The Bank of Canada and the Inflation-Unemployment Trade-Off

Pierre Fortin*

Introduction

There are many reasons to talk about the Phillips curve on this wonderful occasion to honour Chuck. One is simply the *passe-partout* remark once made by Bob Solow: "Any time seems to be the right time for reflections on the Phillips curve. So long as the actuality or threat of inflation remains a current problem, and so long as no clearly better organizing device presents itself, economists will argue about the Phillips curve" (Solow 1976, 3). Much of the time Chuck has spent at the Bank of Canada will be remembered for the long struggle to tame inflation.

A second reason is that one of Chuck's first influential papers written at the Bank of Canada dealt precisely with the inflation-unemployment trade-off. This was Research Memorandum 76–189, entitled "The Phillips Curve in Canada," which to my knowledge was the first serious attempt to estimate a Canadian NAIRU (Freedman 1976). Thus, talking about the Phillips curve is a particularly appropriate way to honour Chuck.

A third reason is that after being pronounced dead by some in the 1970s and 1980s, the Phillips curve is once again enjoying the full respect of most macroeconomic theorists and practitioners. It is widely perceived as an

* I am indebted to John Chant, Chuck Freedman, and Tiff Macklem for very helpful comments and advice.

"inexorable" channel of the effect of monetary policy on inflation (Mankiw 2001). It is one of the hottest topics in current macroeconomic research.

The amount of research on the trade-off done at the Bank of Canada during Chuck's career—the last three decades—has been considerable. My count of Bank technical reports and working papers dealing with the Phillips curve, the output gap, the NAIRU, and wage-price dynamics currently stops at 48, of which more than half came out in the last decade. Reviewing them one by one would be an impossible task. Instead, I will introduce a simple benchmark Phillips curve, and then organize my discussion around the following themes: the vertical long-run Phillips curve, stagflation and the shifting Phillips curve, the cost of disinflation, the non-linear Phillips curve, the puzzle of the missing deflation, and the macroeconomics of low inflation.

1 A Simple Benchmark Phillips Curve

I will refer to the Phillips curve as an equation that explains price inflation. In the theoretical literature, this price-Phillips curve is derived from primitives that usually involve inertial and/or expected inflation, pressure from excess demand, and supply-side influences. I will use the following benchmark description of the Phillips curve, which is general enough for my purpose:

$$i = a + b_1(L)i_{-1} + b_2 i^* + c(L)x + d(L)z + e\,. \tag{1}$$

This equation expresses actual inflation, i, as a linear function of five variables:

(i) past inflation, i_{-1}, and its lags, representing "backward-looking" or adaptive expectations, but also the real-time adjustment of workers and firms to past experience, which is usually thought to be slow owing to many features like imperfect information and competition; costly-to-change and staggered wage and price contracts; rule-of-thumb behaviour; coordination failures; efficiency wages; credit market imperfections; and the complex, interactive, and decentralized input-output structure of the economy;

(ii) purely "forward-looking" expected inflation, i^*;

(iii) an excess-demand variable, x, which can be taken at the excess of actual output over potential (called the *output gap*), the negative of the unemployment rate, a rate of capacity utilization, etc.;

(iv) a zero-mean variable, z, summarizing supply-side shocks, which include shifts in the relative prices of food, energy, and imports;

changes in indirect taxes; changes in actual relative to perceived productivity growth, wage and price controls, etc.;

(v) a stochastic zero-mean error term, e.

The parameter a is the intercept of the linear equation. The three variables i_{-1}, x, and z usually have both contemporaneous and delayed effects on actual inflation, with $b_1(L)$, $c(L)$, and $d(L)$ representing lag polynomials. It has generally been found that the sum of the coefficients of the lag polynomial, $b_1(L)$, and the constant parameter, b_2, which are associated with past and expected inflation, does not exceed unity. Hence, $b_1(1) + b_2 \leq 1$. The dating of the variables can be quarterly or annual.

The notion of a trade-off between inflation and unemployment arises when the negative of the unemployment rate, u, is used as the measure of excess demand, so that $x \equiv -u$ in equation (1). Then, for given past inflation and i^*, z, and e in the short run, an increase of 1 percentage point in u causes a reduction of $c(1)$ percentage points in i once all the lags in $c(L)$ have passed. In other words, slack labour and product markets exert downward pressure on wages and prices. Hence the trade-off: the reduction in inflation is "paid for" by an increase in unemployment. The graphic representation of this short-run trade-off as a negatively sloped line in unemployment-inflation space is precisely what is called the Phillips curve. It was discovered in the 1950s by British, Canadian, and American economists, who looked at several decades of aggregate data on past wages and prices (Phillips 1958; Lipsey 1960; Samuelson and Solow 1960).

2 The Vertical Long-Run Phillips Curve

Various theories of the trade-off imply various interpretations of equation (1) and various restrictions on its parameters. However, all theories make a distinction between the *short-run* Phillips curve described by equation (1) for any given set of values of the variables $b_1(L)i_{-1}$, i^*, x, z, and e, on the one hand, and the steady-state or *long-run* Phillips curve, for which inflation is stable and has come to be accurately anticipated, and there are no supply-side or other random shocks, on the other hand. Formally, this long-run Phillips curve is such that $i^* = i_{-1} = i, z = 0$ and $e = 0$.

Here, two cases must be distinguished: $b_1(1) + b_2 < 1$ and $b_1(1) + b_2 = 1$. In the 1950s and 1960s, it was generally thought, on the basis of statistical estimation, that $b_1(1) < 1$ and $b_2 = 0$. Solving from equation (1), the long-run Phillips curve with $x \equiv -u$ looked like:

$$i = a/(1 - b_1(1)) - [c(1)/(1 - b_1(1))]u. \qquad (2)$$

This implied that countries could permanently sustain lower unemployment provided they learned to live with higher inflation. The long-run slope, $c(1)/(1-b_1(1))$, was steeper than the short-run slope, $c(1)$, but a sustainable permanent trade-off was nevertheless on hand as long as $b_1(1)$ was less than unity. The locus of inflation-unemployment combinations defining the long-run Phillips curve represented a menu from which policy-makers could choose. Several Canadian researchers contributed to estimating these policy options during the 1960s. Studies included the early paper by Reuber (1964); the Economic Council of Canada monograph by Bodkin, Bond, Reuber, and Robinson (1966); and the article by Helliwell, Officer, Shapiro, and Stewart (1969) arising from their work on the Bank of Canada's RDX1 econometric model.

