The Possible Unemployment Cost of
Average Inflation below a Credible Target [*]

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Abstract

The Riksbank in 1993 announced an official target for annual CPI inflation of 2 percent to apply from 1995. Over the 15 years since then, 1997-2011, average CPI inflation has equaled 1.4 percent and has thus fallen short of the target by 0.6 percentage points. In contrast, in Australia, Canada, and the U.K., which have had a fixed inflation target as long as Sweden, average inflation has been on or very close to the target. Has this undershooting of the inflation target in Sweden had any costs in terms of higher average unemployment? This depends on whether the long-run Phillips curve in Sweden is vertical or not. During 1997-2011, average inflation expectations have been close to the target. The inflation target has thus been credible. If inflation expectations are anchored to the target also when average inflation deviates from the target, the long-run Phillips curve is no longer vertical but downward-sloping. Then average inflation below the credible target means that average unemployment is higher than it would have been if average inflation had been on target. The data indicate that the average unemployment rate has been about 0.8 percentage points higher. This is a large unemployment cost of undershooting the inflation target. Some simple robustness tests indicate that the estimate of the unemployment cost is rather robust, but the estimate remains preliminary and further scrutiny may be needed to assess its robustness.

JEL Classification: E24, E31, E52, E58

The Riksbank in 1993 announced an official target for annual CPI inflation of 2 percent, to apply from 1995. By 1997, the new inflation-targeting regime had been established, in the sense that the inflation target was credible (inflation expectations were in line with the target), the repo rate (the Riksbank's policy rate) had been lowered to a normal level, and the Riksbank had had a few years to learn how to conduct inflation targeting. Over the 15 years since then, 1997-2011, average CPI inflation has equaled 1.4 percent and has thus fallen short of the target by 0.6 percentage points (pp). In contrast, in Australia, Canada, and the U.K., which have had a fixed inflation target as long as Sweden, average inflation has been on or very close to the target. Has this undershooting of the inflation target in Sweden had any costs in terms of higher average unemployment? This depends on whether the long-run Phillips curve in Sweden is vertical or not. During 1997-2011, inflation expectations in Sweden have been anchored to the inflation target, in the sense that average inflation expectations have been close to the target. The inflation target has thus been credible. If inflation expectations are anchored to the target also when average inflation deviates from the target, the long-run Phillips curve is no longer vertical but downward-sloping. Then average inflation below the credible target means that average unemployment is higher than it would have been if average inflation had been on target. The data indicate that the average unemployment rate has during 1997-2011 been 0.8 pp higher. This is a large unemployment cost of undershooting the inflation target. Some simple robustness tests indicate that the estimate of the unemployment cost is rather robust, but the estimate is preliminary and further scrutiny is needed to assess its robustness.

The paper is outlined as follows: Section 1 discusses inflation and inflation expectations in Sweden since the inflation target was introduced. Section 2 compares with the inflation outcome in Australia, Canada, and the U.K., which have had a fixed inflation target as long as Sweden, and with the inflation outcome in the euro area and the United States. Section 3 discusses non-rational inflation expectations and wage-setting in Sweden. Section 4 estimates a short- and a long-run Phillips curve for Sweden. Section 5 discusses the unemployment cost of average inflation below the inflation target. Section 6 conducts some robustness tests. Section 7 estimates a long-run Phillips curves for the U.S. for 2000-2011 and shows that it is non-vertical and downward-sloping, something that Fuhrer (2011) has noted. Section 8 does the same for Canada for 1997-2012. Since average inflation has been equal or close to a widely held perception of an unofficial Federal Reserve inflation target of about 2 percent and an official Bank of Canada inflation target of 2 percent, there is no unemployment cost of average inflation below target in these countries. Section 9 concludes. Appendices A1-A4 provide some details.


1. Average inflation below and average inflation expectations on the target

Figure 1 shows quarterly data from 1996 through 2011 of real-time annual CPI inflation, inflation expectations from the survey the Riksbank has commissioned from TNS Sifo Prospera of annual CPI inflation one and two years ahead, and the unemployment rate (15-74 age group). Throughout this paper I assume that the TNS Sifo Prospera survey is representative of private-sector inflation expectations in Sweden.[1]

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[1] In 1995 the Riksbank commissioned Prospera Research (now TNS Sifo Prospera) to conduct a survey of the expectations of inflation and wage increases of a panel of labor market organizations, purchase managers, and money-market players. The first report was published in November, 1995. Initially the survey was to be published three times a year, but from 1996 the survey was conducted quarterly. Later the survey was expanded to include

During the period 1997-2011, average real-time CPI inflation has equaled 1.43 percent, thus undershooting the target of 2 percent by about 0.6 pp. Average revised CPI inflation was even lower, 1.31 percent during the same period. For the purposes of this paper, real-time inflation is arguably more appropriate. It was measures of real-time inflation that was published and discussed and influenced expectations and wage formation.[2] In any case, since average real-time inflation is closer to the target, using real-time rather than revised inflation avoids exaggerating the effects of inflation below the target.

Figure 1. Annual CPI inflation, CPI inflation expectations one and two years ahead (Prospera, all interviewees), and unemployment (15-74 age group).
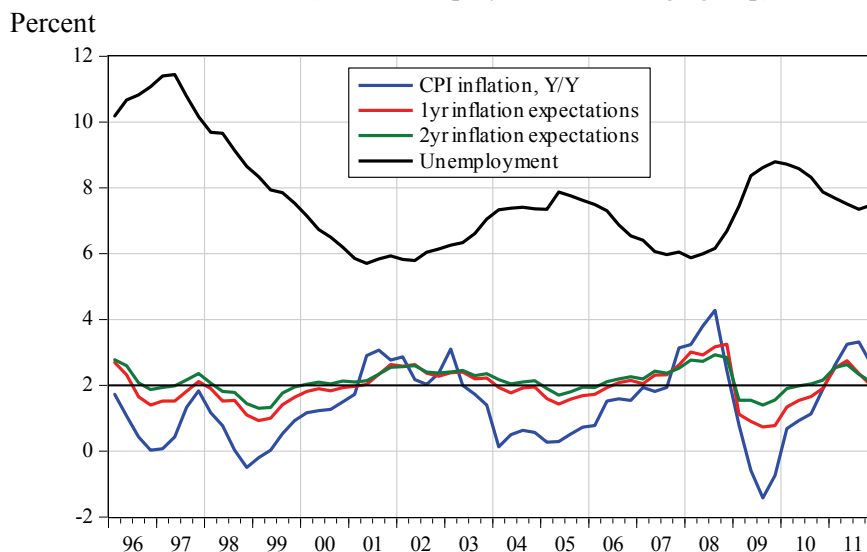
Sources: Statistics Sweden and TNS Sifo Prospera.

As seen in figure 1, one- and two-year-ahead inflation expectations collected by Prospera are close to 2 percent from the second half of 1996 onwards. A different series of inflation expectations with earlier observations, collected by Aragon Securities Fondkommission and referring to expectations of money-market participants only, is shown in figure 2, together with annual CPI inflation, unemployment, and the repo rate (the Riksbank's policy rate). The red curve shows expectations of average inflation for the next two years. The green curve shows expectations of average inflation during the next five years. We see that the credibility of the inflation target was quite low after its announcement in January 1993. The expected average inflation for the next five years was about 4 percent through the first half of 1995. Only toward the end of 1996 are the expected average inflation for the next two and the next five years both close to 2 percent.

The high inflation expectations before 1997 mean that, everything else equal, tighter monetary policy and higher unemployment is needed to bring inflation close to the target. From 1997 onwards, inflation expectations are close to two percent, and this reason for tighter policy no longer applies. Furthermore,

expectations of future GDP growth and repo rates and for money-market players also expectations of future 5-year government bond rates and USD and EUR exchange rates.

[2] As is explained in Sveriges Riksbank (2004), before 2005, CPI inflation was measured by Statistics Sweden not as the annual percentage increase in the CPI but with a method that excluded substitution effects on the composition of the basket, making measured inflation on average 0.2 pp higher. From 2005, CPI inflation is measured as the annual percentage change in the CPI.

figure 2 shows that the repo rate by early 1997 had been lowered to a normal level, 4 percent. Also, by 1997, the Riksbank had had a few years to learn how to conduct monetary policy under inflation targeting.[3] By 1997, the new inflation-targeting regime had established itself. Therefore, it is relevant to scrutinize monetary policy from 1997 and onwards.[4]

Figure 2. Annual CPI inflation, expectations of average CPI inflation the next 2 and 5 years (Aragon), unemployment (15-74 age group), and the repo rate
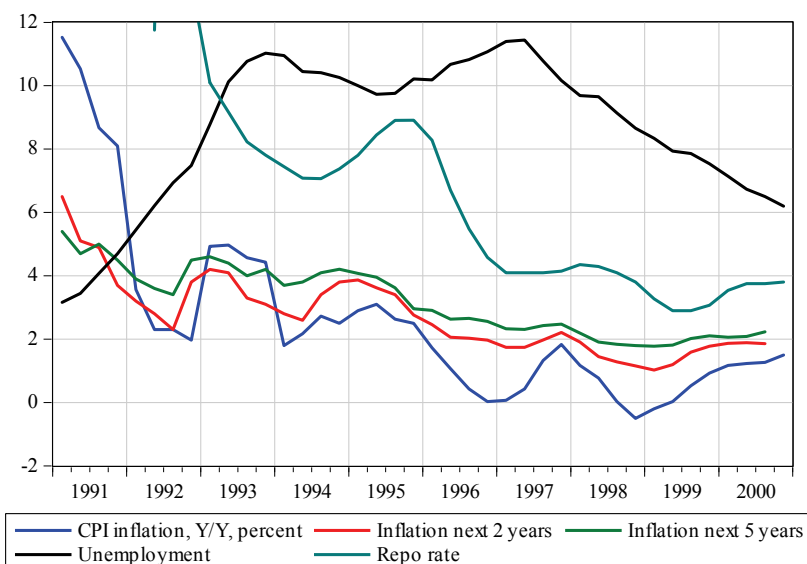
Source: Statistics Sweden, Aragon Securities Fondkommission, Stockholm, and the Sveriges Riksbank

Thus, both the Prospera and Aragon series indicate that inflation expectations were anchored to the inflation target from 1997, but not before, in the sense that average inflation expectations were close to the target. Figure 3 shows five-year moving averages of inflation expectations one and two years ahead and real-time CPI inflation.

For the period 1997-2011, average inflation expectations one and two years ahead are 1.94 and 2.13 percent, respectively. My starting point is therefore that during 1997-2011 inflation expectations have on average equaled the target of 2 percent and that average CPI inflation has fallen 0.6 pp below target. Before examining the consequences of this further, let me compare average inflation in Sweden with average inflation in other countries with a fixed inflation target as long as Sweden.

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[3] The paper Svensson (1997) about the principles of inflation targeting was written in 1996 when I was an advisor the Riksbank and was much stimulated by several meetings with Riksbank staff and management in which the principles of inflation targeting were being debated and developed. These principles were, as far as I can remember, gradually applied from 1997 and onwards.
[4] Andersson, Palmqvist, and Österholm (2012) discuss the inflation target attainment of the Riksbank for the period 1995-2011, note that average real-time CPI inflation was 1.5 percent during this period, but do not discuss the consequences for average unemployment of undershooting the target. In order to discuss the consequences for average unemployment, it would be misleading to include the period 1995-1997 in the sample, since inflation expectations exceeded the inflation target before 1997. For the sample 1995-2011, the long-run Phillips curve is flatter than the benchmark and the excess average unemployment is larger, even if the smaller undershooting of 0.5 percentage point is used. The average real-time CPI inflation is 1.4 percent for the both the samples 1996-2011 and 1997-2011.

