Why Does the NAIRU Change over Time?

—— Identifying Histeresis in Unemployment and Inflation's Grease Effects on the NAIRU ——

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Abstract

This paper investigates the main cause of the change in the NAIRU and tests hysteresis and inflation-as-grease theories empirically. I analyze annual and quarterly data for six low-inflation OECD countries. This study finds that hysteresis theories provide a convincing explanation for the rise in the NAIRU, and that inflation's grease effects can be identified in half of the sample of countries. Results of this paper indicate that countries with long-lived unemployment benefits suffered from a relatively large increase in the NAIRU.

1 Introduction

Over the past decade, a considerable number of studies have been conducted on the increase in unemployment in OECD (Organization for Economic Cooperation and Development) countries. In fact, the average unemployment rate in OECD countries rose from 5.8 % in 1980 to 7.6 % in 1996. The increase in unemployment is particularly severe in European countries, where unemployment rose from 6.4 % in 1980 to 11.1 % in 1996 (Figure 1). Since inflation in the last few years has been roughly constant, there is fairly general agreement that most of the rise in actual unemployment is due to a large increase in the NAIRU—the *N*on-

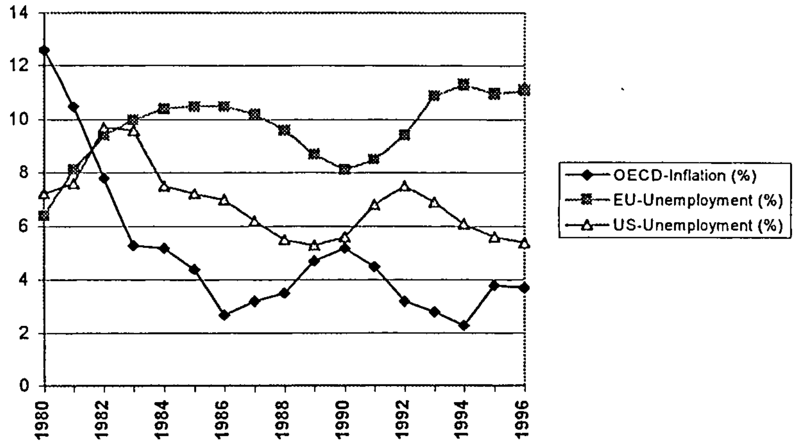

Figure 1 Inflation and Unemployment

*A*ccelerating *I*nflation *R*ate of *U*nemployment.[1] At the same time, as shown in Figure 1, OECD countries succeeded in reducing inflation during the 1980s. Average OECD inflation fell from 12.6 % in 1980 to 3.7 % in 1996.

Why does the NAIRU change over time? The NAIRU has been believed to be determined by a set of microeconomic relationships in the economy, such as labor market imperfections and skill-based technical changes. Labor unions and government interventions are blamed for the cause of the imperfections in the labor market. The degree of imperfections in the labor market can be measured by various labor market variables: the replacement rate, benefit duration, active labor policy, and union coverage. Recent econometric studies that emphasize labor market rigidities seem to succeed in explaining cross-country differences in current unemployment rates, in particular, the difference between the United States and Europe.

Although there is some evidence to support the idea that labor market

1) Many scholars now believe that the NAIRU is not constant but "time-varying." For example, Staiger, Stock, and Watson (1997) attempt to provide a precise estimation of the NAIRU by assuming that the NAIRU has changed over time.

rigidities can account for the cross-country variation in unemployment *levels*, it is not yet clear whether these rigidities can explain the increase in the natural rate over time. To put it more precisely, in order to see whether labor market rigidities can explain the recent increase in the NAIRU, one has to compare the *change* in labor market variables with the *change* in the NAIRU instead of comparing the level of the labor market variables with the level of the NAIRU. Ball (1997) examines whether labor market variables can explain the increase in the NAIRU during the 1980s. His results are negative. He compares the change in the NAIRU from 1980 to 1990 with the change in the labor market variables, and finds that the degree of labor market imperfections was unchanged or lower during the 1980s even though the NAIRU rose in most OECD countries during the same period.[2] Since labor market imperfections cannot account for the rise in the NAIRU, we need to look for other explanations.

This study concerns two theories that focus on the empirical relationship between a rise in the NAIRU and disinflation; those theories are (a) hysteresis theories and (b) inflation-as-grease theories. Both theories imply that disinflation is the main cause of the increase in the NAIRU.

In hysteresis theories, disinflation causes high actual unemployment, and this high actual unemployment leads to an increase in the NAIRU. Hence, one way of testing hysteresis theories is to investigate whether a reduction in the rate of inflation raises the NAIRU.

In inflation-as-grease theories, the NAIRU begins to increase as the

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2) This point is expressed best when he writes (p. 174): "Layard, Nickell, and Jackman (1991) show that measures of labor market distortions explain much of the cross-country variation in unemployment levels in the mid-1980s. It is harder, however, to explain *changes* in unemployment during the 1980s. Most labor market distortions remained constant during the decade or decreased, as some countries weakened firing restrictions and reduced unemployment benefits. These changes go in the wrong direction for explaining why unemployment rose."

inflation rate approaches to zero. The intuition is that, when inflation is zero, one cannot reduce real wages if nominal wages are downward rigid. There are always some obsolescent industries where equilibrium real wages are falling and new industries where wages are increasing. Under price stability, however, real wages in those obsolescent industries cannot be reduced effectively, and are likely to be set higher than the equilibrium level. Zero inflation worsens the allocative efficiency of the labor market, and hence brings about a higher steady-state unemployment rate. By contrast, when inflation is positive, one can reduce real wages without cutting nominal wages: by freezing nominal wages, real wages actually decline by the rate of inflation.

The purpose of this paper is to identify the effects of each theory from aggregate data. The reason why I use aggregate data here is that the importance of these theories becomes doubtful if hysteresis and grease effects are not statistically significant at the aggregate level, even though these effects can be identified from micro data.

My method of identification is straightforward. Although both hysteresis and inflation's grease effects indicate that a disinflation causes a rise in the NAIRU, the predicted relationship between inflation and the NAIRU differs between the two theories. I exploit this difference to identify hysteresis and inflation's grease effects. Hysteresis theories predict that a disinflation will raise the natural rate, and this prediction is independent of the initial level of inflation (Figure 2a). In contrast, in grease theories, the effect of disinflation on the NAIRU depends on initial inflation. For instance, a disinflation will not change the NAIRU when initial inflation is sufficiently high, because high inflation creates substantial room for firms that are doing poorly to reduce real wages without cutting nominal wages. High inflation is, so to speak, a great amount of grease for the wheels in the labor market. Hence, a few percent of disinflation does not make any

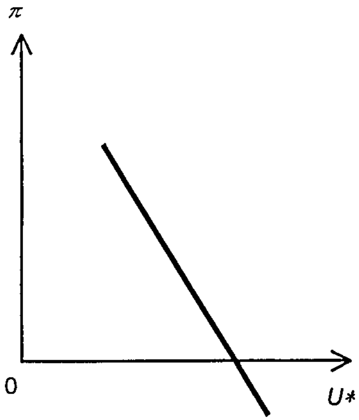

Figure 2a Hysteresis in Unemployment

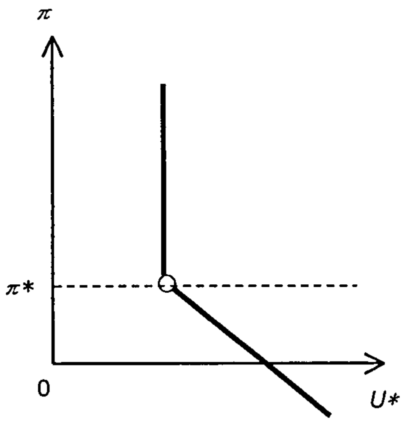

Figure 2b Grease Effects on the NAIRU

difference and does not have any effect on the NAIRU, because there is more than enough grease in the labor market. When initial inflation is close to zero, however, a disinflation will cause an increase in the NAIRU. Low inflation limits the extent to which firms can reduce real wages without nominal wage cuts. A disinflation from low inflation makes real wage cuts even more difficult, and thus the disinflation will push up the NAIRU (Figure 2b). By using the difference in these predictions, I attempt to estimate the changes in the NAIRU caused by hysteresis in unemployment and the changes caused by inflation's grease effects.

