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July 2004

Working Paper # 04015

Department of Economics Working Papers Series

Ames, Iowa 50011

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July 14, 2006

Abstract

Inflation rates in a number of OECD follow a common trend over the past four decades: inflation starts out low in the 1960s, rises for a time before peaking in the 1970s or early 1980s, and then falls back to initial levels. This similarity in the behavior of trend inflation suggests that any explanation of long run inflation trends ought to apply across OECD countries. Ireland (1999) shows that a simple time inconsistency model of monetary policy, modified to allow for a time-varying NAIRU, can explain long run trends in U.S. inflation. In this paper we show that this result cannot serve as an explanation of the common trend in OECD inflation, as it fits the data only in the U.S.. We investigate two important variants of the hypothesis: i) that time inconsistency was an important component of central bank behavior in earlier decades, but has become less significant in recent years, and ii) that time inconsistency problems drive U.S. inflation, which affects inflation rates in other countries as a result of central bankers' attempts to manage nominal exchange rate movements vis a vis the U.S. dollar. We find that the first hypothesis fits the data no better than the baseline model. We find some support for the international spillovers version of the model, but the behavior of non-U.S. central bankers with respect to domestic unemployment rates is not well described by the time inconsistency mechanism.

KEYWORDS: Monetary Policy, Time Inconsistency, Inflation.

JEL CLASSIFICATION: E31, E52, E58.

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1 Introduction

A key feature of inflation in many industrialized economies in recent decades was the substantial run-up of inflation in the late 1960s and 1970s, followed by an equally substantial dis-inflation in the 1980s and 1990s. In the U.S., the period of high inflation is sometimes referred to as the Great Inflation, and has been described as "the greatest failure of American macroeconomic policy in the post war period" (Mayer (1999)). A substantial body of recent research attempts to explain the rise and fall of inflation in the U.S. but has paid little attention to the international dimension of the issue to date. The similarity in the behavior of trend inflation, however, suggests that a good explanation of long run inflation outcomes ought to apply across OECD countries.

In this paper, we ask whether time inconsistency models of monetary policy based on the framework of Kydland & Prescott (1977), and Barro & Gordon (1983), can explain inflation trends across OECD economies. Ireland (1999) finds that the Kydland-Prescott, Barro-Gordon (KPBG) model, extended to allow for a time varying NAIRU, is consistent with the U.S. data. As the model is general enough to encompass the institutional arrangements across OECD countries, it is natural to ask whether the success of the model in matching U.S. outcomes extends to an explanation of the common trend in international inflation. Although the basic KPBG framework is a well known and influential model in macroeconomics, there has been relatively little empirical testing of that framework. Furthermore, policy insiders have questioned the relevance of these models, arguing that the time inconsistency story is a poor representation of policymakers' behavior.[1] Thus, an assessment of the empirical performance of the time inconsistency mechanism for inflation outcomes adds to our understanding of both the causes of historical inflation trends and the relevance of a well established class of macroeconomic models.

Our results suggest that simplest version of the KPBG model does not fit the data very well for countries other than the U.S.. We extend the model to incorporate two plausible variants of the model: i) the hypothesis that time inconsistency was an important component of central bank behavior in earlier decades, but has become less significant in recent years, and ii) the view that time inconsistency problems drive U.S. inflation, which in turn influences inflation rates in other countries as a result of the attempts of central bankers in other countries to manage nominal exchange rate movements vis a vis the U.S. dollar. We find that the first hypothesis fits the data no better than the baseline model. We do find some support for the international spillovers version of the model, but the behavior of non-U.S. central bankers with respect to domestic unemployment rates, as viewed through the lens of a time inconsistency account of monetary policy, remains puzzling.

Our paper is related to the literature investigating the causes of the 'Great Inflation'

[1] Blinder (1997), for example "firmly believe(s) that this theoretical problem is a nonproblem in the real world" stating that "during my brief career as a central banker I never once witnessed or experienced this [the inflationary bias] temptation" (p. 13). McCallum (1995) argues that it is "inappropriate to presume that central banks ... repeatedly engage in fruitless attempts to exploit predetermined but endogenous expectations" (p. 209).

in the U.S.. This literature includes Clarida, Gali, & Gertler (2000), who argue that the rise of inflation in the late 1960s and early 1970s was due to mistakes made by monetary policy authorities. One view of the related literature, is that it attempts to rationalize the conduct of policy makers during this period. Explanations include the possibility that the Fed conducted otherwise correct monetary policy using bad data (Orphanides (2002, 2003)), that the Fed was learning about key parameters of the economy as it went along (Sargent (1999), Primiceri (2004)), and that the Fed was responding to unfavorable fundamentals, perhaps filtered through the lens of time inconsistency problems (Ireland (1999)). Our paper clearly falls into this last category. The main innovation is the use of the common international experience as a way of disciplining our empirical work.

We begin the paper with the observation that there appears to be a common trend in OECD inflation rates. Figures 1-7 reveal a common pattern in inflationary outcomes, measured by annualized quarterly percentage changes in the GDP deflator, in the G-7 countries. The pattern, visible in the raw data, but more transparent in the 7-year centered moving averages also displayed in the figures, is as follows: inflation starts out low in the early 1960s in all countries. This is followed by a period of rising inflation lasting until the late 1970s or early 1980s in all countries except Germany and Japan, where inflation peaks in the early and mid 1970s, respectively. After this period of rising inflation, inflation rates then fall until the present, and are generally as low or lower by the end of the 1990s than they were in the early 1960s. The commonality of OECD inflation rates depicted visually in the figures is confirmed by statistical tests showing that OECD inflation rates are cointegrated with one another.

Ireland (1999) observes that inflation in the KPBG framework depends directly on the NAIRU, implying that inflation and unemployment should both rise and fall with the NAIRU. As the NAIRU rises, central bankers increase their attempts to drive unemployment down, which leads to increasing inflation. Essentially, any long run trend in the NAIRU is reflected in long run inflation and unemployment trends. Furthermore, both inflation and unemployment inherit the time series properties of the NAIRU. If the NAIRU is I(1), then both inflation and unemployment inherit the non-stationarity of the NAIRU and, according to the model, must be cointegrated. This insight provides the basis for statistical tests of the model, which we apply to OECD data.

Our first pass at the data is to apply the insight of Ireland, that the KPBG model requires inflation and unemployment to be cointegrated, to quarterly data from 13 OECD countries going back to 1964. Not surprisingly, given the plots in the previous figures, our results suggest that inflation and unemployment are not cointegrated in OECD countries, with the sole exception of the U.S..

An obvious problem with our simple, first pass approach is that a number of key model parameters (central bank preferences, the slope of the Phillips curve, etc...) are unobserved and difficult to estimate. Furthermore, there is no strong reason to believe that these parameters have remained constant throughout the period of interest.[2] Thus the failure of

[2]In fact, the literature offers a number of channels by which observed changes in macroeconomic conditions

the time inconsistency model to fit the data may be due to a failure of the assumption that the model parameters were unchanged over the estimation period.

To allow for this possibility, we extend the baseline model to incorporate time varying model parameters, and show that shifts in these parameters imply structural breaks in the cointegrating relationship. We then investigate whether allowing for structural breaks significantly improves the empirical performance of the model using the Gregory-Hansen test for cointegration in the presence of a possible structural break in the cointegrating relationship. Our results imply that allowing for time varying model parameters in this way does not overturn the conclusion that the time inconsistency framework does not fit the data for most OECD countries.

An important variant of the KPBG story is the widespread view that policy makers targeted unattainable unemployment rates in the 1960s and 1970s, but, perhaps due to advances in economic theory, became more cautious about trying to use monetary policy to offset high unemployment rates in more recent decades.[3] If correct, this variant of the theory implies that inflation and unemployment should be cointegrated in the first part of the sample, when policy makers were still treating the Phillips curve as an exploitable relationship. In the latter portion of the sample, when policy makers learn not to target unemployment rates below the NAIRU, the time inconsistency model no longer describes the behavior of central bankers, so inflation and unemployment ought not to be related at all.

We test this variant of the basic KPBG model by re-estimating the model using only data from the first part of the sample. Essentially, we ask whether this hypothesis is a reasonable explanation of the rise in inflation in the 1960s and 1970s. Surprisingly, given the prevalence of this hypothesis amongst macroeconomists, the time inconsistency account fits no better when estimated just on data from the 1960s and 1970s than it does on data over the whole sample. The main problem is that the theory can only deliver rising inflation in the presence of increases in the NAIRU, but, outside of the U.S., there is little evidence of a rising NAIRU during the period of rising inflation. We conclude that this variant of the theory finds no more support than the baseline model.

A final variant on the basic framework allows that inflation may have spilled over from the U.S. to other countries, due to a dislike on the part of monetary authorities in smaller countries of large nominal exchange rate movements with respect to the U.S. In this case, an increase in the U.S. NAIRU drives up U.S. inflation, which forces foreign monetary authorities to allow domestic inflation to rise, so as to avoid an appreciation of the domestic currency. We extend the baseline model to incorporate exchange rate targeting, and show that U.S. unemployment rates enter as an additional cointegrating variable into the smaller country's inflation and unemployment relationship.

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might have altered some of the underlying parameters of a baseline time-consistency model. Some of the main possibilities are openness, average inflation, and central bank independence.

[3]Sargent (1999) refers to this account of the rise and fall in inflation as the "the triumph of natural-rate theory" view.

