

# **Does the Barro-Gordon Model Explain the Behavior of Inflation in Canada?**

by

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## **Abstract**

This paper investigates whether the model proposed by Barro and Gordon could explain the behavior of inflation in Canada. Using quarterly and annual Canadian data, I test the restrictions imposed by Barro and Gordon's theory of time-consistent monetary policy on a bivariate time-series model for inflation and unemployment. The results show that the data are not fully consistent with the theory's implications for the long-run behavior of the two variables.

## Dedication

*To my wonderful parents, for your love and support*

## Acknowledgements

I would like to express my gratitude to my senior supervisor, Professor Brian Krauth, for his tremendous support. His critical insights and guidance contributed to my better understanding of this subject. I would also like to thank Professor Jenny Xu and Professor Alexander karaivanov, for their useful comments and suggestions.

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# 1. Introduction

What is the cause of inflation? Economists attempt to study the dynamics of inflation by finding the correlation of inflation with related variables. Kydland and Prescott (1977) and Barro and Gordon (1983) implied that the sharp rise in inflation in many countries in the late 1970s or early 1980s is due to the systematic effort of policymakers to decrease unemployment rate below its natural rate. Ireland (1999) provides an econometric analysis and shows that the long-run dynamics of inflation and unemployment in the United States is compatible with the KPBG analysis. In this paper I investigate whether time-consistency model of inflation (Barro and Gordon (1983)) could explain the behavior of the inflation rate in Canada.

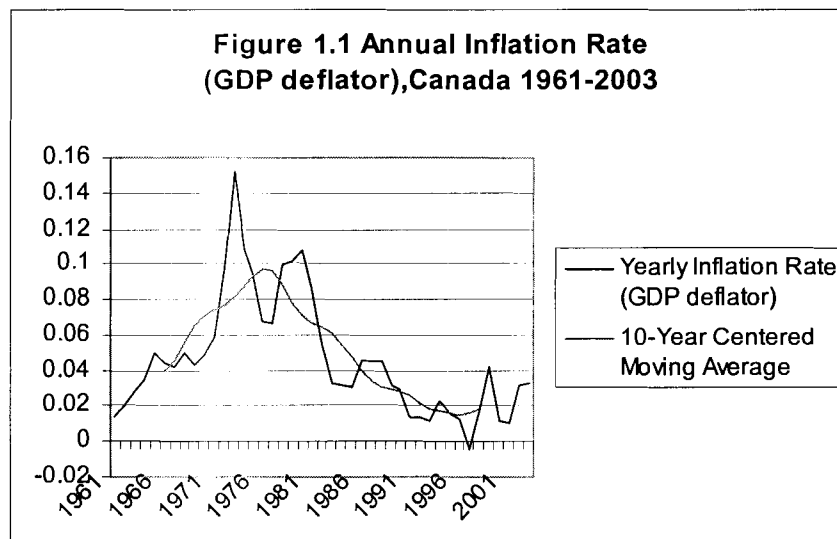
Figures 1.1 to 1.4<sup>1</sup> depict the inflation rate, measured by yearly and quarterly percentage changes in the GDP price deflator and CPI from 1961 to 2004<sup>2</sup>, in Canada. Inflation starts out low in the early 1960s followed by a period of rising inflation lasting until late 1970s. There is also a period of falling inflation just after the rising inflation period until the present. This pattern is more obvious in the 10-year centered moving average which is also provided in these figures.

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<sup>1</sup> Figures 1.2 to 1.5 are in Appendix.

<sup>2</sup> The time horizons of these figures are different due to the limitation of data.

The reason why Figure 1.4 only illustrates the downward trend from late 1970s which is the falling period mentioned above is the limited quarterly data. The best available quarterly, seasonally-adjusted CPI is from the end of 1978. Figure 1.5 shows that there is a similar trend in inflation observed in post-war US data<sup>3</sup>.



The Barro-Gordon model of inflationary bias and time consistency problems provides an explanation of the initial rise followed by a downward trend shown in post-war US inflation rate data. They argue that the initial increase of inflation rate is due to the upward trend in the natural rate of unemployment.

Furthermore, Ireland (1999) shows that the Barro-Gordon model is consistent with the long-term dynamics of the US inflation rate. Therefore, it is reasonable to test whether Barro-Gordon model could also be used to explain the inflation outcome in Canada.

<sup>3</sup> Post-war US data are from Professor Peter Ireland.