I analyze annual and quarterly data for six low-inflation OECD countries (Canada, France, Germany, Japan, Switzerland, and the United States). I find that hysteresis theories provide a convincing explanation for the rise in the NAIRU, and that inflation's grease effects can be found in half of the sample countries. The results of this chapter are consistent with Ball's (1997) findings that countries with long-lived unemployment benefits suffered from a relatively large increase in the NAIRU.

The remainder of this paper contains eight sections. Section 2 reviews hysteresis and inflation-as-grease theories. Section 3 discusses the sample of countries and the sample period, and explains how I measure the NAIRU. Section 4 describes how I identify hysteresis in unemployment and inflation's grease effects from the data, and section 5 reports the baseline results. Sections 6-7 attempt to answer a question about why the effects of disinflation on the NAIRU differ across countries. Section 8 considers robustness, and section 9 offers concluding remarks.

2 Hysteresis in Unemployment and Inflation's Grease Effects

2.1 Hysteresis in Unemployment

If unemployment is high, then there will be excess supply in the labor market. This excess labor supply puts downward pressure on wages, and hence inflation starts to decline. Contrarily, low unemployment indicates excess demand in the labor market, and this excess labor demand puts upward pressure on wages and inflation. If a rate of unemployment induces neither a fall nor a rise in inflation, the rate is called the natural rate of unemployment, or the NAIRU. In this case, actual unemployment is regarded as a precise index of the labor market conditions.

Contrary to this standard approach, hysteresis theories such as in Blanchard (1991) argue that actual unemployment is a poor proxy for labor market conditions.[3] Dividing actual unemployment into long-term and short-term unemployment, hysteresis theories point out that it is the rate of short-term unemployment that reflects labor market conditions, and that the long-term unemployed are irrelevant to the process of wage determination.

Why are the long-term unemployed irrelevant to the process of wage

3) The hysteresis theories were originally propounded by Blanchard and Summers (1986, 1987).

bargaining? There are at least two reasons for believing that the long-term unemployed have little influence on wage bargaining: One is that, because they have been out of work for a long time, the long-term unemployed lose work habits and skills. Since the long-term unemployed lose skills and become unemployable, they are virtually excluded from the labor market. The other reason is that, when firms try to fill up vacancies, they tend to prefer the short-term unemployed over the long-term unemployed. The long-term unemployed become less effective in their job search, and eventually they give up looking for work. They might not formally stop looking for work, and thus be recorded in the unemployment statistics, but in reality, they have dropped out of the workforce. For these reasons, the increase in long-term unemployment hardly means excess supply in the labor market, and thus the long-term unemployed put little pressure on wages. Therefore, the increase in long-term unemployment will lead to a higher natural rate of unemployment.

As Lindbeck (1995) points out, sociological factors may also cause hysteresis in unemployment. When unemployment becomes high, because there are so many unemployed in the society, the unemployed are not ashamed of themselves for being out of work and feel no urgent need to find a job. In this way, since high unemployment makes the life of the unemployed less miserable, the pressure of unemployment on wages becomes low.

For empirical studies, Ball (1997) presents evidence that those OECD countries that experienced larger and longer disinflations have also experienced larger increases in the NAIRU. The most natural explanation is hysteresis in unemployment, because hysteresis theories give a central role to prolonged recessions and long-term unemployment. Larger or longer disinflations induce output to fall and unemployment to rise substantially. This large increase in unemployment leads to a high proportion of long-term unemployed, and this in turn raises the NAIRU. Nickell (1997) divides total unemployment into short-term and long-term unemployment in OECD countries and finds that short-term unemployment is more stable than long-term unemployment.[4)]

2.2 Inflation's Grease Effects

Tobin (1972) introduces a model of *stochastic macro-equilibrium*, which is based on a heterogeneous agent model instead of a representative agent model. The model is "stochastic" because each industrial sector faces perpetual sectoral shocks, and "macro-equilibrium" because macro variables (e.g., employment, wages, and prices) are stable in the aggregate level. Based on the stochastic macro-equilibrium model, he argues that, under downward rigidity in nominal wages, a *positive* rate of inflation is helpful in keeping unemployment low.

To understand his argument, let us start with the case where there is no downward rigidity in nominal wages. Imagine an economy that receives positive and negative sectoral shocks all the time. In sectors that receive positive shocks, firms may want to expand their business and be willing to pay higher wages to attract new workers. By contrast, in sectors that receive negative shocks, firms may want to contract their business and need to lay off some of their workers or cut wages to preserve employment. Because the economy is struck by perpetual sectoral shocks, and wages do not adjust rapidly enough to clear all labor markets, unfilled vacancies and unemployment coexist at any given time. I use the term "full

4) Another line of empirical studies is the one that put emphasis on the technical term "hysteresis" (i.e., the history of actual unemployment has long-lasting or permanent effects on the NAIRU). Song and Wu (1997) and others examine whether the time series process for the unemployment rate contains a unit root. Koustas and Veloce (1996) apply univariate long-memory models in order to measure the degree of persistence of shocks in the unemployment rate.

employment" to refer to the level of employment at which unfilled vacancies are equal to unemployment.

Now, let us introduce downward rigidity in nominal wages and consider the Tobin's claim: If inflation is zero, firms that receive negative shocks cannot reduce real wages because of downward rigidity in nominal wages, and thus they dismiss their employees more than they do when nominal wages are not downward rigid. This leads to unemployment in excess of vacancies and, therefore, the economy cannot achieve full employment. By contrast, if inflation is positive, firms that need to reduce wages can do so by allowing their wages to grow at a slower rate than inflation. Inflation greases the wheels of the labor market, and makes it possible to attain full employment. Akerlof, Dickens, and Perry (1996) constructed a formal model based on this argument and show that the NAIRU starts to increase as the inflation rate approaches to zero.

As is clear from the discussion above, a crucial assumption of this theory is "downward rigidity in nominal wages."[5] In the last few years, several articles have been devoted to the empirical study of the rigidity of nominal wages. A notable example of this is a study done by Akerlof, Dickens, and Perry (1996). Other recent panel studies are Card and Hyslop (1997), Kahn (1996), McLaughlin (1994), Lebow, Stockton, and Wascher (1995), Shea (1997), and Groshen and Schweitzer (1996, 1997).

