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## **Inflation and the Speed of Money**

P\* and the Swedish case

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This thesis investigates the use of combining output and velocity gaps under one coefficient, the price gap, to explain changes in Swedish inflation. The data comprises 1980–2007. A change in the slope of the estimated regression owing to different economic conditions is allowed for. Evidence of a longer term relation between the development in Swedish inflation and the price gap or a separate velocity specification is not provided by the data substantiating this thesis.

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# 1 Introduction

## 1.1 Background

$P^*$  is the long-term price level consistent with current money supply and equilibrium levels of output and velocity. In a much talked of paper, Hallman, Porter and Small (1991) model inflation as a function of actual prices' deviation from  $P^*$ . While the idea that inflation in the long-run is tied to the money supply is hardly novel, HPS show a strong relation which has awoken a keen interest in their model.

Indeed, the  $P^*$  model has been tested on quite a few countries, one being Sweden. However, the latest year from which data has been drawn to examine the applicability of  $P^*$  on the Swedish economy is 1987. Post 1987 (i.e. 1993) Sweden has reverted to times of low inflation, abandoned the fixed exchange rate and deployed a numerical inflation target.

## 1.2 Purpose

This thesis aims to examine whether deviation of actual prices from  $P^*$  is a suitable predictor of Swedish inflation given prevailing conditions before and after 1993.

## 1.3 Limitation

Chief limitation of this thesis is a dedication to its purpose. Furthermore, the study does not seek to evaluate whether money has any effect on output.

## 1.4 Approach

The assessment will be carried out partly as a conventional econometric analysis of particular model's viability and partly as a relative assessment where interest-rate models will be brought into play.

## 1.5 Structure

Firstly, the  $P^*$  model and findings of its followers and opponents are presented. Secondly, the model is specified. Thirdly, data necessary to evaluate the model is described. Fourthly, the model is estimated and a standalone assessment is conducted. Fifthly, a relative in- and out-of-sample analysis of  $P^*$  using the term-structure and the T-bill models is conducted. Finishing off the analysis is a final conclusion.

## 2 Quantitative Thoughts

### 2.1 An introduction of $P^*$

Hallman, Porter and Small (HPS) rely upon long-standing concepts of the equation of exchange,  $MV = PQ$ , where an increase in nominal money supply ( $M$ ) entails an increase in the long-term price level ( $P$ ), given that the expansion is not accompanied by changes in real output ( $Q$ ) and or the level of money velocity ( $V$ ). Money velocity is nominal output divided by the money stock. Based on these fundamentals, HPS construct the variable  $P^*$  as an equilibrium price level consistent with equilibrium in goods and financial markets along with current money supply ( $P^* = MV^*/Q^*$ ), to which the actual price level has to adjust in the long-run.

The occurrence of a changing rate of inflation hangs on the presence of a price gap which predicts the course of inflation development. In the model a price gap is derived from trend deviations in velocity and real output. An equilibrium price level which is below the actual is anticipated to depress inflation till the actual price level is adjusted to the long-run level. Accordingly this lower long-term price level would derive from a lower money stock - rising velocity above its trend - or a below-trend real output or both.

HPS find that shocks to the velocity of money are transitory to the long-run level of ditto and that velocity returns to its own mean. The authors assert that the equilibrium velocity (of  $M2$ ) is constant during their review period, constituting one of the more notorious assumptions in their original definition of the model. In the original paper equilibrium money velocity is thus independent of the development in the money stock or output. Admittedly, HPS do not rule out the possibility that the behavior in equilibrium velocity may well have changed since the end of their sample period, 1981.

### 2.2 Views and previous findings

The  $P^*$  model has been tested on a number of different economies. Leaving aside that the intentions of the studies have differed and that modifications of the original specification are not rare, thus far the research has in principal been endorsing.

Hoeller and Poret (1991) examine the applicability of  $P^*$  on twenty OECD countries. For the greater part, including the USA, Hoeller and Poret are not able to reject the null hypothesis of a unit root in velocity. The authors assert that the methodology of HPS with a constant mean value as measure of equilibrium velocity yields non-stationary price gaps. In its place the authors choose a filter approach to allow for a stochastic trend in velocity, this approach will be tested in this thesis. The results of the study are parted. In eleven cases,  $P^*$  more closely tracks historical data than rival financial models of inflation. Smaller economies included in the study tend to reject  $P^*$  whereas support for ditto is found when using data from the larger economies.

On the topic of the Swedish case the OECD study finds that the price gap enters significantly into the equation. However, the model does not prove a better performer than does the output-gap model augmented by the term-structure. Fact of the matter is that during the period tested for, 1963-89, Sweden had a fixed exchange rate and hence her money stock not determined domestically. This is so for many of the smaller countries,

which may explain why the model in general proved more useful for the larger countries. This not being discussed in the analysis constitutes a shortcoming of the study.

To account for that for countries where the exchange rate is pegged the money supply is settled abroad, Kool and Tatom (1994) include cross-country based price gaps to explore the relation between the German money supply and five European economies. The attempt adds support to the  $P^*$  concept as such in that the models contain information relevant to explain future inflation. The study further determined that the long-run price levels of the five objects were likely to be set up in Germany.

Christiano (1980) acknowledges that  $P^*$  is consistent with the quantity theory, yet he questions this to be useful when forecasting inflation. His line of reasoning is that while inflation-forecasting deals with periods of up to three years, the adjustment phenomenon predicted by the quantity theory require ten to 20 years for realization. Christiano further claims that the HPS version, using a linear time trend, disregards the plausibility of a shift in the growth rate of long-run output. An acceleration in the output trend would have the  $P^*$  model forecasting an inflation higher than conceivable.

The study further points to that while  $P^*$  gives an indication of where prices are going, it does not supply any precise information as to when or by how much they will change. When comparing estimates of  $P^*$  with those of a T-bill model, Christiano finds that the models do equally well but rather explain the level of yesterday's level of inflation. Upholding his position, Christiano concludes that unrealistic assumptions per se do not hamper a model's forecasting ability. Although other studies reviewed do not quite resemble the findings of reversed causality, Christiano's critique is intriguing as it insinuates a discrepancy between economic and statistic inference not alluded to in any other study reviewed.

In doubt of the stationarity of velocity, Orphanides and Porter (2000) set out to model the velocity by using information from a regular money demand equation and the opportunity cost of money, defined as the difference between the T-bill rate and the average interest of M2 balances. They argue that, contrary to the HPS version, their econometric method yields support for the use of  $P^*$  as a forecasting tool.

Another paper taking a critical point of departure is Tatom (1990). Tatom rejects the mean-reverting property of (M2) velocity in the US economy. Part from arguing that the unit root inherited in the velocity requires dealing with, the paper finds that M1-based modeling improves the fit of the model. Please recapture that HPS use the somewhat less narrow aggregate of M2.

### 3 The P\* Model

The estimation of the price gap as presented by HPS begins with the quantity equation:

$$M_t \cdot V_t = P_t \cdot Q_t \quad [1]$$

$M$  is some measure of money supply,  $V$  is the velocity of money,  $P$  is the actual price level and  $Q$  is the level of real output. Equation [1] may be written as:

$$P_t = M_t \cdot V_t / Q_t \quad [2]$$

In the long-run state of the economy, the equilibrium price level is the level that corresponds to the equilibrium values of velocity and output along with current money supply:

$$P_t^* = M_t \cdot V_t^* / Q_t^* \quad [3]$$

By dividing equation [2] by equation [3] and taking logs the following equation is obtained:

$$p^* - p = (v^* - v) + (q - q^*) \quad [4]$$

The lower case letters in consequence denote the natural logarithms of their upper case equivalents. Equation [4] represents the price gap and is the chief explanatory variable in the P\* model. Equation [5] embodies the P\* model as a regression specification. When estimating the model with quarterly estimations, autoregressive lags will be included.

$$\Delta^k p_t = \delta_0 + \delta_1 [p^* - p]_{t-1} + \sum_{j=1}^J \delta_j \Delta p_{t-j} + \varepsilon_t \quad [5]$$

The notation  $k$  represents the difference operator. Notably, the velocity and output gaps are confined to have the same coefficient. This being so, equation [5] is referred to as the restricted model and equation [6] as the unrestricted model i.e. an output-gap model augmented by a velocity gap.

$$\Delta^k p_t = \beta_0 + \beta_1 [q - q^*]_{t-1} + \beta_2 [v^* - v]_{t-1} + \sum_{j=1}^J \beta_j \Delta p_{t-j} + \varepsilon_t \quad [6]$$

When a lower frequency is used in the modeling, say biennial observations rather than quarterly, lagged values of the regressand become redundant and the constrained model reduces to:

$$\Delta^k p_t = \delta_0 + \delta_1 [p^* - p]_{t-1} + \varepsilon_t \quad [7]$$

The unconstrained model is adjusted accordingly.

