NOTE TO USERS

Three Essays on Inflation Targeting

by

Jamal Hejazi, B.Comm. M.A.

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Abstract

This thesis tests various hypotheses about what variables the Bank of Canada and the U.S. Federal Reserve plan to target using monetary policy. In particular, I test whether monetary policy targets inflation or real output, and whether there is a provincial bias in monetary policy.

Chapter 1 uses the Rowe and Yetman (2002) technique to test whether the US Federal Reserve is targeting inflation or growth rates in real Gross Domestic Product. The reasons for this analysis are twofold. First although the United States has not explicitly stated that it targets inflation, we can test whether they do target inflation nonetheless. Second I aim to identify whether the U.S. faced supply as opposed to demand shocks. My findings suggest that the U.S. has probably faced supply as well as demand shocks.

Chapter 2 moves a little further away from Rowe and Yetman (2002) and investigates whether there has been a provincial bias in monetary policy. The first part of chapter 2 used the Rowe-Yetman (2002) technique to determine whether monetary policy has been used to target inflation in certain provinces at the expense of inflation instability in other provinces. My findings suggest that there does not exist a bias in monetary policy. In fact, when the central bank targets national inflation rates, it also smoothes provincial inflation rates. The second part of chapter 2 looks at whether the central bank has attempted to target output growth in certain provinces at the expense of output growth stability in other provinces. My findings show that the Bank of Canada has not smoothed either national or provincial GDP growth rates.

Chapter 3 investigates whether there has been a tradeoff between inflation smoothing and output smoothing. I first review what the consensus has been regarding this subject by various authors for the last 20 years. I then lay out the theoretical basis for why a tradeoff would exist and then draw on my results from the first two chapters to show that there indeed exists a negative tradeoff between inflation and output variability that could only exist with the presence of supply shocks.

Dedication

To my loving wife, who supported me through this long and tedious process called a Ph.D. And in loving memory of my father, who taught me to value and cherish education.

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I would like to thanks the members of my committee, especially Professors Nick Rowe and Steve Ferris, Emmanuel Apel, and James Yetman who gave me not only excellent guidance, but also in patience. I would also like to thank Casey Warman and Shannon Poole. Without their existence, I would have never have gotten through. To them, I will forever be grateful.

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Chapter 1: Is the Federal Reserve Targeting Inflation? An application of the Rowe and Yetman technique to the United States.

Abstract:

I apply the Rowe and Yetman (2002) technique in chapter 1 to determine the monetary policy strategy of the Federal Reserve System in an era where many central banks have decided to explicitly target inflation. Applying the Rowe and Yetman technique to the United States is interesting for two reasons. First, I am able to determine what has been targeted in light of the fact that the U.S. Federal Reserve has been quite vague on this issue. Secondly, I am able to determine when the particular variable was targeted. My empirical findings suggest that the United States Federal Reserve has in fact been *moving towards targeting inflation over the 1990s even though that strategy has not been explicitly stated.* One other interesting finding is that the U.S. Federal Reserve has decided to begin targeting inflation much later than other nations, such as Canada, that have explicitly stated their desire to target inflation earlier in the 1990s. While the U.S. Federal Reserve has made moves to target inflation, it has not targeted output growth.

1. Introduction

Throughout the world, monetary policy has increasingly come to incorporate explicit inflation targets, especially since the early 1990s. Countries with formal targets include Australia, Canada, Finland (prior to 1999), Israel, New Zealand, Spain (prior to 1999), Sweden, and the United Kingdom.[1] Surprisingly, this list does not include the United States, a nation that has had a very conservative central banker who has often instituted tight monetary policy during good economic times in order to tame inflation. Though the United States has led the industrialized world in Gross Domestic Product growth and innovation, its monetary policy has not included explicit inflation targets[2]. The purpose of this paper is to determine whether or not the U.S. Federal Reserve has been implicitly targeting either output or inflation. While the approach I use is that of Rowe and Yetman (2002) who asked the same question of the Bank of Canada, I apply that to the U.S. experience. The focus of this paper is unique given that we are empirically determining what the U.S. Federal Reserve has been really doing in an era where they have been quite vague with respect to how they conduct monetary policy. Using the Rowe and Yetman (2002) technique, I find evidence consistent with the hypothesis that the U.S. Federal Reserve has indeed used monetary policy to target the inflation rate rather than the growth rate of Gross Domestic Product.

Section II of this paper gives a brief discussion of the current mandate of the U.S. Federal Reserve. Section III describes the model used in the paper, while Section IV describes the empirical testing. Section V gives the empirical results with respect to the question of inflation versus output smoothing. Section VI concludes.

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[1] For a detailed description of what these countries targeted specifically, see table 1 in the appendix.

[2] The United States Federal Reserve targeted money growth in the 1970s.

II. What the U.S. Federal Reserve has done and what it should do. A survey:

The current mandate of the U.S. Federal Reserve can be stated as follows:

> "The Board of Governors of the Federal Reserve System and the Federal Open Market Committee shall maintain long run growth of the monetary and credit aggregates commensurate with the economy's long run potential to increase production, so as to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates" (Source: Federal Reserve Act, Section 2A-Monetary Policy Objectives)

In 1913 the Federal Reserve was created with the primary purpose of preventing financial panics in the economy. When the great depression hit the United States in the 1930s, the Federal Reserve mandate changed and was extended into the Employment Act of 1946. This act called for the Federal Reserve to target output in such a way as to achieve full employment. The Full Employment and Balanced Growth Act in 1978 required the Federal Reserve to pursue polices to promote employment along with reasonable price stability.

According to most observers (Thorbecke, 2000), the current mandate of the Federal Reserve has been dual in nature and not one of targeting inflation solely. There exists both empirical evidence and public statements from the Federal Reserve itself that a dual mandate is presently being followed. There is also evidence that the Federal Reserve adjusts its policy instrument to smooth fluctuations in output and inflation. For example, the fact that the Federal Funds Rate is consistent with the Taylor rule is one piece of evidence given by Judd and Rudebusch (1999). The Taylor rule is a process of calculating a recommended rate, assigning equal weight to deviations of output from its potential level and to deviations of inflation from its target (Taylor 1998).

The Taylor rule is given by a function similar to the one below:

$$i=\Pi +0.02 + 0.5y + 0.5(\Pi-0.02),$$

where i=nominal interest rate

Π= the rate of inflation over the previous four quarters

$y=(Y-Y^*)/Y^*$= the percentage deviation of output from full employment output

The Taylor rule requires the real interest rate to respond to:

i) The difference between output from potential

ii) The difference between inflation and target (here taken to be 2%)

(Abel, Bernanke, and Smith, 2003, 540).

Comments by at least one member of the U.S. Federal Reserve also lends support to the notion that both output and inflation smoothing has been targeted. Laurence H. Meyer states that the objectives of monetary policy are short run stabilization of output relative to potential and long run price stability (Meyer, 1996). Federal Reserve Governor Roger Ferguson (2002) suggests similar objectives in his statement of 2002 that the U.S. Federal Reserve stands "ready to do what is necessary to maintain financial stability, as we did on September 11, and to maintain a monetary policy stance that will foster price stability and promote maximum sustainable growth in output" (Ferguson, 2002).

Though the dualism in the Federal Reserve mandate has been legislated, there have been challenges to the dual mandate. The Price Stability Act of 1999 (which failed to pass) called for the Federal Reserve to set inflation stability as the primary goal of the bank's mandate. This Act shows the tendency of some lawmakers and lobbying groups to argue for inflation alone to be the Federal Reserve's target. Those that favor a policy of

stable inflation as the primary goal of the Federal Reserve include Bernanke and Mishkin (1997). Those who think that inflation stability ought to be the primary objective of the Federal Reserve argue that:

1.Explicit targeting would provide a clear framework that would force the Federal Reserve to focus attention on what it can achieve;
2.Inflation targets would help anchor inflation expectations in the economy;
3. Inflation targets would help institutionalize good monetary policy;
4. Given that the current mandate is ambiguous, inflation targets would better assess the Federal Reserves performance and hold it to account for maintaining low inflation; (Rudebusch and Walsh, 1998: 3).

The desire to change the Federal Reserve's mandate to one primarily of inflation targeting is also supported by many economists at the Federal Reserve. These include E. Gerald Corrigan, former President Federal Reserve Bank of New York, W. Lee Hoskins, President, Federal Reserve Bank of Cleveland, Robert T. Parry, President, Federal Reserve Bank of San Francisco and finally Robert Black, President, Federal Reserve Bank of Richmond. These four Federal Branch Presidents gave direct support to the House Joint Resolution 409, which supported giving the Federal Reserve the objective of a zero inflation rate (Federal Reserve Bank of Minneapolis, 1990, pages 1-2).

Some have argued that the Federal Reserve's mandate could be improved by increasing the transparency of the goals and their dual nature. However, achieving transparency in these dual goals is difficult. First, the goal of full employment will never be very transparent given that it is not directly observed, but only estimated (and even this with limited precision). In addition, price stability as a goal is not without ambiguity. For example, recent analysis has uncovered systematic biases on the order of 1 percentage point in the CPI's measurement of inflation (see Motley, 1997).

Because two goals reduce responsibility for any one goal, some economists (Barro and Gordon, 1983) have argued that the goal of the central bank should be more centered on price stability, therefore de-emphasizing business cycle stabilization. Having dual goals will lead to an inflation bias despite the Federal Reserve's attempt to control inflation. This argument stresses the fact that the Bank will attempt to engineer output gains in the short run which will overcome the central bank's desire to control inflation in the long run. As a result of elevated inflation expectations from the public, inflation will end up being higher than the central bank intended, despite its best efforts. This time inconsistency problem has often persuaded many central banks to focus directly on stable prices. However, this does not seem to have happened in the United States, where its policy of having ambiguity surrounding inflation targets has given it the ability to respond successfully to business cycle fluctuations.

The purpose of this paper will be to attempt to use the Rowe and Yetman technique to test the hypothesis that the U.S. Federal Reserve has actually targeted inflation over the period in question. As can be seen by the commentary above, it does not seem quite clear what the mandate actually has been. My findings suggest that behind the vagueness of U.S. monetary policy statements was a process moving towards the deliberate smoothing of inflation rather than output growth.

III. The Model

The model used in my thesis was developed by Nicholas Rowe and James Yetman and published in the Canadian Journal of Economics (2002). I will briefly outline their model as it applies to my problem.

The model begins by first making assumptions regarding a typical policy maker. Given that my thesis deals with the issue of monetary policy, my policy maker is a central banker. Rowe and Yetman (2002) assume that policymakers are rational and attempt to use instruments (D) at their disposal in order to target a specific variable (T). The policy maker has an information set (I_t) at time t, and uses everything in this information set to determine how to alter its instruments in order to achieve this target. The information set includes information obtained in the current period t.

Definitions

Let us define T as the variable being targeted. In the case of a central banker the target would be either inflation or the growth rate of Real Gross Domestic Product, (GRGDP).

Let D be the instrument at the disposal of the policy maker. For the central banker this could be either interest rates or money growth rates.

Let I_t be the information set of the policy maker or central banker;

Rowe and Yetman (2002) assume that the instrument that the central bank uses to target its objective will affect the target (T) only with a lag of j periods. This is because monetary policy takes time to work its way through the economy. Rowe and Yetman (2002) then describe the following relationship:

$$T_{t+j} = F(D_t, \ldots\ldots) \qquad (1)$$

There is then a mechanism by which changes in the current value of the instrument can predictably change the target after j periods.

From today's perspective, the actual outcome of the target variable can be thought of as consisting of two components. The first part is today's rational expectation where that value is conditional on the information available to the central bank at time t. The second part is the deviation of the actual from the rational expectation, called the forecast error. By the definition of rational expectations, the error term e_{t+j} will be uncorrelated with the central banker's information set, I_t. Assuming the policymaker knows the value of its instrument at time t, the instrument D_t will also be included in the information set I_t. All of this assumes that the sample size is large enough so that the sample movements resemble their population counterparts.

Given these assumptions, Rowe and Yetman (2002) rewrite the expression for the targeted variable as a combination of its expected value and forecast error:

$$T_{t+j} = E_t (T_{t+j} \mid I_t) + e_{t+j}. \qquad (2)$$

To test for inflation targeting, Rowe and Yetman also assume that the policy maker wants the targeted variable (T) to follow the following path:

$$T_t^* = B \times t \qquad \text{where B is a constant and t is a time trend} \qquad (3)$$

Given that there exists a j period lag between the setting of the Federal Reserve's instrument and the effect it has on the targeted variable, the arrival of other exogenous events in the interim periods implies means that the central banker will be unable to target the variable perfectly as in equation (3). As a result, the central bank, as a second best choice, must target the variable according to a time trend at control lag j and beyond.

Therefore, the central banker would set its instrument such that it achieves the following (Rowe and Yetman, 2002: 242):

$$E(T_{t+j} \mid I_t) = B(t+j) \quad (4)$$

To solve the model, they then substitute equation (4) into equation (2) yielding (Rowe and Yetman, 2002: 242):

$$T_{t+j} = B(t+j) + e_{t+j} \quad (5)$$

Rowe and Yetman (2002) argue that this is testable and that if it holds then deviations of the targeted variable about its trend must be uncorrelated with anything in the central bank's information set at time t.

In order that the readers can better grasp this subject, Rowe and Yetman (2002) define a given economy in the following way

$$T_{t+j} = \alpha D_t + \beta U_t + e_{t+j} \quad (6)$$

where T is the inflation rate, D_t is the instrument used by the central bank to target inflation rate T, and U are some other factors believed to affect inflation rates (such as growth of Real Gross Domestic Product)[3] and e_{t+j} is an unforecastable mean zero error term. If the central bank were to target a constant inflation target at rate 2%, it will choose D_t according to the following policy reaction function:

$$D_t = (2\% - \beta U_t) / \alpha - (e_{t+j} / \alpha) \quad \text{where } E(D_t \mid I_t) = (2\% - \beta U_t) / \alpha \quad (7)$$

Rowe and Yetman (2002) then substitute the value of the instrument, $E(D_t \mid I_t) = (2\% - \beta U_t)/\alpha$, into the above equation (6) which gives us the following relationship:

[3] It may be argued that one of the independent variables should include Gross Domestic Product relative to potential. One reason why this is not included in our forecasting equations above is due to the fact that reliable data on "potential" is difficult to obtain and therefore not in the bank's information set.

$$T_{t+j} = 2\% + e_{t+j} \qquad (8)$$

Rowe and Yetman (2002) take this to imply that deviations from target i.e. (T_{t+j} -2%) are unanticipated and perfectly unforecastable. If the central bank is targeting an unknown but constant inflation rate over time, then the independent variables in equation (6), either independently or together, will be insignificant as an explanation of variations in the inflation rate from the constant C (Rowe and Yetman, 2002: 243). If the bank targets a constant inflation rate, then the unforecastable variations in inflation rate mean that the Chi Square test statistic of the forecasting equation should be insignificant. Rowe and Yetman (2002) interpret this as evidence of inflation targeting. For the purposes of this thesis, I define "optimal in the Rowe and Yetman sense" as a situation where monetary policy has no observable effect on the deviation of inflation rates from target or the deviation of growth rates of GDP from target.

Developing the Null

This chapter investigates two things separately, namely whether or not the Federal Reserve has decided to smooth inflation or output growth. The first part of this chapter examines whether the central bank has targeted inflation optimally in the sense of Rowe and Yetman (2002). The second part attempts to determine whether GDP growth has been targeted.

To answer the first question, I estimate the following forecasting equation:

$$GCPI_t = C + \alpha_i GRGDP_{t-i} + \beta_i IR_{t-i} + \delta_i GMS_{t-i} + \varphi_i GCPI_{t-i} + e_t$$ [4]

[4] In order to be consistent with Yetman and Rowe with respect to lag structure, I also run a forecasting equation $GCPI_t = C + \sum_{i=j}^{j+k} \alpha_i GRGDP_{t-i} + \sum_{i=j}^{j+k} \beta_i IR_{t-i} + \sum_{i=j}^{j+k} \delta_i GMS_{t-i} + \sum_{i=j}^{j+k} \varphi_i GCPI_{t-i} + e_t$, where j is equal to 6 or 8 and k = 4 (given we are using quarterly data) and obtain similar results.

where i= 6 or 8, $GCPI_t$ is the growth of U.S. consumer price indexes, defined as the first difference of log CPI, GRGDP is the growth of Real U.S. GDP defined as the first difference of log GDP (where log signifies the natural log), IR is the log of the U.S. 90 day financial paper rate, GMS is the first difference of log U.S. M1. I lag the independent variables with a lag of 6 or 8, given that this is the period of time it is believed that monetary policy affects inflation.

For this particular test, the null hypothesis states that the slope coefficients are all simultaneously equal to zero. If I cannot reject the null, this would provide evidence consistent with the hypothesis that the U.S. Federal Reserve has targeted U.S. inflation. Conversely, if the null that all the slope coefficients are simultaneously equal to zero is rejected, or put more simply, if there exists at least one slope coefficient that is not equal to zero, this would provide evidence that the U.S. Federal Reserve has not targeted U.S. inflation.

Data Description

There are four sets of variables in our model. They are first, the U.S. inflation rate; second, the real growth rate of GDP; third, the three month corporate interest rate; and, finally, the growth rate of the money supply (M1). Growth rates are determined as the first difference of the natural logarithms of the variables. The data frequency used in this paper is quarterly with the period of estimation from 1973:Q2 to 2002:Q4. Before proceeding to the test, a few comments must first be made regarding the data. Calculating the growth rates transforms the model variables into stationary series (according to the Phillip-Perron set of criteria see exhibit 1 in the appendix). I use the rate of change of consumer prices as our measure of inflation, where my consumer price measure is the all

item CPI less energy and food prices. Since food and energy are the most volatile components of the Consumer Price Index, they have been excluded.

To be consistent with Rowe and Yetman (2002), I use the growth rate of the money supply (M1) and the interest rates (90 day corporate rate) as the monetary policy instruments. All data, as mentioned earlier, is quarterly in frequency. I use tests of "over identifying restrictions over a rolling sample", adding and dropping one observation in each regression I run. This is important as it accommodates an evolving economic structure through time as well as an evolving target, either of which is likely to result in over-rejection (Rowe and Yetman, 2002: 244).

IV. Empirical Testing

U.S. inflation

In this section, I test the hypothesis that the U.S. Federal Reserve has attempted to target inflation in the sense of Rowe and Yetman. To do so, I estimate regressions on quarterly data that incorporate the key macroeconomic variables that theory suggests should explain the movements of the targeted variable.

The first target considered is the inflation rate, defined as the growth rate of the CPI. To be consistent with Rowe and Yetman, I use their list of regressors.[5] In principle, the Rowe and Yetman (2002) method allows any variable to be considered as a potential forecaster, but in practical terms the degrees of freedom constraint requires us to use only

[5] While there may be other variables that may explain movements in changes in consumer price indices (or growth rates in GDP), the constraint imposed by the degrees of freedom problem limits our discussion to only a few independent variables that economic theory suggests should explain movements in economic activities. We believe that economic lends support to use including the variables that we did. It seems to be widely accepted that money supply, interest rates, gross domestic products and lag values of the inflation rate do causes movements in inflation. Though we could have included more variables, this would have further reduce our degrees of freedom and therefore reduced our ability to make conclusions based on our results with confidence.

those variables that theory would predict might expect to be useful a priori. Hence the growth rates of the consumer price indices are regressed on the growth rates of the money supply (M1), interest rates, growth rates of GDP, and finally lagged inflation rates.

Suppose we wish to test whether the central bank has targeted inflation optimally at C. We would then estimate the following equation:

$$GCPI_t = C + \alpha GRGDP_{t-i} + \beta IR_{t-i} + \delta GMS_{t-i} + \varphi GCPI_{t-i} + e_t \quad \text{where } i=6 \text{ or } 8 \text{ [6]} \qquad (1)$$

To test of whether the U.S. Federal Reserve targeted an inflation rate of "C_0" in the Rowe and Yetman sense the following null hypothesis must hold:

$$Ho: \alpha_i = \beta_i = \delta_i = \varphi_i = 0 \qquad \text{Where } i = 6, 8 \qquad (2)$$

Given we do not know what it has been that the U.S. Federal Reserve has targeted with respect to a specific value for inflation (for example inflation targeted at 2%), we have decided assume that the U.S. has targeted a constant level of inflation. From the forecasting equation, the above econometric model that is run on the data will generate what the constant has been. The purpose of chapter 1 however is not to find out what the explicit inflation rate, if any, is but whether the U.S. is targeting inflation in general. In this sense, my technique is different from that of Rowe Yetman. They were able to assume that the Bank of Canada was targeting its stated targets. However, in this

[6] Originally, the reason why we used the 30-day corporate paper rate for the U.S. experience was due to the fact that we wanted to be consistent with what was used in the Rowe Yetman paper (2002). Yetman and Rowe believed that the overnight rate in Canada was not a good measure of the stance in monetary policy by the Bank of Canada given the fact that it was initially an administrative interest rate (and not a good measure of monetary policy). As a result they used a 3-month corporate paper rate. Over time however, the overnight rate has became a better for indicator of monetary policy in Canada. Given this fact we wanted to use a rate in the U.S. that was similar to the one in Canada. We do understand that the Federal Funds Rate is a better measure for monetary policy in the U.S. As a result, we also ran the above test using the Federal Funds rate and get similar results.

particular case, we must assume what the U.S. Federal Reserve is targeting. I assume that the U.S. Federal Reserve has targeted some constant.

That is, under the null hypothesis, equation (1) collapses to

$$GCPI_t = C_0 + e_t \tag{3}$$

If we fail to reject the null, the implication is that monetary policy is consistent with the U.S. Federal Reserve targeting the inflation rate optimally. If we reject the null, the data is not consistent with the hypothesis that monetary policy has targeted inflation optimally in the Rowe and Yetman sense in the United States.

The Chi Square, its purpose, and how we interpret the results from the rolling regression.

The rolling regression technique identifies whether or not the policy objectives of the U.S. Federal Reserve was optimal in the Rowe and Yetman sense at a particular point of time. Each regression that is run generates a Chi Square test statistic of the joint hypothesis. Through time we are able to generate a series of Chi Square test statistics as we alter our sample period by adding a new observation point while dropping the oldest data point from our sample period. In our exercise, the first regression will be run on the sample period, 1973Q2 to 1992Q2, generating a Chi Square test statistic. We then add and drop an observation, thus adjusting our sample period to 1973Q3: 1992Q3, thus generating a new Chi Square test statistic. This process will continue until we run the last regression on the sample: 1991Q4: 2002Q4. This process will enable us to get a series of 9 years of Chi Square test statistics from which we can infer what the central bank was doing across time.[7]

The Chi Square test is based on the Chi Square distribution. This test statistic has one parameter k, which is the degree of freedom. As k increases, the Chi Square distribution becomes more symmetric. The Chi Square test statistic is a goodness of fit test because it asks whether there is a "fit" between the data and theory. It determines whether the difference between the observed score (O) and expected scores (E) can be

[7] There is an issue with the econometrics that needs to be mentioned here. A sequence of chi-squared tests is not necessarily chi-squared (since they are not independent). As a result we acknowledge that this sequence and the results derived from them may be biased. Given the rolling regressions we utilize add and drop a new data point for each regression that is ran, the chi square test statistics become related and thus dependent. Nevertheless, it can still be concluded that a changing series of chi square test statistics is indicative of monetary policy due to the fact that the adding of new information (even thought the sequence is related) and the subsequent changing in the values of the chi square test on the margin test gives us the changing stance in monetary policy.

attributed to some actual difference in behavior or if this difference between scores is caused by chance, using the formula Chi Square = sum $[(O-E)^2/E]$.

In my particular exercise, we are running the following rolling regression:

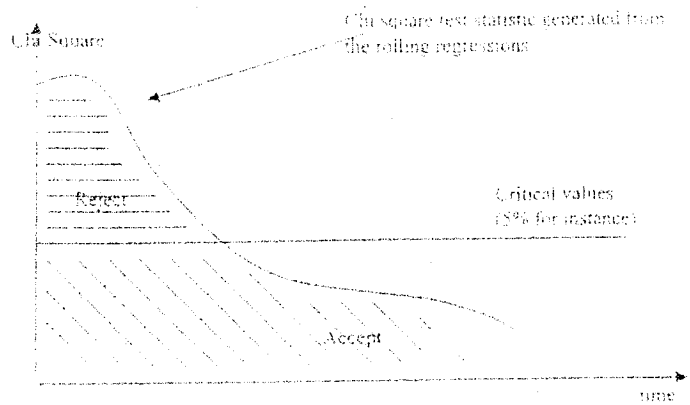
$$GCPI_t = C + \alpha_i GRGDP_{t-i} + \beta_i IR_{t-i} + \delta_i GMS_{t-i} + \varphi_i GCPI_{t-i} + e_t$$

My null hypothesis is that the slope coefficients all equal to zero. If we reject the null hypothesis at .05 level, we will determine whether our Chi Square test statistic, or sequence of Chi Square test statistics, are greater than the critical value of Chi Square that cuts off the upper 5% of the distribution at our particular degree of freedom value. If the value of the Chi Square test statistic was greater than the critical values (in our case the horizontal line in the figure below), we would then reject the null that all the slope coefficients equal zero. In our particular exercise, we want to see whether the Chi-Square test statistic changes as we incorporate more recent data, especially in the 1990s era when many central banks around the world targeted inflation.[8] If it does, it would mean that the Central Bank used monetary policy in such a way as to collapse the forecasting equation to a constant plus error term, thus smoothing inflation variability. If the Chi Square does not fall below the critical value, this means that the Central Bank purposely did not set monetary policy to smooth inflation and therefore was not optimal in the Rowe and Yetman sense.

[8] For a list of countries that have explicit inflation targets, please refer to table one in the appendix to this chapter.

Figure 1: When the null is rejected

Illustration 1: When the null is rejected?



V. Empirical Results for Inflation

The results from running the above rolling regression technique are summarized in the graphs below. Figures one and two illustrate the scenario where the rolling regressions are run using both six and eight lags, respectively.

Figure 2: Graph of Rolling regression: $GCPI_t = C + \alpha_i GRGDP_{t-6} + \beta_i IR_{t-6} + \delta_i GMS_{t-6} + \varphi_i GCPI_{t-6} + e_t$

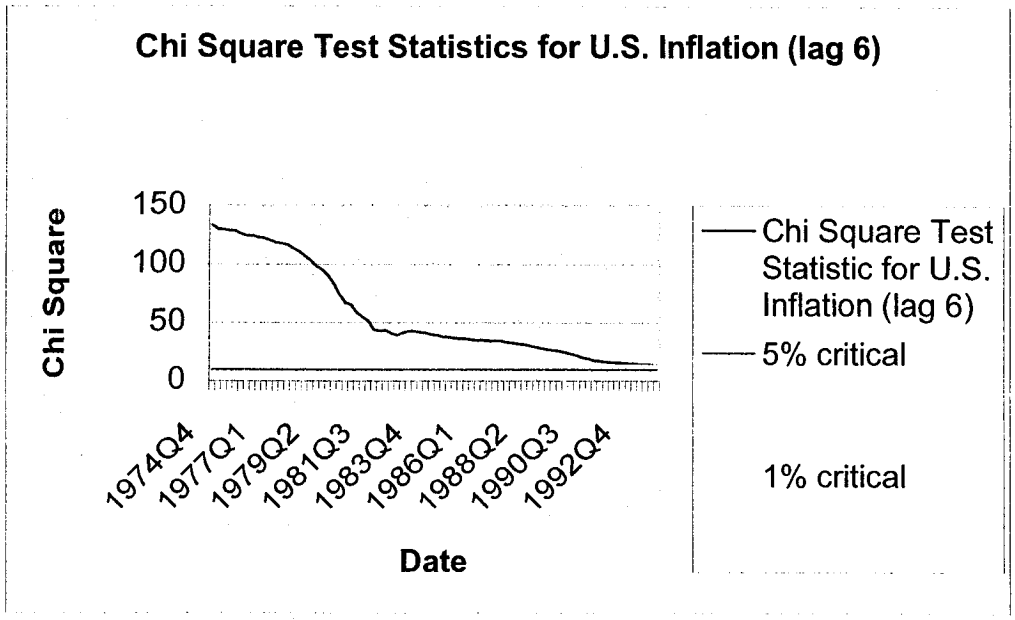
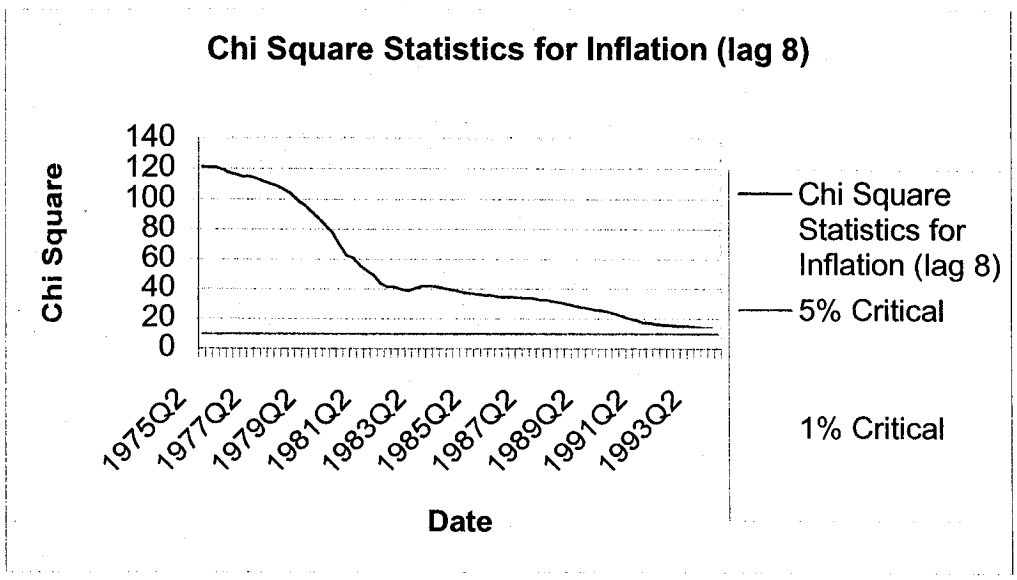


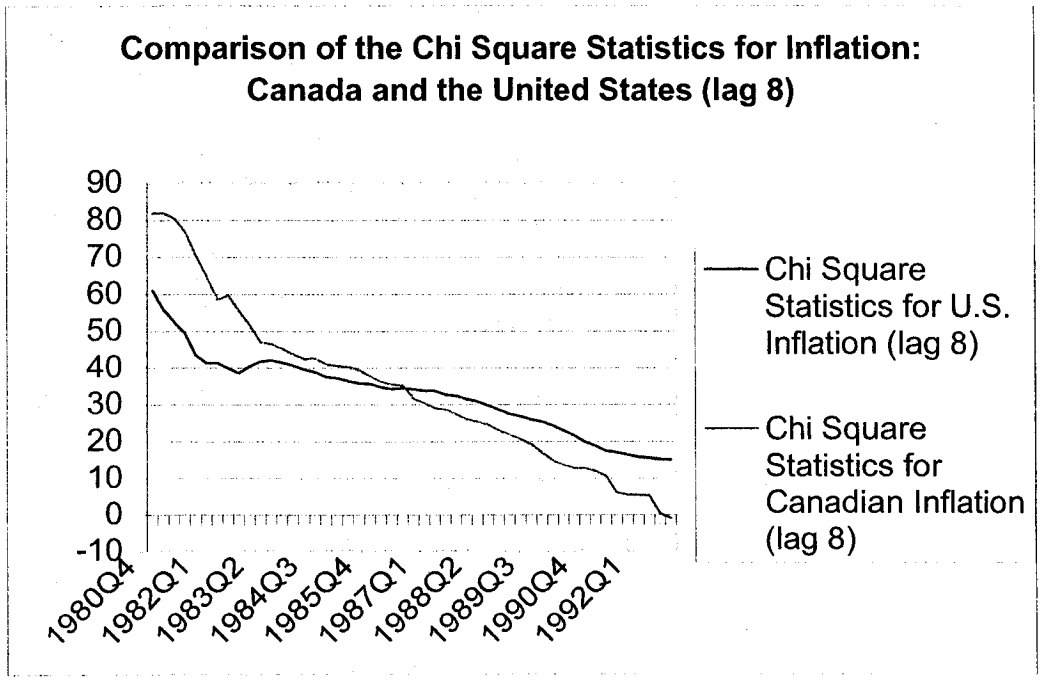
Figure 3: Graph of Rolling regression: $GCPI_t = C + \alpha_i GRGDP_{t-8} + \beta_i IR_{t-8} + \delta_i GMS_{t-8} + \varphi_i GCPI_{t-8} + e_t$



It can be seen that the forecasting equations for inflation, while not collapsing to a constant in the pre 1990 era, do get increasingly close to the critical values in the post 1990 era. It is interesting to note that in the pre 1990 era, the question of whether inflation was being targeted is not in question. We see that the Chi Square test statistics

were quite large and significantly above the critical value, implying that inflation was not being smoothed optimally in the Rowe and Yetman sense. As the rolling regressions begin to incorporate more recent information particularly in the post 1990 era, we see the Chi Square tending towards but not yet crossing, the critical values. We take this to imply that while we do not see explicit inflation targeting on the part of the U.S. Federal Reserve in the Rowe and Yetman sense, the results do suggest that the U.S. Federal Reserve is moving towards Rowe and Yetman inflation targeting. Comparing this policy on the part of the U.S. Federal Reserve with that of other central banks around the world such as the Bank of Canada, our findings suggest that the U.S. Federal Reserve began the process of targeting inflation much later in the 1990s and to a much more gradual extent.

