Why has inflation deviated from target?

A Swedish Phillips Curve

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Abstract

In 1995, the Swedish Riksbank adopted an explicit inflation target of two percent annual inflation. Since then, average inflation has deviated from target by 0.5 to 0.7 percentage points below target, depending on which measure of inflation you use. Some suggested explanations for these deviations have been lower than expected imported inflation and higher than expected increases in productivity. In this paper, we develop a specification of a Phillips Curve which can account for variations in Swedish inflation and then use it to examine why inflation has deviated from its target level. I find little support for the claim that imported inflation and productivity shocks have caused inflation to deviate from its target level. On the contrary, changes in interest rates have caused the largest deviations of inflation from the target.

Keywords: Inflation, Open economy, Phillips Curve.

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1. Introduction

There is an ongoing debate in Sweden concerning monetary policy and the Riksbank's attainment of the official target for inflation. This is due to the fact that average inflation has been well below the target level for inflation. The aim of this paper is to contribute to this debate by developing a model which can account for deviations in inflation and examine the empirical relevance of the proposed reasons for these deviations.

An external evaluation of the Riksbank for the years 1995-2005 by Giavazzi and Mishkin (2006) concludes that "Our evaluation of monetary policy in Sweden indicates that the Riksbank compares favorably with the best central banks in the world [...] However, in recent years the Riksbank has persistently undershot its inflation target; this has been associated with a loss in output and higher unemployment."

Lars E.O. Svensson (2013) reaches the same conclusion and states: "During the 15 years of 1997-2011, average CPI inflation has equaled 1.4 percent and has thus fallen short of the target by 0.6 percentage points. [...] 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 higher average unemployment than it would have been if average inflation had been on target."

In response to the evaluation by Giavazzi and Mishkin, the Deputy Governor at the Riksbank at the time, Kristina Persson (2007) said (paraphrased): "Giavazzi and Mishkin criticize the Riksbank for undershooting its target for inflation during recent years [...] However, one must remember that this was due to surprisingly high productivity growth and low (or decreasing) import prices."

In this paper, I seek to answer the question of why inflation has deviated from target; in other words what drives the variation in inflation and the empirical reasons for these variations. To evaluate optimal policy in this framework is beyond the scope of this paper, as this would require an explanation as to why the average *level* of inflation has been below target. This is something I cannot answer with this approach.

In order to analyze the reasons for why inflation has deviated from target, we need a model of inflation. For that reason, I use a model of an open economy in order to derive an open economy Phillips Curve. I use a representative household with perfect risk-sharing between its members as the relevant decision making unit and assume staggered wage setting, as in Gali (2011). In addition, I open up the economy to international trade as in Gali and Monacelli (2002). This framework allows us to derive an open economy Phillips Curve which includes imported inflation, unemployment and productivity as factors determining inflation. In addition to the previously proposed explanations, I also investigate the interest cost of housing which is included in CPI inflation and this proves to be important for understanding the variations in inflation which we observe in the data.

In the derived Phillips Curve, I consider three different specifications of expectations to see which one best explains the Swedish data. The specifications considered are forward-looking and backward-looking expectations, as well as expectations which are anchored to the inflation target. In addition to the main specification, I also investigate the empirical relevance of two alternative specifications of the Phillips Curve: a classical backward-looking Phillips Curve and the Phillips Curve suggested in Svensson (2013).

Out of the five models I estimate, my preferred specification is a Small Open Economy Phillips Curve with expectations anchored to the inflation target. I find that for my estimated Phillips Curve, the change in the interest cost index can explain more of the variation of CPI inflation around its target than any of the previously proposed explanations.

Other authors have also tried to investigate the reasons for this undershooting. Assarsson (2007) tests whether the low Swedish inflation rate can be explained by systematic forecast errors for import prices, and concludes that the overestimation of inflation is not caused by erroneous Riksbank forecasts for import prices . Andersson, Palmqvist and Österholm (2012) propose a different explanation, based on which measure of inflation is being evaluated. They instead consider CPIF[2] inflation as the relevant measure of inflation. They note that average CPIF inflation for the period 1995-2011 was 1.8 percent compared to average CPI inflation of 1.5 percent. This shows that the direct effect of lowered interest rates on inflation can, in part, explain why inflation has been below target.

In section two, a theoretical model of inflation is formulated, while the data are described in section three. I estimate the model on Swedish data in section four. In section five, I use the estimated model to see if it can help explain why inflation

[2] CPIF differs from CPI as it holds the interest rate that is paid on home mortgages as Fixed when calculating the change in the cost of housing for households.

has deviated from target. In section six, I discuss possible explanations for why inflation has deviated from target, the empirical findings and conclude this paper.

2. The Model

This section combines the pricing decisions of the monopolistically competitive firms with the consumption and labor supply decisions made by the households. This is done in order to derive a small open economy Phillips Curve.

2.1 Firms

Following the setup in Erceg, Henderson, Levin (2000), we assume a continuum of monopolistically competitive firms which all produce a differentiated good consumed by the households. A representative firm produces a good Y_t with CRS technology as below.

$$Y_t = A_t N_t , \tag{1}$$

where N_t is an index[3] of different types of labor input used by the firm. The representative firm maximizes profits, taking the corresponding wage index W_t as given, by choosing how much labor to employ. Prices are completely flexible and firms compete in a monopolistically competitive market so they set prices with a mark-up over marginal cost (the ratio of the wage index to the marginal product of labor). This is given by

$$P_t^h = (1+\mu)\frac{W_t}{A_t} , \tag{2}$$

where P_t^h is the price set by the representative domestic firm, μ is the mark-up and A_t is technology. Taking logs and differentiating equation (2) gives us

$$\pi_t^h = \pi_t^w - \Delta a_t , \tag{3}$$

[3] Of the Dixit-Stiglitz (1977) form.

where lower case letters are used to denote logs. π_t^h is home inflation, π_t^w is wage inflation and Δa_t is the change in productivity.

2.2 The Households

Following Gali (2011), we think of a large representative household with a continuum of members represented by the unit square, indexed by a pair $(i, j) \in [0,1]*[0,1]$. The two dimensions are indexed by i for the type of labor service a household member is specialized in and the j for their disutility[4] from work. Disutility is given by $\chi_t j^{\varphi}$ if employed and zero otherwise, where $\varphi \geq 0$ determines the elasticity of the marginal disutility from working and $\chi_t > 0$ is an exogenous preference shifter. The period utility for the representative household is an integral over its members' utilities. It is given by

$$U\left(C_t, \{N_t(i)\}, \chi_t\right) \equiv \ln C_t - \chi_t \int_0^1 \int_0^{N_t(i)} j^{\varphi} dj di, \tag{4}$$

where C_t is household consumption and $N_t(i) \in [0,1]$ is the fraction of members specialized in labor type i which are working in the given period. We assume logarithmic utility in consumption and full risk sharing within the household. The household seeks to maximize

$$E_0 = \sum_{t=0}^{\infty} \beta^t U\left(C_t, \{N_t(i)\}, \chi_t\right),$$

subject to a sequence of budget constraints

$$P_t C_t + Q_t B_t \leq B_{t-1} + \int_0^1 W_t(i) N_t(i) di + T_t ,$$

[4] We can think of this as the members of the household of labor type i lining up according to their preference for working. The members of the household who really do not like doing much at all are at back of the line. They will only be asked to go out and work if the marginal utility from doing so outweighs their disutility from working. This is due to the fact that, in this setup, this is all evaluated at the level of the household.

where P_t is the price for the consumption bundle[5] consumed by the household, $W_t(i)$ is the nominal wage for labor type *i*, B_t represents purchases of a riskless one period bond at price Q_t and T_t is a lump-sum component of income (e.g. dividends from ownership of firms or taxes/transfers from the government). To this we also add a No Ponzi-condition to prohibit households from accumulating debt in the limit.

Now we extend the setup in Gali (2011) to a small open economy setting and allow the economy to engage in trade with the rest of the world as in Gali and Monacelli (2002). The home market is small, so it takes the world market price (index) P_t^f as given. Households purchase a composite final good C_t with components produced both at home and abroad, as well as paying the interest cost of living in a house Z_t. The composite final good can be expressed as

$$C_t = \left(1-\alpha-\omega\right)^{-(1-\alpha-\omega)} \alpha^{-\alpha} \omega^{-\omega} C_{h,t}^{1-\alpha-\omega} C_{f,t}^{\alpha} Z_t^{\omega}, \qquad (5)$$

where $C_{h,t}$ and $C_{f,t}$ are CES aggregates of goods produced at home and abroad respectively and α can be thought of as the degree of openness of the economy. Z_t is an interest cost index for the cost of living in a house and ω represents the importance of housing consumption. The corresponding CPI is

$$P_t = P_{h,t}^{1-\alpha-\omega} P_{f,t}^{\alpha} P_{z,t}^{\omega}. \qquad (6)$$

If we take logs and the first difference of equation (6) and substitute in equation (3), we get a relationship between the CPI inflation, wage inflation, foreign inflation and the change in the interest cost index. The relationship is given by

$$\pi_t = \left(1-\alpha-\omega\right)\left(\pi_t^w - \Delta a_t\right) + \alpha \pi_t^f + \omega z_t, \qquad (7)$$

[5] The bundle includes both home and foreign goods, as well as the interest cost of housing.

where π_t is CPI inflation, π_t^f is foreign inflation and the interest cost index $z_t \equiv \ln P_{z,t} - \ln P_{z,t-1}$. The next step is to rewrite equation (7) to express inflation in terms of *underlying* inflation. This is given by

$$\pi_f^{CPIF} \equiv \pi_t - \omega z_t = (1-\alpha-\omega)\left(\pi_t^w - \Delta a_t\right) + \alpha \pi_t^f \tag{8}$$

where the left hand side now excludes the direct effect of interest rate on CPI inflation (i.e. CPIF as it is measured in Sweden). Because the Riksbank knows that mortgage rates have a direct effect on CPI inflation, it currently uses the CPIF as a measure of underlying inflation. In the current debate regarding inflation, we can note that in the minutes from the Riksbank meetings, the participants routinely refer to the CPIF as reaching the target level of inflation rather than the CPI (see Sveriges Riksbank (2013a), (2013b)).

In the next section, we will proceed to analyze how wage inflation is determined in this economy.