## 4 Data

### 4.1 Description of

This thesis is based on quarterly data comprising the period of 1980:Q1 - 2007:Q4, which is chosen in accordance with availability of data on the monetary aggregate of M3. The series are retrieved from Statistics Sweden. For model estimation data up to 2004:Q4 is used and the remaining eight quarters are kept for forecast evaluation.

The GDP series chosen is measured with the expenditure approach and 2000 forms the base year for computation of real GDP. The implicit GDP deflator - obtained by dividing current with real values of GDP - is used as the main measure of prices. In addition the forecasting exercise will include CPI.

Economic literature provides little guidance regarding what level of wideness the monetary aggregate should be of to proxy the M in the quantity equation. Since January 2006 aggregates in coherence with ECB recommendations are published. Computation of those series however has been done no further back than to 1998. To the benefit of this thesis Statistics Sweden has prolonged the presentation of official figures of the older series of M3 starting the first quarter of 1980.

There are evident seasonal components in the raw data which are removed for the empirical findings to be viable. An additive model, rather than a multiplicative, is used as the magnitude of the seasonal fluctuations remains fairly stable as the level of the trend progresses. All computations are conducted using these adjusted series.

For estimation of rival models the thesis draws on the returns of the three-month Treasury bill and the ten-year government bond. In accordance with data availability these are deprived from nine and 29 observations in that order as compared to the other series.

The dataset is exploited in an overlapping manner e.g. changes in annual inflation are computed as the year over year change in every fourth quarter's inflation. Annualization of money velocity is carried out by multiplying the quarterly output values by four, which is to be divided by the respective quarter's money supply.

Please refer to appendix C for a graphical depiction of the data used.

### 4.2 The gaps

For extraction of trend values this thesis relies on statistical methods as opposed to economic.<sup>2</sup> This approach is believed to remedy potential errors or biases caused by the engagement in economic definitions of trends. Consequently none of the measures could be strictly interpreted as potential output as derived from economic theory.

Cross correlations are computed to point toward what suitable method of trend extraction. Using regression analysis, a coefficient of determination would yield the same

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<sup>2</sup> Velocity does not revert to a mean value and hence describing its trend with a constant mean as did HPS is not feasible. Information on the test is to be found in appendix D.

order of precedence and by that – since but one parameter is used – an information criterion would add nothing further to the analysis.

The Hodrick Prescott filter is two-sided i.e. it relies on both lag and lead values. Contrary, the moving average filter is based on lagged values only creating a more realistic measure for forecasting purposes.

**Table I – Cross correlations**

**a) Inflation and the output gap**

| $\rho[\Delta p_t, (q_{t-1} - q_{t-1}^*)]$ | -4   | -3    | -2   | -1    | 0    | 1     | 2    | 3     | 4    |
|---|------|-------|------|-------|------|-------|------|-------|------|
| Hodrick Prescott                          | 0,24 | -0,32 | 0,35 | -0,26 | 0,24 | -0,32 | 0,26 | -0,11 | 0,19 |
| Moving average                            | 0,29 | -0,40 | 0,42 | -0,33 | 0,29 | -0,35 | 0,28 | -0,15 | 0,20 |
| Linear trend                              | 0,14 | -0,02 | 0,16 | -0,01 | 0,13 | -0,05 | 0,12 | 0,00  | 0,09 |

**b) Inflation and the velocity gap**

| $\rho[\Delta p_t, (v_{t-1}^* - v_{t-1})]$ | -4    | -3   | -2    | -1   | 0     | 1    | 2     | 3    | 4     |
|---|-------|------|-------|------|-------|------|-------|------|-------|
| Hodrick Prescott                          | -0,53 | 0,49 | -0,55 | 0,68 | -0,67 | 0,57 | -0,52 | 0,56 | -0,57 |
| Moving average                            | -0,57 | 0,53 | -0,60 | 0,74 | -0,73 | 0,61 | -0,55 | 0,59 | -0,61 |
| Linear trend                              | -0,15 | 0,23 | -0,18 | 0,28 | 0,22  | 0,22 | -0,18 | 0,20 | -0,21 |

For both gaps the moving-average technique provides the highest level of correlation and will therefore be the trend extraction of choice in subsequent modeling.

Correlation techniques do not really provide for inference of causality, yet a question regarding its direction owing to the values in *table I* may arise. This matter is dealt with in section 5.3.

Owing to fewer turns the linear trend is less associated with changes in inflation and would in any case produce non-stationary gaps.

## 5 Estimation of P\*

This section considers the explanatory qualities of the P\* model and its constituents on a standalone basis. Firstly, a preliminary estimation of the model disregarding different economic conditions is presented. Next is an evaluation of causality direction and structural stability. The section is rounded off by a few concluding remarks.

### 5.2 Preliminary estimation

The choice of differencing of the log of the price level differs among the studies of P\* reviewed (see for example Hoeller et al. 1991 and Orphanides et al. 2000). But one study reviewed brings this fundamental topic up for discussion: Pecchenino and Rasche (1990) argue that no higher order of differencing should be used than is required for stationarity. The ADF test indicates that the price level is a second-order difference stationary series. Appendix D contains information on the test.

In preliminary modeling it is found that the fourth autoregressive lag is not significant in any quarterly specification and is thus omitted. This is not expected as

inflation modeling normally involves four lags of inflation. Using all quarterly observations, it is found necessary to include one lag of past values of inflation also in the annual estimates.<sup>3</sup> Intercepts will be included in the modeling but omitted from the presentation as they are of insignificant size. This follows from regressing inflation on about-zero turning gaps.

Table II supplies a first indication of the fit between P\* and the review data. The price gap is correctly signed and significant for all frequencies. Drawing on the adjusted coefficient of determination for a quick check, the in-sample ability to forecast inflation is judged to be good but not great. Contrary to the findings of HPS the price gap provides a slightly worse fit than does the estimation of the unrestricted coefficients.

Table II- Estimation of P\* and its constituents

|                     | $p_{t-1}^* - p_{t-1}$ | $v_{t-1}^* - v_{t-1}$ | $y_{t-1} - y_{t-1}^*$ | $\Delta^k \pi_{t-1}$ | $\Delta^k \pi_{t-2}$ | $\Delta^k \pi_{t-3}$ | $\bar{R}^2$ | SSE $\times$ 100 | DW   |
|---------------------|-----------------------|-----------------------|-----------------------|----------------------|----------------------|----------------------|-------------|------------------|------|
| <b>Price Gap</b>    |                       |                       |                       |                      |                      |                      |             |                  |      |
| Quarterly           | 0,30*<br>(4,33)       |                       |                       | -0,13<br>(1,13)      | 0,26*<br>(2,95)      | -0,29*<br>(3,66)     | 0,80        | 1,76             | 1,69 |
| Annual              | 0,28*<br>(3,06)       |                       |                       | 0,57*<br>(7,07)      |                      |                      | 0,34        | 2,02             | 1,69 |
| Biennial            | 1,32*<br>(4,49)       |                       |                       |                      |                      |                      | 0,60        | 3,92             | 2,07 |
| <b>Unrestricted</b> |                       |                       |                       |                      |                      |                      |             |                  |      |
| Quarterly           |                       | 0,28*<br>(4,26)       | 0,62*<br>(2,64)       | -0,11<br>(1,08)      | 0,29*<br>(3,25)      | -0,31*<br>(3,82)     | 0,80        | 1,71             | 1,78 |
| Annual              |                       | 0,25*<br>(2,89)       | 0,94*<br>(4,19)       | 0,59*<br>(7,57)      |                      |                      | 0,40        | 1,93             | 1,69 |
| Biennial            |                       | 1,37*<br>(4,65)       | 0,44*<br>(2,13)       |                      |                      |                      | 0,63        | 3,76             | 1,98 |
| <b>Velocity Gap</b> |                       |                       |                       |                      |                      |                      |             |                  |      |
| Quarterly           |                       | 0,26*<br>(3,80)       |                       | -0,18<br>(1,81)      | -0,23*<br>(2,52)     | -0,28*<br>(3,34)     | 0,79        | 1,82             | 1,62 |
| Annual              |                       | 0,14*<br>(2,34)       |                       | 0,55*<br>(6,64)      |                      |                      | 0,30        | 2,08             | 1,76 |
| Biennial            |                       | 1,23*<br>(3,81)       |                       |                      |                      |                      | 0,53        | 4,23             | 2,00 |
| <b>Output Gap</b>   |                       |                       |                       |                      |                      |                      |             |                  |      |
| Quarterly           |                       |                       | 0,51*<br>(2,01)       | 0,27*<br>(2,77)      | -0,30*<br>(3,06)     | -0,30*<br>(3,42)     | 0,76        | 1,91             | 1,65 |
| Annual              |                       |                       | 0,75*<br>(3,37)       | -0,56*<br>(7,03)     |                      |                      | 0,35        | 2,00             | 1,78 |
| Biennial            |                       |                       | 0,53*<br>(2,71)       |                      |                      |                      | 0,37        | 2,81             | 2,21 |

Notes: An asterix denotes significance at the five percent level. Absolute  $t$ -values are given in parentheses. Quarterly estimations involve the period 1980:Q3-2004:Q4 and comprise 98 observations. Annual and biennial estimations involve the start dates of 1982:Q1 and 1984:Q1 and comprise 94 and 86 observations in that order.