Figure 4: Comparison of Chi Square test statistics for Inflation: Canada versus the United States



Note: As the above graph clearly shows, the Bank of Canada has moved towards smoothing inflation more rapidly than that of the United States, as shown by the steep decline in the Chi Square statistics generated from running the rolling regressions for the inflation equations.

It has been shown by Rowe and Yetman (2002) that the Bank of Canada began targeting core inflation in 1991. As time moves on and we are able to get more data with respect to the U.S., we may be able to determine exactly if and when the U.S. Federal Reserve began to optimally target inflation.

Empirical testing and results for GDP growth

The next part of the chapter examines whether the data is consistent with the counter hypothesis that the U.S. Federal Reserve has optimally targeted the growth of Real Gross Domestic Product. To test this hypothesis, we estimate the following forecasting equation:

$$GRGDP_t = C + \alpha_i GRE_{t-i} + \beta_i IR_{t-i} + \varphi_i GRGDP_{t-i} + \mu_i GMS_{t-i} + e_t \qquad (4)$$

where the definitions are the same as before, but the output equation now includes the percentage change in the real exchange rate (GRE_t), defined as the first difference of log exchange rate. While the inflation equation in the previous section did not incorporate the exchange rate, Rowe and Yetman did include it in their output equations. In order to be consistent with Rowe and Yetman, I also include the exchange rate in the output equation. The approaches taken in running these tests and interpreting the results are the same, except in the second exercise we are determining whether the central bank has targeted output rather than inflation. In order to test whether the U.S. Federal Reserve has decided to put more weight on targeting output rather than inflation, we must rerun our test, this time using growth rates in Gross Domestic Product as the dependent variable. We run the following regression:

$$GRGDP_t = C + \alpha_i GRE_{t-i} + \beta_i IR_{t-i} + \varphi_i GRGDP_{t-i} + \mu_i GMS_{t-i} + e_t$$

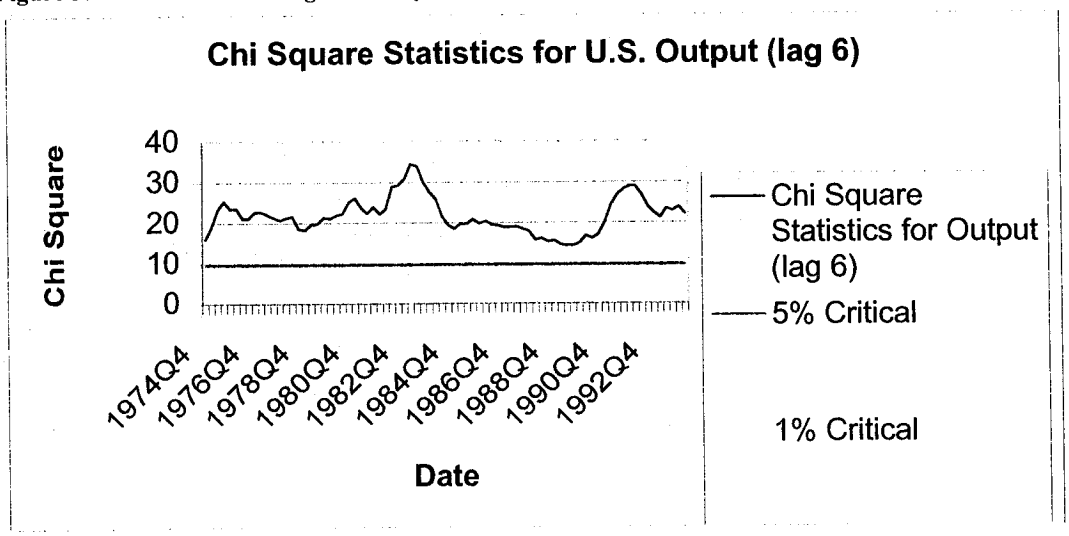
where i= 6 given that it is believed that changes in monetary policy affects output with a 6 quarter lag. GRE_t is the growth rate in the nominal exchange rate taken as a weighted average of major currencies.[9] The other variables are the same as they were in the

[9] While Rowe and Yetman (2002) used the real exchange rate, I used a "basket of exchange rates" given the United States deals with many trading partners.. To see if my results were robust, I also ran this regression using the real exchange rate defined as: the number of Canadian dollars/ 1 U.S. dollar)*(CPI in

inflation equation. For there to be some evidence of output smoothing, the slope coefficients of the independent variables must all simultaneously equal zero. While there is no explicit stated target regarding output in the United States, it is difficult to determine what we should test for. We decided to test whether the U.S. Federal Reserve targets a "constant" growth rate of output growth over the rolling sample.

The results of running the forecasting equation over the rolling sample are summarized below:

Figure 5: Results from running $GRGDP_t = C + \alpha_i GRE_{t-i} + \beta_i IR_{t-i} + \varphi_i GRGDP_{t-i} + \mu_i GMS_{t-i} + e_t$ (lag 6)



As shown, the null hypothesis that the slope coefficients are equal to zero at 95% percent confidence is rejected. As the graph illustrates, output does not seem to be smoothed consistently (given the test statistics were above the 5% critical value). It seems to be the case that the Federal Reserve has put more emphasis on smoothing inflation rather than growth rates of Gross Domestic Product. The fact that the Chi Square test statistic for the inflation equations tends to approach the critical value, while the Chi

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Canada/CPI in U.S.) and obtained similar results to the ones obtained when using "basket of exchange rates".

Square test statistic for output does not, suggests that the U.S. Federal Reserve has put more emphasis on achieving price stability rather than output stability.

VI. Conclusion

I have applied the Rowe and Yetman technique to the U.S. case and found the results consistent with the premise that the U.S. Federal Reserve increasingly *moved towards targeting inflation* while not placing as significant weight on smoothing output. While there has been much debate on what the Federal Reserve's strategy actually has been and what it should be, our results suggest that the U.S. Federal Reserve has made increasing efforts to smooth inflation over the recent time period. While inflation targeting in the Rowe and Yetman sense did not occur (i.e. the Chi Square test statistics did not fall below the critical value) the fact that the Chi Square statistics from the U.S. inflation equations systematically moved towards the critical value and comes very close to it can be interpreted as evidence that the Federal Reserve moved towards achieving targeted inflation, particularly at the end of the our time period.

We have also found that the U.S. Federal Reserve has not targeted or attempted to target growth rates of Real Gross Domestic Product. These findings are interesting for two reasons. First, we have uncovered evidence on the behavior and objectives of the U.S. Federal Reserve with regard to inflation, even though the U.S. Federal Reserve has not explicitly stated any policy objectives. Secondly, we have found evidence that the U.S. Federal Reserve has been slower than other central banks to embrace towards inflation targeting.[10]

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[10] For a depiction of inflation figures for selected countries across decades, please refer to table two in the appendix entitled "Inflation by Decade in Selected Countries".

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VIII. APPENDIX

Table 1: Countries with inflation targets

Country	Price Index	Date of Introduction	Inflation Rate at Date of Introduction	Inflation Target
Australia	CPI	1993	1.8%	Average of 2%-3%
Canada	CPI	February 1991	6.2	1%-3% from 1995
Finland	CPI	Early 1993	2.6%	2% from 1995
Israel	CPI	December 1991	18.0	8%-11% for 1995
New Zealand	CPI	March 1990	7.0	0%-2%
Spain	CPI	November 1995	4.4	Below 3% by 1997
Sweden	CPI	Early 1993	4.8	2% +/ 1% from 1995
United Kingdom	RPIX (defined as Retail Price Inflation excluding mortgage interest payments)	October 1992	4.2	2.5% or less by 1997 and 2.5% thereafter

Source: King, Mervyn. "Should Central Banks Reduce Inflation? Conceptual Issues", Volume: December 1996: 25-52.

Table 2: Inflation by decade in selected countries

Country	1950s	1960s	1970s	1980s	1990-95
Australia	6.5%	2.4%	9.8%	8.4%	3.3%
Canada	2.4%	2.5%	7.4%	6.5%	2.7%
Finland	6.2%	5.1%	10.4%	7.3%	2.7%
New Zealand	5.1%	3.3%	11.5%	11.9%	2.7%
Spain	6.2%	5.8%	14.4%	10.3%	5.3%
Sweden	4.5%	3.8%	8.6%	7.9%	5.0%
United Kingdom	4.3%	3.5%	12.7%	6.9%	4.6%
Germany	1.1%	2.4%	4.9%	2.9%	3.2%
Japan	2.9%	5.3%	8.9%	2.5%	1.6%
United States	2.1%	2.3%	7.1%	5.5%	3.5%

Source: King, Mervyn. "Should Central Banks Reduce Inflation? Conceptual Issues", Volume: December 1996: 25-52.

Table 3: Summary of statistics from the first and last Rolling Regression For Inflation (lag 8) and Growth Rates in Output (lag 6)

First Regression for U.S. output (lag 6): Regression with Newey-West standard errors

Number of observations=36; maximum lag: 1
F(4,31)=0.35
Prob > F = 0.8405

$GRGDP_{t-6}$	Coefficient	Newey-West Standard Error	t statistic	P>|t|	[95% Conf. Interval]
$GRGDP_{t-6}$	-0.0446	0.193084	-0.23	0.819	-.4383989 .3491962
GRE_{t-6}	-0.08319	0.144828	-0.57	0.57	-.3785657 .2121897
GMS_{t-6}	0.033195	0.32066	0.1	0.918	-.6207962 .6871861
Int_{t-6}	-0.04662	0.052807	-0.88	0.384	-.1543229 .0610784
C	1.086497	0.695965	1.56	0.129	-.3329327 2.505927

Last Regression for U.S. output (lag 6):

Number of observations=36; maximum lag: 1
F(4,31)= 1.13
Prob > F = 0.3607

$GRGDP_{t-6}$	Coefficient	Newey-West Standard Error	t statistic	P>|t|	[95% Conf. Interval]
$GRGDP_{t-6}$	0.085109	0.152871	0.56	0.582	-.226673 .3968916
GRE_{t-6}	0.051852	0.05148	1.01	0.322	-.0531416 .156846
GMS_{t-6}	-0.0313	0.066497	-0.47	0.641	-.1669172 .1043272
Int_{t-6}	0.091446	0.070804	1.29	0.206	-.0529596 .2358508
C	0.303079	0.44673	0.68	0.503	-.6080325 1.214191

First Regression for U.S. Inflation (lag 8)
Regression with Newey-West standard errors

Number of observations = 36; maximum lag 1
F(4,31)=4.88
Prob > F = 0.0036

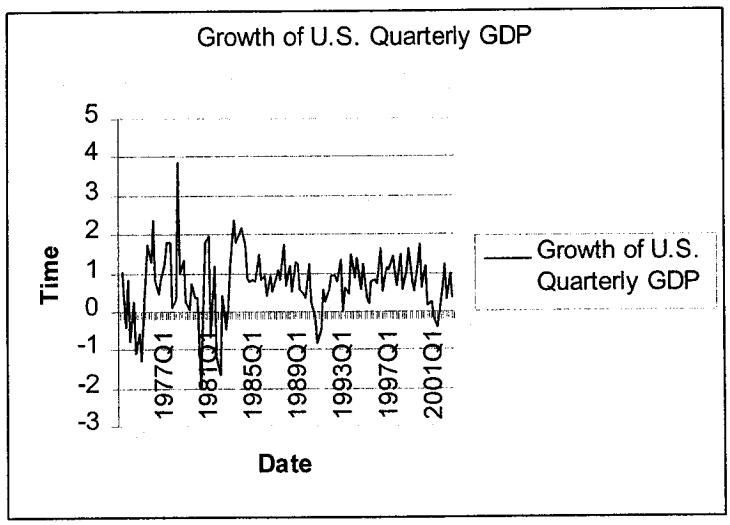
$GCPI_t$	Coefficient	Newey-West Standard Errors	t statistic	P>|t|	[95% Conf. Interval]
$GRGDP_{t-8}$	-0.00994	0.097352	-0.1	0.919	-.2084923 .1886069
$GCPI_{t-8}$	0.287091	0.158636	1.81	0.08	-.0364495 .6106322
GMS_{t-8}	0.225713	0.153089	1.47	0.15	-.0865134 .5379391
IR_{t-8}	-0.14005	0.037716	-3.71	0.001	-0.2801 -.063263
C	2.228319	0.525205	4.24	0	1.157157 3.299482

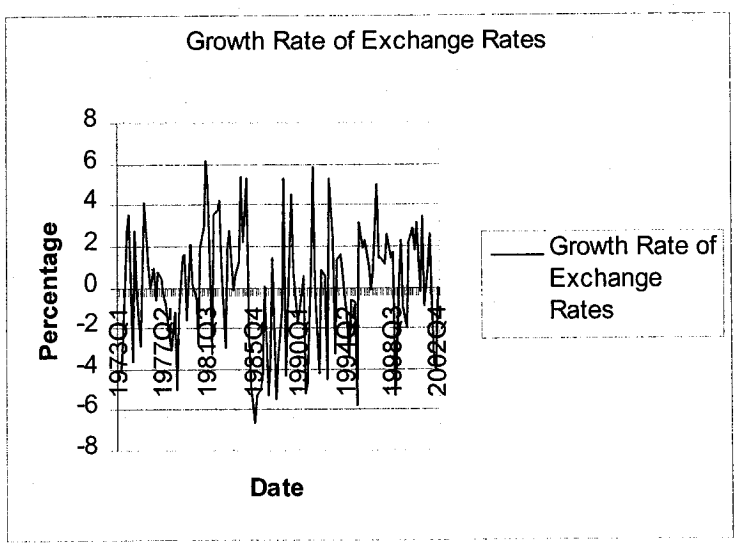
Last Regression for U.S. Inflation (lag 8)

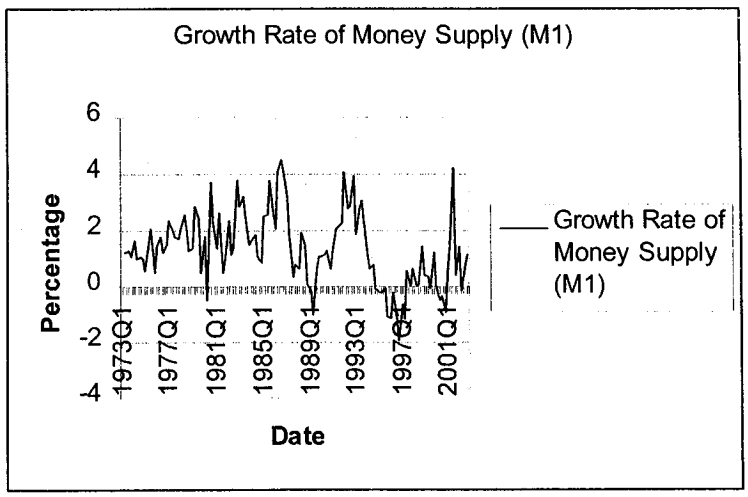
Number of observations=31 ; maximum lag 1
F(4,31)=16.37
Prob > F=0.0000

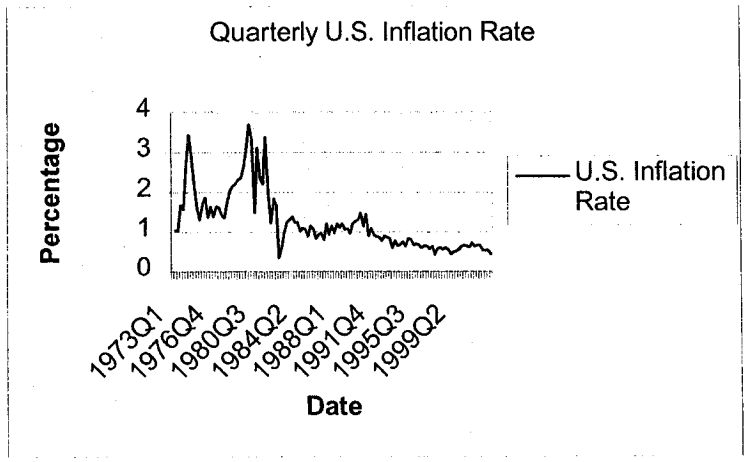
$GCPI_t$	Coefficient	Newey-West Standard Errors	t statistic	P>|t|	[95% Conf. Interval]
$GCPI_{t-8}$	-0.08702	0.031489	-2.76	0.01	-.1512421 .0227995
GMS_{t-8}	0.129758	0.102826	1.26	0.216	-.0799575 .3394733
IR_{t-8}	-.0049707	.0171385	-.29	.774	-.399249 .0299836
$GGDP_{t-8}$	-.0870208	.0314885	-2.76	0.010	-.1512421 -.0227995
C	.6232524	.914298	6.82	0.00	.4367801 .8097248

Figure 6: Growth in Real U.S. Gross Domestic Product, Growth in U.S. Money Supply, Growth in U.S. Exchange Rates, 3 Month Commerical Paper Rate, and U.S. inflation rates over the period 1973Q2: 2002:4.






Growth Rate of Money Supply (M1)
6
4
2
0
-2
-4
Percentage
1973Q1
1977Q1
1981Q1
1985Q1
1989Q1
1993Q1
1997Q1
2001Q1
Date
Growth Rate of Money Supply (M1)


Quarterly U.S. Inflation Rate
4
3
2
1
0
Percentage
1973Q1
1976Q4
1980Q3
1984Q2
1988Q1
1991Q4
1995Q3
1999Q2
Date
U.S. Inflation Rate

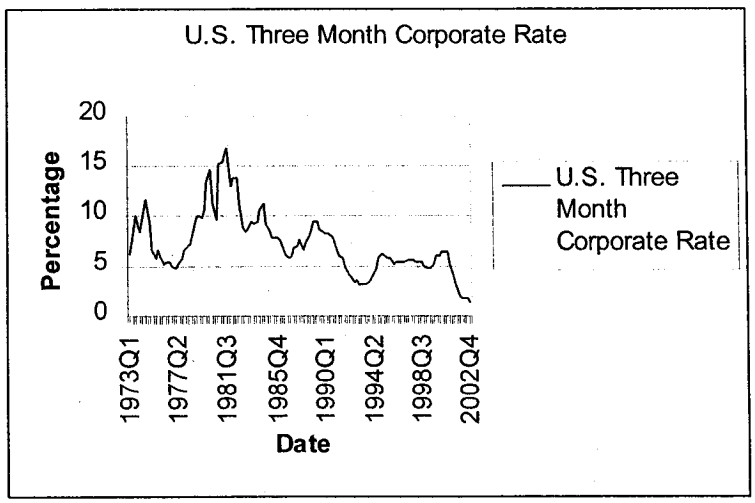

U.S. Three Month Corporate Rate
20
15
10
5
0
Percentage
1973Q1
1977Q2
1981Q3
1985Q4
1990Q1
1994Q2
1998Q3
2002Q4
Date
U.S. Three Month Corporate Rate

Exhibit 1: Unit Root tests (U.S. data)

UNIT ROOT TESTS

Before running any regressions, we must make sure that the series in questions do not contain unit roots. In order to test for this, we utilize the Phillips Perron test. For this particular exercise, our null hypothesis is the data series exhibit a unit root. If our test statistic is greater than (in absolute value) our critical value, than we reject the null hypothesis that we have a unit root, implying our series is stationary. Likewise, if our test statistic is less than (in absolute value) our critical value, we do not reject the null that we have a unit root. In order to make the series in question stationary, we took growth rates of the variables (except for the interest rates).

Growth Rate of Gross Domestic Product

PP Test Statistic	-9.161318	1% Critical Value*	-3.4725
		5% Critical Value	-2.8797
		10% Critical Value	-2.5763

Growth Rate of Money Supply

PP Test Statistic	-11.27625	1% Critical Value*	-3.4725
		5% Critical Value	-2.8797
		10% Critical Value	-2.5763

Growth Rate of Exchange Rate

PP Test Statistic	-9.761333	1% Critical Value*	-3.4725
		5% Critical Value	-2.8797
		10% Critical Value	-2.5763

Interest Rates (3 month corporate rate)

PP Test Statistic	-2.470749	1% Critical Value*	-3.4725
		5% Critical Value	-2.8797
		10% Critical Value	-2.5763

APPENDIX (CONT): SOURCES OF DATA

US INFLATION RATE:

The U.S. inflation rate is defined as the first difference of logs CPI (All item CPI less food and energy). This measure of inflation rate is used given it excludes the two most volatile components of all items CPI and given it has a seasonal component; we decided to exclude it from the inflation calculation. The data used in this paper spans 1973:1 to 2002:4.

The data comes from the FRED database.

US INTEREST RATES:

90-Day Commercial Paper Rate is used in this paper. It is taken from the Cansim Data Base, Label B55412. The data used in this paper spans 1973:1 to 2002:1.

MONEY SUPPLY

The growth in the U.S. money supply is defined as the first difference of log M1. The data used in these paper spans 1973:1 to 2002:4. The money Supply Data is taken from the FRED website. It was given in a monthly frequency, and was converted to a quarterly frequency.

PERCENTAGE GROWTH IN REAL EXCHANGE RATE:

The real exchange rate is defined as the REX:

=Nominal exchange rate * (Price level in Canada)/(Price level in the U.S.)

where the nominal exchange rate is given by: The Canadian dollars/US dollars noon spot rate. This data is taken from CANSIM, label number B3400. The Price levels are also taken from Cansim, and are all items CPI figures (D139135 (1982-84=100) and P100285 (1992=100).

APPENDIX (CONT): DESCRIPTIVE STATISTICS:

US GROSS DOMESTIC PRODUCT:

Growth rate of Quarterly GDP over period 1973:2 to 2002:4: .715 %
Standard Deviation of the Growth Rate in GDP: .84%

INTEREST RATES:

Average interest rates over period: 4.7%
Standard deviation of quarterly interest rates: 1.41%

GROWTH RATE IN MONEY SUPPLY (M1):

Average growth rate in quarterly money supply over period: 1.33%
Standard deviation of growth rate in M1: 1.31

QUARTERLY INFLATION RATES:

Average growth rates in quarterly inflation: 1.23%
Standard deviation in average quarterly inflation rates: .723

DOES CANADIAN MONETARY POLICY HAVE A REGIONAL BIAS?

Abstract

I apply the Rowe and Yetman technique to test whether a regional bias exists in monetary policy measures undertaken in Canada. Rowe and Yetman (2002) showed that if the Bank of Canada used monetary policy optimally to target the inflation rate, and if monetary policy had a lag of j periods in its effect on the inflation rate, then deviations in inflation from the target at time t+j would be unforecastable at time t. This means that deviations of inflation from target at time t+j would be uncorrelated with anything in the Bank of Canada's information set at time t. While Rowe and Yetman look at monetary policy at the national level, I do so at the provincial level. In particular, I repeat the Rowe and Yetman test across the ten provinces independently.

In order to test for a regional bias in monetary policy, suppose that the Bank of Canada cared about inflation stability or output stability primarily in, say Ontario. We would then expect to find the deviations of Ontario's inflation rate or growth rates of output from target to be perfectly uncorrelated with anything in the Bank's information set with a j period lag. But deviations from target for inflation rates or growth rates of output in the other provinces might be correlated, and hence forecastable, with the same information set. This would imply that the Bank of Canada had deliberately used monetary policy to smooth Ontario's inflation rate or growth rates of output at the expense of the other nine provinces.

On the basis of my empirical work, I find no evidence of such a bias in monetary policy with respect to provincial inflation or growth rates in Real Gross Domestic Product. However I find that when national and provincial inflation rates are smoothed, the associated growth rates in provincial and national Gross Domestic Product are not. My findings also suggest that the Canadian economy has been hit by supply shocks (which I will discuss in chapter 3) and may be an optimal currency area.

1. Introduction

The Canadian Central Bank cannot be all things to all provinces. If the Bank of Canada thinks that either inflation or the growth rate of Real Gross Domestic Product is about to be above target, it may raise interest rates to reduce demand for Canadian goods and services. However, if that aggregate shock impacts provinces that are in different stages of their business cycle, then a Central Bank action that is appropriate for the country as a whole may be too strong for some provinces and too weak for others. This asymmetry in response arises for several reasons. First, different provinces may experience different magnitudes of the shock and therefore not react to the same stimulus. Even if the impact were the same, however, different adjustment parameter elasticities may exist across provinces. Different provinces may have different industrial mixes that may make the response to monetary policy more asymmetric. For example, we would expect output to change by a relatively large amount in a province like Ontario where manufacturing activity makes up a large percentage of provincial GDP. This is because manufacturing responds more to changes in monetary policy than many other industries (Beauregard-Tellier, Johnson, and Pichette, 1999).

It follows that a monetary policy measure that is appropriate for some provinces will not be appropriate for others. Hence in a political sense, any Bank of Canada action will be a compromise that may appear to favor one part of the country over another. The empirical question then arises: Does Canadian monetary policy exhibit a provincial or regional bias? In particular, has the Bank of Canada smoothed inflation in, say, Central

Canada at the expense of stability in the other provinces? This paper addresses these questions empirically.

To frame my responses, I expand upon Rowe and Yetman (2002). They show that if the Bank of Canada uses monetary policy to target the inflation rate (or growth rate of real provincial GDP) optimally, and if monetary policy has a lag of j periods before it can affect the inflation rate, then the deviation of the inflation rate from its target at time t+j would be random, unforecastable from any information given in the Bank of Canada's information set at time t. Rowe and Yetman test this hypothesis for Canada on national data. In this paper, I look at monetary policy from a provincial perspective and repeat the tests used in the Rowe and Yetman paper for both inflation and output growth for each of the ten provinces. The idea is that if the Bank of Canada cared only about price stability in one province and ignored the other nine, then by optimally targeting inflation, deviations in that province's inflation rate about target would be uncorrelated with anything in the Bank's information set beyond a j period lag. In addition, the deviation from target of all the other provinces, unless the provinces were always in the same stage of their business cycle and had similar elasticities to Ontario, would be correlated with at least some elements in the same information set and hence would be forecastable. Together these findings would be consistent with the Bank of Canada's deliberate use of monetary policy to smooth the inflation in one province, knowing that it would produce price instability in the other provinces. The above logic is the same for analyzing growth rates of real provincial GDP data. The purpose of this paper is to investigate whether or not the Bank of Canada has targeted inflation stability or output stability in any one particular province, implicitly at the expense of the others.

Section II of this paper discusses whether a bias in monetary policy is possible and what factors could cause provincial inflation rates not to converge to a constant rate. Section III of this thesis discusses the literature in this area. Section IV develops the null hypothesis. Section V describes the data and Section VI outlines the empirical testing. Section VII provides the empirical results and section VIII concludes.

II. A bias in monetary policy: Is it possible?

The possibility of monetary policy bias in Canada challenges the hypothesis that inflation rates across different provinces converge through time. Theoretically, if price levels and inflation rates across provinces do not converge, then there would be room for arbitrage. Individuals would observe that products in a particular province were always relatively less expensive than in other provinces and could profit from purchasing the goods in cheaper provinces for resale in more expensive ones. Through arbitrage, the prices and their rate of change would converge to some number such that there would be no room for further profit, thus eliminating through time the asymmetric effect that monetary policy might have in different provinces.

While there may be many reasons outlined in the literature to explain why this arbitrage does not take place in reality, I discuss two factors present in the literature that are the most likely reasons. The first factor involves the presence of non-traded goods. Non-traded goods are only consumed in the province in which they are produced and cannot be exported or imported. Their presence affects every important feature of an economy, including price determination. When the prices of such goods vary across provinces, we should not expect inflation rates to converge to the same rate.

A second factor involves the presence of transportation costs. Given that there exists a cost of moving goods from the "cheaper" province to the more "expensive" province, the presence of transportation costs makes the benefits of trade less attractive. If transportation costs exceed the expected profits one may derive from undertaking arbitrage activities between provinces, then the process of arbitrage will not take place, allowing inflation rates to be different.

III. Literature Review

Many researchers have attempted to test hypotheses about the targets of policy makers, particularly central bankers (see Bernanke and Mihov(1996)). In much of the research work done to date, the researcher estimates a reaction function for the central banker. This has been done for many of the Central Banks around the world (see Clarida, Gali and Gertler (1998), or Bernanke and Mihov (1996)). In these studies, the dependent variable in the estimation equation is the bank's policy instrument, while the independent variables include both target variables and indicators of these target variables. While such studies attempt to identify the policy maker's underlying preferences, to do so is very difficult, given that it is often not possible to identify preferences independently of the constraints they may face. (See Swand and Swank (1993) Bernanke and Mihov (1995), Favero and Rovelli (1999).

An example of testing the preferences of an agent was done by Hall (1978) when he attempted to test Milton Friedman's Permanent Income Hypothesis. Within this model, agents are assumed to be rational. As such, they attempt to smooth consumption over time. Agents have an information set and use all available information within that information set to form decisions rationally to smooth consumption over time. As a result, changes in the level of consumption between two adjacent periods, say periods t and t+1 should be uncorrelated with anything in the agent's information set at time period t. An interesting feature of Hall's paper is that consumption is chosen contemporaneously. As such, he used an information set that is contemporaneous in nature. As a result, the errors in forecast, i.e. the residuals of his estimating equation, are expected to be serially uncorrelated.

In a similar way, Rowe and Yetman (2002) develop a new test of optimal inflation targeting and implement that test on Canadian monetary policy. Yetman and Rowe show that if a policy maker rationally uses an instrument, say interest rates, to target a particular variable, say inflation, and there is a j period length of time before this instrument can influence the targeted variable, then the deviations of the variable from its target at period t+j should be uncorrelated with anything in the policy maker's information stet at time t, including the instrument itself.

In their paper, Rowe and Yetman test whether the policy announcement by the Bank of Canada in February of 1991 to target inflation a) reflected a change in the behavior of the Bank of Canada and b) represented optimal inflation targeting by the Bank since that announcement. Intuitively, if the analyst can correctly identify the monetary authority's target, then deviations of the targeted variable from that target will be random errors that are uncorrelated with anything in the monetary authority's information set. Rowe and Yetman test this hypothesis of optimally conducted monetary policy using quarterly data.

To test for inflation targeting, Rowe and Yetman (2002) regress the following equation:

$$GCPI_t = C + \sum_{i=j}^{j+k} \alpha_i GRGDP_{t-i} + \sum_{i=j}^{j+k} \beta_i IR_{t-i} + \sum_{i=j}^{j+k} \delta_i GMS_{t-i} + \sum_{i=j}^{j+k} \varphi_i GCPI_{t-i} + e_t$$

where $GCPI_t$ is the growth rate of the Consumer Price Index, C is a constant, $GRGDP_t$ is the growth rate of real quarterly GDP_t, and IR_t is the 90-day corporate paper rate. They also include lagged values of $GCPI_t$ in order to capture persistence. They go on to test the hypothesis that if the Bank of Canada was targeting inflation at say 2% and if there is an 8 quarter lag in the effect of the independent variables on the dependent, then deviations

of inflation from 2% should be unforcastable by and uncorrelated with any information in the Bank of Canada's information set lagged by eight quarters. As a result, the forecasting equation for inflation should collapse to a constant equal to 2% plus an error term. If the above equation does not collapse to 2% plus an error term then deviations from 2% would be correlated with the Bank's information set and therefore could improve the forecast. This would imply that the Bank of Canada did not target inflation optimally. To account for the changing structure of the economy, Rowe and Yetman (2002) use a rolling regression to capture changes in the estimating parameters. The details of this procedure are discussed more fully in chapter 1. This procedure was motivated by the Lucas Critique (Lucas, 1976) that argues that expectations are important to many relationships among the aggregate variables, and that changes in policy will affect those expectations. As a result shifts in policy can change aggregate relationships. In short, if the Bank of Canada attempts to take advantage of pre-existing statistical relationships, effects operating through expectations may cause that relationship to break down.