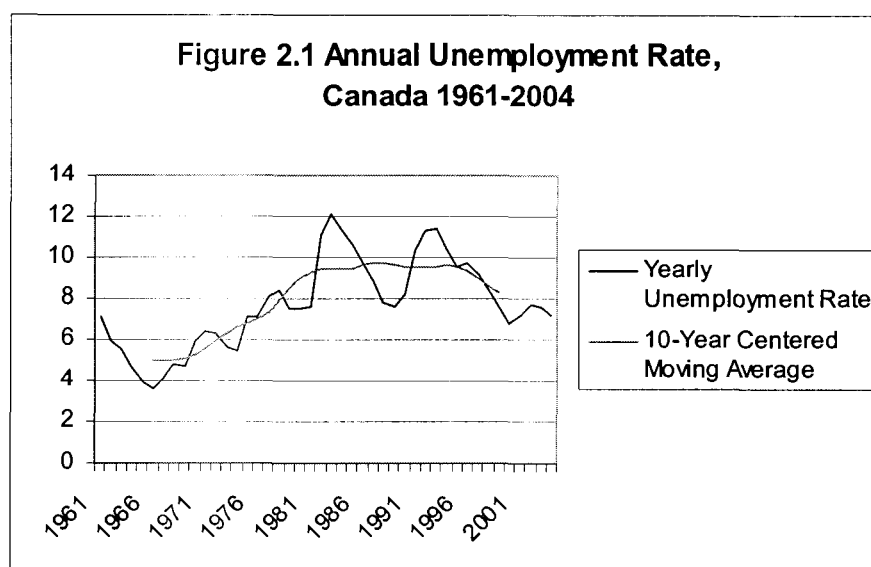
The time-consistency problem in Barro and Gordon is based on three assumptions. First, the policy makers have the desire to reduce unemployment lower than its natural level. Second, the private sector has rational expectations. Households and firms know that the government is tempted to create high inflation, and they make their decisions accordingly. Third, it is impossible for policy makers to commit themselves to keep inflation low. Moreover, given the convex cost function, Barro-Gordon model implies that inflation and unemployment should change in the same direction with the natural rate of unemployment.

Figures 2.1 and 2.2<sup>4</sup> illustrate the behavior of the yearly and quarterly unemployment rate in Canada. Figure 2.1 reveals an upward trend from 1960 to late 1970s and then annual unemployment rate fluctuated around a constant level until the middle of 1990s. From then on, Canada experienced a decline in unemployment rate. This trend is apparent in the 10-year centered moving average. In Figure 2.2, quarterly unemployment rate went up and down around a constant level. The reason for different behavior of yearly and quarterly unemployment rate is the limited qualified quarterly data, since the best available quarterly, seasonally-adjusted unemployment rate data is from 1976. Comparing Figures 2.1 and 2.2 with Figure 1.1 to Figure 1.4, both inflation and

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<sup>4</sup> Figures 2.2 and 2.3 are in Appendix.

unemployment rate rose for the first two decades. But after that, inflation decreased immediately while unemployment rate moved up and down around a constant level for about 15 years before its falling period. Figure 2.3<sup>5</sup> shows the outcome of quarterly unemployment rate in the United States and it has a similar pattern as that of quarterly inflation rate. Therefore, my projection for the result, using Barro-Gordon model to test the relationship between inflation and unemployment in Canada is that these two variables are cointegrated for the first two decades only.



The idea that the proper design of monetary policy is crucial to achieve good inflation outcomes was first proposed by Kydland and Prescott (1977). Barro and Gordon (1983a, b) further developed this idea. Ireland (1999) initially conducted

<sup>5</sup> Post-war US data are from Professor Peter Ireland.

time series tests of the Barro-Gordon model. This paper is based on his application of the modified BG model.

The paper is organized as follows. Section 2 presents the modified Barro-Gordon model proposed by Ireland (1999). Section 3 tests the long-run dynamics of the baseline model. Section 4 provides a conclusion.

## 2. Barro-Gordon Time-Consistency Model

In this section I present a modified version of Barro and Gordon's (1983) model, in which the policymaker, lacking the ability to commit in advance to an optimal policy rule, is tempted to lower unemployment by engineering surprise inflation.