We test for cointegration between domestic inflation, and domestic and U.S. unemployment. The results do suggest that there is a cointegrating relationship, with a positive sign, between domestic inflation and U.S. unemployment in two thirds of the OECD countries in our sample. The evidence, however, suggests that time inconsistency and inflationary bias have not been important determinants of monetary policy in other OECD countries, as trends in domestic unemployment seem to be unrelated to one another. Thus, the evidence is consistent with an account in which time inconsistency problems in U.S. monetary policy caused inflation in the U.S. to rise in the 1960s and 1970s, and that this inflation spilled over into other OECD countries via exchange rates. The behavior of foreign monetary authorities with respect to their domestic unemployment rates, however, is not well described by the KPBG model.

The paper proceeds as follows. In Section 2, we present a typical model of time-consistent monetary policy with a time varying NAIRU as well as extensions of the model incorporating both time varying model parameters, and international spillovers in inflation. In Section 3 we present the results of our econometric tests of the long run restrictions of the baseline model. We also present the results of tests incorporating both structural breaks and international spillovers into the baseline framework. In Section 4 we offer concluding remarks.

2 A Time-Consistency Model of Monetary Policy

In this section we present a version of the simple KPBG time-consistency model of monetary policy in which a central banker, lacking the ability to commit to an optimal policy rule, is tempted to reduce unemployment in each period by engineering surprise inflation. Private agents in the model have rational expectations, however, and understand that the central banker faces this temptation. They adjust their inflationary expectations accordingly and are not surprised by the central bank's inflationary policies. The result is an equilibrium outcome with inefficiently high inflation, but unemployment no lower than it would have been had the policy maker been able to commit to not attempting to inflate.

Following Ireland (1999), our version of the simple KPBG model is extended to allow for a time varying NAIRU. We assume that the NAIRU possesses a unit root in order to allow the model to replicate the unit root behavior of inflation and unemployment that we document in the empirical section of the paper. The model itself makes no predictions regarding the time series properties of the NAIRU, treating it as exogenous. The testable predictions of the model concern the impact of exogenous changes in the NAIRU on inflation. In particular, the inflationary bias and consequently equilibrium inflation depend directly on the NAIRU, implying that equilibrium inflation and the NAIRU are cointegrated.

In Section 2.2 we extend the model to allow for the possibility that unobserved parameters change over the course of the sample. We show that parameter shifts cause the cointegrating vector between inflation and unemployment to change over time. In Section 2.3 we incorporate an exchange rate targeting central bank into the analysis, and show that this implies international inflation spillovers. The testable implication we draw from this is the result that, in the open economy version of the model, a country's domestic inflation rate, domestic unemployment rate and the U.S. unemployment rate are cointegrated.

2.1 A Baseline Model

The standard time-consistency model of monetary policy begins with an equation describing the relationship between unemployment and inflation, which acts as a constraint on policy makers trying to affect inflation and unemployment outcomes. This structural relationship is generally modelled as an expectations augmented short run Phillips curve:

$$u_t = u_t^n - \alpha(\pi_t - \pi_t^e), \tag{2.1}$$

where π_t is the rate of inflation in period t, π_t^e represents household's expectations of period t inflation, u_t is the rate of unemployment, and u_t^n is the NAIRU.

The policy maker in the model is assumed to have preferences over unemployment and inflation outcomes in the economy. These preferences take the form of a loss function, which the policy maker wishes to minimize:

$$L(\pi_t, u_t) = 1/2\ [\ b \cdot \pi_t^2 + (u_t - k \cdot u_t^n)^2\ ], \tag{2.2}$$

where b represents the central bank's distaste for inflation and $k \cdot u_t^n$ represents the central bank's target level of unemployment.[4] It is generally assumed that $k < 1$. In such a case, the central bank wishes to target an unemployment rate below the NAIRU–this leads to the inflationary bias which is at the heart of the time inconsistency story.

The problem facing the policy maker is to minimize:

$$E_{t-1} L(\pi_t, u_t.) \tag{2.3}$$

The policy maker is unable to commit to a monetary policy rule. Instead, in each period, after the private agents have formed their expectations but before the realization of ϵ_t, the policy maker chooses a target rate of inflation π_t^p. Actual inflation in the period is then determined as the sum of the policy maker's inflation target, plus some control error η_t:

$$\pi_t = \pi_t^p + \eta_t, \tag{2.4}$$

where η_t is a serially uncorrelated random variable with mean zero and standard deviation σ_η. The assumption that the central banker controls inflation only imperfectly mainly serves to break the link between the actual unemployment rate and the NAIRU, allowing us to avoid the necessity of identifying all changes in unemployment with changes in the NAIRU.

The policy maker selects π_t^p in order to minimize the loss function given by (2.2), subject to the expectations augmented Phillips curve given by (2.1). The first order condition for this problem is:

$$bE_{t-1}(\pi_t^p + \eta_t) = \alpha E_{t-1}[(1-k)u_t^n - \alpha(\pi_t^p + \eta_t - \pi_t^e)]. \tag{2.5}$$

[4] We could also assume that the central bank targets the deviation of inflation from some optimal level π_t^*. Here we have just assumed $\pi_t^* = 0$ for all t.

Agents have rational expectations, so that $\pi_t^e = \pi_t^p$. This, along with the fact the $E_{t-1}\eta_t = 0$ allows us to reduce Equation (2.5) to:

$$\pi_t^p = \pi_t^e = \alpha\left(\frac{1-k}{b}\right)E_{t-1}u_t^n. \tag{2.6}$$

Equation (2.6) exhibits a key feature of the model: the equilibrium rate of inflation depends directly on the expected value of the NAIRU. This is due to the fact that the central banker's desired target level of unemployment is proportional to the NAIRU. As a result, when the NAIRU is higher, the central banker faces a greater temptation to try to inflate the problem away. Loosely, the inflationary bias is more severe at higher levels of the NAIRU, implying that inflation will be higher in periods when the NAIRU is high. As usual, rational expectations imply that this has no effect on the actual unemployment rate.

A simple version of the model, with a constant NAIRU, implies that both inflation and unemployment are constant. In order to enable the model to speak to trends in inflation, we need to allow the NAIRU to vary over time. The following equation describes the evolution of the NAIRU:[5]

$$u_t^n = u_{t-1}^n + \epsilon_t, \tag{2.7}$$

where ϵ_t is a serially uncorrelated random variable with mean zero and standard deviation σ_ϵ. The assumption that the NAIRU is exogenous can be interpreted simply to mean that the NAIRU is unaffected by monetary policy, and is therefore taken as given by the central banker.

Equations (2.1), (2.4), and (2.6) imply that:

$$u_t = u_t^n - \alpha\eta_t. \tag{2.8}$$

Essentially, Equation (2.8) shows how the control error implies that the actual unemployment rate fluctuates around the NAIRU in equilibrium.

Combining (2.8) with (2.7) yields:

$$u_t = u_{t-1}^n + \eta_t. \tag{2.9}$$

Equation (2.9) describes the equilibrium evolution of unemployment. It shows that equilibrium unemployment depends only on the underlying process for the NAIRU and the control error, which creates unpredictable inflation.

We can derive a similar relationship for equilibrium inflation. Equations (2.7), (2.4), and (2.6) imply that:

$$\pi_t = \alpha\left(\frac{(1-k)}{b}\right)u_{t-1}^n + \epsilon_t - \alpha\eta_t. \tag{2.10}$$

[5] Ireland (1999) follows Gordon (1997) and Staiger, Stock & Watson (1997) in specifying the NAIRU process as: $u_t^n - u_{t-1}^n = \lambda(u_{t-1}^n - u_{t-2}^n) + \epsilon_t$, where $1 > \lambda > -1$. We adopt the simpler unit root process given above for convenience. The essential features of the model are unchanged if we use the more realistic process for the NAIRU instead.

Again, equilibrium inflation depends only on the underlying process for the NAIRU and the control error. Observe that the extent to which inflation varies with the NAIRU depends on the preferences of the central banker. In particular, if k were equal to 1, the central banker would target the NAIRU and there would be no inflationary bias. In this case, inflation would depend only on the unpredictable shocks, ϵ_t and η_t and would have no trend. Any trend in inflation generated by the model is driven by trends in the underlying NAIRU process.

Separately, Equations (2.9) and (2.10) show how inflation and unemployment inherit the unit root from the underlying process for the NAIRU. Combined, these equations give:

$$\pi_t - \alpha\left(\frac{1-k}{b}\right)u_t = -\alpha\left(\frac{1-k}{b}\right)\epsilon_t + \left(1 + \alpha^2\left(\frac{1-k}{b}\right)\right)\eta_t. \tag{2.11}$$

Both inflation and unemployment depend directly on the NAIRU. Any trend displayed by either of these variables in equilibrium is inherited from the underlying NAIRU. Although inflation and unemployment are non-stationary when the NAIRU is non-stationary, a linear combination of these two variables is stationary. In other words, the KPBG model implies that inflation and unemployment should be cointegrated if the NAIRU follows a unit root. It is this implication of the model that we test empirically in Section 3.

2.2 Extension: Structural Breaks

Tests of the model based on Equation (2.11) rely on the maintained hypothesis that the parameters of the model do not change over time. There are three parameters in the baseline model, each of which may have changed over the past few decades: **i)** α, which represents the slope of the short run Phillips curve, **ii)** k, which represents the extent to which the central banker wants to push unemployment below the natural rate, and **iii)** b, which represents the relative importance of inflation versus unemployment deviations from target. In our empirical section, we would like to allow for the possibility that these parameters are not constant throughout the sample. In this section we present a model in which these parameters are permitted to change over time in order to examine how this changes the testable implications of the model.