Figure 3. CPI inflation expectations one and two years ahead (all interviewees) and CPI inflation, five-year moving averages.

Sources: Statistics Sweden and TNS Sifo Prospera.
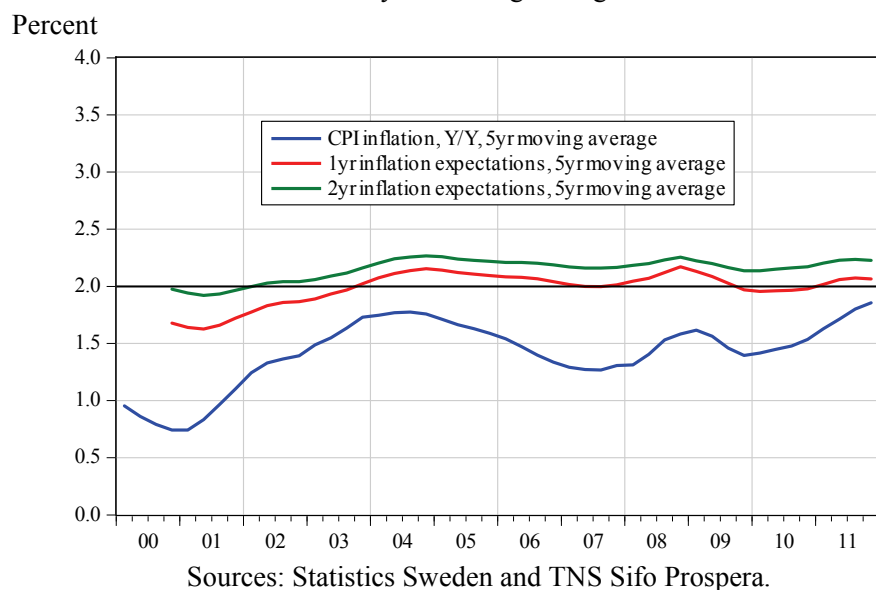
2. Inflation in other countries with a fixed inflation targets as long as Sweden

One cannot of course expect average inflation to have been exactly on target over a period of about 15 years. To get an idea of what is possible, however, we can compare average inflation in Sweden to average inflation in other countries that have had a fixed inflation target as long as Sweden, that is, since the early 1990s. Those countries are Australia, Canada, and the U.K. The first country to introduce explicit inflation targeting was New Zealand in 1990, but its inflation target has not been fixed but adjusted up twice, making the comparison less straightforward. Therefore it is not included in the comparison. It is also reasonable to exempt the very first years of the new inflation-targeting regime for Sweden and other countries, given the regime some time to become establish and the central bank to gains some experience. I therefore compare average inflation over the same period as for Sweden, 1997-2011.

The comparison is summarized in table 1. Australia has had an inflation target since mid-1993. The target is to achieve an average CPI inflation rate of between 2 and 3 percent over the business cycle. As shown in the table, average CPI inflation over 1997-2011 has been 2.7 percent, exceeding the midpoint of the target range by 0.2 pp. Canada has had an inflation target since 1991, which from the end of 1995 is 2 percent for CPI inflation. Average CPI inflation over 1997–2011 is 2.0 percent.

The U.K. has had an inflation target from the end of 1992, which was however somewhat modified at the end of 2003. Up to the end of 2003, the U.K. inflation target was 2.5 percent for the RPIX price index.[5] Average RPIX inflation over 1997–2003 was 2.5 percent. With effect from 2004 the inflation target has been 2 percent for the CPI price index. I do not regard that as any significant change in the inflation target, since CPI inflation has on average been about 0.75 pp lower than RPIX inflation.[6] The average CPI

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[5] In the period 1992-1996 the target was expressed as 2.5 percent *or lower* in terms of the RPIX price index.
[6] The CPI price index in the U.K. is the same as the HICP price index. Since 1993 average CPI inflation has been 0.75 pp lower than average RPIX inflation.

inflation rate over 2004–2007 was 2.0 percent, while the average over the crisis years 2008–2011 is higher, at 3.4 percent. However, given the high unemployment rate in the United Kingdom during the crisis, optimal policy implies that inflation should overshoot the target. As noted previously, one might argue that the crisis years are special and could be excluded. If they are excluded for Sweden, the average CPI inflation rate over 1997-2007 was 1.3 percent, 0.7 pp below the target.

Table 1. Inflation target, average inflation, and average deviation from target for Australia, Canada, Sweden, and the U.K.; implicit inflation target and average inflation for the euro area and the U.S

Country	Target	Index	Period	Average	Average less target
Australia	2–3	CPI	1997–2011	2.7	0.2
Canada	2	CPI	1997–2011	2.0	0.0
Sweden	**2**	CPI	1997-2011	**1.4**	**−0.6**
Sweden	**2**	CPI	1997-2007	**1.3**	**−0.7**
U.K.	2.5 (1992–2003)	RPIX	1997-2003	2.4	−0.1
	2 (2004–)	CPI	2004–2007	2.0	0.0
	2 (2004–)	CPI	2008–2011	3.4	1.4
Euro area	(< 2)	HICP	2000–2011	2.1	
U.S.	(≤ 2)	Core CPI	2000–2011	2.0	
	(≤ 2)	Core PCE	2000–2011	1.9	

Source: Reuters Ecowin and Statistics Sweden

How have things turned out for the large economies, the euro area and the United States? The euro area has had a target for inflation, although during a shorter period than the countries mentioned earlier. The target is that HICP inflation should be below but close to 2 percent. The average HICP inflation rate in the euro area in the period 2000-2011 was 2.1 percent. The United States, on the other hand, did not have an official inflation target until the Federal Reserve announced a target of 2 percent for PCE inflation in January 2012.[7] However, a widely held perception is that the Federal Reserve even prior to this had an unofficial target for core inflation of about 2 percent (Fuhrer 2011, p. 5). The average for core CPI inflation in the United States in the period 2000-2011 was 2.0 percent and for core PCE inflation 1.9 percent.

In this comparison, Sweden stands out, with average CPI inflation having significantly undershot the inflation target, whereas for the other countries average inflation has been quite close to the target or slightly overshot the target (except the U.K. for 2008–2011 when inflation substantially overshot the target).

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[7] PCE inflation is inflation measured with the personal consumption expenditure deflator.

3. Non-rational expectations and wage-setting in Sweden

The average inflation expectations reported in figure 1 are economically and statistically significantly above average inflation.[8] The inflation expectations are not rational, as shown in detail by Jonsson and Österholm (2012). Perhaps they are "near-rational" as in in Akerlof, Dickens, and Perry (2000) (ADP).

In ADP, near-rational behavior means that, when inflation does not deviate too much from zero, a significant fraction of the private sector neglects inflation and behaves as if it would equal zero. When inflation rises sufficiently above zero, an increasing fraction of the private sector becomes rational and has rational expectations. The result is a long-run Phillips curve, reproduced in figure 4. The long-run Phillips curve is vertical for high inflation rates, for which the long-run unemployment rate equals the rational-expectations steady-state rate, what is often called the (long-run) "natural rate" and what I also call the "long-run sustainable unemployment rate".[9] For low positive inflation rates, the long-run Phillips curve has a hump to the left and the long-run unemployment rate is lower than the natural rate. For zero inflation, the long-run unemployment rate is again equal to the natural rate.[10]

Figure 4. The long-run Phillips curve of Akerlof, Dickens, and Perry.

Figure 1. A Hypothetical Long-Run Phillips Curve
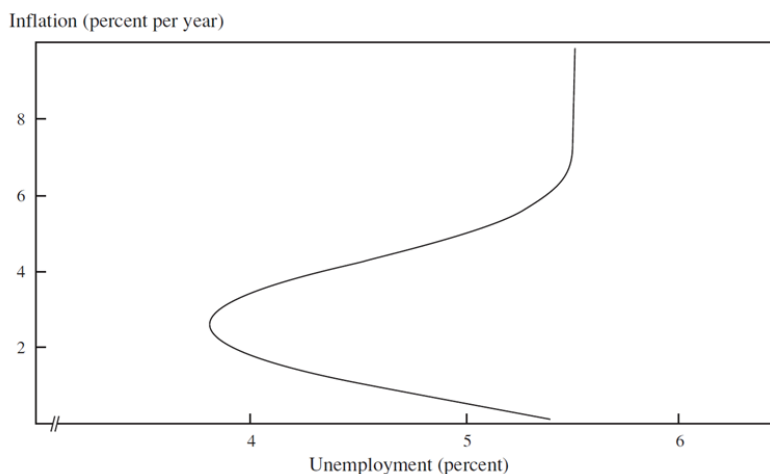
Source: Authors' calculations from calibration of the theoretical model.

Source: Akerlof, Dickens, and Perry (2000, figure 1).

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[8] A regression 1997-2011 of one-year-ahead inflation expectations less CPI inflation on a constant results in the constant 0.51 and a Newey-West standard error (lag 4) of 0.16.

[9] As Rogerson (1997) points out, there are different definitions of "the natural rate of unemployment", but he convincingly claims that the only definition of equilibrium unemployment that is well-specified and unambiguous is the one corresponding to unemployment in a steady state (with the understanding that expectations are rational in the steady state). The literature contains different definitions of short-run and time-varying equilibrium unemployment, such as short-run NAIRU (short-run Non-Acceleration Inflation Rate of Unemployment – the rate of unemployment that will lead to a constant rate of inflation in the short run) and flex-price unemployment (the rate of unemployment that would arise if prices and wages were flexible). These definitions are in practice very dependent on models and not very robust for monetary-policy purposes, as they rely on such a large number of assumptions.

[10] Lundberg and Sacklén have estimated the ADP long-run Phillips curve on Swedish data. Bryan and Palmqvist (2010) test some particular hypotheses that follow from the ADP assumptions.

In the present context, near-rational behavior would mean that, when average inflation does not deviate too much from the inflation target of 2 percent, a significant fraction of the private sector neglects that deviation and behaves as if average inflation would equal the inflation target. A possible explanation is that this fraction of the private sector may have been more influenced by the Riksbank's communication of the inflation target of 2 percent than by actual average inflation. Thus, whereas near-rational behavior in ADP is with reference to zero inflation, here it would be with reference to the inflation target of 2 percent.

Central wage negotiations are important for wage-setting in Sweden. The so-called Industrial Agreement has been in force since 1997 and has become an important institution in Swedish wage formation. The Industrial Agreement came into being after the round of collective bargaining in 1995 when the social partners failed to co-ordinate their negotiations. Co-ordination has improved since the Industrial Agreement was signed and collective agreements in the manufacturing industry have become the norm for other contractual areas. (Sveriges Riksbank 2011)

In particular, central wage negations in Sweden start from an assumption that the Riksbank will attain its inflation target and that CPI inflation will be 2 percent, regardless of what actual inflation is or has been. This is can be seen in documents about the principles of wage negotiations from the Swedish Trade Union Confederation (Morin 2009):

> During the years 1995-2008 the CPI has on average increased by 1.4 percent… That the price increase has fallen short of the inflation target should not be the starting point for a future assessment. Instead, the reference point for wage formation should be that the Riksbank will attain the inflation target of 2 percent… (Morin 2009, p. 15, translated from Swedish)

More recently, the Industrial Trade Unions expressed similar principles in their wage-settlement policy platforms before the wage-negotiations in 2011 and 2012-203 (Facken inom industrin 2011, 2012).