What is little known, even inside the Bank of Canada, is that Governors Coyne and Rasminsky strongly disagreed with the view that you could trade off more inflation against less unemployment in the long run. Their skepticism goes back at least to the early 1960s. It was mentioned in Governor Rasminsky's testimony before the Porter Commission (Bank of Canada 1964, 5). But his doubts were fully articulated in his 1966 Per Jacobsson Lecture. Let me quote the Governor at length:

> It may well be the case that if rising price levels are tolerated, real output will in certain circumstances be raised for short periods of time. But the public authorities have an obligation to take a longer view. Once it became clear to everyone that public policy, even without any explicit admission, was prepared to allow prices to rise at, say, 3 per cent a year indefinitely, then all members of society, including savers, would take whatever economic or political action was available to them to protect themselves against this erosion in the value of money. In this situation the stimulating effect of the 3 per cent per year rise in prices would fade away and there would be pressure for additional expansionary measures. These would cause prices to rise faster than the so-called "acceptable" rate and the policies needed to keep the rise within the 3 per cent limit would appear to be "deflationary" and would be associated with just as much difficulty as the policies that were formerly necessary in the attempt to avoid inflation altogether. Where would the process stop? Would not the end be greater and greater rates of price increases, involving more and more inequity—since all members of society are in actual fact not equally able to protect themselves against inflation—and culminating in a major economic dislocation? (Rasminsky 1966, 29–30)

In this quotation, Governor Rasminsky was making a detailed argument denying that any long-run trade-off between inflation and unemployment existed. That argument was in effect based on the idea that eventually actual inflation would fully feed back into expected inflation. In the long run, only relative wages and prices would matter for nominal wage and price decisions. The same idea was later developed by Edmund Phelps (1967) and Milton Friedman (1968).

In terms of equation (1), the Governor meant that $b_1(1) + b_2 = 1$, so that the long-run Phillips curve with $x \equiv -u$ would reduce to:

$$u = a/c(1). \tag{3}$$

The geometric representation of this equation is as a vertical line in unemployment-inflation space. According to it, there is one and only one rate of unemployment that is consistent with stable inflation and is sustainable in the long run, namely $a/c(1) \equiv u^*$. This unique level was dubbed the *natural rate* of unemployment in the theoretical literature (Friedman 1968), and the *non-accelerating-inflation rate of unemployment* (the NAIRU) in the empirical literature (Modigliani and Papademos 1975). Any attempt by public authorities to keep unemployment persistently above or below the NAIRU would lead to unending price deceleration or acceleration.

The strong policy implication is that monetary policy can choose the permanent rate of inflation along the vertical long-run Phillips curve, but it has no influence on the permanent rate of unemployment. The latter has to be the structurally given NAIRU. As the data from the mid-1960s and later came in, there was mounting empirical evidence in favour of the hypothesis that $b_1(1) + b_2 = 1$. Chuck's 1976 paper was an important contribution to this effort in the Canadian context. As a result, most central bankers began to think—as they still do today—that the primary goal of monetary policy should be to achieve a low and stable rate of inflation over medium- to long-term horizons. They further believe that, whatever the targeted level of inflation, the unemployment rate will converge towards the level of the NAIRU, which is independent of monetary policy.

3 Stagflation and the Shifting Phillips Curve

The 1970s were not a quiet decade for the Phillips curve, however. No sooner had macroeconomic theorists and practitioners begun to realize that the Phillips curve displayed full price-homogeneity, and therefore was vertical at some NAIRU level in the long run, that the curve began to move upwards and to the right on the unemployment-inflation plane. To see what

happened, let $x \equiv -u$, define the NAIRU as $u^* \equiv a/c(1)$ according to equation (3), and rewrite equation (1) as follows:

$$i = b_1(L)i_{-1} + b_2 i^* - c(L)(u - u^*) + d(L)z + e, \quad (4)$$

where $b_1(L)i_{-1} + b_2 = 1$. This equation identifies three potential sources of shifts in the Phillips curve in unemployment-inflation space: changes in i_{-1} and/or i^* (past or expected inflation), changes in u^* (the NAIRU), and changes in z (supply-side shocks).

In the 1970s, three types of inflationary shocks hit industrial economies almost simultaneously: (i) the NAIRU seemed to be on the rise; (ii) there were major increases in the relative prices of food and energy (in 1972–73 and 1978–80); and (iii) naturally, expected inflation soon followed actual inflation upwards. All three developments drove the Phillips curve upwards and to the right. The shift was therefore towards more unemployment *and* more inflation or, as it came to be called, towards *stagflation*. In Canada, from the late 1960s to the late 1970s, unemployment increased from 5 per cent to 7.5 per cent, and inflation from 4 per cent to 11 per cent.

This came as a big surprise to everyone. Some academic economists working in the Walrasian tradition did not recognize that the Phillips curve was shifting. They pronounced the short-run Phillips curve dead (Lucas and Sargent 1978). All others who did not have much taste for premature funerals, including pragmatic central bankers, were kept busy for many years trying to understand what had happened.

Identifying the sources of shifts in the short-run Phillips curve is always a difficult task because two key determinants of inflation, expected inflation, i^*, and the NAIRU, u^* (or equivalently potential output), are not directly observable. Concerning the NAIRU, Canadian researchers, including those at the Bank of Canada, were quick to conjecture that shifts in economic structure and economic policy had raised it. The rising demographic tide of young workers, the 1971 reform of Canadian unemployment insurance, and the slow adjustment of wage aspirations to the permanent decline in productivity growth that occurred in the 1970s were among the frequently cited sources of the increase in the NAIRU. Major contributors to this research effort at the Bank were Jean-Pierre Aubry, Bob Ford, Serena Ng, and David Rose. A comprehensive review of the subject by Rose eventually put the Canadian NAIRU at "around 8 per cent for the end of 1987" (Rose 1988, 44).

Finally, raw materials and imports are significant factors of production. Their prices (as well as indirect taxes) affect marginal costs. They can at times be important sources of positive or negative changes in inflation. This

fact had been stressed in the 1960s by Canadian researchers such as Bodkin, Bond, Reuber, and Robinson (1966) at the Economic Council of Canada, and Helliwell, Officer, Shapiro, and Stewart (1969) at the Bank of Canada. But these warnings had somehow been forgotten. The oil- and food-price shocks of the 1970s brought supply-side influences back into Phillips curve specifications for good (Gordon 1977).

