50%) positively correlated with those in Canada. By contrast, a weak negative correlation characterizes U.S.-Mexico (-4.86%) and Canada-Mexico (-11.52%). The degree of association of Regime 2 across the three countries displays a quasi-similar picture except that the link between Canada and the U.S. is now weaker (25%). In terms of regime 3, the only thing that changes is that correlation between the United States and Mexico is positive. The volatility of the North American business cycle is mostly due to Mexico's contribution as evidenced by the standard errors, the highest of all [see Table 17]. Overall, the results being interpreted so far show that the North American Business cycle uncovered in the multivariate framework is not too different than the combined results obtained from isolated univariate cases, which unequivocally suggests a closer link between U.S. and Canada than between Canada-Mexico and Mexico-United States. The next step is to determine whether the dates inferred by the smoothed probability of recession of the system are close to the official dates of recession dictated by the NBER and ECRI for each country.

Table 16 about here

Table 17 about here

The procedure of classifying the regimes and dating the business cycle is the same as in the univariate cases. Each observation is assigned to a regime on the basis of its smoothed probability value (a 1/2 rule threshold). However, in the multivariate case, the inference is made by taking into consideration the whole set of data points [see Artis et al. (1999)]. Table 18 demonstrates that the trough dates extracted from the common cycle are fairly close to the dates reported by the NBER for the U.S. and by the ECRI for the three countries. The complete regime probabilities (filtered, predicted, and smoothed) of being in any given state are presented in Figure 12. The interpretation of these graphs are as explained in the univariate cases above (see footnote 11). In sum, the exercise indicates that there is a North American business cycle. However, the research does not stop there. There are four interesting questions that one needs to shed light on. The first is to find out whether the common cycle is symmetric. The second is to relate the contribution of that North American business cycle to each country's cycle. The third is to highlight which country "drives" the common cycle. The fourth is to test for a common cycle on a pairwise and on a multivariate settings. Answers to these points follow in the lines below.

Table 18 about here

Figure 12 about here

As repeatedly mentioned in this paper, investigating business cycle asymmetry boils down to testing for sharpness, deepness, and steepness, which are presented in Table 19. This table shows that the North American cycle is symmetric as one fails to reject the null hypothesis of non-sharpness at the 5% level. This means that troughs and peaks are of the same shape. Each of the three countries display non-deepness and non-steepness in the common cycle as one also fails to reject the null hypothesis at the 5% significance level. In other words, the common cycle is characterized by troughs having shorter duration than peaks and by recessions being less steep than expansions. These results are not too different from the aggregate picture of the univariate cases, which on average dictates that ups and downs in the level of economic activity are synchronized across the three countries.

Table 19 about here

The answer to the second question in reference to the contribution of the North American business cycle to each country can be tackled through the decomposition of the vector of endogenous variables into two components: a Gaussian and a non-Gaussian[see Krolzig (1997a, b), Artis et al. (1999)]. The latter captures the effects of regime switching on the system. For example, the MSVAR equation can be written as:

$$\Delta y_t = A_1 L \Delta y_t + A_2 L^2 \Delta y_t + ... + A_p L^p \Delta y_t + v(s_t) + \Sigma^{1/2}(s_t)\epsilon_t \tag{11}$$

in a simpler form

$$A(L)\Delta y_t = v(s_t) + \Sigma^{1/2}(s_t)\epsilon_t \tag{12}$$

where $A(L) = I - A_1 L - ... - A_p L^p$ is the matrix of polynomial in the lag operator L and ϵ_t is the error term conditional on the states that follows a standardized normal distribution. Solving for Δy_t leads to the following expression:

$$\Delta y_t = A(L)^{-1} v(s_t) + A(L)^{-1}\Sigma^{1/2}(s_t)\epsilon_t \tag{13}$$

Figure 13 presents the results. It shows that Canada and the U.S. are affected in a similar fashion by the North American business cycle over the full sample period, what one would call a very close match. However, the full process of synchronization of the three countries in the way they are perturbed by the common cycle seems to have started after the debt crisis in 1982. The 1990s even display a stronger convergence. This finding rejoins Chriszt (2000) that "Canada appears to be more suited for a monetary union arrangement with the United States than does Mexico, and that Mexico was converging to this process."

Figure 13 about here

The answer to which country drives the common cycle is attempted through a generalization called the partial autocorrelation (see PcGive 10 Vol. I, 2001). This technique resumes to using ordinary least squares in order to estimate a linear equation and to interpret the slope coefficient of a given independent variable as the contribution of that variable to the left-hand side variable, ceteris paribus. In the context of this paper, the country that drives the North American business cycle (NABC) is understood as the country with the largest slope coefficient. In this exercise, the smoothed probability of being in recession extracted from the estimation of the multi-variate model [MSIH(3)-VARX(1)] is used as the dependent variable, namely $NABC_R$, where R stands for recession. The independent variables are the smoothed probability of being in Regime 1 for each country when the same model is employed in a univariate setup. As the result demonstrates, the United States drives the North American Business cycle:

$$NABC_R = \underset{(0.02)}{-0.02} + \underset{(0.08)}{0.14}Canada + \underset{(0.06)}{0.75}U.S. + \underset{(0.05)}{0.32}Mexico \tag{14}$$

The standard errors are in parentheses. The influence of the U.S. economy is even stronger (around 0.92) when a lag is incorporated into the regression. This finding is by no means a surprise because of the heavy dependence of Mexico and Canada on the U.S. for trade and investment. Moreover, it also confirms [Del Negro and Obiols-Homs (2001)] contention that fluctuations in output and prices in Mexico are mostly originated from movement in U.S. output, prices, and interest rates. In terms of the feasibility of monetary union, this finding informs that any time the U.S. is in recession there is a high probability that the other countries will also be in recession. Since this state of the economy is of the most concerns for policy-makers, it can be argued that there is no major costs involved for the other nations in entering monetary union with the United States

The issue related to testing for common cycle is dealt with through both a bivariate and a multivariate frameworks according to the strategy proposed by Peersman and Smets (2001) already described above in the methodology section. In the bivariate case, the paper investigates whether Canada or Mexico shares a common cycle with the U.S., and whether the two share a common cycle with each other. The results are reported in Table 20. The Table reveals that Canada as well as Mexico indeed share a common cycle with the U.S.. The sum of the log likelihoods of each country and the U.S. taken separately is greater than the log likelihood of a joint model with U.S.-Mexico and U.S.-Canada.[19] Normally, by transitivity, one may be rushed to point out that Mexico shares a common cycle with Canada. As evidenced by the data, this would be erroneous. For the Log likelihoods of (Canada +Mexico) is less than the log likelihood of (Canada **and** Mexico).

Table 20 about here

The same technique is used in the multilateral setting for testing for common business cycle in North America. Table 21 suggests that, taken as a block, Canada and Mexico share a common cycle with the U.S., U.S. and Mexico share a common cycle with Canada. But Canada and the U.S. do not

[19]The idea here is that by applying the MSIH(3)-VARX(1) to the data of each country separately, one obtains the log likelihoods. Then a simple rule is used if Log likelihood of country i + Log likelihood of U.S is greater than the Log likelihood from a joint model of U.S. and country i, then country i shares a common cycle with the U.S.

share a common cycle with Mexico. These findings may appear bizarre. Yet, the exercise confirms the bivariate results, and most importantly, it lays the ground to believe that developed countries' business cycle may in fact differ from that of less developed countries. As explained above, the tendency in the literature is to study the pattern of countries with similar level of economic development, but there has not been any tangible contribution that backs up this practice. In this respect, this paper believes to have erected the basis for further investigation.

Table 21 about here

As one would expect the predictions of this econometric exercise are only good to the extent that the model used fits the data well. The suitability of the MSIH(3)-VARX(1) is assessed on the basis of the properties of the errors. Figure 14 plots the predicted and smoothed errors and the standardized residuals of each country in the common cycle. The statistical properties of these innovations shown in Figures 15 and 16 demonstrate that the standardized residuals follow a normal distribution and the predicted errors are in accordance with the non-Gaussianity assumption of regime shifting models.[20] Moreover, as outlined by the correlogram and the spectral density,

[20]Recall: the smoothed standard errors are corrected for the effects of regime shifts.

there is little autocorrelation left in the errors. In few words, the model used to arrive at the conclusion reached above is sound.

Figure 14 about here

Figure 15 about here

Figure 16 about here

Overall, the key findings of this paper is that Canada and United States are most suited to form a monetary union as shown by the business cycle research. However, if one has to take into account the synchronization of the business cycle that has been intensifying since the 1990s, there is no doubt that ups and downs in the level of economic activity in one country are closely associated with those of the other two countries. Hence, Canada, United States, and Mexico are good candidates for a monetary union. Also of importance is the fact that this research brings more robustness to the findings of the two first papers of this dissertation. It shows that whether one relies upon the impact of *a-once- and-for-all* shock on the key economic variables [the Structural Vector Autoregression Approach (SVAR)] or Markov switching models where the economy is constantly perturbed, the results are

That is what brings them back to the normal distribution.

the same. There are no major economic adjustment costs involved for the three countries to enter a monetary union.