3 The Long-Run Phillips Relationship

3.1 The Sample

I begin by analyzing data for all OECD countries. In order to test the inflation-as-grease theory, one has to choose a sample of countries with

5) Ball and Mankiw (1994) provide a microeconomic rationale for the downward rigidity in nominal wages when trend inflation is positive. In their model, however, this downward rigidity disappears under price stability.

sufficiently low inflation rates. To this end, I select countries where inflation has fallen below 2.5 percent for several years. I set the threshold of inflation to 2.5 percent, because a recent study by Groshen and Schweitzer (1997) suggests that inflation's grease effects taper off after inflation rises to about 2.5 percent. Low-inflation countries chosen by this criterion are Canada, France, Germany, Japan, the Netherlands, and Switzerland. However, I exclude the Netherlands from the sample; because the Netherlands have made very effective reforms in the labor market and have succeeded in reducing unemployment by half, their experience is not suitable for my test.[6] For comparison, I include the United States in the sample. Thus, those countries whose data I analyze in this chapter are Canada, France, Germany, Japan, Switzerland, and the United States.

The data I examine are annual and quarterly. My main concern is to explain the change in the NAIRU during the post-supply-shocks period. I define the supply-shocks period as a period when one observes a simultaneous rise in inflation and unemployment. I exclude the supply-shocks period from the sample period because supply shocks during the 1970s had substantial effects on the rise in the NAIRU. A more complicated model is needed if one wants to account for the movements of the NAIRU during the 1970s. For this reason, the analysis starts from the early 1980s.

There are a few exceptions, however. First, the sample period for Germany ends 1990 because the data have a huge break between 1990 and 1991. Second, the sample period for Switzerland starts in 1991 since disinflation did not start until 1991. This makes the number of observations for Switzerland small, and thus I use only quarterly data for regressions. Third, to provide historical evidence, I apply the same analysis to the pre-supply-shocks (1893-1972) and pre-Depression (1893-1929) periods for the United States.

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6) On this point, see *OECD Economic Surveys: Netherlands 1998.*

3.2 Measuring the NAIRU

The data on inflation are from the International Monetary Fund's *International Financial Statistics*, and the data on unemployment are from the OECD's *Quarterly Labour Force Statistics*. I measure inflation with the year-over-year change in consumer prices.[7)]

My baseline NAIRU series are the ones constructed by Elmeskov and described in Elmeskov and MacFarlan (1993). Elmeskov's procedure is more desirable than an alternative method—simply smoothing the univariate unemployment series—which will be used in section 8, because Elmeskov's NAIRU series are calculated from data on inflation as well as unemployment.

Elmeskov assumes that the NAIRU is constant between two consecutive periods, and he considers a short-run Phillips curve of the form

(1) $\pi_t - \pi_{t-1} = -a\,(U_t - U_t^+),\ a > 0,$

where U is unemployment, π is inflation, and U^+ is the NAIRU. Furthermore, equation (1) implies that a similar equation

(2) $\pi_{t-1} - \pi_{t-2} = -a\,(U_{t-1} - U_t^+)$

holds in the previous period. Hence, from equations (1) and (2), the NAIRU can be written as

$$U_t^+ = U_t - \left(\frac{U_t - U_{t-1}}{(\pi_t - \pi_{t-1}) - (\pi_{t-1} - \pi_{t-2})}\right) \cdot (\pi_t - \pi_{t-1}).$$

After eliminating outliers from the derived NAIRU series, I apply the Hodric-Prescott (HP) filter to smooth the series so that the NAIRU shifts

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7) The data for the pre-supply-shocks period are from *Historical Statistics of the United States: Colonial Times to 1970*. Because I compute the inflation rate (1893-1972) from the GNP deflator instead of the CPI, inflation becomes highly volatile, particularly in the prewar period. I thereby smooth the inflation series and use the smoothed series for explanatory variables. The smoothed inflation rate is defined as a centered, three-year moving average of the changes in the GNP deflator.

slowly.[8] I set the HP parameter to 25 for annual unemployment data and 400 for quarterly data.

4 Identifying Hysteresis in Unemployment and Inflation's Grease Effects

This section explains a statistical method that attempts to identify hysteresis in unemployment and inflation's grease effects from aggregate data. Because both theories imply that disinflation is the main cause of the increase in the NAIRU, I am careful in explaining the difference between the two. In particular, I wish to stress their distinctive features: hysteresis theories concern the effects of *changes* in inflation on the NAIRU, whereas grease effects focus on the relationship between the *level* of inflation and the NAIRU. For this purpose, it will be instructive to represent in a simple graph the predicted relationship between inflation and the NAIRU for each theory.

In a standard textbook, the NAIRU is assumed to be constant with respect to inflation, and is often drawn as a vertical line. The NAIRU is "ground out" by the microeconomic structure and behavior of the economy, and it does not depend on inflation.

Hysteresis theories argue that, when negative aggregate demand shocks reduce inflation, actual unemployment will increase, and the increase in actual unemployment will in turn cause a rise in the NAIRU. Conversely,

8) Let $\{U_t^+\}$ be the short-run NAIRU series before it is adjusted, and $\{U_t^{++}\}$ be the short-run NAIRU series after it is adjusted. Then, the adjusted short-run NAIRU series (in percentage) is given by

$$U_t^{++} = \begin{cases} 30 & if \;\; U_t^+ \geq 30, \\ U_t^+ & if \;\; 0 < U_t^+ < 30, \\ 0 & if \;\; U_t^+ \leq 0. \end{cases}$$

Elmeskov's NAIRU series $\{U_t^*\}$ can be obtained by applying the HP filter to the adjusted NAIRU series $\{U_t^{++}\}$.

when positive aggregate shocks raise inflation, actual unemployment falls, and that fall in turn reduces the NAIRU. Thus, there exists a negative relationship between inflation and the NAIRU, and such a relationship is represented in Figure 2a.

While hysteresis theories focus on aggregate shocks, inflation-as-grease theories stress sectoral shocks. Sectoral shocks will increase the NAIRU if inflation is near zero and nominal wages are downward rigid. In inflation-as-grease theories, aggregate demand shocks themselves do not cause any change in the NAIRU, and thus the long-run Phillips curve is drawn as a vertical line where inflation is high (Figure 2b). Yet the NAIRU starts to increase when inflation falls below a threshold value. Thus, inflation-as-grease theories predict that the Phillips curve is convex, as shown in Figure 2b.

A more reasonable assumption is that both hysteresis and grease effects exist in the labor market (Figure 2c). Figure 2c can be obtained by summing up the curves in Figures 2a and 2b horizontally. The important points to note in Figure 2c are that the curve has a negative slope at any level of inflation, and that the curve is kinked at a low level of inflation. The slope of the curve becomes flatter when inflation is below a threshold value, so that the overall curve is convex.

To clarify what the convex curve in Figure 2c means, consider two cases of disinflation that reduce inflation by the same percentage points but start form different levels of inflation.[9] Suppose inflation falls from π_A to π_B. Then, the NAIRU increases from U^*_A to U^*_B, and this increase is brought about solely by hysteresis in unemployment. In contrast, a fall in inflation from π_C to π_D raises the NAIRU from U^*_C to U^*_D. This increase in the NAIRU is caused by grease effects as well as hysteresis, and the increase (U^*_D – U^*_C) is larger than (U^*_B – U^*_A).