Since the 1970s, the effects of supply-side shocks on the rate of inflation have remained foremost in the minds of macroeconomists and policy-makers. The main issue is whether they have only temporary effects, or whether their first-round effects are propagated and sustained through wage-price interactions, giving rise to permanent changes in the rate of inflation. Chuck contributed to clarifying this question in a study demonstrating that various views about wage and price behaviour could have sharply different implications for the dynamic response of inflation to demand- and supply-side shocks (Freedman 1977). His paper preceded the somewhat different, but similarly motivated piece by Okun (1978). The inflationary consequences of supply-side shocks have remained a key concern of central banks to this day. Currently, the general view is that first-round effects on inflation should be allowed to pass, and that a strong reaction is warranted only if significant second-round effects persist (e.g., Bank of Canada 2001a).

4 The Cost of Disinflation

The main reason that the Bank of Canada wanted to better understand what had happened in the 1970s was to achieve its objective of reducing inflation at a minimum cost for Canadian society. This effort kept Bank management and researchers busy until the beginning of the 1990s, spanning two-thirds of Chuck's career at the Bank. Again, the precise structure of the inflation-unemployment trade-off was of crucial importance.

According to equation (4), the central bank can reduce inflation by first keeping monetary conditions tight and allowing unemployment to increase above the NAIRU. Then, once inflation has declined as desired, and inertial/expected inflation has followed through, monetary conditions are eased and unemployment is returned to the NAIRU level. Inflation remains steady at its lower value. This process of disinflation trades off a temporary increase in unemployment for a permanent reduction in inflation. The cost of disinflation can then be measured by adding up the total number of point-years of excess unemployment required to do the job. Multiplying this number by an Okun's coefficient then gives the cost of disinflation as a percentage of a year's gross domestic product. Whether calculated in the unemployment or the output dimension, the literature calls the macroeconomic cost of reducing the inflation rate permanently by one percentage point the *sacrifice*

ratio. Since this ratio does not include the non-pecuniary loss due to excess unemployment, it can be conceived of as a lower bound for the total welfare cost of disinflation (Akerlof, Rose, and Yellen 1988).

Intuitively, the sacrifice ratio depends on how much actual inflation responds to increases in unemployment in the short run (given by the size of the slope parameter $c(1)$), and on how quickly the inertial/expected inflation factor $b_1(L)i_{-1} + b_2 i^*$ adjusts to the decline in actual inflation. The steeper the slope $c(1)$ is and the more rapidly $b_1(L)i_{-1} + b_2 i^*$ adjusts to the lower i, the smaller the sacrifice ratio and the less costly the disinflation will be.

Consider two polar cases. At one extreme, assume that expected inflation is purely backward-looking, in which case $b_2 = 0$. The sacrifice ratio is a decreasing function of the short-run slope $c(1)$ and an increasing function of the average lag, say λ, implied by $b_1(L)$. For example, if the weights in $b_1(L)$ decrease geometrically with L, then the sacrifice ratio is equal to $\lambda / c(1)$. An average lag of one year for inflation inertia combined with a slope of one-half for the short-run Phillips curve would give a sacrifice ratio of 2 point-years of excess unemployment.

At the other extreme, assume that there is no inertia and that expected inflation is purely forward-looking. Then $b_1 = 0$ and $b_2 = 1$. If price-setters believe the central bank when it announces it is going to reduce inflation and if they act on this belief in perfect coordination, then expected inflation, i^*, will adjust instantaneously to the lower targeted inflation rate, and the latter will be achieved without any need for unemployment to increase, even temporarily. In this sort of paradise, disinflation is without pain. The sacrifice ratio is zero. So, from the point of view of social welfare, it is crucial to know to what extent inflation is inertial and to what extent expectations are forward-looking. Long lags (a high value of λ) combined with mostly adaptive expectations bring large sacrifice ratios. Short lags combined with mostly forward-looking expectations lead to small sacrifice ratios.

Much of the research effort at the Bank in the 1980s consisted in estimating the value of $c(1)$ and studying the behaviour of the inertial/expected factor $b_1(L)i_{-1} + b_2 i^*$. When the rational-expectations revolution was in full swing in the 1970s, there was initial hope that establishing central bank credibility could help reduce the cost of disinflation through direct influence on the forward-looking element of expectations formation. This has remained an important theme of Bank of Canada documents and speeches over the past 25 years. In particular, establishing central bank credibility has been a key objective of inflation targeting in Canada since 1991. Unfortunately, while there is no question that central bank credibility arising from inflation targeting has been beneficial for the functioning of financial

markets, there has been little Canadian or international evidence demonstrating its importance for wage and price setting in labour and product markets, and for the level of the sacrifice ratio in disinflation episodes (e.g., Laidler and Robson 1993; Ball 1994; Debelle 1996; St-Amant and Tessier 2000).

Consistently with this evidence, research at the Bank has found little or no role for forward-looking expectations in estimated Phillips curves. QPM, the Quarterly Projection Model of the Bank, has conceded a modest weight of $b_2 = 0.3$ to "model-consistent" expectations in its Phillips curve (Coletti, Hunt, Rose, and Tetlow 1996). Khalaf and Kichian (2003) have estimated a Canadian Phillips curve that includes a survey-based inflation expectations variable. They have failed to capture a stable effect of this expectations variable on inflation. U.S. researchers have not had much success with forward-looking expectations in Phillips curves either (e.g., Fuhrer 1997; Roberts 1997). A notable casualty has been the so-called "New Keynesian Phillips curve," which relied solely on rational expectations of future inflation (e.g., Mankiw 2001; Guay, Luger, and Zhu 2003). Always the pragmatist, Chuck recognized that inflation expectations were predominantly adaptive. But he was attracted by Fellner's (1979) argument that a credible central bank could have some direct beneficial impact on inflation expectations, and could to that extent lessen the cost of disinflation (Freedman 1990). The fact that so far countries with inflation targets do not seem to experience decreases in their sacrifice ratios has therefore come as a disappointment to him (Freedman 2001).

