MODEL STABILITY IN THE QUANTITATIVE ANALYSIS OF CANADIAN MONETARY POLICY

by

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ABSTRACT

The purpose of this study is to examine the stability of a small macroeconometric model describing Canadian monetary policy over the 1972-1989 period. Specifically, Gregory and Raynauld's (1985) model with rational expectations restrictions imposed is used to examine whether there are structural changes during the 1970s and the 1980s, and to identify whether the changes are associated with changes in the economic structure or in the execution of monetary policy.

As the descriptive analyses of Canadian monetary policy indicate, there were changes in the execution of the Bank of Canada's policy during the 1970s and the 1980s. Financial innovations and technological advancements constituted major changes to the economic structure in the 1980s. Based upon this descriptive information, it is desirable to examine empirically whether a model based on the economic structure and monetary policy in the 1970s can be appropriately used to explain the economic structure and the Bank of Canada's policy in the 1980s.

After the appropriate lag structures for the system of equations are chosen, the system is estimated using the Full Information Maximum Likelihood method over the period 1972Q1 to 1989Q4. The Rational Expectations Hypothesis is tested.

Godfrey's (1988) likelihood ratio test is used to examine the structural changes over the 1972Q1-1989Q4 period. This study further extends the analysis to identify the causes of the structural changes.

The systemwide stability test result suggests structural changes occurred during the 1970s and the 1980s. The results from further stability tests indicate that although both the conduct of Canadian monetary policy and the structure of the economy changed during the last two decades, the latter is the more important source of structural instability.

The overall evidence suggests that the model is not robust over time, and that the model cannot be used to describe Canadian monetary policy over the 1980s. The empirical analyses further suggest that the Canadian economy has undergone some major changes, such as financial innovations, and technological advancements during the 1980s. This evidence is consistent with the descriptive analyses.

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CHAPTER 1

INTRODUCTION

During the 70s and the 80s, the appropriate instruments and goals of monetary policy have initiated much discussion and debate by media, scholars and the public.[1] As their analyses indicate, there were changes in the economic structure, and the execution of Canadian monetary policy in the past two decades. Their analyses were, however, based upon observed macroeconomic performance rather than a formulated econometric model. Some of those descriptive analyses are discussed in Chapter 2 of the thesis.

The Bank of Canada has constructed a few large-scale econometric models to describe Canadian monetary policy.[2] These models contain hundreds of equations. Gregory and Raynauld (1985) developed a small macroeconometric model describing Canadian monetary policy over the 1970s. The model consists of five interdependent equations with rational expectations restrictions imposed. They claim that a small macroeconometric model has estimation and analytical advantages over a large-scale model. These advantages will

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[1]For instance, Courchene (Apr 1976, Dec 1976, 1977, 1981 & 1983), Lipsey (1983), Howitt (1986), Freedman (1983), and Fine (1990) have provided detailed analyses on Canadian monetary policy.

[2]The models are as follows: the RDX1 model (see Helliwell et al. (1969)), the RDX2 model (see Helliwell et al. (1971)), the RDXF model (see Robertson and Mcdougall, (1982 a & b)), and the Small Annual Model (see Rose and Selody (1985)).

be discussed in Section 3.2.1 of Chapter 3.

There have been studies which specifically address the issue of stability within a single equation framework.[3] It is, therefore, desirable to examine the stability of a simultaneous system of equations characterizing Canadian monetary policy. The objective of this thesis is to utilize Gregory and Raynauld's (1985) model to investigate whether a model that was based on the Canadian economic structure and monetary policy in the 1970s can still be used to explain the execution of Canadian monetary policy, and the economic structure in the 1980s. The above objective is addressed by testing the following null hypotheses:

(1) There are no systemwide structural changes during the 1970s and the 1980s. That is, the model is stable over time.

(2) There is no change in the structure of the economy and in the conduct of Canadian monetary policy.

The organization of this thesis is as follows. Chapter 2 provides a narrative account of the conduct of monetary policy, as well as the structure of the Canadian economy over the 1970s and the 1980s. Chapter 3 reviews Gregory and Raynauld's (1985) model, and replicates their model over the same period of time as they did in their article. Chapter 4

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[3]See, for example, Cameron (1979), Clinton (1973), Hostland (1990), and Carmichael (1991).

reports the lag structure specification, estimation procedures, and results over the 1972-1989 period. Chapter 5 tests the stability of the model that is specified in the previous chapter, and identifies the causes of the instability. Finally, conclusions and implications are presented in Chapter 6.

CHAPTER 2

OVERVIEW OF THE CONDUCT OF CANADIAN MONETARY POLICY, AND THE STRUCTURE OF THE CANADIAN ECONOMY IN THE 70S AND THE 80S

There have been many sophisticated analyses of Canadian monetary policy and the structure of the Canadian economy. For instance, Courchene (Apr 1976, Dec 1976, 1977, 1981 & 1983), Lipsey (1983), Howitt (1986), Freedman (1983), Cote (1990), and Fine (1990) have provided detailed analyses of the conduct of Canadian monetary policy, and of the structure of the Canadian economy during 1970s and the 1980s. The purpose here is to review some of these descriptive analyses before we proceed to examine the structural changes over the past two decades using an econometric model.

2.1 The Conduct of Monetary Policy

2.1.1 The Conduct of Monetary Policy in the 70s

The primary objective of monetary policy was to maintain stability in the general level of prices. This was not a change in policy in the 1970s. In 1966, Governor Louis Rasminsky had already made it clear that monetary policy was concentrated on achieving price stability in the economy. This section reviews the execution of monetary policy during the 1970s.

The stance of monetary policy was rather expansionary during the early 1970s. Figure 2-1 shows that M1 was growing at, approximately, an average annual rate of 16 percent during 1971. The interest rate level was gradually brought down from 7.5 percent in the first quarter of 1970 to 3.1 percent in the second quarter of 1971 (Figure 2-2).

However, monetary policy started to tighten in the course of 1973. Short-term interest rates rose from 3.1 percent in the second quarter of 1971 to over 6 percent in the last quarter of 1973, reflecting the monetary policy restraints, the strong demand for funds, and the rapidly rising US short-term interest rates. After a short-lived reduction in short-term interest rates at the beginning of 1974, interest rates rapidly moved up again (Figure 2-2); the inflation rate had risen substantially (Figure 2-3).

The Anti-Inflation Program, established in October 1975, was initially unsuccessful; the annual inflation rate was over 10 percent (Figure 2-3). Therefore, in November 1975, the Bank adopted a policy of monetary gradualism: a policy to gradually moderate the rate of growth of the narrowly defined money supply (M1)[4] in an attempt to reduce inflationary pressures. The Bank of Canada controlled M1 by setting the interest rate at a level consistent with the desired rate of monetary growth.

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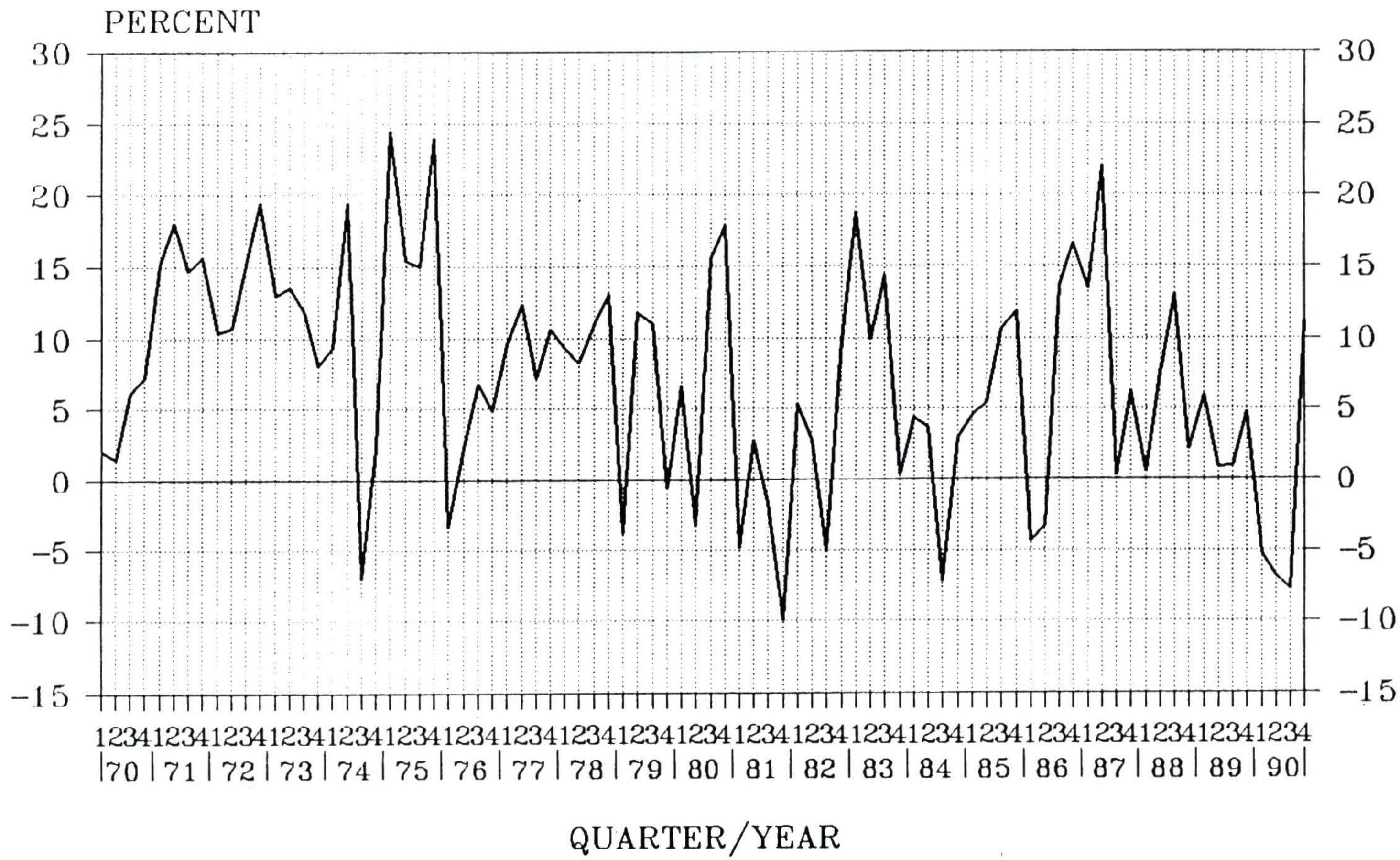
[4]M1 composes of currency and net deposit (i.e., demand deposits net of float).