Rowe and Yetman test whether the announcement of inflation targets in February of 1991 represented an actual change in monetary policy. Their results demonstrate that an inflation target of two percent could not be rejected at 1% level of confidence. To illustrate that the Rowe and Yetman test has sufficient power to discriminate among alternative targeting assumptions, they also tested whether the inflation target was set at 4% with j=8. The null hypothesis, being that the forecasting equation collapses to 4% plus an error term, cannot be rejected for a small number of samples beginning in the early 1980s. However, it can be rejected when most of the quarters in the regression are

from the explicit inflation targeting period following 1991. An inflation target of 4% can then be rejected for all periods as a whole.

One influential study in the literature that comes close to that of Rowe and Yetman is the work of Kuttner and Poser(1999). In their study, they derive and estimate both a reaction function and an inflation forecast equation. They also recognize that under strict inflation targeting, deviations from the target should be unforcastable. What differentiates their study from that of Rowe and Yetman is their lag structure. Kuttner and Poser (1999) use only a one quarter lag in their forecasting equations, while Rowe and Yetman (2002) use lags of 6 and 8 quarters to incorporate the conventional view that monetary policy takes up to two years to fully impact the inflation rate. Another difference between these papers is that Kuttner and Posser use only lagged values of inflation and unemployment in their forecasting equations, while Rowe and Yetman allow any variable into the Bank's information set. In practice, they use a large set of variables in their inflation forecasting equations. As a result, there are substantial differences in the results of these two papers, sufficient to account for the fact that Kuttner and Poser do not find any statistical difference between the pre and post inflation targeting processes in Canada while Rowe and Yetman do.

In this section I review the monetary policy literature, particularly that which has investigated asymmetries in the effects of monetary policy. Most of this attention has been directed at asymmetries at the aggregate level of economic activity. Not as much has been directed at the potentially asymmetric effects of monetary policy on provincial output.

Monetary studies have typically focused on two types of asymmetries. In the first approach Schaller and Garcia (1995), as well as Thoma (1994), show that changes in interest rates have a greater impact on output during recessions than expansions. They suggest that because of credit rationing, changes in interest rates due to a monetary policy shift have a larger effect on the economy during a recession than during an expansion. This is so given that higher interest rates make banks less willing to lend during recessions.

Delong and Summers (1988) are typical of a second approach that find that negative monetary shocks adversely affect output in the United States, while positive shocks have a small and generally insignificant impact.

Aside from these questions of asymmetry, many economists including Harvey (1997), and Cozier and Tkacz (1994) find that the yield spread between the 10-year Treasury Bond and the 3 month Treasury Bond can predict movements in Canadian GDP. In addition, economists have found that such characteristics of the term structure can predict some of the subcomponents of GDP. Harvey (1997), for example, shows that the Canadian term structure can predict movements of Canadian consumption. In his case, a representative agent asset-pricing model is used to link the slope of the term structure to the consumption growth rate. Intuitively, if an investor were to expect a recession one year from now, that investor would today demand assets that pay off better next year when income is expected to be lower. The demand for one-year bonds would therefore increase, driving its yield down and making the yield curve flatter. If the recession then occurs, there will have been a positive co-movement of relation between the change in the slope of the term structure and the change in consumption growth. Cozier and Thacz

(1994) show the yield spread can also explain other movements in aggregate expenditure. They find that a widening of the yield spread results in a higher level of consumption a year later. Similarly, investment spending tends to be influenced a year later.

More recently, a literature has emerged that examines the effect of the yield spread on economic activity at the sector level. For example, Haimowitz (1996) examines how changes in the Federal Funds Rate in the United States affect both prices and output in the manufacturing sector. His analysis examines how industry specific characteristics alter the responses of different industries to the change in the Federal Funds Rate. There are three interesting results steming from his work. First, the durable goods industry is more sensitive to the interest change rate than are non-durable goods. Second, the more concentrated an industry is, the more output will respond to interest rate changes. Third, industries that have higher inventory to sales ratios are more sensitive to interest rates changes than are industries with lower inventory ratios.

Ganley and Salmon (1997) looked at the same sort of questions with respect to British industries. They also found that monetary policy impacted industries differently. For instance, they found both the manufacturing and construction industries to be more sensitive to unanticipated changes in official interest rates than other sectors in the economy.

Hejazi and Pasalis (2002) use monthly Canadian GDP data at the sector level to show that the predictive content of the term structure varies across industries. In particular, they show that the term structure has most power when predicting movements in manufacturing output. The yield spread has significant power, but to a lesser extent, when predicting changes in total services (made up of transportation, communications, utilities,

wholesale and retail trade, finance, insurance, real estate, and community, business and personal services). They also show that the term structure has little predictive power in relation to primary industries.

By examining the impact of the U.S. term structure on Canadian industry, Hejazi and Pasalis also show that the U.S. term structure *alone* has significant predictive power for US tradables but is unable to predict movements in Canadian non-tradables. On the other hand, the Canadian term structure alone is shown to have explanatory power, independent of changes in the US term structure. Finally, their paper also shows that the yield spread subsumes other indicators of monetary policy, namely the money supply and the overnight rate.

Tellier, Johnson and Pichette (1999) measure the effects of the yield spread on different sectors of the Canadian economy. In particular they look at how changes in the yield spread affect different sectors and whether these effects exhibit significant asymmetries. To do this, they run three sets of regressions. In the first set of equations, they regress the log of real GDP at factor cost in different industries on the lagged values of the yield spread in levels together with lagged values of the dependent variable itself in order to capture the persistence of output. Their results suggest that the yield spread is an important explanatory variable in a model of industry level output growth.

Their second set of regressions looks at the metric effects of monetary policy. To do this, they regress changes of output on lagged values of output, as well as two new sets of series: one being the negative of the deviation of the yield spread from its mean (to measure a tightening of monetary policy), and the second being the positive deviation from the mean of the yield spread (to represent a loosening of monetary policy). Their

findings suggest that asymmetries exist in the manufacturing sector as a whole as well as in about half of the individual manufacturing industries.

The third set of regressions test whether the above mentioned asymmetries are robust to the inclusion of other explanatory variables such as U.S. final domestic demand, non energy commodity prices, and the real producer price of oil and real spot CAD/USD exchange rates. They find that the asymmetries disappear in the manufacturing sector as well as in about half of the individual manufacturing industries that originally displayed asymmetries. The results are similar when they investigate durables and non-durables separately.

Another point of interest in their study is that industries with high inventory to sales ratio are more sensitive to the yield spread level, especially to negative deviations from the mean (or tightening of monetary policy), while industries with low inventory to sales ratios do not seem to respond to either positive or negative deviations in the spread. Finally, they find that industries that have robust asymmetries are mainly ones where the timing of output is demand determined, service industries are more affected given that they are demand driven and cannot hold inventories.

Work on monetary policy and the effect it has on different regions has been a topic of interest over the last decade. Although this topic appears every now and then in the popular press, surprisingly little work has been done on how monetary policy affects different regions of a country, especially in the Canadian context. Even though Central Bank directed monetary policy has a uniform monetary effect in all provinces, that effect may impact at different stages in a province's business cycle. Hence because nations are made up of diverse regions, they are both linked to and react differently to the changing

interest rates set by the central bank. The question then arises "Does monetary policy exhibit a regional bias?"

Three reasons are given in the literature for why monetary policy may affect regions differently and so exhibit a regional bias. The first reason involves the fact that different regions may have different mixes of interest sensitive industries. It is well known that different industries have different interest rate elasticities (Carlino and Defina, 1998: 572). A different industry mix across regions may then provide one reason why certain regions may be affected with different intensity by central bank policy. Regions with higher concentrations of construction or manufacturing activity are more likely to be affected by interest rates and hence monetary policy.

A second reason in the literature deals with the fact that different regions of the country are serviced by different types of banks. Anil Kashyap and Jeremy Stein (1995) have done important work in this area. Their work suggests that large banks (defined as banks that have total assets of over 300 million dollars) have more funding options than small ones. Hence regions that are serviced mostly by small banks will respond more to monetary policy changes than regions serviced mostly by large banks. On the other hand, if bank-dependent borrowers can obtain funds from sources outside their region, then the effect of the differences in regions' reliance on small banks will be diluted. Studies by Craig Moore and Joanne Hill (1982) suggest that the banking sector is segmented along regional lines. Their work suggests that regional segmentation arises from asymmetric advantage that banks have in monitoring investments in their own particular regions, giving them a cost advantage relative to small firms that borrow from local banks.

A third and final reason points to the fact that different regions may have a different mix of large and small borrowers. According to the credit view of monetary policy, a Central Bank affects economic activity by altering the charter banks' ability to provide loans. Small firms are more dependent upon the banks while larger firms can access funds outside of local banks and their particular region through national or even international bond or equity markets. As a result, regions with high concentrations of smaller borrowers (who depend mainly on banks for financing) are more likely to be sensitive to changes in credit conditions and interest rates by the Central Bank.

Work done by Oliner and Rudebusch (1995) emphasizes the information asymmetry between borrowers and lenders that results in an increase in the cost of all forms of debt following contractionary monetary policy. Given that small firms will have relatively more severe information problems, the cost of external finance for smaller firms will be considerably higher and so the effect will be that much stronger. The authors also provide evidence that a monetary contraction shifts financing of all types from smaller to larger sized firms.

According to Carlino and Defina (1998), there are problems with existing studies that test for regional bias in monetary policy because they often fail to account for the interrelationships among the regions. For example, monetary policy may directly affect only region i, but through trade, the effect on region i can be spread to region k. In this sense monetary policy indirectly affects region k. Carlino and Defina then use a Vector Auto Regressive approach to illustrate the importance of linkages and feedback effects among U.S. regions. Of their three non-core U.S. regions, the Great Lakes region is most sensitive to monetary policy changes.

IV. Developing the Null

Proceeding from the test developed in chapter 1, we test for optimal monetary policy by running the following equation for each of the ten provinces independently[1]:

$GCPI_t = C + \alpha_i GRGDP_{t-i} + \beta_i IR_{t-i} + \delta_i GMS_{t-i} + \varphi_i GCPI_{t-i} + e_t$ where i=6,8

$GCPI_t$ is the growth rates of provincial GDP, IR_t is the 90 corporate paper rate, and GMS_t is the growth in the money supply.

For this particular exercise, my null hypothesis is that the slope coefficients are all simultaneously equal to zero. Failure to reject the null would provide evidence consistent with the hypothesis of optimal inflation targeting with respect to that particular province. Conversely, if I reject the null that all the slope coefficients are simultaneously equal to zero, or more simply, if I find at least one slope coefficient that is not equal to zero, the result would provide evidence that inflation targeting was not optimal with respect to that particular province. I later test an equation for growth rates of provincial output. My approach and implications are the same for output as they are for inflation.

[1] I followed the Rowe and Yetman (2002) process for the rolling regression applying the Hansen statistic u'ZWZ'u. Due to the degrees of freedom problem, we limit the number of lags we include. Rowe and Yetman include 6 to 10 and 8 to 12 lags for their tests. We run the process using 6 lags and again with 8 lags. While Rowe and Yetman tested to see if the Bank of Canada is targeting inflation at a 2% level, we test to see if there was smoothing of provincial inflation. Therefore, in our tests $u=GCPIX_i$ instead of $u=GCPIX_I - 2$.

V. Data Description

There are four sets of variables in my model for inflation. They are: first, the provincial inflation rates; second, the real growth rates provincial GDP; third the 90-day corporate paper rate; and, finally, the growth rate of the money supply (M1). While some may argue that the overnight rate is a better measure for monetary policy, I used the corporate rate for two reasons. The first reason involves the fact that the overnight rate has changed from an administrative rate (coinciding with the earlier part of my sample period) to a rate more indicative of the stance in monetary policy during the later part of my sample period. As a result, it was not feasible to use this rate for the purpose at hand. The second reason involves the fact that I wanted to be as close to Yetman and Rowe as possible, hence I used what they used.

With respect to the output equations this model encompasses four variables. The first is Real Gross Domestic Product; the second is interest rates (here taken to be the 90 day corporate paper rate). The third is the growth rate of provincial prices (CPI), and the fourth is the exchange rates. The latter two variables are combined in the real exchange rate (RE), defined as:

$$\text{Real exchange rate (RE)} = \text{nominal exchange rate} * (P/P^{us})$$

Where the nominal exchange rate is defined as the number of Canadian dollars it takes to buy one U.S. dollar, P is the Canadian price level, and P^{us} is the U.S. price level.

I use quarterly data with the period of estimation being 1978Q3 to 2000Q4.[2] Growth rates are determined as the first difference of the natural logarithms of the variables.

[2] I would have liked to use more recent data but quarterly data for provinces is very limited.

Before proceeding to the test, a few comments must first be made regarding the data. Calculating the growth rates does transform the model variables that were non-stationary in levels into stationary series (using to the Phillip Perron set of criteria)[3]. The rate of change of consumer prices is our measure of inflation, where the consumer price index used is the all item CPI less energy and food prices. To be consistent, we calculate inflation based on CPI figures that exclude energy and food prices at both the provincial and national level. Though Rowe and Yetman (2002) use a definition of core inflation that also excludes the effects of indirect taxes, CPI figures that exclude indirect taxes for the provinces are not available, and therefore my definition comes as close as possible to that of Rowe and Yetman (2002).

Changes in the money supply (M1) and the 90-day commercial paper rate are used as my measures of changes in monetary policy instruments.

VI. Empirical Testing

If I wish to test whether the central bank has set its policy instrument to target inflation at C, I would then estimate the following equation:

$$GCPI_t = C + \alpha_i GRGDP_{t-i} + \beta_i IR_{t-i} + \delta_i GMS_{t-i} + \varphi_i GCPI_{t-i} + e_t \qquad (1)$$

where i= 6 or 8. Here $GCPI_t$ is the growth rate of Provincial Consumer Price Indexes, IR_t is the 90-day corporate paper rate, and GMS_t is the growth rate of Money Supply.

I have chosen i=6,8 because it is believed that monetary policy affects the targeted variables with a six to eight quarter lag (Rowe and Yetman, 2002: 246).

To test whether the central bank targeted an inflation rate of "C_0" in the Rowe Yetman sense, the following null hypothesis must hold:

[3] I do not take a first difference of interest rates given that economic theory suggests that the level of interest rates have an impact on the growth rates of consumer prices and output and not the growth in interest rates.

$$Ho: \alpha_i = \beta_i = \delta_i = \varphi_i = 0 \qquad \text{where } i=6,8 \qquad (2)$$

That is, under the null hypothesis, equation (1) collapses to

$$GCPI_t = C_0 + e_t \qquad (3)$$

I test this null hypothesis for each province. If I fail to reject the null, the implication is that monetary policy is consistent with the Bank of Canada targeting the inflation rate of that particular province. If I reject the null, monetary policy is not being targeted in that particular province. The same intuition is used when I look at the question of provincial output smoothing.

How can we determine whether a Bias Exists?

The Rowe-Yetman technique tells us if central bank behavior is consistent with optimal inflation targeting and second when this action became consistent. In the Rowe and Yetman technique, a policy maker can smooth output or inflation in a particular region by altering monetary policy in such a way that the forecasting equation for output or inflation collapses to a constant. Since the lagged values of monetary policy and other independent variables are in the above forecasting equation for inflation, the central bank therefore has the information that it needs to make a successful change in monetary policy. Hence if a change in monetary policy affects regions differently, this implies that the central bank will know when it sets its policies that the equation for output and inflation for certain provinces will collapse to a constant while for others it will not. This "bias" in favor of one province or more provinces will be picked up using the Rowe and Yetman technique.

VII. Empirical Results

Results for Inflation

The results of running a rolling regression test for inflation are summarized in Figures 2a and 2b in the appendix to this chapter. To determine whether the test procedures are consistent with that of Yetman and Rowe (2002), I decided to rerun the inflation equation at the national level using the data utilized by Rowe and Yetman (2002). Since my provincial data utilizes an all item CPI measure less food and energy, I therefore use this CPI measure at the national level as well. Even though my CPI measure at the national level is a little different from that of Rowe and Yetman (2002), my results at the national level are similar. As figure 2A in the appendix shows, the results reported here are identical to theirs. I conclude from this that my empirical technique is consistent with that of Rowe and Yetman.

Using the discussion of the chi-square distribution and the interpretation of the rolling regression technique from Chapter 1 as a backdrop, let's interpret one example of this process for the Canadian case. Once this is done, it is easily seen how the results can be interpreted for the provinces. The analysis begins by running a rolling regression for change in CPI over the sample 1978Q3:1987Q3. Once I do this, Chi Square statistic is attributed to the quarter 1978Q3. By adding and dropping one data point to the first regression, the sample adjusts to 1978Q4 to 1987Q4, and the corresponding chi-square is associated to the quarter 1987Q4. The process of rolling in later observations and dropping earlier observations continues through 1991Q4: 2000Q4, our last regression. Hence, the last Chi Square test statistic is associated with 2000Q4. This series of Chi Square statistics is plotted using lags of 6 and 8. The two horizontal lines in figure 2b in

the appendix correspond to the critical value of 5% and 1% respectively. When the chi square statistic is above this line, the hypothesis of optimal smoothing on part of the policy maker is rejected. If it is below the line I accept the hypothesis of smoothing. For the Canadian case, and in particular in the post 1991 era, as the rolling sample begins to incorporate more data from the post 1991 period of explicit inflation targeting, the Chi Square statistics begin to fall below the corresponding critical value, especially during the post 1991 period. This provides evidence that the Bank of Canada has successfully targeted a constant inflation rate at the national level.

My analysis for provincial inflation rates yields additional findings. As Figures 2b in the appendix suggests, my estimated forecasting equations for inflation typically collapsed to a constant, not just for Canada as a whole but for all of the individual Canadian provinces as well. These findings for the country as a whole and the Canadian provinces are robust to the inclusion of different lag length. Regardless of whether we use a six or eight-quarter lag, the results are consistent with the hypothesis that both provincial and national inflation rates are being smoothed optimally.

Results for growth rates of GDP

I test whether the Bank of Canada is smoothing certain provincial output optimally by running the following equation for each of the ten provinces independently:

$$GGDP_t = C + \alpha_i IR_{t-i} + \delta_i GRE_{t-i} + \varphi_i GGDP_{t-i} + e_t \qquad (4)$$

where i= 6 given that it is believed that changes in monetary policy affects output with a six quarter lag. The definition of the variables is the same as in the case of inflation, except GRE_t is the growth rate of the real exchange rate, defined as the number of

Canadian dollars to one American dollar, multiplied by the respective price levels. The U.S. - Canadian exchange rate is used, given that the United States is Canada's largest trading partner.

As for the case of inflation, my null hypothesis is that the slope coefficients are all simultaneously equal to zero. If we cannot reject the null hypothesis for a particular province this would provide evidence consistent with the hypothesis of output smoothing for that particular province. Conversely, if I reject the null that all the slope coefficients are simultaneously equal to zero, or more simply, that there exists at least one slope coefficient that is not equal to zero, this provides evidence consistent with the hypothesis that output was not being smoothed for that particular province.

As in the case of inflation, suppose that the Bank of Canada targeted output growth at a rate of "C", then in the Rowe and Yetman sense the following null hypothesis must hold:

$$\text{Ho: } \alpha_i = \beta_i = \delta_i = \varphi_i = 0 \qquad \text{where } i=6 \qquad (5)$$

That is, under the null hypothesis, equation (4) collapses to

$$GGDP_t = C + e_t \qquad (6)$$

I test this null hypothesis for each province. Failure to reject the null implies smoothing for that particular province. Rejection of the null suggests that the Bank of Canada has intentionally not smoothed output for that particular province.

The results of running the output equation are summarized in Figure 2c of the appendix. Clearly figure 2c shows that my estimating equations do not collapse to a constant plus an error term for Canada, a result similar Rowe and Yetman (2002) who found no evidence of output smoothing by the central bank at the national level. More

interestingly, I also find that output is not smoothed for all of the individual provinces either. Do these results make sense? Taken in isolation these results they may seem odd, especially give the fact that the key economic and political provinces of Ontario, and Quebec did not have their outputs smoothed. However, if I take this result and combine them with those for inflation, the results seem quite plausible. For these results to be economically sound, the economy would have to face supply shocks in the face of a central bank trying to smooth provincial outputs. Had the economy faced negative supply shocks, any attempt by the Bank of Canada to smooth inflation would result in output instability. However, had the economy faced demand shocks, a move to smooth inflation would also smooth output. More on this issue will be discussed in the next chapter.

Is Canada an Optimal Currency Area?

There are at least two significant implications that follow from this finding. First in the pre 1991 era in Canada, when one provincial inflation rate was not smoothed, the nine other provinces found their inflation rates not smoothed either. In the post 1991 era, when one province has its' inflation rate smoothed, the other nine provinces had their inflation rates smoothed as well. What does this imply? Put simply, these results suggest that Canada is an optimal currency area. Mundell (1961) defines an optimal currency are as "an economic unit composed of regions affected symmetrically by disturbances and between which labor and other factors of production flow freely". The fact that monetary policy has not been asymmetric in its impact suggests that the shocks have been symmetric.

Mundell's suggestion that optimal currency areas are those where provinces are hit with similar economic disturbances is a topic that will be discussed in chapter 3. It is clearly possible in the Canadian case. Given that the Central Bank has been shown to target inflation in all provinces while not smoothing output, the only way that this can happen is if all the provinces faced similar supply shocks. Had the economy faced demand shocks, then an action by the Bank of Canada to smooth prices would also have smoothed output. However, in the presence of supply shocks, a move to smooth inflation would result in output not being smoothed. Given that inflation for all provinces is smoothed while output is not, this could occur only if these provinces faced similar supply shocks. As such they suggest (but do not prove) that Canada is an optimal currency area.

Within the Rowe and Yetman sense we can look at the question of optimal currency area in the following way. The Rowe and Yetman technique has shown that when the Bank of Canada smoothes prices across provinces, it comes at the expense of output stability in these provinces. This can only occur if the shocks hitting are correlated. If the shocks hitting the economy are in the bank's information set, than forcastable deviations of the actual inflation rate from target will equal zero. In this sense we see that the Bank of Canada can use monetary policy to smooth forcastable variability of prices across provinces (while not smoothing output) using a single currency and therefore does not need ten different provincial currencies to smooth provincial inflation rates.

VIII. Conclusion

I have used the Rowe and Yetman technique (2002) to determine whether there exists a monetary policy bias by province in Canada. A bias is thought to be a change in monetary policy that affects one province in a more favorable way than another. This bias may involve changing interest rates in a way that smooth provincial inflation rates, say, in Ontario, at the expense of inflation instability, say, in British Columbia. My literature review outlined quite clearly many reasons why there might be a bias, one of which was the fact that provinces have different industries that react differently to changes in interest rates. This chapter was therefore interested in determining whether a bias existed between smoothing inflation in some provinces at the expense of price instability in other provinces. Secondly this chapter investigated whether growth rates of real GDP were being smoothed in some provinces at the expense of not smoothing in others. Using the

Rowe and Yetman technique (2002), I find that the estimating equation for inflation for all of the Canadian provinces collapsed to a constant, and therefore suggested smoothing of provincial inflation rates took place on the part of the Bank of Canada. Using the same technique, all the forecasting equations for provincial output do not collapse to a constant plus an error term for growth rates in provincial GDP. Taken together, these results suggest that the Bank of Canada cares more about provincial inflation rates rather than growth rates of output. Given the fact that they are able to smooth only one variable at the expense of another suggests the Bank of Canada was faced with supply as well as demand shocks. Had the economy faced only demand shocks, any attempt to smooth prices would also smooth output. But when the economy also suffers supply shocks, any attempt to smooth inflation comes at the expense of output instability. It will be my task to explore the subject of supply shocks and the issue of a tradeoff between output and inflation variability in the next chapter.

Finally, this chapter illustrated that Canada may in fact be an optimal currency area. Mundell (1961) defines it as "an economic unit composed of regions affected symmetrically by disturbances and between which labour and other factors of production flow freely". This is clearly possible in the Canadian case. Given that the Central Bank has been shown to target inflation in all provinces, while not smoothing output, the only way that this can happen is if all the provinces faced similar supply shocks. Had the economy faced only demand shocks, then an action by the Bank of Canada to smooth prices in a particular province would also smooth output. However, in the presence of supply shocks, a move to smooth inflation would also result in output not being

smoothed. Given that inflation for all provinces is smoothed while output for all provinces are not, this could occur only if these provinces faced similar supply shocks.

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XI. Appendix

Figure 2a: Duplication of the Rowe and Yetman results from their 2002 paper

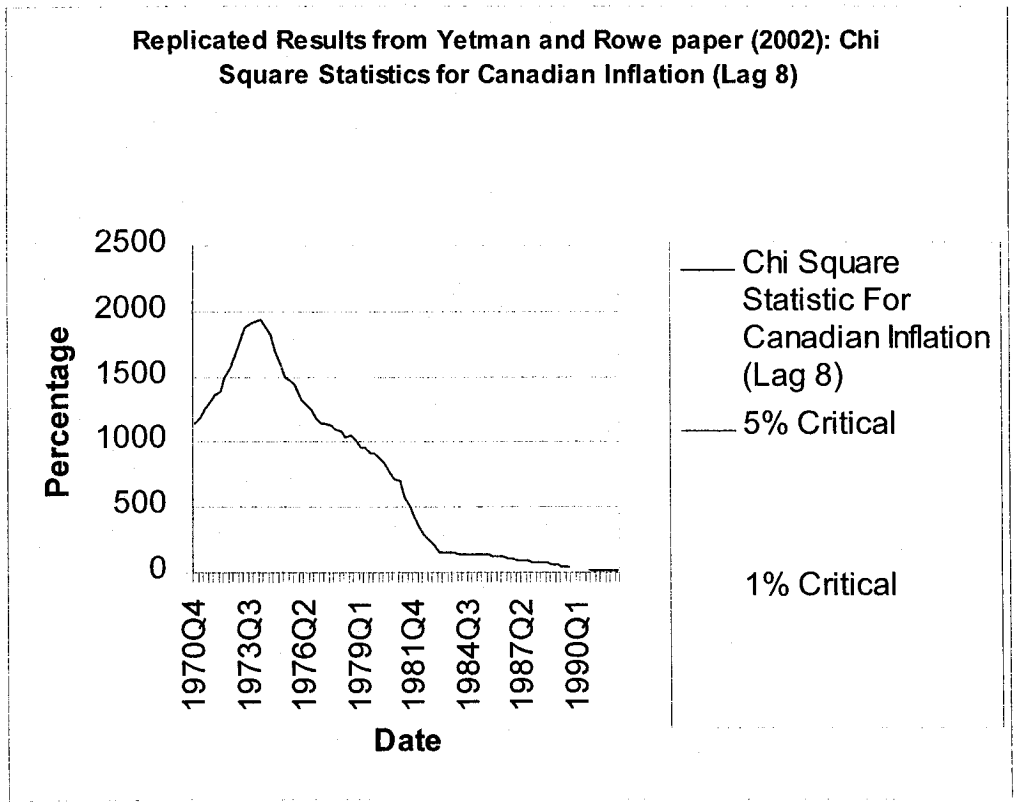
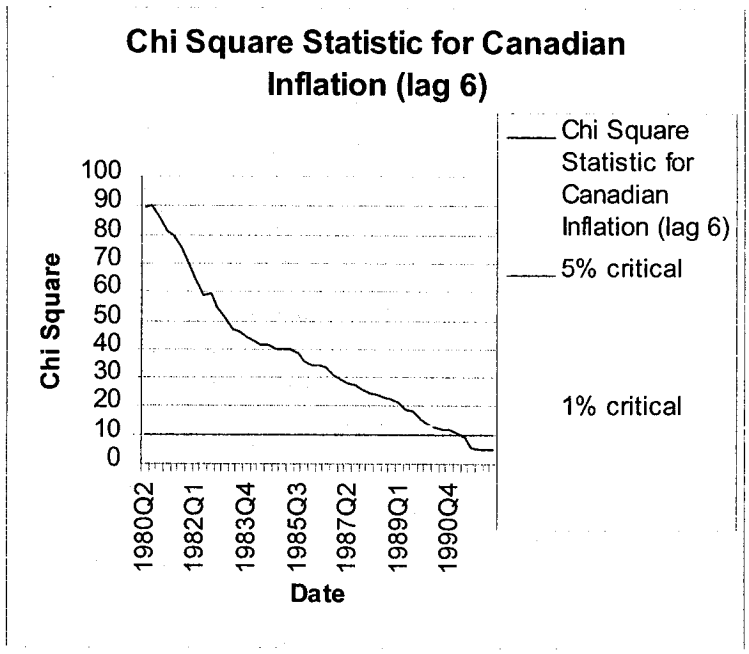
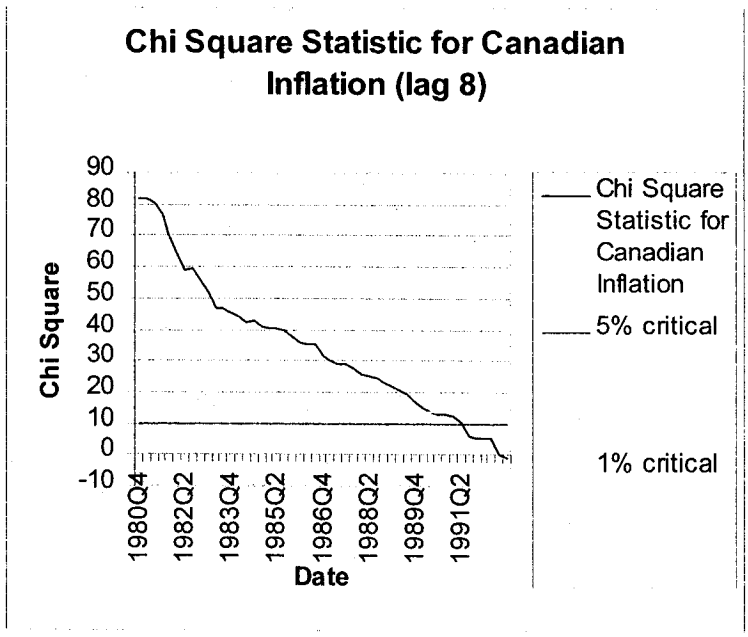
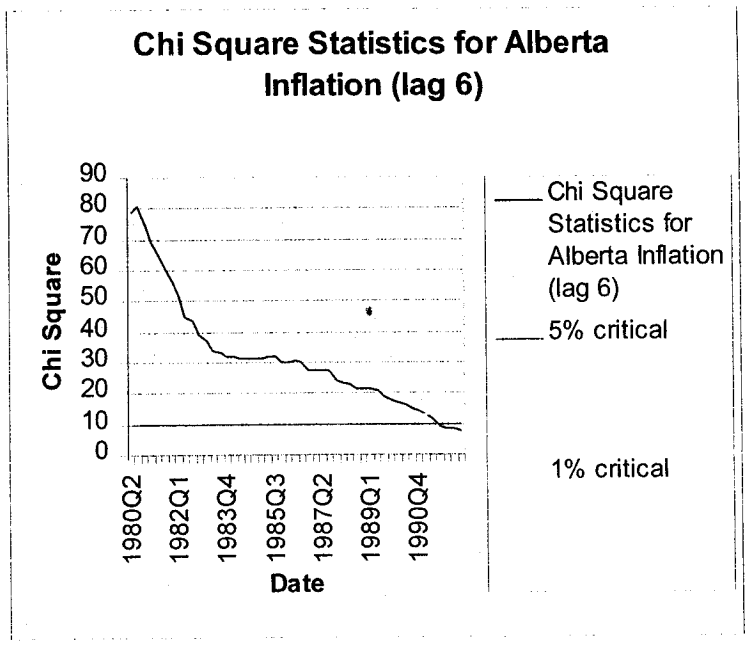
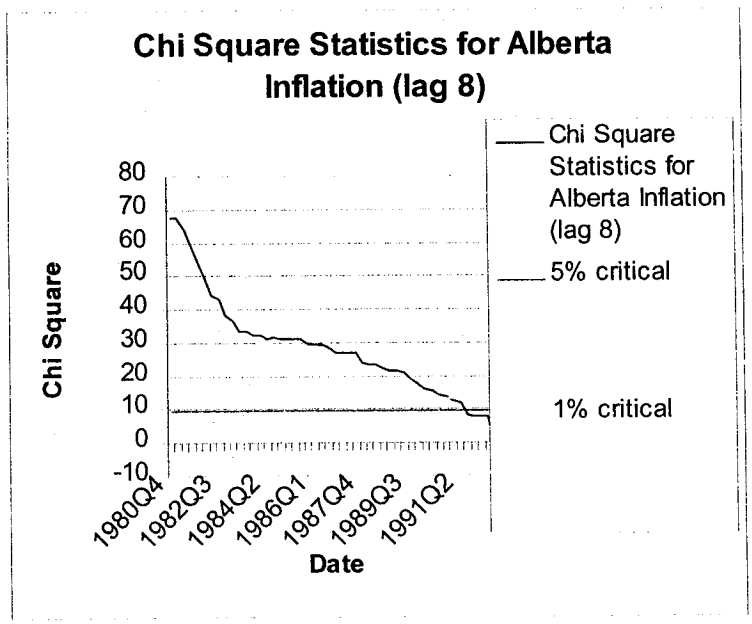