Interestingly, even when it put forward-looking expectations aside and assumed inflation to be fully inertial, empirical research at the Bank has produced only small sacrifice ratios for Canada. As a result of a somewhat high value of the Phillips curve slope (with no hysteresis) and a small average lag length, λ, Cozier and Wilkinson (1991) estimated that the Canadian sacrifice ratio was about 1.6 point-years of unemployment. Combining this with a low Okun's coefficient of 1.3, they found that reducing Canadian inflation by one point required a sacrifice of 2.1 per cent of a year's GDP. Later estimates of the sacrifice ratio by Bank researchers ranged between 1.5 per cent and 2.2 per cent of annual GDP (Dupasquier and Girouard 1991; Duguay 1994; Fillion and Léonard 1997). These estimates are on the very low end of the non-central-bank literature, where sacrifice ratios tend to cluster around 4 to 6 per cent of annual GDP (e.g., Gordon 1997; Howitt 1997; Mankiw and Scarth 2001; Mankiw and Reis 2002).

An important issue is whether the effect of excess demand on inflation is non-linear in the short run. In the early days of the Phillips curve, this type of non-linearity was taken for granted, essentially because of the capacity constraints that become increasingly important as the level of capacity utilization rises. Accordingly, most Phillips curves of the 1960s used the inverse of the unemployment rate ($x \equiv 1/u$) as an activity variable. Let $b_2 = 0$ and $b_1(1) = 1$, omit the lag polynomial $c(L)$ for simplicity, and rewrite equation (4) in a slightly more general form, as follows:

$$i = b_1(L)i_{-1} + f(u) + d(L)z + e, \tag{5}$$

where f is negatively sloped and convex. The corresponding long-run Phillips curve (with $i_{-1} = i, z = 0, e = 0$) is still vertical because price homogeneity is preserved in the long run. The concept of the NAIRU is still well defined: it is the unique unemployment rate, u^*, for which $f(u^*) = 0$.

The convexity of $f(u)$ matters for the strategy of disinflation. Because the marginal disinflation effect decreases as unemployment rises, it takes cumulatively fewer point-years of excess unemployment to achieve a given reduction in the inflation rate if unemployment is increased above the NAIRU by a small amount for several periods than if it is increased by a large amount for only a few periods. In other words, gradual disinflation generates a smaller sacrifice ratio than shock-treatment disinflation. Chuck made this point very clearly in a paper that rationalized the strategy of gradualism that was pursued by the Bank of Canada during the anti-inflation campaign of 1975–80 (Freedman 1978). However, cross-country panel evidence gathered later by Larry Ball (1994) on 65 disinflation episodes in 19 industrial countries suggested, on the contrary, that the sacrifice ratio was a decreasing function of the speed of disinflation: on average, the macro-economic cost would seem smaller if disinflation is quick than if it is slow. This opens up two possibilities: that the short-run Phillips curve could be concave, not convex, or else that big events like shock-treatment disinflation could somehow increase the responsiveness of inflation to market slack, reduce inflation inertia, or both. A third possibility is that the Ball finding may not be so robust and may not survive future reappraisals.

5 The Non-Linear Phillips Curve

With inflation below 2 per cent after 1991, continuing research on non-linear short-run Phillips curves at the Bank was related to a new concern: how best to prevent inflation from rising again. Contributions here were made by researchers currently or formerly associated with the Bank of Canada, particularly Chantal Dupasquier, Jean-François Fillion, Doug Laxton, Tiff Macklem, Paul Masson, Nick Ricketts, David Rose, and Bob Tetlow.

There is a simple connection between a non-linear short-run Phillips curve and inflation prevention. If the marginal effect on inflation increases as output rises towards its potential and unemployment declines towards the NAIRU, then the cost of unknowingly allowing output to exceed its potential and unemployment to fall below the NAIRU is larger than if the inflation-unemployment relationship was strictly linear. In these circumstances, given the lags in effect of monetary policy, there is a case for the central bank to "lean against the wind" and move against inflation earlier and more strongly.

The non-linearity hypothesis was examined in two papers by Laxton, Rose, and Tetlow in 1993. In the first one, they found significant non-linearity in a Canadian Phillips curve estimated with annual data over the period 1975–91 (Laxton, Rose, and Tetlow 1993a). In another paper, they simulated the consequences for output and inflation of incorrectly assuming that the Phillips curve is linear and compared the cost of this error with that of incorrectly assuming the Phillips curve is non-linear. They concluded that, on average over time, "if a central bank cannot be sure of whether the economy is non-linear or linear, it is better off maintaining the a priori position that the economy is non-linear" (Laxton, Rose, and Tetlow 1993b, 27). Presuming that the Phillips curve is non-linear whether it is or not was the policy recommendation of staff.

This provided the Bank with a rationale for managing monetary policy conservatively during the 1990s, leading it "to move interest rates pre-emptively to try and avoid periods of excess demand" (Macklem 1997, 52). The fact that the actual inflation rate was systematically below the official inflation target throughout the 1992–2001 period constitutes prima facie evidence that the Bank acted on this sort of conservative presumption. A clear instance of pre-emptive action occurred in the spring of 1997. The Bank began to raise interest rates when unemployment was still in excess of 9 per cent and inflation was steady at 1.5 per cent, that is, 0.5 point less than the official target of 2 per cent. In this particular case, the effect of the conservative bias was magnified by the Bank's having underestimated potential output and overestimated the NAIRU.

Throughout these years, the contrast with the monetary strategy of the Federal Reserve was striking. The Fed was acting as if it wanted to minimize the risk of incorrectly fighting inflation, while the Bank of Canada appeared to be trying to minimize the risk of incorrectly *not* fighting inflation. U.S. authorities did not hold much fear that the Phillips curve was convex (e.g., Blinder 1998). In fact, the opposite argument was often heard in Washington that the Phillips curve could be concave, a situation that would be consistent

with Ball's earlier finding of a negative correlation between the sacrifice ratio and the speed of disinflation.

Clearly, more research is needed on the true shape of the short-run Phillips curve. Until this issue is settled, I am inclined to agree with Joe Stiglitz (1997) that it is unwise for central bankers to act as if the economy were in danger of falling into a precipice of inflation if actual unemployment became less than the NAIRU. It could be a recipe for stagnation.

6 The Puzzle of the Missing Deflation

Recent research on the Phillips curve at the Bank of Canada has had to deal with the problem of parametric stability. This question was raised by the fact that Canadian Phillips curves estimated with 1970s and 1980s data began to seriously underpredict inflation in the 1990s.