Ireland (1999) modifies the Barro-Gordon model by assuming that the natural rate of unemployment contains a unit root and by introducing control errors for inflation. Unemployment and inflation rate are related by the expectations-augmented Phillips Curve:

$$u_t - u_t^n = -\alpha(\pi_t - \pi_t^e) \quad (1)$$

where  $u_t$  is the actual rate of unemployment,  $u_t^n$  is the natural rate of unemployment,  $\pi_t$  is the actual inflation rate,  $\pi_t^e$  is the expected inflation rate and  $\alpha > 0$  is a parameter which controls how much the actual rate of unemployment falls below its natural rate when inflation is higher than expected.

The natural rate of unemployment  $u_t^n$  varies over time in response to a real shock  $\varepsilon_t$ . Its first difference follows a first-order autoregressive process

$$u_t^n - u_{t-1}^n = \lambda(u_{t-1}^n - u_{t-2}^n) + \varepsilon_t \quad (2)$$

where  $|\lambda| < 1$  and  $\varepsilon_t$  is a serially uncorrelated random variable with zero mean and standard deviation  $\sigma_\varepsilon$ .

The policymaker is unable to commit to a monetary policy rule. Instead, in each period, the policymaker chooses a planned inflation rate  $\pi_t^p$  after the private sector have formed their expectations but before the realization of  $\varepsilon_t$ . The actual inflation rate in each period is the sum of  $\pi_t^p$  and control error  $\eta_t$ .

$$\pi_t = \pi_t^p + \eta_t \quad (3)$$

where  $\eta_t$  is a serially uncorrelated random variable with zero mean and standard deviation  $\sigma_\eta$  and covariance  $\sigma_{\varepsilon\eta}$  with  $\varepsilon_t$ .

In this economy, there are optimal levels for both unemployment and inflation rate which are  $ku_t^n$  and 0 respectively. In order to penalize any deviation from optimal levels, the policymaker chooses  $\pi_t^p$  to minimize the expected loss function:

$$E_{t-1}L = (1/2)[(u_t - ku_t^n)^2 + b\pi_t^2] \quad (4)$$

where  $0 < k < 1$  and  $b > 0$ . Since  $0 < k < 1$ ,  $ku_t^n < u_t^n$ . It is obvious that policymaker wishes to target an unemployment rate below natural rate level. Substituting equation (3) into equation (1):

$$u_t = u_t^n - \alpha(\pi_t^p + \eta_t - \pi_t^e) \quad (5)$$



Combining equation (5) with the loss function (4), the policymaker's objective function becomes to

$$\min_{\pi_t^p} E_{t-1} \{ (1/2) [(1-k)u_t^n - \alpha(\pi_t^p + \eta_t - \pi_t^e)]^2 + b(\pi_t^p + \eta_t) \} \quad (6)$$

The first order condition of this problem is

$$\frac{\partial E_{t-1} L}{\partial \pi_t^p} = \alpha E_{t-1} [(1-k)u_t^n - \alpha(\pi_t^p + \eta_t - \pi_t^e)] - b E_{t-1} (\pi_t^p + \eta_t) = 0 \quad (7)$$

Private agents have rational expectations. In equilibrium, expected and planned inflation should be equal, which means  $\pi_t^e = \pi_t^p$ . Combining this with  $E_{t-1} \eta_t = 0$ ,

Equation (7) becomes to

$$\pi_t^p = \pi_t^e = \alpha A E_{t-1} u_t^n \quad (8)$$

where  $A = (1-k)/b > 0$ . Equation (8) clearly states that planned inflation  $\pi_t^p$  is positively proportional to the expected natural rate of unemployment

$E_{t-1} u_t^n$  which is higher than the optimal level of inflation zero. This implies that  $\pi_t^p$  and  $E_{t-1} u_t^n$  will change in the same direction. Whenever  $E_{t-1} u_t^n$  increases, the policymaker faces a greater temptation to try to inflate the problem away. And since private agents have rational expectations and they know the policymaker's objective minimization function, in equilibrium  $\pi_t^p$  also change in the same direction with  $E_{t-1} u_t^n$ .

Equations (1), (3) and (8) imply that

$$u_t = u_t^n - \alpha\eta_t \quad (9)$$

Equation (9) shows that it is the control error  $\eta_t$ , which causes the fluctuation of the actual unemployment rate  $u_t$  around the natural rate in equilibrium.

Combining (2) with (9) yields

$$u_t = u_{t-1}^n + \lambda\Delta u_{t-1}^n + \varepsilon_t - \alpha\eta_t \quad (10)$$

Equation (10) implies that the equilibrium evolution of unemployment  $u_t$  depends on natural rate of unemployment which contains a unit root. Therefore,  $u_t$  is nonstationary, inheriting a unit root from the natural rate process.