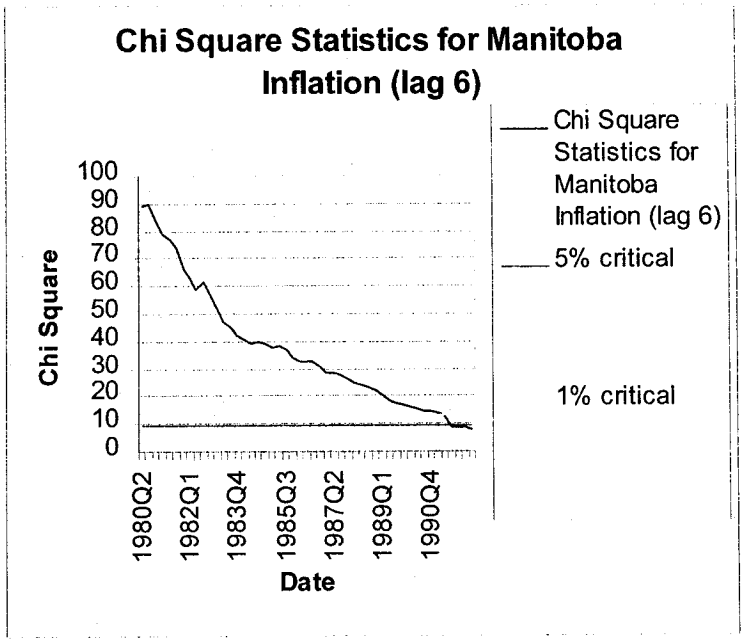
Figure 2b: Chi Square Statistics for National and Provincial Inflation Rates






Chi Square Statistics for Alberta Inflation (lag 6)
Chi Square
90
80
70
60
50
40
30
20
10
0
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Alberta Inflation (lag 6)
5% critical
1% critical


Chi Square Statistics for Alberta Inflation (lag 8)
Chi Square
80
70
60
50
40
30
20
10
0
-10
1980Q4
1982Q3
1984Q2
1986Q1
1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for Alberta Inflation (lag 8)
5% critical
1% critical


Chi Square Statistics for Manitoba Inflation (lag 6)
Chi Square
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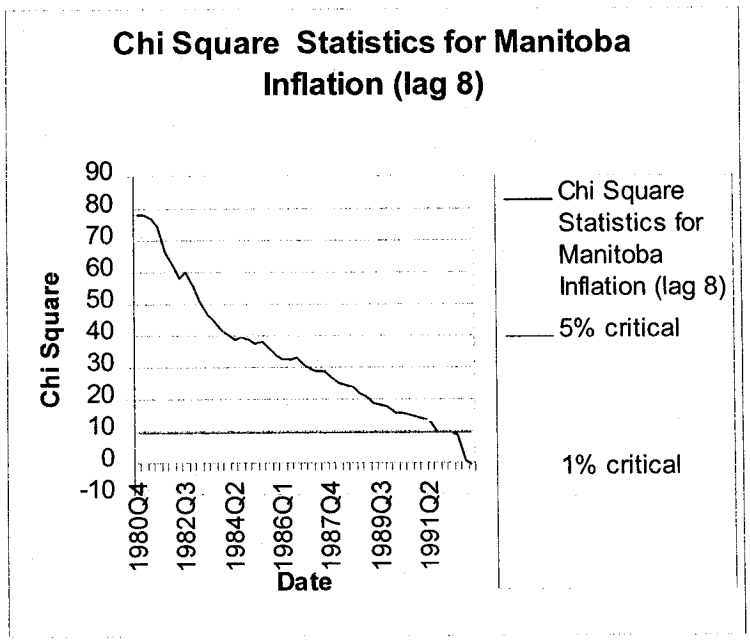
20
10
0
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Manitoba Inflation (lag 6)
5% critical
1% critical


Chi Square Statistics for Manitoba Inflation (lag 8)
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1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for Manitoba Inflation (lag 8)
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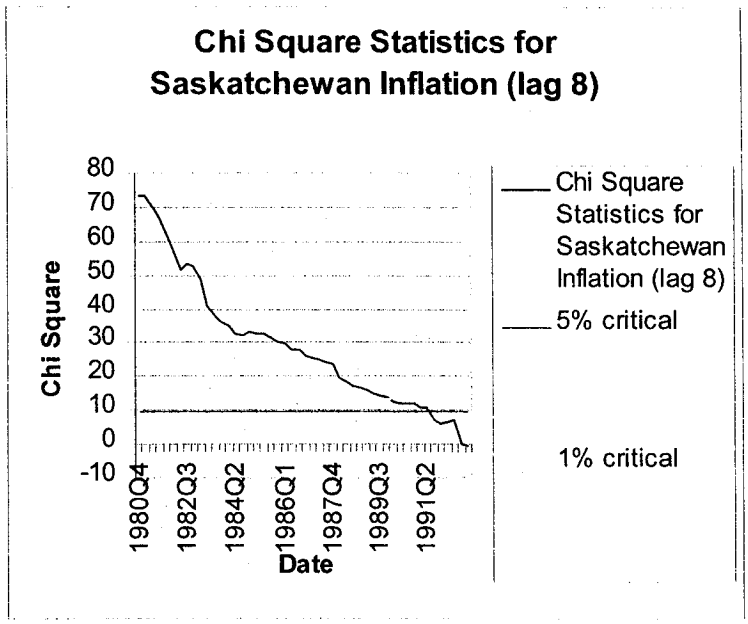
1% critical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Chi Square
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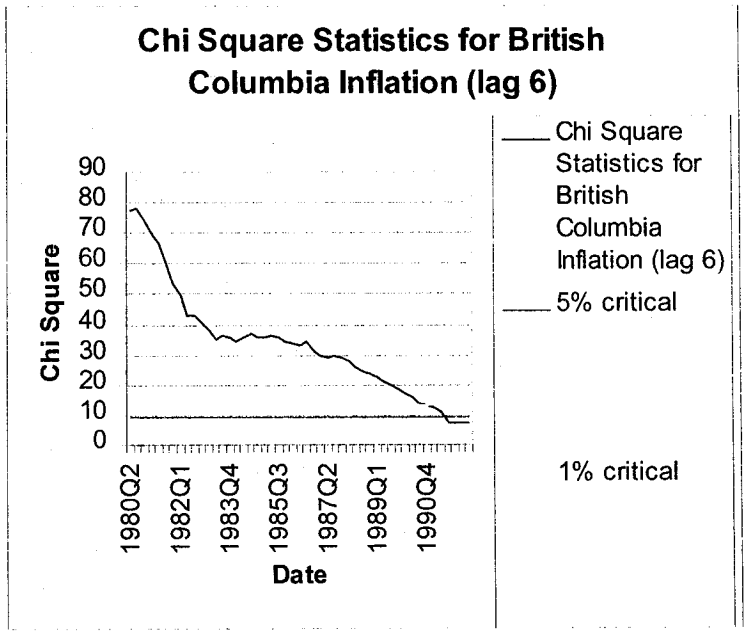
-10
1980Q4
1982Q3
1984Q2
1986Q1
1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for Saskatchewan Inflation (lag 8)
5% critical
1% critical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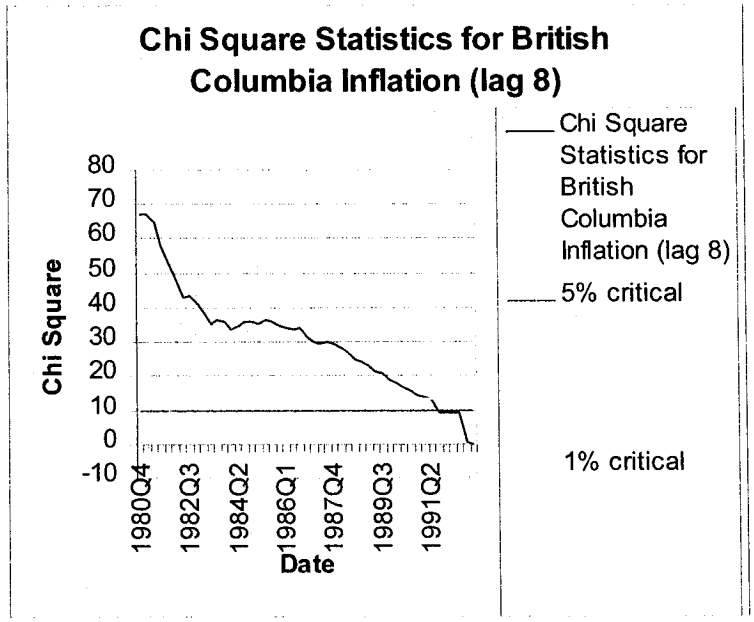
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for British Columbia Inflation (lag 6)
5% critical
1% critical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1980Q4
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1986Q1
1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for British Columbia Inflation (lag 8)
5% critical
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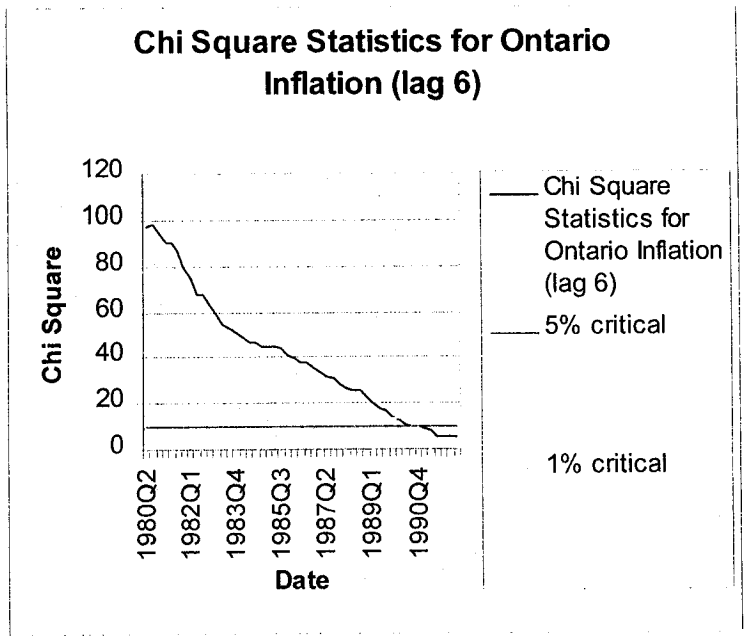
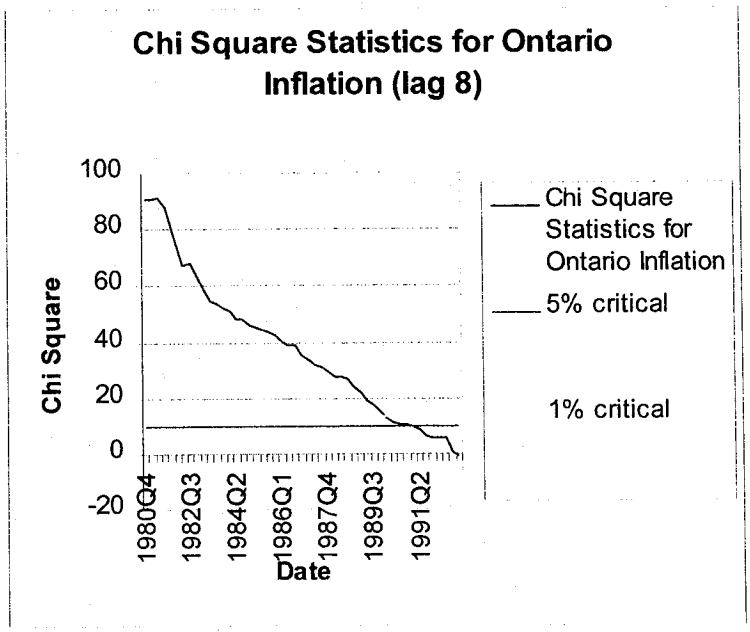

Chi Square Statistics for Ontario Inflation (lag 6)
120
100
80
60
40
20
0
Chi Square
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Ontario Inflation (lag 6)
5% critical
1% critical


Chi Square Statistics for Ontario Inflation (lag 8)
100
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40
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0
-20
Chi Square
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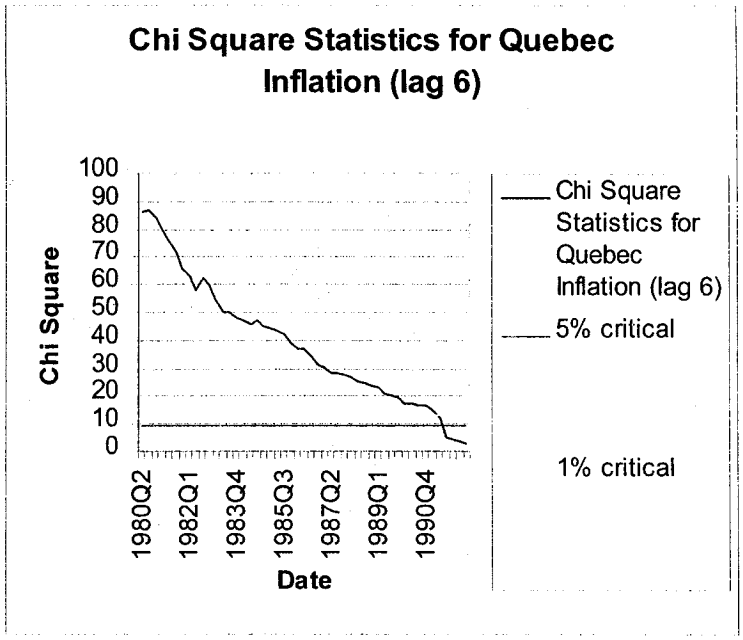
1982Q3
1984Q2
1986Q1
1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for Ontario Inflation
5% critical
1% critical


Chi Square Statistics for Quebec Inflation (lag 6)
Chi Square
100
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80
70
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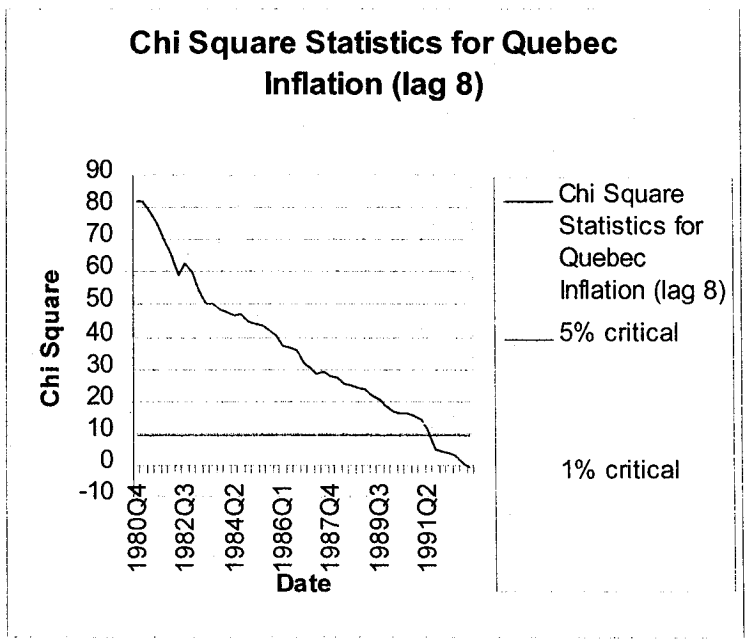
30
20
10
0
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Quebec Inflation (lag 6)
5% critical
1% critical


Chi Square Statistics for Quebec Inflation (lag 8)
Chi Square
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1980Q4
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1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for Quebec Inflation (lag 8)
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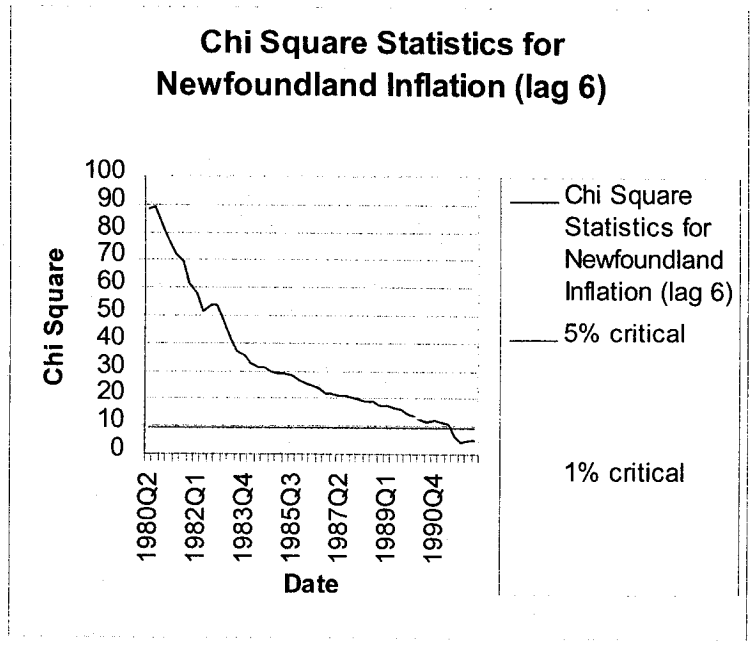
Chi Square Statistics for
Newfoundland Inflation (lag 6)
Chi Square
100
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30
20
10
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1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Newfoundland Inflation (lag 6)
5% critical
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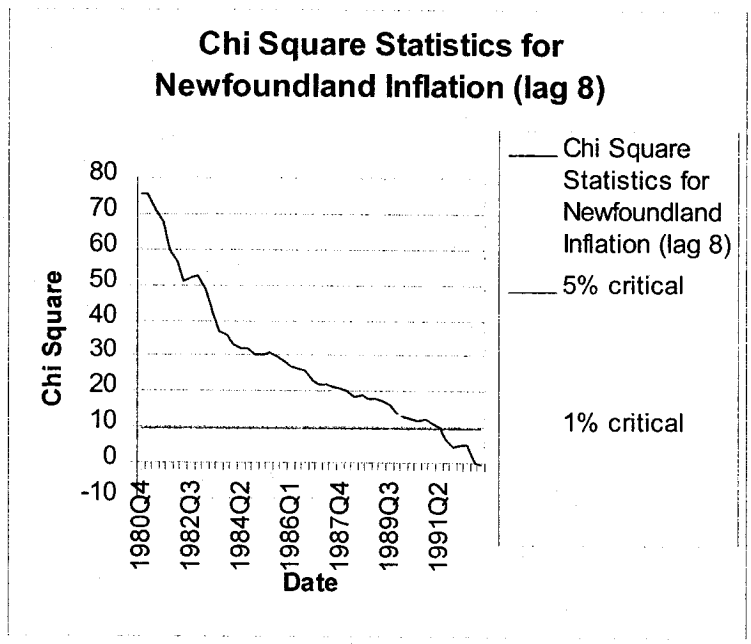
Chi Square Statistics for
Newfoundland Inflation (lag 8)
Chi Square
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40
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10
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-10
1980Q4
1982Q3
1984Q2
1986Q1
1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for Newfoundland Inflation (lag 8)
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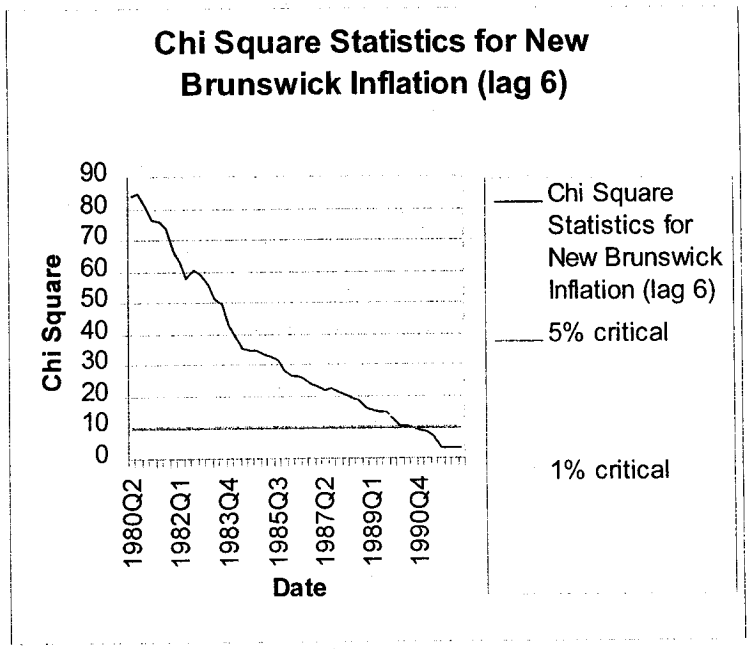
Chi Square Statistics for New Brunswick Inflation (lag 6)
Chi Square
90
80
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30
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10
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1980Q2
1982Q1
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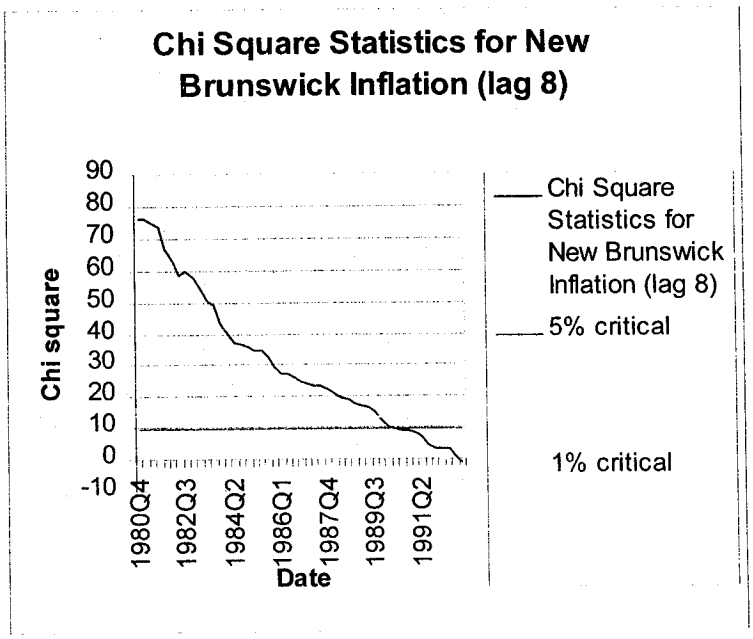
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for New Brunswick Inflation (lag 6)
5% critical
1% critical


Chi Square Statistics for New Brunswick Inflation (lag 8)
Chi square
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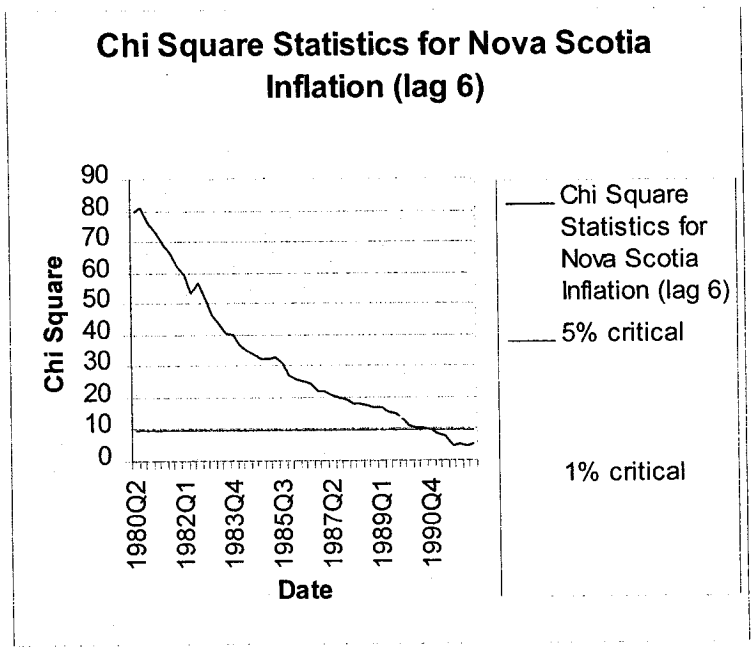
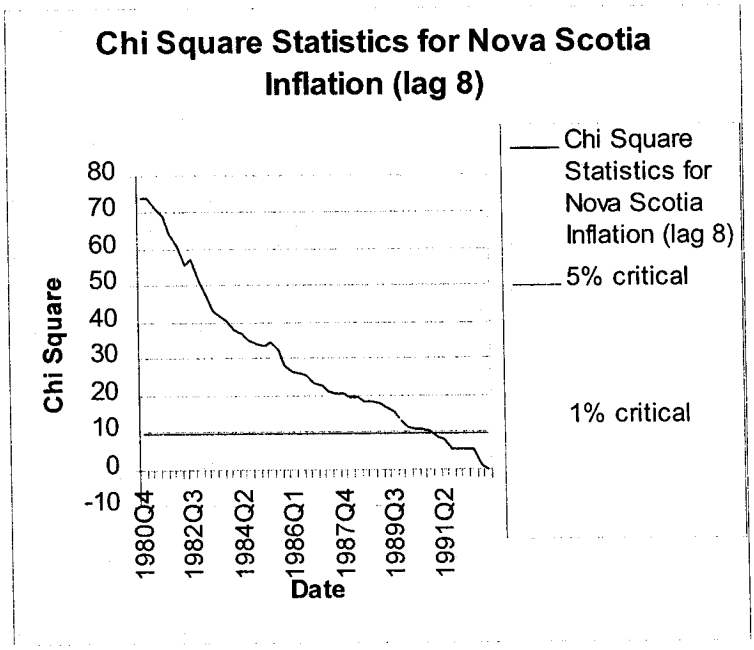
70
60
50
40
30
20
10
0
-10
1980Q4
1982Q3
1984Q2
1986Q1
1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for New Brunswick Inflation (lag 8)
5% critical
1% critical


Chi Square Statistics for Nova Scotia Inflation (lag 6)
Chi Square
90
80
70
60
50
40
30
20
10
0
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Nova Scotia Inflation (lag 6)
5% critical
1% critical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Chi Square
80
70
60
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20
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0
-10
1980Q4
1982Q3
1984Q2
1986Q1
1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for Nova Scotia Inflation (lag 8)
5% critical
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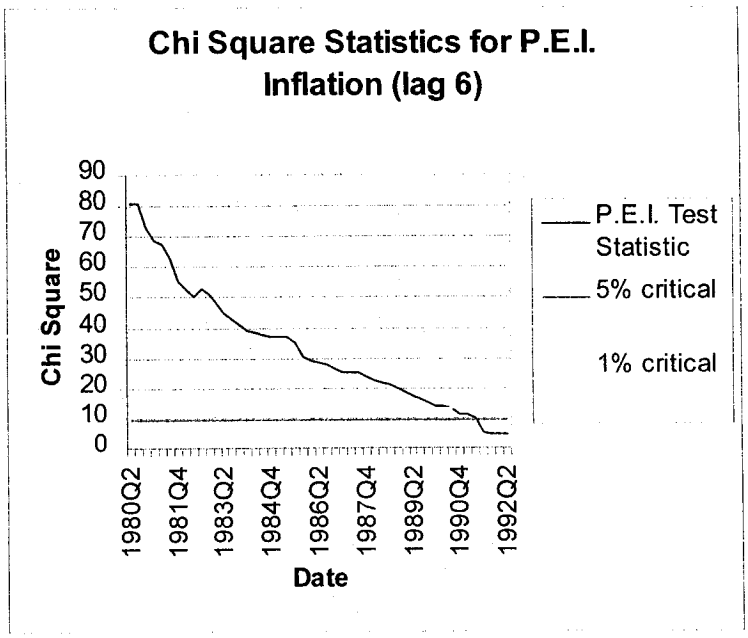
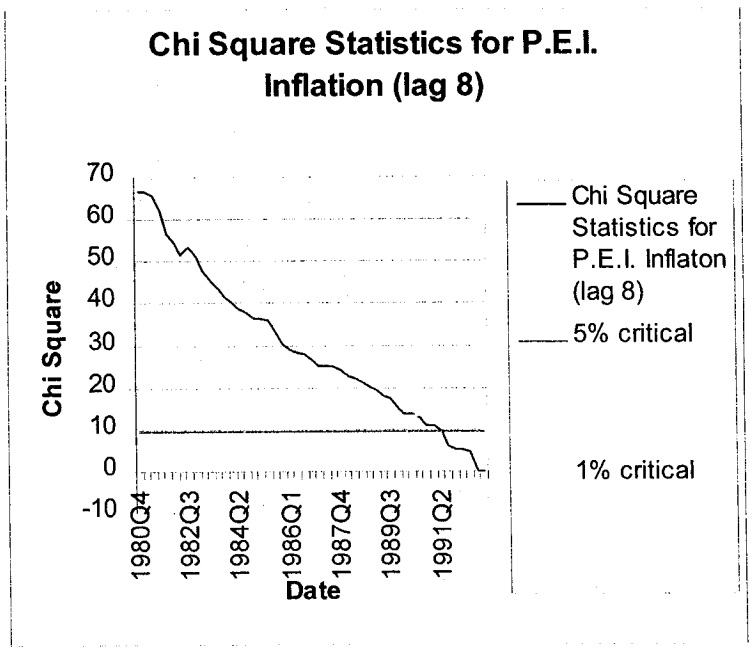