A simple way to see this is by comparing the actual average of the national unemployment rate over 1992–2001 to a reasonable estimate of the average NAIRU over that decade. The actual average was 9.1 per cent. As an estimate of the average NAIRU, 7.5 per cent would not seem too low. It is rather conservative to assume that the Canadian NAIRU declined linearly from 8 per cent around 1990 to 7 per cent around 2000. This gives 1.6 points for an estimate of the average annual gap between actual unemployment and the NAIRU. Given the traditional estimate of one-half for the slope of the short-run annual Phillips curve, inflation should have been reduced by 0.8 point per year, or cumulatively by 8 points over the 10-year period. But in fact, instead of sinking into deflation, core inflation in 2001 was unchanged (at about 1.5 per cent) from its 1992 level. Furthermore, the net accumulation of supply-side shocks over 1992–2001 was not important.

Formal testing by Fillion and Léonard (1997), Kichian (2001), and Khalaf and Kichian (2003) at the Bank leaves no doubt that the Canadian Phillips curve suffered from a case of "missing deflation" during the 1990s. The Canadian problem is the counterpart of the inverse problem of "missing inflation" that hit the U.S. Phillips curve after 1994. In the early 1990s, the U.S. NAIRU was generally thought to be in excess of 6 per cent. But surprisingly, actual unemployment rates of 5 per cent or less in the second half of the decade were not accompanied by rising inflation. Many recent empirical studies have addressed this U.S. puzzle. The most comprehensive are by Staiger, Stock, and Watson (2001) and by Eller and Gordon (2002).

The Bank of Canada and U.S. researchers just mentioned have studied the parametric stability of the Phillips curve using various specifications of equation (1). The shared conclusion is that the parameters have changed over time. They have been "time-varying." But Bank studies and U.S.

studies differ sharply as to which parameters have been the sources of the time variation.

Staiger, Stock, and Watson and Eller and Gordon set $b_2 = 0$. They view the inflation process as inertial, owing to wage and price staggering and time-consuming input-output interactions. They assume up to 24 quarters of lags in $b_1(L)$, and up to four quarters in $c(L)$. Basically, they find the missing inflation of the 1990s in the United States to be explained partly by favourable supply-side shocks (such as a drop in relative import prices and a temporary increase of actual over perceived productivity growth), and partly by some downward drift in the intercept a. The latter implies that the U.S. NAIRU, which is calculated as $u^* = a/c(1)$, declined by 1 to 1.5 points during the 1990s.

The three Bank of Canada studies use an estimated output gap as the activity variable. They view inflation dynamics as driven by rapidly moving expectations, not by slow wage and price staggering and input-output interactions. They differ sharply from the U.S. studies by assuming only two quarters of lags in $b_1(L)$ (instead of 24) and two quarters also in $c(L)$. They find time variation in the intercept a, in the autoregressive coefficients in $b_1(L)$, and in the coefficient of (survey-based) expected inflation, b_2. Changing inflation dynamics is the source of the parametric instability as they see it. They think it could have resulted from the new inflation-targeting regime put in place by the Bank of Canada since 1991.

This "favourable" line of interpretation can be understood as follows. Assume that, before inflation targeting became the official strategy, wage- and price-setters lacked an inflation anchor point, that expected inflation was purely adaptive $(b_2 = 0)$, and that $b_1(L)$ contained just one lag, so that $b_1(L)i_{-1} + b_2 i^* = i_{-1}$. With the advent of inflation targeting in February 1991, the process of expectations formation would have changed, particularly as the new regime became increasingly well understood and credible. Expected inflation would have become a weighted average of last quarter's inflation and of the official inflation target itself, i^T, say $(1 - b_2)i_{-1} + b_2 i^T$. For example, if $b_2 = 0.5$ and $i^T = 2$ per cent, the result would be $b_1(L)i_{-1} + b_2 i^T = 0.5i_{-1} + 1.0$. Compared to the pre-targeting period, the coefficient of i_{-1} would have declined from 1 to 0.5, and the intercept would have increased from zero to 1. The incorporation of the official inflation target into the expectations process would have exerted a drag on changes in inflation. This would explain why there was missing deflation in Canada during the 1990s.

I see four problems with the analysis of parametric stability offered by the Bank of Canada and U.S. studies I have mentioned. First, an *econometric* problem: in Bank research, it is not possible to identify the drift in the

intercept as clearly arising from changes in inflation dynamics instead of other sources. Among the possibilities are too few lags on past inflation, inadvertently left-out non-linearities, shifts in the non-inflationary level of the output gap, etc. (see Johnson and Gerlich 2002 for a discussion). Second, a *theoretical* problem: how should the terms in $b_1(L)i_{-1} + b_2 i^*$, which characterize inflation dynamics in the Phillips curve, be interpreted? Are they driven by rapidly moving expectations (with short lags) as Bank researchers have traditionally believed, or by slow wage and price staggering and input-output interactions (with long lags) as Staiger, Stock, and Watson and Eller and Gordon suggest? Third, an *empirical* problem: in a recent review article, St-Amant and Tessier (2000) do not find any clear international evidence that formal inflation targeting has been of significant help in reducing the cost of disinflation and in anchoring expectations of inflation in labour and product markets. Interpreting changes in the parameters of the Canadian Phillips curve as resulting from the new monetary regime seems premature. Fourth, a *methodological* problem: how should we judge U.S. and Canadian research that allows the NAIRU or inflationary expectations to move over time in such a way that, true or false, the traditional view of the Phillips curve can always fit the facts, and then invents reasons ex post—*dei ex machina*—for any detected time variation in the estimated parameters?

7 The Macroeconomics of Low Inflation

Recently, Akerlof, Dickens, and Perry (1996; 2000) have proposed two complementary theories that reinterpret the inflation-unemployment trade-off in the low-inflation range of, say, 0 to 5 per cent. The first theory is based on the observation that firms and workers resist absolute wage cuts very fiercely for reasons of fairness, morale, and productivity. As a result, nominal wages are highly rigid downwards. This generates an inflation-dependent homothetic contraction of the coefficients of *all* the right-hand variables of the Phillips curve. The second theory is based on the idea that, even if they are perfectly aware of what the inflation rate is, some firms and workers do not use this information (or do not use it fully) when inflation is low, which leads to loss of long-run price homogeneity. This kind of behaviour has been observed by psychologists, compensation professionals, and economists who have studied perceptions of inflation by the general public. Based on the same near-rationality argument as made by Akerlof and Yellen (1985), Akerlof, Dickens, and Perry show that ignoring inflation when it is low is a perfectly sensible rule of thumb because it costs little to firms and workers. Nevertheless, the macroeconomic consequences of this neglect by a subgroup of wage- and price-setters are important.