9) This means that $\pi_A - \pi_B = \pi_C - \pi_D$ and $\pi_A > \pi_C$.

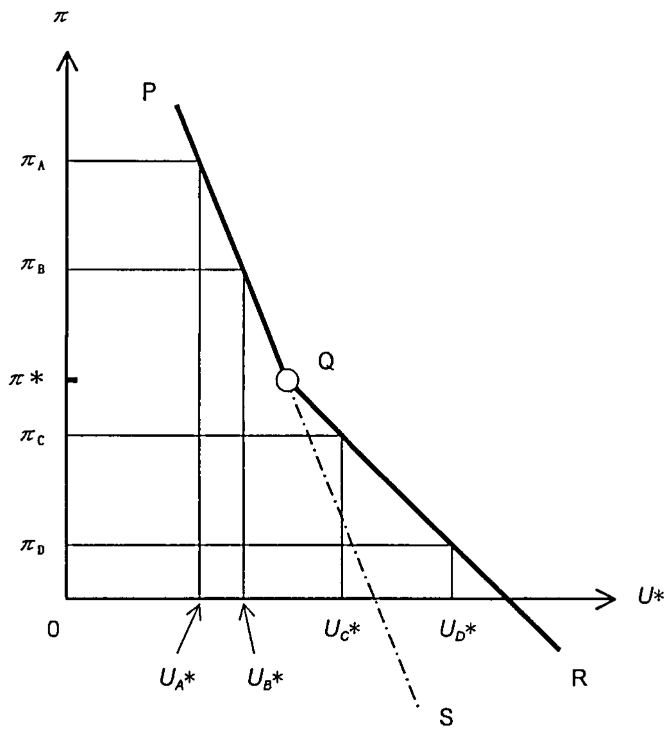

Figure 2c Hysteresis and Grease Effects

From the discussion above, one can identify hysteresis and grease effects in the following way: Consider the curve in Figure 2c as an estimated long-run Phillips curve. Then, if Line PQ (or Line PS) has a negative slope, one can say that hysteresis exists. If an estimated curve is convex (Curve PQR), then grease effects exist. If the slope of Line PQ is negative and Curve PQR is convex, then both hysteresis and grease effects exist in the labor market.

5 Nested Models of Hysteresis in Unemployment and Inflation's Grease Effects

5.1 Statistical Models of the NAIRU

The three statistical models that I estimate in this paper are linear, linear spline, and local regression models. Linear and linear spline models correspond to Figures 2a and 2c, respectively. I also employ a robust method. That is, I estimate the long-run Phillips curve with local regression (or, *loess*).

(1) A linear model

Let U^* be the NAIRU and π be inflation. Then, a linear model is

$$U_t^* = \alpha + \sum_{i=0}^{k} \beta_i \pi_{t-i}.$$

For a given variable x_t, I will denote $\bar{x}$ as the permanent value of x_t. Then, the above equation implies

$$\bar{U}^* = \alpha + \bar{\pi} \sum_{i=0}^{k} \beta_i.$$

Since hysteresis theories predict a negative relationship between inflation (π) and the NAIRU (U^*), the sum of the β's has to be negative if hysteresis exists.

(2) A linear spline model

In order to identify inflation's grease effects, I estimate the long-run Phillips curve with a regression model that allows its slope to change at a threshold value. To make the model more appealing, I also assume that the regression model is piecewise continuous. I employ a linear spline model so that the function is continuous at a threshold value. Let π^* denote a threshold value (or a knot). Then, a linear spline model can be written as

$$U_t^* = \alpha + \sum_{i=0}^{k} \beta_i \pi_{t-i} + \sum_{i=0}^{k} \delta_i d_{it} (\pi_{t-i} - \pi^*),$$

where

$$d_{it} = \begin{cases} 1 & if \quad \pi_{t-i} < \pi^*, \\ 0 & if \quad \pi_{t-i} \geq \pi^*. \end{cases}$$

This equation can be understood in the following way. As before, let $\bar{U}^*$ and $\bar{\pi}$ be the permanent value of U_t^* and π_t, respectively. Then,

$$\bar{U}^* = \alpha + \sum_{i=0}^{k} \beta_i \bar{\pi}$$

$$= \alpha + \bar{\pi} \cdot \sum_{i=0}^{k} \beta_i ,$$

if $\bar{\pi} \geq \pi^*$, and

$$\bar{U}^* = (\alpha - \pi^* \sum_{i=0}^{k} \delta_i) + \bar{\pi} \cdot \sum_{i=0}^{k} (\beta_i + \delta_i)$$

if $\bar{\pi} < \pi^*$ This equation formalizes the relationship between disinflation and the change in the NAIRU. A 1 percent decrease in inflation increases the NAIRU by $-\Sigma\beta_i$ percent if inflation is higher than the threshold value, while the same 1 percent decrease in inflation pushes up the NAIRU by $-\Sigma(\beta_i + \delta_i)$ percent if inflation is lower than the threshold value. It is important to keep in mind that $\Sigma\beta_i$ is negative if hysteresis exists. If grease effects exist, then the slope of the curve becomes flatter when inflation falls below the threshold value. Such nonlinearity implies that the expected sign of $\Sigma\delta_i$ is also negative.

For the specification of lag length, I choose the current and one year lag of inflation ($k = 1$) for annual data, and the current and eight quarter lags ($k = 8$) for quarterly data.[10)]

When a threshold value (or a knot) is given, one can estimate a linear

10) There are a few exceptions. I choose the current and two year lags ($k = 2$) for the annual U. S. data for the pre-supply-shocks (1893-1972) and pre-Depression (1893-1929) periods. The current and four quarter lags of inflation ($k = 4$) are used for Switzerland, because only a small number of observations are available.

spline model. The threshold value, π^*, may either be fixed a priori or estimated. In specifications in which it is fixed, I set the threshold of inflation to 2.5 percent. In specifications in which it is estimated, I follow King, Stock, and Watson (1995) in order to endogenize the knot. I first restrict the range of inflation from which I choose the knot. Let $\bar{\pi}$ and $\underline{\pi}$ be the upper bound and the lower bound of the range. That is,

$$\pi^* \in [\underline{\pi}, \bar{\pi}].$$

The upper and lower bounds are chosen so that

a) the set $\{\pi_t \mid \underline{\pi} < \pi_t < \bar{\pi}\}$ is the middle 70 percent or less of the sample, and

b) both sets $\{\pi_t \mid \pi_t < \underline{\pi}\}$ and $\{\pi_t \mid \bar{\pi} < \pi_t\}$ have at least five observations each.

If the fixed knot ($\pi^* = 2.5$) is not included in the above range, I extend the boundary, either $\bar{\pi} = 2.5$ or $\underline{\pi} = 2.5$. After I establish the range of inflation, I calculate the standard Chow F-statistic for all possible knots within the range. (Knot $= \underline{\pi}$,..., 2.4, 2.5, 2.6, 2.7,..., $\bar{\pi}$.) An estimated knot is defined as the one that yields the largest F-statistic.

(3) A local regression model

It is known that OLS estimation such as linear and linear spline models is very sensitive to outliers and influential observations. One way of dealing with outliers is to employ robust methods in place of OLS. I estimate the long-run Phillips curve by using local regression as a robust method. I choose the loess smoother with a span of 0.75, which is a default value in S-PLUS.