Chi Square Statistics for P.E.I. Inflation (lag 6)
Chi Square
90
80
70
60
50
40
30
20
10
0
1980Q2
1981Q4
1983Q2
1984Q4
1986Q2
1987Q4
1989Q2
1990Q4
1992Q2
Date
P.E.I. Test Statistic
5% critical
1% critical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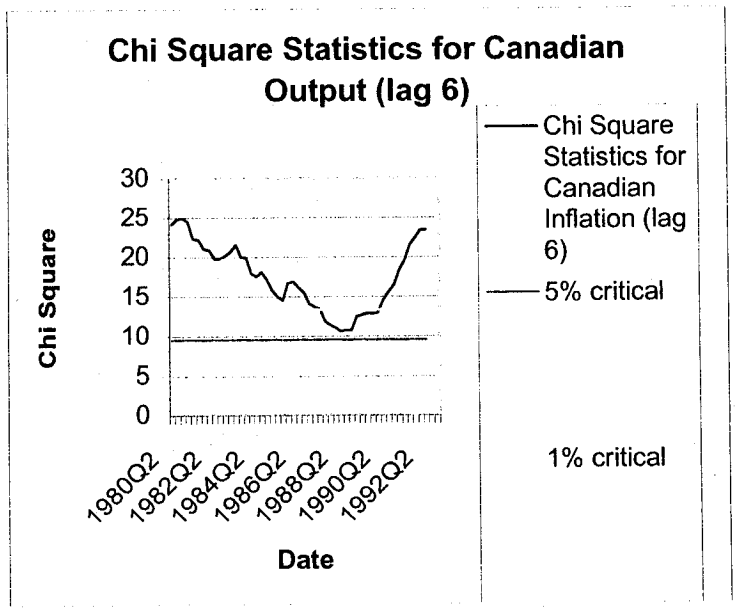
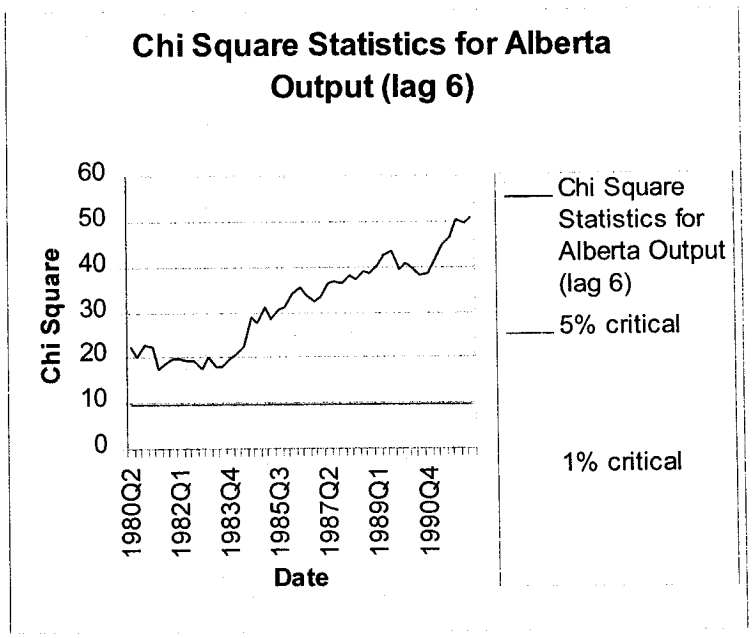
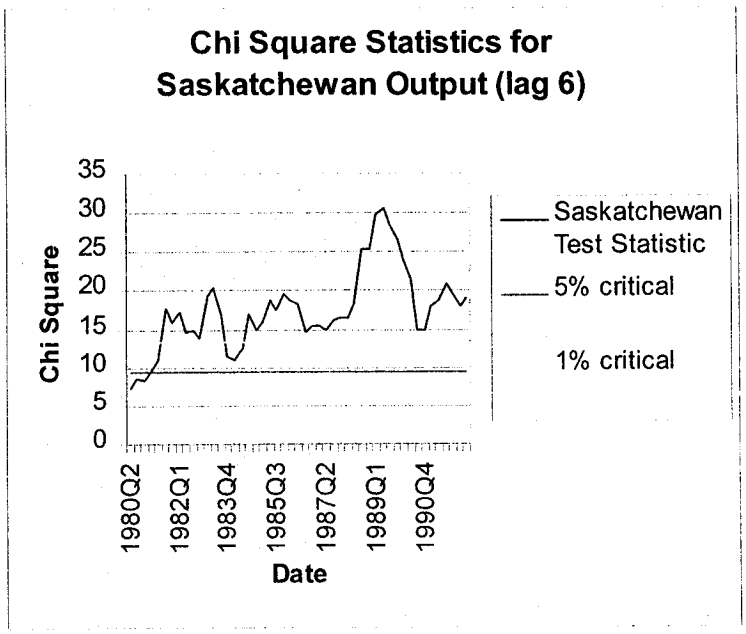
Chi Square
70
60
50
40
30
20
10
0
-10
1980Q4
1982Q3
1984Q2
1986Q1
1987Q4
1989Q3
1991Q2
Date
Chi Square Statistics for P.E.I. Inflaton (lag 8)
5% critical
1% critical

Figure 2c: Chi Square Statistics for National and Provincial Growth Rates in Gross Domestic Product



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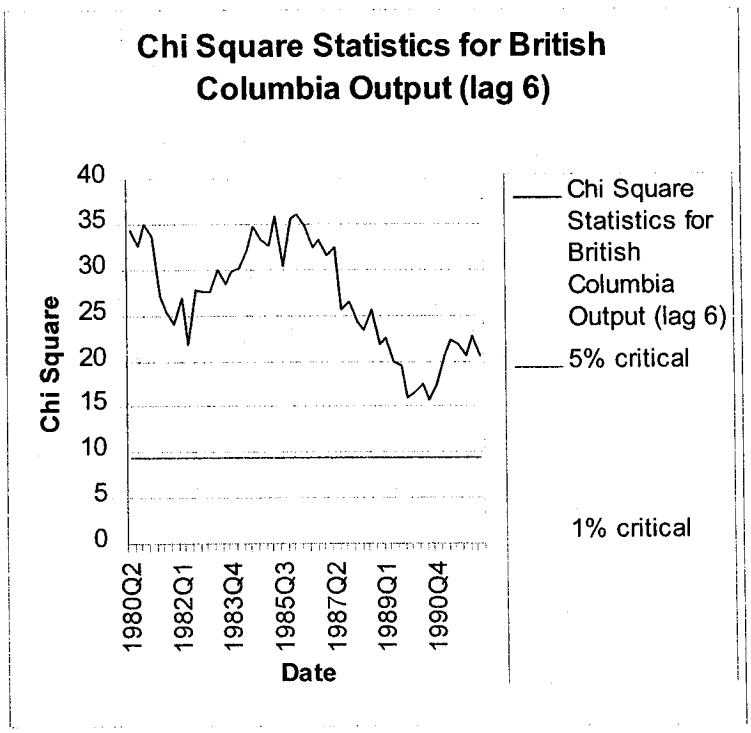
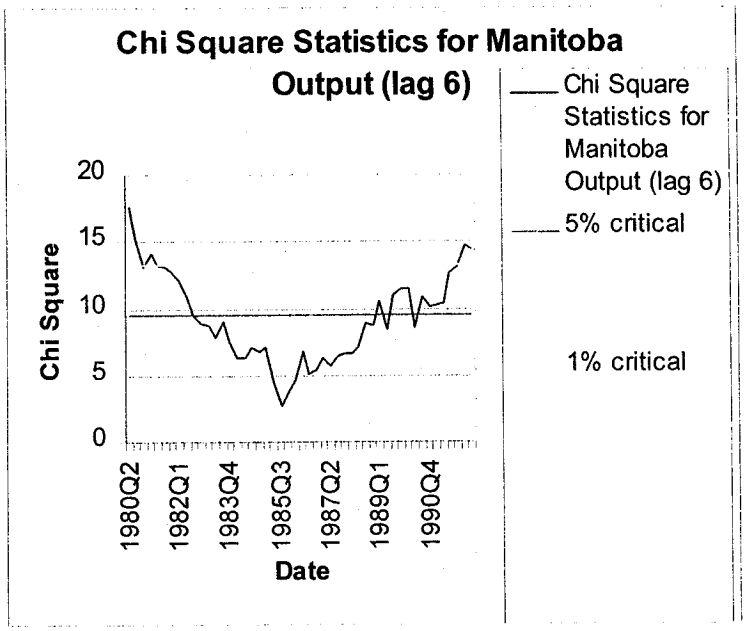
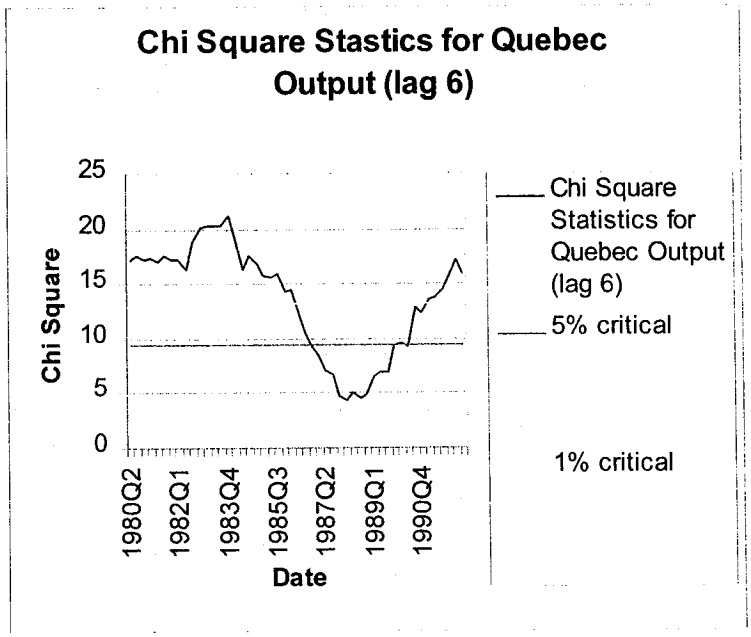
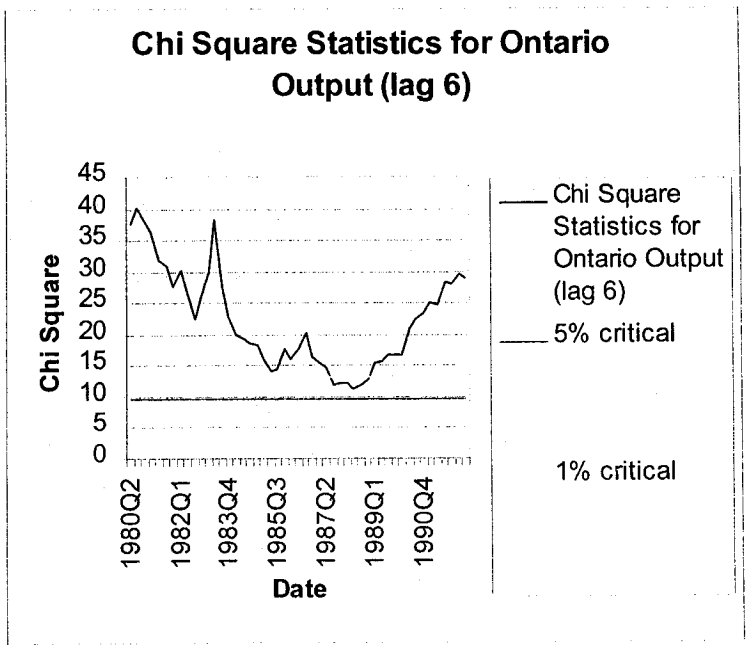
35
30
25
20
15
10
5
0
Chi Square
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Saskatchewan Test Statistic
5% critical
1% critical


Chi Square Statistics for British Columbia Output (lag 6)
40
35
30
25
20
15
10
5
0
Chi Square
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for British Columbia Output (lag 6)
5% critical
1% critical


Chi Square Statistics for Manitoba Output (lag 6)
Chi Square
20
15
10
5
0
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Manitoba Output (lag 6)
5% critical
1% critical


Chi Square Stastics for Quebec Output (lag 6)
Chi Square
25
20
15
10
5
0
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Quebec Output (lag 6)
5% critical
1% critical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Chi Square
45
40
35
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1980Q2
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1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Ontario Output (lag 6)
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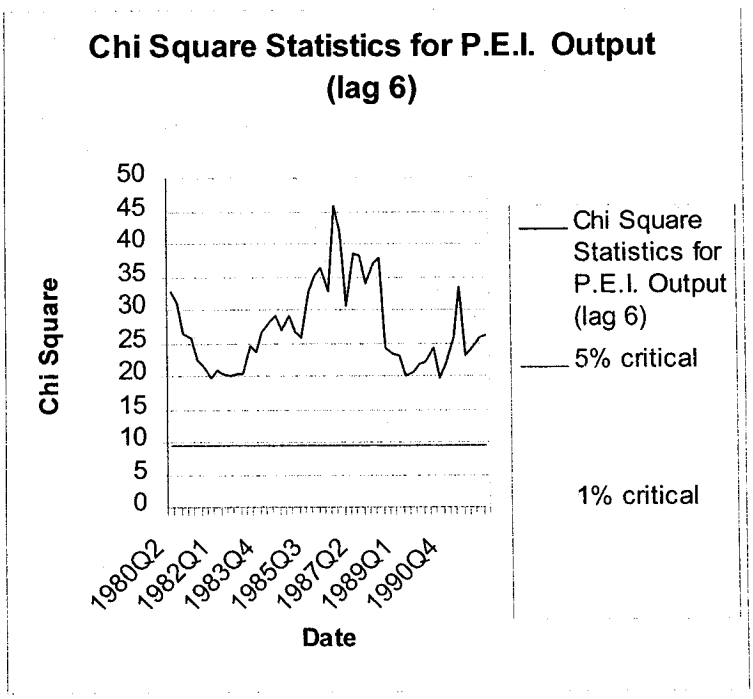
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Chi Square
50
45
40
35
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25
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15
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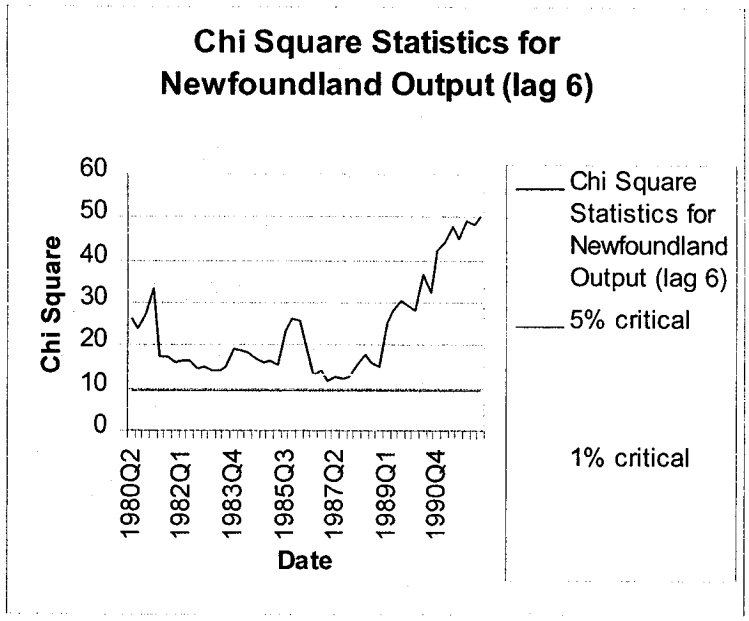
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for P.E.I. Output (lag 6)
5% critical
1% critical


Chi Square Statistics for
Newfoundland Output (lag 6)
Chi Square
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1980Q2
1982Q1
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1989Q1
1990Q4
Date
Chi Square Statistics for Newfoundland Output (lag 6)
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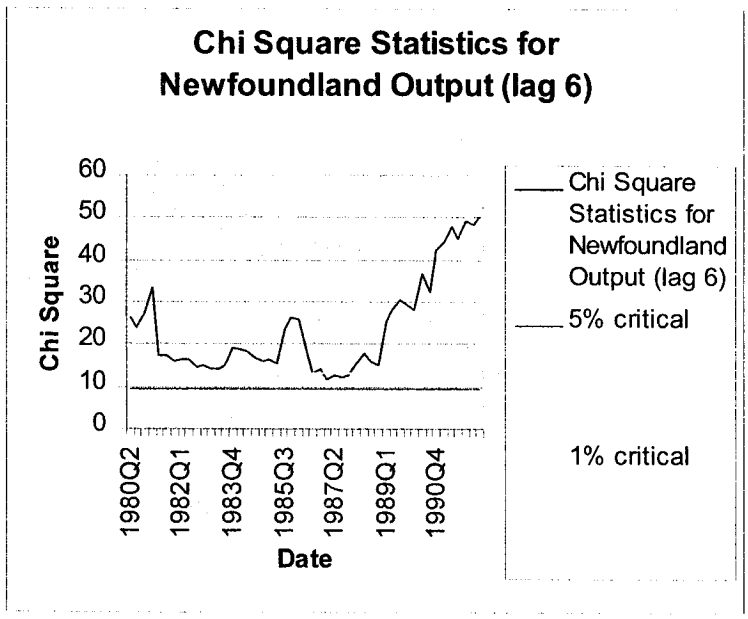
Chi Square Statistics for
Newfoundland Output (lag 6)
Chi Square
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1980Q2
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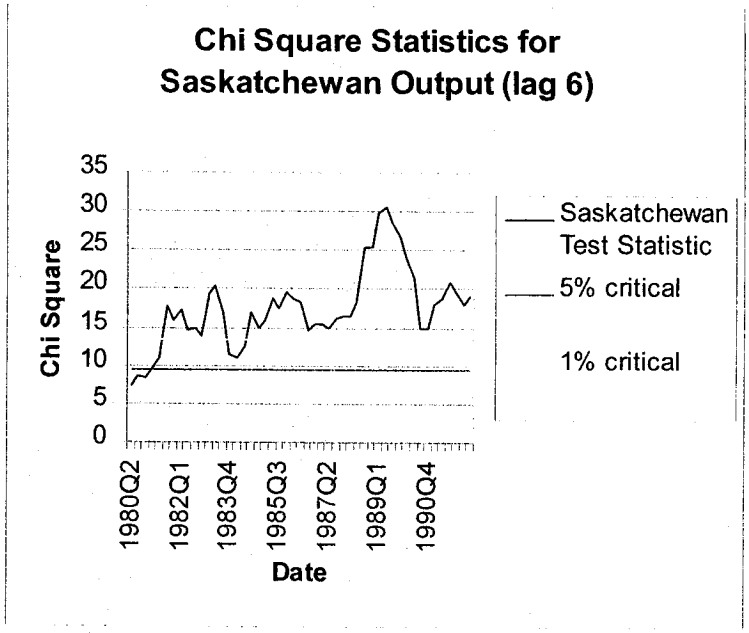
1987Q2
1989Q1
1990Q4
Date
Chi Square Statistics for Newfoundland Output (lag 6)
5% critical
1% critical


Chi Square Statistics for
Saskatchewan Output (lag 6)
Chi Square
35
30
25
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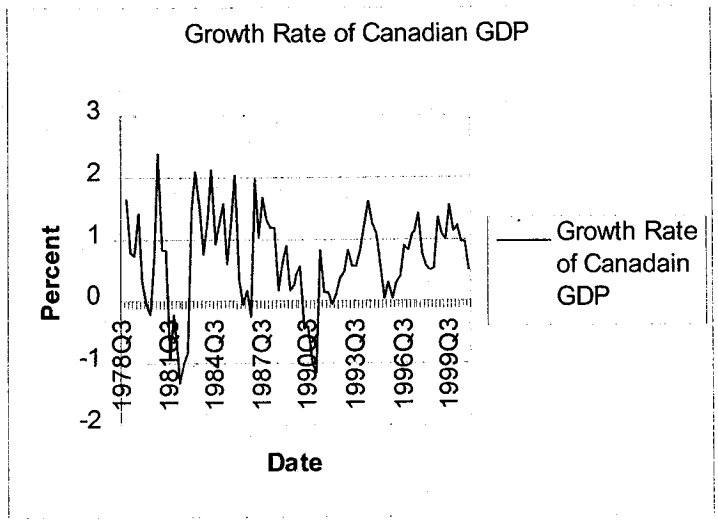
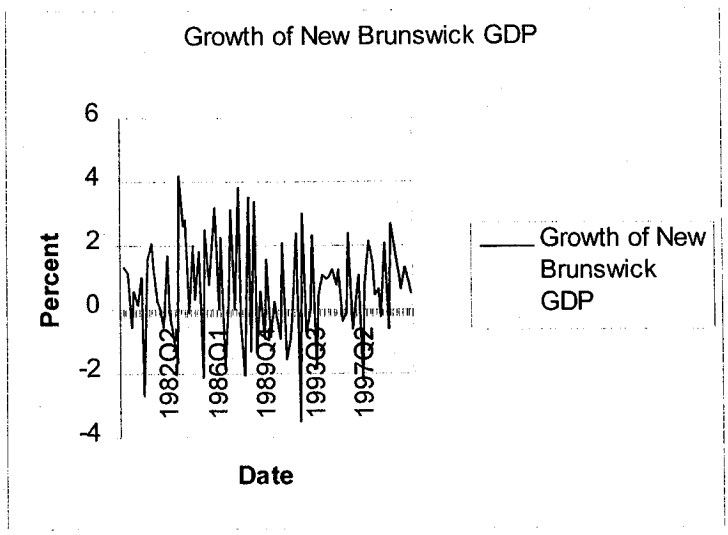
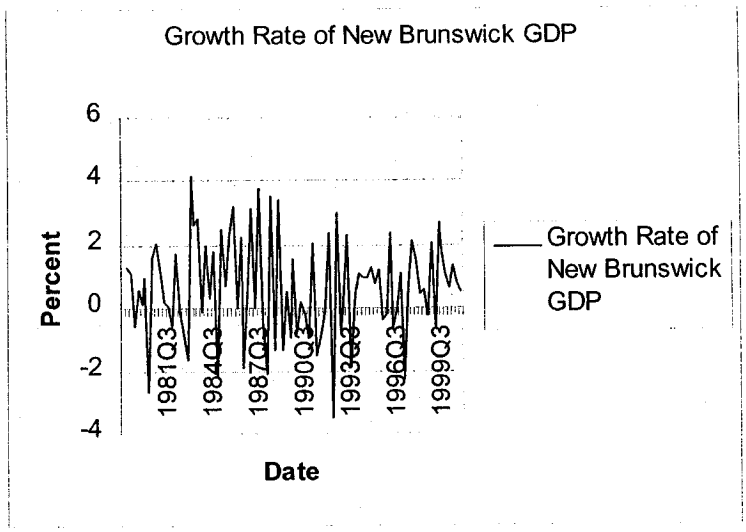
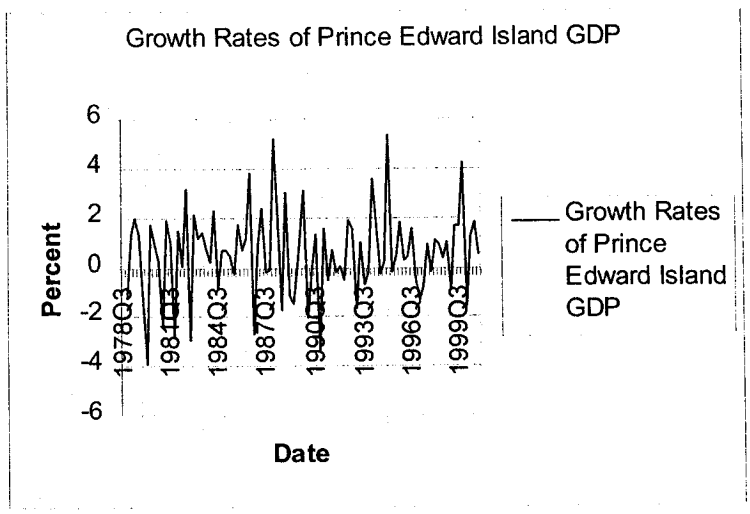
15
10
5
0
1980Q2
1982Q1
1983Q4
1985Q3
1987Q2
1989Q1
1990Q4
Date
Saskatchewan Test Statistic
5% critical
1% critical

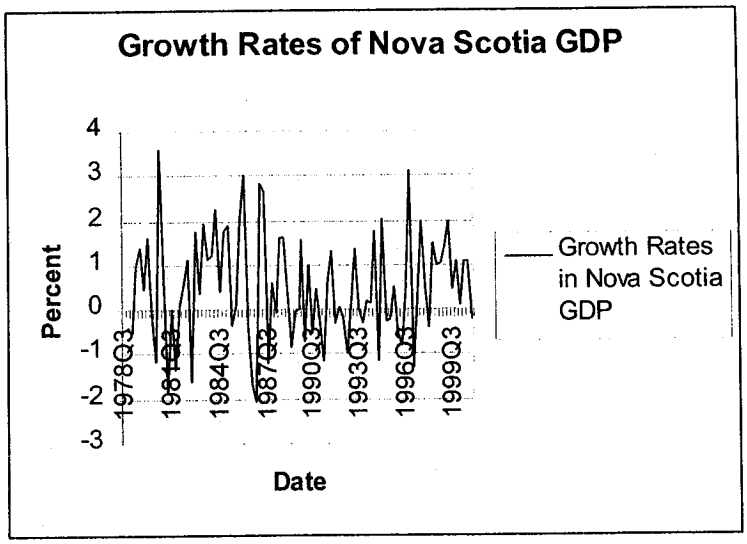
Figure 2d: National and Provincial GDP Growth Rates

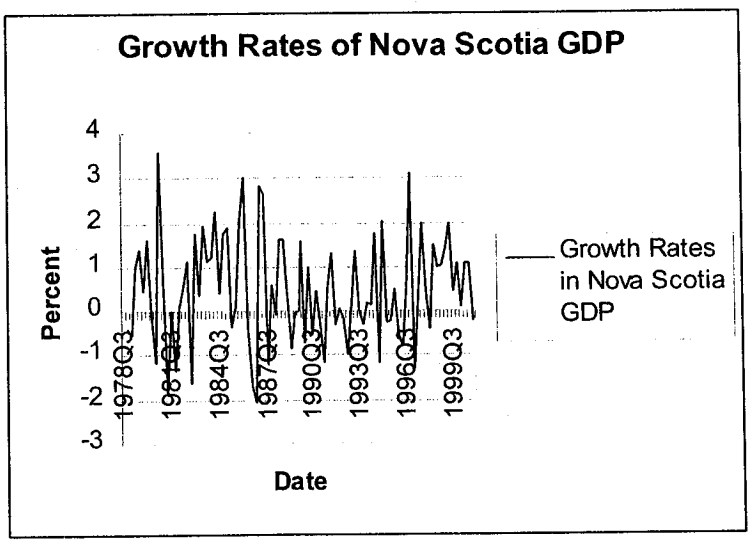


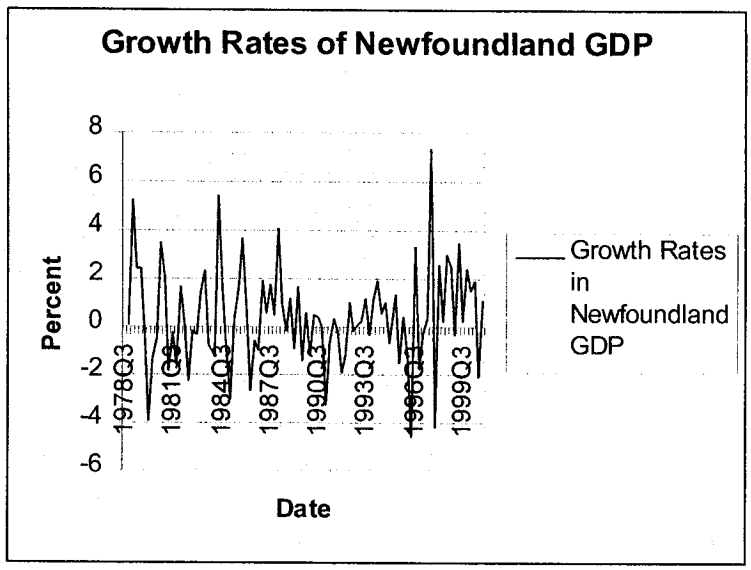


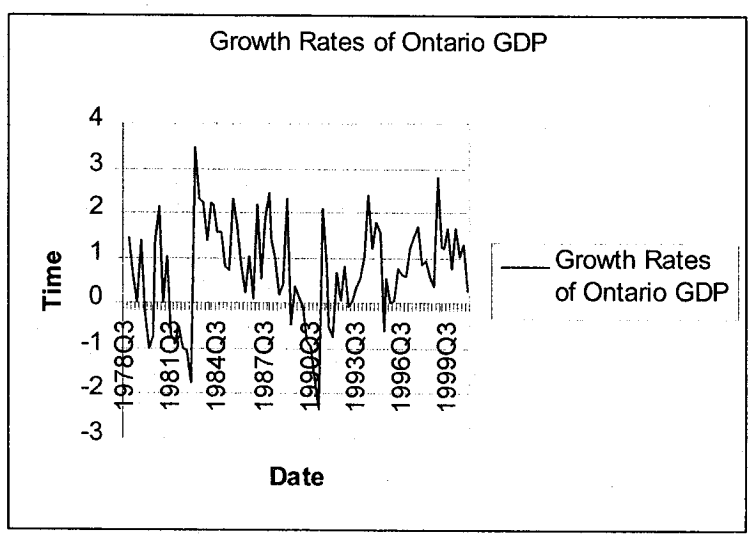

Growth Rate of New Brunswick GDP
6
4
2
0
-2
-4
Percent
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rate of New Brunswick GDP

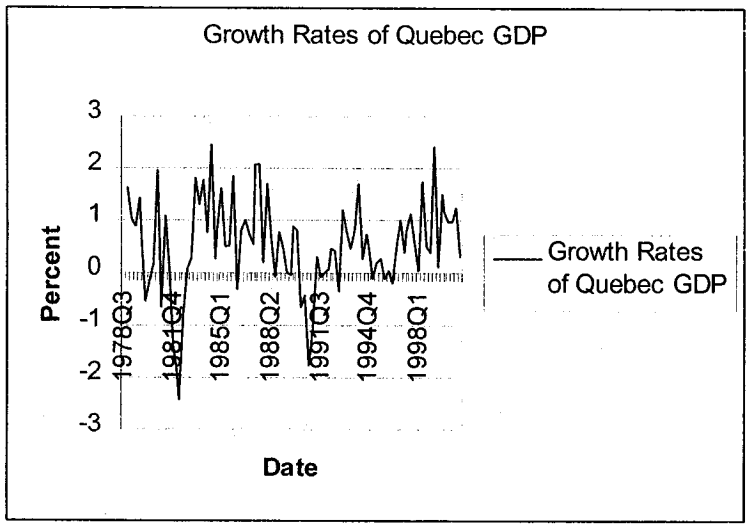

Growth Rates of Prince Edward Island GDP
6
4
2
0
-2
-4
-6
Percent
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rates of Prince Edward Island GDP

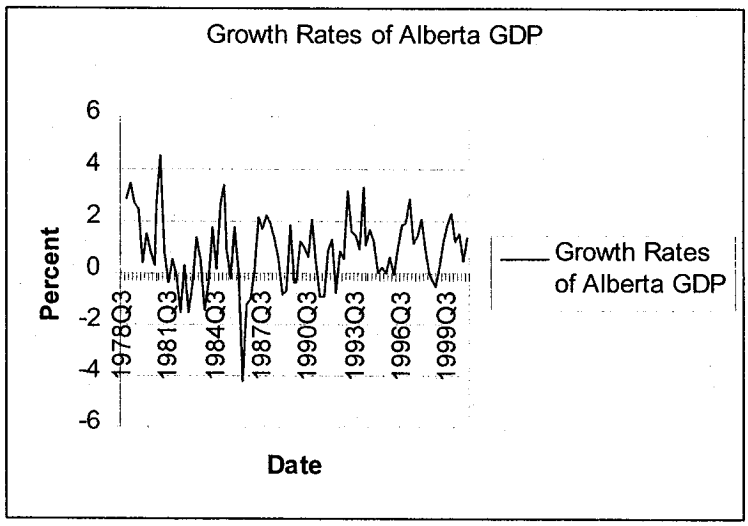

Growth Rates of Nova Scotia GDP
Percent
4
3
2
1
0
-1
-2
-3
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rates in Nova Scotia GDP

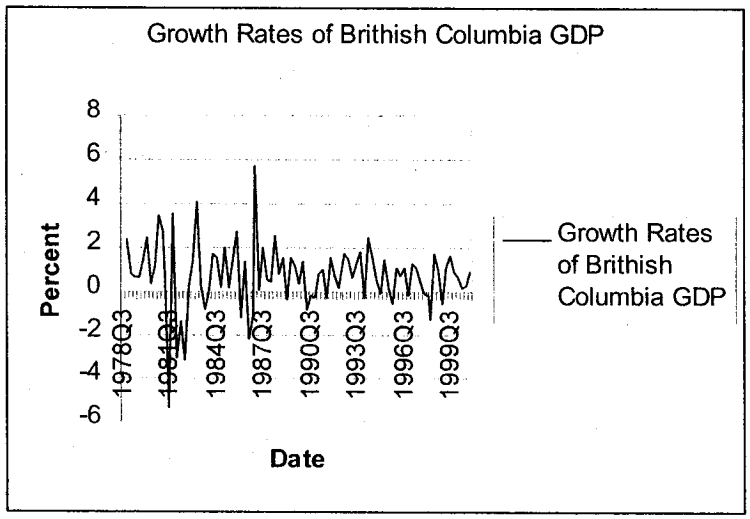

Growth Rates of Nova Scotia GDP
Percent
4
3
2
1
0
-1
-2
-3
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rates in Nova Scotia GDP