Both of these theories would deny that wage and price decisions are made purely in real terms when inflation is low. They would generate a non-price-homogeneous, very flat long-run Phillips relationship in the low-inflation range, while remaining consistent with the price-homogeneous vertical long-run Phillips curve at higher inflation rates. The economic world would be curved as in Einstein, not linear as in Newton. Akerlof, Dickens, and Perry have presented U.S. evidence supporting the two theories in low-inflation environments encompassing the Great Depression of the 1930s, the 1950s and 1960s, and the 1990s. A key policy implication is that, if the inflation target set by the central bank is too low, the national unemployment rate will be raised permanently.

Beginning in 1997, the Bank of Canada put out many working and seminar papers to examine the first of the two theories, that of downward nominal rigidity. Mainly involved in this effort were Allan Crawford, Chantal Dupasquier, Jean Farès, Umar Faruqui, Seamus Hogan, Lise Pichette, and Nick Ricketts, with outside help from Paul Beaudry, Alan Harrison, and Thomas Lemieux. What did they find? First, that for various reasons the spike of the wage-change distribution at zero, which is very conspicuous in union contracts when inflation is low, significantly overestimates the true extent of downward nominal-wage rigidity. Second, that downward nominal-wage rigidity does not seem to generate significant disemployment effects in microdata sets based on Canadian union contract data. Third, that estimated Canadian Phillips curves do not clearly point to downward nominal-wage rigidity as a primary source of changes in wage and price behaviour in the 1990s. Changes in the formation of inflation expectations are more often seen as the prime mover and attributed to the improved monetary regime.

No Bank research document has dealt specifically with the second theory developed by Akerlof, Dickens, and Perry, that based on rule-of-thumb behaviour. Results obtained by Fillion and Léonard (1997) for Canada and by Brainard and Perry (2000) for the United States can be seen as consistent with the theory. They estimate low values for $b_1(1)$ during the low-inflation periods of the 1960s and 1990s, and high values (closer to one) during the high-inflation periods of the 1970s. However, the Bank has clearly rejected, as a matter of principle, the argument that partial ignorance of low inflation based on rules of thumb could be a permanent feature of wage- and price-setting behaviour. In its view, "the premise . . . that behaviour would never fully take account of a persistent low rate of inflation . . . seems untenable" (Bank of Canada 2001b, 64). This led the Bank to conclude in May 2001 that it was best to keep the 1 to 3 per cent inflation-control target range until 2006 (Bank of Canada 2001a).

In my opinion, the last word has not been said on the macroeconomics of low inflation. There are grounds to criticize Bank research in this area. First, any remaining doubts about the true extent of downward nominal-wage rigidity have been cleared by two microeconomic studies that have examined large representative U.S. microdata sets: the data on individual workers from the Panel Study of Income Dynamics (Altonji and Devereux 1999) and the establishment data underlying the Employment Cost Index (Lebow, Saks, and Wilson 1999). Both studies find significant resistance to nominal wage cuts in U.S. labour markets. It would be very surprising if the same degree of resistance would be absent from Canadian markets.

Second, it is true that there is a lack of microeconomic evidence concerning disemployment effects of downward nominal-wage rigidity in Canadian union contract data specifically. But this data set is totally unreliable for studying the question. The reporting error for the employment data is large, few controls are available, and only 10 per cent of total Canadian employment is covered. Furthermore, even if there were no disemployment effects from downward nominal-wage rigidity whatsoever, this would in no way constitute evidence against its potential macroeconomic consequences. The salient fact here is that downward nominal-wage rigidity reduces the anti-inflationary effects of any given level of aggregate unemployment. It is for this reason that the monetary authority has to increase unemployment permanently in order to achieve the pre-set inflation target. The main channel of influence on employment is *macroeconomic*. It results from aggregate demand restriction. The *microeconomic* channel, which works through real-wage changes, does not even need to be operative.

Third, downward nominal-wage rigidity has a clear and strong implication for the Phillips curve: that the coefficients of *all* its right-hand variables should decrease homothetically as one goes from a high- to a low-inflation period. Akerlof, Dickens, and Perry's second theory about near-rational partial neglect of inflation then predicts a further drop in the parameters of the inflation process, $b_1(L)$ and b_2. So far, however, macroeconomic studies attempting to test downward nominal-wage rigidity inside and outside the Bank (e.g., Beaudry and Doyle 2001; Farès and Lemieux 2001) have investigated the parametric stability of a single coefficient, that of unemployment (or the output gap). They have not produced the required evidence against the two candidate theories.

Fourth, in flatly rejecting the idea that partial neglect of inflation might be a permanent feature of the economy, the Bank has taken the doctrinal stance that any theory suggesting that real and money variables are not perfectly dichotomous in the long run must be wrong. I would instead see this as an empirical question. The question of whether fairness-motivated resistance to

absolute wage cuts, and near-rational rule-of-thumb behaviour, are permanent features of modern economies cannot be settled by doctrinal statements about what is or is not "rational," but only by reading and interpreting the factual evidence.

Conclusion

The volume and quality of research on the inflation-unemployment trade-off done at the Bank of Canada in the past three decades has been impressive. This should not come as a surprise. The Research Department of the Bank has simply been for many years the best applied macroeconomics department in the country.

Bank researchers have brought major advances in our understanding of the inflation process. The first was Chuck's demonstration in 1976, following Governor Rasminsky's intuition of 1963, that the Canadian Phillips curve was vertical in the long run, at least in the range of inflation rates experienced during the 1970s. The second important development—a distinctive Canadian innovation—was the focus on policy-induced changes in the NAIRU as could have arisen, say, from unemployment insurance reform and high provincial minimum wages. A third major contribution was the work on the existence and policy consequences of non-linearities in the short-run inflation-unemployment trade-off. This effort was started by Bank researchers in Ottawa, and later expanded by them and colleagues at the IMF in Washington. A fourth characteristic of Bank research on the Phillips curve has been its pragmatic approach to the modelling of inflation dynamics. It has never held the extreme view that disinflation could take place without pain, given a high enough degree of central bank credibility. It has also avoided taking the opposite view that wage and price behaviour would be so rigidly adaptive that no particular context—no "big event," for example—could ever reduce the sacrifice ratio.