We begin with the short run Phillips curve, which is now given by:

$$u_t = u_t^n - \alpha_t(\pi_t - \pi_t^e). \tag{2.12}$$

This differs from the previous specification only in that α_t is allowed to vary over time.

The policy maker's loss function is now given by:

$$L(\pi_t, u_t) = 1/2 \; [\; b_t \cdot \pi_t^2 + (u_t - k_t \cdot u^n)^2 \;]. \tag{2.13}$$

Again, the difference is that b_t and k_t are permitted to change over time. We maintain the assumptions on the control error and the process of the NAIRU, which are given by Equations (2.4) and (2.7) respectively.

As was previously the case, the policy maker selects π_t^p in order to minimize the loss function given by (2.13) subject to the expectations augmented Phillips curve given by (2.12). The first order condition for this problem is:

$$E_{t-1}\Big\{b_t(\pi_t^p + \eta_t)\Big\} = E_{t-1}\Big\{\alpha_t[(1-k_t)u_t^n - \alpha_t(\pi_t^p + \eta_t - \pi_t^e)]\Big\}. \qquad (2.14)$$

Since the policy maker chooses π_t^p at the start of the period, π_t^p is known. Since η is mean zero and i.i.d $E_{t-1}(b_t\eta_t) = E_{t-1}(\alpha_t^2\eta_t) = 0$. After applying the usual Rational Expectations assumption that $\pi_t^e = \pi_t^p$, the above equation reduces to:

$$\pi_t^p = \frac{E_{t-1}\{\alpha_t(1-k_t)u_t^n\}}{E_{t-1}\{b_t\}}. \qquad (2.15)$$

While Equation (2.15) is fairly general, it is not particularly useful. In order to get something more manageable it is necessary to put some structure on the processes generating α_t, b_t and k_t. There are essentially two broad classes of possibilities: i) the date t realizations of these variables are known before the policy maker chooses π_t^p, and ii) the date t realizations are not known to the policy maker when choosing π_t^p.

The first case is much simpler and we will focus exclusively on this case in the discussion here.[6] The policy maker has to pick π_t^p at the beginning of each period t. This means that, even if α_t, b_t and k_t follow stochastic processes, as long as the date t realizations are known before the policy maker chooses π_t^p, we don't have to worry about taking expectations of them. In other words, we can pull these through the expectations operator in Equation (2.15) to get:

$$\pi_t^p = \frac{\alpha_t \cdot (1-k_t)}{b_t} E_{t-1}\{u_t^n\}. \qquad (2.16)$$

Solving the model in the usual manner gives:

$$\pi_t - \alpha_t\left(\frac{1-k_t}{b_t}\right) u_t = -\alpha_t\left(\frac{1-k_t}{b_t}\right)\epsilon_t + \left(1 + {\alpha_t}^2\left(\frac{1-k_t}{b_t}\right)\right)\eta_t. \qquad (2.17)$$

This is essentially Equation (2.11), except that α_t, b_t, and k_t are allowed to vary over time. This implies that there may not be a time invariant cointegrating vector between inflation and unemployment. It is clear from Equation (2.17) that changes in the parameters of the model would cause the cointegrating vector to change over time. We will incorporate this possibility into our empirical work by allowing for structural breaks in the cointegrating vector.

[6]The second case is more complicated, for two reasons. First, it makes the discussion of cointegration more complicated because π_t will depend on expectations of α_t, b_t and k_t where u_t will depend on the realizations. Second, modelling these parameters as uncertain at date t requires specification of the joint process of u_t^n along with α_t, b_t and k_t, in order to be able to calculate any covariances that arise.

2.3 Extension: Open Economies

In this section we extend the model to allow for the possibility that inflation in one country is transmitted to another country via the effect on exchange rates by assuming that central bankers target changes in nominal exchange rates in addition to domestic inflation and unemployment. The model is meant to capture the case of a small economy that unilaterally targets the domestic-U.S. nominal exchange rate.

The domestic monetary authority faces the usual problem of choosing planned inflation (Equation 2.4) to minimize a loss function subject to an expectations augmented Phillips curve (Equation 2.1) taking household expectations as given. As before, we assume that the NAIRU follows a simple unit root process (Equation 2.7).

However, in addition to targeting domestic inflation and unemployment, the policy maker also wants to minimize nominal exchange rate movements. Hence, the loss function becomes:

$$L(\pi_t, u_t, \Delta e_t) = 1/2[b \cdot \pi_t^2 + (u_t - k \cdot u_t^n)^2 + \phi(\Delta e_t)^2], \tag{2.18}$$

where Δe_t is the change in the log of the nominal exchange rate.

We assume that a simple PPP theory describes exchange rates, so that $e_t = p_t - p_t^f$, where p_t is the log of the domestic price level, and p_t^f is the log of the foreign price level. This implies that:

$$\Delta e_t = \pi_t - \pi_t^f. \tag{2.19}$$

Substituting the constraints out, the problem facing the policy maker is:

$$\min_{\pi_t^p} 1/2 \cdot \left[b(\pi_t^p + \eta_t)^2 + \Big((1-k) \cdot u_t^n - \alpha(\pi_t^p + \eta_t + \pi_t^e) \Big)^2 + \phi(\pi_t^p + \eta_t - \pi_t^f)^2 \right], \tag{2.20}$$

with the corresponding first order condition given by:

$$b\mathrm{E}_{t-1}\{\pi_t^p + \eta_t\} - \alpha\mathrm{E}_{t-1}\{(1-k) \cdot u_t^n - \alpha(\pi_t^p + \eta_t + \pi_t^e)\} + \phi\mathrm{E}_{t-1}\{\pi_t^p + \eta_t - \pi_t^f\} = 0. \tag{2.21}$$

Using $\mathrm{E}_{t-1}\eta_t = 0$, and imposing rational expectations ($\pi_t^p = \pi_t^e$) gives an expression for planned inflation:

$$\pi_t^p = \frac{\phi}{b+\phi}\mathrm{E}_{t-1}\pi_t^f + \frac{\alpha(1-k)}{b+\phi}\mathrm{E}_{t-1}u_t^n \tag{2.22}$$

Equilibrium unemployment is given by:

$$u_t = u_t^n + \epsilon_t. \tag{2.23}$$

In order to complete the model, we need to specify the process by which π_t^f is generated, which requires a model of the foreign economy. We make the assumption that the foreign country doesn't target the exchange rate, so foreign inflation is determined by the baseline model. Using an f superscript to denote foreign country parameters and variables, this implies:

$$\pi_t^f = \frac{\alpha^f(1-k^f)}{b^f}\mathrm{E}_{t-1}u_t^{nf} + \eta_t^f \tag{2.24}$$

which gives:

$$\mathrm{E}_{t-1}\pi_t^f = \frac{\alpha^f(1-k^f)}{b^f}(u_t^f - \epsilon_t^f + \alpha^f\eta_t^f). \tag{2.25}$$

Hence, in the domestic country:

$$\begin{aligned}\pi_t - \left[\frac{\alpha(1-k)}{b+\phi}\right]u_t - \left[\frac{\phi\alpha^f(1-k^f)}{(b+\phi)b^f}\right]u_t^f \quad = \quad & -\left[\frac{\alpha(1-k)}{b+\phi}\right]\epsilon_t + \left[\frac{(1+\alpha)\alpha(1-k)}{b+\phi}\right]\eta_t \\ & -\left[\frac{\phi\alpha^f(1-k^f)}{(b+\phi)b^f}\right](\epsilon_t^f - \alpha^f\eta_t^f). \end{aligned} \tag{2.26}$$

Relative to the baseline model, when the foreign government decides to try to minimize exchange rate movements, it is forced to keep domestic inflation in line with foreign inflation. This implies that changes in the NAIRU of the foreign country, which imply changes in the foreign inflation and unemployment rates, also cause changes in the domestic inflation rate. The result is that domestic inflation, domestic unemployment, and foreign unemployment are cointegrated in this version of the model. The restrictions on the model parameters imply that the sign of both $\frac{\alpha(1-k)}{b+\phi}$ and $\frac{\phi\alpha^f(1-k^f)}{(b+\phi)b^f}$ should be positive. Consequently, when the coefficient on domestic inflation is normalized to unity the coefficients on domestic and foreign unemployment in the cointegrating vector should be negative.

3 Testing the Model's Implications

In this section we examine the data from a number of OECD economies to see if inflation and unemployment move together as predicted by the theory.

3.1 The Data

We employ quarterly data from a number of OECD countries. Our variables are the civilian unemployment rate (as reported in the OECD's Main Economic Indicators) and the rate of inflation, measured alternately by the quarterly percentage change in the GDP deflator (taken from the IFS database) and in the Consumer Price Index (again taken from the MEI). We end up with a sample of 13 countries for which sufficient time series data are available at quarterly frequencies.[7]

Given that we wish to explain the pattern of inflation outcomes over a long period of time, we include only those countries for which data goes back until the early 1970s. We exclude countries for which the data starts later than this because inflation has fallen steadily since the mid to late 1970s, and we want to ensure that the model is capable of explaining both the rise and fall of OECD inflation. Due to data availability issues, we use different samples for each country. Also, data limitations with regard to inflation measured by the GDP deflator led us to use this measure only for the G-7 countries. The samples used are described in Tables 1 and 2.

[7]Our sample consists of Australia, Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, the U.K. and the U.S..