The price gap as well as the unrestricted equation explain roughly a third of the short-run variation in inflation even when excluding the autoregressive lags (not shown). Recall that Christiano (1989) objects to the idea of forecasting inflation less than ten years ahead with the help of quantity based theory.

<sup>3</sup> Hallman and Bryden (1992) employ a similar specification, albeit with an augmentation of commodity prices.

### 5.3 Causality

The lead values of the correlations indicated in *table I* would be in agreement with the anticipation that the relations modeled are sticky and the path of causality not evident. Indeed, Christiano (1989) finds that it is inflation that causes the price-gap. Using Granger's causality test, however, Scheide and Trabandt (2000) are able to state the opposite: That inflation contains no relevant information in explaining future price gaps. As for the Swedish case, the test does not reject the null hypothesis that causality is unidirectional and runs from the price gap to inflation. Appendix D contains details on the test.

### 5.4 Structural stability

The eighties and the beginning of the nineties are characterized by high and volatile inflation while during the subsequent period inflation has fluctuated around its historical average value of roughly two percent. Alongside the marked shift in inflation a succession of different exchange rate policies takes place 1992:Q4. Till 1991, Sweden was member of the currency snake, an arrangement of a number of European countries the exchange rates among which were fixed albeit floating in relation to the world around. During 1991-92 the Swedish currency was pegged to the European unit of ECU. The latter period of the sample is set apart by an inflation target of two percent announced in 1993 and effective from 1995:Q1 with an allowed margin of one percent on either side, substituting for an exchange-rate target.

Of importance when evaluating a time series model and a rather missing attribute of the studies reviewed, where admittedly conditions were more stable, is to make sure that the parameters are stable over time. Underlying principle for the time periods chosen are the contingencies mentioned above. *Table III* indicates annual instable beta coefficients of  $P^*$  obtained for the respective periods. The same applies to the velocity gap. As it may be that the sizes of their respective coefficients are stable they do not remain significant when entering the second period. The output gap however is significant over time.

**Table III – Parameter constancy**

| Period         | $p_{t-1}^* - p_{t-1}$ | $v_{t-1}^* - v_{t-1}$ | $y_{t-1}^* - y_{t-1}$ |
|----------------|-----------------------|-----------------------|-----------------------|
| <b>1980-04</b> | 0,28*<br>(3,06)       | 0,26*<br>(3,80)       | 0,51*<br>(2,01)       |
| <b>1980-92</b> | 0,26*<br>(2,79)       | 0,21*<br>(2,29)       | 0,94*<br>(3,98)       |
| <b>1993-04</b> | 0,20<br>(1,73)        | 0,19<br>(0,82)        | 0,70*<br>(2,55)       |

Note: For a complete estimation please refer to table II and tables A-1-2 in appendix for the partial periods.

A Chow test indicates a break 1992-93 in the effect of the price gap on the next period's inflation. Appendix D contains details on the test. As it may be that a break is identified, it is still so that barely the first period presents a higher adjusted coefficient of determination than is found when using one regression line solely. This period constitutes the part of the sample less well attuned to the economic conditions of today. Owing to the loss of degrees of

freedom that would result from cutting the period in half, in agreement with Jacobson et al. (1999) a dummy is included to control for different policies and levels of inflation. The estimation follows a methodology proposed by Pindyck and Rubinfeld (1991). By inclusion of a dummy a change in the slope is allowed for.<sup>4</sup>

Table IV indicates that for all specifications the dummy is significant at the quarterly frequency. For the price –gap specification this is accompanied by a gap with a  $t$ -value of 2,40 as opposed to 4,33 before allowing for the different trends. The lagged values of inflation in the quarterly estimate of the price gap sum up to close to unity which points towards a long-run equality of  $P^*$  and the actual price level (HPS). Please recapture that the intercept is of insignificant size.

Table IV – Allowing for a change in slope

|                     | $p_{t-1}^i - p_{t-1}$ | $v_{t-1}^i - v_{t-1}$ | $y_{t-1}^i - y_{t-1}$ | $D_i$  | $D_j$  | $\Delta^k \pi_{t-1}$ | $\Delta^k \pi_{t-2}$ | $\Delta^k \pi_{t-3}$ | $R^2$ | $SSE \times 100$ | DW   |
|---------------------|-----------------------|-----------------------|-----------------------|--------|--------|----------------------|----------------------|----------------------|-------|------------------|------|
| <b>Price Gap</b>    |                       |                       |                       |        |        |                      |                      |                      |       |                  |      |
| <b>Quarterly</b>    | 0,15*                 |                       |                       | 0,36*  |        | -0,39*               | -0,01*               | -0,39*               | 0,84  | 1,53             | 1,77 |
|                     | (2,40)                |                       |                       | (5,29) |        | (4,06)               | (0,11)               | (5,44)               |       |                  |      |
| <b>Annual</b>       | 0,67                  |                       |                       | -0,45  |        | 0,37*                |                      |                      | 0,12  | 3,01             | 1,65 |
|                     | (1,67)                |                       |                       | (1,09) |        | (6,47)               |                      |                      |       |                  |      |
| <b>Biennial</b>     | 1,02                  |                       |                       | 0,46   |        |                      |                      |                      | 0,56  | 4,08             | 1,93 |
|                     | (1,04)                |                       |                       | (0,34) |        |                      |                      |                      |       |                  |      |
| <b>Unrestricted</b> |                       |                       |                       |        |        |                      |                      |                      |       |                  |      |
| <b>Quarterly</b>    |                       | 0,31*                 | 0,70*                 | -0,30* | -0,68  | -0,16                | 0,19                 | -0,36                | 0,81  | 1,68             | 1,83 |
|                     |                       | (4,07)                | (2,66)                | (2,06) | (1,76) | (1,50)               | (1,91)               | (4,41)               |       |                  |      |
| <b>Annual</b>       |                       | 0,51                  | 1,09*                 | -0,17  | -1,60* | 0,49*                |                      |                      | 0,37  | 2,53             | 1,95 |
|                     |                       | (1,58)                | (2,68)                | (0,47) | (3,30) | (5,47)               |                      |                      |       |                  |      |
| <b>Biennial</b>     |                       | 0,88                  | 4,57                  | -0,04  | -4,80  |                      |                      |                      | 0,59  | 3,97             | 1,65 |
|                     |                       | (0,91)                | (1,80)                | (0,03) | (0,79) |                      |                      |                      |       |                  |      |
| <b>Velocity Gap</b> |                       |                       |                       |        |        |                      |                      |                      |       |                  |      |
| <b>Quarterly</b>    |                       | 0,36*                 |                       | -0,33* |        | -0,11                | 0,23*                | -0,30*               | 0,79  | 1,73             | 1,71 |
|                     |                       | (4,62)                |                       | (2,39) |        | (1,15)               | (2,71)               | (3,83)               |       |                  |      |
| <b>Annual</b>       |                       | 0,17                  |                       | 0,56*  |        | 0,42*                |                      |                      | 0,14  | 2,98             | 1,67 |
|                     |                       | (0,64)                |                       | (2,01) |        | (4,64)               |                      |                      |       |                  |      |
| <b>Biennial</b>     |                       | 0,31                  |                       | 1,21   |        |                      |                      |                      | 0,53  | 4,22             | 1,76 |
|                     |                       | (0,32)                |                       | (1,01) |        |                      |                      |                      |       |                  |      |
| <b>Output Gap</b>   |                       |                       |                       |        |        |                      |                      |                      |       |                  |      |
| <b>Quarterly</b>    |                       |                       | 0,89*                 | -0,97* |        | -0,34*               | 0,18                 | -0,35*               | 0,78  | 1,80             | 1,71 |
|                     |                       |                       | (3,20)                | (2,65) |        | (3,78)               | (1,71)               | (4,20)               |       |                  |      |
| <b>Annual</b>       |                       |                       | 0,82*                 | -1,20* |        | -0,36*               |                      |                      | 0,22  | 2,83             | 1,70 |
|                     |                       |                       | (2,63)                | (2,70) |        | (6,36)               |                      |                      |       |                  |      |
| <b>Biennial</b>     |                       |                       | 4,29                  | -10,4* |        |                      |                      |                      | 0,59  | 3,95             | 1,75 |
|                     |                       |                       | (1,83)                | (4,30) |        |                      |                      |                      |       |                  |      |

Notes: An asterix denotes significance at the five percent level. Absolute  $t$ -values are given in parentheses. The  $D_i$  variable represents the output gap in the unconstrained estimate. Quarterly estimations involve the period 1980:Q3-2004:Q4 and comprise 98 observations. Annual and biennial estimations involve the start dates of 1982:Q1 and 1984:Q1 and comprise 94 and 86 observations in that order.