> [The Riksbank's inflation target] is an important starting point for the labor-market parties when they negotiate about new wages. …
>
> The parties should in negotiations about new wage settlements act as if the Riksbank will attain its inflation target…
>
> Inflation sometimes displays large fluctuations around the Riksbank's inflation target… Should the labor market parties when assessing the room for wage increases try to take such temporary fluctuations into account, wage formation would become very unstable.
>
> While acting as if the Riksbank will attain its inflation target, the parties contribute to inflation expectations around 2 percent. … (Facken inom industrin 2011, p. 6-7, translated from Swedish)

Thus, according to these quotations central wage negotiations in Sweden are conducted with inflation expectations equal to 2 percent, regardless of the fact that average inflation has fallen short of 2 percent and regardless of whether actual inflation deviates from the Riksbank's inflation target at the time of the negotiations.

Suppose that nominal wages are set in negotiations a year in advance to achieve a particular target real wage next year at the price level expected for that year. If inflation expectations are equal the inflation target, the price level expected for next year is the current price level increased by the inflation target. This then together with the target real wage determines the level of nominal wages set for next year. If then actual inflation over the coming year falls short of the inflation target, the price level next year will be lower than anticipated, and the real wage will be higher than the target real wage. This will lead to lower employment and higher unemployment. See appendix A1 for details.[11]

4. The long-run Phillips curve has become downward-sloping

If inflation expectations are anchored on the target in the sense that average inflation expectations equal the target even though average inflation deviates from the target, the long-run expectations-augmented Phillips curve is no longer vertical but downward-sloping.[12] Consider the simplest expectations-augmented Phillips curve,

$$\pi_t = \pi_t^e - \gamma(u_t - u^*) + \varepsilon_t, \tag{1}$$

where π_t denotes inflation in quarter t; π_t^e denotes inflation expectations; u_t denotes the unemployment rate; u^* denotes the natural rate; ε_t denotes possibly serially-correlated cost push shocks with an unconditional mean equal to zero, $\mathrm{E}[\varepsilon_t] = 0$; and γ is a positive constant. For a New Keynesian Phillips curve, π_t^e is the expectation in period t of inflation in period $t + 1$; for a New Classical Phillips curve, π_t^e is the expectations in period $t - 1$ of inflation in period t. Taking the unconditional mean of the Phillips curve (1) then results in the long-run relation between inflation, inflation expectations, and unemployment,

$$\pi = \pi^e - \gamma(u - u^*), \tag{2}$$

where $\pi = \mathrm{E}[\pi_t]$, $\pi^e = \mathrm{E}[\pi_t^e]$, and $u = \mathrm{E}[u_t]$ denote the unconditional means of inflation, inflation expectations and the unemployment rate. Under rational expectations, the unconditional mean of inflation and inflation expectations are equal,

$$\pi = \pi^e, \tag{3}$$

so from (2) and (3) it follows that the unconditional mean of the unemployment rate and the natural rate are equal,

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[11] Flodén (2012) notes that firm's one-year inflation expectations collected and published by the National Institute of Economic Research (NIER) do not on average deviate from actual inflation and that rationality of those inflation expectations cannot be rejected. However, the statements from the Swedish Trade Union Confederation and the Industrial Trade Unions noted above, the fact the TNS Sifo Prospera report inflation expectations of labor market organizations (both for employees and employers) similar to those of all interviewees reported here, and the importance for wage setting of central wage negotiations together indicate that inflation expectations in line with the inflation target are more important than the NIER's firm inflation expectations in affecting wage setting in Sweden.
[12] The anchoring of U.S. inflation expectations to 2 percent and the resulting downward-sloping U.S. Phillips curve have been noted by Fuhrer (2011).

$$u = u^*. \qquad (4)$$

Then the long-run Phillips curve is vertical, the unconditional mean of the unemployment rate is independent of the unconditional mean of inflation, and there is no long-run tradeoff between inflation and unemployment.

However, if the unconditional mean of inflation expectations equals the inflation target, π^*, regardless of the unconditional mean of inflation, the long-run Phillips curve will be

$$\pi - \pi^* = -\gamma(u - u^*). \qquad (5)$$

The long-run Phillips curve is then downward-sloping with (negative) slope γ, and there is a long-run tradeoff between inflation and unemployment. When the average inflation expectations equal the inflation target, average inflation below target will imply average unemployment above the natural rate.[13]

With inflation expectations stuck at the inflation target, the precise steady-state equilibria that result are determined by the aggregate-demand relation in the economy and the central bank's policy rule, as explained in detail in appendix A3.

In order to estimate a long-run inflation Phillips curve, I first estimate a short-run Phillips curve with quarterly real-time seasonally adjusted CPI inflation at an annual rate as the dependent variable and the change in and one lag of unemployment as explanatory variables,[14]

$$\pi_t = \gamma_0 - \gamma_1(u_t - u_{t-1}) - \gamma u_{t-1} + \varepsilon_t, \qquad (6)$$

where the error term ε_t has mean zero and is assumed to be uncorrelated with the unemployment rate and the lagged inflation.[15] That is, unemployment is here assumed to be predetermined one quarter; alternative hypotheses are examined in robustness tests below. The quarterly seasonally adjusted CPI inflation is shown in figure 5.[16]

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[13] This is true if "average" refers to the unconditional mean. If "average" refers to a sample average for a particular sample, it is true if the sample average of the cost-push shocks in (1) is zero. If the sample mean of the shocks is not zero, average inflation below the target implies that average unemployment is higher than what it would have been with the same shocks if average inflation had been equal to the target. See appendix A2 for details.

[14] I find it convenient to express the Phillips curve in terms of inflation deviations from 2 percent. This will only affect the estimate of the intercept, γ_0.

[15] A previous version of the paper estimated a short-run Phillips curve with annual inflation as the dependent variable. Using annual inflation means using overlapping data, which introduces serial correlation in error terms and other econometric complication. Using overlapping data has hardly any advantages according to Harri and Brorsen (2009) compared to using underlying non-overlapping data. In the present case, using quarterly inflation leads to a simpler short-run Phillips curve and is in line with other studies of the Phillips curve. The estimated slope of the long-run Phillips curve is about the same regardless of whether quarterly or annual inflation is used.

[16] The seasonal adjustment of the quarterly inflation is done with EViews and Census X12, additive.

Figure 5. CPI inflation, annual and quarterly seasonally adjusted at annual rate
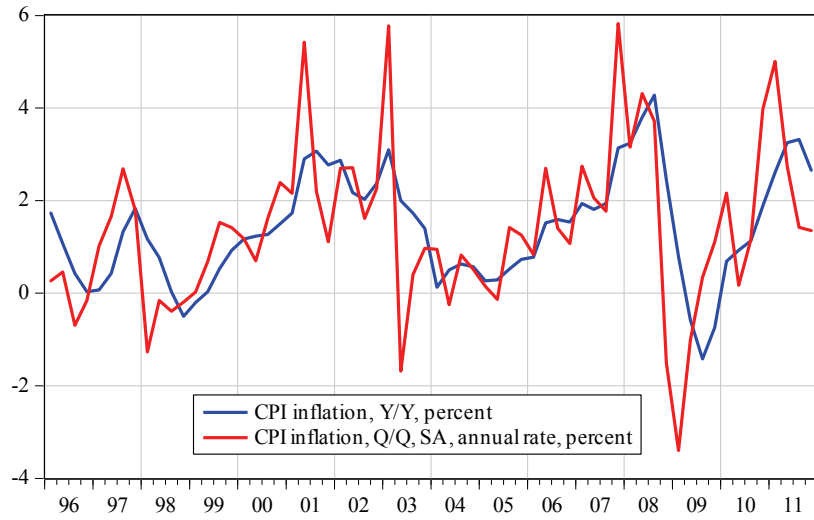
Sources: Statistics Sweden and own calculations.

Taking the unconditional mean of the short-run Phillips curve (6) and using $\pi = \mathrm{E}[\pi_t]$, $u = \mathrm{E}[u_t]$, and $\mathrm{E}[\varepsilon_t] = 0$ then results in the long-run Phillips curve

$$\pi = \gamma_0 - \gamma u, \tag{7}$$

where thus γ is the slope of the long-run Phillips curve.

The result of estimating (6) for the sample 1997Q4-2011Q4 is shown in table 2. The coefficients on the unemployment change and lagged unemployment are highly significant. Serial correlation of the error term can be rejected at the 5 percent confidence level.

Table 2. Short-run Phillips curve, 1997Q4-2011Q4

Coefficient	Estimate	Std. Error	t-Statistic	Prob.
γ_0	7.192254	1.359700	5.289589	0.0000
γ_1	2.700178	0.723132	3.734002	0.0005
γ	0.806734	0.186279	4.330787	0.0001

Note: OLS, $R^2 = 0.30$, adjusted $R^2 = 0.27$, S.E. = 1.53, DW = 1.77.

From the estimates in table 2 it follows that the slope of the long-run Phillips curve is about 0.8. With a standard error of 0.19, it is fairly precisely estimated. A 95-percent confidence interval of the slope is the interval from 0.43 to 1.18. If four lags of inflation are added, a Wald test does not reject the hypothesis that the coefficients on the inflation lags are zero.[17] Clearly, the hypothesis of a vertical Phillips curve, an infinite slope, can be rejected.

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[17] The p-value is about 0.37.

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The rejection of a vertical Phillips curve is in contrast to the case in Rudebusch and Svensson (1999). There, a Phillips curve for the U.S. economy is estimated for the sample 1961Q1-1996Q2. The hypothesis that the coefficients on lagged inflation sum to unity cannot be rejected. Instead, the estimation there is done under the restriction that the coefficients sum to unity and the long-run Phillips curve is vertical.

Figure 6 shows the long-run Phillips curve (7) for the estimates in table 2 (black solid and dashed line) with a scatter plot with quarterly CPI inflation at an annual rate and unemployment for the sample 1997Q4-2011Q4 (red circles with connecting lines). The long-run Phillips curve is solid for average inflation rates less than 1 pp from 2 percent and dashed for average inflation rates farther from 2 percent, in order to emphasize that it is derived under the assumption that average inflation expectations are equal to 2 percent. It may apply only if average inflation does not deviate too far from 2 percent. If average inflation would deviate far from 2 percent, in line with the reasoning of ADP, a higher fraction of the private-sector would have rational expectations and the long-run Phillips curve would bend toward the natural rate.

The slope of the long-run Phillips curve is sensitive to the starting date of the sample. Figure 7 shows the long-run Phillips curve and the scatter plot for the sample 1997Q1-2011Q4, with an earlier sample start. The curve slope is less, 0.46. We see in figure 7 that the observations in early 1997, to the right in the figure with high unemployment and inflation not too far from 2 percent, make a flatter long-run Phillips curve fit better.