2.3 Staggered Wage Setting and the Small Open Economy Phillips Curve

The workers of a given type *i* (we can think of them as a union) get to re-optimize their nominal wage with probability $1-\theta_w$ each period. When the wage has been set, the quantity of workers employed is determined by the representative firm. The representative household willingly meets this demand and sends its specialized workers with the lowest disutility from work, provided that the wage is greater than the disutility of work for the marginal worker. The workers who get to re-optimize set the wage in order to maximize the utility of the representative household. The first order condition given by

$$\sum_{k=0}^{\infty} (\beta\theta_w)^k E_t \left\{ \frac{N_{t+k|t}}{C_{t+k}} \left(\frac{W_t^*}{P_{t+k}} - \mathrm{M}^w \left(\chi_{t+k} C_{t+k} N_{t+k|k}^{\varphi} \right) \right) \right\} = 0$$

where $N_{t+k|k}$ is the demanded quantity of those labor types whose wages are being reset in period *t*. W_t^* is the optimal wage workers choose when they set the wage in period *t*, subject to a sequence of isoelastic demand schedules (for their labor type) and budget flow constraints.[6] The desired wage markup $\mathcal{M}^w = \eta^w / (\eta^w - 1)$ multiplies the marginal rate of substitution between consumption and employment in period *t+k* and η^w denotes the constant wage elasticity of demand for each specialized labor type. This results in an equation for wage inflation, given by

$$\pi_t^w = \beta E_t\left[\pi_{t+1}^w\right] - \lambda_w(\mu_t^w - \mu^w) \tag{9}$$

where $\mu_t^w \equiv w_t - p_t - mrs_t$ (the log average wage markup), $\lambda_w > 0$ and where $mrs_t \equiv c_t + \varphi n_t + \xi_t$ in which $c_t \equiv \ln(C_t)$, $\varphi n_t \equiv \ln(N_t^\varphi)$ and $\xi_t \equiv \ln(\chi_t)$.

To derive an explicit expression for unemployment in this framework, we may think of a household member specialized in labor type *i* with disutility from work $\chi_t j^\varphi$. Taking the prevailing wage for their labor type *as given* and using the household welfare as a criterion, she will find it optimal to supply labor in period *t* if and only if

$$\frac{W_t(i)}{P_t} \geq \chi_t C_t j^\varphi . \tag{10}$$

In other words, she will find it optimal to participate in the labor force whenever the real wage in her trade is above their disutility from working, expressed in terms of consumption. This condition implies an expression for the marginal supplier (employed or unemployed) of labor denoted by $L_t(i)$ and it is implicitly given by

$$\frac{W_t(i)}{P_t} = \chi_t C_t L_t(i)^\varphi . \tag{11}$$

Equation (11) says that $L_t(i)$ workers want to work at the going real wage. If we take logs and integrate over *i* we get

$$w_t - p_t = c_t + \varphi l_t + \xi_t , \tag{12}$$

[6] For more details, see Gali (2011).

where l_t can be thought of as the labor force (labor supply) implied by the model, ξ_t is a preference shifter and w_t is the average wage expressed in terms of logs. We define the unemployment rate as

$$u_t \equiv l_t - n_t \quad . \tag{13}$$

Combining equations (12) and (13) with the expression for the average wage markup, $\mu_t^w \equiv (w_t - p_t) - (c_t + \varphi n_t + \xi_t)$, gives us a simple relationship between the wage markup and the unemployment rate:

$$\mu_t^w = \varphi u_t . \tag{14}$$

We define u_t^n as the *natural* rate of unemployment (i.e. the rate that would exist without nominal wage rigidities). It follows from the assumption of a constant desired wage markup μ_w that the natural rate of unemployment is constant and given by

$$u^n = \frac{\mu^w}{\varphi} . \tag{15}$$

In this model, unemployment is a consequence of the market power of workers, and fluctuations in unemployment arise because wages adjust slowly.

We now combine (9) with (14) and (15) to get the New Keynesian Wage Phillips Curve:

$$\pi_t^w = \beta E\left[\pi_{t+1}^w\right] - \lambda_w \varphi \left(u_t - u^n\right) . \tag{16}$$

Using (16) to replace the wage inflation term in equation (7), we get

$$\begin{aligned} \pi_t^{CPIF} &= (1-\alpha-\omega)\beta E_t\left[\pi_{t+1}^w\right] - (1-\alpha-\omega)\lambda_w \varphi\left(u_t - u^n\right) + \alpha \pi_t^f \\ &-(1-\alpha-\omega)\Delta a_t . \end{aligned} \tag{17}$$

Taking (3) one period ahead, combining it with equation (17) and rearranging the result gives us the Small Open Economy New Keynesian Phillips Curve (SMOPC):

$$\begin{aligned}\pi_t^{CPIF} &= (1-\alpha-\omega)\beta E_t\left[\pi_{t+1}^h\right] - (1-\alpha-\omega)\lambda_w\varphi\left(u_t - u^n\right) + \alpha\pi_t^f \\ &- (1-\alpha-\omega)\Delta a_t + (1-\alpha-\omega)\beta E_t\left[\Delta a_{t+1}\right].\end{aligned} \tag{18}$$

This specification allows for effects of productivity and foreign inflation, while it excludes the direct effect of the interest cost index on CPI inflation. We may therefore estimate it to see if these factors can explain why inflation has deviated from its target at a given point in time, while abstracting from the factor which is directly decided by the Riksbank (i.e. the interest rate).

The intuition for this equation is that expected future home inflation has a positive sign, as it will raise the desired nominal wage for the workers. Higher nominal wages increase marginal costs so that firms raise their prices. Unemployment should enter with a negative sign as it will put a downward pressure on wage inflation. Foreign inflation should enter with a positive sign, because increased import prices raise the price of the foreign goods consumed by the household. Productivity enters in two ways and with opposite signs. Current productivity increases will reduce production costs and therefore price inflation. Expected future increases in productivity raise the desired wages and therefore price inflation today (given expected future home inflation).

2.4 Modeling Expectations

In equation (18), there are two expectation terms which enter the equation: expected future home inflation and expected future productivity. I will model the inflation expectation term in three different ways.

(1) *Forward-looking expectations.* Here I assume that the way people form expectations is to look at some available observations of home inflation (I find that past observations of home inflation work best) and use this information to estimate what the future value will be. I call this specification SMOPC-F.

(2) *Backward-looking expectations.* Here I assume that people observe what home inflation was in the previous period and that this is their best guess of what home inflation will be in the next period. I call this specification SMOPC-B.

(3) *Anchored expectations.* Here I assume that people are confident that the Riksbank will keep inflation on target and that they use the official target rate as their (constant) best guess of what home inflation will be in the next period. Hence expected inflation is constant. I call this specification SMOPC-A.

As for expectations about the future change in productivity, I will assume that they follow the same rule as they do for home inflation in the first two cases. In the third case of anchored expectations for home inflation, I assume backward-looking expectations for productivity.

3. Data

I use quarterly data from Statistics Sweden (SCB). When only monthly data is available, I convert it to quarterly by taking a three-month average. Below, I will briefly describe the data used for the estimation section.

3.1 Variables

I use the consumer price index to measure inflation (π_t), the consumer price index with a fixed interest rate to measure core inflation (π_t^{CPIF}) and the producer price index for home sales of consumption goods, to measure domestic inflation (π_t^h).

To measure foreign inflation (π_t^f), I use the import price index for all imported goods and input materials. I use this measure in order to capture the effect of imported inputs on prices, although they are not explicitly included in the theoretical model.

Unemployment is the unemployment rate for ages 16-64 (u_t). Productivity (a_t) is defined as real value added divided by hours worked in the business sector of the economy, adjusted for reported factor utilization. This is done to avoid problems with measuring productivity (see appendix section 3 for further discussion).

As a measure of the change in the interest cost index (for the cost of housing), I use the log difference of the interest cost index (z_t). This is a sub-group of the CPI which has a time-varying weight which makes up around 4-6% of the consumer basket (in the sample period). The index is computed as the product of two indices: the interest rate index[7] and the house price index. To construct the official measure CPIF, the interest rate index is kept fixed, while the house price index is allowed to change. This measure of core inflation is utilized by the Riksbank and it is often referred to when the Riksbank communicates the underlying inflation rate of the economy.

3.2 Estimation period

In order to estimate a Phillips Curve, one ideally wants to have a constant institutional environment. Two important institutional changes occurred in the Swedish economy during the 1990s, which may have important effects on the determination of inflation.

An inflation target (2% annual CPI inflation) was adopted by the Riksbank in January of 1995. However, wanting to allow the Riksbank some time to establish credibility as an inflation targeter, I start the sample period three years after this date. Another important change concerned the pattern wage bargaining. The first round of negotiations with a new framework in place (Industriavtalet) started in 1998. The new framework implied pattern bargaining with the industrial sector as the wage leader setting the "mark" for the rest of the labor market. The goal was lower nominal wage increases which would hold back high price inflation and result in positive real wage growth (Albåge and Larsson, 2003).

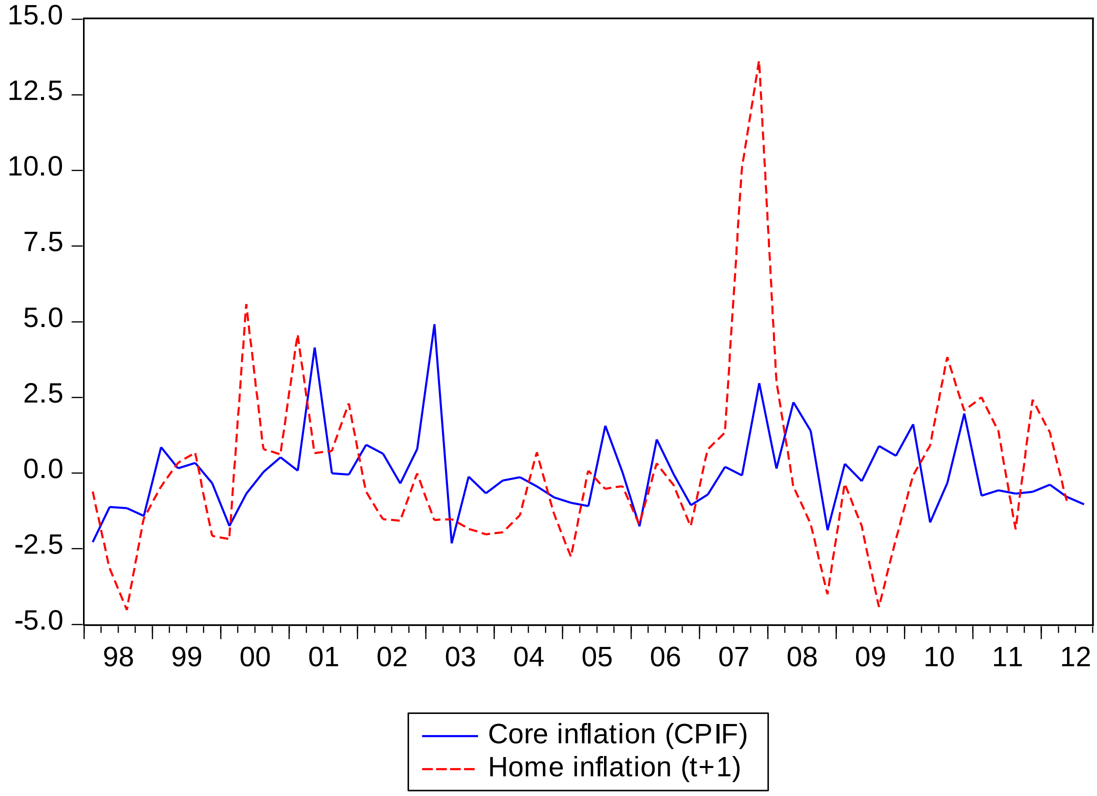
The sample period for the estimation is the first quarter of 1998 to the third quarter of 2012. This allows the Riksbank three years to establish credibility (or two years when I include a four quarter lag as an instrumental variable). The start of the sample period also coincides with the first round of the wage bargaining within the new framework.