Figures 1 through 7 plot the inflation (measured as the annual percentage change in the GDP deflator) and unemployment rates of the G-7 economies, along with a 7-year centered moving average to highlight the longer run trends in each series. A visual inspection of these figures allows us to anticipate the main results of the paper. Figure 1 echoes Ireland's results. Both inflation and unemployment rise steadily until the early 1980s and both decline fairly steadily thereafter.

A quick look at the remaining figures, however, suggests that the U.S. is an outlier in this regard. For Japan and the Western European countries (excluding the U.K), inflation and unemployment exhibit very different trends. While inflation follows the usual rising-then-falling pattern, unemployment rates trend steadily upwards throughout the sample (until at least the late 1990s). If the time inconsistency hypothesis is correct, inflation ought to have continued rising in these economies during the 1980s and 1990s.

The plots for the U.K. and Canada are not quite as clear. In both of these countries, unemployment does exhibit a rise and then fall over the course of the sample. However, the timing of this rise and fall appears to be unfavorable to the time inconsistency hypothesis. In both countries, the largest increase in unemployment is accompanied by declining inflation. The time inconsistency hypothesis suggests that the rise of inflation ought to have occurred starting in the mid 1970s in these countries–this is the very time inflation rates were in fact beginning to decline again.

The next section provides a more detailed analysis, using the model of the previous section as the basis for statistical tests of the hypothesis that time inconsistency problems can explain the observed trends in OECD inflation rates.

3.2 Testing for Cointegration

Equations (2.9) and (2.10) state that, according to the model, both the unemployment rate and inflation rate ought to be unit root processes. Unit root test results are reported in Tables 1 and 2. The test we applied was the Augmented Dickey-Fuller test, de-meaning the data first by GLS and then using Ng and Perron's (2001) Modified AIC to select the number of lagged differences to include in the ADF regression.[8] This test seems to have relatively good size and power properties for series like unemployment and inflation, which tend to have a large negative moving-average root.

Table 1 reports the test results for matched sample periods of the unemployment rate and the CPI-based inflation rate for the 13 OECD countries that form our large sample. Table 2 reports the test results for matched sample periods of the unemployment rate and the GDP Deflator-based inflation rate for the subset of G-7 countries. In no case was it possible to reject the null hypothesis that the series possesses a unit root at the 5% significance level. We can reject the null at a 10% level for the inflation rate in the U.K and the unemployment rate in the U.S. We also reject the null at a 10% level of significance for the inflation rate in Italy when we use the GDP deflator as our measure of prices. Based

[8]This is the test statistic described in Ng and Perron (2001) with $p = 0$ and $\bar{c} = -7.0$.

on the results of Tables 1 and 2, it seems reasonable to treat both the unemployment rate and the inflation rate as unit root processes across all countries and proceed to test for cointegration.

We begin our estimation by verifying econometrically the observation that the time series pattern of inflation outcomes over the past four decades has been similar across the countries in our sample. We do this by applying Johansen's (1988) maximum likelihood approach to test for cointegration between a country's inflation rate and the U.S. inflation rate. As Table 3 shows, the long-run trends in inflation rates are very similar across countries. The null hypothesis of no cointegration is rejected at standard significance levels for all countries in our sample except Austria and Japan. [9] [10] These results suggest that trends in inflation in different countries are related. This is an important observation as it suggests there may be a common explanation of inflation trends in OECD countries.

With these results in hand, we turn to our empirical implementation of the simple model of Section 2.1, applying Johansen's (1988) maximum likelihood approach to test for cointegration between unemployment and inflation rates. The results for the unemployment rate and the CPI inflation rate are reported in Table 4 for the full set of OECD countries. The results for the unemployment rate and the GDP deflator inflation rate are reported in Table 5 for the G-7 countries.

The first thing to note is that the null hypothesis that inflation and unemployment are not cointegrated is rejected at the 5-percent level for the U.S., whether we use the CPI inflation rate or the GDP deflator inflation rate. In this sense our results mirror those of Ireland (1999). However, our results differ from his once we look at other countries in our sample. The null of no cointegration between the unemployment rate and the CPI inflation rate cannot be rejected at the 5-percent level for any of the 13 OECD countries other than the U.S. It can be rejected at the 10-percent level only for the U.S. and Canada.

The null of no cointegration between the unemployment rate and the GDP deflator inflation can is rejected at the 1-percent level for Italy, at the 5-percent level for the U.S. and at the 10-percent level for France. It is not rejected at the 10-percent level for the other four G-7 countries.

These results suggest that simple time inconsistency models of inflation do not provide an adequate explanation for the pattern of rising and then falling inflation rates observed in OECD economies over the past four decades. In subsequent sections we explore the possibility that extensions of the baseline model provide a better explanation of the data.

[9] The result for Japan is sensitive to the starting date. If we look for cointegration over the years 1974-2003, we reject the hypothesis of no cointegration between U.S. and Japanese inflation at a 1% significant level.

[10] In the bivariate setting with both series assumed to be unit root processes, Johansen's λ-max and λ-trace tests are equivalent, since in both cases the null hypothesis is that the cointegration rank is zero and the alternative hypothesis is that the cointegration rank is one.

3.3 Time Varying Parameters

The model we have tested so far is a simple version of the story and our test is a joint test of the mechanism described by the model and a number of other assumptions. Perhaps the most significant of these is the assumption that those aspects of the economy captured by the various parameters of the model (the degree of inflationary bias of central bankers, the slope of the short run Phillips curve, etc ...) have remained constant over the relevant time horizon. There are reasons to think that this assumption is incorrect.

A number of authors in the literature have investigated the possibility that the slope of the short run Phillips curve, α, has shifted in recent decades due to factors such as increased openness (Romer (1993), Campillo & Miron (1997), Lane (1997), and Temple (2002)) or changes in average inflation rates (Lucas (1972), Ball, Mankiw & Romer (1989) and Akerlof, Dickens & Perry (1996)). Alternately, it has been suggested that the central banker's preference parameters, k_t and b_t, may have shifted, perhaps due to increases in central bank independence (Alesina & Summers (1993), Campillo & Miron (1997), Temple (1998) and Brumm (2000)). These factors, and others like them, represent potential sources of parameter changes that might affect the cointegrating vector given by (2.17).

We incorporate the possibility of parameter change into our empirical work by allowing for structural breaks in the cointegrating relationship between inflation and unemployment. The Johansen test for cointegration, like conventional residual-based cointegration tests, tests the null hypothesis of no cointegration against the alternative of cointegration with a fixed level and slope of the cointegration relationship. If inflation and unemployment are cointegrated but the level and/or slope parameter changes over the course of the sample, then the test will have poor power. In particular, the failure to account for regime shifts in the cointegrating relationship may explain why we did not find more evidence of cointegration between inflation and unemployment.

We applied Gregory & Hansen's (1996) residual-based test for cointegration, which allows for the possibility of a regime shift under the alternative of cointegration, although the timing of the regime shift is not known. The null hypothesis is that the series are not cointegrated. The particular version of the Gregory-Hansen test we applied 1) used their ADF* statistic, 2) applied to the residuals from their "regime shift" or "C/S" cointegrating regression, which allows for a change in the intercept and/or slope coefficient, and 3) restricting the possible break point to lie within the middle 70-percent of the sample period. Following Gregory and Hansen, the lag lengths for the ADF-regressions were selected by choosing the smallest lag length for which the t-statistic on the last lag included was less than two in absolute value, with the maximum lag length being equal to eight. Asymptotic critical values were obtained from Table 1 in Gregory and Hansen (1996) using the row m = 1, ADF*, C/S. Note that Monte Carlo simulations by Gregory and Hansen (1996) indicate that the actual size of the test in finite sample applications tends to be larger than the nominal size implied by the asymptotic critical values.

The results are reported in Tables 6 and 7, which differ according to whether the inflation rate is calculated from the CPI or the GDP deflator, respectively. According to Table 6, there is some evidence that Denmark and Norway can be added to the set of countries (i.e., the U.S. and Canada) for which CPI-based inflation rate and the unemployment rate are cointegrated. The results from Table 7 do not provide any additional countries for which the GDP-deflator based inflation rate and the unemployment rate are cointegrated. In fact these results provide weaker evidence for cointegration of unemployment and the GDP-deflator based inflation rate than was the case in the previous section where we ignored the possibility of structural breaks.

3.4 The Triumph of Natural-Rate Theory?

In this section we examine the possibility that inflation and unemployment are cointegrated over the first part of the sample, but not the rest.[11] This case is of particular interest as it corresponds to a commonly held view amongst macroeconomists: in the 1960s and early 1970s central bankers attempted to maintain low unemployment rates by trying to exploit the observed Phillips curve relationship, but due to refinements in economic theory today's central bankers understand that there exists a 'natural' rate of unemployment and do not attempt to push unemployment below this sustainable level. The result of these advances has been an elimination of inflationary bias and time inconsistency problems in monetary policy.

The case where there is no inflationary bias corresponds, in the model, to the case where k takes the value 1. Inspection of Equation (2.17) shows that the implication of $k = 1$ is that inflation and unemployment are no longer cointegrated. In the absence of inflationary bias, the unemployment rate would still follow the NAIRU but the policy maker would not be tempted to try to inflate away this employment with surprise inflation. The inflation rate would hover around the policy makers target, deviating from the target only as a result of the control error.

To test the possibility that there is an inflationary bias in the first but not latter part of the sample, we applied the Johansen cointegration test to the first half of the sample for each country and also to the first two thirds of the sample for each country. We would expect to reject the no cointegration null more often than we did for the full sample if the story that the KPBG model applies only to the first part of the sample is correct.