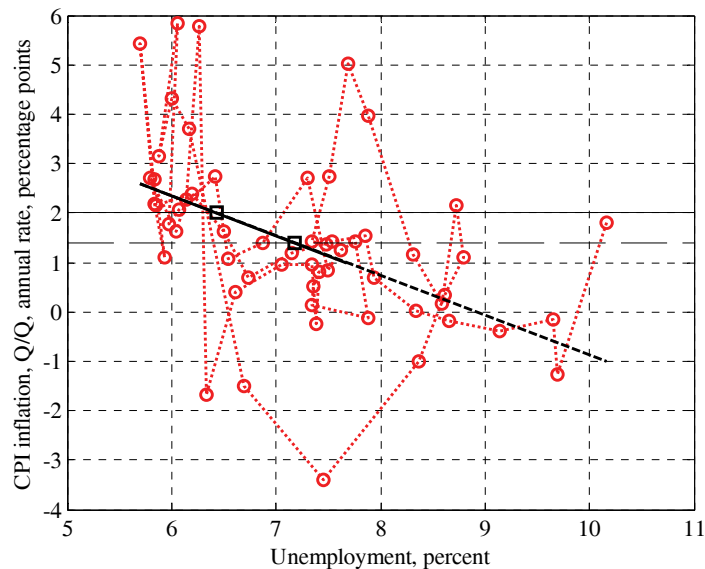Figure 6. The long-run Phillips curve and scatter plot, 1997Q4-2011Q4

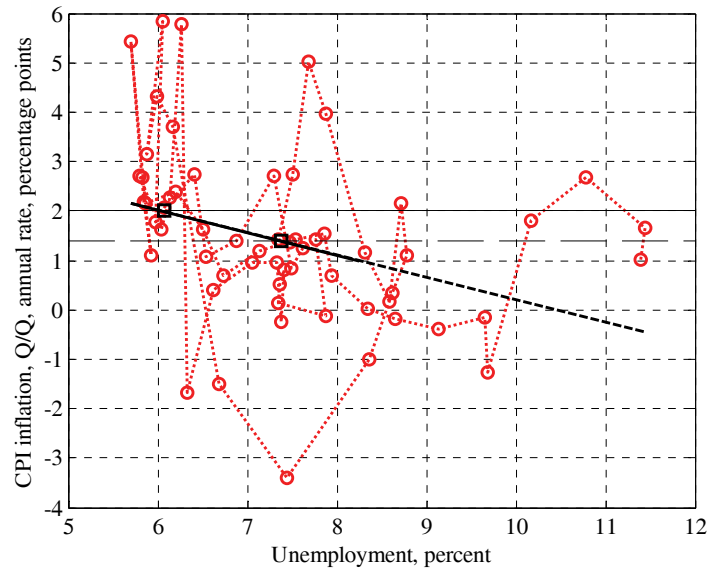Figure 7. The long-run Phillips curve and scatter plot, 1997Q1-2011Q4

Figure 8 shows the slope of the long-run Phillips curve, the coefficient γ, as a function of the sample starting date, with all samples ending 2011Q4. The figure also shows 95-percent confidence intervals (plus/minus two standard errors of the estimate of the slope). The slope varies from a minimum of 0.46 for the sample start 1997Q1 to a maximum of 0.88 for 1998Q1 and then falls to 0.7 for 1999Q2. The average over the sample starts 1997Q1-199Q2 is 0.73. A low slope will result in a high unemployment cost of average inflation below the target, whereas a high slope will result in a low unemployment cost. The highest lower bound of the 95-percent confidence intervals is 0.49 and occurs for the sample start 1998Q1. The lowest higher bound of the 95-percent confidence interval is 0.76 and occurs for 1997Q1. From this, a benchmark of 0.75, a relatively high slope of the long-run Phillips curve, close to the lowest higher bound of the 95-percent confidence interval, seems a rather conservative estimate that will not exaggerate the unemployment cost. It is a bit lower than the slope of the long-run Phillips curve for the sample 1997Q4-2011Q4 reported in table 2 and figure 6.

As a benchmark 95-percent confidence interval around the benchmark slope of 0.75 I will use ± 0.35, that is, the interval [0.4, 1.1]. The benchmark slope is the average of the estimated slope for the sample starts 1997Q3 and 1997Q4 in figure 8, and the benchmark confidence interval is then the average of the estimated confidence intervals for these sample starts.

Figure 8. The slope of the long-run Phillips curve: Sample start 1997Q1-1999Q2
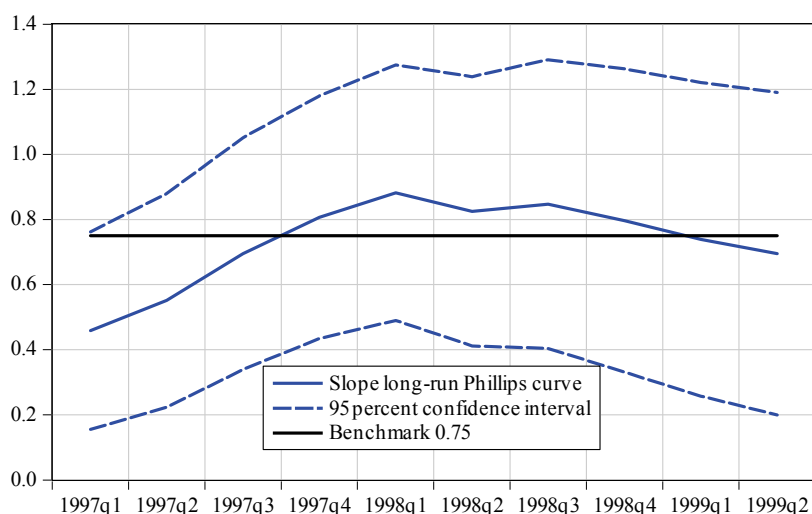
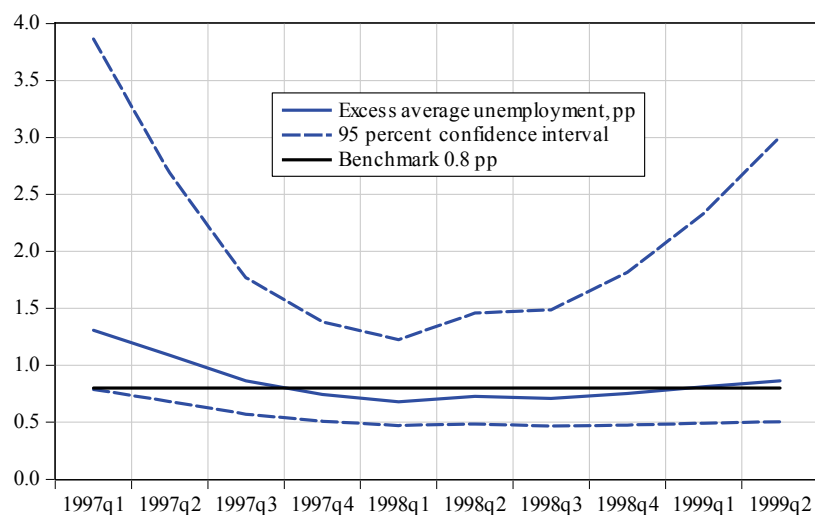## 5. The unemployment cost of average inflation below a credible target

The benchmark slope of the long-run Phillips curve, 0.75, implies that 1 pp lower average inflation is associated with $1/0.75 = 1.33$ pp higher average unemployment. This means that the benchmark 0.6 pp average inflation below target implies a benchmark of $0.6/0.75 = 0.8$ pp higher average unemployment. Using the estimate in table 2 and figure 6, for the sample 1997Q4-2011Q4, as an illustration, the rightmost black square on the long-run Phillips curve in figure 6 shows the average unemployment associated with average inflation 0.6 pp below target. It is 7.18 percent. The leftmost black square shows the average unemployment associated with average inflation on target. It is 6.44 percent.[18] The horizontal distance between the squares shows the unemployment cost of average inflation having fallen short of the target by 0.6 pp. It is 0.74, a bit less than the benchmark 0.8, since the slope of the long-run Phillips curve in figure 6 is 0.81 and a bit steeper than the benchmark 0.75.

Since the slope of the long-run Phillips curve is sensitive to the sample start, so is the excess average unemployment. Figure 9 shows the excess average unemployment, calculated as 0.6 divided by the slope of the long-run Phillips curve, as a function of the sample start. The figure also shows 95-percent confidence intervals, calculated as 0.6 divided by the upper and lower bound of the confidence intervals for the slope of the long-run Phillips curve. The lowest lower bound for the 95-percent confidence interval for the excess average unemployment is 0.46 pp and occurs for 1998Q3. An excess average unemployment of close to 0.5 pp for a period of about 15 years is still pretty high. The highest lower bound is 0.79 pp and occurs for 1997Q1. The lowest upper bound for the excess average unemployment is 1.22 pp and occurs for 1998Q1. From this it follows that the benchmark 0.8 pp for the excess average

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[18] Under the assumption of a constant natural rate u^*, from (7) and (5) and table 2 it follows that $u^* = (\gamma_0-2)/\gamma = 5.19/0.81 = 6.44$, so this number can be seen as an estimate of a constant natural rate during 1997Q1-2011Q4. (The long-run Phillips curve estimated for 1997Q4-2011Q4 is considered to apply also for the beginning of 1997, and average inflation over 1997Q1-2011Q4 is used.) However, in the last few years, substantial structural reforms, tax changes, and other factors, including demography and labor force composition, have according to Forslund (2008), Ministry of Finance (2011), and National Institute of Economic Research (2011) probably reduced the natural rate substantially.

unemployment is a rather conservative benchmark and hardly an exaggeration of the unemployment cost of average inflation below the target.

Figure 9. Excess average unemployment, sample start 1997Q1-1999Q2

Thus, this analysis leads to a benchmark unemployment cost of about 0.8 pp excess unemployment on average for during 1997-2011 due to average inflation having undershot the target by 0.6 pp during this period. This is a large unemployment cost of undershooting the inflation target.

I calculate the benchmark 95-percent confidence interval around the benchmark unemployment cost from the benchmark confidence interval of the slope, [0.4, 1.1]. This results in a benchmark confidence interval of [0.6/1.1, 0.6/0.4] = [0.55, 1.5] pp for the unemployment cost. It is approximately equal to the average of the confidence intervals in figure 9 for the sample starts 1997Q3 and 1997Q4.

6. Some robustness tests

Figure 10 shows a scatter plot with unemployment and annual CPI inflation from 1976Q1 through 2012Q3. We see that the observations during the 1970s and the 1980s with large fluctuations in inflation give the impression that the long-run Phillips curve was vertical then. The observations to the far right are from the big crisis in the early 1990s. The sample 1998Q1-2012Q3 is marked in red.[19] The observations indicate a downward-sloping Phillips curve for that sample. The Riksbank's inflation targeting and inflation expectations anchored to the target imply a regime shift. The figure also shows the benchmark long-run Phillips curve.[20]

One could argue that the crisis years 2008-2011 are special. If one limits the sample to 1997Q1-2007Q4, the average annual CPI inflation is 1.31, so the average inflation is about 0.7 pp below target. The

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[19] Since annual inflation from 1998Q1 and onwards is a moving average of four quarters' quarterly inflation it includes quarterly inflation from 1997Q1 and onwards.
[20] The benchmark long-run Phillips curve, with its (negative) slope of 0.8, is in figure 10 drawn through the point where average unemployment is 7.2 percent and average inflation is 1.4 percent.

estimated slope a long-run Phillips curve for 1997Q4-2007Q4 is 0.83, so the average unemployment cost is about 0.7/0.83 = 0.85 pp, a bit higher than the benchmark unemployment cost; see figure 11.