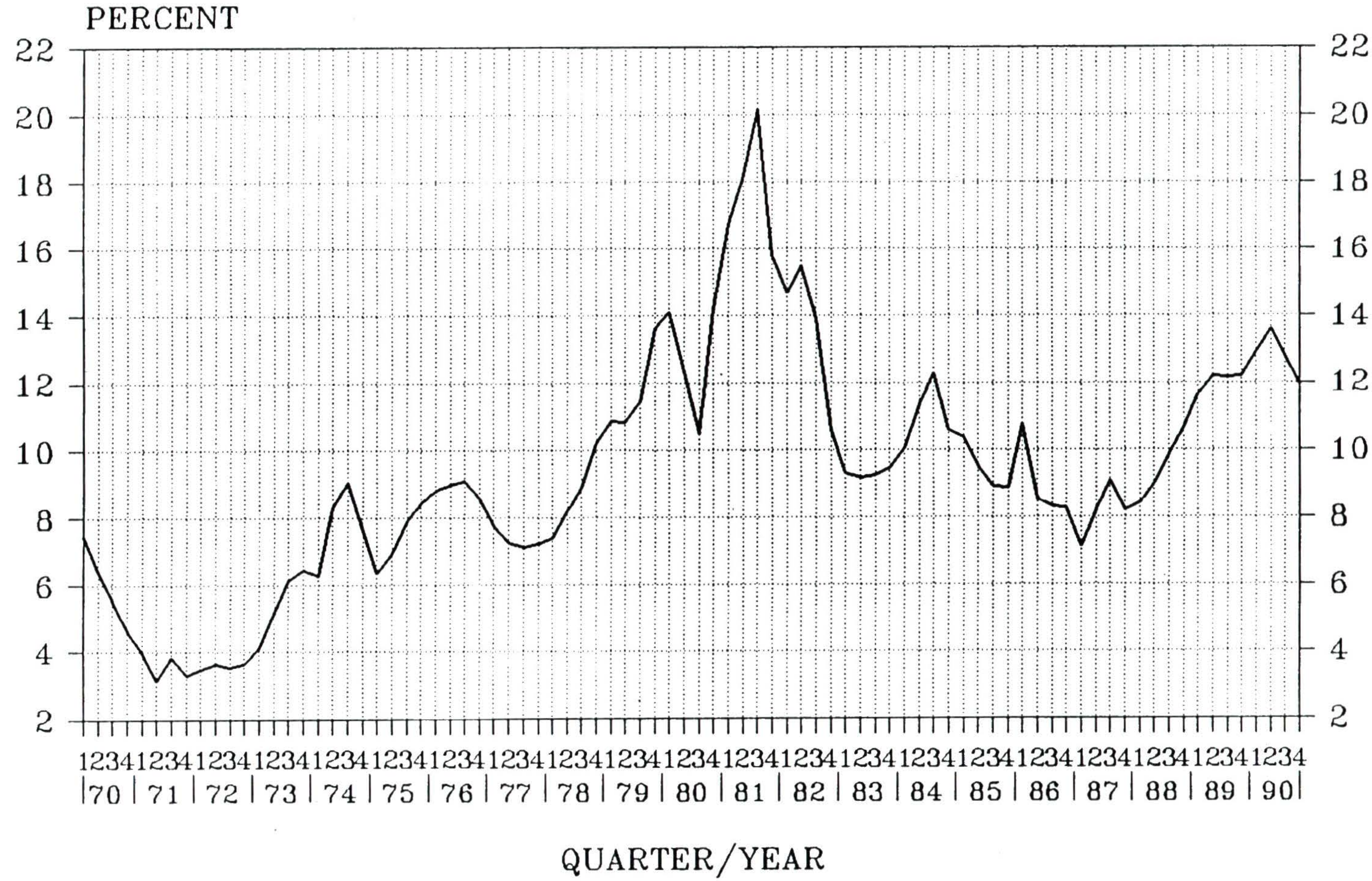
FIGURE 2-1: GROWTH RATE OF CANADIAN M1

% change from previous quarter at
annual rates



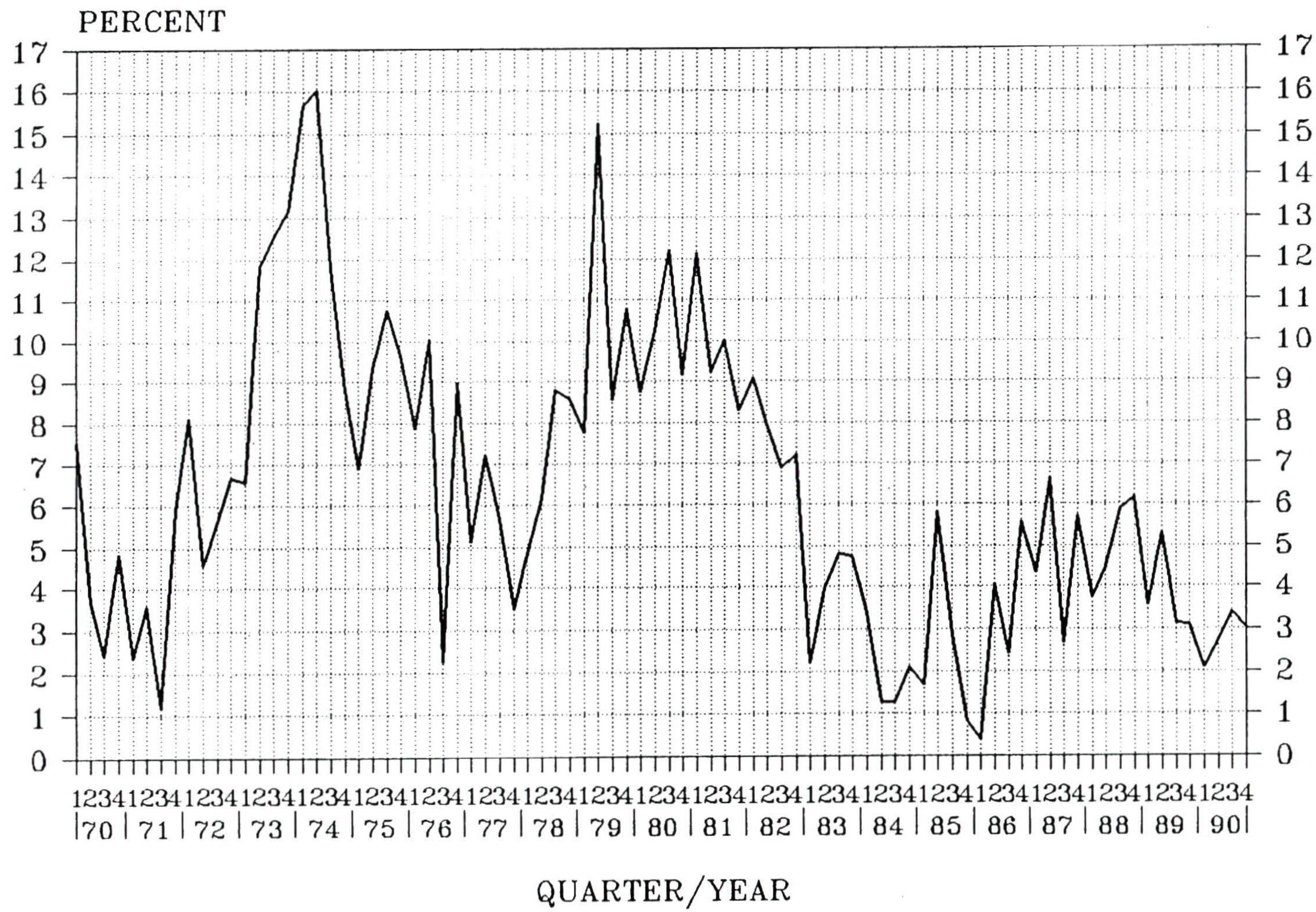
Source: CANSIM - Statistics Canada

FIGURE 2-2: NOMINAL INTEREST RATES:
90-DAY T-BILL RATE



Source: CANSIM - Statistics Canada

FIGURE 2-3: INFLATION RATE



Source: CANSIM – Statistics Canada

2.1.2 The Conduct of Monetary Policy in the 80s

The Canadian economy, in 1980, was characterized by high inflation, low real output growth, and volatile interest rates. The annual inflation rate was averaging 10 percent (Figure 2-3). The growth of real GNP was, however, averaging 1.5 percent (Figure 2-4). Interest rates in the United States were remarkably volatile. US short-term interest rates rose from 14 percent in January to 18 percent in March and then went down to almost 8 percent in the middle of 1980; by the end of 1980 short-term rates went up to approximately 17 percent (Figure 2-5). A much greater amplitude in US short-term interest rates than in Canadian rates is indicated by Figure 2-5; the Canadian-U.S. differential in the bottom half of Figure 2-5 further illustrates this. Exchange rate variations during 1980 conformed very closely to the Canadian-US interest rate differential shown in Figure 2-5. When U.S. interest rates exceed Canadian interest rates, the exchange rate depreciates, and vice versa.

The Bank contended: "[e]xpectations and confidence play an important role in the determination of exchange rates."[5] Therefore, to moderate the impact of the large swings in US interest rates on the Canadian exchange rate, the Bank of

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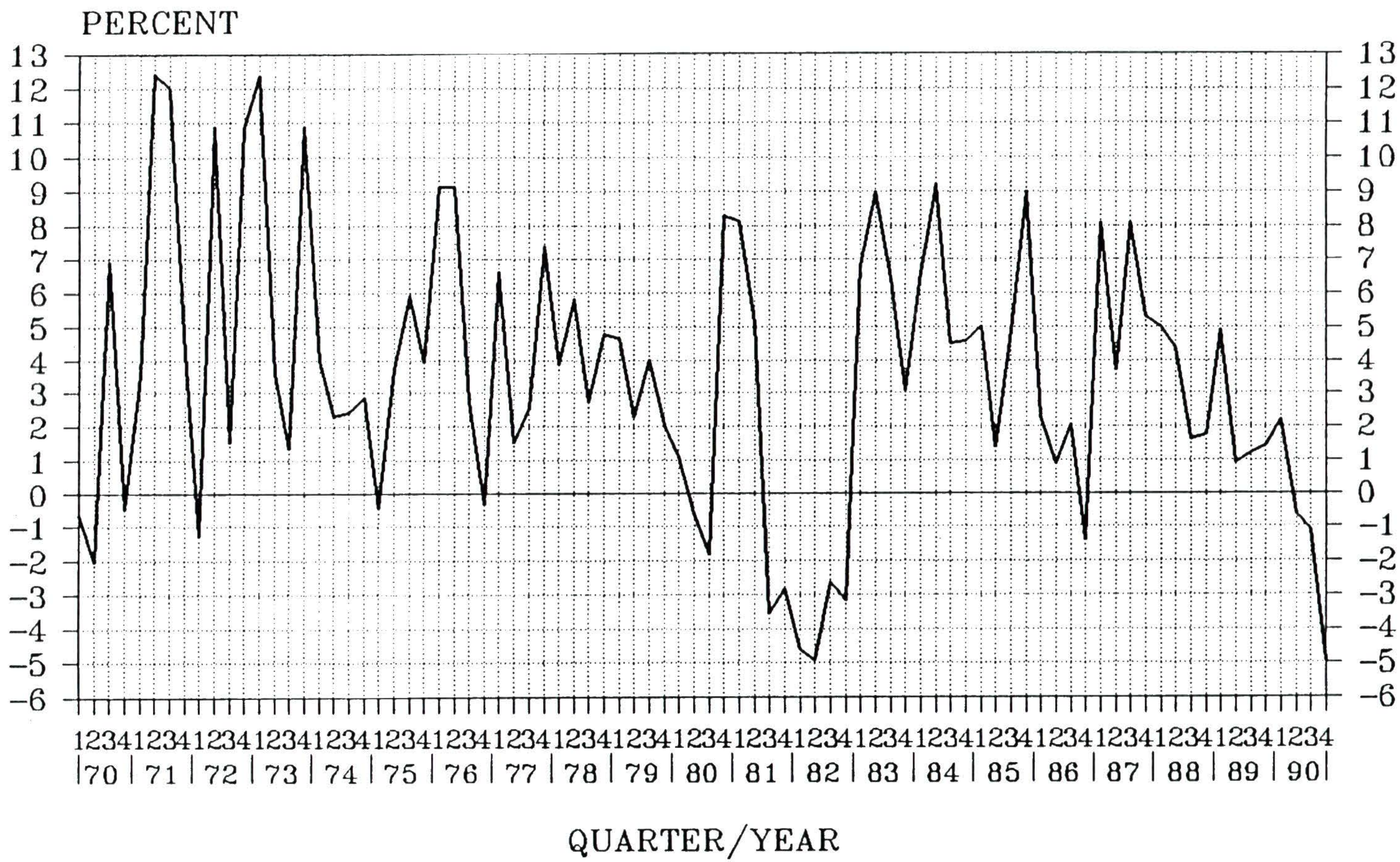
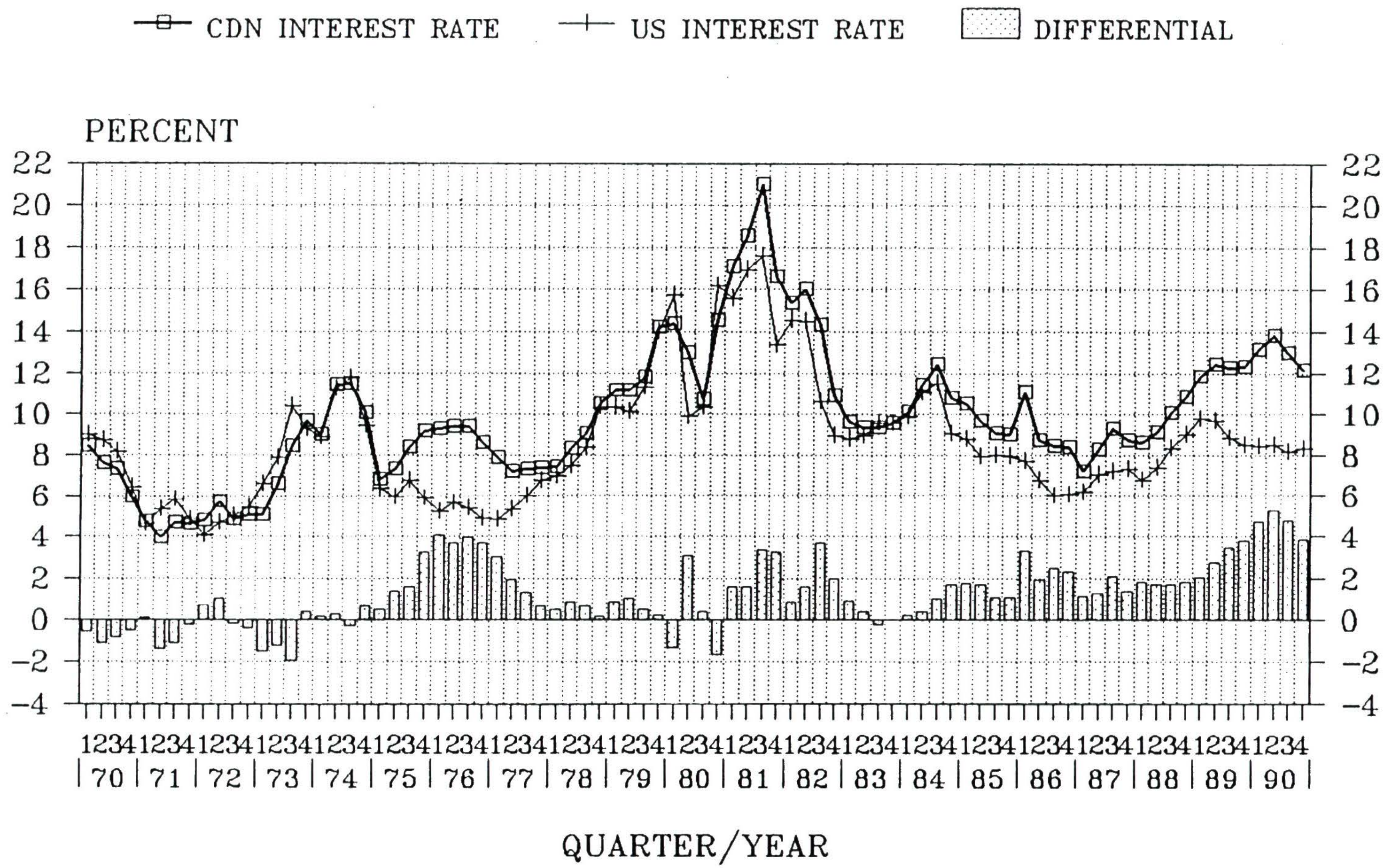
[5]Bank of Canada (1980), Annual Report of the Governor to the Minister of Finance, Ottawa: Bank of Canada, p. 10

FIGURE 2-4: REAL GROSS NATIONAL PRODUCT
% change from previous quarter at annual rates



Source: CANSIM - Statistics Canada

FIGURE 2-5: CANADIAN AND US SHORT-TERM INTEREST RATES



Source: CANSIM - Statistics Canada

Canada compelled domestic interest rates to move in line with the US interest rate movements (Figure 2-5). The Bank of Canada allowed exchange rate considerations to dominate monetary policy.[6]

During the first three quarters of 1981, the Canadian dollar depreciated vis-a-vis the US dollar (Figure 2-6). The Bank of Canada chose to support the Canadian dollar in order to suppress the rise of imported inflation. This action resulted in growth of M1 well below the lower limit of the 4-8 percent target range; Figure 2-1 denotes a decrease of 22 percentage points in the first quarter of 1981.[7] The policy of gradualism was, therefore, compromised by the exchange rate problems, along with financial innovations and technological developments.[8]

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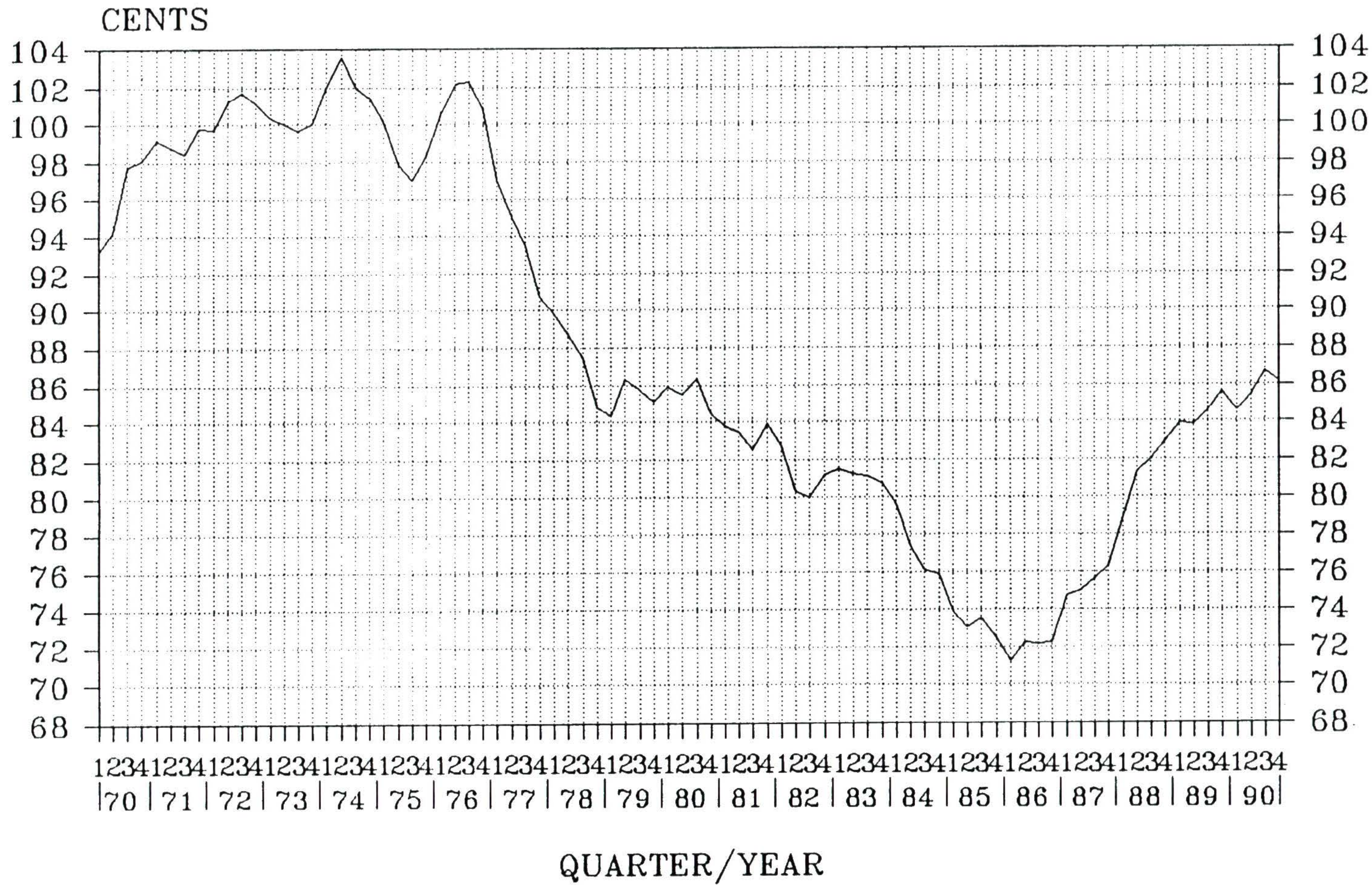
[6]Thomas Courchene (1983), Money, Inflation, and the Bank of Canada: An analysis of Monetary Gradualism, 1975-80, (Montreal) pp.77-90, and Peter Howitt (1986), Monetary Policy in Transition: A Study of Bank of Canada Policy, 1982-85, Policy Study No. 1, (Toronto), pp. 90-107 provided a detailed discussion on supporting the value of the Canadian dollar.