According to the results, presented in Table 8, there is little evidence that inflation and unemployment are cointegrated in the earlier portion of the sample period. This hypothesis is rejected, in favor of the null of no cointegration, in all but one instance. These results suggest that the empirical shortcomings of the model documented in the previous sections are not just due to problems fitting the data at the end of the sample, where one might expect issues related to time inconsistency to play a smaller role in monetary policy. In fact the model also fails to fit the data well even in the earlier period, where the existence of an

[11] This is just an extreme example of changing parameters discussed in the previous section, in which the inflationary bias vanishes because k becomes equal to 1. However, this hypothesis is not covered by the tests we reported in the previous section.

inflationary bias is more plausible.

3.5 Open Economy Spillovers

We have seen that while the time inconsistency model fits the U.S. data, it does not do a very good job at explaining inflation in other countries. In this section, we test the version of the model presented in Section 2.3, in which inflationary pressures generated by a rising U.S. NAIRU spill over into the other OECD economies as a result of monetary authorities' attempts to manage nominal exchange rate movements of their domestic currencies vis a vis the U.S. dollar.

The implication of this model is that domestic inflation, domestic unemployment, and U.S. unemployment should be cointegrated. According to the results presented in Table 9, these three variables do appear to be cointegrated in many countries. Column 1 presents the Johansen trace statistic for the null hypothesis that there are no cointegrating vectors for domestic inflation, domestic unemployment, and U.S. unemployment in the twelve non-U.S. countries in our sample. The null of no cointegrating vectors is rejected at the 10% level in 8 countries, and at the 5% level or greater in 6 of the 12 countries.[12]

One potential concern regarding these results is the possibility that the presence of cointegration is due to cointegration between domestic and U.S. unemployment rates, while the coefficient on domestic inflation in the cointegrating vector is zero. We check whether this is the case by applying the ADF residual based test for cointegration, for which the coefficient on domestic inflation is normalized to one. A rejection of the null hypothesis of no cointegration, using this test implies that the coefficient on domestic inflation in the cointegrating vector cannot be zero. Column 2 of Table 9 presents the results, which echo the results of the Johansen test in rejecting the null of no cointegration for most countries.

A secondary concern is whether all three variables are cointegrated, or whether the result of cointegration is just due to cointegration between domestic inflation and U.S. unemployment (i.e. is the coefficient on domestic unemployment in the cointegrating vector equal to zero). A finding of a zero coefficient on domestic inflation in a country does not invalidate the model, but implies that one of two special cases must hold: either i) domestic unemployment does not enter the central bank's loss function (i.e. $b = 0$) for that country, or ii) the central banker in that country does not suffer from inflationary bias in that country (i.e. $k = 1$).

We can test whether the coefficient on domestic unemployment is zero by testing to see whether or not domestic inflation and U.S. unemployment are cointegrated in countries for which there is evidence of cointegration in the three variable model: if there is cointegration between all three variables, but also cointegration between domestic inflation and U.S. unemployment, then the coefficient on domestic unemployment in the cointegrating

[12]Three of the countries for which there is no evidence of cointegration between these three variables are Germany, Japan, and the UK. It is perhaps not surprising that the model doesn't fit for these countries, given the stature of their currencies and the fact that the small open economy assumption on which the model is based is perhaps less applicable.

vector in the three variable case has to be zero. If there are two I(1) variables (π^d, and $u^{U.S.}$) for which a linear combination is stationary, adding a third I(1) variable (u^d) to this stationary combination, the resulting term will not be I(0) except in the special case where the coefficient on the third I(1) term is zero.

Conversely, if there is cointegration between all three variables, and no cointegration between domestic inflation and U.S. unemployment, then the coefficient on domestic unemployment in the cointegrating variable cannot be zero. In this case, a linear combination of three I(1) variables (π^d, u^d, and $u^{U.S.}$) is stationary. If no linear combination of π^d and $u^{U.S.}$ is stationary, then it cannot be the case that the coefficient on u^d in the three variable cointegrating vector is zero (because adding zero to a combination of variables that is non-stationary cannot produce a stationary variable).[13]

Columns 3 and 4 of table 9 present the results of Johansen and ADF tests of the null hypothesis that domestic inflation and U.S. unemployment are not cointegrated. The Johansen test rejects the null of no cointegration in 9 out of 12 cases, and in 8 of the 9 countries for which the Johansen test rejected the null of no cointegration in the tri-variate model. The results of the ADF test are somewhat less supportive of the notion that domestic inflation and U.S. unemployment are cointegrated, rejecting the null of no cointegration in 6 of 12 countries.[14] Overall, the results of columns 3 and 4 provide some evidence that the coefficient on domestic unemployment is zero.[15] [16]

The results presented in this section provide some support for the view that the KPBG model, extended to allow for international inflation spillovers, is consistent with OECD inflation trends. However, the evidence suggests that the coefficient on domestic unemployment may be equal to zero. In words, the results are consistent with the following version of the time inconsistency hypothesis: time inconsistency and inflationary bias were important components of monetary policy in the U.S., but not in other OECD countries. The common trend in OECD inflation rates was fundamentally driven by the trend in the NAIRU in the

[13]Note that this logic implies that the coefficient on U.S. inflation cannot be zero, as the results of previous sections established that domestic inflation and domestic unemployment are not cointegrated in the countries in our data set.

[14]The discrepancy between the two sets of results may be due to the Johansen test having more power than the residual based test, though power comparisons have yielded mixed results (See Boswijk & Frances (1992), Haug (1996), and Pesavanto (2004)).

[15]Our test of a zero coefficient on domestic unemployment assumes that there is a unique (up to a scalar multiple) cointegrating vector between domestic inflation, domestic unemployment, and foreign unemployment. If there are multiple cointegrating vectors, a finding of a zero coefficient on domestic unemployment would apply only to one of these cointegrating vectors. A Johansen test of null hypothesis of one or fewer cointegrating vectors rejects the null in favor of multiple cointegrating vectors at the 5% level in only two countries: Australia and Italy. Only one of these countries (Italy) is among the countries for which both a) domestic inflation, domestic unemployment, and foreign unemployment are cointegrated, and b) domestic inflation and foreign unemployment are cointegrated.

[16]Of note, we estimated the cointegrating vector using OLS and found that, while the coefficients on U.S. unemployment were uniformly negative across the sample, coefficients on domestic unemployment were uniformly positive. The open economy version of the KPBG model we presented implies that these coefficients must be non-positive, where the coefficient on domestic inflation equals zero only in the special cases described above.

U.S., which drove trend inflation in the U.S.. The trend in U.S. inflation in turn spilled over into other OECD countries via the exchange rate.

4 Concluding Remarks

Inflation outcomes in many OECD economies have followed a similar pattern over the past forty years. It is reasonable to look for a common explanation of this common trend. The KPBG model of inflationary bias and time inconsistency problems provides a natural starting point. The mechanisms at the heart of this model ought to apply to the conduct of monetary policy in most OECD countries, and in previous work the model has been shown to have had some success explaining the inflationary experience of the U.S. over this period. In this paper, we have shown that a simple time-consistency story does not provide an adequate explanation for the pattern of rising and then falling inflation rates observed in OECD economies over the past 4 decades.

We examined some plausible reasons why the simple model may be inadequate, focusing first on the possibility that unobserved parameters of the baseline model may have shifted over the sample period. Expanding our empirical work to allow for the possibility of regimes shifts in the cointegrating relationship did not appear to improve the ability of the model to explain long run inflation trends. The widely held hypothesis that time inconsistency was historically an important feature of monetary policy making that is no longer relevant does not seem to be a solution to the empirical shortcomings of the baseline model.

While there is little evidence that cointegration between the inflation rate and the unemployment rate is widespread across OECD countries, U.S. inflation and unemployment in the U.S. do appear to be cointegrated. There is some support for the view that time inconsistency problems in the U.S. drove U.S. inflation, which then spilled over into other OECD countries' inflation rates, even though time inconsistency and inflationary bias were not important drivers of monetary policy in the rest of the OECD. Whether refinements of this hypothesis can explain whether and why time inconsistency problems affected monetary policy in the U.S. but not in other OECD countries, or whether a complete explanation for the common trend in OECD inflation rates lies outside the KPBG time inconsistency framework remains a question for future research.

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Table 1. Augmented Dickey Fuller Unit Root Tests: CPI Inflation and Unemployment

Country	Sample	π	u
Australia	1966:3-2003:3	-1.56	-0.55
Austria	1964:1-2003:3	-1.11	0.28
Canada	1964:1-2003:3	-1.55	-0.75
Denmark	1970:1-2003:3	-0.79	-0.77
Finland	1964:1-2003:3	-1.01	-0.55
France	1967:4-2003:3	-1.10	-0.13
Germany	1964:1-2003:3	-1.34	-0.40
Italy	1964:1-2003:3	-1.39	-0.29
Japan	1964:1-2003:3	-0.94	0.69
Norway	1964:1-2002:2	-1.26	-0.94
Sweden	1970:1-2003:3	-1.18	-1.01
United Kingdom	1964:1-2003:3	-1.66 *	-1.29
United States	1964:1-2003:3	-0.93	-1.78 *

The test statistic is the test statistic in Ng and Perron (2001). Asymptotic critical values for the statistic are: -1.62 (10%), -1.98 (5%), -2.58 (1%).

H_0: The series possesses a unit root.