7 Conclusion

This paper has investigated the feasibility of a monetary union between Canada, United States, and Mexico on the basis of the path of their business cycles. The study is carried out in two phases. In the first phase, a generalization of the original Hamilton's model is estimated in order to extract and date the business cycle of each country. In this process, asymmetry is tested and one also obtains the regime probabilities of being in recession, which are then used in a cross correlation and contingency analysis in order to determine whether there are features of the univariate models that may dictate certain commonality among the three countries. These exercises reveal that the three countries follow the same business cycle patterns but the speed at which Canada and the U.S. reach the turning points is different from that at which Mexico reaches the same. Further evidence demonstrates that there is a higher degree of concordance between U.S. and Canada than between U.S.-Mexico or Canada-Mexico, which seems to have confirmed the belief that countries with the same degree of economic development are likely to share the same business cycle. This paper is believed to be the first one to have asserted such claim. As a word of caution, more research is needed in this area.

The second phase of this paper is a multivariate generalization of the Hamilton model where the three countries are modeled jointly in a vector autoregression with switching intercept and covariance matrix. This device is used in order to determine whether the co-movement of the variables suggests a common cycle that one can term the North American cycle. This part of the research is carried out according to the two-stage procedure recommended by [Krolzig (1997a)]. In the first stage, the Johansen maximum likelihood procedure was used in order to test for cointegration between the levels of the industrial production index of the countries. The trace statistic as well as the Maximum-eigenvalue tests reject the null hypothesis of cointegration between the series at the 5% significance level. Hence, there is no long-run relationship between the variables. The cointegration test also enables one to decide on the type of model to use in the second stage as to whether it should be MSVAR or MSVECM. The absence of cointegration confirms that the MSVAR is the appropriate technique. The second stage was then carried out in order to extract, date the North American business cycle, and test for asymmetry. By the same process, the regime probabilities of being in a recession that is based on the full sample was recovered and was later used in 1) the test for a common cycle between subsets of the general model, and 2) the partial autocorrelation. The main results are the following. On the basis of business cycle asymmetry, the system-based model display almost the same picture as the aggregate univariate models, which means that there is synchronization of the business cycles of the three countries. In other words, monetary union from this view is justifiable between Canada, United States, and Mexico. On the basis of co-movement of economic variables, Canada and Mexico each share a common cycle with United States but not with each other. When taken as a block, Canada and the United States do not share a common cycle with Mexico. These findings inform that a monetary union is only justifiable between Canada and the United States. However, when importance is given to the process of convergence of the three economies that has been amplifying since the 1990s, there is room to argue that Mexico may be suitable for a monetary union with its NAFTA partners, though it is and may even remain "the weakest link."

There may be some competing effects at work in the common cycle research. The fact that the U.S. shares a common cycle with Canada and Mexico combined, and Canada shares a common cycle with US and Mexico combined may simply indicate that in each block the cycles of the developed countries absorb that of Mexico. If this is really the case, what is being observed in both cases is just that Canada and the U.S. share a common cycle. Once again, further research may help clarify those points.

What are the possible grounds on which this study may be criticized? First of all, it must have been noted that none of the univariate models contains a dummy variable that captures the end of the Golden era but the multivariate model does. One may even wonder to what extent this fact might have altered the predictions of the models. However, the simple answer is that these models were also estimated with a dummy but the information criteria led to the rejection of these models. Another issue is that although the paper has underlined the weaknesses associated with a two-regime model, it has not gone into testing for such specification. It might be the case that a two-regime model might well suit the data of one of the countries [Canada being the most susceptible -see Figure 2]. In this regard, it is worth mentioning again that this path was undertaken but the information criteria has led to the adoption of a 3-regime. The paper does not report those details.

It would have been quite an accomplishment if this paper could compare the response of the individual countries' industrial output due to a North American recession [the transition from regime 2 to regime 1] and the effect of a high growth regime in North America [shift to regime 3] as in [Krolzig and Toro (1999), Clements and Krolzig (2000)]. Unfortunately, the software does not allow for such luxury. Since the impulse response features are part of the "To do" list of Krolzig (1998), one therefore believes that once these features are available, the paper could be expanded in that direction.

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Table 1. The Business Cycle Facts

SUMMARY	Variable	Direction	Timing
The Cyclical Behaviour of Key Macroeconomic Variables	**Production**		
	Industrial Production	Procyclical	Coincident
	Durable goods industries are more volatile than non-durable goods and services		
	Expenditures		
	Consumption	Procyclical	Coincident
	Business fixed investment	Procyclical	Coincident
	Inventory investment	Procyclical	Leading
	Trade balance	Procyclical	Leading
	Investment is more volatile than consumption		
	Labour Market Variables		
	Employment	Procyclical	Coincident
	Unemployment	Countercyclical	Coincident
	Average labour productivity	Procyclical	Leading
	Real wage	Acyclical	--
	Money Growth and Inflation		
	Money Growth	Procyclical	Leading
	Inflation	Procyclical	Lagging
	Financial Variables		
	Stock prices	Procyclical	Leading
	Nominal interest rates	Procyclical	Lagging
	Real interest rates	Acyclical	--
	Note: This table is taken from Abe, Bernanke, and Smith (1999) p. 299. Variables that move in the same direction as the phases of the business cycle are said to be procyclical. Those that move in opposite directions are countercyclical. When there is no clear pattern, these variables are considered acyclical. In terms of timing, variables that are considered as leading variables announce the business cycle, while the lagging variables display the ups and downs after the occurrence of the business cycle.		

Table 2. Unit Root Tests for both Output Levels and Growth

	Canada		Mexico		United States	
Output	Level	Difference	Levels	Differences	Level	Difference
ADF	-2.01	-4.55	-2.27	-5.65	-1.95	-5.28
PP	-2.55	-5.15	-2.52	-9.83	-1.76	-6.56
Growth						
ADF	-5.48		-5.39		-5.38	
PP	-8.58		-10.98		-6.98	
ADF and PP Critical values at 1, 5, and 10% are - 4.02, -3.44, and –3.14, respectively.						

Table 3. Descriptive Statistics for Growth Rates of Quarterly Industrial Production Index (quarter to quarter, %)

	Mean	Std. Deviation	Minimum	Maximum
Canada				
1963:3 – 2002:4	0.853	**1.785**	-4.664	7.416
1960s	1.778	1.140	-0.437	3.972
1970s	0.970	**1.566**	-4.665	3.811
1980s	0.583	**2.511**	-3.798	7.420
1990s +	0.510	**1.361**	-3.088	2.870
Mexico				
1963:3 – 2002:4	1.259	2.328	-6.175	6.690
1960s	2.410	2.028	-0.980	6.656
1970s	**1.624**	2.408	-3.200	6.700
1980s	0.690	2.381	-5.242	5.530
1990s +	0.844	2.163	-6.175	5.839
United States				
1963:3 – 2002:4	0.805	1.606	-7.924	4.440
1960s	1.600	**0.974**	-0.650	3.661
1970s	0.800	2.276	-7.925	4.440
1980s	**0.500**	1.610	-4.049	4.142
1990s +	0.653	1.055	-2.240	2.101
1960s = 1963:3 – 1969:4; 1970s = 1970:1 – 1970:4; 1980s =1980:1 – 1980:9; 1990s + = 1990:1 – 2002:4				

Table 4. Correlations Between Growth Rates of Industrial Production Index

	Mexico	United States
Canada		
1963:3 – 2001:4	0.163	0.610
1960s	-0.005	0.284
1970s	0.080	0.595
1980s	0.150	0.651

1990s +	0.112	0.760
Mexico		
1963:3 – 2001:4		0.260
1960s		-0.012
1970s		0.250
1980s		0.210
1990s +		0.280
1960s = 1963:3 – 1969:4; 1970s = 1970:1 – 1970:4; 1980s =1980:1 – 1980:9; 1990s + = 1990:1 – 2002:4		

Table 5. Correlation Between Levels of Industrial Production Index

	Canada	Mexico	United States
Canada	1.000000	0.975929	0.986167
Mexico	0.975929	1.000000	0.973392
United States	0.986167	0.973392	1.000000

Table 6. Choice of Univariate Markov-Switching Model

Canada	AIC	HQ	SC
MSMH(3) – AR(3)	3.7256	3.8453	4.0202
MSMH(3) – AR(4)	3.7097	3.8379	4.0252
MSIH(3) – AR(3)	3.7417	3.8613	4.0362
MSIH(3) – AR(4)	**3.6897**	**3.8179**	**4.0053**
Mexico			
MSMH(3) – AR(3)	**4.5318**	**4.6514**	**4.8263**
MSMH(3) – AR(4)	4.5406	4.6687	4.8561
MSIH(3) – AR(3)	4.5396	4.6593	4.8342
MSIH(3) – AR(4)	NC	NC	NC
United States			
MSMH(3) – AR(3)	3.2310	3.3506	3.5255
MSMH(3) – AR(4)	**3.2212**	**3.3494**	**3.5367**
MSIH(3) – AR(3)	3.2679	3.3961	3.5875
MSIH(3) – AR(4)	3.2545	3.3741	3.5490
Note: NC = No convergence even after 150 iterations.			