Equilibrium also exhibits the similar pattern for inflation. Equations (2), (3) and (8) imply that

$$\pi_t = \alpha A u_{t-1}^n + \alpha A \lambda \Delta u_{t-1}^n + \eta_t \quad (11)$$

which means inflation  $\pi_t$  is also nonstationary due to the underlying unit root process of natural rate of unemployment.

However, combining Equations (10) and (11) yields

$$\pi_t - \alpha A u_t = -\alpha A \varepsilon_t + (1 + \alpha^2 A)\eta_t \quad (12)$$

Since the first two moments of both  $\varepsilon_t$  and  $\eta_t$  are time invariant which means these two processes are stationary, Equation (12) implies that this particular linear combination of  $\pi_t$  and  $u_t$  is stationary.

From the above analysis, the modified Barro-Gordon model implies that if the natural rate of unemployment follows a unit root, in the long-run, both inflation and the unemployment rate are nonstationary individually, but they should be cointegrated.

### 3. Statistical tests

In this section, I will perform statistical tests of the modified Barro-Gordon model's implications using Canadian data.

#### 3.1 The data

Two frequencies of Canadian data, yearly and quarterly, from the Statistics Canada CANSIM<sup>6</sup> database and the Statistics Canada Publication "Historical Statistics of Canada"<sup>7</sup> are used. The variables are unemployment rate and inflation rate. The unemployment rate is from Labour Force Survey. The inflation rate is calculated as the yearly and quarterly percentage change in the GDP deflator and Consumer Price Index (CPI). The time horizon of annual unemployment rate is from 1961 to 2003. The quarterly unemployment rate is from 1976 to the 3<sup>rd</sup> quarter of 2004. The annual GDP deflator inflation rate is from 1961 to 2003, while the quarterly variable is from 1976 to the 3<sup>rd</sup> quarter of 2004. The annual CPI inflation rate is from 1961 to 2001, while the quarterly variable is from the 4<sup>th</sup> quarter of 1978 to the 3<sup>rd</sup> quarter of 2002.

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<sup>6</sup> 1976-2004 quarterly and yearly unemployment rate data are from Series V2062815. GDP deflator is from Series V1997756. Annual CPI is from Series P100000. Quarterly CPI is from Series V737311.

<sup>7</sup> 1946-1975 annual unemployment rate data are from Series D233 in this publication.

When doing the cointegration tests, I test four groups of inflation and unemployment rates, two low-frequency groups and two high-frequencies. Group 1 consists of annual unemployment rate and GDP deflator inflation rate from 1961 to 2003. Group 2 includes the annual unemployment rate and CPI inflation rate from 1961 to 2001. Group 3 contains the quarterly unemployment rate and GDP deflator inflation rate from 1976 to the 3<sup>rd</sup> quarter of 2004. Group 4 is quarterly unemployment rate and CPI inflation rate from the 4<sup>th</sup> quarter of 1978 to the 3<sup>rd</sup> quarter of 2002.

### **3.2 Testing for Unit Root**

Equations (10) and (11) show that according to the model, both inflation and unemployment rate ought to be unit root process. This hypothesis is tested using the Phillips and Perron (1988) test in order to allow for serial correlation in the regression error. Table 1 reports the results of Phillips-Perron unit root test for the selected four groups, 8 variables. The null hypothesis of this test is  $\rho = 1$ , where  $\rho$  is the coefficient by estimating the first-order autoregression of each variable which contains a constant as one independent variable in each regression. The table shows the coefficient  $\rho$ ,  $t$  statistic and Phillips-Perron  $z$  statistic for testing the null. The optimal lag truncation parameter  $q$  based on Andrews' (1991) method is also provided.  $q$  is required to form the Newey-West estimator that adjusts the serial correlation.