Figure 10. Unemployment and annual CPI inflation, 1976Q1-2012Q3,
and the benchmark long-run Phillips curve, 1997-2011
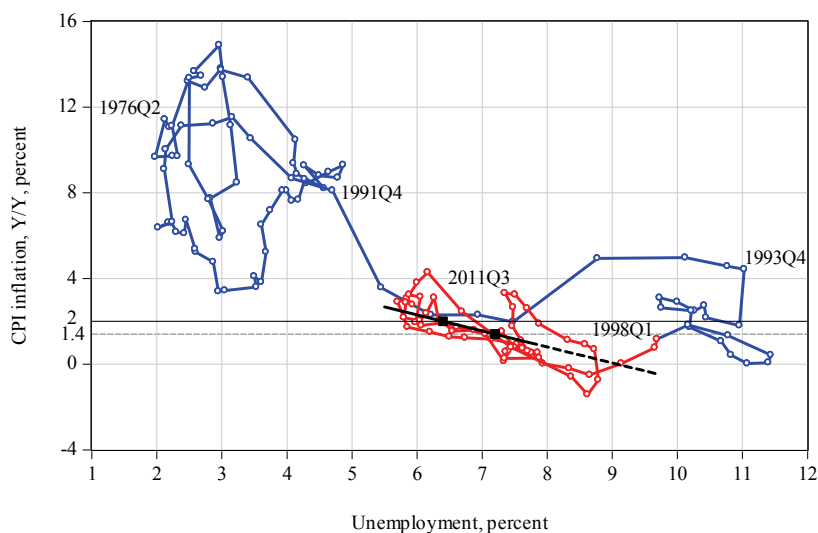
Through the *Monetary Policy Update* of April 2008, the Riksbank used CPIX inflation as an operational target rather than CPI inflation. From the *Monetary Policy Report* of July 2008, the Riksbank has emphasized CPIF inflation rather than CPIX inflation. As explained in Sveriges Riksbank (2008), the price index CPIX differs from the CPI in that the effects of changes in mortgage costs and the direct effects of changes in indirect taxes and subsidies are excluded. The price index CPIF differs from the CPI in that mortgage costs are calculated with a constant mortgage rate. Given this, one may want to consider the long-run Phillips curve with CPIX/CPIF inflation instead of CPI inflation, where CPIX/CPIF inflation refers to CPIX inflation through 2008Q1 and CPIF inflation from 2008Q2.[21]

The Riksbank has also published an estimate of time-varying "long-term" unemployment.[22] One may want to consider a long-run Phillips curve for an unemployment gap between unemployment and the Riksbank's long-term unemployment instead of just the unemployment rate. Figure 12 shows CPIX/CPIF inflation and the Riksbank's estimate of long-term unemployment together with CPI inflation and unemployment.

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[21] Andersson, Palmqvist, and Österholm (2012) discuss Riksbank target attainment for 1995-2011 in terms of CPIF inflation, and at the same time emphasize the relevance of using real-time data. Since the CPIF index did not exist before 2008 and the Riksbank used CPIX inflation before 2008 as an operational target, it is arguably more relevant to discuss target attainment in terms of CPIX inflation than in terms of CPIF inflation.

[22] The Riksbank's estimate of long-term unemployment is shown in Sveriges Riksbank (2010, figure B23).

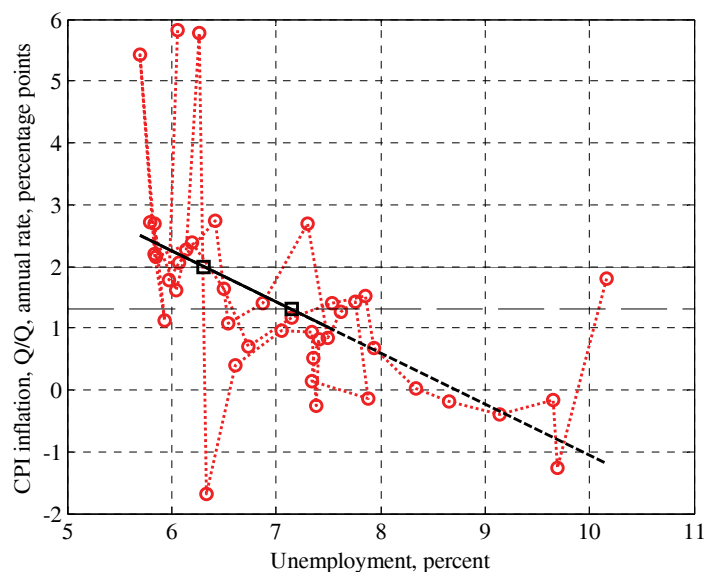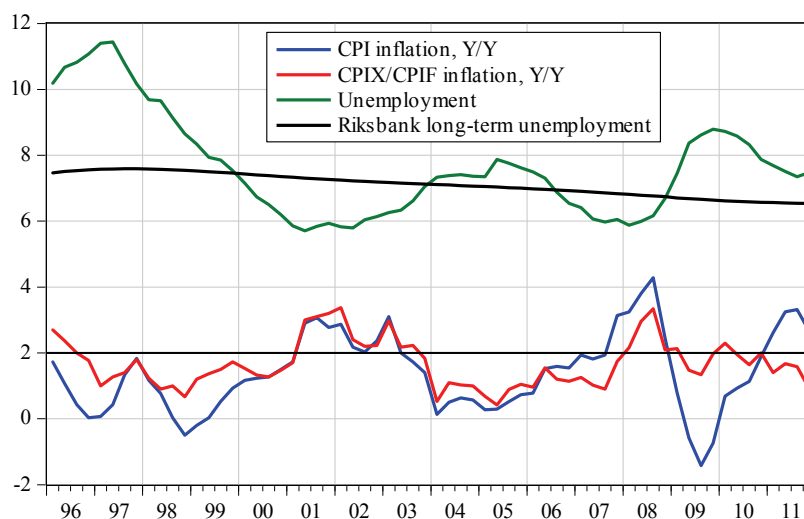Figure 11. The long-run Phillips curve and scatter plot, 1997Q4-2007Q4

Figure 12. Annual CPI and CPIX/CPIF inflation, unemployment,
and the Riksbank's estimate of long-term unemployment

Percent

Sources: The Riksbank and Statistics Sweden.

Average real-time CPIX/CPIF inflation was 1.64 percent during 1997-2011 and hence fell short of the target by about 0.4 pp. Estimating a long-run Phillips curve from the short-run Phillips curve (6) for unemployment with quarterly seasonally adjusted CPIX/CPIF inflation at an annual rate instead of CPI inflation leads to a flatter long-run Phillips curve with a slope of 0.36 and a higher unemployment cost of $0.4/0.36 = 1.1$ pp. This is shown in figure 13. For CPIX/CPIF inflation, the fit is not as good as for CPI inflation. R^2 and adjusted R^2 are only 0.09 and 0.05 for CPIX/CPIF inflation compared with 0.30 and 0.27 for CPI inflation.

Figure 13. The long-run Phillips curve with CPIX/CPIF inflation and unemployment, 1997Q4-2011Q4
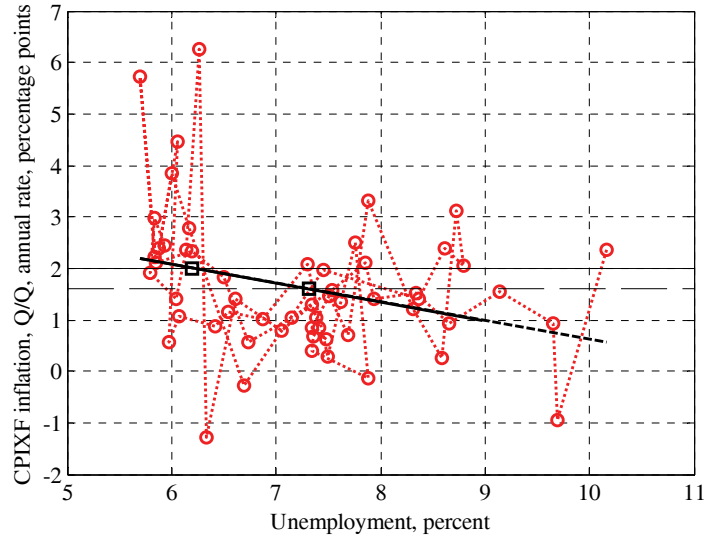
Using CPI inflation with the gap between unemployment and the Riksbank's estimate of long-term unemployment instead of just unemployment means estimating a short-run Phillips curve such as

$$\pi_t = \gamma_0 + \gamma_1[(u_t - u_t^*) - (u_{t-1} - u_{t-1}^*)] + \gamma(u_{t-1} - u_{t-1}^*) + \varepsilon_t, \qquad (8)$$

where u_t^* denotes a time-varying long-term unemployment rate rather than a constant natural rate. This leads to a flatter long-run Phillips curve with a slope of 0.65 and a larger unemployment (gap) cost, 0.93 pp, see figure 14. The fit is worse than with unemployment, with R^2 and adjusted R^2 equal to 0.22 and 0.19, respectively.

Interestingly, the average unemployment gap associated with average inflation equal to target is –0.75, as shown by the leftmost black square in figure 14. This indicates that the Riksbank's estimate is biased upwards. Of course, estimates of any long-run unemployment rate from observed data from this sample period under the maintained assumption of rational expectations (or even just unbiased expectations) will be biased upwards, given that average inflation has systematically undershot average inflation expectations. Figure 15 shows a revised Riksbank estimate, constructed by just subtracting 0.75 from the Riksbank's estimate of the long-term unemployment rate.[23]

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[23] Riksbank (2012) presents a new Riksbank estimate of the long-run sustainable rate of unemployment of 6.25 percent (the midpoint of an interval between 5 and 7.5 percent). In Svensson (2012), I argue that this estimate has an upward bias of 0.75 pp, and that a corrected Riksbank estimate should therefore be 5.5 percent.