The price gaps estimated annually and biennially do not remain significant. For the annual estimate of the price gap the  $t$ -value drops from 3,06 to 1,67 when including the dummy. The analogous drop of the biennial frequency is more notable: From 4,49 to

<sup>4</sup> To the restricted and unrestricted equations [5]-[7] a dummy is added:  $D_{jt}(y_t - y_{t_0})$  where  $D_t = \begin{cases} 1 & \text{if } t > t_0 \\ 0 & \text{otherwise} \end{cases}$  and  $t_0$  is the date of the break, 1992:Q4. This operation is intended for the price gap and its components. An additional dummy is applied in the unconstrained estimations.

1,04. The sensitivity of these estimations to the inclusion of the dummy would suggest an absence of underlying relations. Contemplating the unrestricted and single estimations of the velocity and output gaps, it is noticeable that it is the velocity gap that does not remain robust when allowing for a change in the slope. The output gap remains significant for the annual estimates and close to significant at the biennial frequencies with  $t$ -values of at least 1,8. These results correspond well with *table III* where the output gap is seen to be significant for both partial periods whereas the velocity gap is significant only for the first partial period.

As a general remark it is noted that the gaps are adequately signed. This being so, inflation is expected to rise as actual prices are below the trend as derived from the quantity equation. The unconstrained estimation predicts that inflation will rise when the velocity is below trend owing to a larger money supply. The estimation further confirms that inflation is expected to rise when current output is above trend owing to tighter production-factor markets.

It is further noted that right through a null hypothesis of no – positive - serial correlation is kept with the Durbin-Watson statistic being between 1,64 and 2,00

This marks the end of the standalone assessment of the applicability of  $P^*$  on the Swedish economy. In the next section a relative assessment is carried out whereupon final conclusions will be drawn.

## 6 Relative Performance

The standalone assessment of the model above provides no evidence that  $P^*$  is a significant predictor of the change Swedish inflation one or two years ahead. It cannot, however, be rejected that  $P^*$  contains information relevant to explain short-run changes in inflation. In this section this idea is furthered and the performance of  $P^*$  and its components contra two interest-rate models is tested.

As it may be that the  $P^*$  model is not created to make shorter term predictions, for the sake of completeness this section also contains results of out-of sample forecasts of one quarter ahead changes in the implicit GDP deflator and CPI.

### 6.1 In-sample tracking

Point of departure for the relative model assessment is an autoregressive lags model of inflation augmented by either

- i) a lagged first order difference of short-term interest rates,  $\gamma_3[r_{t-1} - r_{t-2}]$ , proxied by the rate of return on three-month Swedish Treasury bill, i.e. the T-bill model, or
- ii) a lagged yield gap being the difference between the rate of return on the ten year and three month government papers,  $\varphi_3[R_{t-1} - r_{t-1}]$ , i.e. the term-structure model.

The assessment of how well the different models track the in-sample data draws on J-tests. In the first trial, the null hypothesis that  $P^*$  is rejected by a rival is tested by including values predicted by the  $P^*$  model as regressors in the T-bill and term-structure models

respectively.<sup>5</sup> If the coefficient of the predictive values is insignificant the P\* model is rejected. The subsequent test reverses the estimation to see if P\* rejects its rivals.

Table V– *J* tests

|         | <i>H</i> <sub>0</sub> : P* is rejected by |        | <i>H</i> <sub>0</sub> : P* rejects |        |
|---------|---|--------|------------------------------------|--------|
|         | Yield gap                                 | T-bill | Yield gap                          | T-bill |
| 1980-04 | 3,83                                      | 3,68   | 3,37                               | 7,65   |
| 1980-92 | 3,18                                      | 2,57   | 1,83                               | 0,55   |
| 1993-04 | 1,21                                      | 0,88   | 1,30                               | 4,55   |

Notes: Absolute *t*-values of the coefficients of the predictive values of rival models are given in the table. Quarterly estimations of the P\* coefficient is used seeing that these are significant also when using the dummy. The periods estimated are adjusted to 1982-2004 for T-bill and 1987-2004 for the yield gap containing 90 (period one 43) and 71 (period one 23) observations respectively. One influential observation in the short-term interest rate series from 1992:Q3 has been omitted.

From the *t*-values reported in table V there are a few things to note. Firstly, contemplating the period as a whole the test is inconclusive. P\* is not rejected by the rivals i.e. its predicted values of inflation enter in to their respective equations significantly on the five percent level. Similarly in the second hypothesis the predicted values of interest-rate models constitute significant regressors in the P\* specification. T-bill very much so with a *t*-value of 7,65. Naturally, larger discrepancies for the whole period are anticipated when estimating the models using no autoregressive lags.

Regarding the first partial period P\* is the model that more closely tracks the in-sample data. With *t*-values of 3,18 and 2,57 respectively the null hypothesis that P\* is rejected by its rivals is turned down. Furthermore, with *t*-values of 1,83 and 0,55 the null hypothesis that P\* rejects its rivals is kept.

Creating a state of opposition, the T-bill rejects the P\* model on both accounts considering the second partial period with *t*-values of 0,88 and 4,55. Regarding the yield gap yet another inconclusive result is obtained in that P\* is rejected by ditto but also rejects it. The *t*-value is slightly higher for the yield-gap predictions, but the divergences remain too small for coincidence to be omitted from the discussion.

Table V indicates that the T-bill contained little explanatory power during the period of a fixed exchange rate where devaluation would be the tool of keeping down inflation. The subsequent period where inflation is anchored with a numerical target brings with it the anchoring of inflation forecasts. Their being transparent entails anchoring of inflation expectations which in turn are indicated by interest-rate evolvment.

This thesis' putting results in relation to different policies is but one inference of the data examined. At any rate one could more safely state that the change in the behavior of the price level is attributable to policy changes. For the deduction to be extended to also relate the connection between the price level and P\* to policy changes further research would be desired.

<sup>5</sup> Hoeller and Poret (1991) use a similar test albeit with *t*-statistic from the "incumbent variable" and hence their null hypotheses are reversed. The results, however, would point in the same directions.

## 6.2 Out-of sample forecasting

In this section an assessment of how the models perform one quarter ahead is presented. The forecasting period comprises a total of 12 quarters. For the focus to be kept on model assessment known values of the regressors are used. In practice in Sweden there is an information lag of on average 60 days for publication of quarterly output. Hence, RMSE to depict the relative performance rather than the forecasted values as such is of interest.<sup>6</sup> The RMSE values may be given a relative interpretation and not an absolute, in effect the forecasted values are presented in appendix B to indicate operational adequacy.

Table VI– Out-of sample forecasting RMSE

|     | <i>PGAP</i> | <i>OGAP</i> | <i>VGAP</i> | <i>Unrest</i> | <i>Yield gap</i> | <i>T – bill</i> |
|-----|-------------|-------------|-------------|---------------|------------------|-----------------|
| GDF | 0,974       | 0,876       | 0,995       | 0,968         | 0,981            | 1,045           |
| CPI | 0,696       | 0,689       | 0,682       | 0,689         | 0,724            | 0,779           |

Notes: RMSE values of the one quarter ahead predictive values of the implicit GDP deflator and CPI respectively are given in the table. The period for which change in inflation is predicted comprises 2005:Q1 – 2007:Q4. The predictions draw on estimations from 1980-2004 for P\* and 1982-2004 and 1987-2004 for the T-bill and yield-gap models respectively. For ease of exposition the values have been multiplied by a 100.

Considering the implicit GDP deflator, P\* performs better than do the yield gap and T-bill models which would be expected drawing on previous studies (see for example Hoeller and Poret 1991). Among P\* and its components the simple output-gap model yields the best forecasts. The volatility in the financial markets as represented by the velocity gap is larger than that of the production-factor markets. The smaller output-gap values thus entail a weaker distortion of the influence of the autoregressive lags. This further provides the account from which the price gap presents little divergence from the velocity gap.