Table 1 <sup>8</sup>				
Unit root test: Phillips-Perron				
	$\rho$	$t$ - statistic	$q$	$z$ - statistic
Annual unemployment rate <sup>9</sup>	0.9082	-1.3944	1	-1.6226
Annual GDP deflator inflation rate	0.8364	-1.9506	0	-1.9506
Annual unemployment rate <sup>10</sup>	0.9091	-1.348	1	-1.5713
Annual CPI inflation rate	0.8705	-1.6141	0	-1.6141
Quarterly unemployment rate <sup>11</sup>	0.9696	-1.3339	3	-1.9656
Quarterly GDP deflator inflation rate	0.6645	-4.9434	0	<b>-4.9434*</b>
Quarterly unemployment rate <sup>12</sup>	0.9706	-1.1176	3	-1.7767
Quarterly CPI inflation rate	0.8222	-3.1296	0	<b>-3.1296**</b>

The results show that, for both high and low frequency unemployment rate, we fail to reject the null that  $\rho = 1$ , which means that unemployment rate in Canada from year 1960 to 2004 followed unit root process couldn't be rejected. This result is consistent with the model's implication. However, the unit root hypothesis for inflation rate is not clear. Both GDP deflator and CPI inflation rates in low-frequency groups fail to reject the null hypothesis, while for high-frequency groups the unit root hypothesis can be rejected at 1% level for GDP deflator

<sup>8</sup> There are four groups in this test. Even though some variable names are the same, they belong to different groups.

<sup>9</sup> Sample size of the first group is 43. 1%, 2.5% and 5% critical values are -3.58, -3.22 and -2.93.

<sup>10</sup> Sample size of the second group is 41. 1%, 2.5% and 5% critical values are -3.58, -3.22 and -2.93.

<sup>11</sup> Sample size of the third group is 115. 1%, 2.5% and 5% critical values are -3.51, -3.17 and -2.89.

\* Significance at the 1% level.

<sup>12</sup> Sample size of the fourth group is 96. 1%, 2.5% and 5% critical values are -3.51, -3.17 and -2.89.

\*\* Significance at the 5% level.

inflation and 5% level for CPI inflation. Perron and Ng (1996) argue that using Phillips-Perron test for US inflation rate tends to reject the unit root null hypothesis in finite samples. The result that quarterly inflation rate in Canada doesn't contain unit root might be explained by this. Since the result that low-frequency inflation rate follows unit root process can be supported by Phillips-Perron test, it may be appropriate to regard inflation rate as also nonstationary and do the cointegration test based on these results.

### **3.3 Testing for Cointegration**

Equation (12) implies that the linear combination of unemployment rate and inflation is stationary, even though these two variables are nonstationary independently. The Phillips and Ouliaris (1990) test is used for testing cointegration. In Table 2, I reported the results of Phillips-Ouliaris cointegration test for the selected four groups. The slope coefficient  $\gamma$  obtained by running a regression of inflation on unemployment is provided. The null of this test is  $\rho = 1$ , where  $\rho$  is the slope coefficient got by running the first-order autoregression of the residue. Traditional  $t$  statistic is also reported in Table 2. In order to allow for serial correlation in the regression error, the Phillips-Perron  $z$  statistic is used to test the null.

Table 2					
Cointegration test: Phillips-Ouliaris					
	$\gamma$	$\rho$	$t - statistic$	$q$	$z - statistic$ <sup>13</sup>
Group 1	0.0052	0.8586	-1.7922	0	-1.7922
Group 2	0.0053	0.8536	-1.7486	0	-1.7486
Group 3	0.001	0.7024	-4.6746	0	<b>-4.6746*</b>
Group 4	0.001	0.8413	-2.983	0	<b>-2.983**</b>

Table 2 shows that low-frequency groups, group 1 and group 2, fail to reject the null hypothesis, which means that linear combination of annual unemployment rate and inflation rate is not stationary. However, as for high-frequency groups, the cointegrated relationship between quarterly unemployment rate and inflation rate are strongly supported by Phillips-Ouliaris test.

From Phillips-Perron unit root test, the results of cointegration test should be reversed, since there is a strong evidence of nonstationarity for low-frequency variables while for quarterly inflation rate, the unit root process is not clear. It seems that there is a conflict between Phillips-Perron unit root test and Phillips-Ouliaris cointegration test. One explanation might be that even though we could not reject the unit root null hypothesis for annual unemployment rate, from figure 2.1 the evolution of it might be regime-switching. Annual unemployment rate rose from early 1960s to late 1970s. After that it began to fluctuate around a constant level. It is possible that since policymakers changed their

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<sup>13</sup> 1%, 2.5% and 5% critical values are -3.39, -3.05 and -2.76 respectively.

\* Significance at the 1% level.

\*\* Significance at the 5% level.



unemployment policy from late 1970s, this variable experienced such kind of behavior. Due to the possibility of regime-switching for annual unemployment rate, low-frequency groups in this PO cointegration test fail to reject the null hypothesis which means that the linear combination of annual inflation and unemployment rate is not stationary.