5.2 The Interpretation of Equilibrium Multipliers ($\Sigma\beta_i$ and $\Sigma\delta_i$)

Tables 1 and 2 present regressions for linear and linear spline models. The tables show the countries (column 1), sample period (column 2),

Table 1 Annual Data

Country	Sample Period	Model	Knot	α	$\Sigma\beta_i$	$\Sigma\delta_i$	$\bar{R}^2$	Chow F-test	Figure
Canada	1981-1996	linear		9.573***	-0.077		0.005		
				(0.318)	(0.056)				
		linear spline	π^* = 2.5	8.525***	0.059	-1.333***	0.615	11.31***	
			fixed	(0.298)	(0.045)	(0.282)			
			π^* = 4.0	8.331***	0.082**	-0.666***	0.787	24.80***	3
			estimated	(0.232)	(0.035)	(0.095)			
United States	1980-1996	linear		5.329***	0.162***		0.343		4
				(0.298)	(0.053)				
		linear spline	π^* = 2.5	5.112***	0.186***	-2.597	0.389	1.54	
			fixed, estimated	(0.313)	(0.053)	(1.491)			
Japan	1980-1996	linear		2.408***	0.001		-0.122		5
				(0.083)	(0.030)				
		linear spline	π^* = 2.5	2.439***	-0.006	0.014	-0.293	0.07	
			fixed	(0.225)	(0.057)	(0.115)			
			π^* = 1.1	2.373***	0.010	-0.080	-0.283	0.12	
			estimated	(0.146)	(0.043)	(0.218)			
France	1980-1996	linear		10.806***	-0.325***		0.767		
				(0.308)	(0.044)				
		linear spline	π^* = 2.5	10.021***	-0.252***	-2.515***	0.913	12.81***	
			fixed	(0.248)	(0.031)	(0.497)			
			π^* = 2.6	9.966***	-0.247***	-2.234***	0.915	13.14***	6
			estimated	(0.252)	(0.031)	(0.436)			
Germany	1981-1990	linear		6.419***	-0.089***		0.935		7
				(0.026)	(0.008)				
		linear spline	π^* = 2.5	6.414***	-0.086***	-0.003	0.928	0.66	
			fixed, estimated	(0.059)	(0.014)	(0.031)			

Note Standard errors are in parentheses.

*, **, and *** significant at the 0.10, 0.05, and 0.01 levels respectively.

Table 2 Quarterly Data

Country	Sample Period	Model	Knot	α	$\Sigma\beta_i$	$\Sigma\delta_i$	R^2	Chow F-test
Canada	81:Q3-97:Q1	linear		9.649***	-0.105***		0.511	
				(0.164)	(0.031)			
		linear spline	$\pi^* = 2.5$	8.964***	-0.005	-0.736***	0.537	1.32
			fixed	(0.267)	(0.044)	(0.232)		
			$\pi^* = 5.0$	8.465***	0.051	-0.328***	0.611	2.52**
			estimated	(0.361)	(0.053)	(0.098)		
United States	80:Q2-97:Q1	linear		5.919***	0.207***		0.389	
				(0.299)	(0.059)			
		linear spline	$\pi^* = 2.5$	5.936***	0.222***	1.114	0.319	0.33
			fixed	(0.351)	(0.067)	(1.386)		
			$\pi^* = 3.4$	6.880***	0.120	1.869***	0.417	1.31
			estimated	(0.485)	(0.076)	(0.624)		
Japan	80:Q3-97:Q1	linear		2.804***	-0.146***		0.474	
				(0.052)	(0.021)			
		linear spline	$\pi^* = 2.5$	2.378***	-0.043	-0.222***	0.523	1.65
			fixed	(0.148)	(0.042)	(0.074)		
			$\pi^* = 0.7$	2.600***	-0.090***	-0.579***	0.563	2.30**
			estimated	(0.077)	(0.026)	(0.203)		
France	81:Q4-97:Q1	linear		11.880***	-0.399***		0.675	
				(0.212)	(0.042)			
		linear spline	$\pi^* = 2.5$	10.466***	-0.261***	-3.939***	0.976	73.80***
			fixed, estimated	(0.082)	(0.013)	(0.160)		
Germany	81:Q4-90:Q4	linear		6.159***	-0.124***		0.590	
				(0.122)	(0.041)			
		linear spline	$\pi^* = 2.5$	6.410***	-0.191*	0.141	0.494	0.43
			fixed	(0.462)	(0.107)	(0.259)		
			$\pi^* = 0.8$	6.322***	-0.182***	0.417	0.666	1.68
			estimated	(0.200)	(0.055)	(0.416)		
Switzerland	91:Q2-96:Q2	linear		4.120***	-0.291***		0.799	
				(0.128)	(0.035)			
		linear spline	$\pi^* = 2.5$	5.432***	-0.561***	0.879***	0.967	16.05***
			fixed	(0.185)	(0.039)	(0.118)		
			$\pi^* = 3.4$	6.137***	-0.707***	0.747***	0.977	23.77***
			estimated	(0.264)	(0.057)	(0.093)		

Note Standard errors are in parentheses.
*, **, and *** significant at the 0.10, 0.05, and 0.01 levels respectively.

regression models (column 3), and the threshold value for linear spline models (column 4). Columns 5, 6, and 7 of the tables report OLS estimates together with $\bar{R}^2$ in column 8. The Chow F-statistic in column 9 is used to test the null hypothesis that the model is linear.

The important results are the sum of coefficients ($\Sigma\beta_i$ and $\Sigma\delta_i$) in columns 6 and 7, and the Chow F-statistic in column 9. $\Sigma\beta_i$ measures hysteresis in unemployment, while $\Sigma\delta_i$ is related to inflation's grease effects. For both $\Sigma\beta_i$ and $\Sigma\delta_i$, the predicted signs by theory are negative.

To take an example, let us consider the regressions using annual data for Canada. The results are presented in Table 1. To start with, I need to determine whether the relationship between inflation and the NAIRU is linear or nonlinear. For this purpose, I use the Chow F-test statistic in column 9. In the case of Canada, the usual Chow F-test indicates that the null hypothesis of linearity is rejected at the 0.01 significance level for both linear spline models: the F-statistic is 11.31 for a fixed knot and 24.80 for an estimated knot. Thus, the linear spline models are better suited than the linear model for describing the relationship between inflation and the NAIRU. For these two spline models, the one with an estimated knot ($\bar{R}^2$ = 0.787) has greater overall explanatory power than the one with a fixed knot ($\bar{R}^2$ = 0.615). Hence, I choose the linear spline model with an estimated knot (π^* = 4.0) as a baseline model for Canada. Now, the sums of coefficients for this baseline model are

$$\Sigma\beta_i = 0.082, \quad \textit{and} \quad \Sigma\delta_i = -0.666.$$

These sums of coefficients imply that a 1 percent decrease in inflation reduces the NAIRU by 0.082 percent when inflation is higher than 4.0 percent, while a 1 percent decrease in inflation increases the NAIRU by 0.584 percent (= 0.082 + (–0.666)) when inflation is lower than 4.0 percent. Recall that $\Sigma\beta_i$ is negative if hysteresis exists, and that $\Sigma\delta_i$ is also negative if inflation has grease effects. From these results, I conclude that inflation has grease effects but hysteresis does not exist in Canadian unemployment.

By applying the same procedure to other data sets, one can identify hysteresis in unemployment and inflation's grease effects for other countries. The results for the other countries are explained in the appendix.