[7] The interest rate index represents a value-weighted mix of floating and fixed mortgage rates.

3.3 Descriptive statistics

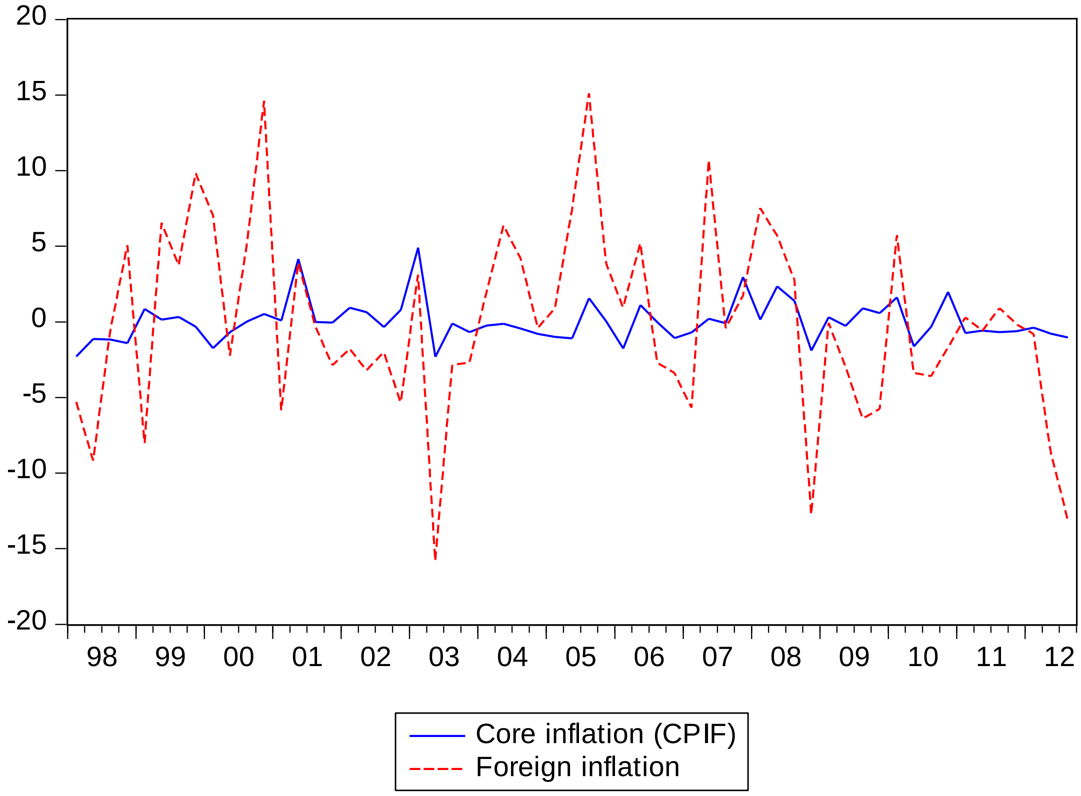
In this section, I present pairwise comparisons of the dependent variable, core inflation (CPIF), together with each of the explanatory variables (adjusted for season). The seasonal adjustments are made with a constant and three quarter dummies. Scatter plots for the same variables can be found in the Appendix section 2, Figure A1-A5. The graphs show quarterly inflation expressed in annual rates (in other words, 0.5 percent quarterly inflation represents an annual rate of 4*0.5=2 percent).

Figure 1. Core inflation and Home inflation, adjusted for season.



An expected increase in the price for goods produced at home should cause workers to demand higher wages, which in turn will increase marginal costs and therefore raise prices. Figure 1 suggests that core inflation is positively correlated with future home inflation, although there are periods, such as 2007 – 2008, where home inflation to a large degree differs from core inflation. The correlation for the entire sample period is 0.109.

Figure 2. Core inflation and foreign inflation, adjusted for season.



When foreign prices go up, core inflation will increase as a result of the imported inflation. Figure 2 shows that foreign inflation is much more volatile than core inflation, but that there is a weak positive correlation, 0.160, between core inflation and foreign inflation.

Figure 3. Core Inflation and the change in productivity, adjusted for season.

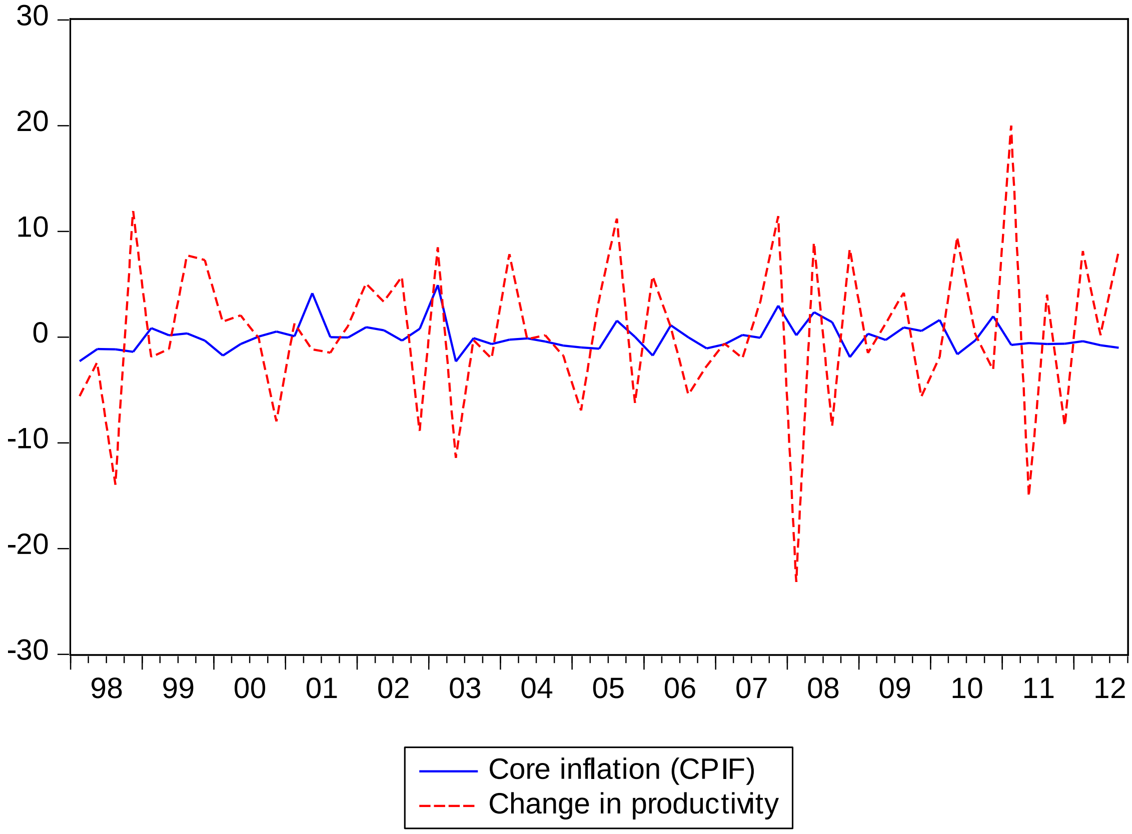


Figure 3 shows that the change in productivity (adjusted for factor utilization) exhibits a much higher degree of variation than core inflation does. Theory would predict that higher productivity would lower marginal costs and therefore core inflation, and thus we would expect a negative correlation. All in all, it is hard to see what the sign of the correlation might be, which is explained by the fact that the computed correlation for the unadjusted series is a mere 0.042.

Figure 4. Inflation and unemployment, adjusted for season.

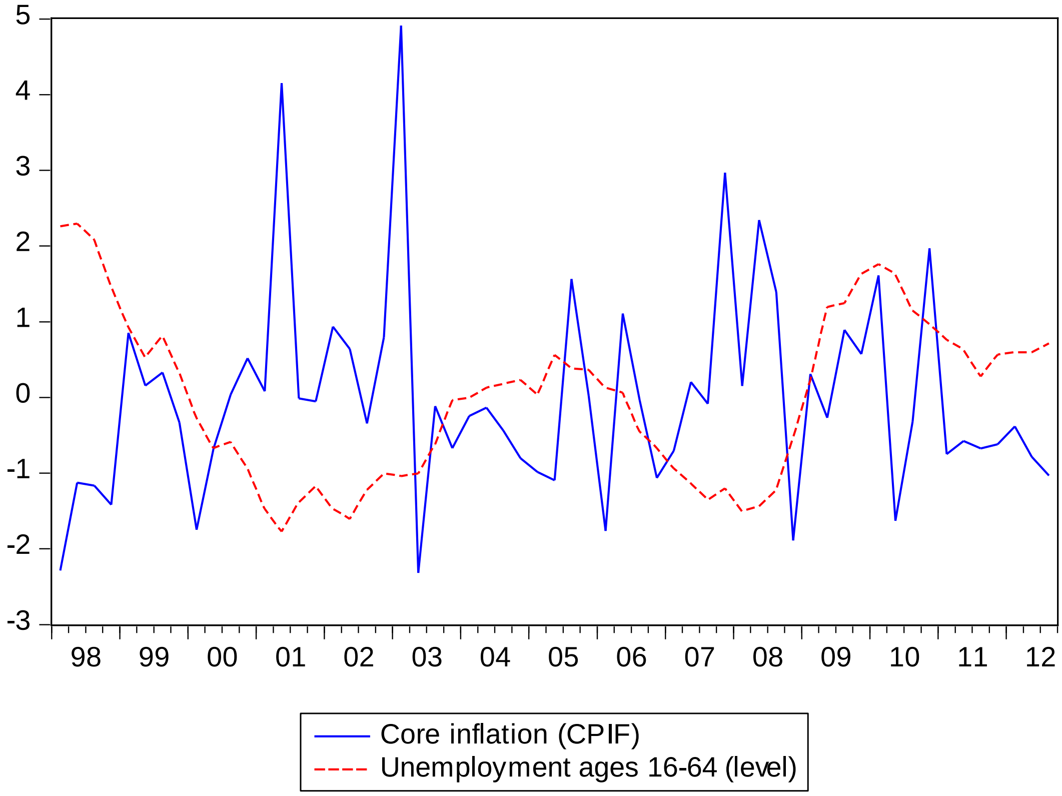


Figure 4 shows a negative correlation between inflation and unemployment in the period 2000-2008. In the other periods, however, the nature of this relationship is less clear. Over the entire sample, the correlation between core inflation and the level of unemployment is 0.133.

4. Estimation Results

In this section, I investigate the empirical relevance of the models presented in section 2. All variables are measured in percentage points; meaning that one percent inflation is reported as 1 and a coefficient of 0.5 means that a one percentage point increase corresponds to 0.5 percentage points higher inflation. In all estimations quarterly inflation rates have been transformed to annual rates, which simply means that they have been multiplied by four.