[7]This confirms Richard Lipsey's (1983) "The Great Anti-inflation War 1975 - ?," the E.S. Wooodward Lectures in Economics delivered at the University of British Columbia, (Vancouver), pp. 11-14 argument that a large reduction in the rate of monetary expansion was required in order to support the value of the Canadian dollar on foreign exchange markets, causing an acute rise in interest rates.

[8]The Bank of Canada's 1982 Annual Report illustrates some examples of what happened to the relationship between M1 and economic development. Charles Freedman (1983), "Financial Innovation in Canada: Causes and Consequences," American Economic Review, May 1983, p. 101 pointed out that the reasons

(continued...)

FIGURE 2-6: CANADIAN-US EXCHANGE RATE
Canadian dollar in US funds



Source: CANSIM – Statistics Canada

Freedman (1983) identified three approaches that the Bank of Canada can use to adjust the monetary aggregate target.[9] One of these approaches is to redefine the monetary aggregate to reflect the changes; this is the approach chosen by the Bank of Canada. As a result, the Bank of Canada formally abandoned the monetary targeting of M1 in November 1982:

> Over the past two years the relationship between M1 and economic developments has become so distorted that M1 can no longer be taken at its face value; both the process of financial innovation and the response of bank customers have been rapid and continuing. Since neither can be reliably predicted, appropriate ranges for the future growth of M1 cannot be chosen with any confidence.[10]

The year 1987 was considered to be the fifth consecutive year of economic expansion; real GNP grew at an annual rate of over 6 percent (Figure 2-4), while the unemployment rate was declining during the course of that year (Figure 2-7). In the summer of 1987, the Bank of

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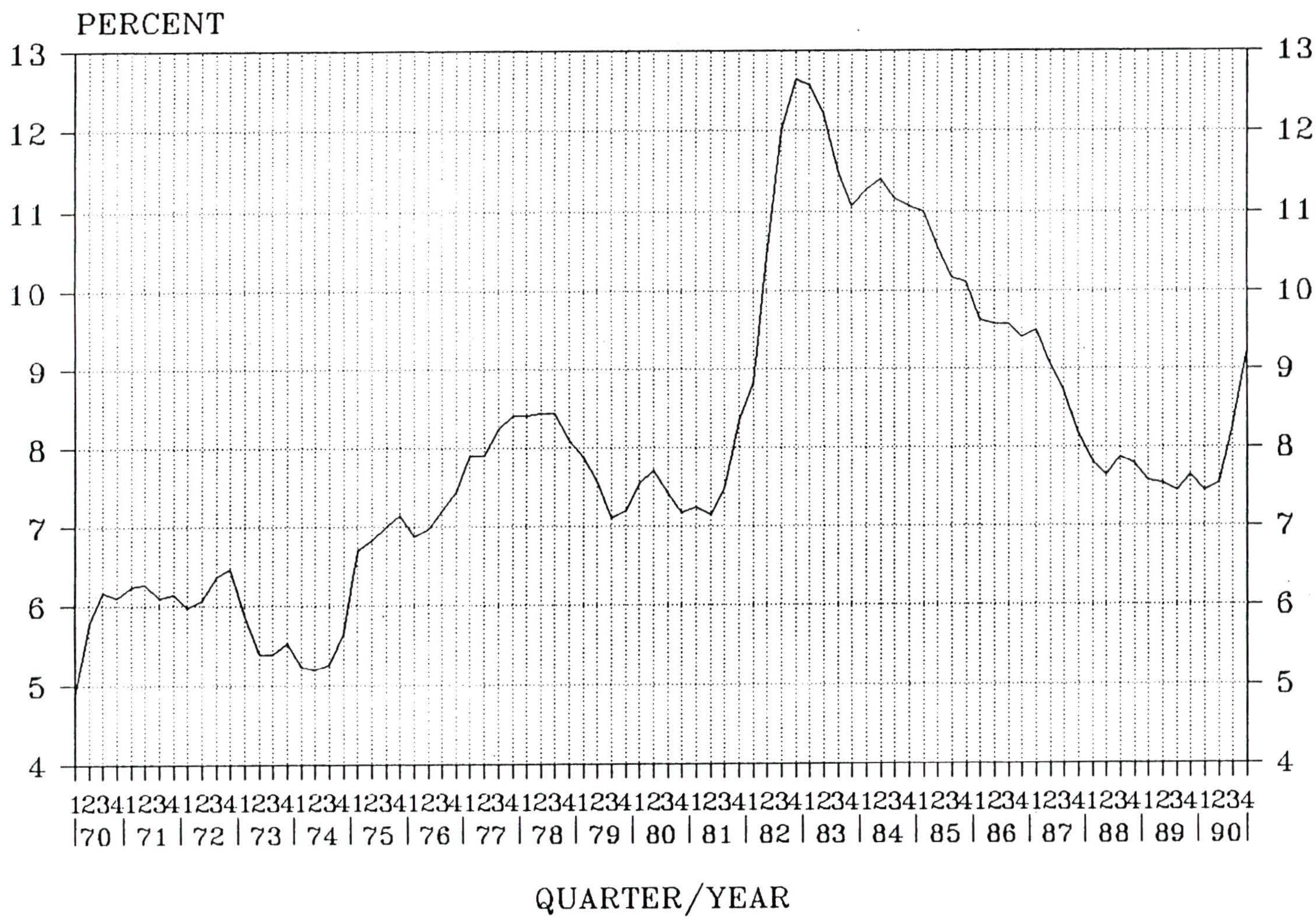
[8](...continued) for the success of the financial innovations were the high interest rate environment in the mid- to late-70s, and the use of computers in financial institutions and corporations. Also see Ibid., pp. 101-106 for detailed analyses of financial innovations and technological developments.

[9]For the three ways of adjustment, see Charles Freedman, op. cit., pp. 104-106.

[10]Bank of Canada (1982). Annual Report of the Governor to the Minister of Finance. Ottawa: Bank of Canada, p. 27.

FIGURE 2-7: UNEMPLOYMENT RATE



Source: CANSIM – Statistics Canada

Canada was prompted to tighten monetary policy because of domestic overheating, rapid advances in nominal spending, and continuing strength in world commodity prices.

In the 1988 Hanson Memorial Lecture at the University of Alberta, the Bank of Canada Governor John Crow explicitly announced that monetary policy should concentrate on stabilizing the general level of prices, and that price stability was the Bank of Canada's long-term objective for monetary policy.[11] The announced goal of monetary policy is to establish a zero-inflation rate in Canada.

Since the Autumn of 1988 the Bank of Canada restrained monetary conditions further, causing short-term interest rates to increase substantially. Short-term interest rates were averaging 9.5 percent during 1988, and above 12 percent by the end of 1989 (Figure 2-2). It is evident that the Bank of Canada continues to pursue the goal of achieving zero inflation.

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[11]John W. Crow (1988), "The Work of Canadian Monetary Policy," (Eric J. Hanson Memorial Lecture delivered at the University of Alberta, Edmonton, Jan. 18, 1988); reprinted in Bank of Canada Review, Feb. 1988, pp. 3-17. Governor John Crow's 1988 Hanson lecture also explained why the primary objective of monetary policy was price stability, and why it was so important in the eighties.

2.2 The Structure of the Canadian economy

2.2.1 Financial Innovation

Freedman (1983) stated that as a result of the 1967 revision of the Bank Act, there had been financial innovations in the late 1960s and early 1970s. Freedman (1983) pointed out that those financial innovations had no significant direct effects on monetary policy, but had implications for the stability of the demand for money and the definitions of monetary aggregates.[12]

The pace of financial innovation in Canada increased substantially in the late 1970s and early 1980s because of the interaction of high interest and inflation rates, because of advances in information technology, and finally because of competition among financial institutions.[13] Financial innovation affects both the household and corporate sectors. Freedman (1983) indicated that there were four specific episodes of financial innovation in the late 1970s and early 1980s. The two main periods of financial innovation in the household sector were the

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[12]See Charles Freedman, op. cit., pp. 101-106 for the rationale of the innovations that did not affect the monetary policy.

[13]See Charles Freedman, op. cit., pp. 101-106 and Ed Fine (1990) " Institutional Developments Affecting Monetary Aggregates," in Monetary Seminar, a seminar sponsored by the Bank of Canada, May 7-9, (Ottawa), pp. 555-563 for a detailed description of financial innovation in Canada.

introduction of daily interest savings account (DISA) in 1979, and the introduction of daily interest chequing account (DICA) in 1981.[14] The former innovation reduced the demand for personal chequing accounts and hence the demand for M1; the latter innovation also caused a decline in demand for M1 because the DICA is classified as a notice deposit and is included in M2, but not in M1. The most recent financial innovation was the introduction of tiered investor accounts in retail banking in 1985.[15] The investor accounts were widely adopted in late 1987.

There were two main episodes of financial innovation affecting corporations. The first occurred in the mid-1970s when banks started to offer sophisticated cash management services to large firms and large governmental organizations. The second episode occurred in the early 1980s when smaller-sized firms began to utilize these services and banks started to offer companies interest-bearing chequing accounts. As a consequence, there were reductions in firms' transaction balances and a shift of funds from current accounts into non-personal notice

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[14]Charles Freedman, op. cit., pp. 101-102 provided detailed descriptions regarding the reasons for and factors lead to the introduction of these two types of household accounts.

[15]Francesco Caramazza et al. "Studies on the Demand for M2 and M2+ in Canada," in Monetary Seminar, a seminar sponsored by the Bank of Canada, May 7-9, 1990, p. 13 provided some discussions on the investor accounts.

deposits.[16]

In addition to the above innovations, there were other financial innovations. Courchene (1990) indicated that there were innovations that embodied transfer of risk, that enhanced liquidity, and that enhanced access to markets. For instance, interest-rate swaps and currency swaps had widened access to financial markets. As Lesourne (1990) pointed out, the four financial pillars (banks, insurance and brokerage firms, and trust companies) were in the process of merging. He further stated that the globalization of financial markets had generated instability and a higher degree of competition in foreign exchange and money markets.

2.2.2 Technological Change

In the 1980s, the pace of technological change accelerated remarkably. The cost of computers fell by a factor of 300 between 1970 and 1985.[17] The speed and capacity of computers were increasing dramatically. Technological change in computers, therefore, had a major

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[16]See Charles Freedman, op. cit., pp. 102-103 for a detailed discussion. Non-personal notice deposit is a component of M2.

[17]See Marcel Cote (1990),"The Competitiveness of the Canadian Economy to the Year 2000." In Perspective 2000: Proceedings of a Conference Sponsored by the Economic Council of Canada, December 1988, (Ottawa: Supply and Services Canada), pp. 141-57.

influence on employment in Canada. Osberg (1990) stated that labor demand shifted away from occupations which handled merely routine types of informational transactions. For instance, automatic teller machines replaced bank tellers, computerized check-outs reduced the demand for cashiers, and filing clerks lost their function in the paperless office.

Technological progress was not limited to the computer.[18] Although oil prices rose from $30 to $35, the price of an economy ticket for a Montreal-Paris flight fell 20 per cent in real terms.[19] Freedman (1983) pointed out that in the financial market, there were technological advancements in telecommunication and computerization. These innovations led to the availability of different cash management packages.

2.2.3 International Trade

With respect to international factors, the Canadian economy did not experience any major changes. In the 1970s, our export markets mainly focused on the United States. Our export markets continued to center on the United States in the 1980s, despite the efforts of the Canadian government to

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[18]Ibid., pp. 141-57.

[19]Ibid., pp. 141-57.

diversify our international trade.[20]

The nature of international competition had, however, changed in the 1980s. The newly industrializing countries of the Pacific Rim had increased their penetration of world markets. Canadian industry had to compete with Korean and Taiwanese firms in industries such as automobiles and consumer durables during the 1980s.[21]

2.3 Summary

In this chapter, we have reviewed the conduct of Canadian monetary policy, and the structure of the Canadian economy over the 1970s and 1980s. It is clear that price stability was the primary goal of the Bank of Canada during the last two decades. The Bank of Canada set explicit targets for the narrow monetary aggregate, M1, in November 1975. Exchange rate movements played an important role in the conduct of Canadian monetary policy during the late 1970s and early 1980s. The Bank of Canada abandoned M1 targeting in November 1982. The announced goal of monetary policy in 1988 by Governor Crow was zero inflation.

The financial innovation that occurred in the 1980s was

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[20]Ibid., pp. 141-57.

[21]See Lars Osberg (1990), "Distributional Issues and the Future of the Welfare State." In Perspective 2000: Proceedings of a Conference Sponsored by the Economic Council of Canada, December 1988, (Ottawa: Supply and Services Canada), p. 164.

a response to a number of forces, the most important of which were high inflation and interest rates, rapid technological progress in the provision of financial services and the increase in competition among the different financial pillars. The net effect of the financial innovations in the 1980s was to reduce the demand for M1.[22]

In the 1980s, there were many technological advances in different areas in the Canadian economy. Technological changes not only transformed the employment pattern, but also increased the importance of research for the design of new industrial processes. Furthermore, the Canadian economy did not undergo major changes in the international trade in the 1980s; the nature of international competition had been changed. Hence Canada had to compete with the newly industrializing countries of the Pacific Rim on durable products.

In summary, although there were changes in the conduct of monetary policy during the 1970s and the 1980s, price stability was the primary goal of monetary policy in the last two decades. However, the structure of the Canadian economy, in the 1980s, had undergone some major changes such as financial innovations, technological advancements, and

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[22]See Patrice Muller (1990), "The Information Content of Financial Aggregates During the 1980s," in Monetary Seminar, a seminar sponsored by the Bank of Canada, May 7-9, Table 1 p. 188 discusses the declining share of M1 in the broad money aggregates.

the nature of international trade. All these had affected the pattern of employment and the demand for money in Canada. Given the descriptive discussions of the structural changes in the execution of Canadian monetary policy, and in the structure of the Canadian economy, we can then proceed to examine those structural changes empirically.

CHAPTER 3

REVIEW OF GREGORY AND RAYNAULD'S MODEL

3.1 Introduction

This chapter has two purposes. The first purpose is to introduce Gregory and Raynauld's (G&R) (1985) model which will be used in chapter 4 to extend the estimation period to cover the 1980s. Secondly, G&R's (1985) model is re-estimated to see whether the same results can be obtained.

The Bank of Canada has constructed and used large-scale econometric models, such as the RDX1 model (see Helliwell et al. (1969)), the RDX2 model (see Helliwell et al (1971)), and the RDXF model (see Robertson and Mcdougall, (1982 a & b)). These models consist of several hundred equations. More recently, the Bank of Canada developed the Small Annual model (see Rose and Selody 1985) which consists of about two dozen behavioral equations, and less than one hundred total equations. The complexity of a large-scale model makes it difficult to specify what the constraints should be.[23] In addition, the limitations of estimation technology make it impossible to estimate simultaneously a large number of equations. Therefore, G&R (1985) developed a small macroeconometric model describing Canadian monetary policy

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[23]For example, it is difficult to specify the Rational Expectations restrictions in the model.

over the 1970s.

G&R's (1985) model is a five-equation model. The model is estimated using the Full Information Maximum Likelihood (FIML) method. The Rational Expectations Hypothesis is also examined. The following section provides reasons for developing a small system rather than a large-scale model. It also introduces and discusses the model used in this study. Data utilization, estimation procedures and results are discussed in Sections 3.3 and 3.4. Finally, Section 3.5 discusses the test for the Rational Expectations Hypothesis.