Figure 14. The long-run Phillips curve with CPI inflation and
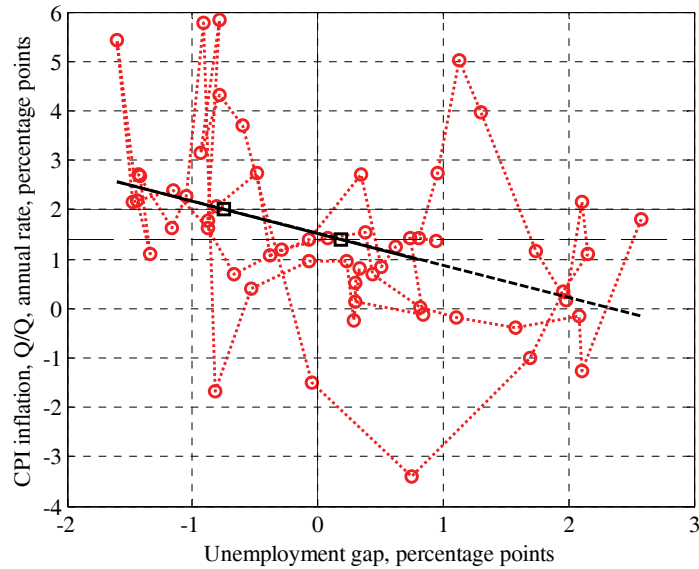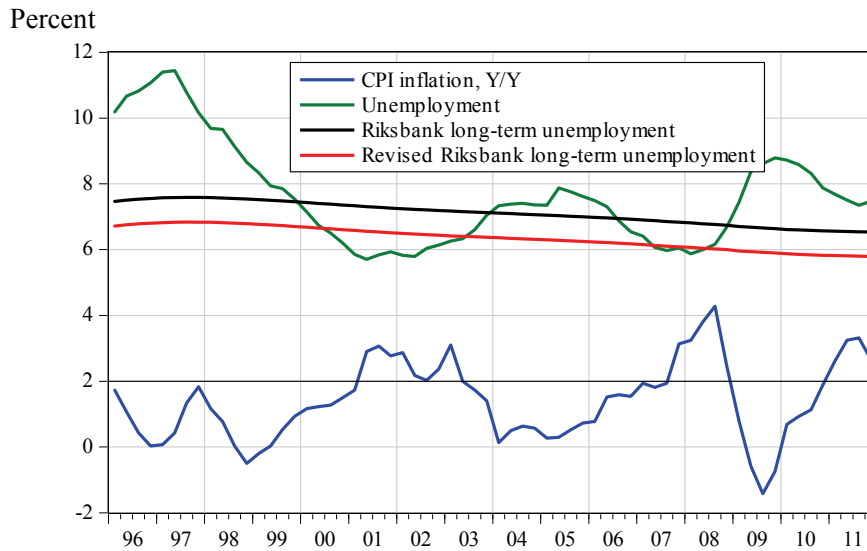the Riksbank's unemployment gap, 1997Q4-2011Q4

Figure 15. A revised Riksbank estimate of long-term unemployment, the Riksbank's estimate of
long-term unemployment, and annual CPI inflation

Sources: The Riksbank, Statistics Sweden, and own calculations.

In the estimated short-run Phillip curve (6), unemployment is considered predetermined and therefore uncorrelated with the error term. If we instead use the lagged change in unemployment rate and a second lag of the unemployment rate as explanatory variables, that is, $u_{t-1} - u_{t-2}$ and u_{t-2} on the right side of (6), we get a flatter long-run Phillips curve with a slope of 0.64 and a higher unemployment cost of 0.93 pp; see figure 16. The fit is worse with lagged unemployment than with current unemployment, with R^2 and adjusted R^2 equal to 0.23 and 0.20, respectively.

Another way to handle possible endogeneity and correlation between unemployment and the error term in (6) is to use instrumental variables. Table 3 shows the results of a two-stage least squares estimation with three lags of unemployment as instrumental variables. The slope is 0.83, a bit higher than the benchmark, and the average unemployment cost is 0.72, a bit smaller than the benchmark.

Table 3. Short-run Phillips curve, 1997Q4-2011Q4
Two-stage least squares, instruments three lags of the unemployment rate

Coefficient	Estimate	Std. Error	t-Statistic	Prob.
γ_0	7.343972	1.461589	5.024648	0.0000
γ_1	2.908611	1.029998	2.823899	0.0066
γ	0.829147	0.202397	4.096646	0.0001

Note: Two-stage least squares, $R^2 = 0.30$, adjusted $R^2 = 0.27$, S.E. = 1.54, DW = 1.78.

A possible source of correlation between unemployment and the error term might be inflation expectations depending on unemployment. In (1), if inflation expectations, π_t^e would depend on unemployment, u_t, the error term, ε_t, in (6) would be correlated with u_t. However, a regression of inflation expectations on unemployment, lagged inflation, and lagged inflation expectations shows that inflation expectations do not depend on unemployment. The coefficient on employment is very small and not significant (see table A1 in appendix A4).

Figure 16. The long-run Phillips curve with CPI inflation and the lagged change in unemployment and a second lag of unemployment, 1997Q4-2011Q4


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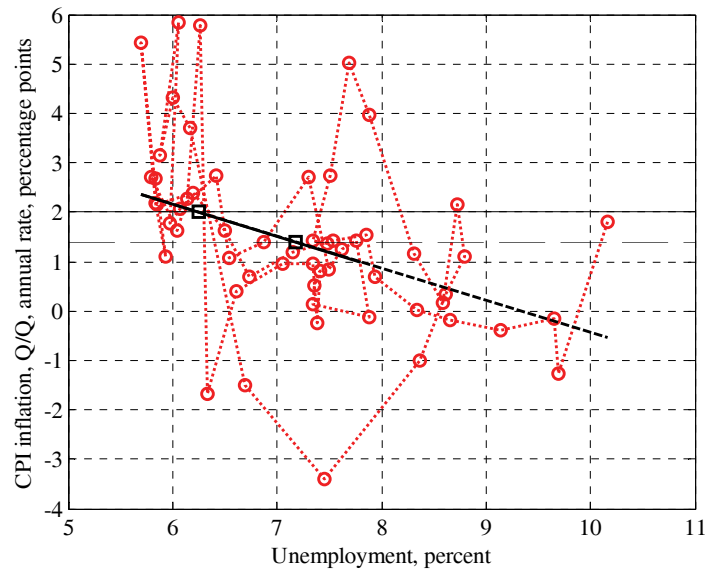
7. A U.S. long-run Phillips curve

The data indicate that stable inflation expectations round the inflation target in Sweden since 1997 has led to a non-vertical long-run Phillips curve in Sweden for 1997-2011. Has the same happened in the U.S.?

As noted above, the United States have not had an explicit inflation target until the Federal Reserve announced a target of 2 percent for PCE inflation in January 2012. However, a widely held perception is that the Federal Reserve even prior to this targeted a core inflation rate of about 2 percent. Over the period 2000-2011, average inflation for the core CPI index was 2.0 percent and for the core PCE deflator 1.9 percent. Figure 17 shows the U.S. unemployment rate, the CBO's estimate of February 2013 of the long- and short-run natural unemployment rate, the annual core-CPI inflation rate, and the quarterly core CPI inflation at an annual rate.

Figure 17. The U.S. unemployment rate, the CBO long- and short-run natural rates, annual core CPI inflation, and quarterly core CPI inflation at an annual rate, 1997-2012
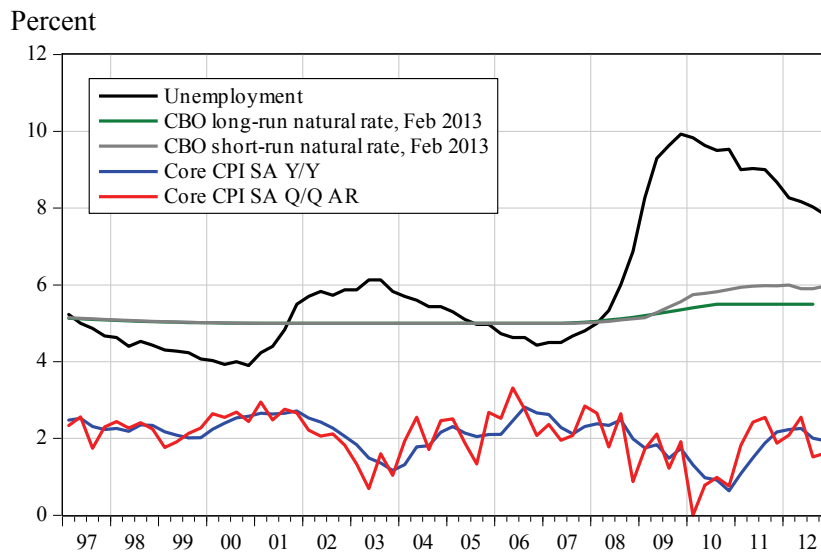
Source: Ecowin, CBO February 2013.

Fuhrer (2011) notes that various measures of inflation expectations have stabilized around 2 percent from 2000 onwards, and he notes that this implies that that there may be a non-vertical long-run Phillips curve in the U.S. He then estimates a long-run Phillips curve for quarterly core CPI inflation at an annual rate and an unemployment gap with a slope of 0.26 for the sample 200Q1-2011Q2 (Fuhrer 2011, table 1).

Here I estimate a short-run Phillips curve of the following form, using the same sample period as Fuhrer,

$$\pi_t = \gamma_1 + \gamma_2 \pi_{t-4} - \gamma_3 u_{t-1} + \varepsilon_t, \tag{9}$$

where π_t denotes quarterly core CPI inflation at an annual rate in quarter t; u_t denotes the unemployment rate; and ε_t denotes possibly serially-correlated cost push shocks with an unconditional mean equal to zero. This specification with a 4-quarter lag of inflation and a one-quarter lag of unemployment fits the data well, as we will see below. Fuhrer uses an unemployment gap between the unemployment rate and the natural rate as explanatory variable. The estimation results are not sensitive to

whether the unemployment rate or an unemployment gap relative to the CBO's estimates of the natural rate are used, since the natural rate only varies at the end of the sample.

The result for the sample 2000Q1-2011Q2 is shown in table 4.

Table 4. U.S. short-run Phillips curve, 2000Q1-2011Q2

Variable	Coefficient	Std. Error	t-Statistic	Prob.
γ_1	4.504289	0.358683	12.55787	0.0000
γ_2	−0.331886	0.102607	−3.234529	0.0023
γ_3	0.303734	0.038717	7.845017	0.0000

Note: Newey-West standard errors, $R^2 = 0.50$, adjusted $R^2 = 0.33$, S.E. = 0.52, DW = 1.56.

The long run Phillips curve is then given by (7), were $\gamma_0 = \gamma_1 / (1 - \gamma_2) = 3.3819$ and

$\gamma = \gamma_3 / (1 - \gamma_2) = 0.228$. The slope is similar to the slope estimated by Fuhrer (2011). It is clear that the

coefficient γ_2 is significantly different from unity, so the long-run Phillips curve is not vertical. This is in contrast to the Phillips curve estimated in Rudebusch and Svensson (1999) for the sample 1961Q1-1996Q2, for which the sum of the coefficients of four lags of inflation were not significantly different from unity.

Figure 18 shows U.S. unemployment and annual core CPI inflation during 1970-2012. The sample 2000Q1-2012Q4 is marked in red. We see that the data for 2000-2012 look different than the data for 1970-1999, consistent with inflation expectations having stabilized from 2000 onwards. The estimated long run Phillips curve is shown as the black line. Figure 19 shows unemployment and quarterly core CPI inflation at an annual rate together with the long-run Phillips curve.

Figure 18. U.S. unemployment and annual core CPI inflation, 1970Q1-2012Q4,
and a U.S. long-run Phillips curve, 2000Q1-2011Q2
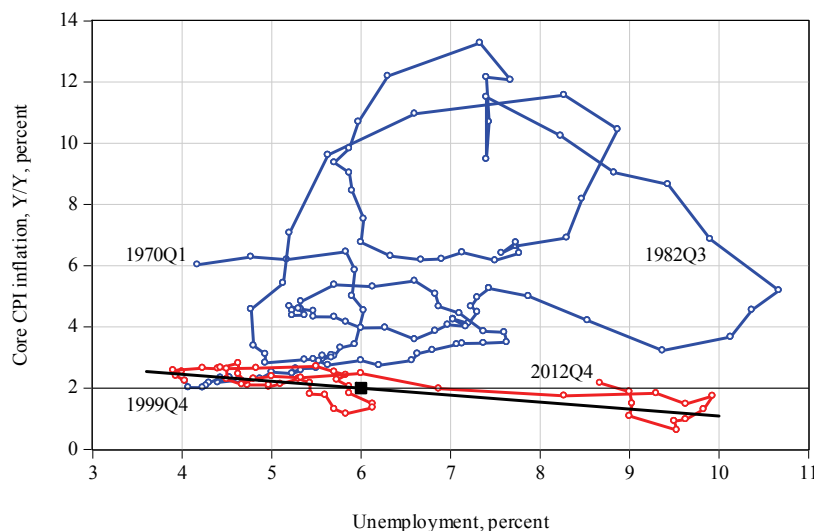
We realize from figures 19 that the slope of the Phillips curve is affected by the observations during the crisis period after 2008. Without these observations, the curve would be steeper. Thus, the U.S. long-run Phillips curve is less stable to variations in the sample end than the Swedish long-run Phillips curve.