The stationarity of high-frequency groups is also inconsistent with PP unit root test. The reason might be that the coefficient of quarterly unemployment rate is pretty low. Therefore the linear combination of quarterly inflation and unemployment rate might follow a stationary process.

Actually, there is a draw back using Phillips and Ouliaris (1990) cointegration test, since the result greatly depends on the choice of dependent and independent variables. In the Barro-Gordon model from Equation (12), it is appropriate to use inflation rate as dependent variable and unemployment rate as independent variable. Because the Phillips-Ouliaris test is not robust, Johansen's (1988) maximum likelihood approach is used to get more robust result.

Table 3 reports the results of Johansen's cointegration test. Eigenvalues  $\lambda_1$  and  $\lambda_2$  used in evaluating Johansen's likelihood function, the value of parameter

estimates (cointegration vector) and likelihood ratio statistic used to test the hypothesis which is no cointegration are provided.

Table 3				
Cointegration test: Johansen				
	$\lambda_1$	$\lambda_2$	Cointegration Vector	$lr^{14}$
Group 1	0.2438	0.0008	$26.0995 \pi_t - 0.1514 u_t$	<b>11.4549*</b>
Group 2	0.3049	0.0045	$29.7516 \pi_t - 0.1833 u_t$	<b>14.1824**</b>
Group 3	0.0803	0.0017	$118.5640 \pi_t - 0.1226 u_t$	9.4584
Group 4	0.0798	0.0059	$118.2157 \pi_t - 0.1192 u_t$	7.8185

Likelihood ratio statistic offers strong evidence for the stationarity of low-frequency data. But the high-frequency groups, group 3 and 4, fail to reject the no cointegration hypothesis, which means the linear combination of quarterly unemployment rate and inflation rate is nonstationary using Johansen's cointegration test. The opposite results for low frequency groups using two different cointegration tests might be explained by the choice of quarterly data. The beginning points of groups 3 and 4 start from late 1970s. The graphs imply that both inflation and unemployment rate began to fall since then. Since the limited quarterly data only provide the falling periods, the results of Johansen's

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<sup>14</sup> 1%, 2.5% and 5% critical values are 15.69, 13.27 and 11.44 respectively.

\* Significance at the 5% level.

\*\* Significance at the 2.5% level.

test might imply that inflation and unemployment rate were not cointegrated when they began to fall after the rising period.

From Barro-Gordon model, the inflationary bias which is the difference between the true inflation and optimal value comes from the policymaker's preference for good unemployment outcome. The policymaker tries to keep unemployment rate lower than the natural rate of unemployment level. Equations (8) and (11) imply that if policymaker does not try to push unemployment rate below the natural level which means that  $k = 1$ , inflation and unemployment rate will not cointegrated. It is highly possible that at first, policymaker's objective unemployment rate is lower than the natural rate level. But in equilibrium, the actual unemployment rate is not lower than the natural rate level, while inflation is higher than its optimal value. With the rising natural unemployment rate from 1960s to late 1970s, both the actual unemployment and inflation rate increased correspondingly during the same period. But eventually, policymaker will realize that the effort is not successful and the unemployment target is not achieved. Then they will adjust their policy and do not keep such optimal unemployment target. The Johansen's cointegration test might imply that the linear combination of unemployment and inflation rate is stationary during the rising period when the policymaker has the unemployment rate target which is lower than the natural rate level, while these two variables are not cointegrated

for the falling period when policymaker realizes the unsuccessful effort for the optimal unemployment level.

Compared with Phillips-Ouliaris and Johansen cointegration test, the results are in conflict with each other. Even though there is a potential drawback for using PO test, from equation (12) the Barro-Gordon model does imply that inflation is the dependent variable. But the  $z$  statistic in Table 2 is inconsistent with the model's prediction. However using the more robust Johansen test, the result supports the model's implication only to some extent. Due to the different results from the above two cointegration tests, there is no strong evidence to support the idea that Barro-Gordon model could fully explain the long-run behavior of inflation in Canada. The possibility that the policymakers try to keep its unemployment target over the past four decade is low based on the above statistical tests, while it might be possible that only during the first two decades, policymakers tried to decrease unemployment rate below the natural rate level.