4.1 SMOPC with forward-looking expectations

In this specification, I assume that agents form their expectations about future home inflation based on information available in the current period. More specifically, I assume that the information in the instruments being used in the first stage in this estimation represents the information set agents use to form their expectations about future home inflation. The equation being estimated is given by

$$\pi_t^{CPIF} = c + \beta_1 E_t\left[\pi_{t+1}^h\right] + \beta_2 u_t + \beta_3 \pi_t^f + \beta_4 \Delta a_t + \beta_5 E_t\left[\Delta a_{t+1}\right] + \boldsymbol{\beta}_q \mathbf{D}_{quarter} + \varepsilon_t, \quad \textbf{SMOPC-F}$$

where $\mathbf{D}_{quarter}$ is a 3x1 vector of dummy variables for quarters 2-4 and $\boldsymbol{\beta}$ is the 1x3 vector of coefficients for the dummy variables. The SMOPC-F was estimated with GMM using instrumental variables for the expectation terms in the equation. The instrument set is the four quarter change in home inflation ($\pi_{t,4q}^h$), home inflation in the previous period (π_{t-1}^h) and the four quarter change in productivity ($\Delta a_{t,4q}$), as well as the reported expected factor utilization in the next period $E_t\left[FU_{t+1}\right]$.[8] The standard errors are adjusted for heteroscedasticity and autocorrelation.

Table 1 shows the estimation results for five different specifications of SMOPC-F. Column (1) is a stripped down version of the model where the only explanatory variables are expected future home inflation and unemployment. Column (2) adds foreign inflation, (3) adds productivity change and (4) is the full set

[8] For each instrument set in all specifications, the J-test for over-identifying restrictions cannot reject the null hypothesis that the model is correct at the 5% significance level.

of explanatory variables from SMOPC-F. Column (5) removes productivity change in this period from (4) to evaluate how this affects the other coefficients.

The main specification is column (4) and the only coefficient estimates in this specification significantly different from zero is for foreign inflation, with a coefficient point estimate of 0.1, and for unemployment, with a coefficient estimate of about -0.4.

Column (1) shows that the coefficient for expected home inflation in the next period and unemployment in the same period is not significantly different from zero. In column (2) the coefficients for home inflation and unemployment do not enter significantly different from zero, while the coefficient for foreign inflation does.

Columns (3)-(5) add productivity to the specification, but the estimated coefficients are not significantly different from zero. Had the coefficients been significant with the same point estimates, they would have entered with an opposite sign from what we would expect from economic theory.

Table 1. Estimation results for SMOPC-F.

	1	2	3	4	5
$E_t\left[\pi_{t+1}^h\right]$	0.034	-0.139	-0.133	-0.036	0.366
	(0.241)	(0.290)	(0.275)	(0.108)	(0.435)
u_t	-0.405	-0.493	-0.511	-0.444*	-0.206
	(0.273)	(0.324)	(0.322)	(0.264)	(0.412)
π_t^f	-	0.070*	0.068*	0.101***	0.069***
		(0.035)	(0.034)	(0.033)	(0.013)
Δa_t	-	-	0.026	0.014	-
			(0.030)	(0.062)	
$E_t\left[\Delta a_{t+1}\right]$	-	-	-	-0.031	-0.258
				(0.124)	(0.192)
Constant	3.160	4.020	4.172	3.519	0.579
	(2.612)	(3.025)	(3.001)	(2.202)	(4.289)

Notes: Sample period 1998Q1-2012Q2, 58 observations after adjustments. Estimation with GMM, quarter dummies and heteroscedasticity and autocorrelation consistent covariance computation estimation weights. Lag lengths chosen by AIC as max lag 3 and a Newey-West fixed bandwidth. Standard errors and covariance computed using estimation weighting matrix. Weighting matrix iterates to convergence. Robust standard errors in parenthesis.
* is significantly different from zero at the 10%-level, ** the 5%-level and *** the 1%-level. All numbers are rounded to three decimal places.

4.2 SMOPC with backward-looking expectations

In this specification, I assume that agents use a purely backward-looking rule to form their expectations of future home inflation. In other words, I assume that their best guess of what home inflation will be in the next period is what home inflation was in the previous period, $E_t\left[\pi_{t+1}^h\right]=\pi_{t-1}^h$. I assume that they follow the same rule with respect to expectations about productivity change. The equation being estimated is given by:

$$\pi_t^{CPIF} = c + \beta_1\pi_{t-1}^h + \beta_2 u_t + \beta_3\pi_t^f + \beta_4\Delta a_t + \beta_5\Delta a_{t-1} + \boldsymbol{\beta}_q\mathbf{D}_{quarter} + \varepsilon_t \qquad \textbf{SMOPC-B}$$

where $\mathbf{D}_{quarter}$ is a 3x1 vector of dummy variables for quarters 2-4 and $\boldsymbol{\beta}$ is the 1x3 vector of coefficients for the dummies being estimated. The SMOPC-B is estimated with OLS, the standard errors are adjusted for heteroscedasticity and autocorrelation.

In Table 2, the main specification is reported in column (4). In this specification, the coefficient for home inflation does not enter significantly and neither does the coefficient estimates for productivity, while the coefficient estimates for unemployment and foreign inflation both do.

In columns (1) and (2), the coefficient estimate for home inflation does not enter significantly different from zero and in columns (3)-(5), I add productivity to the specification without a significant coefficient estimate on productivity for any of these specifications.

We should note that in Table 2, all specifications have the coefficient estimate for home inflation entering not significantly different from zero, while the constant is significantly different from zero in all of them. This can be thought of as a measure of our ignorance with respect to the determinants of inflation. It could also partly be the result of expectations which are not backward-looking, but instead anchored to the target as argued in Svensson (2013). In this case, the expectations should not enter the equation other than through the constant.

Table 2. Estimation results for SMOPC-B.

	1	2	3	4	5
π_{t-1}^{h}	-0.0002	-0.020	-0.013	-0.009	-0.020
	(0.059)	(0.058)	(0.058)	(0.063)	(0.058)
u_t	-0.443***	-0.420**	-0.416**	-0.413**	-0.420**
	(0.190)	(0.196)	(0.192)	(0.193)	(0.199)
π_t^f	-	0.066**	0.065**	0.064**	0.066**
		(0.027)	(0.027)	(0.027)	(0.027)
Δa_t	-	-	0.019	0.024	-
			(0.023)	(0.025)	
Δa_{t-1}	-	-	-	0.010	-0.002
				(0.027)	(0.026)
Constant	3.532**	3.200*	3.148*	3.118*	3.203*
	(1.567)	(1.647)	(1.611)	(1.630)	(1.674)
R^2	0.611	0.650	0.654	0.655	0.650
R_{adj}^2	0.575	0.610	0.607	0.600	0.602

Notes: The sample period is 1998q1-2012q3, 59 observations. Estimation with OLS, quarter dummies and a heteroscedasticity and autocorrelation adjusted coefficient estimation matrix. Pre-whitening with lag length chosen by AIC, lags specified at max 3 and Newey-West fixed bandwidth. Robust standard errors in parenthesis.
* is significantly different from zero at the 10%-level, ** at 5%-level and *** is 1%-level. All numbers are rounded to three decimal places.

4.3 SMOPC with anchored expectations

In this section, I assume that home inflation expectations are anchored to the target π^T , while I still assume a backward-looking rule for the expected future productivity change.

$$\pi_t^{CPIF} = \pi^T + \beta_1 u_t + \beta_2 \pi_t^f + \beta_3 \Delta a_t + \beta_4 \Delta a_{t-1} + \boldsymbol{\beta}_q \mathbf{D}_{quarter} + \varepsilon_t \quad \textbf{SMOPC-A.}$$

The SMOPC-A is estimated with OLS, and since expectations are anchored to the target they will enter the constant term. The standard errors are adjusted for heteroscedasticity and autocorrelation.

Table 3. Estimation results for the SMOPC-A.

	1	2	3	4	5
u_t	-0.442**	-0.394**	-0.399**	-0.401**	-0.394**
	(0.167)	(0.162)	(0.165)	(0.167)	(0.164)
π_t^f	-	0.065**	0.064**	0.064**	0.065**
		(0.026)	(0.026)	(0.026)	(0.026)
Δa_t	-	-	0.019	0.024	-
			(0.023)	(0.024)	
Δa_{t-1}	-	-	-	0.011	-0.001
				(0.026)	(0.025)
Constant	3.530***	2.982**	3.008**	3.019**	2.981**
	(1.3001)	(1.288)	(1.306)	(1.313)	(1.299)
R^2	0.611	0.649	0.654	0.655	0.649
R^2_{adj}	0.583	0.616	0.614	0.608	0.609

Notes: The sample period is 1998q1-2012q3, 59 observations. Estimation with OLS, quarter dummies and a heteroscedasticity and autocorrelation adjusted coefficient estimation matrix. Pre-whitening with lag length chosen by AIC, lags specified at max 3 and Newey-West fixed bandwidth. Robust standard errors in parenthesis.
* is significantly different from zero at the 10%-level, ** at 5%-level and *** is 1%-level. All numbers are rounded to three decimal places.

In Table 3, the main specification in column (4) has the coefficient estimates of unemployment, foreign inflation and the constant entering significantly different from zero, while the coefficients for productivity change do not have estimates which are significantly different from zero at the ten percent level. In columns (1) and (2), unemployment has a negative coefficient of about -0.4 and foreign inflation has a coefficient of 0.065, which are robust across all specifications in Table 3.

In columns (3)-(5), the coefficient for the change in productivity (past and present) enters not significantly different from zero in all three cases.

4.4 Estimation results and Preferred Specifications

To summarize the estimation results of the equations in section 4.1-4.3, I report the main specifications of each SMOPC in Table 4.

Table 4. SMOPC Main specifications

	SMOPC-F	SMOPC-B	SMOPC-A
$E_t\left[\pi_{t+1}^h\right]$	0.036	-	-
	(0.108)		
π_{t-1}^h	-	-0.009	-
		(0.063)	
u_t	**-0.444***	**-0.413****	**-0.401****
	(0.264)	**(0.193)**	**(0.167)**
π_t^f	**0.101*****	**0.064****	**0.064****
	(0.033)	**(0.027)**	**(0.026)**
Δa_t	0.014	0.024	0.024
	(0.062)	(0.025)	(0.024)
$E_t\left[\Delta a_{t+1}\right]$	-0.031	-	-
	(0.124)		
Δa_{t-1}	-	0.010	0.011
		(0.027)	(0.026)
Constant	3.519	**3.118***	**3.019****
	(2.202)	**(1.630)**	**(1.313)**
R_{adj}^2	-	0.600	0.608

Of the three main specifications for the SMOPC reported in Table 4, I choose to proceed with the SMOPC-A (with anchored expectations) by the principle of parsimony. It has the most explanatory variables entering with coefficients significantly different from zero, and it can explain about 60% of the variation in inflation. This is not a crucial assumption given how robust the coefficients are across specifications.

In the SMOPC-A, foreign inflation has a significant coefficient of 0.064, which is the same as in SMOPC-B but slightly smaller than the estimate in SMOPC-F. In all three specifications, the coefficient for unemployment is roughly -0.4 and significantly different from zero across specifications. Therefore, the SMOPC-A is a reasonable representative of the three models because it includes all explanatory variables suggested by theory, while noting that this has little importance for the estimates of the significant coefficients which are robust across the different specifications in Table 4, as well as in Table 1-3.