3.2 The Structure of the Model

3.2.1 An overview of the model

G&R (1985) constructed a small macroeconometric model describing Canadian monetary policy over the 1970s. They estimated the model in order to gain a better understanding of the implementation and effects of Canadian monetary policy in the 1970s. G&R (1985) used a small system of nonlinear equations rather than a large-scale linear model. Some justifications regarding their use of a small system are as follows:

(a) It allows researchers to model in a coherent and cogent manner the interdependencies of the various postulated relations.

(b) The model can be efficiently estimated by such system methods as Full Information Maximum Likelihood (FIML).

(c) Rational Expectations may be solved from the system of equations analytically.

G&R's (1985) model comprises five interdependent equations: the interest rate reaction equation, the demand for money equation, the demand for real output equation, the inflation rate equation, and the exchange rate equation. Table 3-1 lists and defines the variables used in the model. In the interest rate reaction equation, the interest rate (r_t) responds to the lagged value of the nominal interest rate, the deviations between the US nominal interest rate and the lagged domestic interest rate, and the gap between lagged and targeted nominal money supply. G&R (1985) related the demand for money (m_t-p_t) to real output, the current nominal interest rate, and the lagged value of real balances. In the demand for real output equation, real output (y_t) is a function of lagged values of real output, real money balances, real interest rates, real exchange rate and US real output. The exchange rate (s_t) and the inflation rate (π_t) are modelled as univariate autoregressive moving average processes.

Dynamic effects are captured by utilizing lagged terms in each equation. Distributed lags are finite and need not be the same. Expectations of real and nominal interest rates are formed rationally. The actual model is presented

TABLE 3–1

VARIABLE DEFINITIONS

All variables are expressed in their natural logarithms except for the interest and inflation rates.

y_t = percentage deviation of Canadian real output from trend ($y_t = Y_t - Y_t^P$ where Y_t is Canadian real output and Y_t^P corresponds to its trend value). Simply called Canadian real output in this paper.

y_t^* = percentage deviation of US real output from trend ($y_t^* = Y_t^* - Y_t^{P*}$ where Y_t^* is US real output and Y_t^{P*} corresponds to its trend value). Simply called US real output in this paper.

m_t = nominal money supply

m_t^T = target nominal money supply

r_t = Canadian nominal interest rate

r_t^* = US nominal interest rate

$\tilde{r}_t$ = conditional expectations of the Canadian nominal interest rate , given information through period t−1

s_t = spot exchange rate

p_t = Canadian price level

p_t^* = US price level

π_t = inflation rate ($p_{t+1} - p_t$)

$\tilde{\pi}_t$ = conditional expectations of the inflation rate ($p_{t+1} - p_t$), given information through period t−1

D_t = dummy variable for the money target (= 0 before 1975Q2, =1 from 1975Q2 to 1982Q4, and =0 after 1982Q4) in section 3.2.2. Detailed discussions of each equation are presented in the following section.

3.2.2 Description of Each Equation in the Model

(a) Interest Rate Reaction Equation

In light of the execution of monetary policy in the past two decades, it is evident that interest rates were the principal instrument. G&R (1985) provided a summary of the changes in goals by the Bank of Canada in managing interest rates during the seventies.[24] The policy overview in Chapter 2 also provided evidence that the Bank of Canada had adopted exchange rate targeting during the late seventies and the early eighties; interest rates were used as the principal instrument to achieve the target.

Many researchers in the past had modelled the execution of Canadian monetary policy through the interest rate reaction function. Courchene and Kelly (1971) specified a reaction function embodying the four announced objectives of Canadian monetary policy over the period 1955:3 to 1965:4. Fortin (1975) related the yield on one-to-three year Government of Canada securities to the US treasury bill rate, the percentage change in the over-all Canadian

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[24] See A. W. Gregory and J. Raynauld (1985), "An Econometric Model of Canadian Monetary Policy over the 1970s," Journal of Money, Credit, and Banking, Vol. 17 (1), pp. 46-47 for detailed discussions.

official international reserve position, the unemployment rate, the rate of increase in the consumer price index, the rate of increase in the index of industrial production, and some financial variables. Likewise, G&R (1985) used an interest rate reaction equation to describe the behavior of the Bank of Canada in managing interest rates in the conduct of monetary policy. The equation is as follows:

Interest Rate Reaction Equation

$$r_t = \delta_o + \sum_{i=1}\delta_{1i}r_{t-i} + \sum_{i=0}\delta_{2i}(r^*_{t-i} - r_{t-1-i}) + \sum_{i=0}\delta_{3i}D_t(m^T_{t-i} - m_{t-1-i}) + e_{1t} + \sum_{i=1}\theta_i e_{1t-i} \tag{3.1}$$

The effects of past changes in interest rates are captured by the distributed lag on interest rates in equation (3.1). The short-term spread between Canadian and US interest rates (i.e. $r^*_{t-i} - r_{t-1-i}$) is used to pick up any exchange rate considerations employed by the Bank of Canada in determining interest rates. The magnitude of δ_{2i} is determined by the degree of capital mobility. If capital were perfectly mobile, then the Canadian interest rate could not deviate from the US interest rate for any length of time. On the other hand, if capital were not perfectly mobile, then δ_{2i} would reflect the degree to which the Bank of Canada takes into account movements in US interest rates. Additional lagged terms are included in this equation to capture possible delays in adjustment.

The term $(m^T_t - m_{t-1})$ is the spread between the current money target and the actual lagged value of the nominal money supply. If the lagged money supply is above the current target, we expect the Bank of Canada to raise interest rates to keep the money supply within the announced target. A priori, we expect that δ_{3i} will be negative. The dummy variable D_t is set equal to one from 1975Q2-1982Q4 and is set equal to zero after the Bank abandoned the monetary targeting of M1 in 1983. Dynamic influences are picked up through the lagged terms of the explanatory variables.

(b) Demand for Money Equation

The following equation represents the real demand for money.

Demand for Money Equation

$$m_t - p_t = \beta_o + \beta_1(y_t + Y^P_t) + \beta_2\tilde{r}_t + \beta_3(m_{t-1} - p_{t-1}) + e_{2t} + \sum_{i=1}\phi_i e_{2t-i} \tag{3.2}$$

This equation is analogous to Goldfeld's (1973) partial adjustment specification. Many researchers in Canada have used this conventional specification to model the demand for money. For example, Poloz (1980) modelled the demand for money in Canada using a partial adjustment technique. He found empirically that the partial adjustment model of the real demand for money surpassed other types of model specifications. Additionally, Clinton (1973), Foot (1977), Cameron (1979), and Hostland (1990) modelled the demand for money equation using partial adjustment techniques.

The dependent variable in equation (3.2) is the demand for real money balances. Since the income variable is logarithmic (natural), the estimated coefficient is in fact the income elasticity. The coefficient β_1 can, therefore, be interpreted as the short-run income elasticity; the long-run income elasticity is $\beta_1/(1-\beta_3)$. Theory suggests that real income and real demand for money have a positive relationship; therefore, β_1 should be positive.

Increases in expected nominal interest rates would have a negative effect on the real demand for money; hence we expect that β_2 will be negative. We assume economic agents form their expectations of the nominal interest rates rationally. Part (e) in this section will discuss rational expectations in some length. The rational expectations solution of this equation will also be presented in that section.

Actual money demand is assumed to adjust logarithmically to the gap between the desired equilibrium level and last period's demand. Hence the speed of adjustment between desired money holdings and last period's money holdings is measured by $(1-\beta_3)$. Its value is between 0 and 1.

(c) Demand for Real Output Equation

The demand for real output equation takes the following form.

Demand for Real Output Equation

$$y_t = \alpha_o + \sum_{i=1}\alpha_{1i}y_{t-i} + \sum_{i=0}\alpha_{2i}(m_{t-i} - p_{t-i}) + \alpha_3(\tilde{r}_t - \tilde{\pi}_t) + \sum_{i=0}\alpha_{4i}(p_{t-i} - s_{t-i} - p^*_{t-i}) + \sum_{i=0}\alpha_{5i}y^*_{t-i}$$

$$+ e_{3t} + \sum_{i=1}\psi_i e_{3t-i} \qquad (3.3)$$

It is modelled similarly to Taylor's (1979) closed-economy aggregate demand equation, except that it is modelled in this study as an open-economy aggregate demand equation. That is, terms of trade and US real output are incorporated in the equation as explanatory variables. Any multiplier-accelerator effects and other sources of persistence are captured by distributed lags on real output in this equation.

The term $(m_{t-i} - p_{t-i})$, real money balances, is an explanatory variable in the demand for real output equation. Real money balances are expected to have a positive effect on the demand for real output for the following reason. Economic agents save to accumulate wealth. However, a rise in wealth tends to reduce the incentive to save, thereby increasing consumption. This will then lead to an increase in the demand for money and an increase in aggregate demand.

Real cash balances are allowed to influence real output with a lag.

The expected real interest rate, $(\tilde{r}_t - \tilde{\pi}_t)$, affects the demand for real output in two ways. First, if real interest rates increase, economic agents will reduce current consumption, thereby reducing real output; this is the substitution effect. Second, the real return from assets increases as real interest rates rise, thereby increasing real output; this is the income effect. In reality, it is difficult to identify whether changes in real output are due to income or substitution effects. Therefore, it cannot be determined how the expected real interest rate affects real output through the investment and consumption channels; thus, the coefficient α_3 is either positive or negative. Economic agents are assumed to form their expectations of the real interest rate rationally.

Finally, an unrestricted distributed lag on the terms of trade $(p - s - p^*)$ is incorporated in this equation. A currency depreciation will raise import prices relative to export prices; therefore, it lowers the terms of trade, improving the competitiveness of the country. Relatively higher import prices cause both domestic and foreign buyers of goods and services to switch their purchases of output from foreign to domestic suppliers, thus increasing domestic output. In light of this, we would expect α_{4i} to be negative. Dornbusch and Krugman (1976), however, argued that export prices and physical trade adjust slowly to the currency depreciation; import prices respond immediately to the depreciation. Therefore, the direction of the trade effect is the reverse of that described above, with trade balances worsening in the short term and bettering only over time. That is, a J curve exists. Hence, α_{4i} would be positive and then would be followed by negative magnitudes.

Finally, foreign aggregate demand (y^*_t) is also included in the equation to capture the effect of domestic output through the changes in the export channel. Trade theory suggests that an increase in foreign aggregate demand will increase exports to that country, thereby increasing domestic output. We therefore would expect that α_{6i} would be positive. Lagged terms are also allowed for y^*_t to capture the dynamic effects.

(d) Inflation and Exchange Rate Equations

G&R (1985) used pure time series techniques to specify the inflation rate equation. The equation is a univariate autoregressive moving average (ARMA) process.

Inflation Rate Equation

$$\pi_t = \lambda_o + \sum_{i=1} \lambda_{1i}\pi_{t-i} + e_{4t} + \sum_{i=1} \eta_i e_{4t-i} \qquad (3.4)$$

G&R (1985) attempted the price/wage determination specification of Taylor (1979) with Canadian data.[25] The equation, however, performed poorly under this specification. Therefore, due to the absence of adequate econometric specifications to model inflation movements in Canada, the inflation rate equation is modelled as a pure time series equation.

Exchange rate movements are also formed by using pure time series techniques.

Exchange Rate Equation

$$s_t = \mu_o + \sum_{i=1} \mu_{1i} s_{t-i} + e_{5t} + \sum_{i=1} \vartheta_i e_{5t-i} \qquad (3.5)$$

It is quite common to use pure time series representations to describe exchange rate movements. Both Leiderman (1979) and Backus (1982) had employed time series methods to model price and exchange rate movements. G&R (1985) also claimed

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[25]Taylor's (1979) price/wage determination equation is as follows: $\pi_t=\pi_{t-1}+\gamma_1\hat{y}_t+\gamma_0+v_t$, where π_t is the rate of inflation defined as $p_{t+1}-p_t$ and $\hat{y}_t$ is the conditional expectation of the deviation from trend of the log of real expenditures given information through period t-1.

that modelling the inflation and exchange rates by a vector autoregressive moving average process was not statistically superior to a univariate autoregressive moving average (ARMA) process.

(e) Rational Expectations Solution

It is assumed that expectations of real and nominal interest rates in this model are formed rationally. This section presents the rational expectations solution to these two unobservable variables: expected nominal ($\tilde{r}_t$) and real ($\tilde{r}_t - \tilde{\pi}_t$) interest rates. However, some comments on the use of rational expectations in the model must be made before the presentation of the rational expectations solution.

The Rational expectations hypothesis (REH) states that economic agents have access to all relevant information available in the model, thereby forming their expectations on the basis of the true structural model. Economic agents with rational expectations do make mistakes, but they do not make the same mistake each time. An editorial from The Economist (Nov 10, 1990) asserted that "the crucial insight from the literature on rational expectations (RE) is this: people learn from their mistakes."[26] Hence, if errors occur, people will learn from them, revise their

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[26]The Economist, "Schools Brief: Tales of the expected," The Economist, Nov 10, 1990, p. 90.

expectations and make a more accurate forecast. Thus the Rational Expectations Hypothesis asserts that economic agents do not make systematic errors in forecasting the future.

Another type of expectations formation, namely, the Adaptive Expectations Hypothesis is contrary to the Rational Expectations Hypothesis. This expectations hypothesis is a backward-looking way of forming expectations. More specifically, the Adaptive Expectations Hypothesis means that in any one period, economic agents' expectations are revised in the light of past errors of expectations. This way of forming expectations is subject to two deficiencies. In the first place, it implies that agents will make non-random errors in predicting the future. Secondly, this hypothesis ignores relevant information that may be available to economic agents at the time of expectations formation but not at the time of the past events. Because of these two primary objections, we use the Rational Expectations Hypothesis in our model rather than the Adaptive Expectations Hypothesis.

In the model, economic agents are assumed to have knowledge of the structure of the model when performing forecasting. All the exogenous and lagged dependent variables are contained in agents' information set I, at time t. Moreover, agents are assumed to know the current value of the money target and any changes to the target growth rate. It is further assumed that the current exchange rate is also observed.

To obtain the rational expectations solution of the model, expectations of the interest rate reaction equation (3.1) and the inflation rate equation (3.4) are taken conditional upon agents' information set I_t at time t. The resulting equations are then substituted into the demand for money equation (3.2) and the demand for real output equation (3.3). As a result, two nonlinear equations with no unobservable variables are obtained. Appendix B presents the rational expectations results of the demand for money equation (3.2a) and the demand for real output equation (3.3a).

The two nonlinear equations (3.2a) and (3.3a), together with equations (3.1) (3.4), and (3.5) form a system of restricted equations.[27] This system of equations is used to test whether the cross-equation restrictions implied by the Rational Expectations Hypothesis are valid. Section 3.5 provides in-depth discussion of the test.

[27] The system of equations is listed in Appendix B.

3.3 Data Utilization

The Canadian macroeconomic variables used in this study are as follows: real GNE, GNE implicit price deflator, M1, money target, spot exchange rate, and 90-day prime corporate paper rate. The US macroeconomic variables used in this study are as follows: US real GNE, US nominal GNE, and 90-day commercial paper rate. The data set contains quarterly data from 1970Q1 to 1991Q1. Data are obtained from the CANSIM[28] University Base Series Directory for the abovementioned economic indicators. They are seasonally adjusted. Data sources are given in Appendix A. Each of these variables will be discussed below.

Canadian real GNE is used in this model. GNE adds to GDP[29] foreign investment income of Canadians and deducts domestic income of non-residents. In practice, GDP and GNE are very highly correlated.[30] The log of its trend value is subtracted from the log of real GNE to obtain percentage deviations of real GNE from trend. The GNE implicit price deflator is used to compute the inflation rate in the model.

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[28]CANSIM is the acronym for Canadian Socio-Economic Information Management, the computerized databank created and maintained by Statistics Canada.

[29]GDP measures the production of all goods and services taking place within Canada.

[30]D. Hostland et al. (1978), An Analysis of the Information Content of Alternative Monetary Aggregates, Bank of Canada Technical Report No. 48, p. 9 indicated that the correlation coefficients between GNE and GDP was 0.996.