5.3 Figures

Figures 3-7 plot the observations along with the fitted curves.[11] The fitted curves are chosen in the following manner. If the Chow F-test does not reject the null hypothesis of linearity, the linear model is chosen to draw the fitted curve. If the Chow F-test rejects the null hypothesis of linearity, I choose the model that has the largest $\bar{R}^2$ among the regressions I have estimated. For a robust method, I estimate the long-run Phillips curve with local regression. Fitted curves obtained from local regression are presented along with linear (or linear spline) models. The frequency of observations is indicated by the density of tick marks for the loess estimates. The loess estimates in the figures confirm that linear (or linear spline) models fit the data fairly well.

5.4 Results

By choosing a baseline model for each country and examining the sums of coefficients ($\Sigma\beta_i$ and $\Sigma\delta_i$) in Tables 1 and 2, one can identify hysteresis in unemployment and inflation's grease effects. The main results obtained in this paper can be summarized by the following three points.

1) Strong hysteresis can be found in Switzerland, France, and Germany, and some hysteresis can be found in Japan. However, there is little evidence that hysteresis exists in Canada or the United States.

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11) Figures are shown only for annual data. Dots (observations) in the figures indicate the pairs of the NAIRU and current inflation.

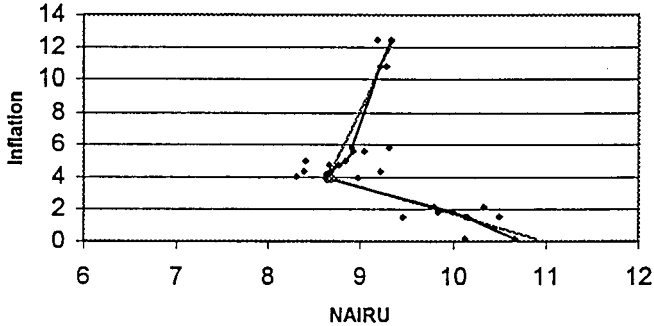

Figure 3 Canada (1981-1996) Knot = 4.0

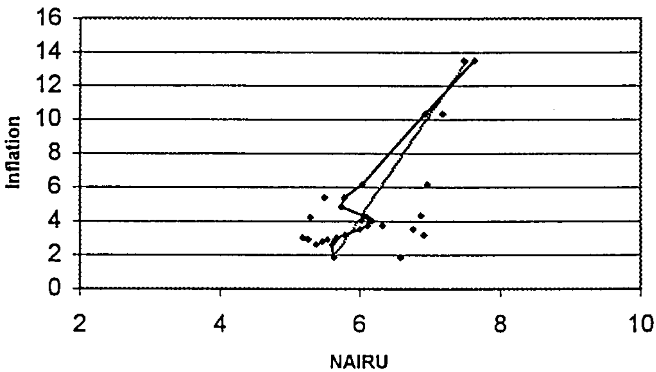

Figure 4 United States (1980-1996)

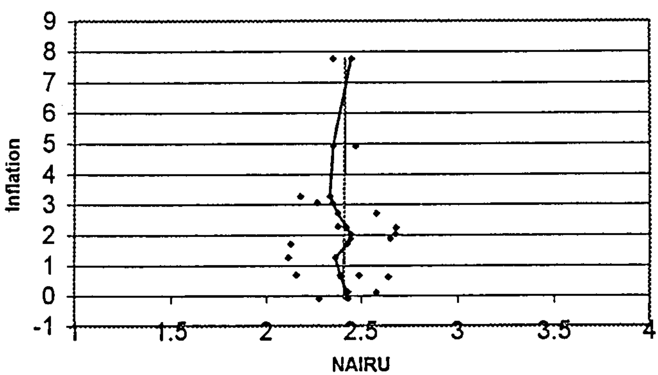

Figure 5 Japan (1980-1996)

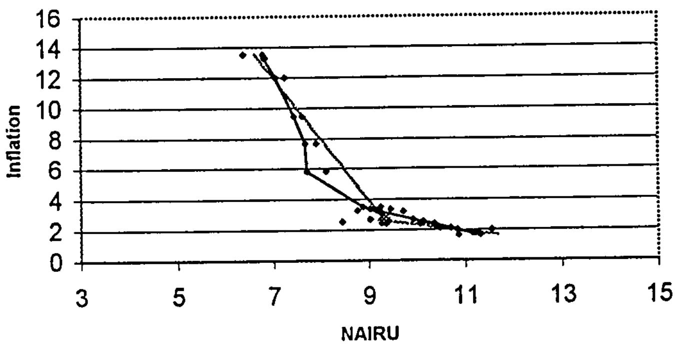

Figure 6 France (1980-1996) Knot = 2.6

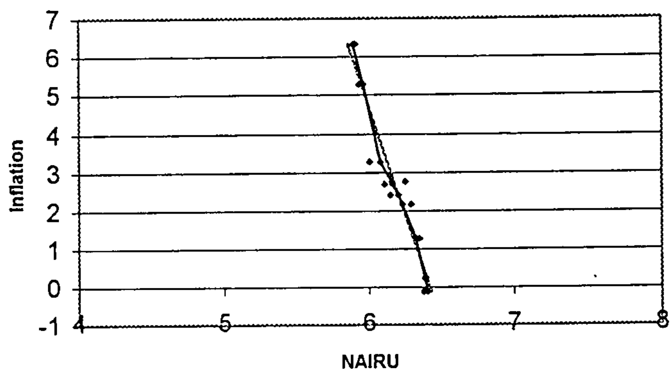

Figure 7 Germany (1981-1990)

2) Inflation's grease effects are found only in France, Canada, and Japan. My experiments fail to identify grease effects in the United States, Germany, and Switzerland.

3) To explore the historical evidence, I apply the same analysis to the U.S. data for the pre-supply-shocks (1893-1972) and pre-Depression (1893-1929) periods.[12] The results are reported in Table 3 and Figure 8, and they indicate strong grease effects in the labor market.

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12) The later sample period is examined in order to determine whether grease effects are due to the Great Depression.

Table 3 United States Annual Data (pre-supply shocks)

Sample Period	Model	Knot	α	$\Sigma\beta_i$	$\Sigma\delta_i$	$\bar{R}^2$	Chow F-test	Figure
1893-1972	linear		9.389***	-0.537***		0.166		
			(0.548)	(0.129)				
	linear spline	$\pi^* = 2.5$ (fixed)	6.713***	-0.096	-1.100***	0.244	3.61**	
			(0.972)	(0.183)	(0.337)			
		$\pi^* = 3.8$ (estimated)	5.126***	0.059	-1.179***	0.250	3.84**	8a
			(1.369)	(0.215)	(0.351)			
1893-1929	linear		7.529***	-0.199*		0.017		
			(0.493)	(0.105)				
	linear spline	$\pi^* = 2.5$ (fixed)	5.326***	0.055	-0.889***	0.162	2.90*	
			(0.885)	(0.136)	(0.302)			
		$\pi^* = 1.6$ (estimated)	5.857***	0.005	-0.947***	0.171	3.04**	8b
			(0.735)	(0.127)	(0.317)			

Note Standard errors are in parentheses.
*, **, and *** significant at the 0.10, 0.05, and 0.01 levels respectively.