Below, I will only refer to the estimates from the main specification from the SMOPC-A, where unemployment has a coefficient estimate that is about -0.4. This means that if unemployment is one percentage point higher (e.g. 7% instead of 6%), it will lower (annual) inflation by 0.4 percentage points. Foreign inflation enters with a coefficient estimate of 0.064, which means that if foreign inflation goes up by 1 percentage point (e.g. it is 2% instead of 1%), inflation will increase by 0.064 percentage points.

5. Sensitivity Checks

The results in section 4 are reassuringly robust across specifications. In this section, I will test if these results can withstand further scrutiny in terms of additional robustness checks.

5.1 Inflation Augmented Phillips Curve (IAPC)

In addition to the theoretical model we have derived, there are competing inflation models. For instance, we have the original Phillips Curve in Phillips (1958) augmented with a backwards-looking inflation expectation:

$$\pi_t^{CPIF} = c - \beta_1 u_t + \beta_2 \pi_{t-1}^{CPIF} + \varepsilon_t . \qquad \textbf{IAPC}$$

This specification has unemployment and lagged inflation as determinants of inflation. The backwards-looking term in this equation differs from the one in the

SMOPC-B because it uses lagged CPIF inflation as a determinant for current inflation rather than lagged home inflation as in SMOPC-B.

To this model, I then add the explanatory variables from the SMOPC – foreign inflation and productivity change – to see if they can help explain the data.

The equation is estimated with OLS and quarter dummies, the standard errors are adjusted for heteroscedasticity and autocorrelation.

Table 5. Estimation results for IAPC.

	1	2	3
u_t	-0.496**	-0.432**	-0.431**
	(0.203)	(0.198)	(0.195)
π_{t-1}^{CPIF}	-0.140	-0.096	-0.081
	(0.097)	(0.085)	(0.084)
π_t^f	-	0.062**	0.061**
		(0.024)	(0.024)
Δa_t	-	-	0.017
			(0.022)
Constant	4.304**	3.536**	3.477**
	(1.838)	(1.750)	(1.695)
R^2	0.619	0.653	0.657
R_{adj}^2	0.583	0.613	0.609

Notes: The sample period is 1998q1-2012q3, 59 observations. Estimation with OLS, quarter dummies and a heteroscedasticity and autocorrelation adjusted coefficient estimation matrix. Pre-whitening with lag length chosen by AIC, lags specified at max 3 and Newey-West fixed bandwidth. Robust standard errors in parenthesis.
* is significantly different from zero at the 10%-level, ** at 5%-level and *** is 1%-level. All numbers are rounded to three decimal places.

In Table 5, column (1) shows that the only coefficient significantly different from zero except, for the constant, is the one for unemployment.

In column (2), the coefficient for foreign inflation enters significantly and makes the coefficient for unemployment enter slightly less negative, while the constant is now smaller. In column (3), I add productivity change in this period and its coefficient is not significantly different from zero. Had it been significantly different from zero, however, the point estimate would have been entered with the wrong sign according to economic theory.

This IAPC specification differs from the main specification of the SMOPC-B in that it includes lagged CPIF inflation instead of lagged home inflation. A comparison of the estimation results of the main specifications for these two equations shows that the coefficients are roughly the same in both specifications. We also note that neither specification has the coefficient for the lagged inflation term entering significantly different from zero. This would suggest that perhaps inflation expectations are anchored as they are in the SMOPC-A or in Svensson (2013).

5.2 Lars E.O. Svensson's Phillips Curve

I run the specification suggested in Svensson (2013) because the previous estimations in section 4 and 5.1 seem to suggest that expectations may be anchored to the target as they are in Svensson (2013). I will also augment this Phillips Curve with the flavors of the SMOPC: foreign inflation and productivity change.

$$\pi_t^{CPIF} = c - \beta_1 \Delta u_t - \beta_2 u_{t-1} + \varepsilon_t \qquad \textbf{LEOS Phillips Curve}$$

The equation is estimated with OLS, quarter dummies and standard errors which are adjusted for heteroscedasticity and autocorrelation.

In column (1) in Table 5, the coefficient for the change in unemployment does not enter with a significant coefficient, and the coefficient for past unemployment has a significant estimate of about -0.4. However, this equation may be re-written in a way which allows the entire effect of unemployment on inflation to go through u_{t-1}. For this reason, we should not conclude anything about the insignificance of the difference term.

In column (2) and (3), when I add foreign inflation and productivity change, the coefficient for the change in unemployment still does not enter significantly, and neither does the coefficient for productivity change. The coefficients for unemployment and foreign inflation, however, are significantly different from zero and very close to what we have seen in Table 1-5.

Consequently, for LEOS Phillips Curve, the specification in column three (3) is very close to the main specification for SMOPC in Table 4 and IAPC in Table 5.

So, with respect to the main specifications in Table 4 and the IAPC, we can see that, although they start out with different first specifications, including different explanatory variables, we end up with specifications which all have significant coefficient estimates within the same range. This is a nice result, because it suggests I have included variables which are important explanatory variables for the variation in inflation. These all have a clear economic interpretation, the coefficient estimates are reasonably robust across specifications and they fit the data about the same. This gives me some degree of confidence when I investigate whether the explanatory variables can explain why inflation has deviated from target.

Table 6. Estimation results for LEOS Phillips Curve.

	1	2	3
Δu_t	-0.252	0.040	0.004
	(0.508)	(0.511)	(0.528)
u_{t-1}	-0.441**	-0.387**	-0.393**
	(0.166)	(0.157)	(0.162)
π_t^f	-	0.070**	0.068**
		(0.026)	(0.026)
Δa_t	-	-	0.018
			(0.023)
Constant	3.368**	2.578*	2.631*
	(1.434)	(1.407)	(1.457)
R^2	0.612	0.654	0.658
R^2_{adj}	0.576	0.614	0.611

Notes: The sample period is 1998q1-2012q3, 59 observations. Estimation with OLS, quarter dummies and a heteroscedasticity and autocorrelation adjusted coefficient estimation matrix. Pre-whitening with lag length chosen by AIC, lags specified at max 3 and Newey-West fixed bandwidth. Robust standard errors in parenthesis.
* is significantly different from zero at the 10%-level, ** at 5%-level and *** is 1%-level. All numbers are rounded to three decimal places.

5.3 Productivity

A problem with the measure of productivity which is not adjusted for factor utilization is that it can pick up a change in factor utilization rather than the underlying technological change. If this is the case, it can cause the correlation to go in the opposite direction from what theory would predict.

In fact, this is what I find when I estimate the models with productivity change which is not adjusted for reported factor utilization. The estimated coefficients on current and expected future productivity change enter significantly with signs opposite of what economic theory would suggest, or not significant at all. That this result is partially driven by the financial crisis can be observed in figure A7-A8 in the Appendix. These figures show that both labor productivity and multifactor productivity goes down in response to the financial crisis, which coincides with lowered inflation and contributes to the reversed correlation.

5.4 Sample period

Splitting the sample period in the middle mainly affects the size and significance of the estimated coefficient for unemployment. The coefficient for unemployment becomes bigger and significantly different from zero when the equation is estimated on the first half of the sample, and it is insignificantly different from zero when the equation is estimated on the second half of the sample. Ending the sample period before 2009 improves the fit of the model and gives a larger coefficient estimate for unemployment, while the other explanatory variables have coefficients which remain roughly the same – all significantly different from zero.

5.5 Estimation method

Estimating the forward-looking equation SMOPC-F with TSLS or using time series forecasting methods to generate expected future vales and estimating the equation with OLS does not qualitatively change the results.

6. Why has inflation deviated from its target level?

In this section, I will use the estimated SMOPC-A to shed light on the question of why the Riksbank has missed its target. Evidence from structural vector autoregressive models shows that inflation responds with a delay[9] to monetary policy and therefore the Riksbank cannot stabilize (annual) inflation at exactly two percent when unexpected events occur (assuming they could hit the target

[9] The Riksbank has a time horizon of one to two years for its target attainment Berg (2005).

otherwise). If there are shocks to imported inflation or productivity, then inflation will sometimes overshoot the target and undershoot it at other times.

It is important to note here is that we have estimated our equations on core inflation to abstract from the direct effect which interest rates have on CPI inflation. This resulted in a specification with only three significant coefficients, given by

$$\pi_t^{CPIF} = c - 0.401u_t + 0.064\pi_t^f \ . \tag{19}$$

If we now want to investigate the reasons for why inflation has varied around target, we need to rewrite the equation in terms of CPI inflation, since CPI is the official target variable. This can be done by simply adding the interest cost index times its weight in CPI to both sides of equation (19) to get

$$\pi_t = c - 0.401u_t + 0.064\pi_t^f + \omega z_t \, . \tag{20}$$

This specification includes the interest cost index just as it is included in the official CPI inflation target together with the estimated coefficients for unemployment and foreign inflation. Below, we proceed to evaluate the impact of each explanatory variable on the variation around target exhibited by inflation.

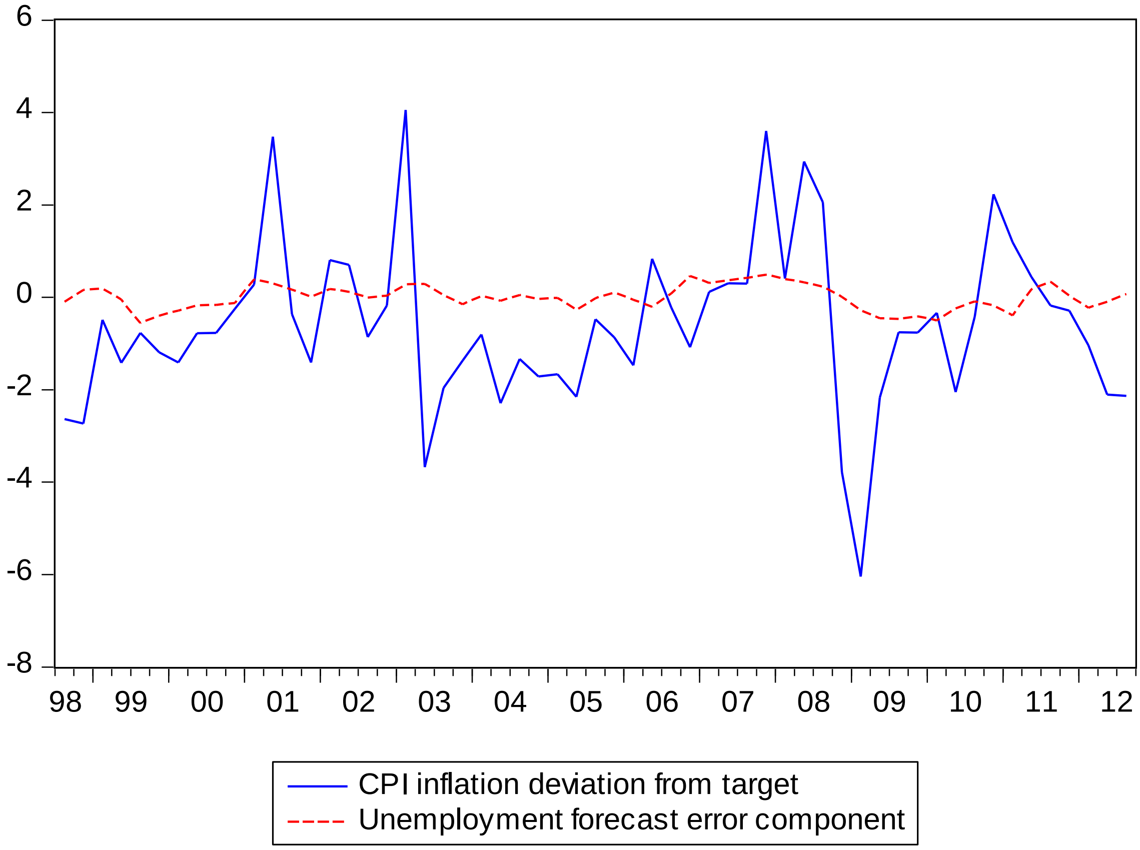
6.1 Deviations from the inflation target and forecast errors