Table 7. Estimation Results of the MS-AR of Each Country

	United States	Mexico		Canada
Mean			**Intercept**	
Regime 1	-1.6078	-1.5792	Regime 1	-1.9969
Regime 2	0.8534	1.1850	Regime 2	0.8203
Regime 3	2.2777	2.9704	Regime 3	5.9304
Autoregressive Parameters				
α_1	0.5706	-0.2060		0.3015
α_2	-0.2702	0.0915		0.0989
α_3	0.2415	0.2792		0.0583
α_4	-0.1499			-0.2254
Duration				
Regime 1	3.38	3.63		2.16
Regime 2	10.59	2.37		16.27
Regime 3	6.22	1.75		1.00
Probability				
Regime 1	0.1836	0.2095		0.1017
Regime 2	0.5747	0.4548		0.8791
Regime 3	0.2417	0.3357		0.0192
Standard Error				
Regime 1	1.5787	1.7322		0.88792
Regime 2	0.5744	1.0811		1.0947
Regime 3	0.9368	2.0443		0.7366
Log-likelihood	**-232.03**	**-336.21**		**-268.11**
LR linearity test:	**61.011**	**20.59**		**34.33**

Sample 1963:3-2002:4
Other alternative tests to the LR test include: Chi(4) = [0.0000]** Chi(10) = [0.0241]* DAVIES = [0.0000]** DAVIES = [0.0075]**

* and ** indicate 5 and 1 percent significance level respectively.

Table 8 Comparison of Recession Dates Based on the Smoothed Probabilities

	United States	Mexico	Canada
1970-1972	1970:2 – 1971:2	1970:3 - 1970:3 1971:3 –1971:4	
73-75	1974:2 – 1975:1		
75-78		1975:3 – 1975:3 1976:4 – 1977:2	1975:1 –1975:3
78-80	1978:3 – 1978:3		
80-82	1980:4 – 1981:1		1980:4 – 1980:4
82-84	1982:2 – 1983:2	1982:4 – 1984:2	1982:1 –1983:2
84-86			1984:3 – 1984:3
86-88		1986:2 – 1987:2	

88-90		1988:3 –1989:1	
90-92	1991:2 – 1991:3		1991:1 – 1991:3
92-94			1992:2 – 1992:2
94-96		1995:2 – 1996:1	
96-98			
1998-2000			
2000-2002	2001:2 – 2002:2	2001:2 – 2002:3	2001:3 – 2001:3

Official Business Cycle Dates

1) NBER – USA: Feb. 1961 – Nov. 1970 – March 1975 – July 1980 – Nov. 1982 – March 1991.
2) ECRI – Mexico: Jan. 1983 – Aug. 1986 – July 1988 – Aug. 1993 – Apr. 1995 – Jan. 1999.
3) ECRI – Canada: Nov. 1964 – Feb. 1968 – May 1970 – Sep. 1972 – Jan. 1975 – Sep. 1977 – May 1980 – Jul. 1982 – Nov. 1986 – Feb. 1991 – June 1996 – July 1998 .

Sources: http://www.businesscycle.com/research/intlcycledates.php
http://www.nber.org

Table 9 Probability of Transition Between Regimes

	Regime 1	Regime 2	Regime 3
United States			
Regime 1	0.7045	0.08406	0.2114
Regime 2	0.0944	0.9056	1.291e-005
Regime 3	9.688e-008	0.1607	0.8393
Mexico			
Regime 1	0.7245	3.379e-005	0.2755
Regime 2	0.1269	0.5773	0.2957
Regime 3	4.573e-008	0.5726	0.4274
Canada			
Regime 1	0.5375	0.3427	0.1198
Regime 2	0.0535	0.9385	0.007983
Regime 3	0.0002076	0.9998	3.447e-009

Table 10 Asymmetry Testing

	United States	Mexico	Canada
Sharpness	0.4696 [0.9255]	1.5771 [0.6646]	2.964 [0.3972]
P_12 = p_32	0.4564 [0.4993]	0.0195 [0.8888]	0.053 [0.8180]
P_13 = p_31	0.0005 [0.9827]	0.0036 [0.9520]	0.0371 [0.8473]
P_21 = p_23	0.0109 [0.9169]	1.5524 [0.2128]	2.8647 [0.0905]+
Deepness	0.8163 [0.3663]	0.4601 [0.4976]	0.9908 [0.3196]
Steepness	7.8923 [0.0050]**	1.7061 [0.1915]	20.797 [0.0000]**

The values in brackets represent the probabilities of $Chi^2(1)$ under the null hypothesis and + indicates significance at the 10 percent level.

Table 11 Cross-Correlations of the Smoothed Probability of the Recession Regime

Lag i / Lag 0	United States	Mexico	Canada
United States			
Lag (Lead) 0	1.0		
Lag (Lead) 2			
Lag (Lead) 4			
Mexico			
Lag (Lead) 0	0.22 (0.22)	1.0	
Lag (Lead) 2	0.29 (0.03)		
Lag (Lead) 4	0.20 (-0.15)		
Canada			
Lag (Lead) 0	0.59 (0.59)	0.14 (0.14)	1.0
Lag (Lead) 2	0.21 (0.31)	0.01 (0.23)	
Lag (Lead) 4	0.10 (-0.02)	-0.12 (0.21)	

Note: *The figures in parentheses represent the cross-correlations at different leads, that is, t, t+2, and t+4.*

Table 12 Contingency table

	Expansion	Recession	
Expansion	n_{00}	n_{01}	$n_{0.}$
Recession	n_{10}	n_{11}	$n_{1.}$
	$n_{.0}$	$n_{.1}$	N

Table 13 Corrected Contingency Coefficient

	United States	Canada	Mexico
United States	100		
Canada	57.4	100	
Mexico	38.07	37.0	100

Table 14 Cointegration Results

Series: Industrial Production Index: Canada, United States, and Mexico				
Lags interval (in first differences): 1 to 4				
Unrestricted Cointegration Rank Test				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5 Percent Critical Value	1 Percent Critical Value
None	0.072747	26.00491	34.55	40.49
At most 1	0.056747	14.44898	18.17	23.46
At most 2 *	0.035376	5.510542	3.74	6.40
*(**) denotes rejection of the hypothesis at the 5%(1%) level				
Trace test indicates no cointegration at both 5% and 1% levels				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5 Percent Critical Value	1 Percent Critical Value
None	0.072747	11.55593	23.78	28.83
At most 1	0.056747	8.938442	16.87	21.47
At most 2 *	0.035376	5.510542	3.74	6.40
*(**) denotes rejection of the hypothesis at the 5%(1%) level				
Max-Eigenvalue test indicates no cointegration at both 5% and 1% levels				

Table 15 Estimation Results For the Multivariate model

	Canada	United States	Mexico
Intercept			
Regime 1	-0.972	-0.952	-0.957
Regime 2	0.552	0.635	1.558
Regime 3	1.221	1.302	1.715
Parameters			
Ycan_1	0.198	0.076	-0.002
Yus_1	0.110	0.275	-0.191
Ymex_1	0.0515	-0.006	0.068
Dummy	0.820	0.511	1.426
Standard errors			
Regime 1	1.401	1.664	2.275
Regime 2	0.969	0.589	1.921
Regime 3	2.134	1.307	1.964
Duration			
Regime 1	3.19		
Regime 2	8.06		
Regime 3	5.67		
Transition Probability Matrix			
	Regime 1	Regime 2	Regime 3
Regime 1	68.63	15.70	15.68
Regime 2	12.23	87.60	0.17
Regime 3	4.04	13.58	82.38

Table 16 Contemporaneous Correlation Based on the System

	Canada	**United States**	**Mexico**
Canada	Regime 1	Regime 2	Regime 3
Regime 1	1.00	51.60	-11.52
Regime 2	1.00	24.62	-8.97
Regime 3	1.00	18.79	-29.04
United States			
Regime 1	51.60	1.00	-4.86
Regime 2	24.62	1.00	-11.12
Regime 3	18.79	1.00	11.00
Mexico			
Regime 1	-11.52	-4.86	1.00
Regime 2	-8.97	-11.12	1.00
Regime 3	-29.04	11.00	1.00

Table 17 Standard Errors of the Multivariate Model

	Canada	United States	Mexico
Intercepts			
Regime 1	0.2939	0.3568	0.4685
Regime 2	0.1861	0.1151	0.3103
Regime 3	0.4104	0.2674	0.4633
Canada_1	0.0803	0.0546	0.1261
USA_1	0.1048	0.0774	0.1398
Mexico_1	0.0460	0.0323	0.0791
Dummy	0.2554	0.1800	0.4435

Table 18 Comparison of Recession Dates Based on the Smoothed Probabilities of the System