* = reject at the 10-percent level

Table 2. GDP Deflator Inflation and Unemployment (G-7)

Country	Sample	π	u
Canada	1964:1-2003:3	-1.59	-0.75
France	1970:2-1998:4	-0.86	-0.18
Germany	1964:1-2002:4	-1.08	-0.40
Italy	1964:1-2003:3	-1.67*	-0.29
Japan	1964:1-1999:4	-1.30	1.01
United Kingdom	1964:1-1998:4	-1.66*	-1.21
United States	1964:1-2003:3	-1.46	-1.78 *

The test statistic is the test statistic in Ng and Perron (2001). Asymptotic critical values for the statistic are: -1.62 (10%), -1.98 (5%), -2.58 (1%).

H_0: The series possesses a unit root.

* = reject at the 10-percent level

Table 3. Johansen Cointegration Tests: U.S. CPI Inflation Foreign CPI Inflation

Country	λ-Statistic
Australia	15.86**
Austria	8.85
Canada	25.09***
Denmark	20.92***
Finland	16.04**
France	19.69***
Germany	14.35*
Italy	19.99***
Japan	7.84
Norway	13.25*
Sweden	17.00**
United Kingdom	16.01**

The sample period is 1964:1-2003:3, except for Denmark, which is 1967:1-2003:3. The test statistic is the Johansen λ-max (= λ-trace in the present setting) test statistic for testing the null of no-cointegration. An 8-lag VECM was used to compute the statistic. Asymptotic critical values for the statistic are: 12.78 (10%), 14.60 (5%), 18.78 (1%).

* = reject at the 10-percent level
** = reject at the 5-percent level
*** = reject at the 1-percent level

Table 4. Johansen Cointegration Test: CPI Inflation and Unemployment

Country	Sample	λ-Statistic
Australia	1966:3-2003:3	8.89
Austria	1964:1-2003:3	11.07
Canada	1964:1-2003:3	14.03*
Denmark	1970:1-2003:3	9.29
Finland	1964:1-2003:3	7.66
France	1967:4-2003:3	6.99
Germany	1964:1-2003:3	11.59
Italy	1964:1-2003:3	8.77
Japan	1964:1-2003:3	6.73
Norway	1964:1-2002:2	8.07
Sweden	1970:1-2003:3	9.66
United Kingdom	1964:1-2003:3	5.15
United States	1964:1-2003:3	15.15**

The test statistic is the Johansen λ-max (= λ-trace in the present setting) test statistic for testing the null of no-cointegration. An 8-lag VECM was used to compute the statistic. Asymptotic critical values for the statistic are: 12.78 (10%), 14.60 (5%), 18.78 (1%).

* = reject at the 10-percent level
** = reject at the 5-percent level

Table 5. GDP Deflator Inflation and Unemployment (G-7)

Country	Sample	λ-Statistic
Canada	1964:1-2003:3	9.25
France	1970:2-1998:4	14.04*
Germany	1964:1-2002:4	8.46
Italy	1964:1-2003:3	27.25***
Japan	1964:1-1999:4	6.26
United Kingdom	1964:1-1998:4	5.92
United States	1964:1-2003:3	16.31**

The test statistic is the Johansen λ-max (= λ-trace in the present setting) test statistic for testing the null of no-cointegration. An 8-lag VECM was used to compute the statistic. Asymptotic critical values for the statistic are: 12.78 (10%), 14.60 (5%), 18.78 (1%).

* = reject at the 10-percent level
** = reject at the 5-percent level

Table 6. Gregory-Hansen Cointegration Test: CPI Inflation Rate and Unemployment Rate

Country	Sample	Unemployment Rate ADF*-Statistic	Inflation Rate ADF*-Statistic
Australia	1966:3-2003:3	-2.69	-3.39
Austria	1964:1-2003:3	-2.77	-4.62
Canada	1964:1-2003:3	-4.29	-3.66
Denmark	1970:1-2003:3	-3.18	-4.81*
Finland	1964:1-2003:3	-3.00	-2.76
France	1967:4-2003:3	-3.08	-3.26
Germany	1964:1-2003:3	-4.04	-2.96
Italy	1964:1-2003:3	-2.30	-2.67
Japan	1964:1-2003:3	-2.61	-4.54
Norway	1964:1-2002:2	-3.15	-4.79*
Sweden	1970:1-2003:3	-2.54	-4.10
United Kingdom	1964:1-2003:3	-2.88*	-3.73
United States	1964:1-2003:3	-3.43	-4.21*

The test statistic is the ADF* statistic in Gregory-Hansen (1996). The null hypothesis is that the unemployment and inflation rates are not cointegrated. The alternative hypothesis is that they are cointegrated with a possible break in the intercept and slope of the cointegrating regression. The asymptotic critical values (from Gregory-Hansen, Table 1, m = 1, C/S) are: -4.68 (10%), -4.95 (5%), -5.47 (1%).

* = reject at the 10-percent level
** = reject at the 5-percent level
*** = reject at the 1-percent level

Table 7. GDP Deflator Inflation and Unemployment (G-7)

Country	Sample	Unemployment Rate ADF*-Statistic	Inflation Rate ADF*-Statistic
Canada	1964:1-2003:3	-4.43	-3.89
France	1970:2-1998:4	-3.99	-2.63
Germany	1964:1-2002:4	-3.93	-4.25
Italy	1964:1-2003:3	-3.85	-5.60***
Japan	1964:1-1999:4	-4.52	-3.88
United Kingdom	1964:1-1998:4	-1.68	-3.51
United States	1964:1-2003:3	-4.26	-4.91*

The test statistic is the ADF* statistic in Gregory-Hansen (1996). The null hypothesis is that the unemployment and inflation rates are not cointegrated. The alternative hypothesis is that they are cointegrated with a possible break in the intercept and slope of the cointegrating regression. The asymptotic critical values (from Gregory-Hansen, Table 1, m = 1, C/S) are: -4.68 (10%), -4.95 (5%), -5.47 (1%).

* = reject at the 10-percent level
** = reject at the 5-percent level
*** = reject at the 1-percent level

Table 8. Johansen Cointegration Test
CPI Inflation Rate and Unemployment Rate For First 1/2 and 2/3 of Sample

Country	Full Sample	λ-Statistic 1st 1/2 of Sample	λ-Statistic 1st 2/3 of Sample
Australia	1966:3-2003:3	6.92	5.46
Austria	1964:1-2003:3	4.12	7.70
Canada	1964:1-2003:3	9.35	11.96
Denmark	1970:1-2003:3	8.37	9.90
Finland	1964:1-2003:3	7.92	12.54
France	1967:4-2003:3	12.83*	12.24
Germany	1964:1-2003:3	5.59	9.91
Italy	1964:1-2003:3	6.39	5.97
Japan	1964:1-2003:3	8.96	8.85
Norway	1964:1-2002:2	11.32	10.82
Sweden	1970:1-2003:3	12.38	11.54
United Kingdom	1964:1-2003:3	5.33	3.71
United States	1964:1-2003:3	10.34	12.61

The test statistic is the Johansen λ-max (= λ-trace in the present setting) test statistic for testing the null of no-cointegration. An 8-lag VECM was used to compute the statistic. Asymptotic critical values for the statistic are: 12.78 (10%), 14.60 (5%), 18.78 (1%).

* = reject at the 10-percent level

Table 9. Johansen Cointegration Test
CPI Inflation, Unemployment, and U.S. Unemployment

	Tri-variate Model		Bi-variate Model	
	Johansen	ADF	Johansen	ADF
Australia	28.88*	-3.43**	11.71	-2.66*
Austria	37.18***	-4.01**	19.55**	-2.98**
Canada	33.27**	-3.89**	14.67*	-2.47
Denmark	27.72*	-3.89**	13.91*	-2.56*
Finland	19.56	-2.98	12.66	-2.01
France	35.30**	-4.16***	20.41***	-2.04
Germany	24.82	-3.24*	17.65**	-2.25
Italy	37.17***	-3.80**	17.53**	-2.48
Japan	18.14	-3.57**	10.69	-2.95**
Norway	31.07**	-3.46**	13.62*	-2.03
Sweden	39.04***	-4.32***	26.74***	-2.77*
U.K.	24.84	-3.33*	14.82*	-2.84**
1%	35.46	-4.04	19.94	-3.40
5%	29.80	-3.39	15.50	-2.82
10%	27.07	-3.06	13.43	-2.49

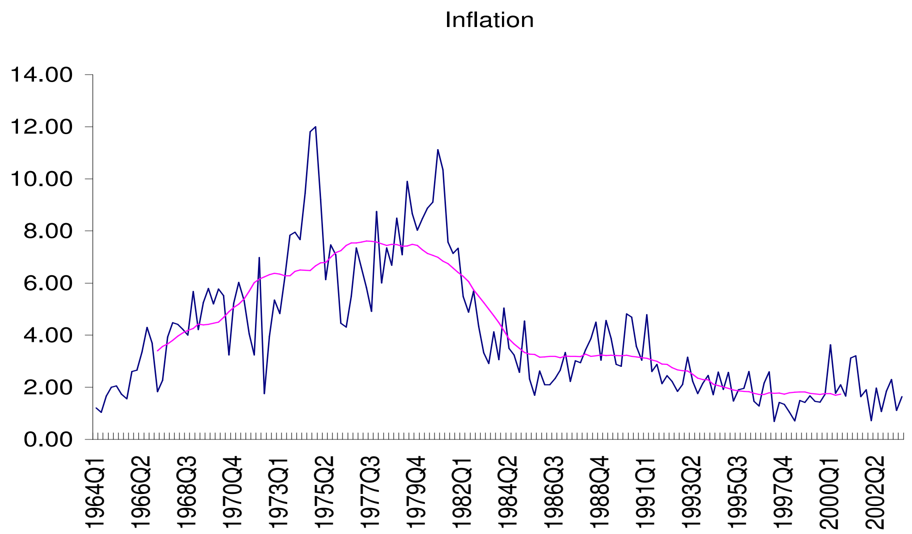
The test statistic reported in columns 1 and 3 is the Johansen trace statistic. An 8-lag VECM was used to compute the statistic. The null hypothesis is that there is no cointegrating vector ($r = 0$).