The coming years will be exciting in the area of Phillips curve research. Most pressing is the need for clarifying the role and interpretation of inertia and expectations in the inflation process, for selecting the "right" activity variable, for modelling the NAIRU explicitly, and for exploring the ideas of short- and long-run non-linearity more fully. No one should doubt that Bank researchers will remain at the forefront of this effort.

Critics will point out that the research put out by the Bank on the inflation-unemployment trade-off has usually leaned to the conservative side. In Bank documents, fighting unemployment does not seem to carry the same urgency as fighting or preventing inflation. For example, in the 1980s, the Bank's estimate of the NAIRU was the highest around. Then, its estimate of the

sacrifice ratio was the lowest. Later, in the 1990s, non-linearities were seen as a justification for adopting a strongly pre-emptive posture to prevent inflation from rising again. Next, the enigma of the missing deflation was resolved by arguing that it was simply a benefit derived from the Bank's inflation-targeting strategy. Finally, any thought that the negatively sloped long-run Phillips curve has returned and that very low inflation has to be paid for by permanently higher unemployment has been dismissed in strong terms.

I agree that the Bank of Canada is a very conservative institution, more so than the U.S. Federal Reserve. But there is no outrage, provided there are appropriate counterweights. My concern is that theoretical, empirical, and policy debates about macroeconomic objects such as the Phillips curve and about monetary policy in general remain rich, open, and lively inside the Bank and outside as well. As an academic turned central banker, Chuck has always put a lot of effort in achieving this objective. He was a strong supporter of the Bank's annual conferences from the start. He sometimes went out to chide Canadian academics for their lack of interest in Canadian economic problems and policies. He was right to do so. This is a key reason why he will be so sorely missed.

References

Akerlof, G.A., W.T. Dickens, and G.L. Perry. 1996. "The Macroeconomics of Low Inflation." *Brookings Papers on Economic Activity* (1): 1–59.

———. 2000. "Near-Rational Wage and Price Setting and the Long-Run Phillips Curve." *Brookings Papers on Economic Activity* (1): 1–44.

Akerlof, G.A., A.K. Rose, and J.L. Yellen. 1988. "Job Switching and Job Satisfaction in the U.S. Labor Market." *Brookings Papers on Economic Activity* (2): 495–582.

Akerlof, G.A. and J.L. Yellen. 1985. "A Near-Rational Model of the Business Cycle, with Wage and Price Inertia." *Quarterly Journal of Economics* (Supplement), 100 (5): 823–38.

Altonji, J.G. and P.J. Devereux. 1999. "The Extent and Consequences of Downward Nominal Wage Rigidity." NBER Working Paper No. 7236.

Ball, L. 1994. "What Determines the Sacrifice Ratio?" In *Monetary Policy*, edited by N.G. Mankiw, 155–82. Chicago: University of Chicago Press.

Bank of Canada. 1964. *Evidence of the Governor Before the Royal Commission on Banking and Finance*. Ottawa: Bank of Canada.

———. 2001a. *Renewal of the Inflation-Control Target: Background Information*. Ottawa: Bank of Canada.

Bank of Canada. 2001b. "Technical Background Document 1: A Brief Review of the Literature on Whether a Low-Inflation Regime Leads to Economic Difficulties." *Bank of Canada Review* (Summer): 64–66.

Beaudry, P. and M. Doyle. 2001. "What Happened to the Phillips Curve in the 1990s in Canada?" In *Price Stability and the Long-Run Target for Monetary Policy*, 51–82. Proceedings of a seminar held by the Bank of Canada, June 2000. Ottawa: Bank of Canada.

Blinder, A.S. 1998. *Central Banking in Theory and Practice*. Cambridge, MA: MIT Press.

Bodkin, R.G., E.P. Bond, G.L. Reuber, and T.R. Robinson. 1966. *Price Stability and High Employment: The Options for Canadian Economic Policy, An Econometric Study.* Special Study No. 5, Economic Council of Canada. Ottawa: Queen's Printer.

Brainard, W.C. and G.L. Perry. 2000. "Making Policy in a Changing World." In *Economic Events, Ideas, and Policies: The 1960s and After*, edited by G.L. Perry and J. Tobin, 43–69. Washington, DC: Brookings Institution.

Coletti, D., B. Hunt, D.E. Rose, and R. Tetlow. 1996. *The Bank of Canada's New Quarterly Projection Model, Part 3. The Dynamic Model: QPM*. Technical Report No. 75. Ottawa: Bank of Canada.

Cozier, B. and G. Wilkinson. 1991. *Some Evidence on Hysteresis and the Costs of Disinflation in Canada*. Technical Report No. 55. Ottawa: Bank of Canada.

Debelle, G. 1996. "The Ends of Three Small Inflations: Australia, New Zealand and Canada." *Canadian Public Policy/Analyse de politiques* 22 (1): 56–78.

Duguay, P. 1994. "Empirical Evidence on the Strength of the Monetary Transmission Mechanism in Canada: An Aggregate Approach." *Journal of Monetary Economics* 33 (1): 39–61.

Dupasquier, C. and N. Girouard. 1991. "Une nouvelle courbe de Phillips au Canada." Unpublished paper. Ottawa: Bank of Canada.

Eller, J.W. and R.J. Gordon. 2002. "Inflation and Unemployment in the New Economy: Is the Trade-off Dead or Alive?" Paper presented at a workshop on *The Phillips Curve: New Theory and Evidence*. Stockholm: Trade Union Institute for Economic Research.

Farès, J. and T. Lemieux. 2001. "Downward Nominal-Wage Rigidity: A Critical Assessment and Some New Evidence for Canada." In *Price Stability and the Long-Run Target for Monetary Policy*, 3–31. Proceedings of a seminar held by the Bank of Canada, June 2000. Ottawa: Bank of Canada.

Fellner, W. 1979. "The Credibility Effect and Rational Expectations: Implications of the Gramlich Study." *Brookings Papers on Economic Activity* 1 (79): 167–78.

Fillion, J.-F. and A. Léonard. 1997. "La courbe de Phillips au Canada : un examen de quelques hypothèses." Working Paper No. 97–3. Ottawa: Bank of Canada.

Freedman, C. 1976. "The Phillips Curve in Canada." Research Memorandum 76–189. Ottawa: Bank of Canada.

———. 1977. *Models of Inflation: A Taxonomy of Effects*. Technical Report No. 8. Ottawa: Bank of Canada.