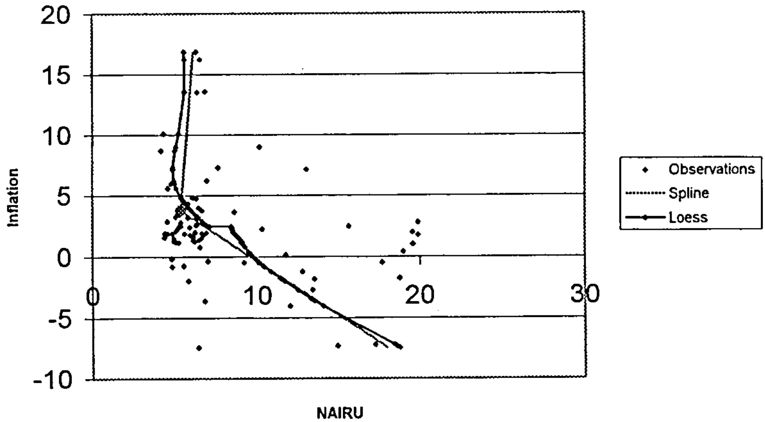

Figure 8a United States (1893-1972) Knot = 3.8

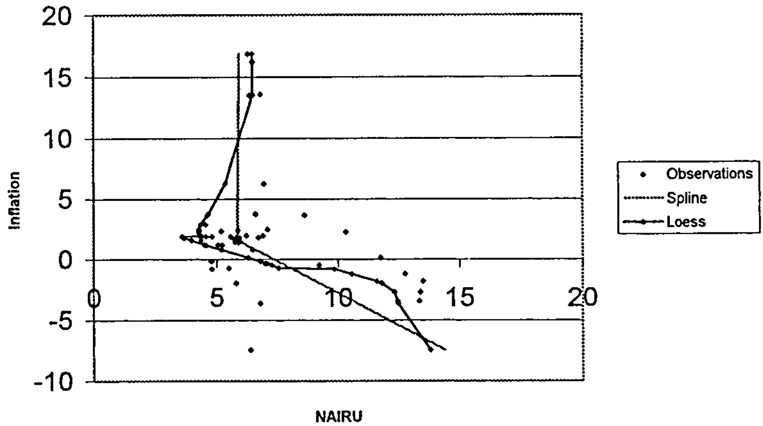

Figure 8b United States (1893-1929) Knot = 1.6

In the following two sections, I seek to explain why the results obtained in this section differ from country to country.

6 Interactions between Hysteresis in Unemployment and the Duration of Unemployment Benefits

In the previous section, I found substantial variation in the effects of disinflation on the NAIRU across countries. In this section and the next, I attempt to evaluate whether the cross-country variation in the effects of disinflation on the NAIRU, i.e., the cross-country variation in hysteresis and grease effects, can be explained.

Table 4 shows the sum of coefficients on hysteresis terms ($\Sigma\beta_i$), the duration of unemployment benefits, and the length of disinflation. The countries are ranked by the sum of coefficients on hysteresis terms. The sum of hysteresis terms indicates how much the NAIRU changes when inflation changes by 1 percent. If the sum of coefficients is negative, it means that the NAIRU increases by its absolute value when inflation falls by 1 percent. The sums indicate that Switzerland should experience the biggest rise in the NAIRU by a given fall in inflation, while the United States is least likely to suffer from hysteresis in unemployment.

One can divide these six countries into two groups: countries that show strong hysteresis in unemployment (Switzerland, France, and Germany) and countries that show weak hysteresis (the United States, Canada, and Japan). As expected, strong hysteresis can be seen in countries with long-lived unemployment benefits (Switzerland: 1 year, France: 3.75 years, and Germany: 4 years), whereas hysteresis is weak in countries where unemployment benefits are shorter lived (Unemployment benefits last only half a year in the United States, Canada, and Japan.).[13] The rationale for this finding is that generous unemployment benefits aggravate the increase in the long-term unemployed. Long-term unemployment contributes very little to holding down wage pressure, and thus the increase in long-term unemployment leads to a rise in the NAIRU. The same argument applies to the length of disinflation in place of the benefit duration.

13) Data on the duration of unemployment benefits and the length of disinflation are taken from Ball (1997). From Table 4, one may also notice that the NAIRU rose more in countries with longer disinflations.

Table 4 Hysteresis in Unemployment

Rank	Country	Frequency of Observation	[Baseline] Elmeskov (levels)	Elmeskov (differences)	HP-filtered (levels)	Duration of Unemployment Benefit (years)	Longest Disinflation (years)
1	Switzerland	(A)	NA			1	3
		(Q)	-0.707***	-0.540***	-0.486***		
2	France	(A)	-0.247***	-0.129*	-0.286***	3.75	6
		(Q)	-0.261***	-0.217***	-0.213***		
3	Germany	(A)	-0.089***	-0.079***	-0.309***	4	5
		(Q)	-0.124***	-0.527***	-0.060		
4	Japan	(A)	0.001	-0.047**	-0.076***	0.5	3
		(Q)	-0.090***	-0.106***	-0.089***		
5	Canada	(A)	0.082**	-0.026	-0.065***	0.5	4
		(Q)	0.051	-0.104*	0.118***		
6	United States	(A)	0.162***	0.027	0.101**	0.5	3
		(Q)	0.207***	-0.120*	0.256***		

Note *, **, and *** significant at the 0.10, 0.05, and 0.01 levels respectively.

7 Interactions between Inflation's Grease Effects and Nominal Wage Rigidity

Table 5 presents the sum of coefficients on grease terms ($\Sigma\delta_i$), together with an index of nominal wage responsiveness.[14] Inflation's grease effects can be found in France, Canada, and Japan, but my experiment fails to find grease effects in the United States, Germany, and Switzerland. A negative and large absolute value of the sum of coefficients indicates strong grease effects in the labor market. As shown in the first column of Table 5, countries are ranked by the sum of coefficients on grease terms.

The index of nominal wage responsiveness is constructed from three variables: the duration of wage agreements, the degree of indexation, and the degree of synchronization. To each of these variables, a value of zero, one, or two is assigned. Higher values mean shorter, more indexed, and more synchronized agreements. The wage responsiveness index is the sum of three values.

Unfortunately, one cannot find any relationship between inflation's grease effects and nominal wage rigidity. Thus it remains an unsettled question what factors induce inflation's grease effects in France, Canada, and Japan.

8 Robustness

8.1 An Alternative NAIRU Variable

The NAIRU is not directly observable, and thus it has to be estimated from observable data such as unemployment and inflation. Thus far I have used Elmeskov's NAIRU as a baseline case, but there are other ways to

14) The indices of nominal wage responsiveness are taken from Bruno and Sachs (1985). Useful information on nominal wage rigidity is given by Ball (1994), pp. 174-76.

Table 5 Inflation's Grease Effects

Rank	Country		[Baseline] Elmeskov (levels)	Elmeskov (differences)	HP-filtered (levels)	Duration of agreement	Degree of indexation	Synchronization	Responsiveness index
1	France	(A)	-2.234***	-0.242	-1.854***	1	2	0	3
		(Q)	-3.939***	-1.334***	-5.495***				
2	Canada	(A)	-0.666***	——	-0.090**	1	1	0	2
		(Q)	-0.328***	——	-0.406***				
3	Japan	(A)	——	——	——	2	0	2	4
		(Q)	-0.579***	——	-0.696**				
4	United States	(A)	——	——	——	0	1	0	1
		(Q)	——	——	——				
4	Germany	(A)	——	——	——	2	0	2	4
		(Q)	——	——	——				
4	Switzerland	(A)	NA			0	0	0	0
		(Q)	——	——	——				

Note *, **, and *** significant at the 0.10, 0.05, and 0.01 levels respectively. —— implies that the Chow F-test of the regression does not reject the null hypothesis of linearity.