To see whether we can explain why CPI inflation has deviated from its target, at a given point in time, we can make a six quarter forecast for each of the explanatory variables and compare this forecast with the outcome for that quarter in order to construct a forecast error ($x_{t+6} - \hat{x}_{t+6}$). For example, if the forecast for foreign inflation six quarters ahead is 2% (annual rate) and the actual value six quarters later is 1%, then the forecast error is 1%-2%=-1%. This would cause inflation in that period to be lower than target, everything else being equal. A zero value would mean no forecast error. The forecast equations are reported in the Appendix Section 3.2.

Below, I plot the forecast errors multiplied by their estimated coefficients (β_x) from the SMOPC-A, which I will call the *forecast error component*, against inflations deviation from target. Note here that in order to make the forecasts, lagged values of the explanatory variables are used and therefore the forecast period will be shorter than the sample period.

For the interest cost index, the error component will not be a forecast, but rather the co-variation of CPI inflation deviation from target with the weighted change in the interest cost index.

Figure 5. Inflation adjusted for season and the forecast error component for unemployment.



In Figure 5, a positive forecast error component for unemployment indicates that unemployment was overestimated. This is because the estimated coefficient for unemployment is negative and a negative forecast error will therefore become a positive forecast error *component* when they are multiplied. This would mean that inflationary pressures would be overestimated (i.e. a positive relationship), all other things being equal. To quantify this relationship, I calculated what I will call the imputed[10] R^2 for figure 5, and it is 0.14. This means that the unemployment forecast

[10] This concept is described in the Appendix Section 3.3.

error component can explain about 14% of the variation around target for the sample period.

Figure 6. Inflation adjusted for season and the forecast error component for foreign inflation.

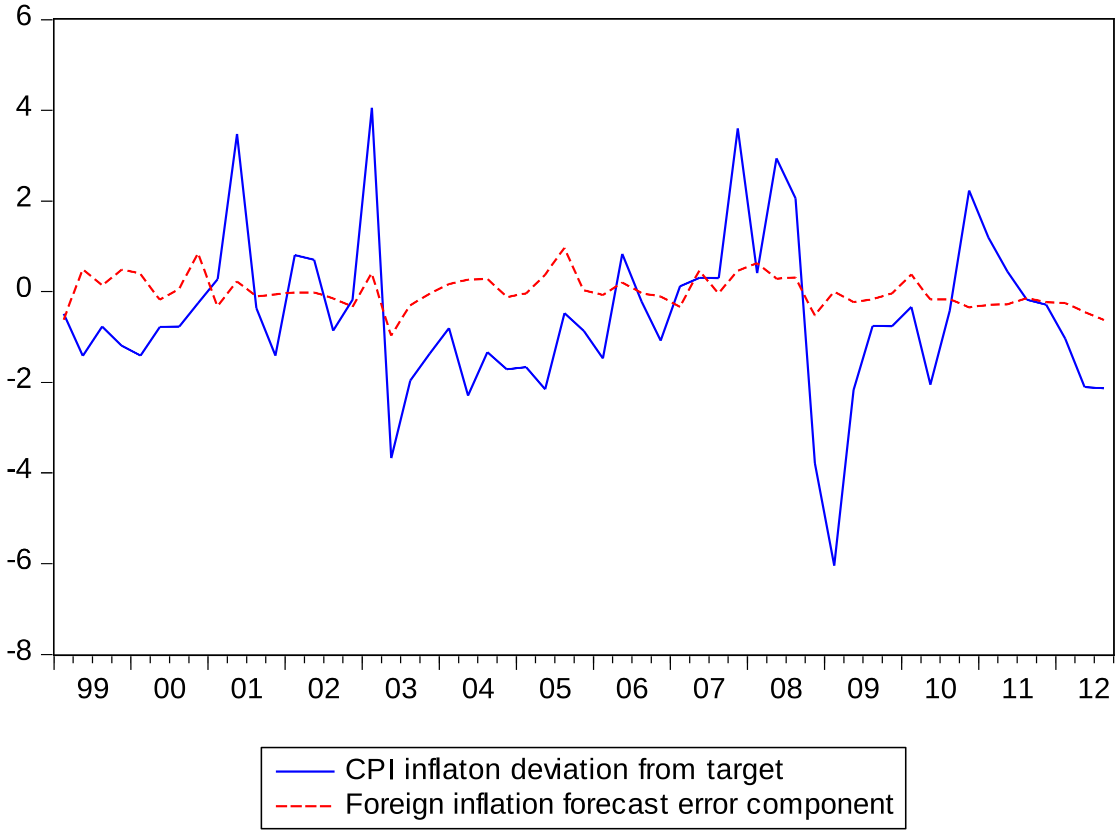
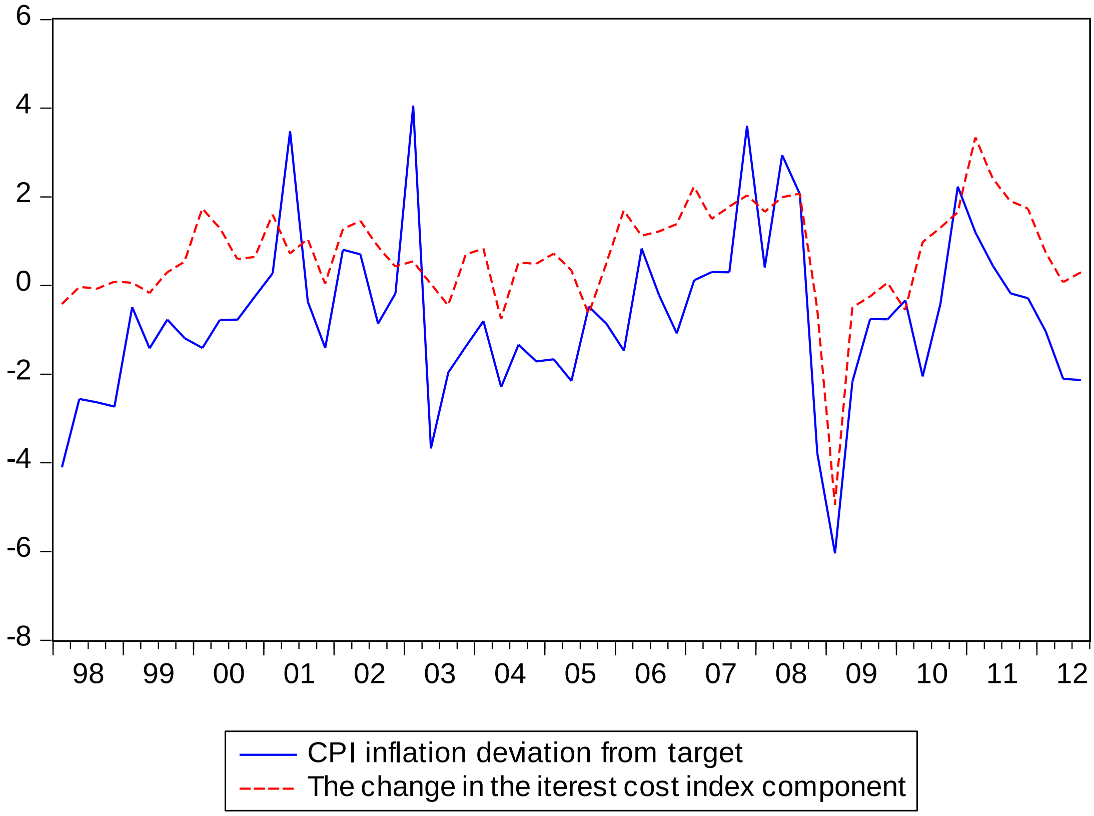


Figure 6 shows that inflation varies much more than the forecast error component for foreign inflation. We would predict a negative relationship between the forecast error component for foreign inflation and inflation. If the Riksbank expects a higher value than the actual value, it will have overestimated the inflationary pressure and inflation in that period should come in lower all other things equal. The imputed R^2 for figure 6 is 0.13. So the forecast error component for foreign inflation can explain around 13% of the variation around target for CPI inflation.

Figure 7. Inflation adjusted for season and the change in the interest cost index.



In Figure 14, the interest cost index component should be positively correlated with inflations deviation from target. If interest rates are raised, the interest cost index will go up and inflation will be higher, all other things being equal. This is what we can see in the figure and the imputed R^2 for figure 7 is 0.55, meaning that more than half of the variation in inflation from target can be explained by changes in the interest cost index.

This result is in line with the findings in Andersson, Palmqvist and Österholm (2012). When the Riksbank cuts the repo rate, mortgage rates normally fall too. If the Riksbank cuts the repo rate in order to increase inflation in later periods, the initial effect will therefore be, all other things being equal, that inflation will fall in this period due to the decrease in the interest cost index. Depending on the response in mortgage rates (with different time horizons), this effect on inflation may persist for up to eight years.[11]

[11] A household can set its mortgage rate at a variable interest rate or at a fixed rate for 1, 2, 3, 5 or 8 years.

7. Concluding remarks

This paper has set out to test whether some of the proposed reasons for Swedish inflations deviations from target hold empirically. However, with my chosen approach I am limited to testing and discussing deviations from the inflation targeted, not the level of inflation. Of course, there are other competing or complementary explanations for why the level of inflation has deviated from target, some of which we cannot test. The simplest one being an asymmetric goal function for the Riksbank, meaning that it dislikes above-target inflation more than it dislikes below-target inflation. This would explain why the Riksbank more often err on the side of too low inflation and therefore why average inflation has come in below target. Other possible explanations for this are: biased inflation forecasts (ref), poor assessment of the natural rate of unemployment and inflation pressures (ref), a decrease in the effectiveness of monetary policy (ref) or that the Riksbank pursued other agendas (e.g. financial stability) (ref).

6.1 Conclusions

This paper sets out to answer the question of why inflation has deviated from target. The usual suspects are unexpected changes in imported foreign inflation and productivity.