Figure 19. U.S. unemployment and quarterly core CPI inflation at an annual rate 2000-2012 and a long-run Phillips curve 2000Q1-2011Q2
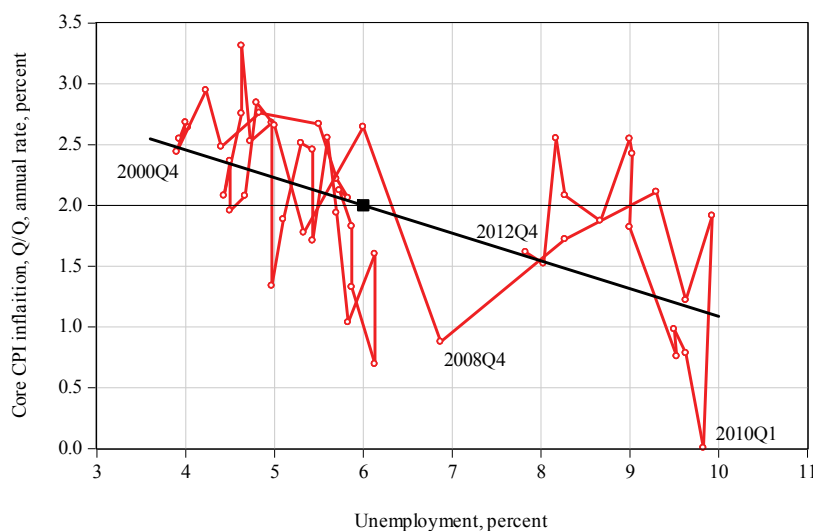
Since average core CPI inflation is 2 percent and there is a widely held perception of an unofficial Federal Reserve inflation target of about 2 percent during the period, there is no unemployment cost of average inflation below the perceived target for the US.

8. A Canadian long-run Phillips curve

As mentioned, Canada has had an inflation target since 1991, which from the end of 1995 is 2 percent for CPI inflation. Average CPI inflation over 1997–2011 is 2.0 percent. Does Canada have a non-vertical long-run Phillips curve during this period? Figure 20 shows the unemployment rate, annual CPI inflation, and quarterly CPI inflation at an annual rate during 1997-2012.

In figure 21 we see a scatter plot of unemployment and annual CPI inflation for the longer sample 1970Q1-2012Q4, with the sample 1997Q1-2012Q4 in red. We see that the data look different during the latter sample, consistent with stable inflation expectations and a non-vertical long-run Phillips curve.

Figure 20. Canadian unemployment, annual CPI inflation,
and quarterly CPI inflation at an annual rate, 1997-2012

Percent
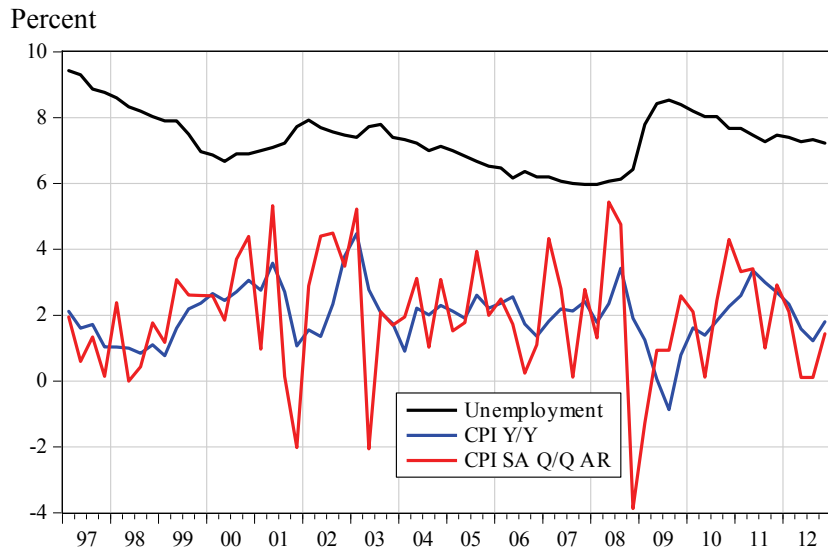
Figure 21. Canadian unemployment and annual CPI inflation, 1970-2012,
and a Canadian long-run Phillips curve, 1997Q1-2012Q4
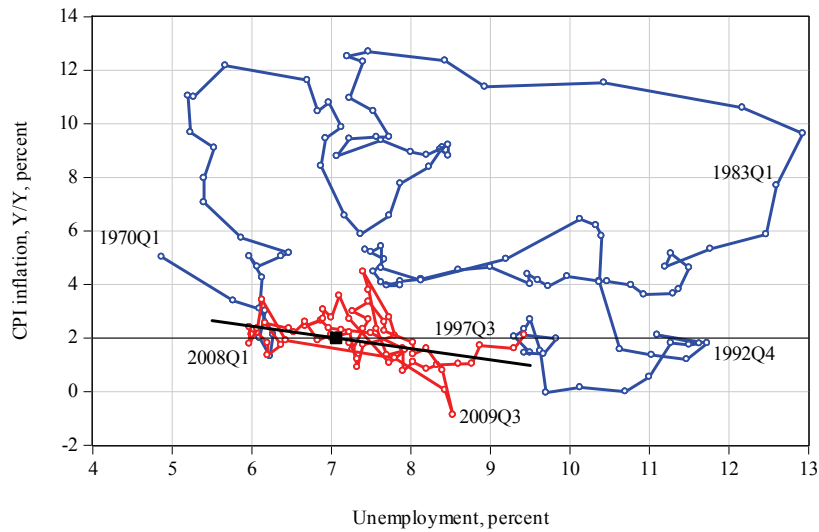
In table 5 I report the estimation of a short-run Phillips curve of the same form as (6). The long-run Phillips curve has a slope of 0.42.

Figure 22 shows the observations of unemployment and CPI inflation during 1997-2012 and the long-run Phillips curve. Since average inflation has been exactly on target in Canada, there is no unemployment cost of average inflation below target.

Table 5. Canadian short-run Phillips curve, 1997Q1-2012Q4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
γ_0	4.941594	1.510374	3.271768	0.0018
γ_1	2.570092	0.578747	4.440789	0.0000
γ	0.416737	0.201222	2.071034	0.0426

Note: Newey-West standard errors, $R^2 = 0.13$, adjusted $R^2 = 0.11$, S.E. = 1.72, DW = 2.12.
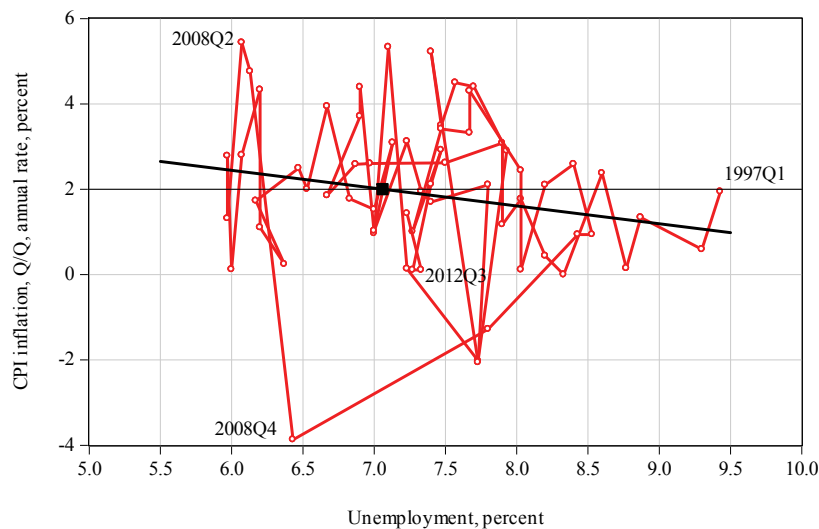
Figure 22. Canadian unemployment and quarterly CPI inflation at an annual rate 1997-2012
and long-run Phillips curve 1997Q1-2012Q4

9. Conclusions

By 1997, the new inflation-targeting regime had been established, in the sense that the inflation target was credible (inflation expectations were in line with the target), the repo rate (the Riksbank's policy rate) had been lowered to a normal level, and the Riksbank had had a few years to learn how to conduct inflation targeting. Over the last 15 years since then, 1997-2011, average CPI inflation has fallen short of the inflation target of 2 percent by 0.6 percentage points. But average inflation expectations according to the TNS Sifo Prospera survey have been close to the target. Thus, average inflation expectations have been anchored to the target and the target has been credible. If average inflation expectations are anchored to the target when average inflation differs from the target, the long-run Phillips curve is not vertical. Then lower average inflation means higher average unemployment. The data indicate that average inflation below target has been associated with average unemployment being about 0.8 percentage points higher over the last 15 years than would have been the case if average inflation had been equal to the target. This is a large unemployment cost of average inflation below a credible target. Some simple robustness tests indicate that the estimate of the unemployment cost is rather robust, but the estimate remains preliminary and further scrutiny may be needed to assess its robustness.

For the U.S., as noted by Fuhrer (2011) and confirmed here, there seems to be a non-vertical Phillips curve from 2000 onwards. Since average core inflation has been equal or close to what is widely

perceived as an unofficial Federal Reserve inflation target of about 2 percent from 2000 until the announcement of an official target in January 2012, there is no unemployment cost of average inflation below the perceived target for the U.S. For Canada, there seems to be a non-vertical long-run Phillips curve from 1997 onwards. Since average inflation has been equal to the target, there is no unemployment cost of average inflation below the target for Canada. Average inflation significantly below the target data and a substantial average unemployment cost of this seems to be a Swedish phenomenon.

The difference between average inflation and average inflation expectations in Sweden and the evidence of the existence of a downward-sloping long-run Phillips curve raises several questions that I believe need to be addressed. Why has average inflation fallen below the target for 15 years? Certainly, the experience of Australia, Canada, and the U.K. shows that it is possible to instead keep average inflation quite close to target during such a long period. What are the policy implications for the future? Do these findings make price-level targeting or the targeting of average inflation over a longer period relatively more attractive, since they would better ensure that average inflation over longer periods equals the target?