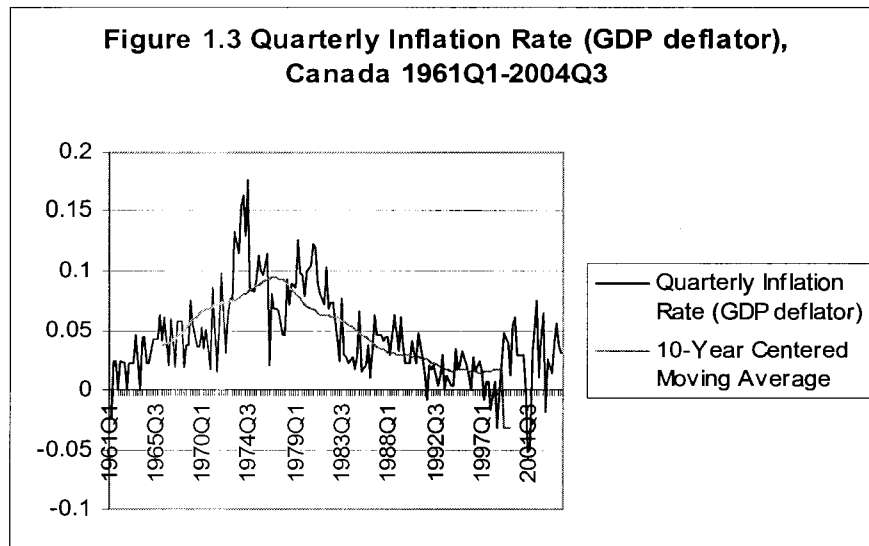
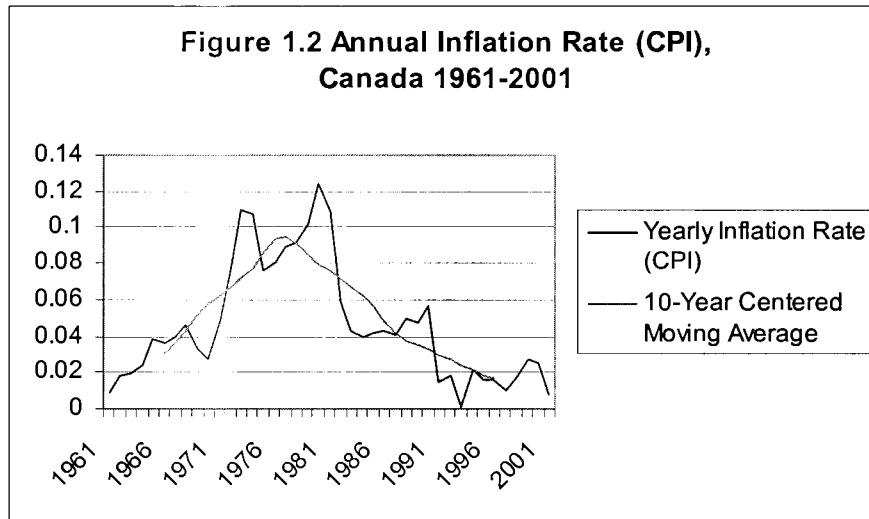
The different results using Barro-Gordon model to explain the behavior of inflation in Canada and United States might come from the different inflation and unemployment targets in these two countries. The policymakers in Canada changed their policies in the middle of the last four decades, while for the United States, the optimal unemployment and inflation rate targets are time invariant.

## 4. Conclusion

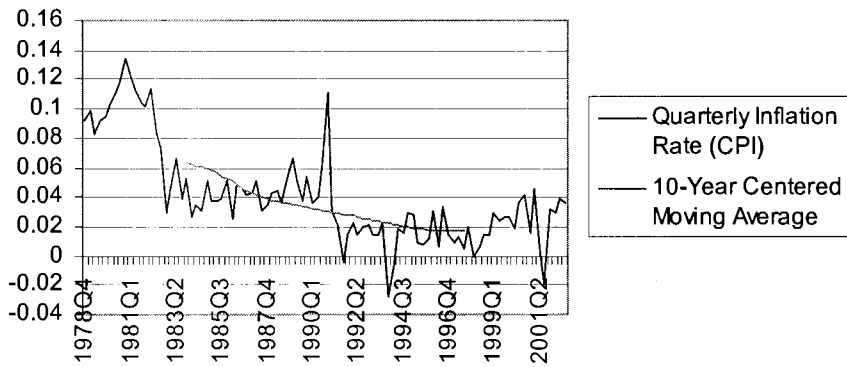
In this paper I investigate whether the modified Barro-Gordon time-consistency problem could explain the behavior of inflation in Canada. The model implies that both inflation and unemployment rate process depend on the evolution of the natural rate of unemployment. Under the assumption that natural rate of unemployment follows a unit root process, inflation and unemployment rate should be nonstationary while in the long-run, these two variables are cointegrated.