All variables are on a scale between 0 and 2. The index scores have the following meaning. Under Duration of agreement, 0 = 3-year contract length; 1 = 1 - 3 years, open-ended; 2 = 1 year or less. Under Degree of indexation, 0 = no indexation clauses; 1 = partial indexation, or reopening clause triggered by price increases; 2 = widespread indexation. Under Synchronization, 0 = no synchronization; 1 = partial synchronization; 2 = centralized national settlements.

estimate the NAIRU. Hence, I need to check whether the results obtained using Elmeskov's NAIRU measure still hold when other estimates of the NAIRU are used. To this end, I employ estimates of the NAIRU based solely on unemployment. I apply the HP filter directly to the unemployment series. I set the HP parameter to 100 for annual unemployment data and 1600 for quarterly data. I then redo my regression with this HP-filtered unemployment. The resulting estimated values of key parameters ($\Sigma\beta_i$ and $\Sigma\delta_i$) are reported in Tables 4 and 5. Since the results are quite similar to those in the baseline case (the Elmeskov's NAIRU), one can conclude that the findings in this study do not depend on a particular approach to measuring the NAIRU.

8.2 Regressions in Differences

In the baseline model, variables are expressed in *levels*. I now estimate the model with variables that are expressed in *differences*, and compare the results with the baseline case.[15] The estimated values of $\Sigma\beta_i$ and $\Sigma\delta_i$ from the difference regressions are presented in Tables 4 and 5. Though the coefficients of hysteresis estimated in differences are quite similar to those estimated in levels, inflation's grease effects estimated in differences are weaker than those estimated in levels.

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15) Linear models are specified as

$$\Delta U_t^* = \sum_{i=0}^{k} \beta_i \Delta\pi_{t-i},$$

and linear spline models are

$$\Delta U_t^* = \sum_{i=0}^{k} \beta_i \Delta\pi_{t-i} + \sum_{i=0}^{k} \delta_i \Delta\{d_{it}(\pi_{t-i} - \pi^*)\},$$

where $\Delta x_t \equiv x_t - x_{t-1}$, *and*

$$d_{it} = \begin{cases} 1 & if\ \pi_{t-i} < \pi^*, \\ 0 & if\ \pi_{t-i} \geq \pi^*. \end{cases}$$

9 Conclusion

The aim of my research was to investigate the main cause of the changes in the NAIRU for various OECD countries. Since traditional explanations based on labor market rigidities are empirical failures, I looked at another approach that emphasizes the empirical relationship between disinflation and the NAIRU. This study focused on hysteresis and inflation-as-grease theories. Because both hysteresis and inflation-as-grease theories claim that disinflation causes an increase in the NAIRU, each theory's contribution to the increase in the NAIRU must be identified.

I analyzed annual and quarterly data for six low-inflation OECD countries, and identified hysteresis in unemployment and inflation's grease effects in the labor market. I found that the effects of disinflation on the NAIRU vary across countries, and confirmed that countries with long-lived unemployment benefits suffer more from hysteresis in unemployment. However, it remains open to question why inflation's grease effects are found in France, Canada, and Japan, but not in other countries.

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Appendix

Results from Tables 1 and 2

Canada (Figure 3): For annual data, since the null hypothesis of linearity is rejected, the linear spline model with an estimated knot ($\pi^* = 4.0$) is used as a baseline model. The coefficient on the hysteresis term is 0.082 (a wrong sign and statistically significant) and the coefficient on the grease term is –0.666 (a correct sign and statistically significant). Hence, I can identify inflation's grease effects, but hysteresis in unemployment does not seem to exist. For quarterly data, since the null hypothesis of linearity is rejected, the linear spline model with an estimated knot ($\pi^* = 5.0$) is used as a baseline model. The coefficient on the hysteresis term is 0.051 (a wrong sign and statistically insignificant) and the coefficient on the grease term is –0.328 (a correct sign and statistically significant). Hence, grease effects are again identified and hysteresis is not.

The United States (Figure 4): For annual data, since the null hypothesis of linearity is not rejected, the linear model is used as a baseline model. This means that inflation's grease effects are not identified. The coefficient on the hysteresis term is 0.162 (a wrong sign and statistically significant). Hence, I cannot identify hysteresis in unemployment, either. Similarly, for quarterly data, the null hypothesis of linearity is not rejected, and thus the linear model is used as a baseline model. The coefficient on the hysteresis term is 0.207 (a wrong sign and statistically significant). Hence, neither hysteresis nor grease effects are identified.

Japan (Figure 5): For annual data, since the null hypothesis of linearity is not rejected, the linear model is used as a baseline model. The coefficient on the hysteresis term is 0.001 (a wrong sign and statistically insignificant) Hence, neither hysteresis in unemployment nor inflation's grease effects are identified. For quarterly data, because the null hypothesis of linearity is rejected, the linear spline model with an estimated knot ($\pi^* = 0.7$) is used as a baseline model. The coefficient on the hysteresis term is –0.090 (a correct sign and statistically significant) and the coefficient on the grease term is –0.579 (a correct sign and statistically significant). Hence, both hysteresis and grease effects are identified.

France (Figure 6): For annual data, since the null hypothesis of linearity is rejected, the linear spline model with an estimated knot ($\pi^* = 2.6$) is used as a baseline model. The coefficient on the hysteresis term is –0.247 (a correct sign and statistically significant) and the coefficient on the grease term is –2.234 (a correct sign and statistically significant). Hence, I can identify both hysteresis in unemployment and inflation's grease effects. For quarterly data, the null hypothesis of linearity is again rejected, and thus the linear spline model with an estimated knot ($\pi^* = 2.5$) is used as a baseline model. (In this case, the estimated knot value (2.5) happens to coincide with the fixed knot value.) The coefficient on the hysteresis term is –0.261 (a correct sign and statistically significant) and the coefficient on the grease term is –3.939 (a correct sign and statistically significant). Hence, very strong hysteresis and grease effects are observed.

Germany (Figure 7): For annual data, since the null hypothesis of linearity is not rejected, the linear model is used as a baseline model. This means that inflation's grease effects are not identified. The coefficient on the hysteresis term is –0.089 (a correct sign and statistically significant).

Hence, I can identify hysteresis in unemployment. Similarly, for quarterly data, the null hypothesis of linearity is not rejected, and thus the linear model is used as a baseline model. The coefficient on the hysteresis term is –0.124 (a correct sign and statistically significant). Hence, hysteresis is identified but grease effects are not.

Switzerland : For Switzerland, only quarterly data are available. Since the null hypothesis of linearity is rejected, the linear spline model with an estimated knot ($\pi^* = 3.4$) is used as a baseline model. The coefficient on the hysteresis term is (a correct sign and statistically significant) but the coefficient on the grease term is 0.747 (a wrong sign and statistically significant). Hence, I can identify hysteresis in unemployment but not inflation's grease effects.