——— (with F. Scotland). 1978. "Gradualism: Theory and Practice." In *Issues in Canadian Public Policy (I)*. Proceedings of a conference held at the Donald Gordon Centre, 43–51. Institute for Economic Research. Kingston, ON: Queen's University.

———. 1990. "La politique monétaire des années 90 : leçons et enjeux." *L'actualité économique* 66 (2): 147–86.

———. 2001. "Inflation Targeting and the Economy: Lessons from Canada's First Decade." *Contemporary Economy Policy* 19 (1): 2–19.

Friedman, M. 1968. "The Role of Monetary Policy." *American Economic Review* 58 (1): 1–17.

Fuhrer, J.C. 1997. "The (Un)Importance of Forward-Looking Behavior in Price Specifications." *Journal of Money, Credit and Banking* 29 (3): 338–50.

Gordon, R.J. 1977. "The Theory of Domestic Inflation." *American Economic Review* 67 (1): 128–34.

———. 1997. "The Time-Varying NAIRU and Its Implications for Economic Policy." *Journal of Economic Perspectives* 11 (1): 11–32.

Guay, A., R. Luger, and Z. Zhu. 2003. "The New Phillips Curve in Canada." In *Price Adjustment and Monetary Policy,* 59–94. Proceedings of a conference held by the Bank of Canada, November 2002. Ottawa: Bank of Canada.

Helliwell, J.F., L.H. Officer, H.T. Shapiro, and I.A. Stewart. 1969. "Econometric Analysis of Policy Choices for an Open Economy." *Review of Economics and Statistics* 51 (4): 383–98.

Howitt, P. 1997. "Low Inflation and the Canadian Economy." In *Where We Go from Here*, edited by D. Laidler, 27–67. Toronto: C.D. Howe Institute.

Johnson, D.R. and S. Gerlich. 2002. "How Has Inflation Changed in Canada? A Comparison of 1989–2001 to 1964–1988." *Canadian Public Policy/ Analyse de politiques* 28 (4): 563–79.

Khalaf, L. and M. Kichian. 2003. "Testing the Stability of the Canadian Phillips Curve Using Exact Methods." Working Paper No. 2003–7. Ottawa: Bank of Canada.

Kichian, M. 2001. "On the Nature and Stability of the Canadian Phillips Curve." Working Paper No. 2001–4. Ottawa: Bank of Canada.

Laidler, D.E.W. and W.B.P. Robson. 1993. *The Great Canadian Disinflation: The Economics and Politics of Monetary Policy in Canada, 1988–93*. Toronto: C.D. Howe Institute.

Laxton, D., D. Rose, and R. Tetlow. 1993a. "Is the Canadian Phillips Curve Non-Linear?" Working Paper No. 93–7. Ottawa: Bank of Canada.

———. 1993b. *Monetary Policy, Uncertainty, and the Presumption of Linearity.* Technical Report No. 63. Ottawa: Bank of Canada.

Lebow, D.E., R.E. Saks, and B.A. Wilson. 1999. "Downward Nominal Wage Rigidity: Evidence from the Employment Cost Index." Finance and Economics Discussion Series 1999–31. Washington: Board of Governors of the Federal Reserve System.

Lipsey, R.G. 1960. "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1862–1957: A Further Analysis." *Economica* 27 (105): 1–31.

Lucas, R.E. and T.J. Sargent. 1978. "After Keynesian Macroeconomics." In *After the Phillips Curve: Persistence of High Inflation and High Unemployment*. Boston: Federal Reserve Bank of Boston.

Macklem, T. 1997. "Capacity Constraints, Price Adjustment, and Monetary Policy." *Bank of Canada Review* (Spring): 39–56.

Mankiw, N.G. 2001. "The Inexorable and Mysterious Tradeoff Between Inflation and Unemployment." *Economic Journal* 111 (471): 45–61.

Mankiw, N.G. and R. Reis. 2002. "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve." *Quarterly Journal of Economics* 117 (4): 1295–328.

Mankiw, N.G. and W. Scarth. 2001. *Macroeconomics*. 2nd Canadian Edition. New York: Worth Publishers.

Modigliani, F. and L. Papademos. 1975. "Targets for Monetary Policy in the Coming Year." *Brookings Papers on Economic Activity* (1): 141–65.

Okun, A.M. 1978. "Efficient Disinflationary Policies." *American Economic Review* 68 (2): 348–52.

Phelps, E.S. 1967. "Phillips Curves, Expectations of Inflation and Optimal Unemployment Over Time." *Economica* 34 (3): 254–81.

Phillips, A.W. 1958. "The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861–1957." *Economica* 25 (100): 283–99.

Rasminsky, L. 1966. “The Role of the Central Banker Today.” Per Jacobsson Memorial Lecture. Ottawa: Bank of Canada.

Reuber, G.L. 1964. “The Objectives of Canadian Monetary Policy, 1949–61: Empirical ‘Trade-Offs’ and the Reaction Function of the Authorities.” *Journal of Political Economy* 72 (2): 109–32.

Roberts, J.M. 1997. “Is Inflation Sticky?” *Journal of Monetary Economics* 39 (2): 173–96.

Rose, D.E. 1988. *The NAIRU in Canada: Concepts, Determinants and Estimates*. Technical Report No. 50. Ottawa: Bank of Canada.

Samuelson, P.A. and R.M. Solow. 1960. “Analytical Aspects of Anti-Inflation Policy.” *American Economic Review* 50 (2): 177–94.

St-Amant, P. and D. Tessier. 2000. “Résultats empiriques multi-pays relatifs à l’impact des cibles d’inflation sur la crédibilité de la politique monétaire.” *Canadian Public Policy/Analyse de politiques* 26 (3): 295–310.

Solow, R.M. 1976. “Down the Phillips Curve with Gun and Camera.” In *Inflation, Trade and Taxes: Essays in Honor of Alice Bourneuf*, edited by D.A. Belsley, E.J. Kane, P.A. Samuelson, and R.M. Solow, 3–22. Columbus, OH: Ohio State University Press.

Staiger, D., J.H. Stock, and M.W. Watson. 2001. “Prices, Wages and the U.S. NAIRU in the 1990s.” NBER Working Paper No. 8320.

Stiglitz, J. 1997. “Reflections on the Natural Rate Hypothesis.” *Journal of Economic Perspectives* 11 (1): 3–10.