Kuttner (1990) conveys the criticism that the implicit GDP deflator does not reflect pure prices but is rather a mix of prices and quantity changes. Hence, the forecasting exercise is accompanied by CPI. Here too P\* and its components perform better than do the interest-rate models, to be precise the velocity-gap augmentation produces the lowest RMSE value. No attention should be paid to the CPI errors' being lower as this is more related to a higher relevance of past values of CPI than the augmentations. Please recapture that this operation is based on quarterly data.

<sup>6</sup>  $RMSE = \text{Root Mean Square Error} = \sqrt{\frac{1}{T} \sum_{t=1}^T e_{t+k,t}^2}$ , where  $e$  denotes prediction errors.

## 7 Conclusion

This thesis has investigated the use of combining output and velocity gaps under one coefficient to explain changes in Swedish inflation. Drawing on data from the early eighties, prevailing economic conditions necessitated an allowance for a shift in the slope. In doing so, it is not found that evidence of a longer term relation between the development in Swedish inflation and  $P^*$  or the velocity specification is provided by the data substantiating this thesis.

Running a periodic assessment relative the yield-gap and the T-bill models with quarterly estimations, it is indicated that the T-bill model constitutes a better predictor of Swedish inflationary development under prevailing conditions. Creating a state of opposition,  $P^*$  proves a better predictor in yesterday's economic conditions with a fixed exchange rate.

Conducting one quarter ahead predictions of the implicit GDP deflator and CPI drawing on the whole sample period and allowing for a change in slopes:  $P^*$  and its constituents outperform the interest-rate models.

## Bibliography

- Blix, M. (1999), "Forecasting Swedish Inflation With a Markov Switching VAR". Bank of Sweden, Working Paper Series no. 76
- Christiano, L.J. (1989), "P\*: Not the Inflation Forecaster's Holy Grail". Federal Reserve Bank of Minneapolis, Quarterly Review, 1314.
- Hallman, J. and Bryden, E. (1992), "Commodity Prices and P-Star". The Federal Reserve Bank of Cleveland.
- Hallman, J., Porter R.D. and Small D.H. (1991), "Is the Price Level Tied to the M2 Monetary Aggregate in the Long Run?". *The American Economic Review*, vol. 81, no. 4, pp. 841-858.
- Hoeller, P. and Poret P. (1991), "Is P-Star a Good Indicator of Inflationary Pressure in OECD Countries?". OECD Economic Studies no. 17.
- Humphrey, T. M. (1989), "Precursors of the P-Star Model". *Economic Review*. Federal Reserve Bank of Richmond, issue July/August pp. 3-9.
- Jacobson, Tor., Jansson, Per., Vredin, Anders and Warne, Anders. (1999), "A VAR Model for Monetary Policy Analysis in a Small Open Economy". Working Paper Series 77, Bank of Sweden.
- Kool, C. and Tatom J. (1994), "The P-Star Model in Five Small Economies". *The Federal Reserve Bank of St. Louis Review*, vol. 76, no. 3, pp. 11-30.
- Kuttner K.N. (1990), "Inflation and the Growth Rate of Money". *Economic Perspectives*, Federal Reserve Bank of Chicago, issue January, pp. 2-11.
- Lee, Jim. (1999), "Alternative P\* Models of Inflation Forecasts". *Economic Inquiry*, vol. 38, no. 2, pp. 312-25.
- Mayer. T. (1980), "David Hume and Monetarism". *The Quarterly Journal of Economics*, vol. 95, no. 1, pp. 89-101.
- Orphanides, A. and Porter R.D. (2000), "P\* Revisited: Money-Based Inflation Forecasts with a changing Equilibrium". *Journal of Economics and Business*. pp. 87-100.
- Pecchino, R.A. and Rasche R.H. (1990), "P\* Type Models: Evaluation and Forecasts". *International Journal of Forecasting*, vol. 6, no. 3, 421-440.

Pindyck, R. and Rubinfeld, D. (1991), *Econometric Models and Economic Forecasting*.  
Singapore: McGraw Hill

Scheide, J. and Trabandt, M. (2000), "*Predicting Inflation in Euroland, the P-star Approach*". Kiel Institute of World Economics. Working paper no. 1019.

Tatom, J.A. (1990), "The P-Star Approach to the Link between Money and Prices".  
Federal Reserve Bank of St. Louis. Working Paper 1990-008A.

## Appendix A

Table A-1 1980-1992

|                     | $p_{t-1}^* - p_{t-1}$ | $v_{t-1}^* - v_{t-1}$ | $y_{t-1} - y_{t-1}^*$ | $\Delta^k \pi_{t-1}$ | $\Delta^k \pi_{t-2}$ | $\Delta^k \pi_{t-3}$ | $\bar{R}^2$ | SSE $\times$ 100 | DW   |
|---------------------|-----------------------|-----------------------|-----------------------|----------------------|----------------------|----------------------|-------------|------------------|------|
| <b>Price Gap</b>    |                       |                       |                       |                      |                      |                      |             |                  |      |
| Quarterly           | 0,31*                 |                       |                       | -0,17                | 0,02                 | -0,51*               | 0,90        | 1,65             | 1,82 |
|                     | (3,89)                |                       |                       | (1,1)                | (0,13)               | (4,77)               |             |                  |      |
| Annual              | 0,26*                 |                       |                       | 0,57*                |                      |                      | 0,34        | 2,06             | 1,70 |
|                     | (2,79)                |                       |                       | (6,86)               |                      |                      |             |                  |      |
| Biennial            | 1,56*                 |                       |                       |                      |                      |                      | 0,38        | 4,67             | 2,16 |
|                     | (2,41)                |                       |                       |                      |                      |                      |             |                  |      |
| <b>Unrestricted</b> |                       |                       |                       |                      |                      |                      |             |                  |      |
| Quarterly           |                       | 0,41*                 | 0,58*                 | -0,13                | -0,03                | -0,52                | 0,92        | 1,54             | 1,95 |
|                     |                       | (4,72)                | (2,08)                | (0,88)               | (0,19)               | (4,99)               |             |                  |      |
| Annual              |                       | 0,21*                 | 1,06*                 | 0,58*                |                      |                      | 0,41        | 1,94             | 1,71 |
|                     |                       | (2,29)                | (4,46)                | (7,70)               |                      |                      |             |                  |      |
| Biennial            |                       | 1,56*                 | 4,14                  |                      |                      |                      | 0,35        | 4,75             | 2,00 |
|                     |                       | (2,36)                | (2,36)                |                      |                      |                      |             |                  |      |
| <b>Velocity Gap</b> |                       |                       |                       |                      |                      |                      |             |                  |      |
| Quarterly           |                       | 0,37*                 |                       | -0,13                | -0,1                 | -0,52*               | 0,91        | 1,60             | 1,83 |
|                     |                       | (4,21)                |                       | (0,86)               | (0,06)               | (4,21)               |             |                  |      |
| Annual              |                       | 0,14*                 |                       | 0,55*                |                      |                      | 0,29        | 2,12             | 1,77 |
|                     |                       | (2,24)                |                       | (6,44)               |                      |                      |             |                  |      |
| Biennial            |                       | 1,37*                 |                       |                      |                      |                      | 0,27        | 5,03             | 1,98 |
|                     |                       | (2,01)                |                       |                      |                      |                      |             |                  |      |
| <b>Output Gap</b>   |                       |                       |                       |                      |                      |                      |             |                  |      |
| Quarterly           |                       |                       | 0,30                  | -0,54*               | -0,09                | -0,41*               | 0,87        | 1,89             | 1,66 |
|                     |                       |                       | (0,88)                | (4,09)               | (0,57)               | (3,31)               |             |                  |      |
| Annual              |                       |                       | 0,94*                 | 0,56*                |                      |                      | 0,39        | 1,98             | 1,79 |
|                     |                       |                       | (3,98)                | (7,00)               |                      |                      |             |                  |      |
| Biennial            |                       |                       | 2,60*                 |                      |                      |                      |             |                  |      |
|                     |                       |                       | (2,68)                |                      |                      |                      |             |                  |      |

Notes: An asterix denotes significance at the five percent level. Absolute  $t$ -values are given in parentheses. Quarterly estimations involve the period 1980:Q3-1992:Q4 and comprise 50 observations. Annual and biennial estimations involve the start dates of 1982:Q1 and 1984:Q1 and comprise 44 and 36 observations in that order.