The contribution of this paper is the use of a theoretical model to test whether these explanatory variables can help explain the variation in inflation. We derived a small open economy Phillips Curve which included the proposed variables, as well as the interest cost index, for the representative household. When I estimated this model, I found a main specification with anchored inflation expectations which does a good job explaining the data (around 70% of the variation). I then used this specification to analyze potential reasons for why inflation has deviated from target.

I cannot claim to explain much of the deviation target for the period up until 2008, but after 2008 one particular explanation is important: I find that the large changes in the interest cost index have been the prime movers of inflation. If we study Figure 8, we can see this clearly in the first quarter of 2009, where there was a -6 percentage point drop in the annual inflation rate out of which -5 percentage points came from the drop in the interest cost index due to lowered interest rates.

The role of the interest cost index and its impact on inflation seems to be more important in the period after 2008; a period characterized by historically low interest rates and large changes of interest rates. The fact that interest rates have been lowered significantly below their "normal" level is the reason why inflation has fallen far below its target level. This is a counterintuitive explanation in a conventional theoretic setting without the interest cost index. But, given the empirical relevance of the interest cost index relative to the conventional explanations, it is an important channel for understanding why CPI inflation has deviated to such a large degree from its target level.

Now that we have established the fact that we have low inflation today, in part, because the repo rate was lowered to raise inflation in the future, we need to think about the implications of this result.

> "We cannot solve our problems with the same thinking we used when we created them." – Albert Einstein

A novel explanation would be that inflation behaves differently in high and low interest rate environments; meaning that in a low interest rate environment, even small changes in interest rates have large effects on inflation. This is especially true if this coincides with a period of great uncertainty about the future of the economy (e.g. after a crisis). If economic activity is unusually cautious, a lowered interest rate does not necessarily raise the level of economic activity, and unless a (positive) shock moves inflation away from that environment, the prescribed medicine of lowered interest rates is the cause, rather than the cure, of the problem of inflation deviating from its target.

Given the impact of the interest cost index on CPI inflation, we cannot ignore the fact that changes in the interest cost index can explain a large proportion of the deviations in inflation and, consequently, why a period of lowered interest rates can fail to raise CPI inflation. This is a non-negligible direct impact on inflation from the repo rate which is set by the Riksbank and it raises some interesting questions. How do we value below-target inflation today in order to avoid too low inflation in the future? Under which conditions can the Riksbank choose to disregard the change in the interest cost index and instead focus on the CPIF? Is it only when it lowers inflation below target or is it symmetric, so that higher interest rate costs for home owners can be disregarded if it causes CPI inflation to deviate too much above the target level? These questions certainly warrant a discussion about the relevant measure of inflation.

If we argue that the CPIF is the relevant measure of inflation because the interest cost index has a large effect on CPI inflation, and support that position with the fact that the CPI and the CPIF theoretically converge in the long run, we need to consider the potential consequences of this position. The first issue comes from the fact that we have seen a long downward trend in the interest rate and the second issue comes from the asymmetric nature of the interest rate component. The change in the interest rate depends on the level from which the change takes place. An increase from 2% to 3% is a 50% change while an increase from 1% to 2% is a 100% change in the interest rate.

Even if the two measures (the CPI and CPIF) converge in the long run, there are no guarantees that we will not experience long periods with CPI inflation below target as a consequence of negative shocks hitting the economy. Lowered interest rates in response to these shocks would only perpetuate the problem.

We cannot have a situation where the official target is CPI inflation only when it is in line with the target and CPIF inflation, as this makes it impossible to evaluate the actions of the Riksbank. Without a sustained target and accountability for its attainment, the Riksbank will lose credibility. A lack of credibility, in turn, will change the way expectations about future inflation are formed.

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Appendix

1. Unit Root tests

Table A1. Unit root tests for the variables used in the regressions. The test was performed on the level of the series presented, with an intercept, a Bartlett kernel and Newey-West bandwidth selection. All test are evaluated at the 5% significance level.

	ADF, has a Unit Root	**KPSS, reject Stationarity**
π^f	**No*****	**No*****
Δa	**No*****	**No*****
π	**No*****	**No*****
u	**Yes**	**No*****

Unemployment

I use the linked series for the entire sample period provided by Statistics Sweden to account for breaks in the time series which occurred in 2005 and 2007.[12]

[12] Running a regression with a dummy for the old series of unemployment up until the break in 2005 does not result in a significant effect for the old series, so we proceed to estimate our equations with only the linked series.

2. Scatter plots for the explanatory variables against inflation.

Figure A1. Home inflation against core inflation.

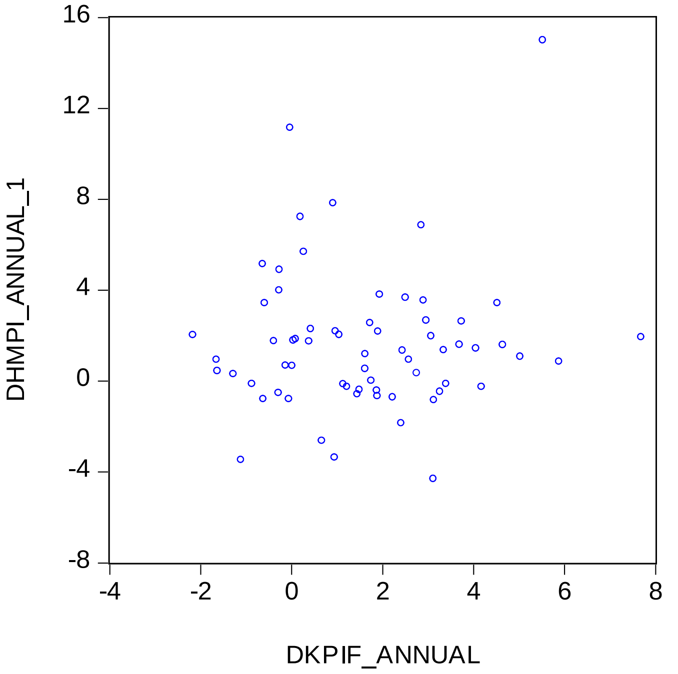


Figure A2. Foreign inflation against core inflation.

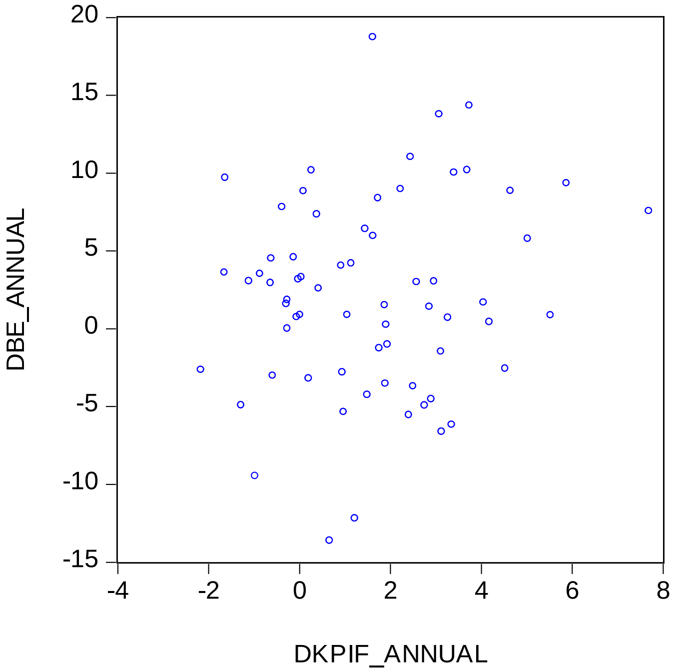


Figure A3. Change in productivity against core inflation.

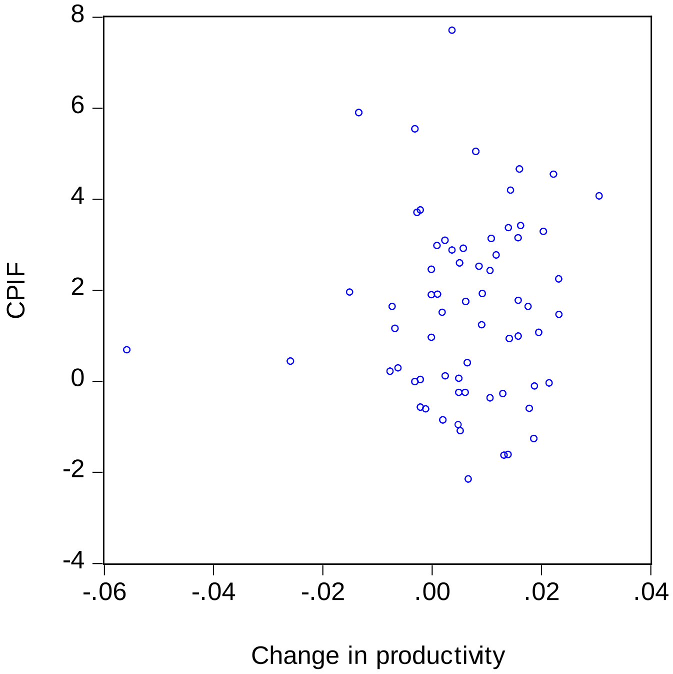

8
6
4
2
0
-2
-4
CPIF
-.06
-.04
-.02
.00
.02
.04
Change in productivity

Figure A4. The change in the interest cost index against Inflation.

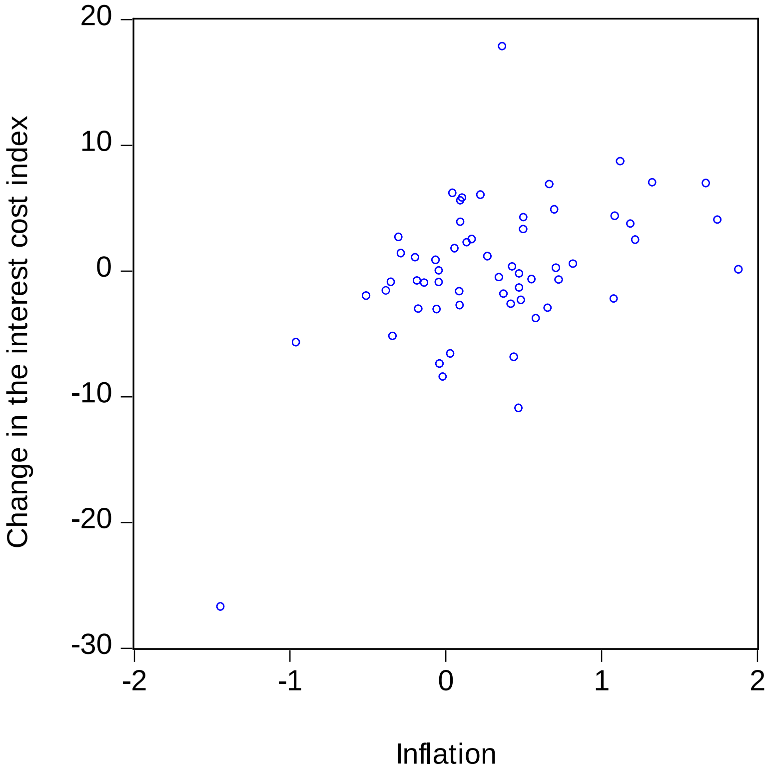


Figure A5. The level of Unemployment against core Inflation.