There are some controversies regarding the use of the GNE implicit price deflator or the consumer price index. The GNE implicit price deflator is used in this model for two reasons. Firstly, it is the most comprehensive index of price level; secondly, most publications, including the Bank of Canada's publications apply the GNE implicit price deflator in their model estimations.

M1[31], the narrowly defined money supply, is used as the nominal money supply in the model. In 1975, Governor Bouey publicly announced that the rate of growth of M1 is used as the intermediate target. Hence, M1 is used in the model as a measure of the nominal money supply.

The Bank of Canada publicly announced the money target growth ranges periodically during November 1975 to February 1981. To construct the money target in the model, G&R (1985) used the middle value of the announced target growth range to obtain the base period. The procedure was repeated for each money target growth announcement. The resulting money target series is used in this study.

Interest rates and the exchange rate are crucial macroeconomic variables. The Canadian interest rate used in the model is the 90-day prime corporate paper rate. The spot exchange rate measures Canadian cents per one US dollar.

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[31]M1 includes currency in circulation and demand deposits.

One of the foreign variables used in the model is the US real GNE implicit price deflator. To obtain the US real GNE implicit price deflator, we divide US nominal GNE by US real GNE, and multiply the result by 100. The other two foreign variables used in the model are US real GNE, and the 90-day corporate paper rate.

3.4 Estimation Procedures and Results

3.4.1 Ordinary Least Squares (OLS) Estimation and Results

G&R (1985) use a single-equation approach to estimate the interdependent system of equation. They use the ordinary least squares techniques to determine the appropriate lag and error structures of each equation. The system of equations is then estimated using the Full Information Maximum Likelihood (FIML) method.[32] G&R (1985) justify the use of single-equation techniques based upon the following arguments.

First, there is a potential misspecification in forming an equation. If part of the model is misspecified, FIML estimation can yield inconsistent parameter estimates. Second, non-linear system estimation involves substantial computation cost. The single-equation method, however, saves time and computation cost.

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[32]Discussion of the FIML method is provided in section 3.4.2.

The estimation period is from 1970Q3 to 1981Q3. Each equation is estimated independently using seasonally adjusted quarterly data. The expected nominal and real interest rates are unobservable at time t. Therefore, when estimating the demand for money equation (3.2), and the demand for real output equation (3.3) by the OLS method, expected nominal and real interest rates are replaced by their actual ex post values. To determine the lag lengths of the variables in each equation, Gregory and Raynauld (1985) set the maximum lag length at four.[33] They then use F-tests to investigate whether the lags could be shortened. G&R's (1985) OLS results are reported in Table 3-2.

The purpose here is to replicate G&R's (1985) model. Their model is replicated using the OLS method. The sample period (1970Q3-1981Q3) is the same as G&R's estimation period. G&R (1985) used custom software to estimate their model, treating the disturbances as moving average processes. As our ultimate objective is to estimate the model by system methods, and as no commercially available software treats model disturbances as moving averages in a systems context, no attempt is made here to replicate the G&R (1985) treatment of the equation disturbances. Hence our estimation results will not reproduce those of G&R

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[33] A. W. Gregory and J. Raynauld, op. cit., p. 52 claimed that they set the maximum lag length at four because quarterly data is used.

TABLE 3–2

GREGORY AND RAYNAULD'S OLS ESTIMATES (1970Q3 TO 1981Q3) [a]

Interest Rate Reaction Equation:

$$r_t = \underset{(5.14)}{0.2943} + r_{t-1} + \underset{(9.07)}{0.5676}\,(r_{t-1}-r_{t-2}) + \underset{(18.56)}{0.5496}(r^*_t-r_{t-1}) - \underset{(7.36)}{0.3196}\,(r^*_{t-1}-r_{t-2}) - \underset{(4.20)}{18.0916}\,D_t\{(m^T_t-m_{t-1})-(m^T_{t-1}-m_{t-2})\} + \underset{(6.75)}{0.5429}\,e_{1t-2} \qquad R^2=0.9678$$

Demand for Money Equation:

$$m_t - p_t = \underset{(3.32)}{0.0718}\,(y_t+Y^p_t) - \underset{(6.93)}{0.0047}\,r_t + \underset{(15.68)}{0.8316}\,(m_{t-1}-p_{t-1}) \qquad R^2=0.9324$$

Demand for Real Output Equation:

$$y_t = \underset{(3.81)}{0.4031}\,y_{t-1} + \underset{(3.44)}{0.0975}\,(m_{t-1}-p_{t-1}) - \underset{(5.45)}{0.0020}\,(r_t-\pi_t) + \underset{(3.43)}{0.1009}\,(p_t-s_t-p^*_t) + \underset{(2.21)}{0.1266}\,y^*_t \qquad R^2=0.9263$$

Inflation Rate Equation:

$$\pi_t = \underset{(2.16)}{2.4427} + \underset{(2.76)}{0.4017}\,\pi_{t-1} + \underset{(2.33)}{0.3357}\,\pi_{t-2} \qquad R^2=0.4466$$

Exchange Rate Equation:

$$s_t = s_{t-1} + \underset{(3.56)}{0.5067}e_{5t-1} \qquad R^2=0.9657$$

[a]Gregory and Raynauld (1985, p. 53, Table 1)
Absolute t–ratios are in parentheses.

(1985) exactly. The replicated OLS estimation results are reported in Table 3-3.

Comparing the replicated OLS results with G&R's (1985) OLS results, it is found that the estimated coefficients in the demand for money, the demand for real output, and the inflation rate equations possess the same signs and magnitudes as those reported in G&R's (1985) OLS estimation results. The estimated coefficients in the interest rate reaction equation possess the same signs as those presented in G&R's (1985) model. Their magnitudes, however, differed slightly from those of G&R (1985); the t-ratios are also lower in the replicated OLS estimation than those in G&R's OLS estimation. This is probably because the equation suffers from not being corrected for autocorrelation in the error terms. Finally, the exchange rate equation is modelled as a random walk which is the same as what G&R (1985) have done. Overall, this study has successfully replicated G&R's (1985) model for the 70s using the OLS method.

3.4.2 Full Information Maximum Likelihood (FIML) Estimation and Results

Using the model obtained from the OLS method, G&R (1985) estimated the model again by the FIML method with rational expectations restrictions imposed. The FIML method

TABLE 3–3

REPLICATED OLS ESTIMATES OF GREGORY AND RAYNAULD'S MODEL (1970Q3 TO 1981Q3)

Interest Rate Reaction Equation:

$$r_t = \underset{(2.2585)}{0.3189} + r_{t-1} + \underset{(3.6056)}{0.5486}\,(r_{t-1}-r_{t-2}) + \underset{(7.2980)}{0.5483}\,(r^*_t-r_{t-1}) - \underset{(2.9099)}{0.3076}\,(r^*_{t-1}-r_{t-2}) - \underset{(1.6369)}{15.8380}\,D_t\{(m^T_t-m_{t-1})-(m^T_{t-1}-m_{t-2})\} \qquad R^2=0.9564$$

Demand for Money Equation:

$$m_t - p_t = \underset{(3.3166)}{0.0718}\,(y_t+Y^p_t) - \underset{(6.9619)}{0.0047}\,r_t + \underset{(15.6740)}{0.8316}\,(m_{t-1}-p_{t-1}) \qquad R^2=0.9328$$

Demand for Real Output Equation:

$$y_t = \underset{(3.5542)}{0.4031}\,y_{t-1} + \underset{(3.4226)}{0.0975}\,(m_{t-1}-p_{t-1}) - \underset{(5.4388)}{0.0020}\,(r_t-\pi_t) + \underset{(3.4094)}{0.1009}\,(p_t-s_t-p^*_t) + \underset{(2.1963)}{0.1266}\,y^*_t \qquad R^2= 0.9262$$

Inflation Rate Equation:

$$\pi_t = \underset{(2.1565)}{2.4427} + \underset{(2.7655)}{0.4017}\,\pi_{t-1} + \underset{(2.3333)}{0.3357}\,\pi_{t-2} \qquad R^2=0.4467$$

Exchange Rate Equation:

$$s_t = s_{t-1}$$

Note: Absolute t–ratios are in parentheses.

is used as the estimation technique for this model so that the cross-equation rational expectations restrictions can be tested. The estimated results are presented in Table 3-4. G&R (1985) found that the estimated results did not differ substantially from the OLS estimated results.

The objective is to replicate G&R's (1985) model over the same sample period (1970Q3-1981Q3). Table 3-5 presents the replicated FIML results. The results do not differ much from those of G&R (1985). It is found that our estimated coefficients are of the same signs as those estimated by G&R (1985). The magnitudes are very close to those of G&R (1985); t-ratios are also lower in the replicated FIML estimation than those in G&R's FIML estimation. The probable reason for the difference in the results is that G&R (1985) modelled the error terms in the interest rate reaction equation and the exchange rate equation as moving averages; however, we model them as normally distributed with mean zero and variance σ^2. The overall replication of G&R's (1985) model using the FIML method is quite successful.

3.5 The Rational Expectations Hypothesis Test

One of the advantages of using a small system of nonlinear equations is that rational expectations can be solved from the system of equations analytically. Pesaran

TABLE 3–4

GREGORY AND RAYNAULD'S FIML ESTIMATES (1970Q3 TO 1981Q3) [a]

Interest Rate Reaction Equation:

$$r_t = \underset{(1.80)}{0.2979} + r_{t-1} + \underset{(4..40)}{0.6202}\,(r_{t-1}-r_{t-2}) + \underset{(12.50)}{0.5833}\,(r^*_t-r_{t-1}) - \underset{(4.15)}{0.3661}\,(r^*_{t-1}-r_{t-2}) - \underset{(2.00)}{18.0270}\,D_t\{(m^T_t-m_{t-1})-(m^T_{t-1}-m_{t-2})\} + \underset{(4.02)}{0.5212}\,e_{1t-2}$$

Demand for Money Equation:

$$m_t - p_t = \underset{(4.30)}{0.0958}\,(y_t+Y^p_t) - \underset{(7.38)}{0.0053}\,\tilde{r}_t + \underset{(14.20)}{0.7734}\,(m_{t-1}-p_{t-1})$$

Demand for Real Output Equation:

$$y_t = \underset{(3.62)}{0.4032}\,y_{t-1} + \underset{(3.55)}{0.0995}(m_{t-1}-p_{t-1}) - \underset{(4.90)}{0.0023}\,(\tilde{r}_t-\tilde{\pi}_t) + \underset{(3.53)}{0.1028}\,(p_t-s_t-p^*_t) + \underset{(2.51)}{0.1431}\,y^*_t$$

Inflation Rate Equation:

$$\pi_t = \underset{(2.47)}{2.8972} + \underset{(2.63)}{0.3760}\,\pi_{t-1} + \underset{(2.32)}{0.3074}\,\pi_{t-2}$$

Exchange Rate Equation:

$$s_t = s_{t-1} + \underset{(4.19)}{0.6069}\,e_{St-1}$$

[a] Gregory and Raynauld (1985, p. 54, Table 2)
Absolute t–ratios are in parentheses.

TABLE 3–5

REPLICATED FIML ESTIMATES OF GREGORY AND RAYNAULD'S MODEL (1970Q3 TO 1981Q3)

Interest Rate Reaction Equation:

$$r_t = 0.2568 + r_{t-1} + 0.5862(r_{t-1}-r_{t-2}) + 0.5146(r^*_t-r_{t-1}) - 0.3383\,(r^*_{t-1}-r_{t-2}) - 11.0600\,D_t\{(m^T_t-m_{t-1})-(m^T_{t-1}-m_{t-2})\}$$

(0.76) (1.62) (3.58) (1.39) (0.47)

Demand for Money Equation:

$$m_t - p_t = 0.0902\,(y_t+Y^p_t) - 0.0052\,\tilde{r}_t + 0.7871\,(m_{t-1}-p_{t-1})$$

(2.38) (3.07) (8.58)

Demand for Real Output Equation:

$$y_t = 0.4019\,y_{t-1} + 0.1010(m_{t-1}-p_{t-1}) - 0.0023\,(\tilde{r}_t-\tilde{\pi}_t) + 0.1044\,(p_t-s_t-p^*_t) + 0.1421\,y^*_t$$

(1.49) (1.60) (2.25) (1.59) (1.20)

Inflation Rate Equation:

$$\pi_t = 2.8296 + 0.3819\,\pi_{t-1} + 0.3036\,\pi_{t-2}$$

(1.26) (1.08) (0.65)

Exchange Rate Equation:

$$s_t = s_{t-1}$$

Note: Absolute t–ratios are in parentheses.

(1987) indicated that one possible method of testing the rational expectations hypothesis is to see if the cross-equation restrictions implied by the hypothesis are valid.

Pesaran (1987) further stated that a suitable procedure for testing the cross-equation restrictions is the likelihood ratio (LR) test, in which we denote the maximized values of the log-likelihood functions of the unrestricted model and the restricted model as LLU and LLR, respectively. The likelihood ratio (LR) statistic for testing the cross-equation restrictions is the following: LR = 2(LLU-LLR). The test statistic is distributed as $\chi^2(r)$, where r is the number of restrictions. We test the null hypothesis that rational expectations restrictions are true against the alternative hypothesis that the rational expectations restrictions are not true. If the computed LR is greater than the critical value from a χ^2 table at the chosen level of significance, then the null hypothesis is rejected in favor of the alternative hypothesis.

Pesaran (1987) commented that the rejection of cross-equation restrictions, in general, does not necessarily lead to the rejection of the Rational Expectations Hypothesis. It can be argued that cross-equation restrictions have been rejected due to misspecification in the underlying model, but not because the Rational Expectations Hypothesis is false.

G&R (1985) performed a likelihood ratio test on fourteen non-linear rational expectations restrictions. The computed LR statistic of 23.62 is marginally less than the critical value of 23.67 at 5 percent significance level A likelihood ratio test based on the FIML model described in Table 3-5 is also performed.[34] The computed LR statistic is 16.16 with twelve restrictions[35] imposed in the model. This statistic is less than the critical value of 21.03 at 5 percent significance level. Hence the replicated result agrees with G&R (1985) that it fails to reject the rational expectations restrictions.

3.6 Summary

This chapter reviews the Gregory and Raynauld (1985) model. The model consists of five interdependent equations modelling the behavior of the Bank of Canada in the 70s. The model assumes economic agents form their expectations on nominal and real interest rates rationally. Ordinary least squares are used to obtain the appropriate lag and error structures of each equation in the model. FIML estimation is used to estimate the system of equations simultaneously.

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[34]This table presents the replicated model using the FIML estimation.

[35]We did not model the error term in interest rate reaction equation as moving averages; therefore, we have two restrictions less than did Gregory and Raynauld.

The Rational Expectations Hypothesis is also examined.

Reasonable approximations of G&R's estimation results are obtained using both the OLS and the FIML methods. The econometric package that is used to perform both the FIML and the OLS estimations does not allow the error terms to have moving average specifications. Therefore, the exact results as reported by G&R (1985) cannot be reproduced. Nevertheless, this chapter reveals that we are able to replicate G&R's (1985) model over the 1970s. Chapter 4 in this study will examine if this model can be used to explain the economy and the execution of monetary policy over the period 1972-1989.

CHAPTER 4

LAG STRUCTURE SPECIFICATION, ESTIMATION, AND RESULTS: 1972-1989

4.1 Introduction

Gregory and Raynauld (G&R) (1985) developed a model consisting of five interdependent equations. They used the model to examine the conduct of Canadian monetary policy over the 70s. G&R's (1985) model was reviewed in Chapter 3. The purpose of this chapter is to utilize the G&R (1985) model to extend the examination period to the 1980s. That is, the examination period is from the early 1970s to the end of the 1980s.