Table A-2 1993-2004

|                     | $p_{t-1}^i - p_{t-1}$ | $v_{t-1}^i - v_{t-1}$ | $y_{t-1}^i - y_{t-1}$ | $\Delta^k \pi_{t-1}$ | $\Delta^k \pi_{t-2}$ | $\Delta^k \pi_{t-3}$ | R <sup>2</sup> | SSE × 100 | DW   |
|---------------------|-----------------------|-----------------------|-----------------------|----------------------|----------------------|----------------------|----------------|-----------|------|
| <b>Price Gap</b>    |                       |                       |                       |                      |                      |                      |                |           |      |
| Quarterly           | 0,13<br>(1,48)        |                       |                       | -0,58*<br>(5,76)     | -0,36*<br>(3,17)     | -0,58*<br>(5,42)     | 0,58           | 1,12      | 1,69 |
| Annual              | 0,20<br>(1,73)        |                       |                       | 0,48*<br>(4,24)      |                      |                      | 0,28           | 1,27      | 1,61 |
| Biennial            | 0,34<br>(1,38)        |                       |                       |                      |                      |                      | 0,13           | 1,38      | 2,37 |
| <b>Unrestricted</b> |                       |                       |                       |                      |                      |                      |                |           |      |
| Quarterly           |                       | 0,06<br>(0,73)        | 0,34<br>(1,37)        | -0,61*<br>(6,01)     | -0,32*<br>(2,64)     | -0,51*<br>(3,97)     | 0,58           | 1,13      | 1,76 |
| Annual              |                       | 0,19<br>(0,82)        | 0,70*<br>(2,55)       | 0,49*<br>(4,60)      |                      |                      | 0,35           | 1,21      | 1,73 |
| Biennial            |                       | 1,02<br>(2,49)        | 6,14*<br>(3,33)       |                      |                      |                      | 0,28           | 3,14      | 2,71 |
| <b>Velocity Gap</b> |                       |                       |                       |                      |                      |                      |                |           |      |
| Quarterly           |                       | 0,07<br>(0,82)        |                       | -0,60*<br>(5,92)     | -0,38*<br>(3,32)     | -0,61*<br>(5,59)     | 0,57           | 1,13      | 1,73 |
| Annual              |                       | 0,14<br>(0,91)        |                       | 0,46*<br>(3,91)      |                      |                      | 0,25           | 1,33      | 1,62 |
| Biennial            |                       | 0,96<br>(1,58)        |                       |                      |                      |                      | 0,23           | 4,76      | 1,64 |
| <b>Output Gap</b>   |                       |                       |                       |                      |                      |                      |                |           |      |
| Quarterly           |                       |                       | 0,35<br>(1,43)        | -0,60*<br>(6,01)     | -0,31*<br>(2,57)     | -0,54*<br>(4,42)     | 0,58           | 1,12      | 1,71 |
| Annual              |                       |                       | 0,55*<br>(2,49)       | 0,46*<br>(3,99)      |                      |                      | 0,29           | 1,30      | 1,86 |
| Biennial            |                       |                       | 5,72<br>(1,51)        |                      |                      |                      | 0,20           | 4,84      | 1,67 |

Notes: An asterix denotes significance at the five percent level. Absolute  $t$ -values are given in parentheses. Quarterly estimations involve the period 1993:Q3-2004:Q4 and comprise 50 observations. Annual and biennial estimations involve the start dates of 1995:Q1 and 1997:Q1 and comprise 44 and 36 observations in that order.

## Appendix B

## Out-of sample forecasting

$$\Delta p_{t,t+1} = \delta_0 + \delta_1[1]..[6] + \sum_{j=1}^J \delta_2 \Delta p_{t-j} + \delta_3 D_{it}(y_t - y_{t_0}) + \varepsilon_t$$

Table B-1 Forecasts of changes in the log of the implicit GDP deflator

|             | Actual | <i>PGAP</i> <sup>[1]</sup> |              | <i>YGAP</i> <sup>[2]</sup> |              | <i>VGAP</i> <sup>[3]</sup> |              | <i>Unrest</i> <sup>[4]</sup> |              | <i>Yield gap</i> <sup>[5]</sup> |              | <i>T – bill</i> <sup>[6]</sup> |              |
|-------------|--------|----------------------------|--------------|----------------------------|--------------|----------------------------|--------------|------------------------------|--------------|---------------------------------|--------------|--------------------------------|--------------|
|             |        | Pre.                       | Error        | Pre.                       | Error        | Pre.                       | Error        | Pre.                         | Error        | Pre.                            | Error        | Pre.                           | Error        |
| 2005:Q1     | -2,06  | -0,31                      | -1,75        | -0,54                      | -1,52        | -0,35                      | -1,71        | -0,31                        | -1,75        | -0,41                           | -1,65        | -1,27                          | -0,79        |
| 2005:Q2     | 0,87   | 1,29                       | -0,42        | 1,66                       | -0,79        | 1,74                       | -0,87        | 1,19                         | -0,32        | 1,61                            | -0,74        | 1,25                           | -0,38        |
| 2005:Q3     | 0,52   | 0,28                       | 0,24         | 0,37                       | 0,15         | 0,04                       | 0,48         | 0,34                         | 0,18         | 0,04                            | 0,48         | -0,33                          | 0,85         |
| 2005:Q4     | 2,23   | 1,38                       | 0,85         | 1,63                       | 0,6          | 1,39                       | 0,84         | 1,38                         | 0,85         | 1,53                            | 0,7          | 0,99                           | 1,24         |
| 2006:Q1     | -2,00  | -0,42                      | -1,58        | -0,75                      | -1,25        | -0,44                      | -1,56        | -0,42                        | -1,58        | -0,45                           | -1,55        | -1,57                          | -0,43        |
| 2006:Q2     | 1,70   | 0,94                       | 0,76         | 1,47                       | 0,23         | 0,98                       | 0,72         | 0,95                         | 0,75         | 1,27                            | 0,43         | 0,62                           | 1,08         |
| 2006:Q3     | -0,57  | -0,39                      | -0,18        | -0,65                      | 0,08         | -0,43                      | -0,14        | -0,39                        | -0,18        | -0,65                           | 0,08         | -1,16                          | 0,59         |
| 2006:Q4     | 2,79   | 2,17                       | 0,62         | 2,04                       | 0,75         | 2,19                       | 0,6          | 2,17                         | 0,62         | 1,89                            | 0,9          | 1,57                           | 1,22         |
| 2007:Q1     | -1,27  | -0,99                      | -0,28        | -1,25                      | -0,02        | -1,06                      | -0,21        | -0,98                        | -0,29        | -0,92                           | -0,35        | -1,76                          | 0,49         |
| 2007:Q2     | 2,23   | 1,13                       | 1,1          | 1,54                       | 0,69         | 1,10                       | 1,13         | 1,15                         | 1,08         | 1,47                            | 0,76         | 0,95                           | 1,28         |
| 2007:Q3     | -0,99  | -1,48                      | 0,49         | -1,35                      | 0,36         | -1,54                      | 0,55         | -1,47                        | 0,48         | -1,14                           | 0,15         | -1,76                          | 0,77         |
| 2007:Q4     | 3,56   | 2,03                       | 1,53         | 1,80                       | 1,76         | 2,04                       | 1,52         | 2,02                         | 1,54         | 1,71                            | 1,85         | 1,46                           | 2,1          |
| <b>RMSE</b> |        |                            | <b>0,974</b> |                            | <b>0,876</b> |                            | <b>0,995</b> |                              | <b>0,968</b> |                                 | <b>0,981</b> |                                | <b>1,045</b> |