	Regime 1	**United States**		**Canada**	**Mexico**
Dates		**NBER**	**ECRI**	**ECRI**	**ECRI**
1967-1969	1967:3-1967:4	May 67	May 67	Feb. 68	
69-71	1969:4-1971:4	Nov. 70	Nov. 70	May 70	
71-73				Sept. 72	
73-75	1974:3-1975:3	Mar. 75	Mar. 75	Jan. 75	
75 - 77				Sep. 77	
77-79					
79-81	1980:4-1980:4	July 80	Jun. 80	May 80	
81-83	1982:2-1983:2	Nov. 82	Jul. 82	Jul. 82	Jan. 83
83-85					
85-87	1986:3-1987:1		Jan. 87	Nov. 86	Aug. 86
87-89					July 88
89-91	1990:1-1990:1				
91-93	1991:2-1991:3	Mar.91	Feb. 91	Feb. 91	

93-95	1995:3-1995:4				Aug.93 Apr. 95
1996-2000			Jan. 86 Sept. 99	June 96 July 98	Jan. 99
2001-2002	2001:2-2002:2	CK	CK	CK	CK
Note: NBER and ECRI have not yet reported their official business cycle dates for the recessions that have occurred in early 2000s. Since these recessions are recent, they are considered known by everyone that has been following the news, hence, they are classified as common knowledge (CK). Sources: http://www.businesscycle.com/research/intlcycledates.php http://www.nber.org					

Table 19 Asymmetry of the North American Business Cycle

Sharpness	P_12 = p_32	P_13 = p_31	P_21 = p_23
2.726 [0.4359]	0.022 [0.8831]	1.247 [0.2641]	1.237 [0.2661]
	Canada	**United States**	**Mexico**
Deepness	0.812 [0.3675]	0.735 [0.3913]	1.522 [0.2173]
Steepness	1.344 [0.246]	2.565 [0.1093]	0.091 [0.7631]
The values in brackets represent the probabilities of $Chi^2(1)$ under the null hypothesis and + indicates significance at the 10 percent level.			

Table 20 Test of Common Business Cycle With United States (Log Likelihood)

Countries	United States + 1country	2 countries
Canada	-517.33	-497.66
Mexico	-582.76	-580.82
	Canada + 1 country	
Mexico	-617.54	-619.44

Table 21 Test of Common Business Cycle – Multivariate Analysis

Countries	2 + 1 countries	3 countries
Canada	(US-Mexico) -860.71	-841.62
United States	(Canada-Mexico) -856.88	-841.62
Mexico	(US-Canada) -839.14	-841.62