Lag structures in the G&R (1985) model[36] are examined using the F-test, the Akaike Information Criterion (AIC), the Schwarz Criterion (SC), and the Amemiya Final Prediction Criterion (PC). These criteria allow us to select the appropriate lag lengths for the regressors in the model, and to estimate the model for the 70s and the 80s. Detailed discussion is provided in Section 4.3.2. After the appropriate lag structure is selected for each equation, the Full Information Maximum Likelihood (FIML) method is used to estimate the system of equations. Section 4.3.3 describes the estimation procedures and provides the estimation results. Economic agents are assumed to form their

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[36]The model is presented in Appendix B.

expectations rationally. A test for the validity of the rational expectations restrictions is performed. The test and results are discussed in Section 4.3.4.

4.2 Data Utilization

Data for the 70s and the 80s are obtained from the CANSIM University Base Series Directory.[37] They are seasonally adjusted. Data sources are given in Appendix A. The Canadian and US macroeconomic variables used are the same as those described in Section 3.3 of Chapter 3. The narrowly defined money supply, M1, is still being used for estimations in the 80s. The Bank of Canada had abandoned targeting M1 in the early 80s, and M1 was found empirically to be unstable over time in the 80s.[38] However, there is no explicit targeting for any monetary aggregates; therefore, M1 is still used in this study. The dummy variable associated with the money target is set equal to zero after the Bank of Canada had stopped announcing the money target in 1982.

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[37]Data for the 70s are the same as G&R's data set. The base year of some of the data are adjusted to the same base year as G&R's data. As a result, the two data sets can be bridged together, and a consistent data set in estimation is formed.

[38]See K. Clinton (1973), "The Demand for Money in Canada, 1955-70: Some Single-Equation Estimates and Stability Tests," Canadian Journal of Economics, Vol. 6(1), p. 58.

4.3 Estimation Procedures and Results

4.3.1 An Overview

The objective here is to extend G&R's examination period from the 70s to the end of the 80s. It is, therefore, necessary to re-examine the lag specification of each equation in the model. The model examined is presented in Appendix B.[39] Various regressor selection criteria are used to determine the lag lengths in each equation. One of the criteria used is the F-test. It is a conventional way to evaluate the inclusion of an additional variable on the basis of its significance level. Using this test, the resulting parameter estimators are actually pretest estimators. However, the sampling properties of pretest estimators are unknown in general.[40] The F-test has the pretest problem. Furthermore, the inclusion of an additional variable also depends on the significance level chosen.

As a result, other criteria are also used to determine the lag structure of the model. The criteria are as follows: the Akaike Information Criterion (AIC), the Schwarz Criterion (SC), and the Amemiya Final Prediction Criterion (PC). Each criterion is based on an explicit consideration

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[39]See Section 3.2 of Chapter 3 for the description of the model.

[40]See G. Judge et al. (1985), The Theory and Practice of Econometrics, (New York), Chapter 3 for details.

of a loss (risk) function. Durbin's h-test[41] is also used to check for the presence of an autocorrelation (AR) error structure. Detailed discussion of specifications of lag length is provided in Section 4.3.2.

After the appropriate lag lengths of the regressors in each equation are determined, the FIML method is used to estimate the system of equations simultaneously. This estimation method is a system-method which applies to all the equations of the model and yields estimates of all the structural parameters simultaneously. Section 4.3.3 illustrates the FIML estimation procedures and discusses the results.

Economic agents are assumed to form their expectations of nominal and real interest rates rationally. A cross-equation restrictions test is used to test the validity of the Rational Expectations Hypothesis. Section 4.3.4 discusses the test for rational expectations in detail.

[41]Since the Durbin-Watson statistic is biased in the presence of a lagged dependent variable, Durbin' h-test is used to test for serial correlation when some of the regressors are lagged dependent variables in an equation.

4.3.2 Specification of Lag Structure

Various regressor selection methods are used to determine the appropriate lag lengths of the explanatory variables in the model.[42] Autocorrelation of error terms is also examined. This section begins by introducing the criteria that are used to determine the lag structure in the model. Based upon these criteria, procedures to perform the determination of the lag structure are described. Finally, the lag structure results are reported.

(a) Discussion of the Criteria

The F-test is used to test whether the inclusion of an explanatory variable in an equation has statistically significantly improved the explanation in the variation of the dependent variable. Denote the equation without the additional regressor as the restricted equation. The equation that includes the additional regressor is denoted as the unrestricted equation. The null hypothesis is that the additional regressor does not improve the proportion of the variation explained by the restricted equation. This hypothesis is tested against the alternative hypothesis that the restricted equation is not true.

The F-statistic is the following:

$$[(SSE_r - SSE_u)/r]/[SSE_u/(N-K)],$$

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[42]The model is specified in Appendix B.

where SSE_r= restricted error sum of squares (i.e. the error sum of squares when the null hypothesis is imposed), SSE_u= unrestricted error sum of squares, r= number of restrictions imposed by the null hypothesis, K= number of regressors including the constant term, and N= number of observations. The F-statistic has an F distribution with (r) and (N-K) degrees of freedom. If the calculated F-statistic is greater than the critical value from the F-distribution table at the chosen significance level, the null hypothesis is rejected and the alternative hypothesis that the additional variable is an important explanatory variable is accepted.

The F-test is the conventional way of judging the significance of additional explanatory variables by analyzing the variance and the F-statistic. However, whether the null hypothesis is rejected depends mainly on the pre-chosen significance level. Another disadvantage in using the F-test to determine whether the inclusion of an additional variable is statistically significant, is that the resulting parameter estimators are pretest estimators. The sampling properties of the pretest estimators are, however, unknown.

Akaike developed a regressor selection criterion based on the consideration of a loss function.[43] He proposed the following criterion called the Akaike Information Criterion (AIC):[44]

$$\ln \sigma^2 + (2K/N),$$

where K = number of regressors, N = number of observations, and σ^2 = the error sum of squares divided by the number of observations (i.e. SEE/N). The objective is to calculate the AIC for each alternative equation, and to choose the equation that has the minimum AIC value.

Schwarz (1978) stated that the AIC gives a mathematical formulation of the principle of parsimony in model building. The AIC also avoids the inference problems of sequential estimators. Finally, it rewards good fit but penalizes the loss of degrees of freedom. The AIC, however, retains a probability of leading to overfitting even as the number of observations approaches infinity.

Schwarz (1978) derived a regressor selection criterion using Bayesian arguments. Schwarz's Criterion (SC) is as follows:[45]

$$\ln \sigma^2 + [K(\ln N)/N],$$

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[43]See T. Amemiya (1980), "Selection of Regressors," International Economic Review, Vol. 21, p. 341 for the form of the loss function.

[44]This criterion is obtained from G. Judge et al. (1985), The Theory and Practice of Econometrics, (New York), p. 242.

[45]Ibid., p. 242.

where K = number of regressors, N = number of observations, and σ^2 = the error sum of squares divided by the number of observations (i.e. SEE/N). The objective is to compute the SC for each alternative equation. The equation that has the minimum SC value is chosen.

Amemiya (1980) constructed a criterion based on the mean square prediction error. The objective is to take into consideration the losses associated with choosing an incorrect model. Amemiya's Criterion is called the Prediction Criterion (PC), and is in the form:[46]

$$\sigma^2 \; [(N+K)/(N-K)],$$

where K = number of regressors, N = number of observations, and σ^2 = the error sum of squares divided by the number of observations (i.e. SEE/N). The objective is to calculate the PC for each alternative model, and to choose the model that has the minimum PC value.

The PC can be used as a selection criterion in a linear and nonlinear regression model, including the case of an error term which has a general variance-covariance matrix without a specified distribution. This criterion, therefore, has a wide applicability. It also imposes a higher penalty upon increasing the number of regressors than does Theil's adjusted R^2.

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[46]Ibid., p. 242.

(b) Summary of the Criteria

The F-test is used to test a sequential inclusion of explanatory variables in regression analysis. It has the pretest problem. The AIC, SC, and PC are based on an explicit consideration of a loss function. They avoid the inference problem of the F-test. The objective is to minimize the criterion for each alternative model and to choose the model that gives the minimum criterion value.

The PC and AIC give very similar results.[47] The PC imposes a slightly heavier penalty on the inclusion of regressors than the AIC. The PC and AIC are complementary because the PC can be used in linear and nonlinear regression model and/or without a specified distribution; the AIC can be used in any model where the likelihood function is specified. The PC is, however, preferred because of its simplicity. The SC is the same as the AIC, except the SC puts a heavier penalty on additional regressors. Hence one should choose a model which is no larger than the model chosen using the AIC.

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[47]See T. Amemiya (1980), "Selection of Regressors," International Economic Review, Vol. 21, p. 345, Table 1.

(c) Determination of the Lag Structure

To determine the lag structure of each equation in the model, the maximum lag on each variable is set equal to eight.[48] The following sequential searching method is employed to the interest rate reaction equation, the demand for real output equation, the inflation equation and the exchange rate equation. All the variables in the above equations are lagged once, except for those variables contain zero lag. The aforementioned criteria[49] are then used to determine the appropriate lags on each variable in the model, using the Ordinary Least Squares technique. An additional lag is then added to each variable in the equations. The procedure is repeated until the pre-chosen maximum lag is reached. The procedures and results are described below in detail.

To perform the selection of the appropriate lag lengths, additional lags are added to an equation one at a time. Each time a F-test is carried out on the associated variable. The equation containing that additional variable is denoted as the unrestricted equation, whereas the equation without that additional variable is treated as the restricted equation. The value of the F-statistic is

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[48]Degrees of freedom limitations prevent us from testing the model with longer lags on each explanatory variable.

[49]The criteria are the F-test, the AIC, the SC, and the PC.

compared with critical F-value at a selected significance level. If the F-value is significant when compared with a critical F-value, the additional variable is then included in the equation. In other words, the hypothesis that the coefficient of the additional variable in the equation is zero, is rejected. As soon as an F-value is found to be non-significant, the testing procedure is terminated, and the corresponding variable and all succeeding variables are deleted from the equation.

Autocorrelation of error terms that is found to be significant can be because of true autocorrelation of the error terms, or because of the omission of lagged dependent and independent variables. Durbin's h-test[50] is used to determine the presence of an autoregressive error structure. Durbin's h-test examines the null hypothesis of no first-order autocorrelation versus the alternative hypothesis of first-order autocorrelation. The h-statistic[51] is approximately normally distributed with unit variance. If the computed h-statistic is higher than the critical value

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[50]It is inappropriate to use the Durbin-Watson test in equations containing lagged dependent variables. Its statistic is biased toward 2.0 when there is a lagged dependent variable. Therefore, Durbin's h-test is used in this study.

[51]See R. Pindyck and D. Rubinfeld (1981), Econometric & Models Economic Forecasts, 2nd., (New York), p. 194 for the formula of the h-statistic. In this study, we used the h-statistic calculated by the TSP program. TSP used the same formula as it is used in Pindyck and Rubinfeld (1981).

in the Normal-distribution table at a selected level of significance, the null hypothesis of no autocorrelation is rejected.

The aforementioned selection procedures, as well as Durbin's h-test, are applied to the following equations: the interest rate reaction, the demand for real output, the exchange rate, and the inflation rate equations. The results are presented in Table 4-1. The results indicate that, in all four equations, an F-test on the second lag of the variables is statistically insignificant at 5 percent level. As a consequence, the F-test procedure is terminated and the second lag on the explanatory variables is dropped, retaining only the first lag of the explanatory variables. Durbin's h-tests at 5% significance level show that autocorrelation of error terms exist in all four equations. This may indicate dynamic misspecification.

Since the F-test has the pretest problem, as alternatives, the AIC, SC, and PC are used to select the appropriate lag lengths of the four equations.[52] The equations are estimated using ordinary least squares. Explanatory variables are lagged once in an equation; values of the AIC, SC, and PC are then calculated. The criterion values are calculated each time when an additional

[52]The four equations are the exchange rate equation, the inflation rate equation, the interest rate reaction equation, and the demand for real output equation. (See Appendix B).

TABLE 4-1

SELECTION OF REGRESSOR RESULTS

INTEREST RATE REACTION EQUATION:

REGRESSOR / NUMBER OF LAGS **CRITERIA**

r_{t-i}	$r^{*}_{t-i}-r_{t-1-i}$	$D_t(m^T_{t-i} - m_{t-1-i})$	AKAIKE	SCHWARZ	AMEMIYA PREDICTION	ACCEPT F-TEST ?	REJECT DURBIN H-TEST ?
* 3	2	0	−0.41409	−0.19275	0.66135	N/A	NO
1	0	0	−0.20565	−0.07917	0.81421	N/A	YES
2	1	1	−0.26119	−0.03984	0.77061	YES	YES
3	2	2	−0.34237	−0.02616	0.71137	N/A	NO
4	3	3	−0.30730	0.10377	0.73838	N/A	NO
5	4	4	−0.30548	0.20045	0.74235	N/A	NO
6	5	5	−0.29969	0.30110	0.75059	N/A	NO
7	6	6	−0.23942	0.45622	0.80311	N/A	NO
8	7	7	−0.23877	0.55174	0.81168	N/A	NO

* This is the selected lag specification for the Interest Rate Reaction Equation.

Note: 5% significance level is used for both F-tests and Durbin's h-tests.

TABLE 4-1 (CONTINUED)

SELECTION OF REGRESSOR RESULTS

DEMAND FOR REAL OUTPUT EQUATION:

REGRESSOR / NUMBER OF LAGS CRITERIA

	y_{t-i}	$m_{t-i}-p_{t-i}$	$r_t-\pi_t$	$p_{t-i}-s_{t-i}-p^*_{t-i}$	y^*_{t-i}	AKAIKE	SCHWARZ	AMEMIYA PREDICTION	ACCEPT F-TEST ?	REJECT DURBIN H-TEST ?
*	1	1	0	1	1	−8.90589	−8.65293	0.00014	N/A	NO
	1	0	0	0	0	−8.81229	−8.62257	0.00015	N/A	YES
	2	1	0	1	1	−8.87444	−8.55823	0.00014	YES	NO
	3	2	0	2	2	−8.88916	−8.44647	0.00014	N/A	YES
	4	3	0	3	3	−8.79329	−8.22413	0.00015	N/A	YES
	5	4	0	4	4	−8.81078	−8.11514	0.00015	N/A	YES
	6	5	0	5	5	−8.88403	−8.06190	0.00014	N/A	NO
	7	6	0	6	6	−8.82267	−7.87406	0.00016	N/A	NO
	8	7	0	7	7	−8.76032	−7.68523	0.00017	N/A	NO

* This is the selected lag specification for the Demand for Real Output Equation.

Note: 5% significance level is used for both F-tests and Durbin's h-tests.

TABLE 4-1 (CONTINUED)

SELECTION OF REGRESSOR RESULTS

INFLATION RATE EQUATION:

REGRESSOR / NUMBER OF LAGS **CRITERIA**

	π_{t-i}	CONSTANT	AKAIKE	SCHWARZ	AMEMIYA PREDICTION	ACCEPT F-TEST ?	REJECT DURBIN H-TEST ?
*	3	–	3.17055	3.29703	23.82329	N/A	NO
	1	–	3.22951	3.29275	25.26758	N/A	YES
	2	–	3.19916	3.29402	24.51318	YES	NO
	4	–	3.19737	3.35547	24.47360	N/A	NO
	5	–	3.22395	3.41367	25.13695	N/A	NO
	6	–	3.25108	3.47242	25.83403	N/A	NO
	7	–	3.26668	3.51964	26.24832	N/A	NO
	8	–	3.28963	3.57421	26.86824	N/A	NO

* This is the selected lag specification for the Inflation Rate Equation.

Note: 5% significance level is used for both F-tests and Durbin's h-tests.

TABLE 4-1 (CONTINUED)

SELECTION OF REGRESSOR RESULTS

EXCHANGE RATE EQUATION:

REGRESSOR / NUMBER OF LAGS **CRITERIA**

s_{t-i}	AKAIKE	SCHWARZ	AMEMIYA PREDICTION	ACCEPT F-TEST ?	REJECT DURBIN H-TEST ?
* 2	-8.48914	-8.42590	0.00021	N/A	NO
1	-8.30498	-8.27336	0.00025	N/A	YES
3	-8.46225	-8.36739	0.00021	YES	NO
4	-8.48860	-8.36212	0.00021	N/A	NO
5	-8.48340	-8.32530	0.00021	N/A	NO
6	-8.46093	-8.27121	0.00021	N/A	NO
7	-8.43346	-8.21212	0.00022	N/A	YES
8	-8.48497	-8.23201	0.00021	N/A	NO

* This is the selected lag specification for the Exchange Rate Equation.