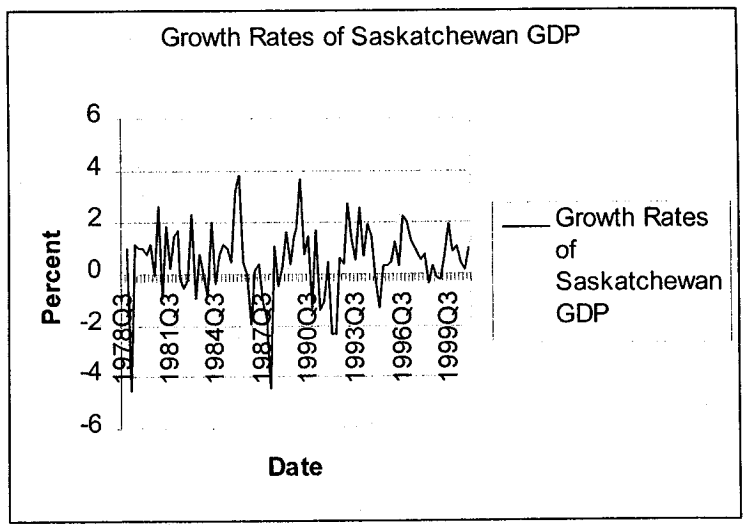

Growth Rates of Newfoundland GDP
8
6
4
2
0
-2
-4
-6
Percent
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rates in Newfoundland GDP


Growth Rates of Ontario GDP
4
3
2
1
0
-1
-2
-3
Time
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rates of Ontario GDP


Growth Rates of Quebec GDP
3
2
1
0
-1
-2
-3
Percent
1978Q3
1981Q4
1985Q1
1988Q2
1991Q3
1994Q4
1998Q1
Date
Growth Rates of Quebec GDP


Growth Rates of Alberta GDP
6
4
2
0
-2
-4
-6
Percent
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rates of Alberta GDP


Growth Rates of Brithish Columbia GDP
8
6
4
2
0
-2
-4
-6
Percent
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rates of Brithish Columbia GDP


Growth Rates of Saskatchewan GDP
6
4
2
0
-2
-4
-6
Percent
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rates of Saskatchewan GDP

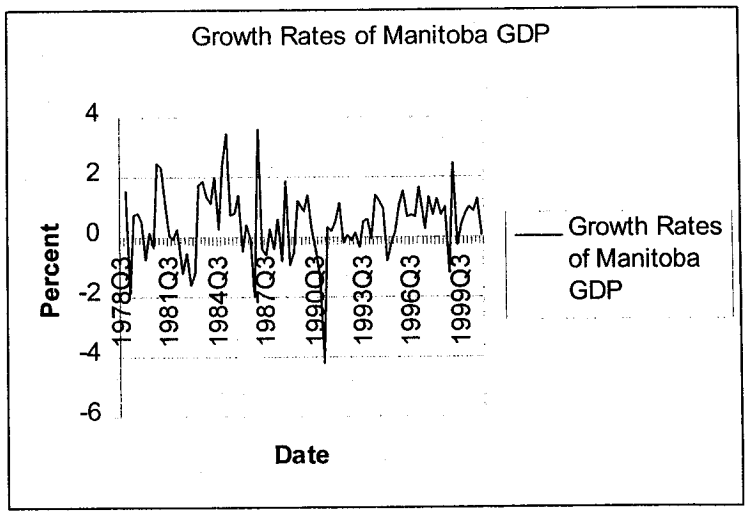
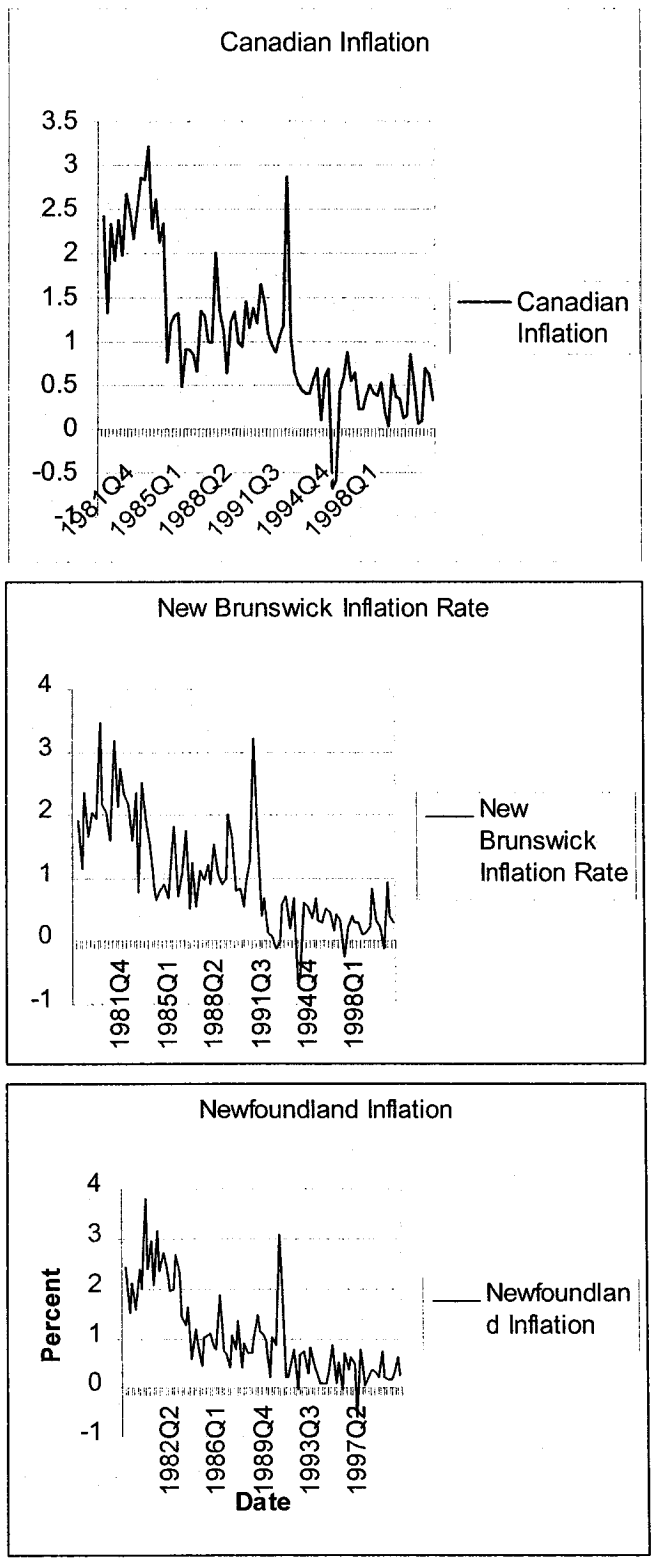
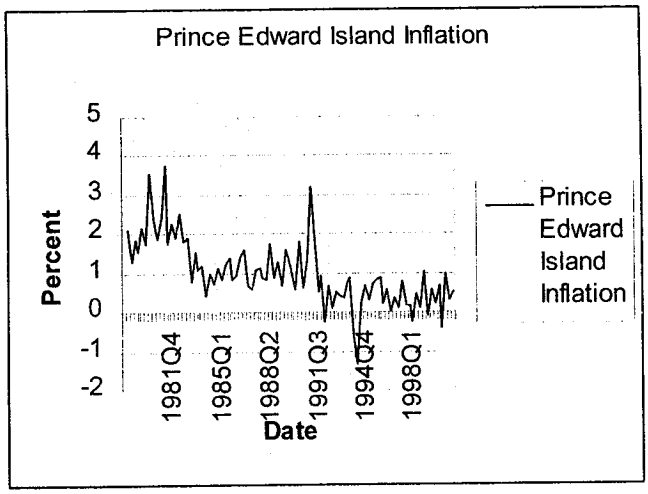
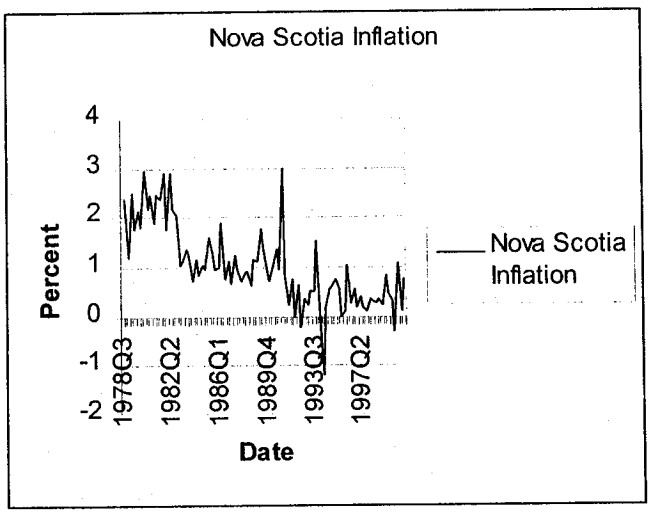
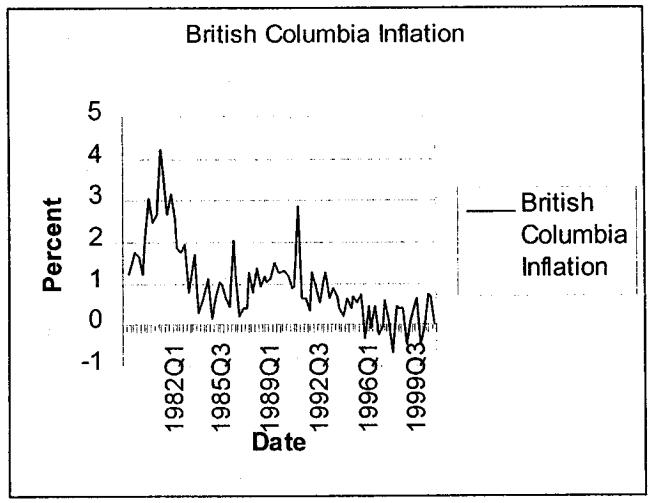

Growth Rates of Manitoba GDP
4
2
0
-2
-4
-6
Percent
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Growth Rates of Manitoba GDP

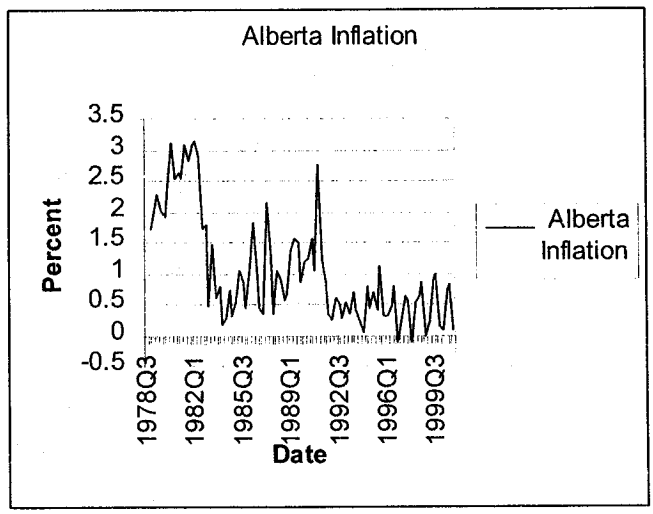
Figure 2e: Provincial Inflation Rates

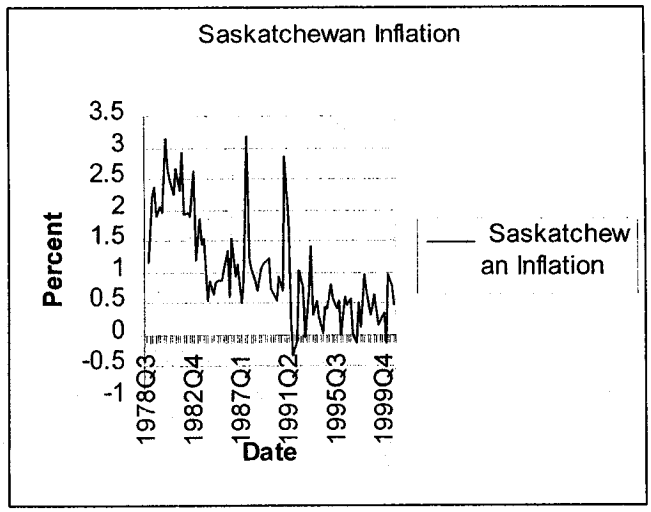


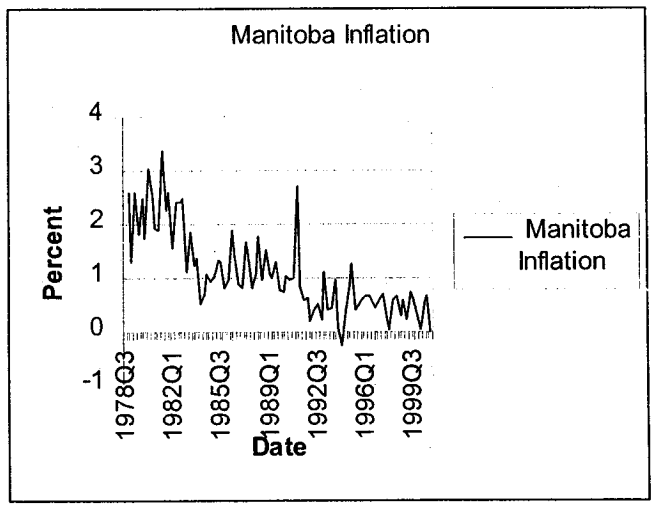

Prince Edward Island Inflation
5
4
3
2
1
0
-1
-2
Percent
1981Q4
1985Q1
1988Q2
1991Q3
1994Q4
1998Q1
Date
Prince Edward Island Inflation

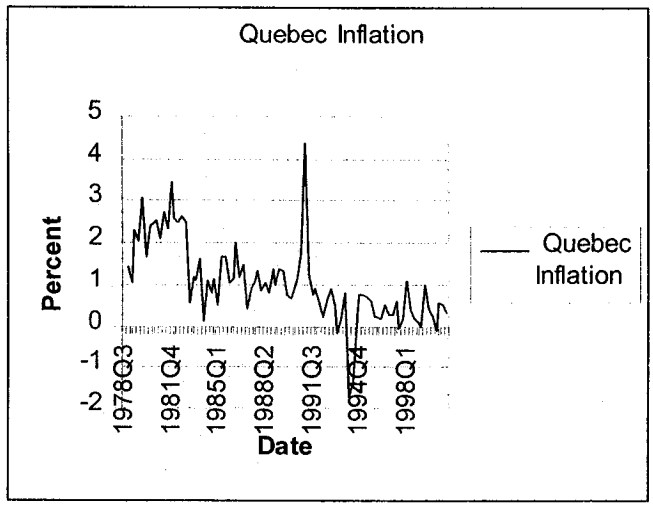

Nova Scotia Inflation
4
3
2
1
0
-1
-2
Percent
1978Q3
1982Q2
1986Q1
1989Q4
1993Q3
1997Q2
Date
Nova Scotia Inflation

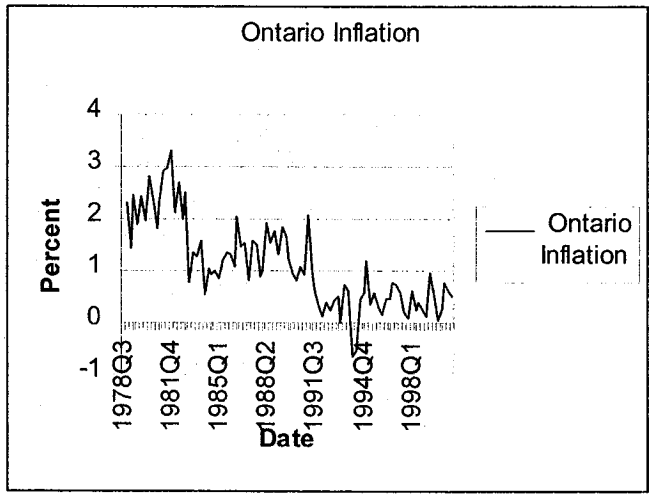

British Columbia Inflation
5
4
3
2
1
0
-1
Percent
1982Q1
1985Q3
1989Q1
1992Q3
1996Q1
1999Q3
Date
British Columbia Inflation


Alberta Inflation
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
Percent
1978Q3
1982Q1
1985Q3
1989Q1
1992Q3
1996Q1
1999Q3
Date
Alberta Inflation


Saskatchewan Inflation
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
Percent
1978Q3
1982Q4
1987Q1
1991Q2
1995Q3
1999Q4
Date
Saskatchewan Inflation


Manitoba Inflation
4
3
2
1
0
-1
Percent
1978Q3
1982Q1
1985Q3
1989Q1
1992Q3
1996Q1
1999Q3
Date
Manitoba Inflation


Quebec Inflation
5
4
3
2
1
0
-1
-2
Percent
1978Q3
1981Q4
1985Q1
1988Q2
1991Q3
1994Q4
1998Q1
Date
Quebec Inflation


Ontario Inflation
4
3
2
1
0
-1
Percent
1978Q3
1981Q4
1985Q1
1988Q2
1991Q3
1994Q4
1998Q1
Date
Ontario Inflation

Appendix (cond):

Descriptive statistics for provincial inflation rates (1978Q3:2000Q4)
(All Item inflation less food and energy)

Table 1:Provincial and National Inflation Statistics

PROVINCE OR CANADA	AVERAGE INFLATION (4 QUARTER MOVING AVERAGE)	STANDARD DEVIATION
ONTARIO	1.10 (HIGHEST)	.75
QUEBEC	1.05	.82 (HIGHEST)
BRITISH COLUMBIA	1.01	.80
ALBERTA	1.03	.77
SASKATCHEWAN	1.03	.70
MANITOBIA	1.09	.66
NEWFOUNDLAND	1.01	.77
PRINCE EDWARD ISLAND	1.0	.71
NOVA SCOTIA	1.0	.70 (LOWEST)
NEW BRUNSWICK	1.0 (LOWEST)	.74
CANADA	1.06	.75

Descriptive statistics for growth rates in quarterly gross domestic product

Table 2: Provincial and National GDP Statistics

PROVINCE OR CANADA	AVERAGE QUARTERLY REAL GDP	STANDARD DEVIATION
ONTARIO	239496	43548
QUEBEC	131232	16521
BRITISH COLUMBIA	71609	13507
ALBERTA	68794	13537
SASKATCHEWAN	19551	2601
MANITOBIA	21328	2298
NEWFOUNDLAND	8189	676
PRINCE EDWARD ISLAND	2060	304
NOVA SCOTIA	15046	1744
NEW BRUNSWICK	11554	1739
CANADA	592217	95754

Phillips Perron (PP) Test for All Item Inflation Less Food and Energy

Canadain Inflation

PP Test Statistic	-3.878579	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Alberta Inflation

PP Test Statistic	-3.416058	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

British Columbia Inflation

PP Test Statistic	-5.625869	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Manitoba Inflation

PP Test Statistic	-5.866900	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

New Brunswick Inflation

PP Test Statistic	-5.322403	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Newfoundland Inflation

PP Test Statistic	-5.815746	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Nova Scotia Inflation

PP Test Statistic	-5.669285	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Ontario Inflation

PP Test Statistic	-3.734542	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Prince Edward Island Inflation

PP Test Statistic	-5.747240	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Quebec Inflation

PP Test Statistic	-4.628994	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Saskatchewan Inflation

PP Test Statistic	-5.741688	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Phillips Perron (PP) Test for Growth Rates of Gross Domestic Product

Canadian GDP

PP Test Statistic	-4.212707	1%	Critical Value*	-3.5312
5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

Newfoundland GDP

PP Test Statistic	-15.41006	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Prince Edward Island GDP

PP Test Statistic	-19.67615	1%	Critical Value*	-3.5312
5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

Nova Scotia GDP

PP Test Statistic	-15.00593	1%	Critical Value*	-3.5312
5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

New Brunswick GDP

PP Test Statistic	-16.32030	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Quebec GDP

PP Test Statistic	-19.57205	1%	Critical Value*	-3.5312

5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

Ontario GDP

PP Test Statistic	-6.035251	1%	Critical Value*	-3.5312
5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

Manitoba GDP

PP Test Statistic	-11.19274	1%	Critical Value*	-3.5312
5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

Saskatchewan GDP

PP Test Statistic	-13.26888	1%	Critical Value*	-3.5312
5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

Alberta GDP

PP Test Statistic	-10.06136	1%	Critical Value*	-3.5312
5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

British Columbia GDP

PP Test Statistic	-11.17934	1%	Critical Value*	-3.5312
5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

Phillips Perron (PP) Test for Interest Rates and Growth Rates of Money Supply

90 Day Corporate Paper Rate

PP Test Statistic	-6.519154	1%	Critical Value*	-3.5312
5% Critical Value	-2.9055			
10% Critical Value	-2.5899			

Growth in Money Supply

PP Test Statistic	-3.761515	1%	Critical Value*	-4.1013
5% Critical Value	-3.4779			
10% Critical Value	-3.1663			

Appendix (cond): Sources of data

INFLATION:

The Canadian inflation rate is defined as the first difference of logs CPI (All item CPI less food and Energy). This measure of Inflation rate is used given it excludes the two most volatile components of all items CPI and given it has a seasonal component; we decided to exclude it from the inflation calculation. The data used in these paper spans 1978:3 to 2000:4. Provincial Inflation rates are computed in the same manner.

The data comes from the CANSIM database.
More Specifically:

CPI (all item less food and energy)

Canada	P100285
Newfoundland	P101127
PEI	P102127
NS	P103127
NB	P104127
Québec	P105127
Ontario	P106127
Manitoba	P107127
Saskatchewan	P108127
Alberta	P109127
British Columbia	P110127

CANADIAN INTEREST RATES:

90-Day corporate paper Rates the rate used in this paper. It is taken from the Cansim Data Base, Label B14017. The data used in this paper span 1978:3 to 2000:1.

MONEY SUPPLY

The growth in the U.S. money supply is defined as the first difference of log M1. The data used in this paper span 1978:3 to 2000:1.

The money Supply Data is taken from the Cansim Data Base (D100045).

GROWTH IN REAL EXCHANGE RATE:

The real exchange rate is defined as the REX:

=Nominal exchange rate * (Price level in Canada)/(Price level in the U.S.)

where the nominal exchange rate is given by: The Canadian dollars/US dollars noon spot rate in Canadian dollars. This data is taken from CANSIM, label number B3400. The Price levels are also taken from Cansim, and are all items CPI figures (D19279 and D1928. Both these series are in the same base year of 100=1990.

TESTING FOR A TRADEOFF BETWEEN INFLATION VARIABILITY AND OUTPUT VARIABILITY

Abstract:

I have applied the Rowe and Yetman (2002) technique in chapter 1 to determine whether the United States Federal Reserve has put more emphasis on smoothing inflation variability rather than output variability. Chapter 2 moves further away from the Rowe and Yetman (2002) technique and examines whether or not a regional bias exists in Canadian monetary policy. I show that the Bank of Canada has used monetary policy to smooth provincial inflation rates in Canada at the expense of output instability. The apparent trade-off that exists between output and inflation variability leads to the question of what particular shocks have hit the Canadian and U.S. economies over the last two decades. My analysis suggests that both economies have suffered some supply shocks. This is especially true for Canada given we have empirically shown that the Bank of Canada has explicitly targeted inflation and not growth rates of provincial GDP. However the results for the U.S. are not as clear as the Canadian case given it is only suggested by my empirical exercises that the U.S. Federal Reserve is moving towards the smoothing of inflation rates while not explicitly achieving price stability as of yet. As a result, the existence of a trade-off with respect to the U.S. will not be as clear given a definite trade-off will exist only when the targeting of one variable has already been achieved.

I. Introduction

The first two chapters of this thesis suggest that achieving any one particular policy objective has come at the expense of something else. My work on the Canadian provinces and the United States illustrates this premise quite clearly, suggesting that the United States Federal Reserve and the Bank of Canada have changed interest rates to smooth the rates of inflation and this has occurred at the same time that we see greater variability in real output. This paper summarizes the results of the first two papers and determines whether these results are consistent with each other and with the existing literature. To interpret my results as suggesting that a trade-off does exist between inflation variability and output variability, the economy would have to be influenced by supply shocks (rather than demand shocks) hitting the economy. This chapter explores this possibility.

The structure of this paper is as follows. Section II gives a brief literature review. Section III provides a theoretical explanation as to when we should find a trade-off between inflation variability and output. Section IV discusses the empirical evidence for the Canadian provinces and the United States, which suggests the existence of a trade-off. Section V concludes.

II. Literature Review

There has been a new emphasis in the literature regarding the question of whether a trade off exists between output and inflation variability. Current research suggests that any attempt by the Central Bank to keep inflation constant may cause fluctuations in real output and employment (Walsh, 1998). The current thinking is best summarized by two propositions stated by John Taylor (1996). The first proposition, which is a conclusion echoed by the majority of economists, is that there exists no long run trade off between the rate of inflation and the rate of unemployment or level of output (Taylor, page 186, 1996). This is a proposition about the relationship between levels of variables. It is the second proposition that is more contentious. It states that there is a short run trade off between inflation variability and output variability. It is this second proposition that we are more interested in. It involves the relationship between the first differences of variables (i.e. variability) rather than the relationship across level.

Why might a trade-off exist in differences?

To best explain why a trade off may exist, it is easiest to think of economy facing a negative supply shock. When a negative shock hits the economy, the result is an increase in inflation defined as a rise in the rate of growth of a price index. If the monetary authority acts quickly to bring inflation back to target, the monetary authority must reduce aggregate demand to make the deviation of inflation less but doing so will make output more variable. Hence under supply shocks, if the Central Bank acts to bring inflation back to target, the less variable will become inflation and the more variable will become output.

There is some evidence to support the importance of supply shocks at the aggregate level. For example, research has found that the presence oil price shocks have had important effects on the U.S. economy (Hamilton, 1983,1988,1996; Taton, 1988, Mark 1989, 1994, Fin, 1991). The common impact of these shocks on both the United States and Canada is consistent with my suggestion that a common concern with inflation targeting by the United States and Canadian economies would have produced observations arising in the data.

Is there any support in policy circles for the recognition of the importance of supply shocks? A recent paper presented by Robert J. Gordon at the OECD Jobs Conference in Helsinki Finland, entitled "Explaining the U.S. Economic Miracle", argues that the economic phenomenon of low inflation and unemployment occurring simultaneously is the result of twelve separate and largely unrelated real factors. The main factors include: 1) Falling real import prices through early 1999, 2) Falling real oil prices through early 1999, and 3) The productively growth revival.[1] By and large it has been the existence of increasing productivity (coupled with the other factors mentioned) that has seemingly resulted in both lower prices and higher outputs (Gordon, 2002: 8).

[1] Other factors include 1) measurement improvements that reduced measured inflation relative to true inflation, 2) the deceleration in medical care inflation, 3) accelerated decline in the rate of computer prices, 4) favorable demographics, 5) get tough anti crime and anti drug policies, 6) the growth of temporary help agency, 7) the flood of legal and illegal immigrants, 8)the declining importance of unions, 9) decline in

Some Examples of Improvements in U.S. Productivity

Figure 1: Productivity in Manufacturing

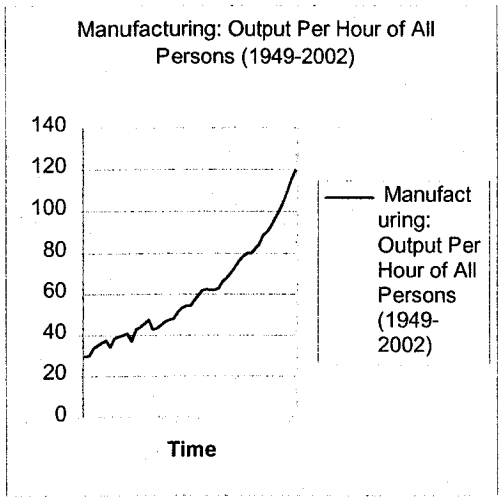


Figure 2: Multifactor Productivity

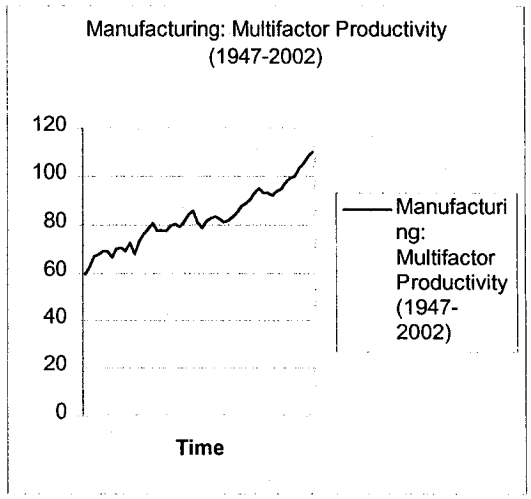
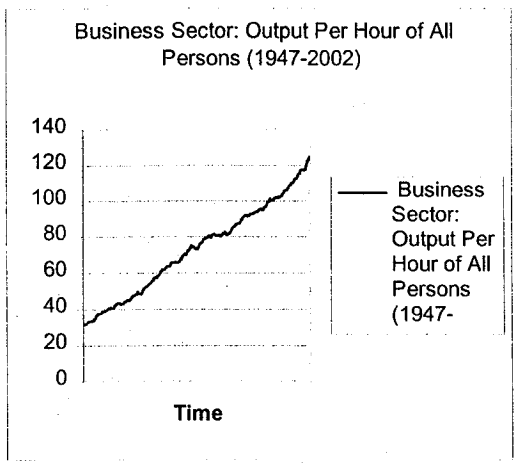


Figure 3: Business Sector Productivity



Source: Federal Reserve Economic Data

Still others, such as John P. Judd, Vice president and Associate Director of Research at the Federal Reserve Bank of San Francisco, suggest that during the 1990s, the economy had suffered supply shocks (Judd, 1997: 4) namely in the form of productivity shocks that putting downward pressure on prices. At the same time it has been noted that the presence of supply shocks increased employment as well.

More recent work by Trehan (1999) has noted that the forecasted output has been consistently higher than actual, while the behavior of inflation has been on a steady decline since the 1990s. Trehan suggests that this is most likely due to the presence of positive supply shocks, with the likely sector being the technology area. For Trehan the obvious cause is the introduction of computers and computing in general that increased productivity. Productivity has changed in size over time as well. Data in the 1970s shows only productivity growth of one percent in contrast to productivity growth of about 2.3 percent per year between 1996 – 1998 period (Trehan, 1999).

A different focus in research has shown that it is not so much that these oil price shocks or other real shocks have changed GDP and inflation but that the response to these factors through monetary policy within the United States that is responsible for this trade-off (Bernanke, Gertler and Watson (1997), hereafter BGW). To show this, BGW estimate a Vector Auto Regressive (VAR) model. This VAR approach uses seven variables: real GDP, the GDP deflator, a commodity price index, the price of oil, the Federal Fund Rate, and short and long term interest rates. For oil prices BGW use the "net oil price" calculated as the difference between the current price and maximum price witnessed in the last year. BGW defined neutrality in monetary policy as the Federal Reserve leaving the Federal Funds rate constant in response to a supply shock. With neutral money, BGW find a positive oil price shock increases real GDP. BGW has found that monetary policy has not been neutral in response to oil price shocks. The fact that GDP has changed shows that it has been changes in monetary policy, in response to oil price shocks, that has caused the economic fluctuations. Work done by Brown, and Yucel (1999) use a different definition of monetary neutrality than that used by BGW, to show that different

definitions of monetary neutrality will affect the conclusion that monetary policy is responsible for economic fluctuations. Like BGW, they construct a VAR model of the U.S. economy. The model includes seven key variables: real GDP, commodity prices, the GDP deflator, oil prices, the federal funds rate and short and long term interest rates. They find that using the same definition of money neutrality used by BGW, oil price shocks have prompted a tightening of monetary policy. They also find that under different definitions of neutrality, such as keeping a constant nominal GDP, the Federal Reserve has taken a more neutral approach.