Figure 1. Density and Box Plot of Growth Industrial Production Index

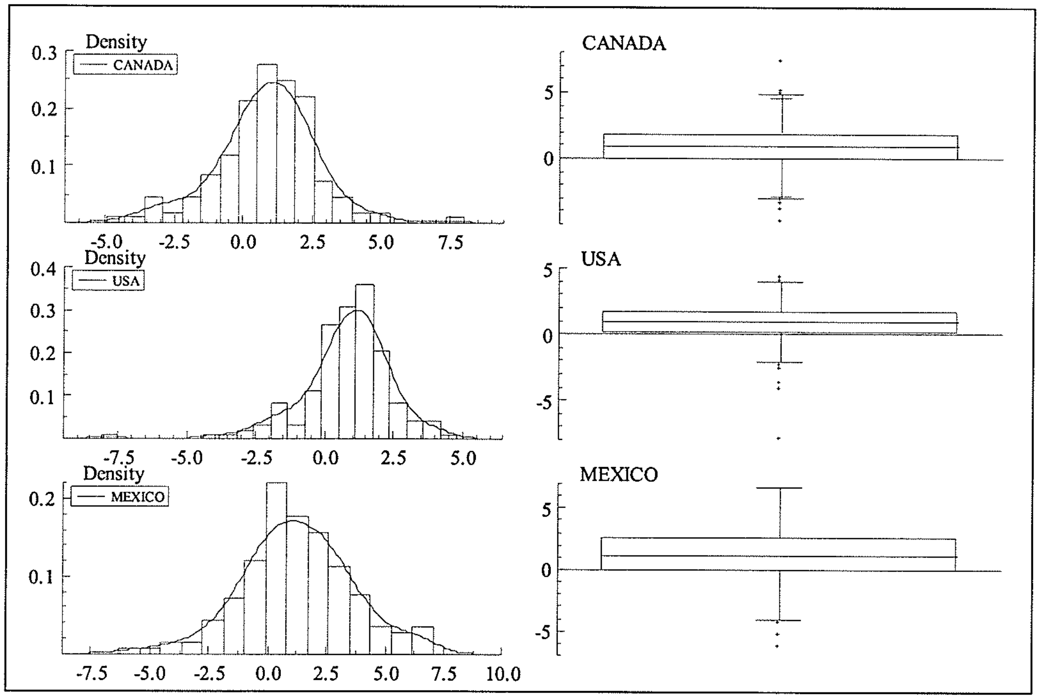


Figure 2. Canada Business Cycle

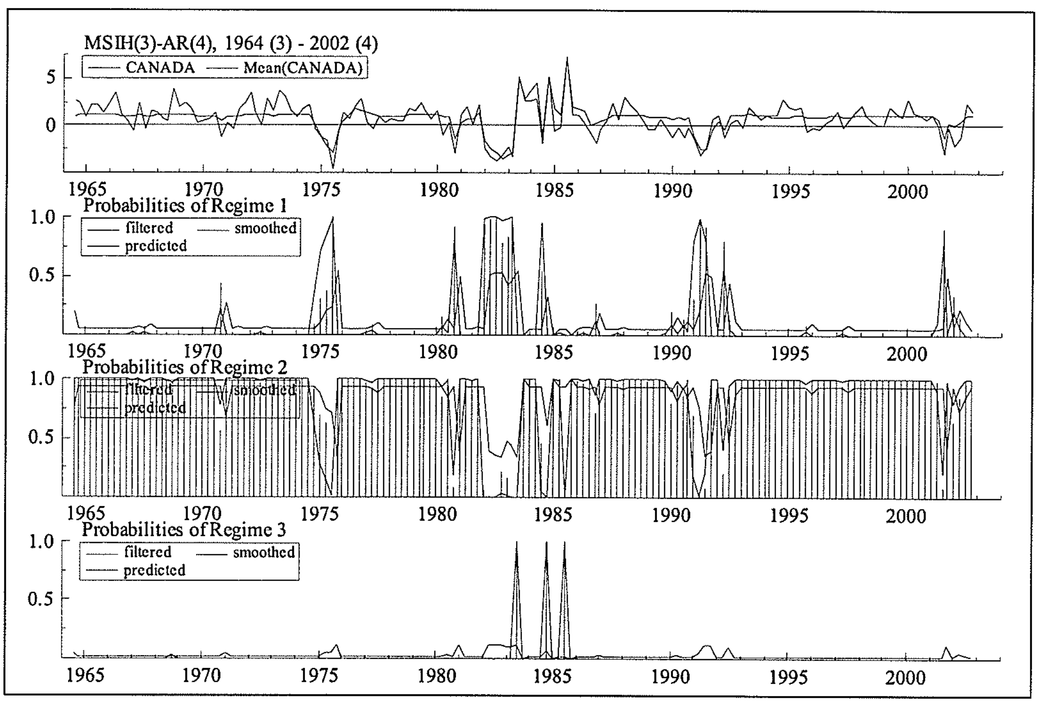


Figure 3. United States Business Cycle

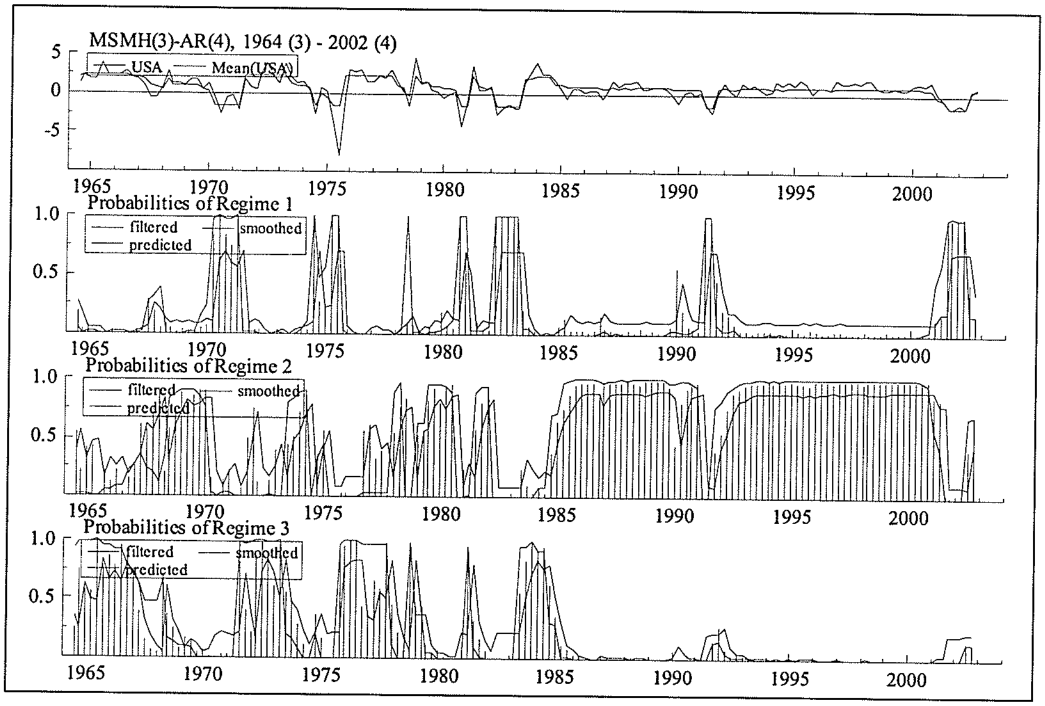


Figure 4. Mexico Business Cycle

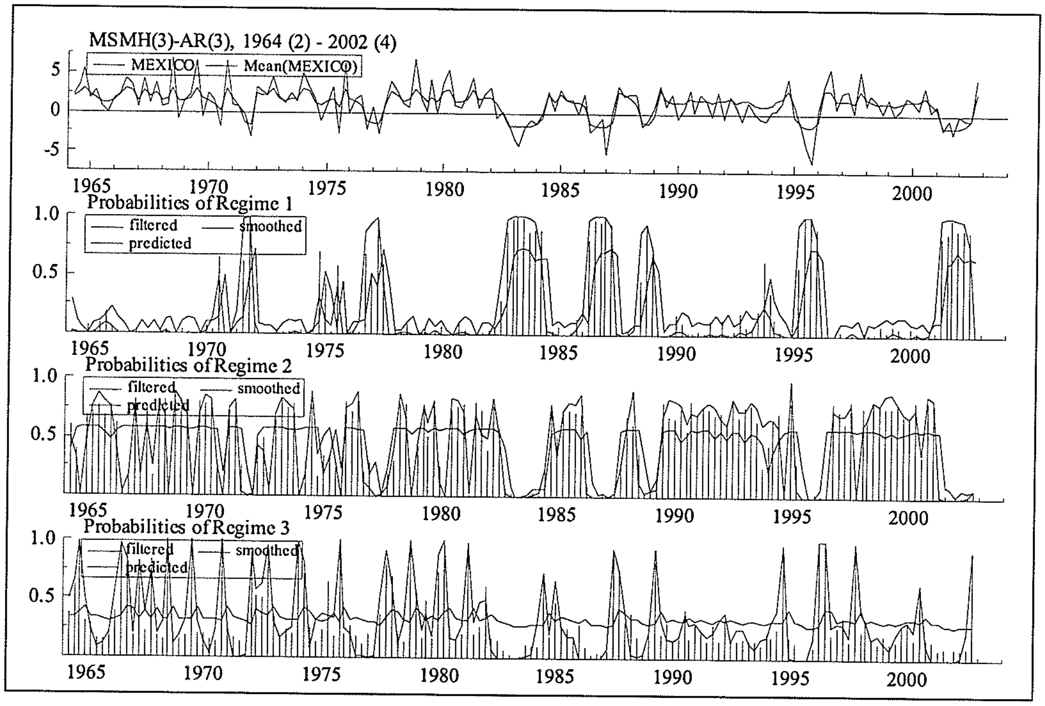


Figure 5. Comparison of Recession periods

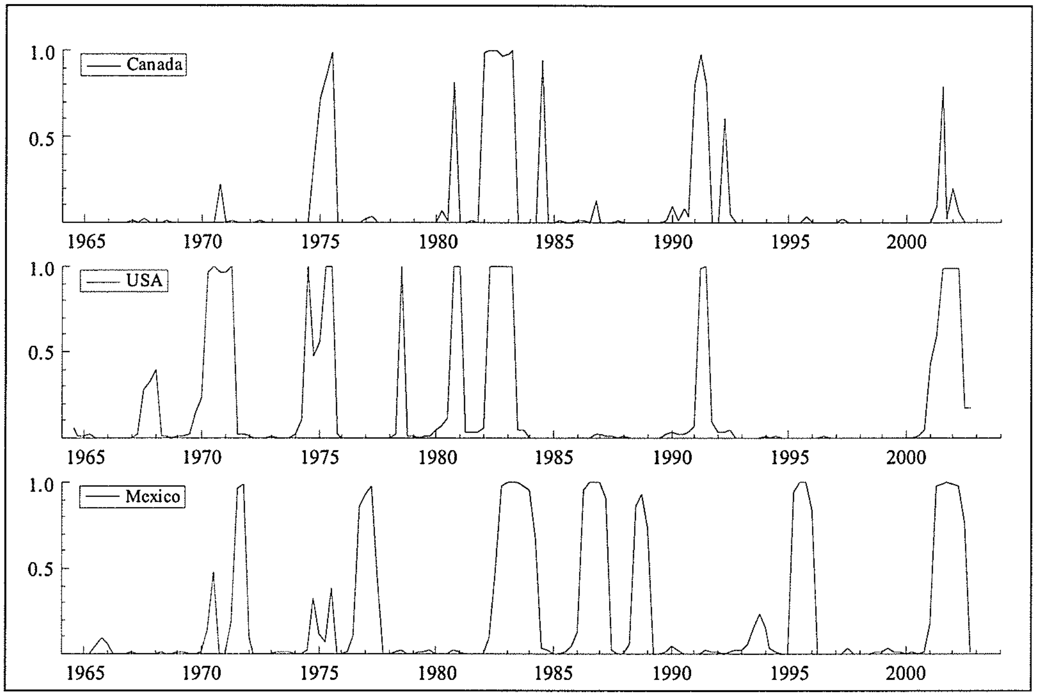


Figure 6. Errors Associated to Canada's Model