The test statistic reported in columns 2 and 4 is the ADF test on the residuals of an OLS estimation of the cointegrating vector. 4 lags of the residual were included in the ADF regression. The null hypothesis is that there is no cointegrating vector.

The last 3 rows of the table report the critical values of the relevant test statistics at the 1-, 5-, and 10- percent levels.

* = reject at the 10-percent level, ** = reject at the 5-percent level, *** = reject at the 1-percent level

Figure 1. U.S. Inflation and Unemployment rates, and 7-year centered Moving Average



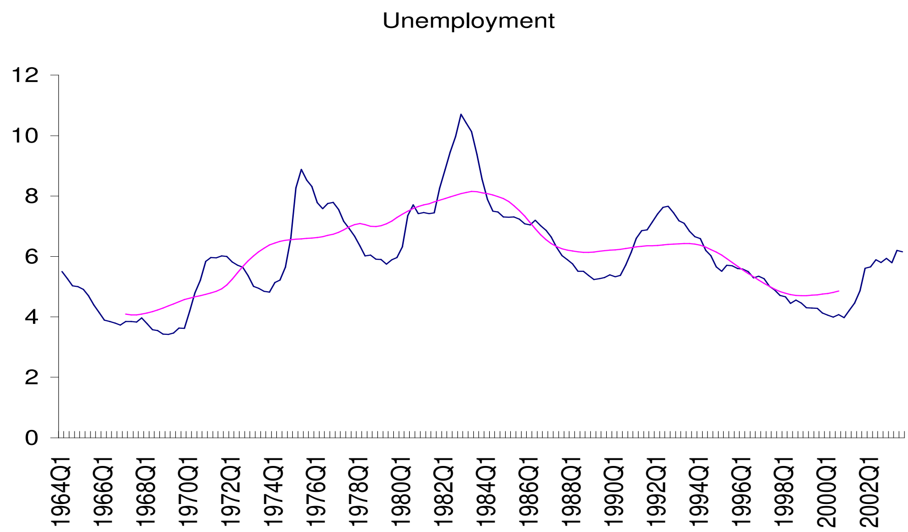
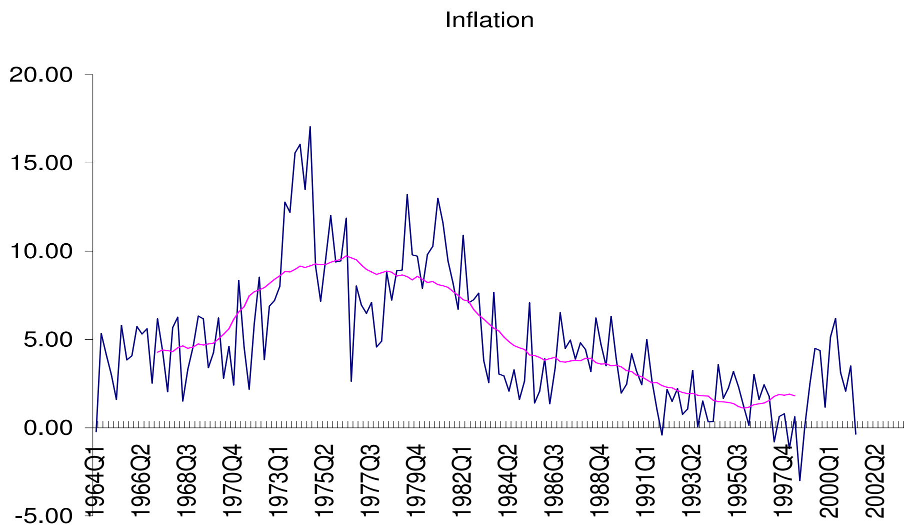


Figure 2. Canadian Inflation and Unemployment rates, and 7-year centered Moving Average



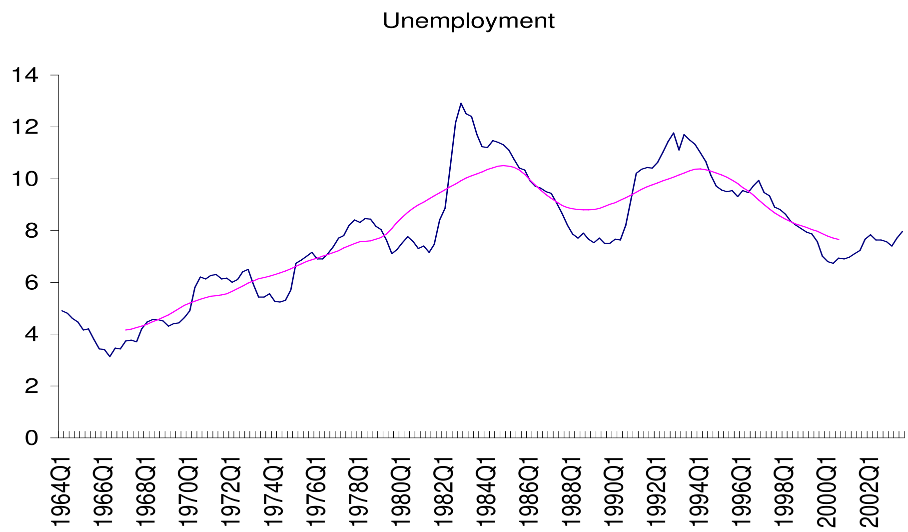
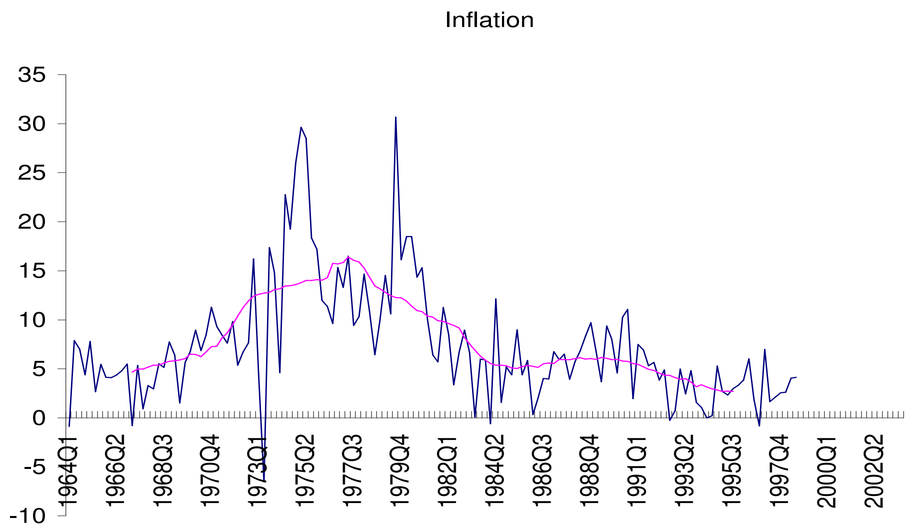


Figure 3. U.K. Inflation and Unemployment rates, and 7-year centered Moving Average



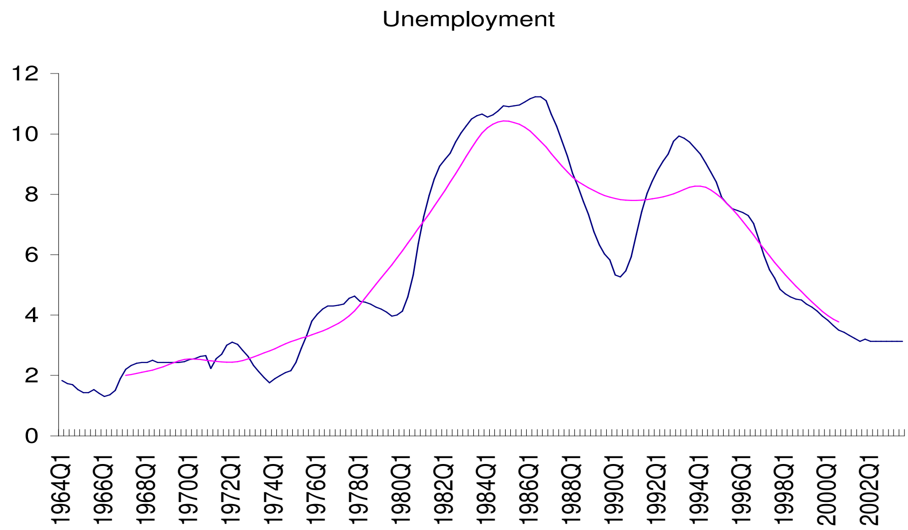
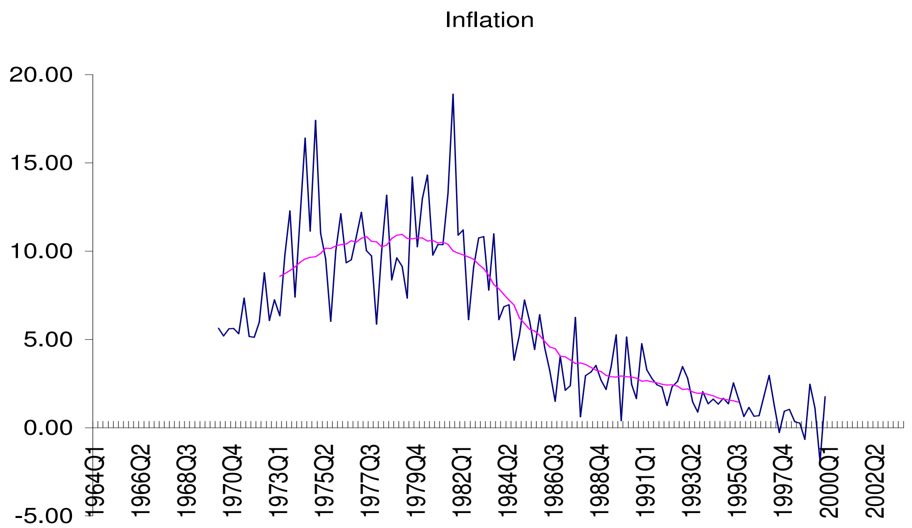