Note: 5% significance level is used for both F-tests and Durbin's h-tests.

explanatory variable is added to the equation. Since the maximum lag lengths in this study are set equal to eight, the procedure is repeated until the explanatory variables included are lagged eight times. The objective is to minimize the criteria; hence, we choose the equation that provided the minimum AIC, SC, and PC values. Durbin's h-test for autocorrelation of error terms is also performed.

Table 4-1 reports the lag specification results. All three criteria provided consistent results for the exchange rate equation. A model with two lags of the exchange rate has the minimum AIC, SC, and PC values, and has no autocorrelation of the error term. This lag structure is, therefore, selected to represent the exchange rate equation in the model. Both the AIC and PC have minimum values when the inflation rate is lagged three times. A model with two lags of the inflation rate is found to have the minimum SC value. Again the result indicates that the hypothesis of serial correlation is rejected, and three lags of the inflation rate has a lower Durbin's h-test value than that of two lags. As a result, three lags of the inflation rate equation is selected.

The interest rate reaction equation in the following form provides the minimum AIC, SC and PC values: three lags of the nominal interest rate (r_{t-i}), two lags of the spread between Canadian and US interest rates

($r^*_{t-i} - r_{t-1-i}$), and one lag of the spread between the current money target and the lagged value of the nominal money supply. The demand for real output equation in the following form provides the minimum AIC, SC and PC values: the real interest rate ($r_t - \pi_t$), one lag of Canadian real output (y_{t-i}), real money balances ($m_{t-i} - p_{t-i}$), terms of trade ($p_{t-i} - s_{t-i} - p^*_{t-i}$), and US real output ($y^*_{t-i}$). In addition, no autocorrelation of error terms exists in these equations. The resulting specifications of the model are reported in Table 4-2. Before we perform the Full Information Maximum Likelihood (FIML) estimation of the model, some OLS estimation results are discussed below.

The interest rate reaction equation reveals that financial capital between Canada and the United States is mobile. As indicated in the OLS results, Canadian and US interest rate differentials are significant in determining the change in Canadian interest rates. In other words, exchange rate considerations as captured by interest rate differentials are important determinants of Canadian interest rates. This confirmed the Bank of Canada's policy in the past two decades that interest rates were used as a tool to achieve exchange rate targeting.

The estimated short-run income elasticity in the demand for money equation is 0.04; the estimated long-run elasticity is 0.44. These magnitudes are much lower than

TABLE 4-2

OLS ESTIMATES OF THE MODIFIED MODEL (1972Q1 TO 1989Q4)

Interest Rate Reaction Equation:

$$r_t = 1.3290 r_{t-1} + 0.1104 r_{t-2} - 0.4037 r_{t-3} + 0.5964 (r^*_t - r_{t-1}) - 0.0604 (r^*_{t-1} - r_{t-2}) - 0.3573 (r^*_{t-2} - r_{t-3}) - 4.5863 D_t(m^T_t - m_{t-1}) \qquad R^2 = 0.9443$$

(9.9001) (0.4943) (2.8458) (9.9052) (0.5160) (3.5580) (1.1638)

Demand for Money Equation:

$$m_t - p_t = 0.0391 (y_t + Y^P_t) - 0.0048 r_t + 0.9122 (m_{t-1} - p_{t-1}) \qquad R^2 = 0.8850$$

(3.4333) (5.3990) (32.4930)

Demand for Real Output Equation:

$$y_t = 0.8411 y_{t-1} + 0.2282 (m_t - p_t) - 0.2295 (m_{t-1} - p_{t-1}) - 0.0004 (r_t - \pi_t) - 0.0210(p_t - s_t - p^*_t) + 0.0194(p_{t-1} - s_{t-1} - p^*_{t-1}) + 0.4961 y^*_t - 0.3482 y^*_{t-1}$$

(12.4360) (3.9473) (4.0982) (1.3577) (0.4957) (0.4710) (3.6588) (2.4518)

$R^2 = 0.9251$

Inflation Rate Equation:

$$\pi_t = 2.4304 + 0.2197 \pi_{t-1} + 0.1782 \pi_{t-2} + 0.2337 \pi_{t-3} \qquad R^2 = 0.2221$$

(2.1626) (1.8592) (1.4948) (1.9862)

Exchange Rate Equation:

$$s_t = 1.4369 s_{t-1} - 0.4367 s_{t-2} \qquad R^2 = 0.9853$$

(13.382) (4.0651)

Note: Absolute t-ratios are in parentheses.

those obtained by Clinton (1973) over the period 1955-70.[53] The expected nominal interest rate responds negatively with the demand for money; this is as expected. The elasticities of the estimated short-run and long-run interest rates are -0.005 and -0.05, respectively. The magnitudes are higher than those estimated during 1955-1970.[54] The speed of adjustment between desired money holdings and last period's money holdings is 0.09.

The estimated coefficients in the demand for real output equation are all jointly statistically significant and of the proper signs. Real output responded to changes in real money balances and US real output with two lags. As indicated in Section 3.2 of Chapter 3, the expected real interest rate influences real output through both an income effect and a substitution effect. The OLS estimation results suggest that real interest rates influence real output negatively; this means that the substitution effect dominates the income effect.

Finally, the demand for real output reacts negatively on the terms of trade at time t, indicating that a J-curve does not exist. The result does not support Dornbusch and

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[53]K. Clinton, op.cit., p. 57 Table 1 indicates that the short-run and the long-run income elasticities using M1 were 0.1 and 0.9, respectively.

[54]K. Clinton, op. cit., p. 57, Table 1 indicates that the short-run interest rate elasticity using M1 was -0.03, and the long-run interest rate elasticity was -0.3.

Krugman's (1976) argument that export prices and physical trade adjust slowly to currency depreciation but import prices respond immediately. One reason for the non-existence of a J curve might be because of the high degree of capital mobility between Canada and the United States. Moreover, because of the capital mobility between Canada and the United States, US real output influenced Canadian real output significantly.

4.3.3 Full Information Maximum Likelihood (FIML) Estimation and Results

Using the model presented in the previous section, the system of equations is simultaneously estimated by the FIML method with rational expectations restrictions imposed. This estimation method applies to the five interdependent equations of the model, and yields estimates of all the structural parameters simultaneously. The FIML method assumes the following: (1) the complete specification of all the equations of the model is known; and, (2) the disturbance terms of the structural equations are normally distributed with zero means and constant variances. The FIML estimates possess the desirable properties of efficiency and consistency.

The estimation period is from 1972Q1 to 1989Q4. The FIML estimation results are reported in Table 4-3. The

TABLE 4-3

FIML ESTIMATES OF THE MODIFIED MODEL (1972Q1 TO 1989Q4)

Interest Rate Reaction Equation:

$$r_t = 1.3594 r_{t-1} + 0.0644 r_{t-2} - 0.3896 r_{t-3} + 0.5795 (r^*_t - r_{t-1}) - 0.0852 (r^*_{t-1} - r_{t-2}) - 0.3367 (r^*_{t-2} - r_{t-3}) - 5.3422 D_t(m^T_t - m_{t-1})$$

(6.4737) (0.1779) (1.7706) (5.3629) (0.5077) (1.6853) (0.6457)

Demand for Money Equation:

$$m_t - p_t = 0.0499 (y_t + Y^P_t) - 0.0052 \tilde{r}_t + 0.8858 (m_{t-1} - p_{t-1})$$

(2.4725) (3.2473) (17.6550)

Demand for Real Output Equation:

$$y_t = 0.8707 y_{t-1} + 0.2311 (m_t - p_t) - 0.2285 (m_{t-1} - p_{t-1}) - 0.0002 (\tilde{r}_t - \tilde{\pi}_t) - 0.0469 (p_t - s_t - p^*_t) + 0.0496 (p_{t-1} - s_{t-1} - p^*_{t-1}) + 0.4959 y^*_t - 0.3818 y^*_{t-1}$$

(5.7103) (0.7678) (0.8416) (0.1314) (0.6289) (0.8296) (1.5017) (0.9948)

Inflation Rate Equation:

$$\pi_t = 2.5148 + 0.3673 \pi_{t-1} + 0.0894 \pi_{t-2} + 0.1614 \pi_{t-3}$$

(0.6775) (0.7871) (0.2372) (0.8888)

Exchange Rate Equation:

$$s_t = 1.4535 s_{t-1} - 0.4532 s_{t-2}$$

(7.9029) (2.4646)

Note: Absolute t–ratios are in parentheses.

estimated coefficients obtained from the restricted FIML estimation do not differ substantially in magnitudes from those obtained from the OLS estimation. The FIML estimates are able to preserve the same signs as the OLS estimates. The t-ratios are, however, lower than those obtained from the OLS estimation. These FIML estimation results will be used in the next chapter to examine the robustness of the model.

4.3.4 The Rational Expectations Hypothesis Test

The model contains two unobservable variables: expected nominal ($\tilde{r}$) and real interest ($\tilde{r}$ - $\tilde{\pi}$) rates (see Appendix B). Economic agents are assumed to form their expectations on nominal and real interest rates rationally. The lag specification result yields a model with the following structures: seven parameters in the interest rate reaction equation, eight parameters in the demand for real output equation, four parameters in the inflation rate equation, and two parameters in the exchange rate equation. To test the Rational Expectations Hypothesis, the interest rate reaction and the inflation rate equations are substituted into the demand for money equation (see equation (3.2) in Appendix B) and the demand for real output equation, forming two nonlinear equations with no unobservable variables. Besides the coefficients (βs), the demand for money equation contains the seven coefficients (δs) of the interest rate reaction equation. The demand for real output equation also contains the seven δs and the four πs, coefficients of the interest rate reaction and inflation rate equations, respectively. Hence the rational expectations solution of the model, presented in Appendix B, involves a total of eighteen cross-equation restrictions. To obtain an unrestricted system of equations, variables are entered linearly into the demand for money and the demand for real output equations and no cross-equation restrictions are imposed.

The Rational Expectations Hypothesis (REH) is tested, using the following methodology. The likelihood ratio (LR) test statistic is LR=2(LLU-LLR). Here, LLU denotes the maximum value of the log-likelihood function of the unrestricted model; LLR denotes the maximum value of the log-likelihood function of the restricted model. The test statistic is distributed as $\chi^2(r)$, where r is the number of restrictions imposed in the model. The null hypothesis that rational expectations restrictions are true is tested against the alternative hypothesis that rational expectations restrictions are not true.

A likelihood ratio test based on the model in Table 4-2 is performed. The calculated LR statistic is 74.03 with eighteen restrictions imposed in the model. This statistic is greater than the critical value of 28.87 at 5 percent significance level. It fails to accept the null hypothesis that rational expectations restrictions are true.

Some justifications need to be made regarding the above conclusion. As argued in Section 3.5 of Chapter 3, rejection of the cross-equation restrictions can be because of misspecification in the underlying model or because the Rational Expectation Hypothesis is false. In this study, although the null hypothesis of the cross-equation restrictions test is rejected, one cannot conclude whether the model is misspecified or the Rational Expectations Hypothesis is false.

4.4 Summary

Gregory and Raynauld's (1985) model is used to analyze the conduct of Canadian monetary policy over the 1970s. This chapter utilizes their model to extend the examination period to the end of the 1980s. Lag structures of the explanatory variables in the model are, therefore, required to be re-examined. Four regressor selection criteria are used in this study: the F-test, the Akaike Information Criterion (AIC), the Schwarz Criterion (SC), and the Amemiya Final Prediction Criterion (PC).

The F-test is the conventional way to select the optimal regressors to be included in an equation. However, it has the pretest problem. This problem is avoided by the other three criteria which select a model based on the consideration of a loss function. These three criteria provide consistent results regarding the lag structures in the model. Durbin's h-test is also used to test for the presence of autocorrelation in error terms.

Based upon the model selected by the aforementioned criteria, the system of equations was estimated simultaneously using the FIML method with rational expectations restrictions imposed. The estimation period is from 1972Q1 to 1989Q4. The results indicated that the estimated coefficients do not differ substantially from those under the OLS estimation. The t-ratios are, however, lower than those in the OLS estimation. The rational expectations restrictions are also rejected. This model will be used in Chapter 5 to examine its stability over time.

CHAPTER 5

STABILITY TESTS DURING THE 70s AND THE 80s

5.1 Introduction

The empirical findings of the model described in the previous chapter yield estimates of proper sign and of statistical significance. Clinton (1973) stated that the usual criteria of high t-ratios and high R^2s do not, however, preclude significant shifts in the estimated coefficients between different sub-periods. It is, therefore, desirable to check for the presence of structural changes in the model. Stability tests are also carried out to examine whether the structural changes are associated with changes in the structure of the economy or in the conduct of Canadian monetary policy.

As discussed in Chapter 2,[55] there were changes in the execution of Canadian monetary policy after the 70s. Firstly, the Bank of Canada abandoned targeting the narrow monetary aggregate, M1, in 1982. Secondly, interest rates were used to support the exchange rate in the early 80s. Finally, the Bank of Canada adopted a zero inflation target in 1988. The structure of the Canadian economy had also changed in the 80s. Financial innovations and technological

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[55]Chapter 2 provides a historical review of the economy and the conduct of monetary policy during the 70s and the 80s.

advancements are the key changes during the 80s.[56] Based upon this descriptive information, one can conclude that the conduct of monetary policy, as well as the structure of the economy in the 80s was different from that in the 70s.

The purpose here is to investigate empirically the stability of both the conduct of Canadian monetary policy and the structure of the economy during the 70s and the 80s within a system of equations framework. Godfrey's (1988) likelihood ratio (LR) test is used to examine whether the estimated parameters change significantly around breakpoints in the full-sample period. This chapter extends the analysis to identify the causes of structural changes: a shift in the execution of monetary policy, and a shift in the structure of the economy.

This chapter is arranged as follows. The following section introduces the test statistic, and describes the procedures that are used to test for systemwide structural changes over the 1972Q1 to 1989Q4 period. Section 5.3 presents the procedures that are used to identify the sources of structural changes. A brief summary of the tests, as well as implications for economic forecasting and for monetary policy is provided in Section 5.4.

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[56]See Chapter 2 for details.

5.2 Systemwide Stability Test and Results

5.2.1 Procedures

A stability test is used to test for parameter constancy. Specifically, it is used to determine whether structural changes in the estimated parameters occur in the sample period under study. Procedures to perform the test of parameter constancy are illustrated below.

Godfrey (1988) claimed that discussions of system tests have usually been based on the likelihood principle. In this study we, therefore, use Godfrey's (1988) Likelihood Ratio (LR) test as a system test of parameter constancy. Analogous to Chow (1960), the full-sample is divided into two sub-samples. The two sub-samples must contain enough observations to permit the estimation of the complete parameter vector by the FIML method. The null hypothesis, that there are no structural changes in the model over the entire period, is tested against the alternative hypothesis that structural changes do occur.

The LR test statistic is the following:[57]

$$LR = 2(LR1+LR2-LRR)$$

LRR is denoted as the maximized log-likelihood function associated with the FIML estimation based upon the full-sample period. This is the restricted maximized log-

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[57]This formula is obtained from L. G. Godfrey (1988), Misspecification Tests in Econometrics, (New York), p. 200.

likelihood function under the null hypothesis. LR1 and LR2 denote the maximized log-likelihood functions derived from the first and second sub-samples, respectively. (LR1 + LR2) is the unrestricted maximized log-likelihood under the alternative hypothesis. The LR test statistic is distributed as $\chi^2(r)$ under the null hypothesis, where r is the number of restrictions. The decision rule is as follows: if the observed LR value is greater than the critical value of the χ^2 distribution at a pre-chosen level of significance, reject the null hypothesis, which indicates that there is evidence of structural changes.