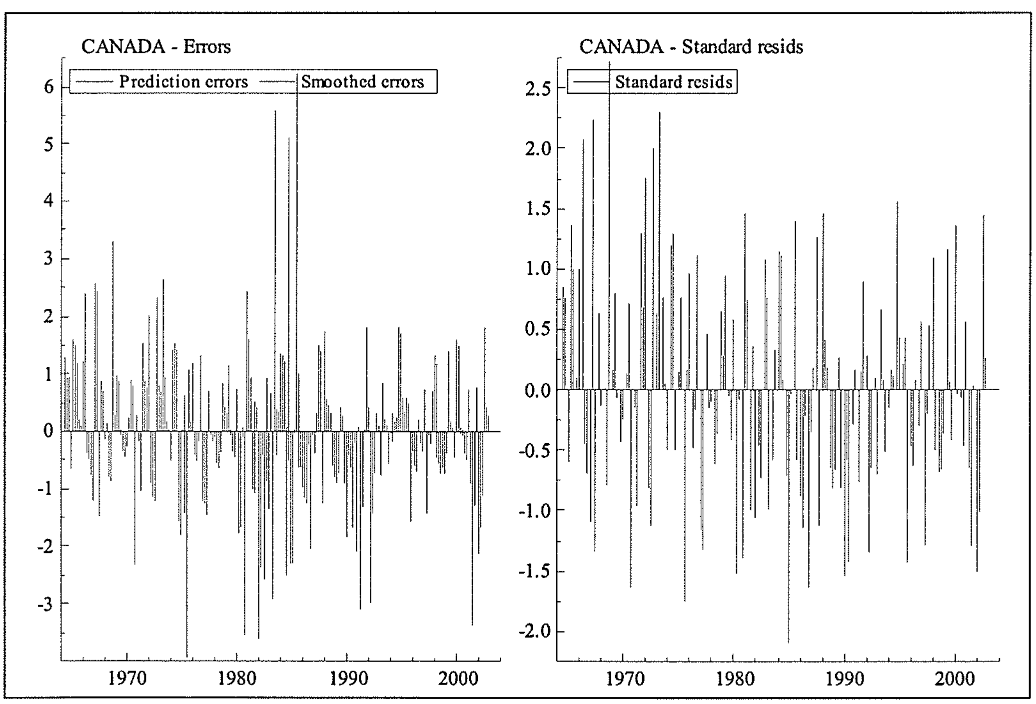


Figure 7. Errors Associated to USA's Model

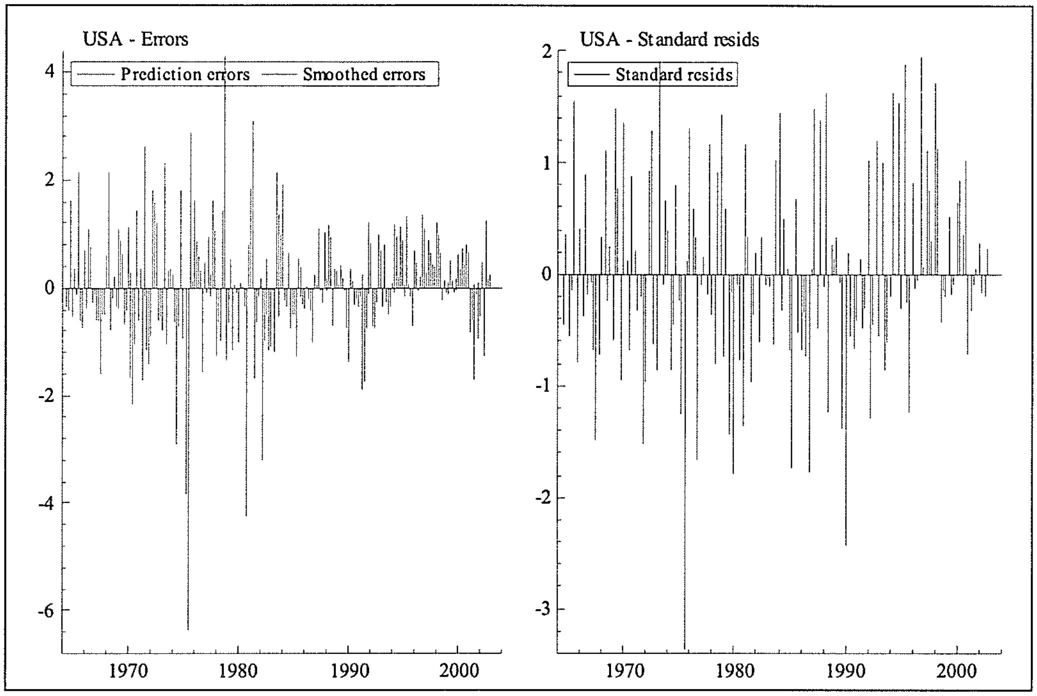


Figure 8. Errors Associated to Mexico's Model

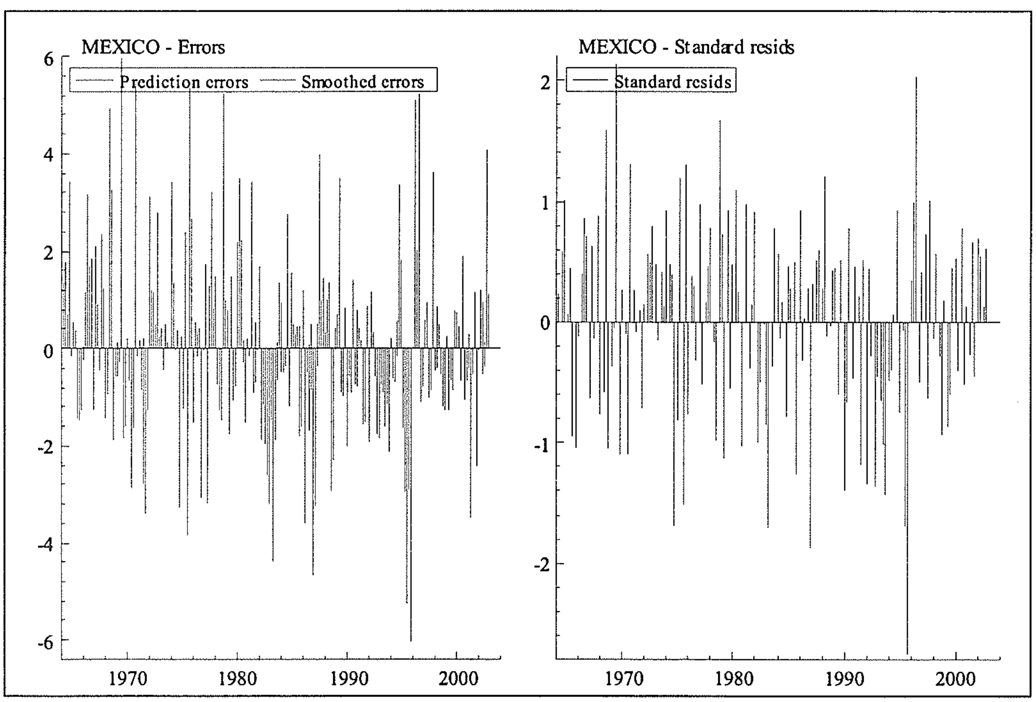


Figure 9. Statistical Properties of the Errors in Canada's Model

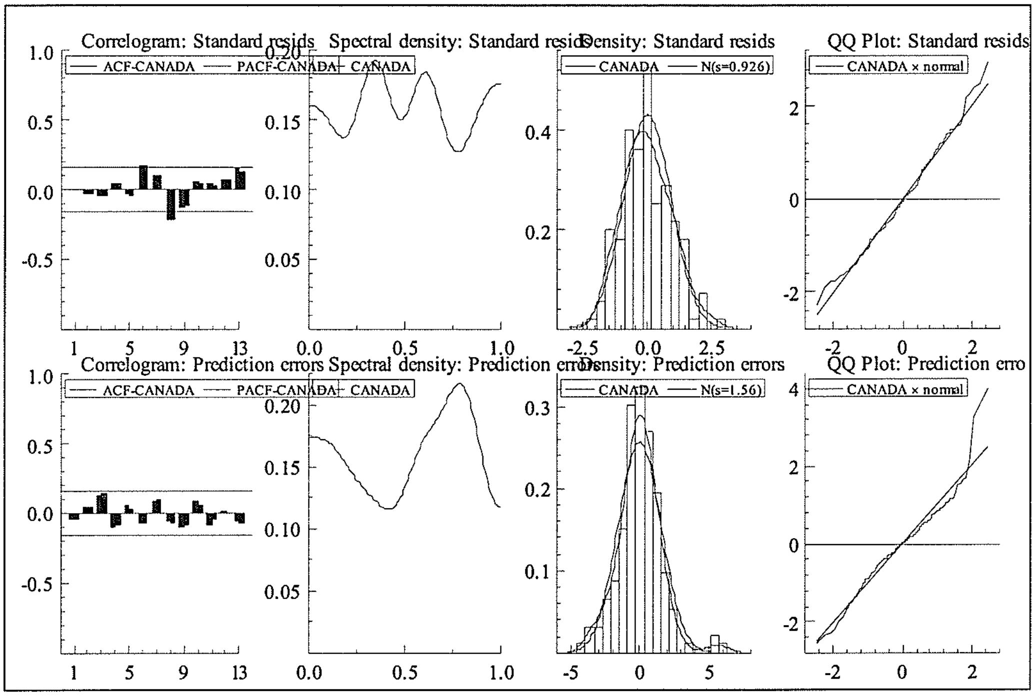


Figure 10. Statistical Properties of the Errors in USA's Model

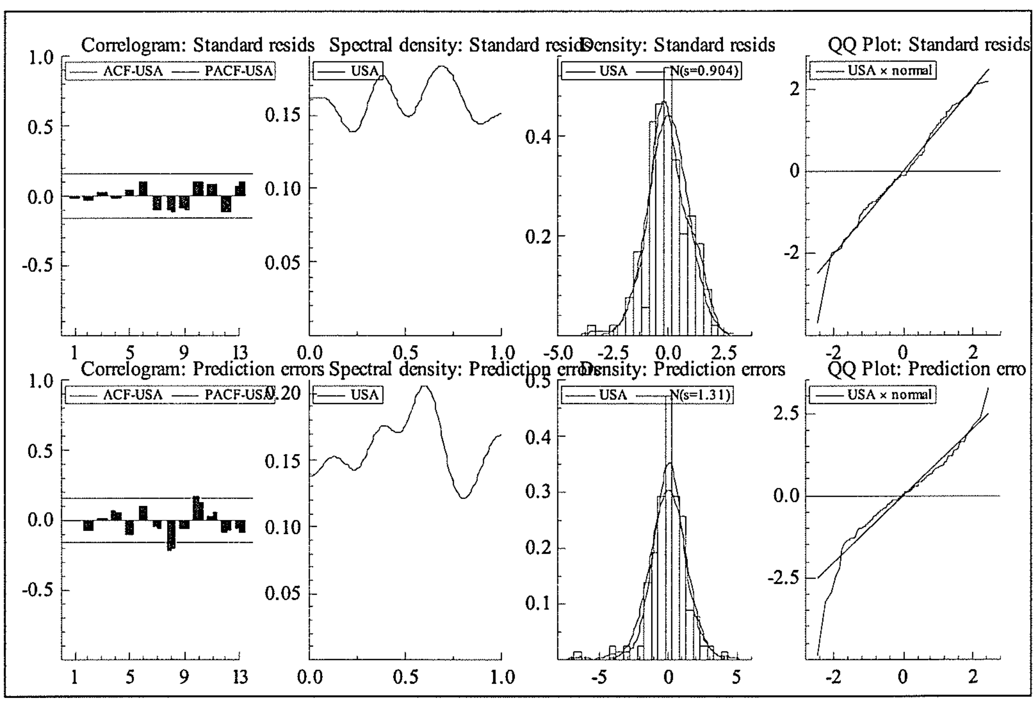


Figure 11. Statistical Properties of the Errors in Mexico's Model