In a background study of the 2012 IMF Article-IV report on Sweden, Batini and Ishi (2012) note four possible reasons why the Riksbank has undershot the inflation target during the 1997-2011 period:

> One possibility is that (1) the Riksbank may have conducted monetary policy in an asymmetric manner, de facto favoring lower inflation outcomes to higher ones. Alternatively, despite symmetric stabilization preferences, (2) the Bank may have systematically overestimated potential unemployment. (This is reminiscent of the argument of Orphanides that the Fed caused too high inflation in the 1970s by underestimating potential unemployment). Or more generally, the Riksbank may have systematically overestimated inflationary pressures, one story being that (3) imported inflation systematically came in below expectations and (4) growth in productivity higher than expected. Last but not least, (5) (at least since the Great Recession) the pass-through from the repo rate to other rates, notably the mortgage rate, may have weakened, meaning that easy monetary conditions were not reflected de facto in an easier monetary stance, and implying a stronger disinflationary effect of policy than desired. (Batini and Ishi 2012, p. 39-40, numbers added)

To this one could add that (6) the Riksbank has missed or neglected a downward trend in mortgage rates, which has contributed to average CPI inflation being lower than average CPIX and CPIF inflation (this is a possible reason emphasized in Andersson, Palmqvist, and Österholm 2012) . Reason (2)-(4) and (6) involve systematic mistakes or neglects during the 15-year period, mistakes or neglects without which average inflation might have been on target and unemployment about 0.8 pp higher. The last reason, if applying only since the Great Recession, can account only for the last third of the 15-year period. However, if there is a suspicion that monetary policy is too tight because it is less effective, the appropriate policy response is easier policy than otherwise warranted. (This is an argument that I have put forward several times at the policy meetings.) Thus, these reasons hardly provide an excuse for undershooting the target and achieving higher average unemployment than necessary.

More generally, regardless of the reasons for the systematic undershooting of the inflation target, more expansionary policy during 1997-2011 could have brought both average inflation in line with the target

and lower average unemployment. Given this, the unemployment loss during the 15-year period was unnecessary.[24]

What are the policy implications for the future? One immediate conclusion is that it is important to keep average inflation over a longer period in line with the target, a kind of average inflation targeting (Nessén and Vestin 2005). This could also be seen as an additional argument in favor of price-level targeting, with a price-level target rising at the rate of the inflation target. On the other hand, in Australia, Canada, and the U.K., and more recently in the Euro area and the U.S., the central banks have managed to keep average inflation on or close to the target (the implicit target when it is not explicit) without an explicit price-level targeting framework.

Should the central bank try to exploit the downward-sloping long-run Phillips curve and secretly by more expansionary try to keep average inflation a bit above the target, so as to induce lower average unemployment than for average inflation on target? My answer to that question is no. It would involve saying one thing (the target is 2 percent) and deliberately doing another (keeping average inflation above 2 percent). This would be cheating and inconsistent with an open and transparent monetary policy. Regardless of the moral quality of the policy, the truth might eventually be leaked or discovered, in which case the inflation target would lose credibility and inflation expectations rise above the target, in which case the possible benefit of inflation above target would vanish.

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[24] See appendix A2 for details.

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Appendix

A1. Wage-setting with inflation expectations equal to the inflation target

Consider a situation with centralized wage-setting, where nominal wages are set a period in advance (for instance a year) in negotiations between a trade union and an employers' association. Assume that the negotiations result in a constant target (log) real wage, denoted $\tilde{w}^*$. The nominal (log) wage, w_t, is then set in period $t-1$ according to

$$w_t = \tilde{w}^* + p_t^e, \tag{A1}$$

where p_t^e denotes expectations in period $t-1$ of the (log) price level in period t. Furthermore, assume that inflation expectations in period $t-1$ equal the inflation target, π^*, so

$$p_t^e = p_{t-1} + \pi^*, \tag{A2}$$

where p_{t-1} is the (log) price level in period $t-1$.

The actual (log) real wage in period t, denoted $\tilde{w}_t$, satisfies

$$\tilde{w}_t \equiv w_t - p_t = (\tilde{w}^* + p_{t-1} + \pi^*) - (p_{t-1} + \pi_t), \tag{A3}$$

where I have used (A1), (A2) and that actual inflation, π_t, satisfies

$$\pi_t \equiv p_t - p_{t-1}. \tag{A4}$$

It follows that

$$\tilde{w}_t - \tilde{w}^* = \pi^* - \pi_t. \tag{A5}$$

That is, average inflation below the inflation target will imply that the average real wage will exceed the target real wage, implying lower employment and higher unemployment than consistent with the target.

A2. The average unemployment cost of average inflation below the target is independent of the reasons for missing the target

Consider a stylized model, where the structural relation between inflation and unemployment is given by the short-run Phillips curve,

$$\pi_t = \gamma_0 - \gamma_1(u_t - u_{t-1}) - \gamma u_{t-1} + \varepsilon_t, \tag{A6}$$

where π_t and u_t denote inflation and unemployment rates in period t and ε_t is an exogenous shock. Assume that the unemployment rate in period t can be affected by a stylized policy instrument in period $t-1$, i_{t-1}, according to

$$u_t = \alpha i_{t-1} + \eta_t , \tag{A7}$$

where η_t is an exogenous shocks. Unanticipated shocks are possible reasons why inflation may deviate from the target.

Consider sample averages over a given sample (for instance, 1997-2011),

$$\bar{\pi} = \gamma_0 - \gamma\bar{u} + \bar{\varepsilon} , \tag{A8}$$

$$\bar{u} = \alpha\bar{i} + \bar{\eta} , \tag{A9}$$

where a bar over a variable denotes its sample average ($\bar{i}$ denotes the sample average of i_{t-1}) and the sample average of $u_t - u_{t-1}$ is assumed to be zero. Let $\bar{u}^0$ denote the hypothetical sample average unemployment rate that is consistent with a sample average inflation rate equal to the inflation target, π^*. It satisfies the identity

$$\pi^* \equiv \gamma_0 - \gamma\bar{u}^0 + \bar{\varepsilon} . \tag{A10}$$

Define the excess average unemployment rate, $\Delta\bar{u}$, as

$$\Delta\bar{u} \equiv \bar{u} - \bar{u}^0 . \tag{A11}$$

It follows from (A11), (A8), and (A10) that the excess average unemployment rate is given by

$$\Delta\bar{u} = (\pi^* - \bar{\pi}) / \gamma . \tag{A12}$$

Thus, the excess average unemployment rate is independent of the sample averages of the exogenous shocks, $\bar{\varepsilon}$ and $\bar{\eta}$. The sample averages of the shocks may be part or all of the reason why average inflation have deviated from the target. The excess average unemployment rate is the average unemployment cost of average inflation below the target that is being estimated in this paper. It is thus independent of unanticipated shocks that may explain why average inflation has deviated from the target.

Note that $\bar{u}^0$ is a sample average and not necessarily the (long-run) natural rate, the sustainable rate of unemployment, denoted u^*. The latter might in this stylized model be defined as the sample average consistent with average inflation equal to π^* and the sample average of ε_t equal to zero. Then the natural rate satisfies the identity

$$\pi^* \equiv \gamma_0 - \gamma u^* . \tag{A13}$$

The excess of $\bar{u}^0$ over the natural rate is given by

$$\bar{u}^0 - u^* = (\pi^* - \bar{\pi}) / \gamma + \bar{\varepsilon} / \gamma \tag{A14}$$

and depends on the sample average of the shock in the Phillips curve (A8).

A3. Steady-state equilibria with unemployment different from the natural rate

In order to understand what steady-state equilibria are possible, start from the Phillips curve (1), which may represent a New Keynesian Phillips curve or a New Classical Phillips curve, depending on whether the inflation expectations are current expectations of future inflation or previous expectations of current inflation. Assume that inflation expectations are stuck at the inflation target and consider the unconditional

mean, resulting in the long-run Phillips curve (5), reproduced here:

$$\pi - \pi^* = -\gamma(u - u^*) . \tag{A15}$$

Consider now two alternative aggregate demand relations. First, consider a somewhat ad hoc aggregate-demand relation,

$$u_t - u^* = \sigma(r_t - r^*), \tag{A16}$$

where r_t denotes a real policy rate that the central bank can control, r^* is a constant neutral real interest rate, and σ is a positive constant. Second, consider a New Keynesian aggregate-demand relation in the form of an Euler condition for the unemployment gap,

$$u_t - u^* = \mathrm{E}_t(u_{t+1} - u^*) + \sigma(r_t - r^*), \tag{A17}$$

where $\mathrm{E}_t(u_{t+1} - u^*)$ denotes current expectations of the future unemployment gap. This can be derived from the standard Euler condition for the output gap, under the assumption that the output gap is proportional to unemployment gap with the opposite sign.

Assume that in both cases, the central bank follows a policy rule of the form

$$r_t - r^* = \alpha(\pi_t - \pi^0), \tag{A18}$$

where π^0 is a constant determining the intercept of the policy rule and α is positive constant.

First, consider the ad hoc aggregate demand relation (A16). Combining it with the policy rule and taking the unconditional mean gives

$$u - u^* = \sigma\alpha(\pi - \pi^0) . \tag{A19}$$

Using this with (A15) to eliminate the unemployment gap gives

$$\pi - \pi^* = -\frac{\gamma\sigma\alpha}{1 + \gamma\sigma\alpha}(\pi^* - \pi^0) . \tag{A20}$$

That is, if $\pi^0 < \pi^*$, we will have $\pi^0 < \pi < \pi^*$ and by (A15) $u > u^*$. From (A18) we will have $r > r^*$. Thus, with the ad hoc aggregate-demand relation (A16), in a steady state with inflation below the inflation target, the unemployment is higher than the natural rate and the real policy rate is higher than the neutral real policy rate.

Second, consider the New Keynesian aggregate-demand relation (A17). Taking the unconditional mean, we get

$$u - u^* = \mathrm{EE}_t(u_{t+1} - u^*) + \sigma(r - r^*), \tag{A21}$$

where E denotes the unconditional mean. Assuming that the unconditional mean of the expectations of future unemployment gaps equal the unconditional mean of the output gap, we get $r = r^*$. From (A18) it follows that $\pi = \pi^0$. That is, if $\pi^0 < \pi^*$, we will have $\pi^0 = \pi < \pi^*$ and $u > u^*$. Thus, with the New Keynesian aggregate-demand relation (A17), in a steady state with inflation below the inflation target, the unemployment is higher than the natural rate and the real policy rate equals the neutral policy rate.

For both alternative aggregate-demand relations, whether or not the steady-state equilibrium has inflation below target and unemployment above the natural rate is determined by whether or not the constant π^0 in the policy rule is below the inflation target.

A4. Inflation expectations depending on the unemployment rate

A possible source of correlation between unemployment and the error term might be inflation expectations depending on unemployment. In (1), if inflation expectations π_t^e would depend on unemployment u_t, the error term ε_t in (6) would be correlated with u_t. However, an OLS regression of inflation expectations,

$$\pi_t^e - 2 = \beta_0 + \beta_1(\pi_{t-1}^e - 2) + \beta_2(\pi_{t-1} - 2) + \beta_3(\pi_{t-2} - 2) + \beta_4 u_t + \varepsilon_t,$$

shows that inflation expectations do not depend on unemployment. As seen in table A1, the coefficient on unemployment is very small and not significant. Even if it were be significant, the coefficient is so small that it would not matter for the results in the paper.

Table A1. Regression of one-year- ahead inflation expectations on annual CPI inflation
and unemployment, 1996Q2-2011Q4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	0.305724	0.167610	1.824021	0.0733
π_{t-1}^e	0.529811	0.132555	3.996910	0.0002
π_{t-1}	0.421106	0.061617	6.834281	0.0000
π_{t-2}	-0.320164	0.054593	-5.864521	0.0000
u_t	-0.037169	0.022897	-1.623345	0.1099

Note: OLS, $R^2 = 0.84$, adjusted $R^2 = 0.83$, S.E. of regression = 0.23, Durbin-Watson = 1.77