Table B-2 Forecasts of changes in the log of CPI

|             | Actual | <i>PGAP</i> <sup>[1]</sup> |              | <i>YGAP</i> <sup>[2]</sup> |              | <i>VGAP</i> <sup>[3]</sup> |              | <i>Unrest</i> <sup>[4]</sup> |              | <i>Yield gap</i> <sup>[5]</sup> |              | <i>T – bill</i> <sup>[6]</sup> |              |
|-------------|--------|----------------------------|--------------|----------------------------|--------------|----------------------------|--------------|------------------------------|--------------|---------------------------------|--------------|--------------------------------|--------------|
|             |        | Pre.                       | Error        | Pre.                       | Error        | Pre.                       | Error        | Actual                       | Pre.         | Error                           | Pre.         | Error                          |              |
| 2005:Q1     | -0,35  | 0,46                       | -0,81        | 0,44                       | -0,79        | 0,46                       | -0,81        | 0,46                         | -0,81        | 0,28                            | -0,63        | 0,53                           | -0,88        |
| 2005:Q2     | 0,49   | 0,00                       | 0,49         | 0,22                       | 0,27         | 0,15                       | 0,34         | 0,07                         | 0,42         | -0,06                           | 0,55         | 0,06                           | 0,43         |
| 2005:Q3     | 0,03   | 0,46                       | -0,43        | 0,36                       | -0,33        | 0,33                       | -0,30        | 0,40                         | -0,37        | 0,37                            | -0,34        | 0,60                           | -0,57        |
| 2005:Q4     | 0,55   | 0,08                       | 0,47         | 0,24                       | 0,31         | 0,10                       | 0,45         | 0,09                         | 0,46         | 0,06                            | 0,49         | 0,19                           | 0,37         |
| 2006:Q1     | -0,30  | 0,53                       | -0,83        | 0,57                       | -0,87        | 0,56                       | -0,86        | 0,54                         | -0,84        | 0,46                            | -0,76        | 0,58                           | -0,88        |
| 2006:Q2     | 1,22   | 0,15                       | 1,07         | 0,21                       | 1,01         | 0,14                       | 1,08         | 0,15                         | 1,07         | 0,05                            | 1,18         | 0,11                           | 1,11         |
| 2006:Q3     | 0,10   | 0,74                       | -0,64        | 0,75                       | -0,65        | 0,73                       | -0,63        | 0,74                         | -0,64        | 0,65                            | -0,55        | 0,86                           | -0,76        |
| 2006:Q4     | 0,50   | 0,44                       | 0,06         | 0,38                       | 0,12         | 0,45                       | 0,05         | 0,44                         | 0,06         | 0,13                            | 0,37         | 0,16                           | 0,34         |
| 2007:Q1     | 0,10   | 0,73                       | -0,63        | 0,71                       | -0,61        | 0,72                       | -0,62        | 0,73                         | -0,63        | 0,62                            | -0,52        | 0,79                           | -0,69        |
| 2007:Q2     | 1,09   | 0,28                       | 0,81         | 0,36                       | 0,73         | 0,27                       | 0,82         | 0,27                         | 0,82         | 0,29                            | 0,80         | 0,30                           | 0,79         |
| 2007:Q3     | 0,23   | 0,55                       | -0,32        | 0,74                       | -0,51        | 0,54                       | -0,31        | 0,54                         | -0,31        | 0,77                            | -0,54        | 0,81                           | -0,58        |
| 2007:Q4     | 1,68   | 0,63                       | 1,05         | 0,50                       | 1,18         | 0,64                       | 1,04         | 0,64                         | 1,04         | 0,40                            | 1,28         | 0,36                           | 1,32         |
| <b>RMSE</b> |        |                            | <b>0,696</b> |                            | <b>0,689</b> |                            | <b>0,682</b> |                              | <b>0,689</b> |                                 | <b>0,724</b> |                                | <b>0,779</b> |