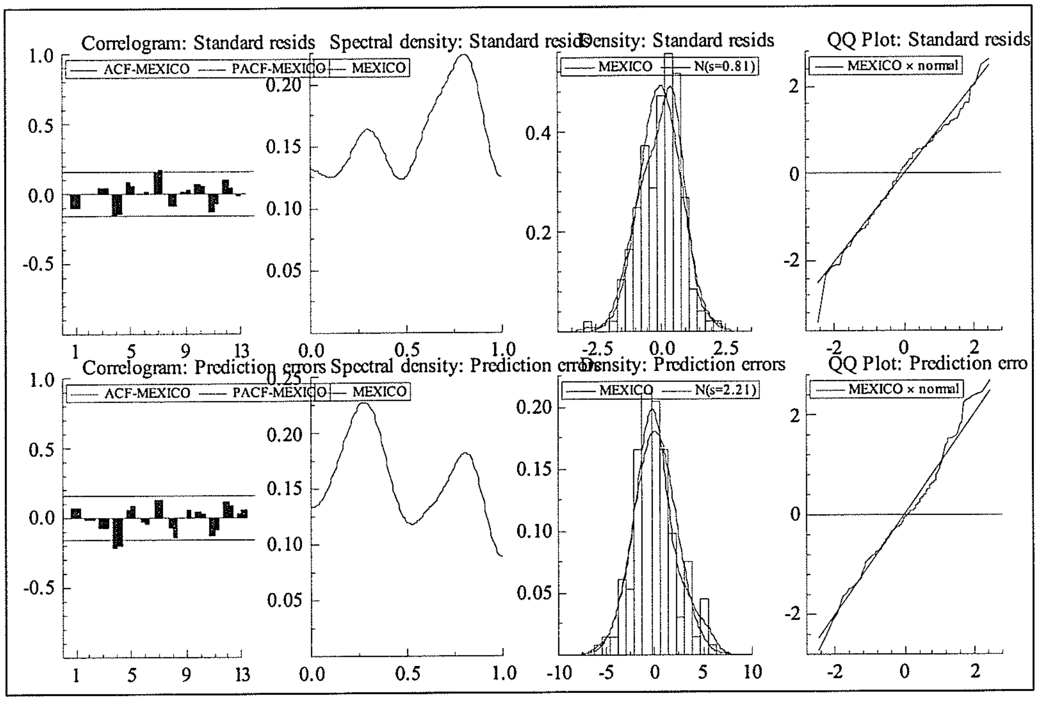


Figure 12. The North American Business Cycle

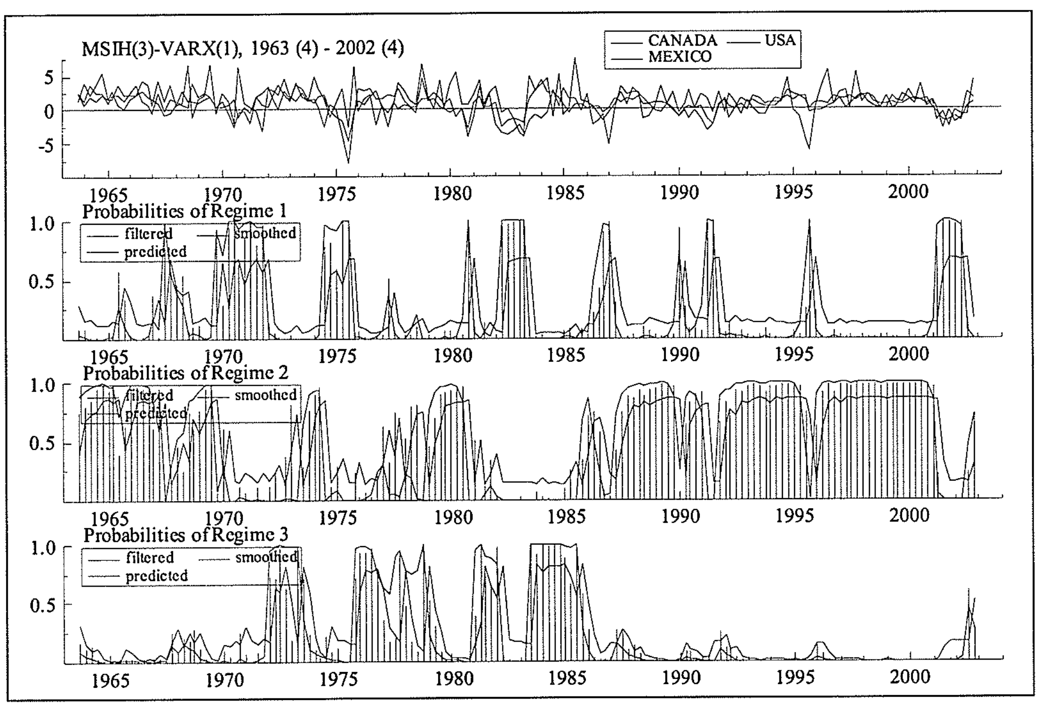


Figure 13. Contribution of the North-American Cycle to Individual Countries

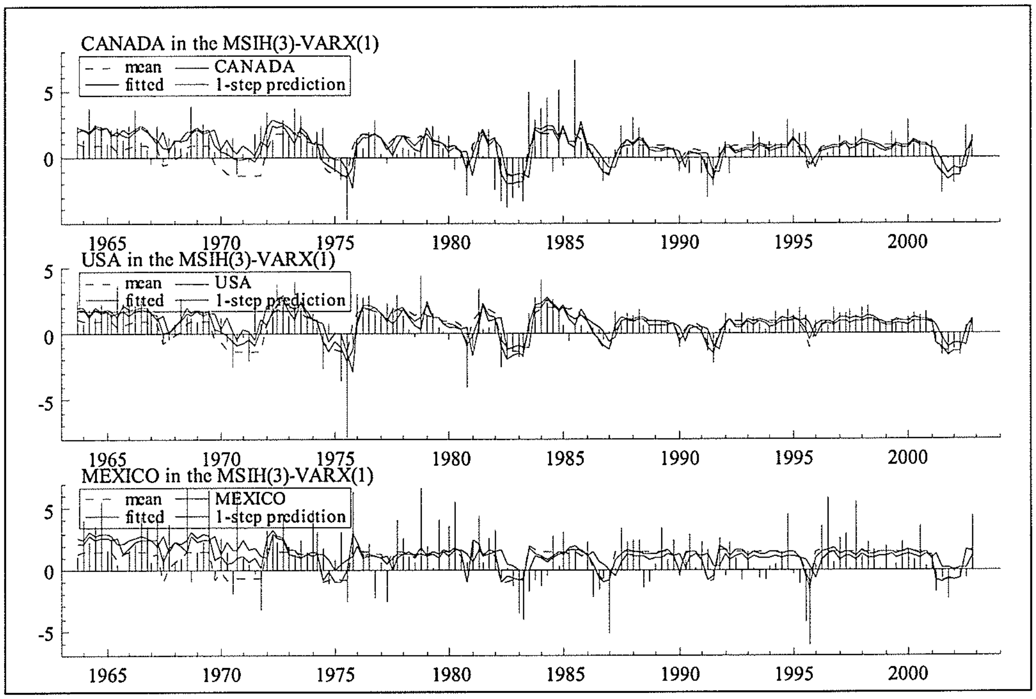


Figure 14. Predicted errors and Standardized Residuals of the North-American Model

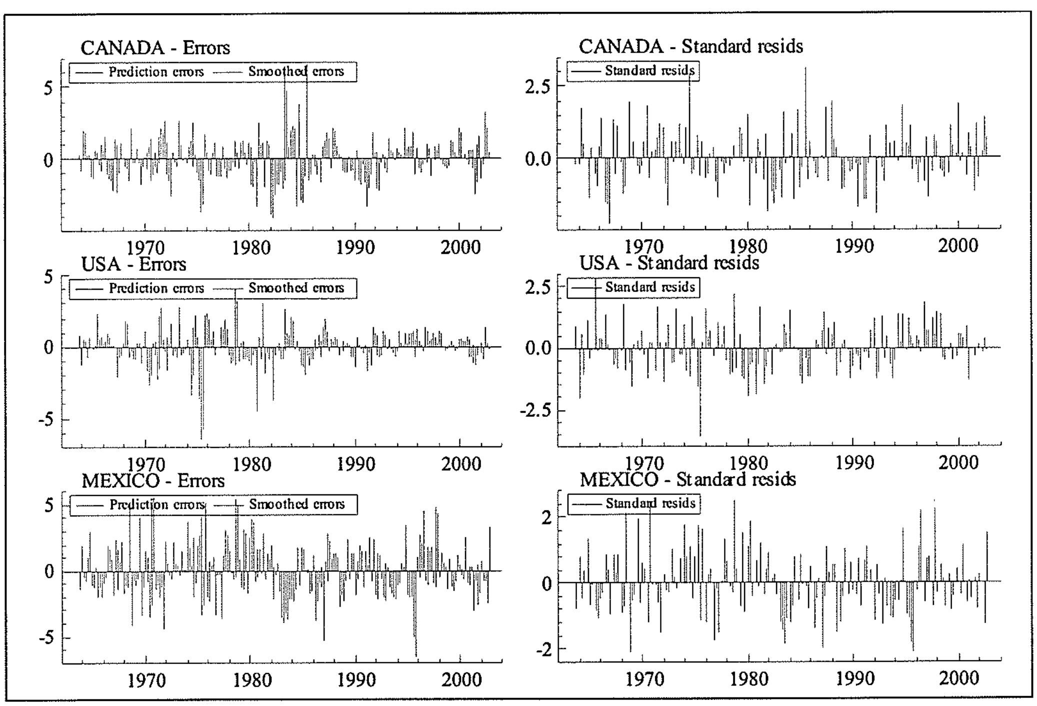


Figure 15. Statistical Properties of the Standardized Residuals of the MSVAR Model