Even though Ireland (1999) using the modified Barro-Gordon model successfully explained the long-run dynamics of inflation behavior in US which has the similar pattern as Canada, the results in this paper do not support using the same model to fully explain long-term inflation behavior in Canada. The result indicates that the inability for policy maker to commit in advance to a monetary policy could not explain the initial rise in inflation rate followed by a falling period, even though from the graph there is a similar trend in the unemployment rate process.

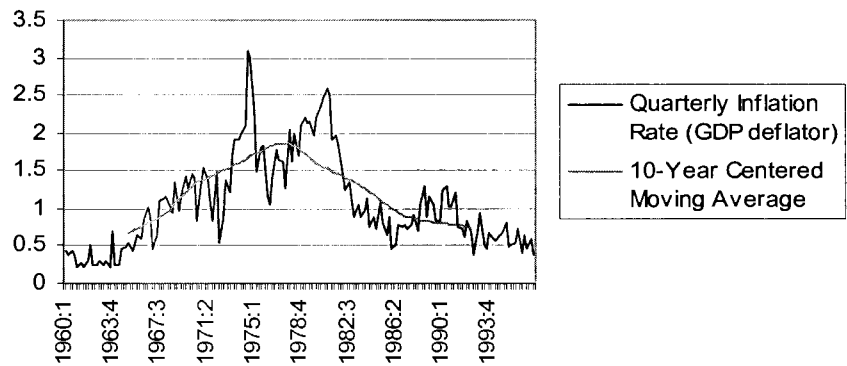
# Appendix



**Figure 1.4 Quarterly Inflation Rate (CPI),  
Canada 1978Q4-2002Q3**



**Figure 1.5 Quarterly Inflation Rate (GDP deflator), USA 1960Q1-1997Q2**



**Figure 2.2 Quarterly Unemployment Rate, Canada 1976Q1-2004Q4**

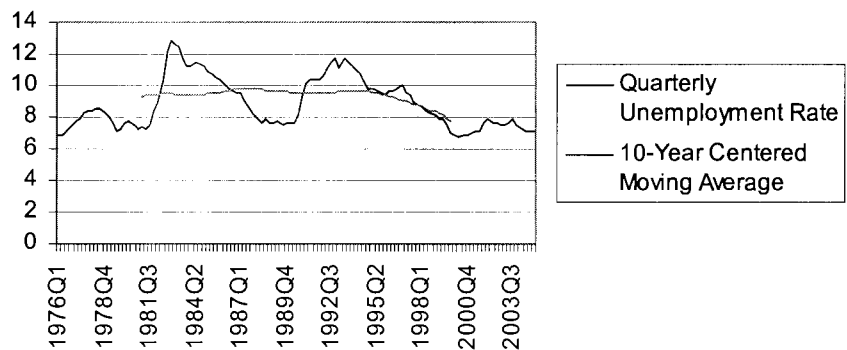
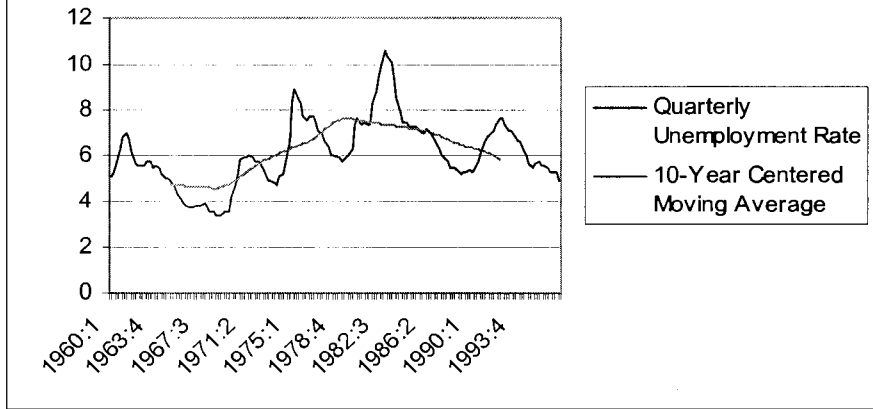


Figure 2.3 Quarterly Unemployment Rate,  
USA 1960Q1-1997Q2





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