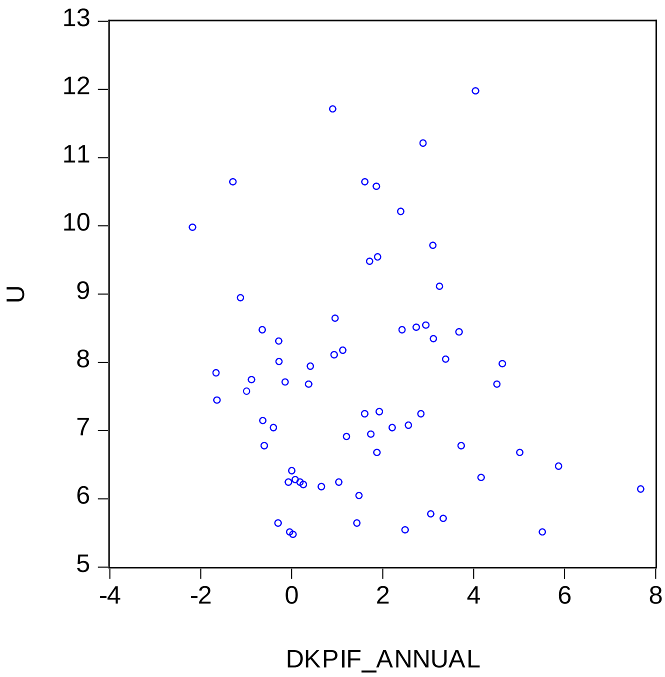
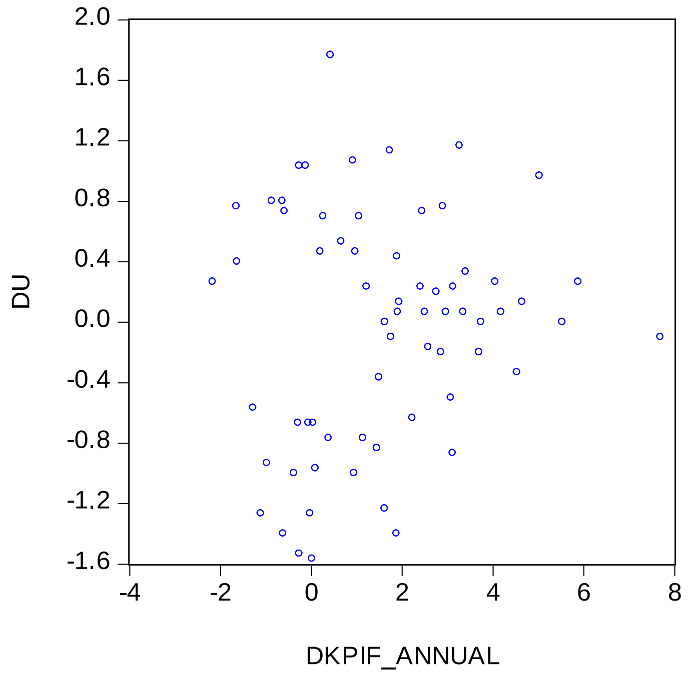


Figure A6. The change in the unemployment rate against inflation.



3. Productivity

A problem when measuring productivity occurs when production goes down in a recession and factor utilization goes down at the same time. In that case, value added divided by hour worked will pick up all of this as lowered productivity when it coincides with lowered inflation (as in a crisis), and this can affect the estimated impact of "true" productivity on inflation.

Figure A7. Labor productivity and multi factor productivity, yearly data.

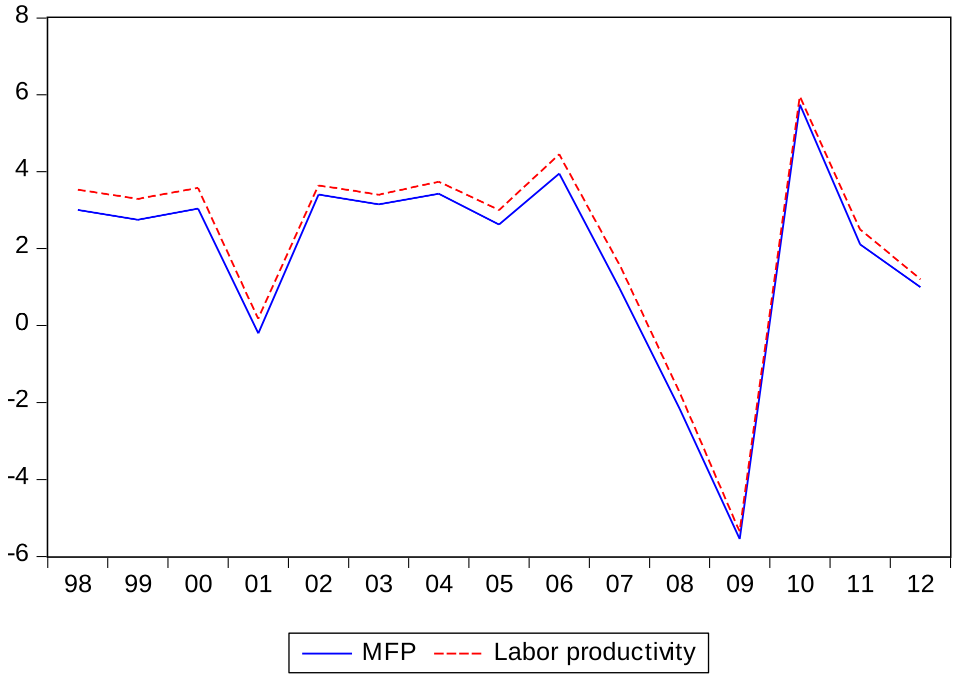


Figure A8. Labor productivity and multi factor productivity, yearly data.

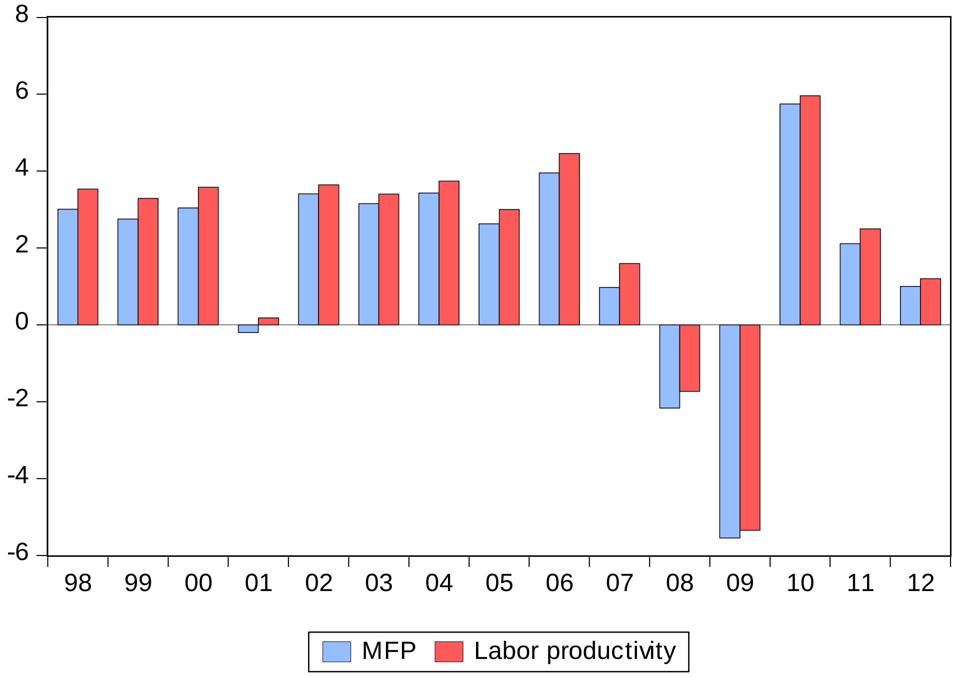


Figure A8 shows the same data as in Figure A7 in order to illustrate how closely the two measures move together.

3.1 Descriptive statistics

Table A1. Descriptive statistics

	π_t^{CPIF}	z_t	π_t^f	u_t
Mean	1.554	-0.009	0.575	7.301
Median	1.453	-0.037	0.644	7.233
Maximum	7.692	17.796	4.678	10.200
Minimum	-2.164	-26.756	-3.406	5.467
Std. Dev.	2.064	5.905	1.619	1.203

The sample period is 1998q1-2012q3.Values are reported in whole percentage point i.e. one percent is a 1 in the table.

In Table A1, we can see that the average quarterly inflation is 0.324 percent, compared to 0.5 percent, which is the theoretical quarterly counterpart to the target of 2 percent annual inflation. An average quarterly inflation of 0.324 percent corresponds to 1.3 percent annually, if the quarterly increase was the same for four consecutive quarters. This is to illustrate how the level of inflation in the sample relates to its annual target level. However, it is not realistic to assume that an annual target of two percent inflation corresponds to four consecutive quarters of 0.5 percent inflation. This is to say that a single deviation from target using quarterly data cannot in and of itself say that the Riksbank has missed the target level for annual inflation. We can, however, see if a deviation co-moves with any of our computed components and thus shed light on why the deviation occurred.

3.2 Forecast errors

The forecast equations used for the six–quarter-at-the-time-forecasts were the ones with a zero bias proportion and the lowest Thiel Inequality Coefficients. They are given by

$$\hat{u}_{t+6} = c + \beta_1 u_t + \ldots + \beta_5 u_{t-4} + \beta_6 z_t + \beta_7 z_{t-1} + \beta_8 z_{t-2} + \beta_9 \pi_t + \beta_{10} \pi_{t-1} + \beta_{11} \pi_{t-2} + \beta_{12} D_2 + \beta_{13} D_3 + \beta_{14} D_4,$$

and

$$\hat{\pi}^f_{t+6} = c + \beta_1 \pi^f_t + \ldots + \beta_7 \pi^f_{t-6} + \beta_8 z_t + \ldots + \beta_{12} z_{t-4} + \beta_{13} D_2 + \beta_{14} D_3 + \beta_{15} D_4.$$

3.3 Imputed R-square

To get an idea about how much of the variation of CPI inflation around target, which can be explained by the component, we can calculate an imputed R-square. We calculate this value by treating the component series as the only explanatory variable in a linear regression, on the deviation from target series which is plotted in the same graph. We can apply the formula for explained variance for this relationship as

$$R^2_{imputed} = \frac{\sum_{n=0}^{N} \left(fec_{t+n} - \bar{\pi}^{dev} \right)^2}{\sum_{n=0}^{N} \left(\pi^{dev}{}_{t+n} - \bar{\pi}^{dev} \right)^2},$$

where $fec_{t+n} \equiv 0 + \beta_x(\mathrm{x}_{t+n} - \hat{\mathrm{x}}_{t+n})$, π^{dev}_{t+n} is the deviation from target and $\overline{\pi}^{dev}$ is the sample mean of the deviation from target.