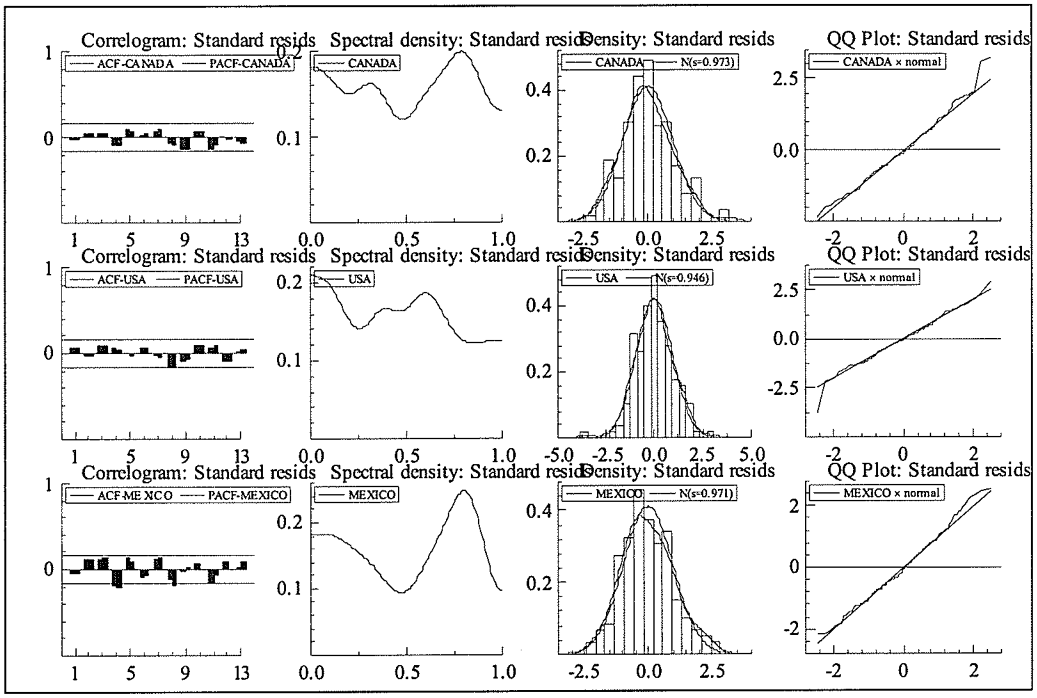
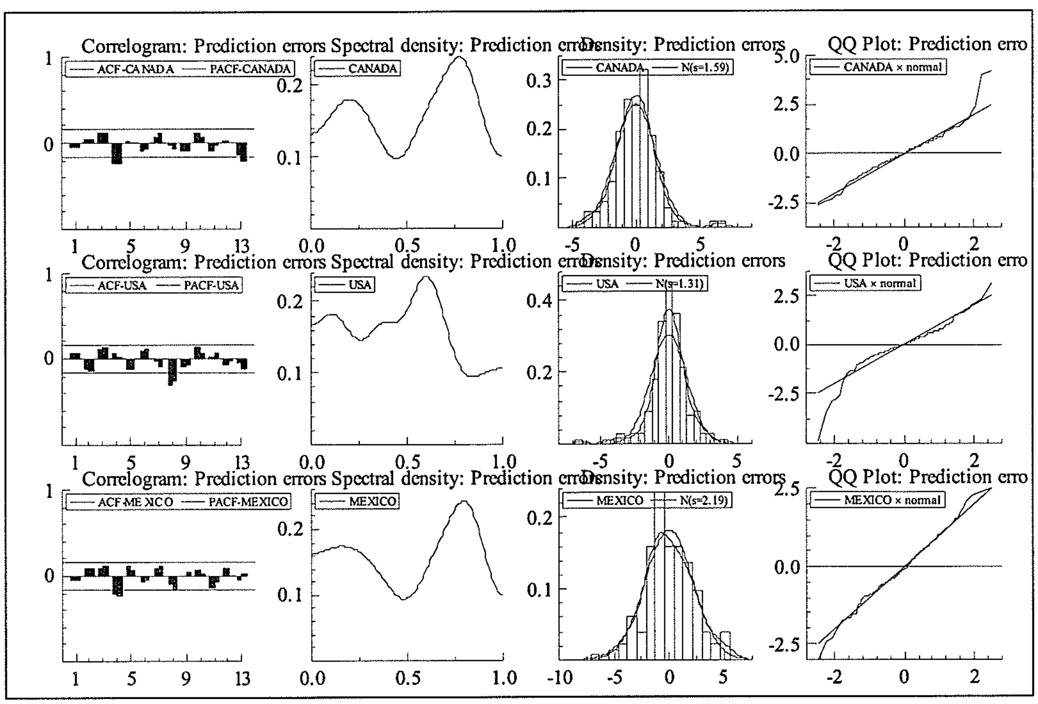


Figure 16. Statistical Properties of the Predicted Errors of the MSVAR Model



GENERAL CONCLUSION

This thesis has studied the behavior of macroeconomic shocks between the United States, Canada, and Mexico in order to determine to what extent a monetary union is feasible between the three countries. This policy issue is tackled through two econometric methods: the structural vector autoregression (SVAR) and the Markov switching framework. The first technique is used in the first two essays while the latter is used in the third essay. The first two essays are pairwise comparisons between a) The United States and Canada; and b) Mexico and Canada and between Mexico and the United States while the third essay looks at the business cycle linkages between the three countries.

The first essay, which looks at whether shocks affecting the U.S. and Canada economies are symmetric or asymmetric, models the U.S. as a relatively closed economy with an SVAR of four variables (output, oil price, fund rate, GDP deflator) and Canada as an open economy with an SVAR of five variables (output, fund rate, Bank of Canada's rate, consumer price index, and real exchange rate). These variables were carefully chosen to reflect the dynamics of each economy. Each model is identified with a combination of short- and long-run restrictions similar to Gali (1992). Essay 1 has traced out both the responses of Canada's economy to structural supply, demand, U.S. monetary policy, domestic policy, and real exchange rate shocks for the period 1961Q1 – 2000Q4 and the responses of the U.S. economy to structural non-oil, oil supply, demand, and policy shocks for the period 1961Q1 – 1999Q2. The key results are that 1) aggregate demand and aggregate supply shocks are symmetric; 2) U.S. monetary policy shocks have stronger effects on Canada's output than Canada's own domestic policy shock. This latter finding is new to the existing literature thus far. On these grounds, the essay has therefore argued that a monetary policy is feasible between the two countries.

Building upon the structural shocks extracted for Canada and the U.S. from Essay 1 and using the same techniques, Essay 2 has estimated two models for Mexico, which only differs in terms of the foreign monetary policy instrument, depending on the country chosen as the large country. Based on data that spans the period 1960Q1 – 2000Q4, the study has shown that the degree of shocks symmetry or asymmetry between Mexico and Canada and between Mexico and the United States depends on the order of integration of Mexico's money stock. This finding led us to argue that shocks between Mexico and the other countries may not be categorically asymmetric, as other studies have found.

Given the facts that the two first essays have only informed how the three countries are perturbed due to a once-and-for-all shock and how the shocks are related, the third essay has taken up the task to investigate the patterns of cycles across these three countries. This study is carried out in two phases. In the first phase, an extended version of the original Hamilton's univariate model is estimated for each country in order to determine whether there is certain commonality among the countries. The exercise reveals that Canada, United States and Mexico follow the same business cycle patterns but the speed at which Canada and the United States reach the turning points is different from that at which Mexico reaches the same. The second phase of Essay 3 is a multivariate generalization of the Hamilton model where the industrial production indexes of the countries are modeled jointly in a vector autoregression with switching intercept and covariance matrix. The objective was to determine whether the co-movement of the variables suggests a common cycle that one could term the North American Cycle. Using a two-stage procedure proposed by Krolzig (1997), this exercise has informed that, on the basis of business cycle asymmetry, the system-based model display almost the same picture as the aggregate univariate models. This means that there is synchronization of the business cycles of Mexico, Canada, and the United States. However, on the basis of co-movement of economic variables the test for a common cycle reveals that Canada and Mexico each share a common cycle with the United States but not with each other. Hence, these findings indicate that a monetary union is most feasible between Canada and the United States. However, when importance is given to the process of convergence of the three economies that has been amplifying since the 1990s, there is room to argue that Mexico may be suitable for a monetary union with its NAFTA partners, though it is and may even remain 'the weakest link."

As in any empirical work, a word of caution is necessary in interpreting the results. This thesis has answered a specific question: Does a monetary union feasible between United States, Canada, and Mexico on the basis of shocks or business cycle asymmetry? Should these criteria change, the results of this thesis may no longer hold. There are a number of related area of research such as labour market, health care and taxation systems integration, which also need further attention if Canada has to enter a monetary union. I intend to deepen my research by exploring these social issues in the future.