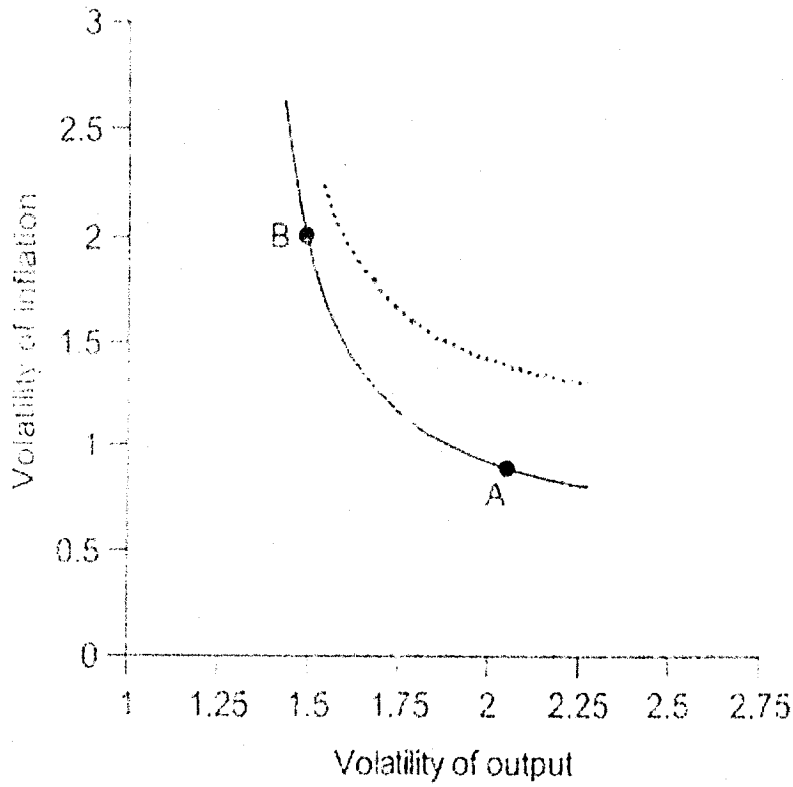
The evidence on whether a trade-off does in fact exist comes from mainly simulated evidence. Fuhrer (1997) provides one such example for the U.S. case. By defining a particular policy rule, Fuhrer determines the nature of the variability trade-off by estimating what the inflation output gap trade-off faced by the U.S. Federal Reserve would be. He begins by assuming that "optimal" monetary policy is the policy that minimizes variability of the Federal Reserve's objectives about their targets i.e. inflation and the output gap. For policy makers who care about the minimal deviations of inflation around target and output from potential, the estimated trade off represents the optimal policy frontier. Even defining the structure of an economy and determining it to be stable across recent shifts in monetary policy still allows changes in monetary policy to inflation and output to imply substantial differences in long run inflation and output variances.

Fuhrer (1997), defines the optimal policy as an efficient set of weighted combinations of inflation and output variances, then estimates an optimal policy frontier. Fuhrer (1997) finds a tradeoff but one in which the variance trade-off becomes quite

severe when either the standard deviation of inflation or output drops much below two percent.

Taylor (1993) argues that the Federal Reserve adjusts the Federal Funds rate due to deviations of inflation from target and unemployment from the natural rate. Using this rule for the Federal Funds Rate, in conjunction with specific values for how much the funds rate is adjusted as inflation and output gap changes, this can determine the degree of variability between output variability and inflation. Then by determining how the Federal Funds Rate changes in response to movements of inflation and output, a different combination of inflation variability and output variability will be suggested. Looking at these different combinations of inflation and output variability, a combination arises. Likewise, the frontier associated with a different rule for adjusting the Federal Funds Rate, such as one that responds to nominal income movements, can also be derived. A change in the nature of the economic disturbances would cause the trade off frontier to move. Other factors determining whether the frontier moves include volatility of energy prices, which would lead to more inflation and output variability.

Figure 4: Illustrative volatility trade-off



Source: Fuhrer, Jeffrey C. (1997) : 214-234.

While looking at simulated evidence is a good tool for examining whether a trade-off could exist, it does have drawbacks. Does a simulation capture the true behaviour of the economy? It is also difficult to find evidence of the trade-off from actual economies. The reason for this is simple. Recall from our figure above that each point of the trade-off frontier is associated with a particular monetary policy stance. If this policy has been stable and been the same over a long period of time, then the observed volatility of output and inflation would provide an observation on a single point on the frontier. Evidence on just a single point does not provide information on the entire trade-off frontier. Even if monetary policy had changed, the fact that some points were on the

frontier while others points were off the frontier (an inefficient monetary policy), would suggest that we would not be able to estimate the frontier.

My Approach To Testing For A Trade-off Between Output And Inflation Variability

Chapter 2 of my thesis tests the null hypothesis that the slope coefficients of the forecasting equations for inflation and growth rates of Real Gross Domestic Product all equal to zero, or more put simply, that the Central Bank has optimally targeted a constant growth rate in inflation or output. In this chapter I look at the correlation between the two series of Chi Square statistics as a means of testing whether a trade-off does in fact exist between variability of output and inflation. By looking at the chi square statistic over time, we can determine how actual inflation rates vary predictably from the constant, hence giving us a measure of forecastable variability. Hence by looking at the correlation between the two chi square test statistics we can assess whether the forecast variances are moving together or in opposition.

To see this argument, recall that the Central Bank in question sets monetary policy to target inflation given the fact that the relevant independent variables used in the forecasting equations are lagged and are therefore potentially in the bank's information set. As a result, if the Central Bank wants to target inflation optimally, it will change its instruments so that the independent variables, taken together, have no significance in explaining the deviations from target. If information on demand and supply shocks hitting the economy are in the bank's information set, then this information will be used to implement policy, thus eliminating any forecastable variability from target. In such a way inflation would equal the predictable constant plus a random error term. However if the information on these shocks was not in the bank's information set, then the resulting

deviations of inflation from target would be unforecastable, a random component in addition to the traditional error term. Hence as a Central Bank better targets inflation, it will begin to better use the variables in its information set and so begin to reduce its forcastable variance. This will be reflected in a fall in the chi square statistic. Therefore by looking at how a series of chi square test statistics varies over time, we can determine how the forecastable error varies. It is in this sense that the chi square statistic is a measure of the degree of forecastable variability.

III. Analysis of our results: Theory and Implications

Chapters 1 and 2 of my thesis suggest that when the Central Banker targeted one variable, inflation, the smoothing of inflation rates about the target appears to have come at the expense of greater variability in another variable, Real Gross Domestic Product. In the Canadian case, we found that inflation rates in Canada's provinces are smoothed and growth rates of GDP are not. With respect to the United States case, we find evidence that the Federal Reserve has moved closer to inflation targeting, even though the chi square statistic generated from the rolling regression does not actually fall below the critical value (but comes extremely close). At the same time, the non-convergence of U.S. growth rates in GDP does indicate that output variability was not smoothed optimally.

One may ask under what circumstances these findings make economic sense. The answer is for an economy subject to supply shocks. Suppose, for example, that the Central Bank wanted to target inflation in one particular region, say Ontario. Suppose also that Ontario faced a negative supply shock. Given this adverse supply shock, the inflation rate would rise and output growth would fall in Ontario as the short run supply

curve shifts left. As a result, the Central Bank would intervene to decrease aggregate demand and raise interest rates in order to bring the inflation rate back to target. However such an act will have a negative affect on output, causing a larger change in output growth than otherwise expected. If the other provinces in the economy faced similar supply shocks, then a process of targeting inflation in Ontario would smooth inflation both in Ontario and in the other nine provinces.[2] The growth rates in these other provinces would become more volatile as well. Had the provinces faced different and uncorrelated supply shocks our results to the above scenario would be quite different.

To make this analysis clearer, suppose there are two regions in the country, the East and the West. Also suppose that the Central Bank can undertake only one policy at a time that will affect both regions. In general these regions could face demand or supply shocks or a combination of both.

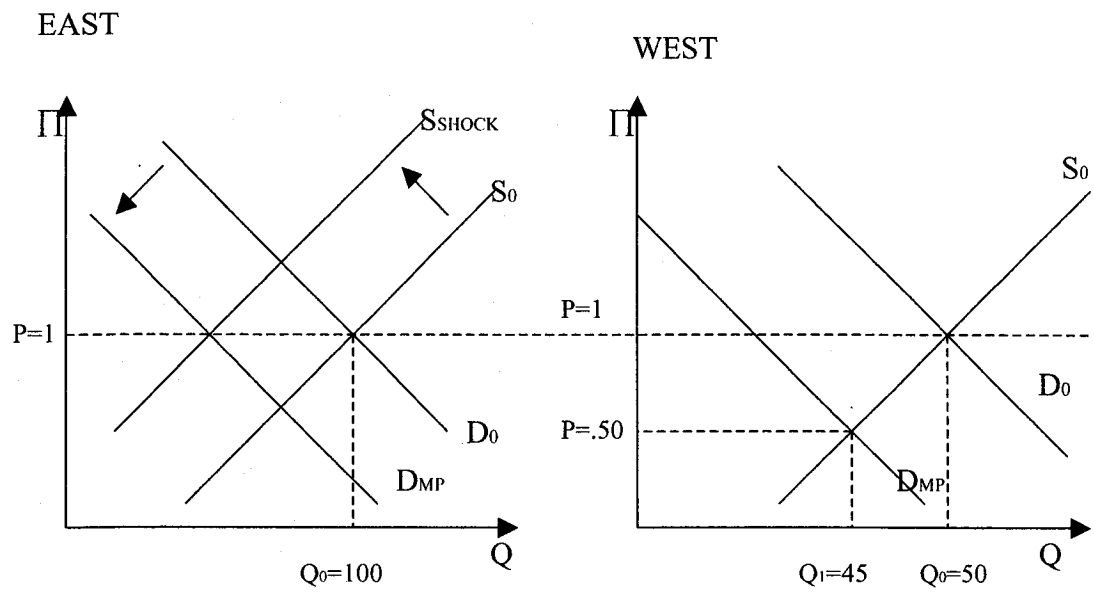
Supply Shocks

Suppose the Eastern region face a negative supply shock while the West does not. Also suppose that the Central Bank wanted to keep the same inflation rate in the East. This would require the Bank of Canada to intervene. To target inflation in the East, the Central Bank would raise interest rates, thus further lowering aggregate demand in the East, and causing the inflation rate in the East to fall back to target. In this way the inflation is smoothed over time. However, given that a change in monetary policy affects both regions, the raising of interest rates would also reduce aggregate demand in the West, causing the inflation rate and output in the West to both fall (see case 1 below). In

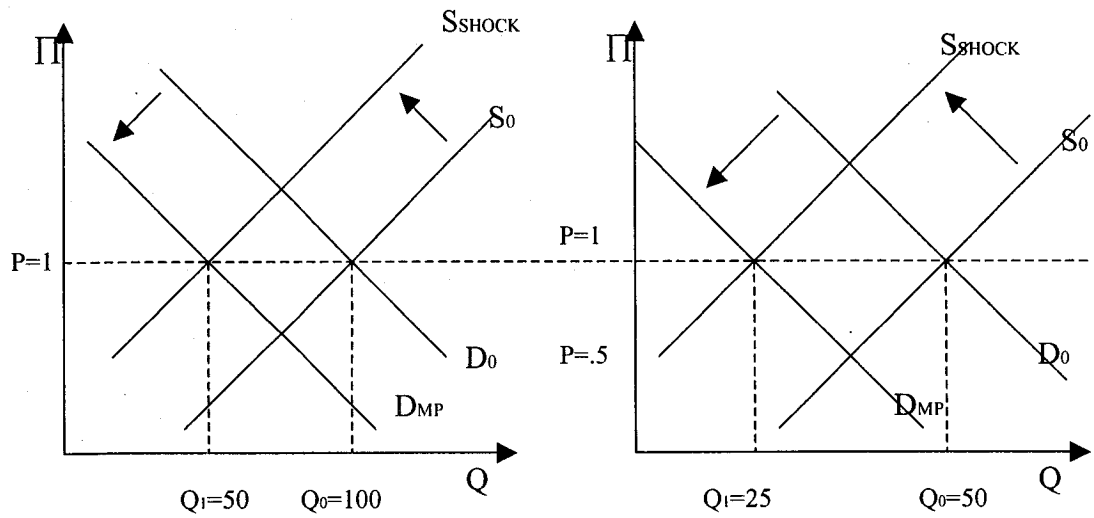
[2] For a detailed model illustrating the effect of correlated supply shocks across provinces, please refer to the appendix to this chapter.

this case we would find that neither inflation nor output growth rates were smoothed through time.

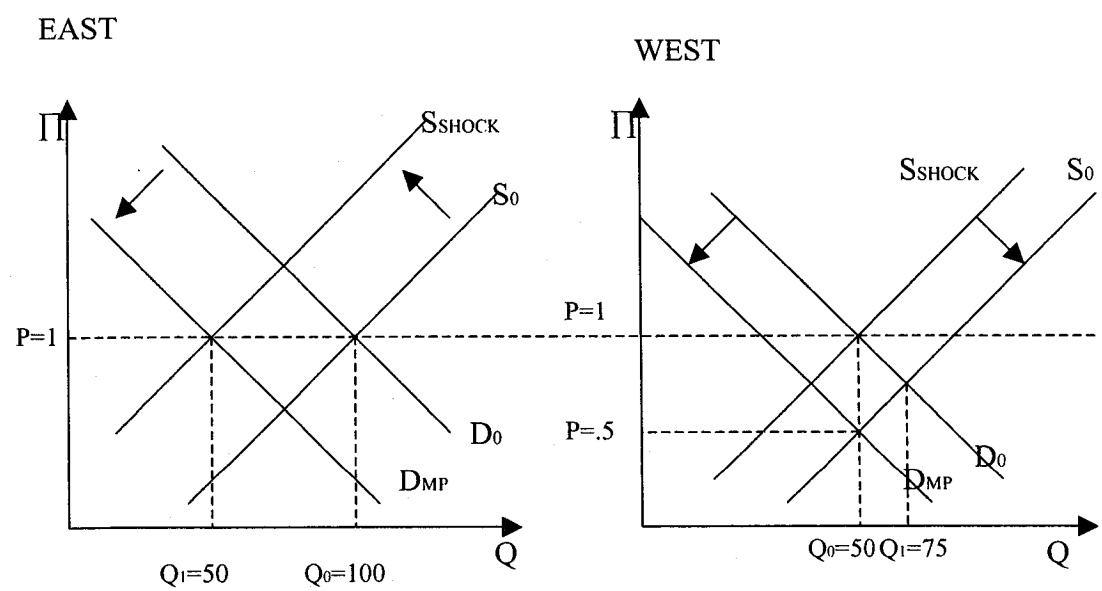
CASE 1: Uncorrelated Supply shocks



CASE 2: Positively correlated supply shock



CASE 3: Negatively correlated shock



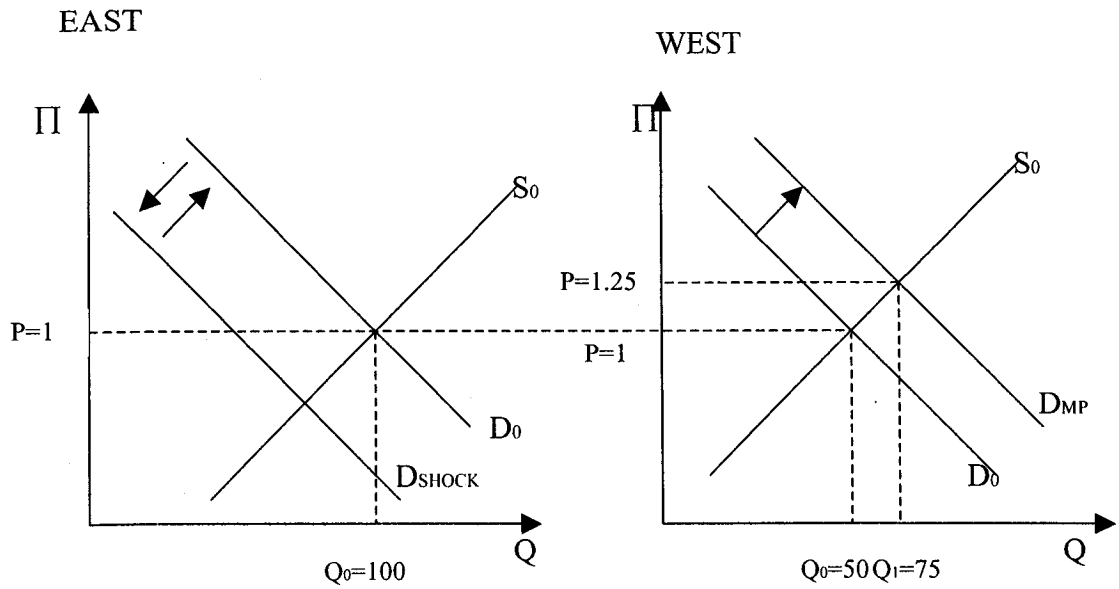
The example above assumed that the supply shocks where uncorrelated. Had the supply shocks been positively correlated, the Central Banks action to target inflation in the East would not only smooth inflation rates there but also result in inflation in the West being smoothed. In this case we would expect great output instability in both regions (see cases 2 and 3 above).

As one can see, a Central Bank that faces a common negative supply shock across regions also faces a trade-off between smoothing inflation and smoothing output in all regions. Therefore, if all provinces faced similar supply shocks and the Bank of Canada decided to intervene to target and smooth inflation, we could expect that there would be a negative trade-off between inflation variability and output variability. However, if only some provinces face negative supply shocks while other provinces do not, the Bank of Canada's decision to intervene in order to smooth inflation in those provinces would result in their inflation rates being smoothed at the expense of output stability. The other provinces not facing the supply shock would have both output and inflation rates becoming less stable.

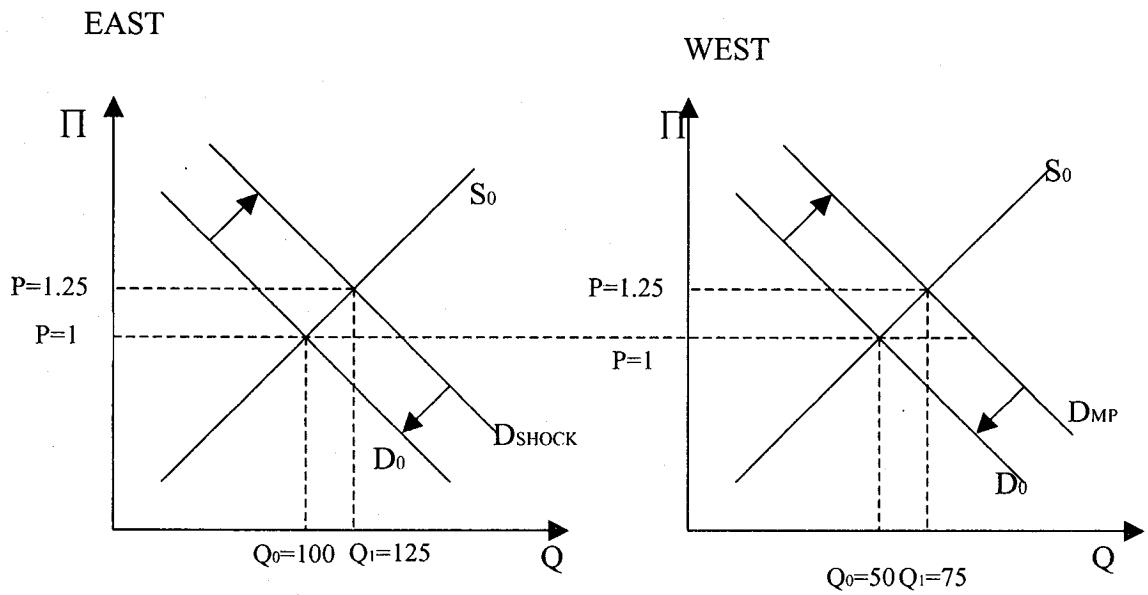
Demand Shocks

The effects of demand shocks on the economy are much different than supply shocks.

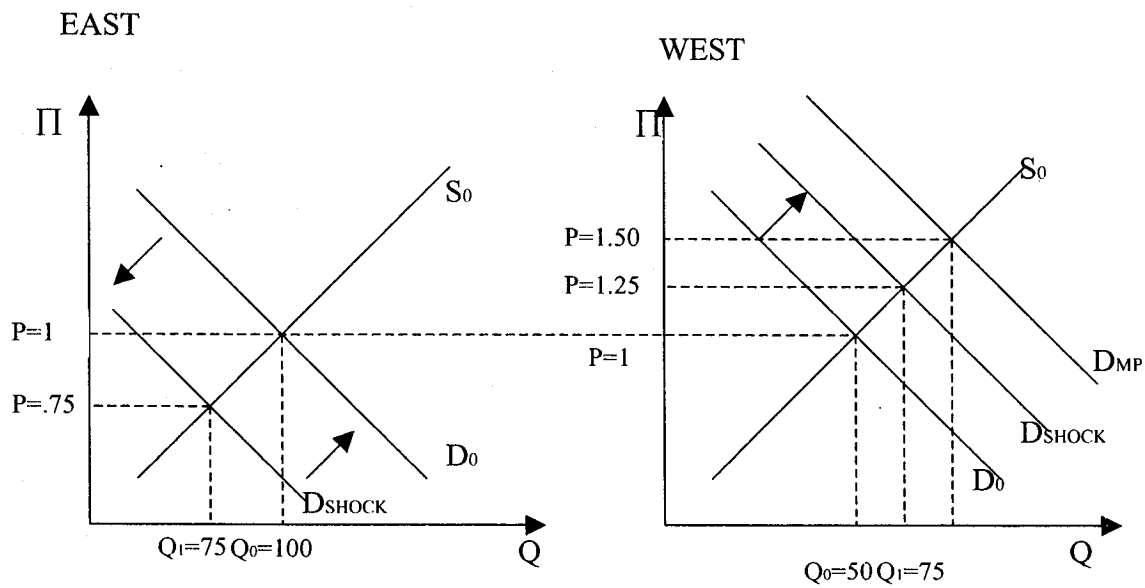
CASE 1: Uncorrelated shocks (demand)



CASE 2: Positively correlated demand shocks



CASE 3: Negatively correlated demand shocks



Also suppose that we operate under the scenario that the Central Bank is to smooth inflation in the East and that the Eastern region suffered a negative demand shock. If the Central Bank wanted to use monetary policy to smooth inflation in the East, it would need to lower interest rates to stimulate aggregate demand. While this would result in both output and inflation being smoothed in the East, it would result in both inflation and output growth instability in the West.

Had the shock been negatively or positively correlated such that a negative demand shock had hit both the East and West (cases two and three under demand shocks above), then the objective of the Central Bank to smooth inflation in the East would also have similar consequences on the West. Under this scenario both inflation and output are smoothed in both regions.

Table 1: Summary of the theoretical possibilities

	Positively Correlated	Negatively Correlated
Demand Shocks	Targeted Region: Both output and inflation will be smoothed. Untargeted Region: Both output and inflation will be smoothed.	Targeted Region: Both output and inflation will be smoothed Untargeted Region: Output and Inflation will not be smoothed
Supply Shocks	Targeted Region: Prices will be smoothed while output will not be. Untargeted Region: Prices will be smoothed while output will not be.	Targeted Region: Prices will be smoothed while output will not be. Untargeted Region: Output will be smoothed while inflation will not be smoothed.

IV. Is there a tradeoff between output variability and inflation variability?

Before looking at the correlation between the Chi Square statistics, I first want to summarize the results in table format. As the table below illustrates, a negative relationship exists between output growth stability and inflation targeting given all the provinces and Canada as a whole fall in the North East quadrant, where inflation smoothing occurs, with no output smoothing. This may suggest that the Canadian economy, as explained earlier, suffered common supply shocks and not demands shocks under inflation targeting.

Table 2: Tradeoff between output growth smoothing and inflation smoothing: Canada and its provinces (post 1991). All provinces fell in the quadrant where inflation smoothing existed, with no output smoothing.

	Inflation Smoothing	**No Inflation Smoothing**
No Output smoothing	Canada Ontario Quebec Alberta British Columbia Manitoba Saskatchewan Prince Edward Island Nova Scotia New Brunswick Newfoundland **(NW)**	**(NE)**
Output Smoothing	**(SW)**	**(SE)**

Note: As can be see, if there were only demand shocks, then we would expect to see all provinces in either quadrate SW (if they were targeted) or in quadrant NE if they were not targeted. If there were significant supply shocks, we would expect to see all provinces either in quadrant NW if they were targeted or in southeast, if inflation was not being targeted.

Another approach to illustrating whether a trade-off exists is to look at our results at two separate points in time, namely 1980Q2 and 1992Q2. We deliberately choose one point in the post 1991 era (given that inflation targeting was being practiced) and one point in the pre 1991 era when there was no targeting. On the figure, we plotted the chi square statistic generated from the rolling regression for the inflation equations (x-axis) and the output smoothing equation on the y-axis. We also plotted the critical values for these equations (here taken to be 9.488 at 5% critical value), which repeat both the

horizontal and vertical lines in the figure below. If the data points fall in South West Quadrant, this would suggest that both variables were smoothed. If the points fall in the South East quadrant, this implies that inflation was not being smoothed but output was. If the points fall in the North West quadrant, this provides evidence that inflation is being smoothed at the expense of output instability. And lastly, if the points fall in the North East quadrant, this would suggest that both output and inflation are not being smoothed. Our results are summarized below.

As the figure 5 illustrates, during the 1980Q2 period, the data point lies in the North East quadrant where both output and inflation are not being smoothed. This lack of a tradeoff makes sense given the Central Bank did not smooth any variable at this time (see chapter 2). With respect to the graph pertaining to the 1992Q2 period, we see that all provinces lie in the North West quadrant given the Bank of Canada had smoothed provincial inflation rates while not smoothing output. However in the post 1991 era, given the fact we see that all of the provinces have had their chi square statistic from the rolling regression fall in the North West quadrant suggests provincial inflation rates were being smoothed at the expense of output instability. This shows evidence of a trade-off.

Figure 5: Illustration of where the Chi square lies in 1980Q2

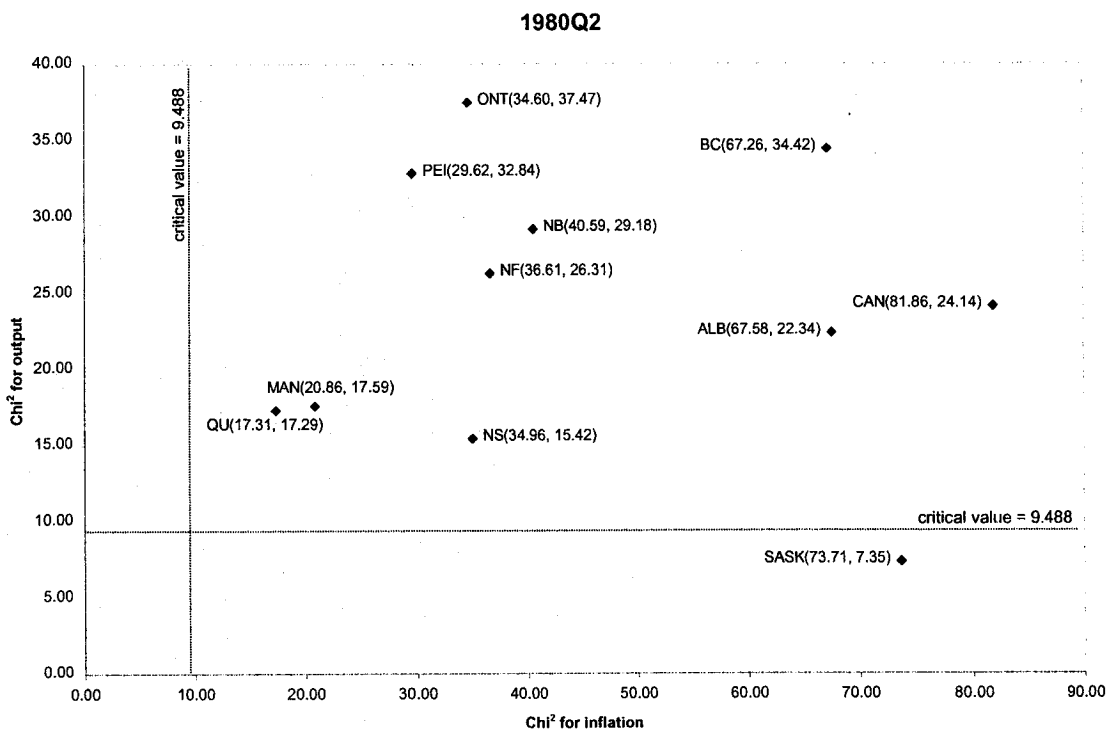
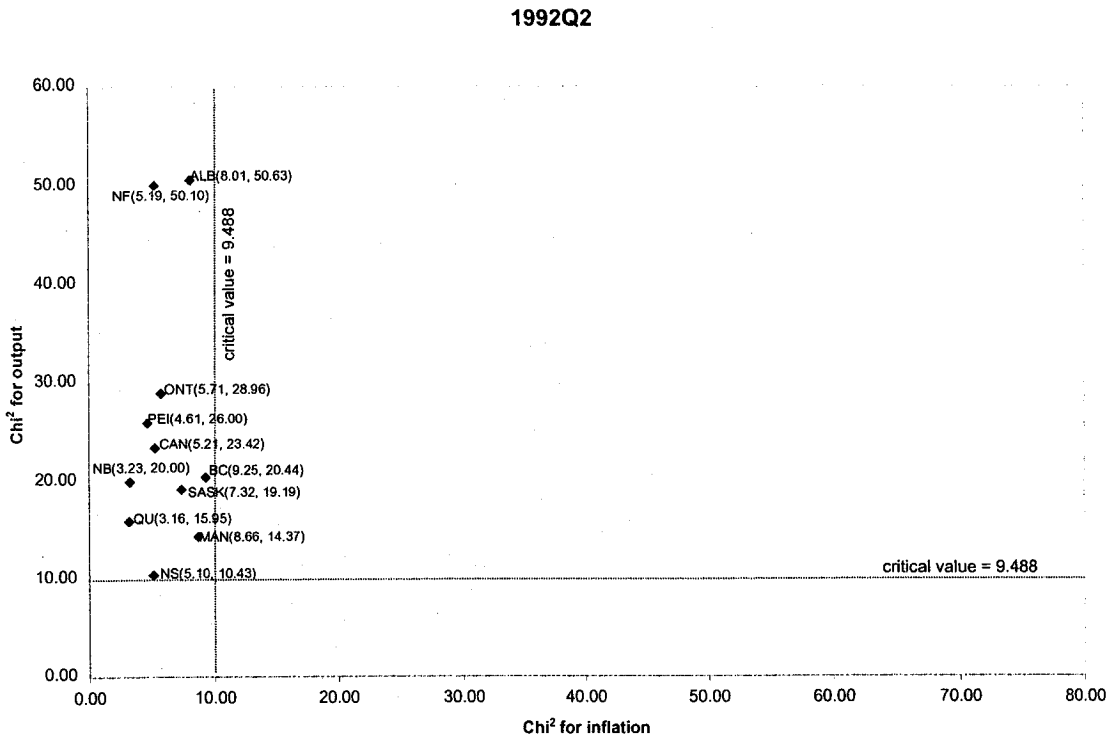


Figure 6: Illustration of where the Chi square lies in 1992Q2



IV (i) Empirical Evidence for Canada

In order to quantify whether a trade off exists between inflation and output variability, we run a simple correlation test between the chi square statistics obtained from running the rolling regressions for inflation and the chi square statistics obtained from running the rolling regressions for growth in GDP of chapter 2. The purpose of this exercise is to find some empirical evidence substantiating the apparent existence of a tradeoff. While it may, at first sight, seem empirically questionable as to why I would employ such a technique, especially given the fact that my technique involves taking a statistic of a statistic, the results of the test and its interpretation lends support to the hypothesis that a trade-off existing. Using a rolling regression technique incorporates new information with respect to changing policy regimes. If a sequence of chi square test

statistics taken in the Rowe and Yetman sense increase over time, it is evidence consistent with the hypothesis that smoothing is not taking place. Conversely, if a sequence of chi square test statistics in the Rowe and Yetman sense is decreasing over time, it is evidence consistent with the hypothesis that smoothing is taking place. For my particular exercises, I want to examine whether a negative trade-off exists between inflation and output over time. If a negative trade-off exists, it means that one sequence of chi-square statistics are falling (say inflation) and hence being smoothed, while the other variable (say output) is rising over time and hence not being smoothed. Looking at the correlation between these two variables, while it may not be as sophisticated in empirics as other tests, does nonetheless provide the necessary evidence supporting the existence of a trade-off.