Figure 4. French Inflation and Unemployment rates, and 7-year centered Moving Average



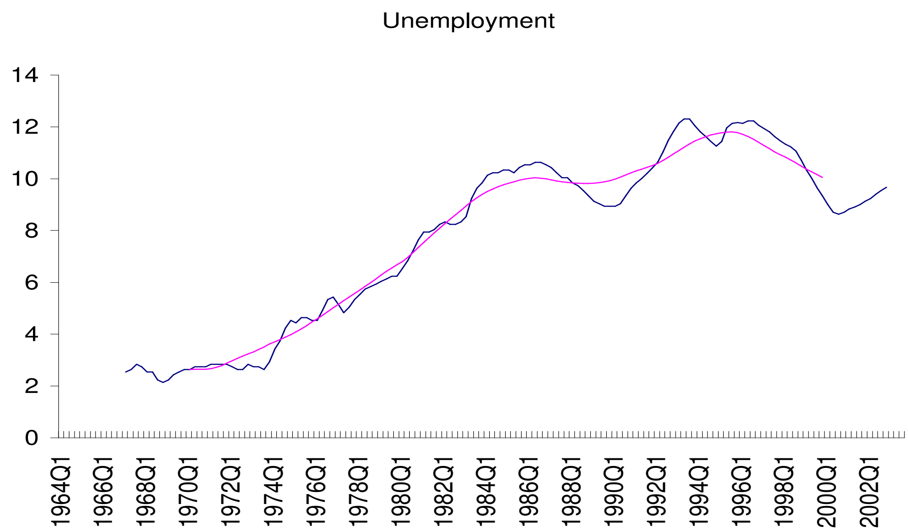
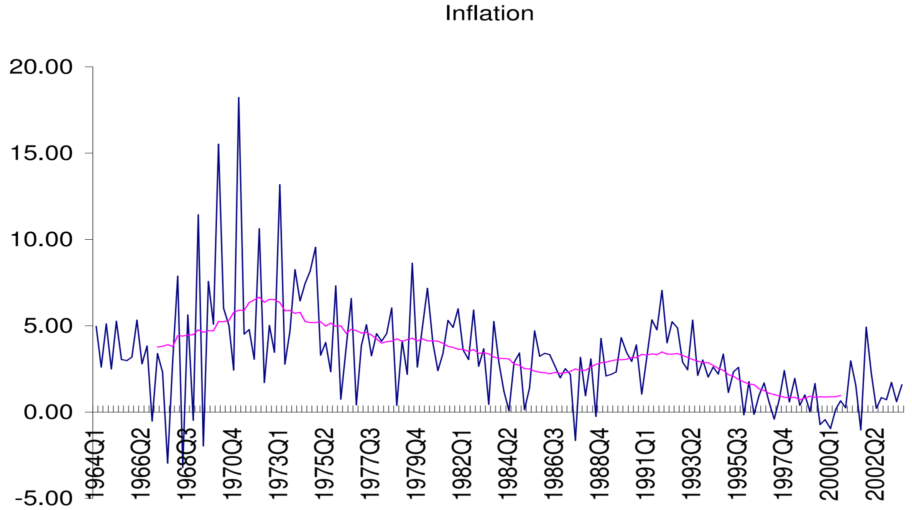


Figure 5. German Inflation (NSA) and Unemployment rates, and 7-year centered Moving Average



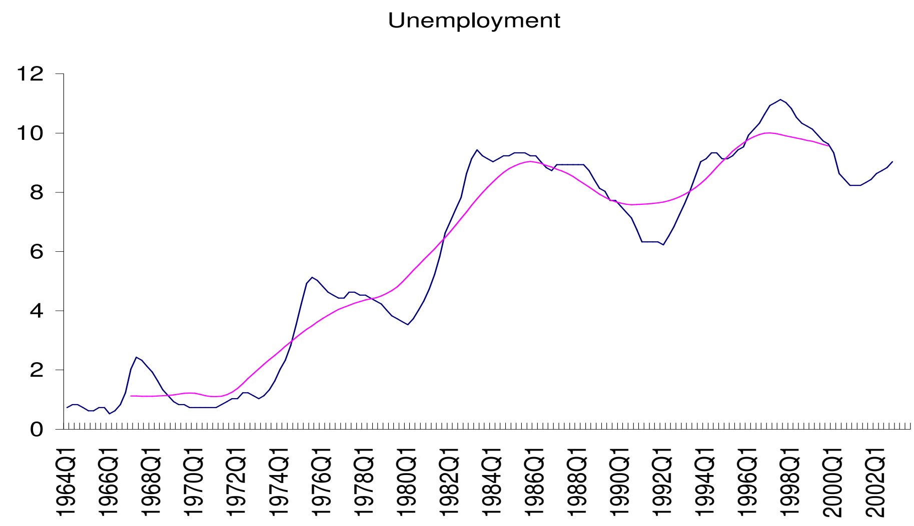
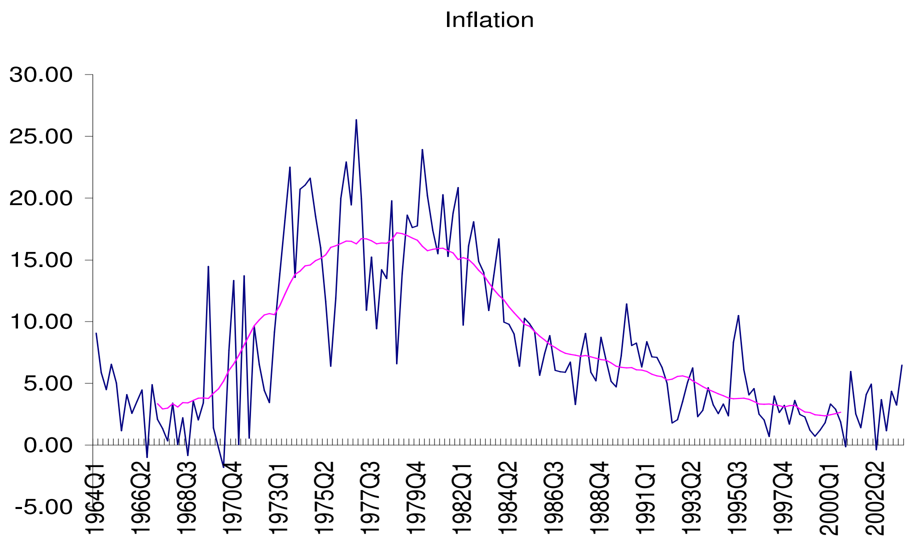


Figure 6. Italian Inflation and Unemployment rates, and 7-year centered Moving Average



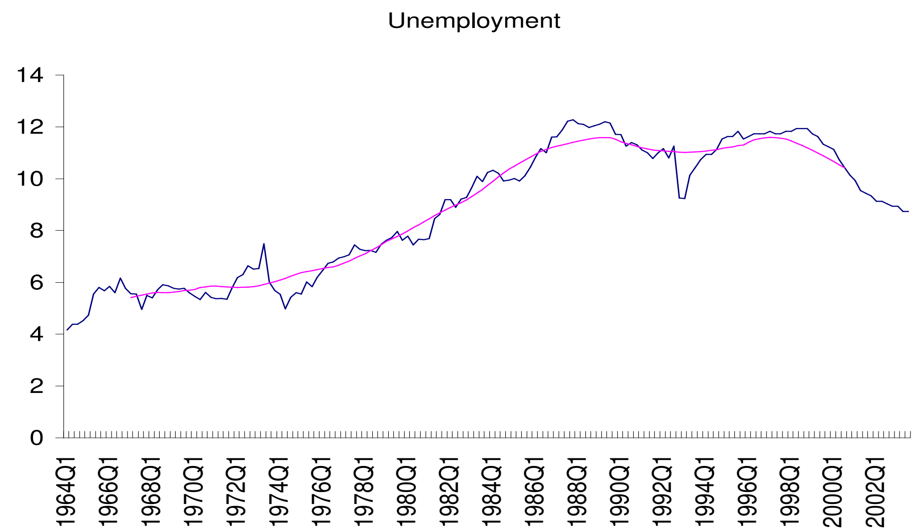


Figure 7. Japanese Inflation and Unemployment rates, and 7-year centered Moving Average