5.2.2 Examinations and Results

Gregory and Raynauld (1985) estimated the model over the 1970s. The actual estimation period was 1970Q3-1981Q3. The purpose here is to extend the estimation period to the last quarter of 1989 and to examine if there are any structural changes after 1981Q3. Therefore, the structural break is 1981Q4. Numerical problems, however, occur when we attempt to estimate the model using 1981Q4 as the breakpoint. The breakpoint is then moved one quarter backward until numerical problems disappear. 1980Q2 is the closest structural break to the 1981Q4 breakpoint. The full-sample period 1972Q1-1989Q4 is, therefore, divided into two sub-periods: 1972Q1-1980Q1 and 1980Q2-1989Q4.

Godfrey's (1988) LR test is used to investigate the stability of the model. The null hypothesis that there are no structural changes in the 70s and the 80s is tested against the alternative hypothesis that there are structural changes in the past two decades. To test the null hypothesis, the following approach is employed.

The model (see Table 4-3) is estimated using the FIML method for the entire 1972Q1 to 1989Q4 period. The value of the restricted maximized log-likelihood function, LRR, is calculated. The system of equations is then re-estimated for the two sub-periods: 1972Q1-1980Q1, and 1980Q2-1989Q4. The values of the unrestricted maximized log-likelihood functions, LR1 and LR2, are computed. The LR statistic is then calculated.[58] Table 5-1 presents the stability test results. The calculated LR value is 141.68 with thirty-nine restrictions imposed in the model. We employ a 5 percent significance level to test the null hypothesis of stability. The computed LR value is greater than the critical χ^2 value of 43.77. Therefore, the null hypothesis that there are no structural changes is rejected.

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[58] LR=2(LR1+LR2-LRR)

TABLE 5–1

SYSTEMWIDE STABILITY TEST RESULTS: 1972Q1 TO 1989Q4

ESTIMATION PERIOD	MAXIMIZED LOG-LIKELIHOOD FUNCTION	RESULT
1972Q1–1989Q4	LRR	327.15
1972Q1–1980Q1	LR1	209.99
1980Q2–1989Q4	LR2	188.0
	LR = 2 (LR1 - LR2 + LRR)	141.68*

Note: The critical value of $\chi^2_{0.05}$ (39) = 43.77.
* statistically significant at the 5% level

LR: The likelihood ratio test statistic

5.3 Further Stability Tests and Results

5.3.1 Procedures

The result of the systemwide stability test indicates that there were structural changes over the period 1972Q1-1989Q4. The objective in this section is to examine the causes of those structural changes. The causes can result from changes in the conduct of Canadian monetary policy, and/or in the structure of the economy. To test the structural changes of the coefficients in the model, dummy variables are attached to the policy variables and the private agents' behavior variables. The model is then estimated using the FIML method. A likelihood ratio test is used to check if structural changes occur in the conduct of monetary policy and/or in the structure of the economy.

The model contains five equations. The interest rate reaction equation models the conduct of monetary policy, whereas the demand for money equation and the demand for real output equation model private agents' behavior. The exchange rate and the inflation equations are time series equations.[59] As a consequence, the variables associated with the interest rate reaction equation are policy variables; the variables associated with the demand for money and the demand for real output equations are the

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[59]A. W. Gregory and J. Raynauld, op. cit., pp. 49-50 provided some justifications in using time series to model these two equations.

variables of the structure of the economy. To test the structural changes in the conduct of Canadian monetary policy and/or in the structure of the economy, dummy variables are incorporated into the policy variables and individual's behavior variables, respectively. The model is estimated using the FIML method.

A likelihood ratio (LR) test is used to test the null hypothesis that there are no structural changes in the model against the alternative hypothesis that there are structural changes. The LR test statistic is as follows:

$$LR = 2(LLU - LLR).$$

LLR is the maximized log-likelihood function when the null hypothesis is imposed. LLU is the unrestricted maximized log-likelihood function under the alternative hypothesis. This statistic follows a χ^2 distribution with r restrictions. If the computed LR statistic is greater than the critical value of the χ^2 distribution at a pre-selected significance level, reject the null hypothesis that there are no structural changes in either the conduct of monetary policy or the economic structure over the 70s and the 80s.

5.3.2 Examinations and Results

As the result of the systemwide stability test indicates, there were structural changes during the period under examination (1972Q1-1989Q4). Those changes can result from changes in the economic structure and/or in the execution of the Bank of Canada's policy. Two stability tests are performed. Firstly, we test whether the structural changes correspond to changes in the conduct of Canadian monetary policy. Secondly, whether the structural changes are due to changes in the structure of the economy is also examined.

The sample period is from 1972Q1 to 1989Q4. The breakpoint is the same as that is used in the systemwide stability test. Dummy variables are set equal to zero from 1972Q1 to 1980Q1, and are set equal to one over the 1980Q2-1989Q4 period. The model is estimated using the FIML method for the entire 1972Q1 to 1989Q4 period.

Firstly, the model is estimated without incorporating dummy variables into the system of equations. This is the restricted model under the null hypothesis that there are no structural changes. LLR, the restricted maximized log-likelihood function, is equal to 327.15 (see Table 5-2).

Secondly, dummy variables are included in the model to shift the coefficients associated with the policy variables. The null hypothesis, in this case, is that there are no changes in the execution of monetary policy. Using the FIML method, the model is estimated over the 1972Q1 to 1989Q4 period. The result is reported in Table 5-2. The

TABLE 5-2

STABILITY TEST RESULTS: THE CONDUCT OF CANADIAN MONETARY POLICY AND THE STRUCTURE OF THE CANADIAN ECONOMY

STRUCTURAL CHANGES	MAXIMIZED LOG-LIKELIHOOD FUNCTION	LIKELIHOOD RATIO TEST STAT	χ^2 CRITICAL VALUE	REJECT H_0 ?
MONETARY POLICY	LLU = 334.29 LLR = 327.15	14.29	$\chi^2_{.01}(7)$ =18.48 $\chi^2_{.05}(7)$ =14.07	NO[a] YES[b]
THE STRUCTURE OF THE ECONOMY	LLU = 364.47 LLR = 327.15	74.64	$\chi^2_{.01}(11)$ =24.73 $\chi^2_{.05}(11)$ =19.68	YES[a] YES[b]

[a] at the 1 percent significance level
[b] at the 5 percent significance level

LLU: the unrestricted maximized log-likelihood function
LLR: the restricted maximized log-likelihood function
H_0: the null hypothesis of no structural change

computed value of the unrestricted maximized log-likelihood function, LLU, is 334.29. The LR value is equal to 14.29 with seven restrictions imposed under the null hypothesis. The null hypothesis of no change in the conduct of monetary policy is marginally rejected at a 5 percent significance level; however, it is accepted at a 1 percent level.

Finally, it is desirable to examine whether the structure of the economy had changed during the 1980s. Dummy variables are used to shift the coefficients of the demand for real output equation and the demand for money equation. This unrestricted model is estimated using the FIML method for the 1972Q1-1989Q4 period. The null hypothesis is that there are no changes in the structure of the economy during the 1980s. Table 5-2 presents the test result. The calculated value of the unrestricted maximized log-likelihood function, LLU, is 364.47. The LR value of 74.64 with eleven restrictions imposed in the model reject the null hypothesis at both 5 percent and 1 percent levels. That is, there is evidence of changes in the structure of the economy in the 1980s. As the LR value indicates, the rejection of no change in the structure of the economy is very large. This indicates that there were large changes in the structure of the economy over the 1980s.

5.4 Summary and Implications

The systemwide stability test indicates that there were structural changes during the 70s and the 80s. That is, either the structure of the economy or the execution of Canadian monetary policy is not stable during the period under investigation. The result is consistent with the literature survey documented in Chapter 2.

Two stability tests are performed to examine whether the structural changes result from changes in monetary policy, and/or in the structure of the economy. The results indicate that both the conduct of monetary policy and the structure of the Canadian economy changed during the 70s and the 80s. A large portion of those changes are, however, due to changes in the structure of the economy. It is consistent with the descriptive analysis presented in Chapter 2 that the Canadian economy had undergone major changes in financial markets, technology, and the nature of international trade during the 1980s.

These results have implications for economic forecasting and policy analysis. The findings indicate that the economic model developed upon the 70s data cannot be used to explain and forecast both the structure of the economy and the conduct of Canadian monetary policy in the 80s. Policy decisions are often based upon the nature of certain important relationships. Because structural changes exist in the model, policy makers should, therefore, be made aware of the above parametric changes that had taken place in the past.

CHAPTER 6

CONCLUSIONS AND IMPLICATIONS

The instruments and goals of Canadian monetary policy have initiated much discussion and debate by the media, scholars, and the public. As the literature survey in Chapter 2 indicates, there were changes in the structure of the economy, and in the execution of Canadian monetary policy during 1970-1989. Using an econometric model, this thesis examines those structural changes over the past two decades empirically.

Gregory and Raynauld (1985) developed a system of five interdependent equations to investigate Canadian monetary policy during the 1970s. In their model, economic agents are assumed to form their expectations rationally. The FIML method is used to estimate the system of equations simultaneously. The Rational Expectations Hypothesis is tested. The result indicated that it is not rejected during the 70s.

This thesis utilizes their model to extend the investigation period to the end of the 80s. Lag lengths in the model are re-examined because a longer sample period is employed. Four different regressor selection criteria are used to determine the lag structures of the system of equations. They are the F-test, the Akaike Information

Criterion (AIC), the Schwarz Criterion (SC), and the Amemiya Final Prediction Criterion (PC). Durbin's h-test is also used to check for the presence of autocorrelation in error terms.

After the appropriate lag structures are determined, the FIML method is used to estimate the model for the period 1972Q1 to 1989Q4 with rational expectations restrictions imposed. The estimated coefficients display the proper signs. The t-ratios are, however, low. The validity of the Rational Expectations Hypothesis in the model is also tested. The null hypothesis that economic agents form their expectations rationally is rejected. This rejection is either because the Rational Expectations Hypothesis is not true or because the model is misspecified.

The model is tested for systemwide stability over time by re-estimating the equations for the sub-periods 1972Q1-1980Q1 and 1980Q2-1989Q4, and then by employing the Likelihood Ratio test over the period 1972Q1-1989Q4. The result indicates that there were structural changes during the 70s and the 80s. It implies that the model cannot be used to explain the conduct of Canadian monetary policy and the structure of the economy in the 80s; the model is not robust over time. These structural changes also explain the rationale behind the inferior FIML estimation results during the period 1972Q1 to 1989Q4.

The structural changes can result from changes in the structure of the economy and/or in the execution of monetary policy. Two structural tests are, therefore, used to identify the causes of the structural changes in the last two decades. The tests are performed by employing dummy variables to shift the coefficients of the policy variables, and the structure of the economy variables in the model. The Likelihood Ratio test is used to test the null hypothesis that there is no structural shift. The results indicate that both the execution of Canadian monetary policy and the structure of the economy changed during the 70s and the 80s. The latter is, however, the more important source of structural instability.

In light of the above conclusions, the model is required to be modified according to the changes in the structure of the economy during the 70s and the 80s to yield structural stability. Furthermore, other monetary aggregates such as M2 or M2+ should be used instead of M1 because results from past analyses indicated that using M1 as the monetary aggregate yielded instability in the demand for money equation.

The empirical findings in this study have implications for economic forecasting and policy analysis. If the model exhibits instability over time, it can no longer be used for economic forecasting and policy analysis. If policy makers continue to use the model to forecast or to evaluate the impacts of monetary policy, incorrect results will be yielded. Policy makers when performing economic forecasting or policy analysis should, therefore, aware of the existence of structural instability in a model.

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APPENDIX A

DATA SOURCES

All series are from the Cansim databank except for the Canadian GNE and Canadian GNE implicit price deflator in the 80s.

Data for the Canadian GNE and Canadian GNE Implicit Price Deflator in the 80s are obtained from the Bank of Canada Review, various issues.

All series are seasonally adjusted.

CANADIAN VARIABLES:	CANSIM DATABANK NO.
Real GNE	D40593 (for the 70s) Bank of Canada Review, various issues (for the 80s)
GNE Implicit Price Deflator	D40625 (for the 70s) Bank of Canada Review, various issues (for the 80s)
M1	B1627
Spot Exchange Rate	B40001
90-day Prime Corporate Paper Rate	B14017

U. S. VARIABLES:	CANSIM DATABANK NO.
U.S. Real GNE	D360013
U.S. Nominal GNE	B50201
90-day U.S. Commercial Paper Rate	B54412

APPENDIX B

THE MODEL

Interest Rate Reaction Equation

$$r_t = \delta_o + \sum_{i=1}\delta_{1i}r_{t-i} + \sum_{i=0}\delta_{2i}(r^*_{t-i} - r_{t-1-i}) + \sum_{i=0}\delta_{3i}D_t(m^T_{t-i} - m_{t-1-i}) + e_{1t} + \sum_{i=1}\theta_i e_{1t-i} \quad (3.1)$$

Demand for Money Equation

$$m_t - p_t = \beta_o + \beta_1(y_t + Y^P_t) + \beta_2\tilde{r}_t + \beta_3(m_{t-1} - p_{t-1}) + e_{2t} + \sum_{i=1}\phi_i e_{2t-i} \quad (3.2)$$

Demand for Real Output Equation

$$y_t = \alpha_o + \sum_{i=1}\alpha_{1i}y_{t-i} + \sum_{i=0}\alpha_{2i}(m_{t-i} - p_{t-i}) + \alpha_3(\tilde{r}_t - \tilde{\pi}_t) + \sum_{i=0}\alpha_{4i}(p_{t-i} - s_{t-i} - p^*_{t-i}) + \sum_{i=0}\alpha_{5i}y^*_{t-i}$$

$$+ e_{3t} + \sum_{i=1}\psi_i e_{3t-i} \quad (3.3)$$

Inflation Rate Equation

$$\pi_t = \lambda_o + \sum_{i=1}\lambda_{1i}\pi_{t-i} + e_{4t} + \sum_{i=1}\eta_i e_{4t-i} \quad (3.4)$$

Exchange Rate Equation

$$s_t = \mu_o + \sum_{i=1}\mu_{1i}s_{t-i} + e_{5t} + \sum_{i=1}\vartheta_i e_{5t-i} \quad (3.5)$$

APPENDIX B (CONTINUED)

THE RATIONAL EXPECTATIONS SOLUTION

Demand for Money Equation

$$m_t - p_t = \beta_o + \beta_1(y_t + Y^P_t) + \beta_2 [\delta_o + \sum_{i=1}\delta_{1i}r_{t-i} + \sum_{i=0}\delta_{2i}(r^*_{t-i} - r_{t-1-i})$$

$$+ \sum_{i=0}\delta_{3i}D_t(m^T_{t-i} - m_{t-1-i}) + \sum_{i=1}\theta_i e_{1t-i}] + \beta_3(m_{t-1} - p_{t-1})$$

$$+ e_{2t} + \sum_{i=1}\phi_i e_{2t-i} \qquad (3.2a)$$

Demand for Real Output Equation

$$y_t = \alpha_o + \sum_{i=1}\alpha_{1i}y_{t-i} + \sum_{i=0}\alpha_{2i}(m_{t-i} - p_{t-i})$$

$$+ \alpha_3[(\delta_o + \sum_{i=1}\delta_{1i}r_{t-i} + \sum_{i=0}\delta_{2i}(r^*_{t-i} - r_{t-1-i}) + \sum_{i=0}\delta_{3i}D_t(m^T_{t-i} - m_{t-1-i}) + \sum_{i=1}\theta_i e_{1t-i})$$

$$- (\lambda_o + \sum_{i=1}\lambda_{1i}\pi_{t-i} + \sum_{i=1}\eta_i e_{4t-i})]$$

$$+ \sum_{i=0}\alpha_{4i}(p_{t-i} - s_{t-i} - p^*_{t-i}) + \sum_{i=0}\alpha_{5i}y^*_{t-i} + e_{5t} + \sum_{i=1}\vartheta_i e_{5t-i} \qquad (3.3a)$$

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