As the second chapter of my thesis suggests, the chi square statistics did become very small over time for inflation, suggesting that the unforecastable variability of inflation has fallen as actual inflation has tended towards a constant. With respect to output, the results are quite different. This sequence of Chi Square statistics associated with our forecasting equation for output suggests that the independent variables do matter and that growth rates in output are not tending towards a constant, implying greater forecastable variability. Our results from running the correlation tests are summarized below:

Table 3: Correlation values between the Chi Square test statistics from running the rolling regression for growth in GDP equations and the inflation equations (using a lag of 6 in the forecasting equations).

Canada	Ontario	Quebec	Alberta	British Columbia	Manitoba	Saskatchewan	Price Edward Island	Nova Scotia	NB	NFLD
-.96	-.92	-.82	-.94	-.11	-.91	-.53	.54	-.68	-.93	-.61

Table 4: Correlation values between the Chi Square test statistics from running the rolling regression for growth in GDP equations and the inflation equations (using a lag of 8 in the forecasting equations).

Canada	Ontario	Quebec	Alberta	British Columbia	Manitoba	Saskatchewan	Price Edward Island	Nova Scotia	NB	NFLD
-.97	-.97	-.93	-.90	.86	-.80	-.78	-.34	-.22	-.97	-.68

As the tables above demonstrate, there seems to be a negative relationship between the Chi Square test statistic generated from running the growth rate in output equation and the Chi Square test statistic generated from running the inflation equation. This result is robust to the inclusion of lag length, except for British Columbia and Prince Edward Island. While British Columbia and Prince Edward Island have both negative and positive correlations (depending on the lag lengths used), the fact that the correlation of one of the lag lengths was negative implies at least some evidence of a negative tradeoff in all cases. Unlike the other provinces, monetary policy may produce a trade off in these

provinces at only one particular lag length, rather than both. This provides further support for my earlier findings that a negative relationship exists between output and inflation variability. In that case we saw that one variable was smoothed in the Rowe and Yetman sense while the other was not.

Vii) Empirical Evidence for the United States:

Looking at whether a trade off exists in the U.S. is not as clear as in Canada. Unlike the Canadian case where we are certain that inflation is being targeted while output is not, the U.S. case is not as clear. Our test finds that neither inflation nor output have yet been targeted, with the Federal Reserve only moving towards targeting inflation. Closer examination of my results for U.S. inflation does indicate that the Chi Square test statistics are very close to crossing the critical value, particularly as more data from the post 1991 era are incorporated into the rolling regression. That the test statistics for inflation approach but do not cross the critical value does suggest that the U.S. has put increasing weight on smoothing inflation, especially given the absence of evidence that the U.S. Federal Reserve has moved towards smoothing output. As a result there is less evidence of a clear tradeoff in the U.S. case because there is less clear evidence of the smoothing of any one variable.

In order to quantify whether there has been evidence of a tradeoff between output and inflation forecast variability in the U.S., I run a simple correlation test between the two sets of Chi-Square statistics obtained from running the rolling regression equations for inflation and output. Here we used only the chi square test statistics from the post 1992 era as the period of inflation targeting given the U.S. Federal Reserve moved to smooth inflation much later than many other Central Banks like Canada (which did so in early 1991). Our results are summarized below.

Table 5: Correlation values between inflation and GDP growth during the 1990s

Date	Chi square test statistic (lag 6)	Chi Square test statistic (lag 8)
1991Q1: 1994Q1	.54	.55
1992Q3: 1994:Q1	.055	.033
1993Q1: 1994:Q1	-.29	-.36

As the table above shows, there does seems to be some evidence of a negative trade-off between inflation smoothing and output smoothing but only in the later part of the time period under analysis. As we generate more chi square values for both inflation and output growth by expanding into the post 1993 era, the correlation test between these series of chi square test statistics become more negative (as inflation smoothing becomes more apparent with smoothing of output not occurring).

Summary of results: A conceptual interpretation

In order to apply structure to our notion of a trade-off refer to the graph below. Lets imagine monetary policy operating at two distinct points in time, one during the pre 1991 era and the other in the post 1991 era. The post 1991 era witnessed both the U.S. Federal Reserve and the Bank of Canada smoothing (or significantly moving towards smoothing) inflation at the expense of greater output instability. It is this finding that suggests a trade-off does indeed exist.

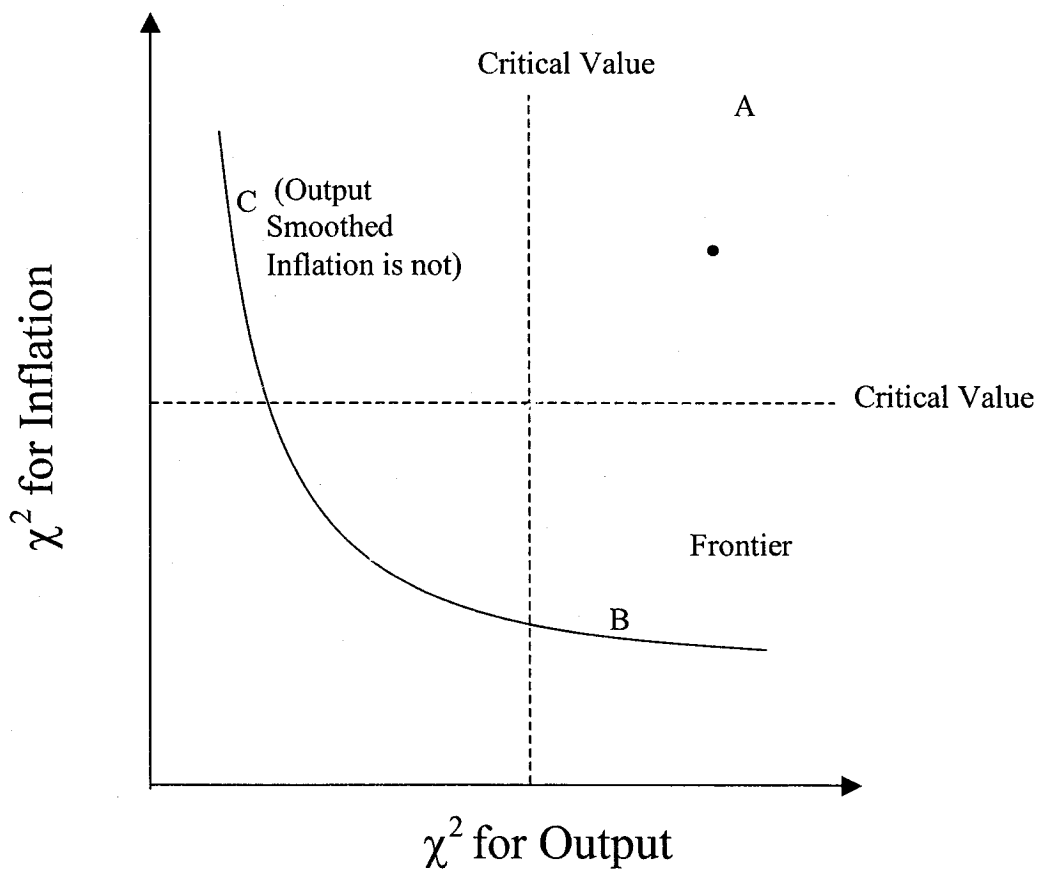
A Central Bank's decision to smooth one particular variable does so at the expense of greater instability in the other and thus operates on the frontier portion of the graph below (see figure 7). On this frontier, the monetary authority faces a negative trade-off where more inflation stability implies less output stability and vice versa. More

specifically, a point like "B" can characterize a policy objective of "inflation targeting" where the existence of inflation smoothing comes at the expense of output instability. Had Central Bank cared more about output stability, conducting monetary policy to smooth growth rates in GDP in the Rowe and Yetman sense would also imply inflation instability.

In contrast to the post in1991 period, the pre 1991 era witnessed both the U.S. Federal Reserve and the Bank of Canada conducting policy that failed to smooth neither inflation nor growth rates pf GDP. As a result no trade-off existed. Conceptually during this period, we can imagine monetary policy operating on a point like A, where the associated Chi Square test statistics are high for both inflation and output suggesting no variable has been "smoothed".

Taking our results as a whole, we can think of monetary policy in both Canada and the United States as moving from a point characterized by A to a point such as B where the desire on the part of the Bank of Canada and the U.S. Federal Reserve to smooth inflation comes at the expense of more output instability.

Figure 7: Changing Monetary Policy Towards Targeting Suggests a Tradeoff Between Inflation Variability and Output Varitability



Difficulty in empirically determining whether a trade off exists

While we have attempted to determine whether a negative tradeoff exists, some difficulties exist in attempting to do so. One difficulty in determining whether a negative tradeoff exists empirically is this problem depends on the time horizon we consider. For example, while at some time horizons (say lags four through eight) smoothing inflation may preclude smoothing output, at longer horizons there is potentially no conflict. Also the analysis gets more difficult depending on the monetary transmission mechanism. One common view is that monetary policy influences output with a lag of two to four quarters and inflation with a lags of six to eight quarters. Therefore smoothing output at short horizons may look like smoothing inflation at a slightly longer horizon (although that would depend on the nature of the shock).

V. Conclusion

My empirical evidence has shown that there does seem to exist a trade-off facing monetary authorities when conducting monetary policy. More specifically, I have shown that when the Bank of Canada and the U.S. Federal Reserve have moved to smooth inflation this comes at the expense of more output variability. This empirical finding is supported in theory by the presence of supply shocks.

My results in chapter 2 show that when the Bank of Canada has conducted monetary policy to smooth provincial inflation rates, it has come as a result of having growth rates in output not being smoothed. Using the chi square statistic as our measure of variability and measuring variability as the deviation of target from the constant, we witness that while inflation has become less variable over time, growth rates of Real Gross Domestic product have not. This position has been supported by many commentators, such as Mankiw, who suggest that the economy has been hit by both negative oil shocks and positive technology shocks.

With respect to the U.S. the results are not as strong. As paper one shows, the U.S. has not explicitly targeting inflation but has moved towards doing so, while clearly not smoothing output. If one variable has not been explicitly smoothed, it becomes more difficult to determine whether a tradeoff exists or not. With this in mind, we do find that in the post 1993 era, the correlation test between the chi square statistics for inflation and output show a negative relationship suggesting a tradeoff does exists. This trade-off, as section III states, could only come in play in the presence of supply shocks.

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VII. Appendix

Model depicting affect of supply shocks across provinces

My thesis has shown that when the central bank uses monetary policy to smooth prices, this policy results in output not being smoothed. This is consistent with the hypothesis that all provinces face negative supply shocks. To show this, lets illustrate the following model. Suppose there exists two provinces in our model, East and West. Suppose the following can represent each province:

East:

$$AD_e: Y_t^d = \alpha + \gamma (M_t - P_t) + V_t \qquad (1)$$

$$AS_e = Y_f + \beta(Pt - P_t^e) + u_t \qquad (2)$$

West

$$AD_w: Y_t^d = \alpha + \gamma (M_t - P_t) + V_t \qquad (3)$$

$$AS_w = Y_f + \beta(Pt - P_t^e) + u_t \qquad (4)$$

Where M_t is the money supply, P_t is the price level, V_t is the demand shock, Y_f is the full employment level, u_t and is the supply shocks. We take α, β, and γ as constants.

We want to show that the only way for variations in prices to be smoothed (or minimized) while not smoothing variations in output is for there to be correlated supply shocks hitting economy across provinces.

Supply shocks:

Suppose we represent monetary policy as:

$$M_t = M_t^e + \varepsilon_t \qquad (5)$$

Where $M_t^{\ e}$ is what agents in the economy expect monetary policy to be and ε_t is the part of monetary policy that the Bank of Canada can change. Given the Central Bank has only one instrument that affects both regions, than the Bank of Canada policy towards each region is the same while its impact may or may not be. For each province, we must equate aggregate demand equals to aggregate supply to get the equilibrium values of price and output. Given we believe that the East and West are the same except in the potential shocks that it can face, our equations for the East are the same as for the West. Lets begin our analysis from the viewpoint of the East:

$$AD_e = AS_e$$

$$\alpha + \gamma\,(M_t - P_t) + V_t \;=\; Y_f + \beta(Pt - P_t^e) + u_t$$

$$\beta\, P_t + \gamma P_t = \alpha + \gamma(M_t^{\ e} + \varepsilon_t) - Y_f + \beta P_t^e + V_t^e - U_t$$

$$Pt = 1/\,(\beta + \gamma) * [\alpha + \gamma(M_t^{\ e} + \varepsilon_t) - Y_f + \beta P_t^e + V_t - U_t]$$

$$P_t^e = 1/\,(\beta + \gamma)[\,\alpha + \gamma M_t^e - Y_f + \beta P_t^e]$$

Taking the square of the difference between $P_t - P_t^e$ gives us the variance of price in the East:

$$[P_t - P_t^e]^2 = [1/\,(\beta + \gamma)\,[\gamma\,\varepsilon_t + V_t - U_t]]^2 \qquad (6)$$

The variance of output in the east is given by the following expression taking from equation (2) above:

$$Y^s_t - Y_f = \beta(P_t - P_t^e) + u_t$$

Substituting in the value for the variation in output from (3) gives us:

$$Y^s_t - Y_f = \beta([1/\,(\beta + \gamma)\,[\gamma\,\varepsilon_t + V_t - U_t]) + u_t$$

To obtain the variance of output, we must square the above expression:

$$[Y^s_t - Y_f]^2 = [\beta([1/\,(\beta + \gamma)\,[\gamma\,\varepsilon_t + V_t - U_t]]) + u_t]^2 \qquad (7)$$

Suppose that the central bank wanted to smooth inflation in the East. It would use monetary policy such that the variations in price, given by equation 6 equal zero. As a result, monetary policy would be set equal to:

$$\varepsilon_t = [Vt + Ut]/\gamma$$

If the Bank of Canada implements this policy, than prices in the East would be smoothed. However this policy, while smoothing prices in the east, would have a destabilization affect on output, thus increasing the variability of output in the process. To prove this simply requires that we substitute in our value for the optimal monetary policy (that smoothes prices) into the output variation equation in (7) above. Substituting ε_t into the above output variance equation gives us:

$$[Y^s_t - Y_f]^2 = [\beta([1/(\beta+\gamma)[\gamma[Vt + Ut]/\gamma + V_t - U_t]]) + u_t]^2$$

$$=[Y_t^s - Y_f]^2 = [U_t]^2$$

Notice that by setting monetary policy such that the variance of prices equal zero, we directly do not smooth the variance in output. Incorporating this fact into our model, the only way that we can se the smooth of prices across the West as well, while outputs are not being smoothed, is if all provinces face correlated supply shocks. If the West suffered the same type of shock as the East, than monetary policy set by the Bank of Canada that smooth prices in the east, would also smooth prices in the West. To see this, we simply substitute in the equation for monetary policy into the price variation equation for the West:

$$[P_t - P_t^e]^2 = [1/(\beta+\gamma)[\gamma\,\varepsilon_t + V_t - U_t]]^2$$

$$[P_t - P_t^e]^2 = [1/(\beta+\gamma)[\gamma[Vt + Ut]/\gamma + V_t - U_t]]^2$$

$$[P_t - P_t^e]^2 = 0$$

Like the case in the East however, output in the west will also be destabilized:

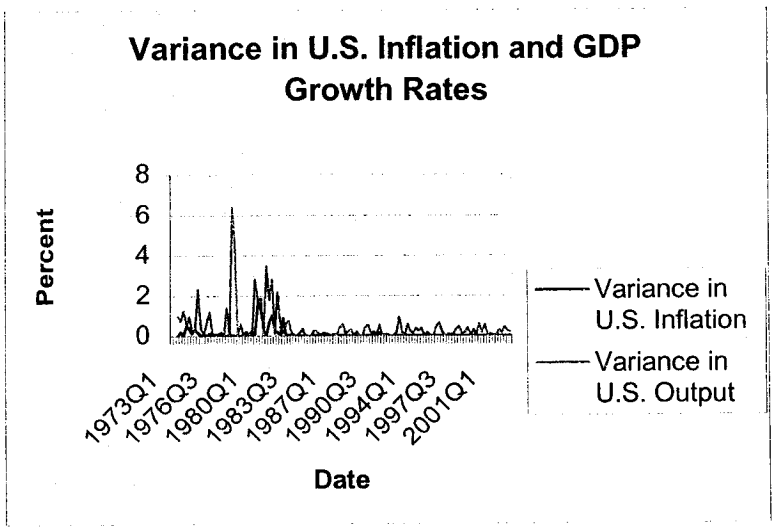
$$[Y^s_t - Y_f]^2 = [\beta([1/(\beta+\gamma)[\gamma[Vt + Ut]/\gamma + V_t - U_t]]) + u_t]^2$$

$$= [Y_t^s - Y_f]^2 = [U_t]^2$$

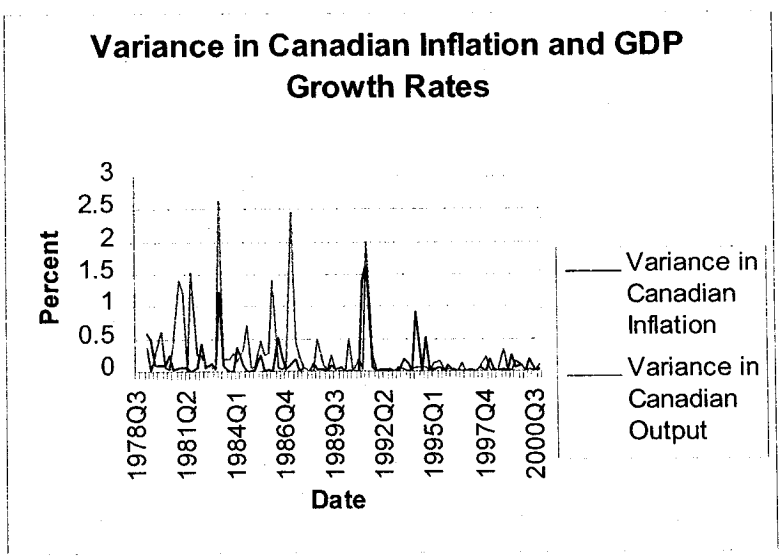
As a result, if the provinces face similar supply shocks, than a policy action by the Bank of Canada that smoothes inflation in the East would also smooth inflation in the West. This would come however at the expense of output stability in both regions. Had both provinces faced different supply shocks and the Central Bank wanted to smooth inflation in the East, than this policy, while achieving it's objective, would cause for prices in the West to be destabilize with output's in both provinces being destabilized.

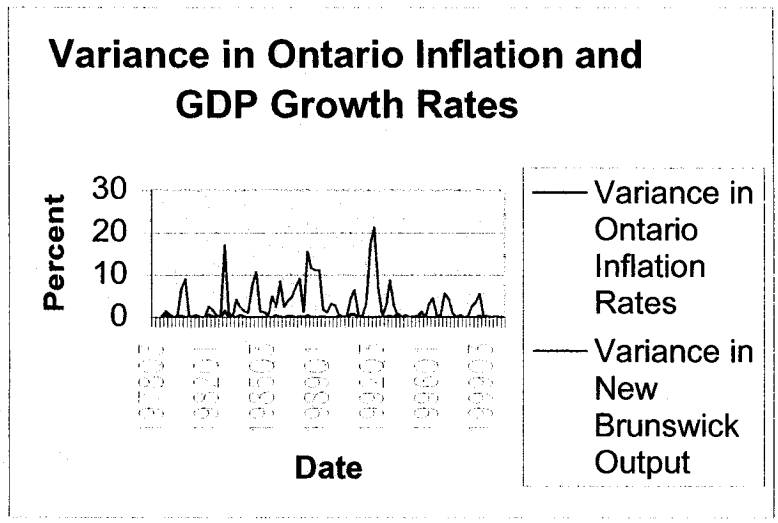
Figure 8: Variances in the Growth Rates of U.S. and Canadian Consumer Price Indexes and Output

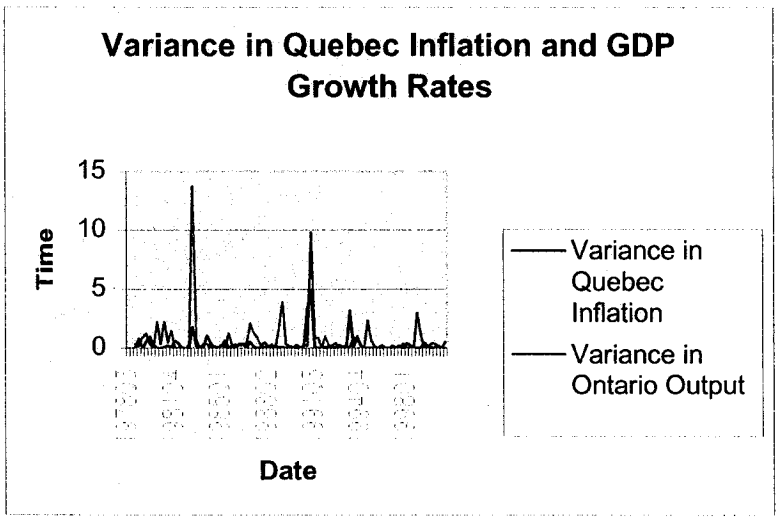
UNITED STATES

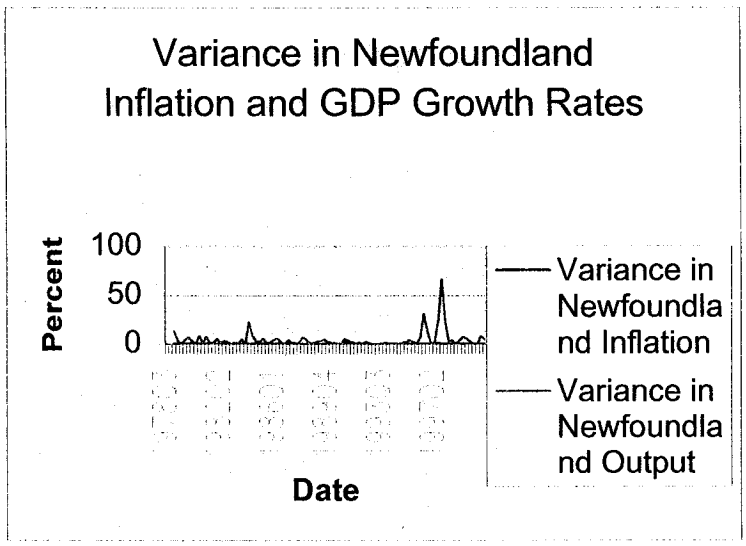


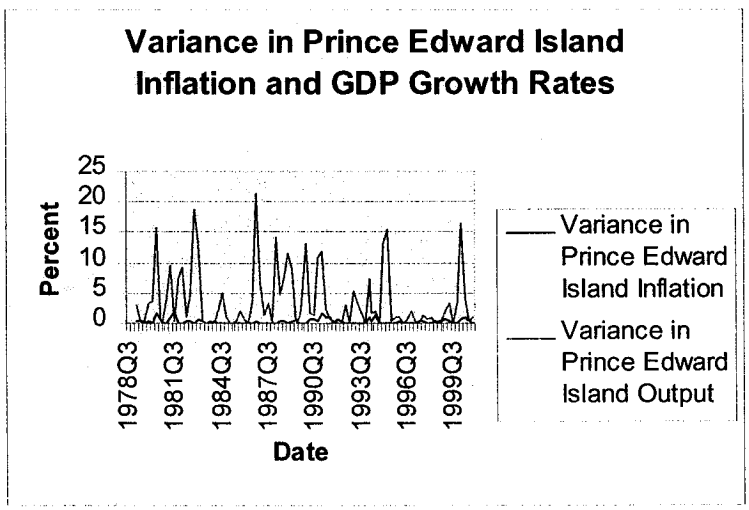
CANADA AND THE PROVINCES

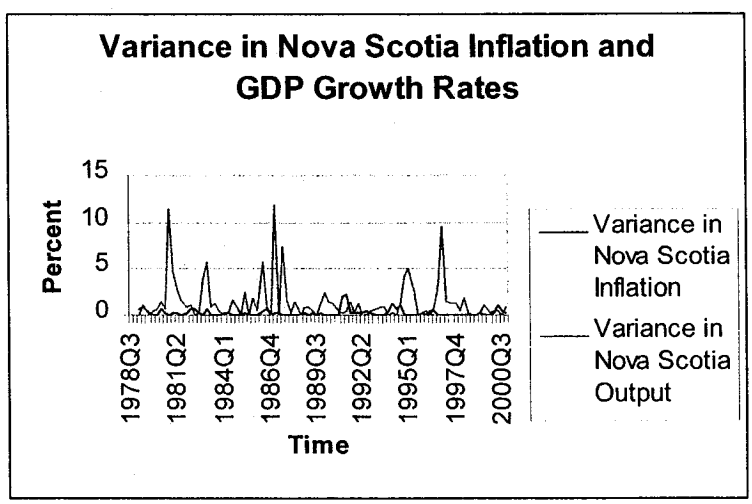


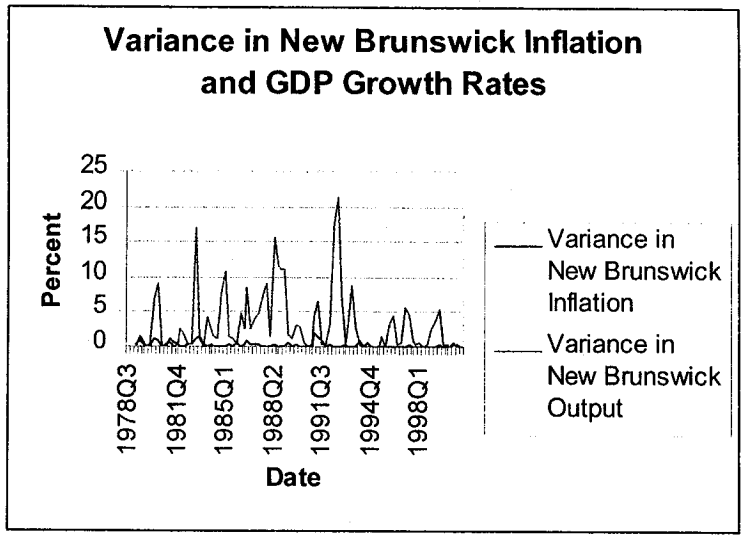

Variance in Ontario Inflation and GDP Growth Rates
Percent
30
20
10
0
Date
Variance in Ontario Inflation Rates
Variance in New Brunswick Output

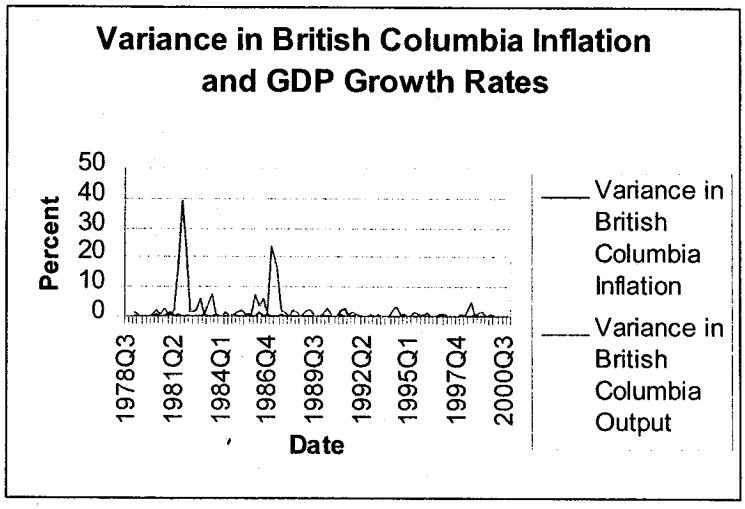

Variance in Quebec Inflation and GDP Growth Rates
Time
15
10
5
0
Date
Variance in Quebec Inflation
Variance in Ontario Output

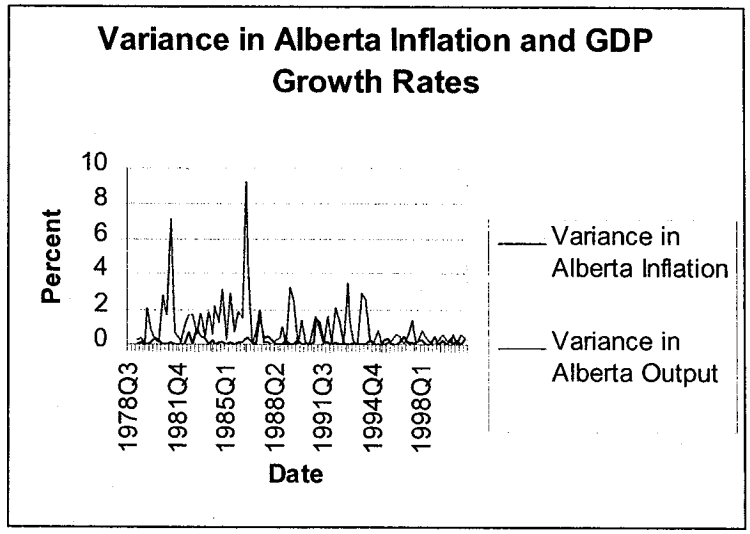

Variance in Newfoundland
Inflation and GDP Growth Rates
Percent
100
50
0
Date
Variance in Newfoundland Inflation
Variance in Newfoundland Output

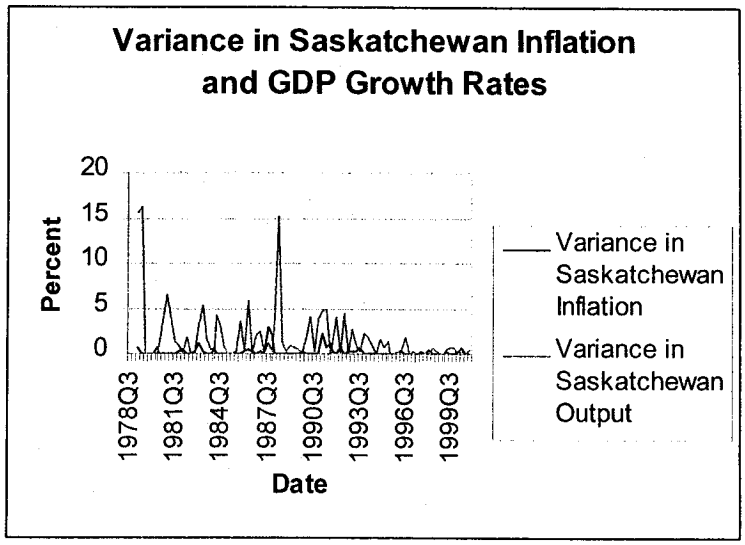

Variance in Prince Edward Island
Inflation and GDP Growth Rates
Percent
25
20
15
10
5
0
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Variance in Prince Edward Island Inflation
Variance in Prince Edward Island Output


Variance in Nova Scotia Inflation and
GDP Growth Rates
Percent
15
10
5
0
1978Q3
1981Q2
1984Q1
1986Q4
1989Q3
1992Q2
1995Q1
1997Q4
2000Q3
Time
Variance in Nova Scotia Inflation
Variance in Nova Scotia Output


Variance in New Brunswick Inflation and GDP Growth Rates
Percent
25
20
15
10
5
0
1978Q3
1981Q4
1985Q1
1988Q2
1991Q3
1994Q4
1998Q1
Date
Variance in New Brunswick Inflation
Variance in New Brunswick Output


Variance in British Columbia Inflation and GDP Growth Rates
Percent
50
40
30
20
10
0
1978Q3
1981Q2
1984Q1
1986Q4
1989Q3
1992Q2
1995Q1
1997Q4
2000Q3
Date
Variance in British Columbia Inflation
Variance in British Columbia Output


Variance in Alberta Inflation and GDP Growth Rates
Percent
10
8
6
4
2
0
1978Q3
1981Q4
1985Q1
1988Q2
1991Q3
1994Q4
1998Q1
Date
Variance in Alberta Inflation
Variance in Alberta Output


Variance in Saskatchewan Inflation and GDP Growth Rates
Percent
20
15
10
5
0
1978Q3
1981Q3
1984Q3
1987Q3
1990Q3
1993Q3
1996Q3
1999Q3
Date
Variance in Saskatchewan Inflation
Variance in Saskatchewan Output