## Appendix C

### Graphical representation of the variables

Figure C-1 – The implicit GPD deflator

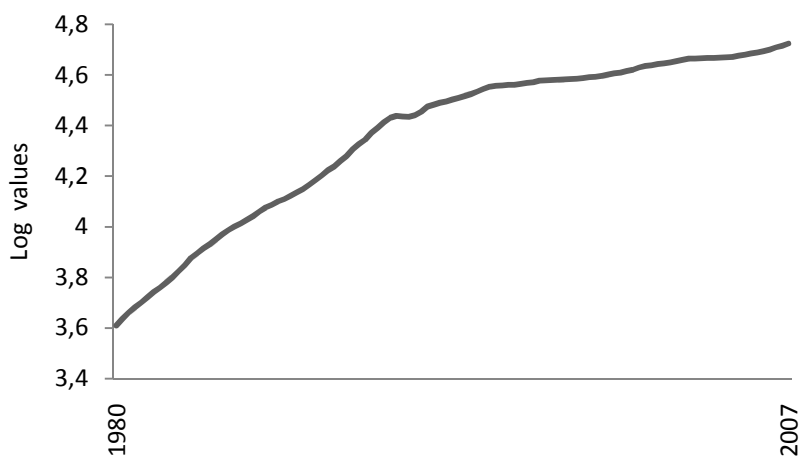


Figure C-2 – Real output

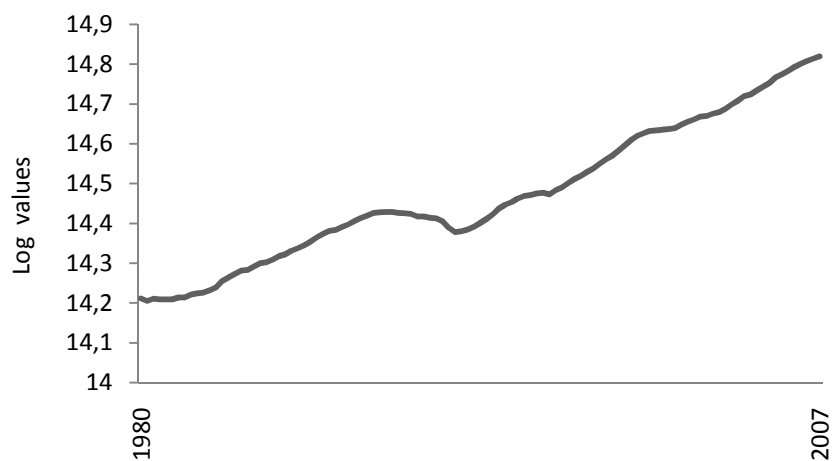


Figure C-3 – Money velocity

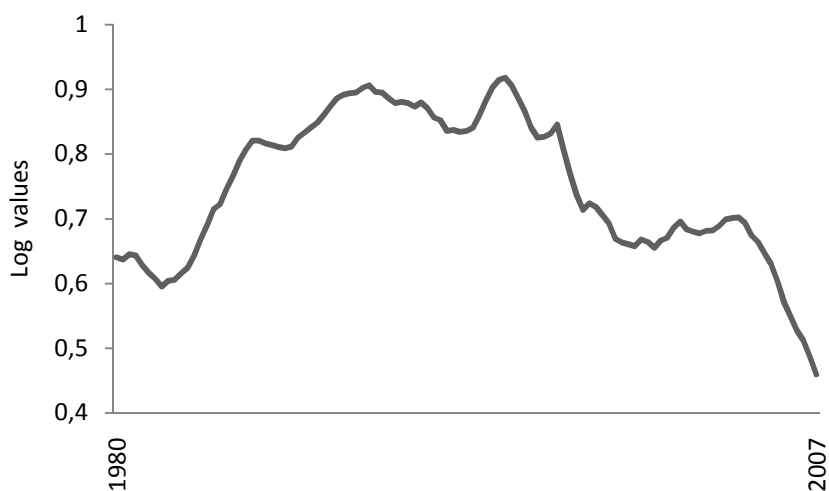


Figure C-4 - Inflation

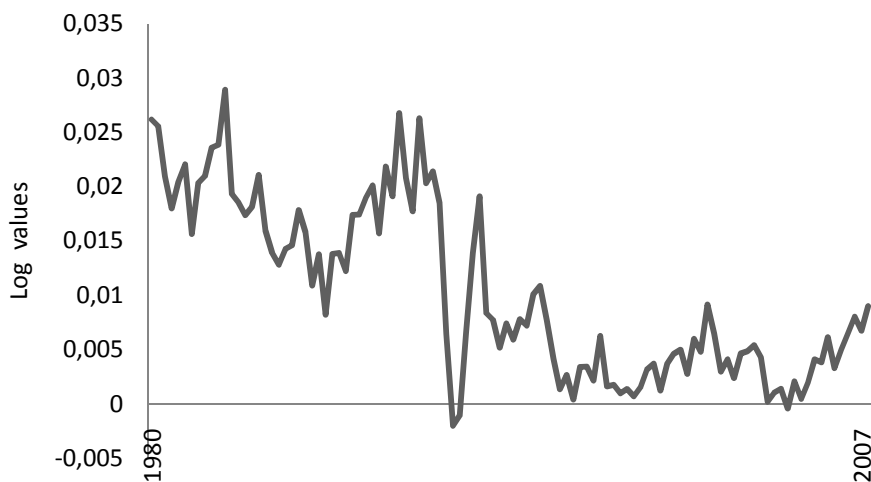


Figure C-5 - The price gap

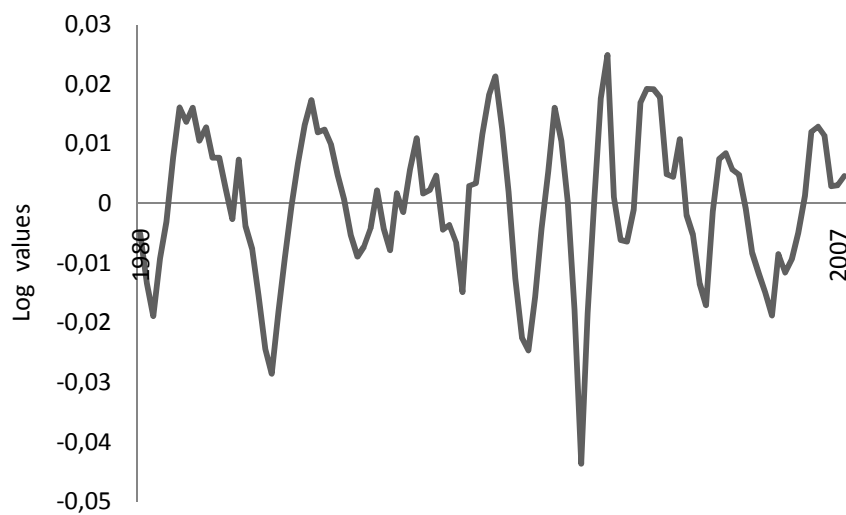


Figure C-6 - The output gap

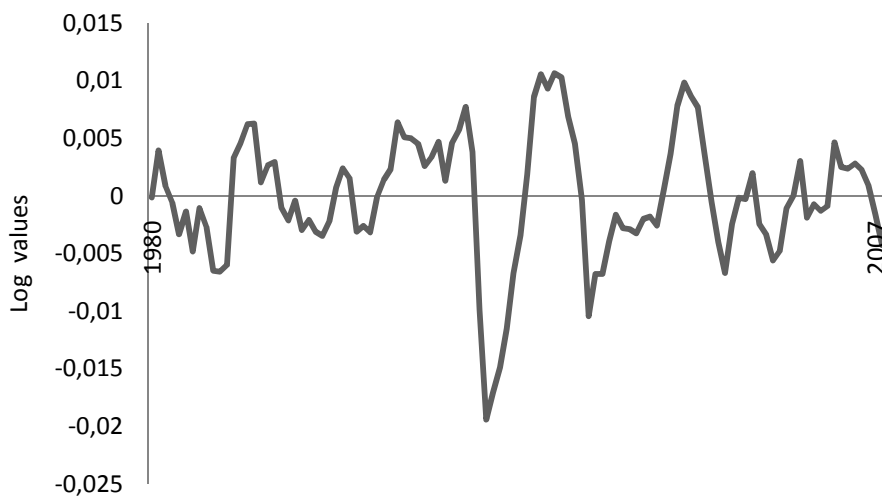


Figure C-7 – The velocity gap

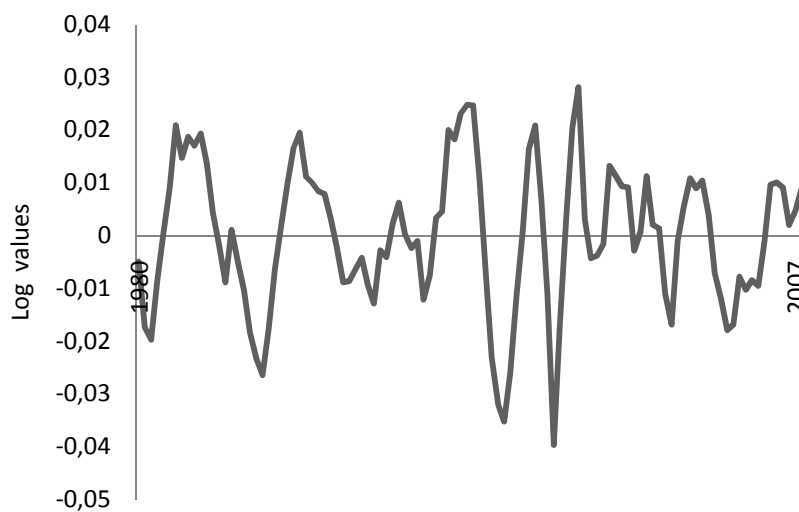


Figure C-8 – The T-bill

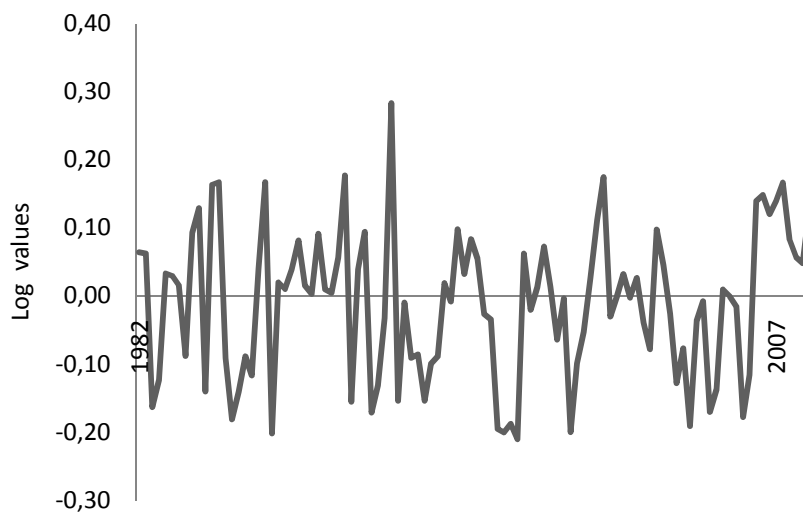
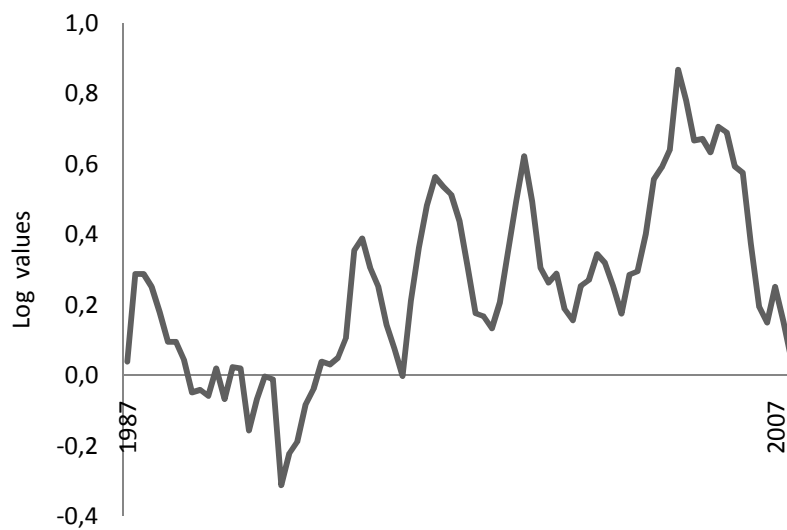


Figure C-9 – The yield gap



## Appendix D

### Statistical tests

#### Testing for Stationarity

The underlying macroeconomic data of this study (GDP, the GDP deflator and the different measures of money supply) are by nature non-stationary. Nevertheless the computed variables of price change and gaps used in the modeling ought to be stationary. In order to test for this the Augmented Dickey Fuller test is applied. Subjects to assessment are the gaps and the quarterly change in the GDP deflator.

When testing for stationarity of velocity and of the yield gap, the following equation is used:

$$\Delta z_t = \vartheta + \delta T + \theta z_{t-1} + \alpha_i \sum_{t=1}^m \Delta z_{t-i} + \varepsilon_t$$

Quarterly inflation and the first difference of the short term interest rate are potentially fast turning around zero. Accordingly, a test equation with neither an intercept nor a trend of the following form is used:

$$\Delta z_t = \theta z_{t-1} + \alpha_i \sum_{t=1}^m \Delta z_{t-i} + \varepsilon_t$$

The number of lagged dependents is set as high as allowed without budging on statistical significance.

**Table D-1 Dickey-Fuller statistics**

|         | $\Delta p_t$ | $\Delta^2 p_t$ | $\Delta^2 cpi_t$ | $v_t$    | $v_t^* - v_t$ | $y_t - y_t^*$ | $R_t - r_t$ | $\Delta r_t$ |
|---------|--------------|----------------|------------------|----------|---------------|---------------|-------------|--------------|
| 1982-07 | 2,09 (0)     | 9,79 (4)       | 12,78 (2)        | 0,36 (1) | 6,04 (1)      | 5,54 (2)      | 2,94 (0)    | 9,63 (0)     |
| 1982-92 | 1,53 (0)     | 6,96 (4)       | 7,69 (2)         | 1,57 (2) | 3,57 (2)      | 2,62 (1)      | 2,01 (0)    | 7,13 (0)     |
| 1993-07 | 0,77 (1)     | 6,59 (3)       | 8,49 (2)         | 0,15 (1) | 5,39 (1)      | 4,50 (2)      | 2,45 (1)    | 3,58 (0)     |

Notes: T-values are given in absolute terms. The number of lags of the target variable is indicated in brackets.

## Granger's test for causality

To see whether inflation helps explain part of the variation in the price gap the following equations are estimated:

*Unrestricted (UR)*

$$price\_gap_t = \theta_0 + \sum_{i=1}^m \alpha_i price\_gap_{t-i} + \sum_{i=1}^m \beta_i \Delta p_{t-i} + \varepsilon_{1t}$$

*Restricted (R)*

$$price\_gap_t = \theta_0 + \sum_{i=1}^m \alpha_i price\_gap_{t-i} + \varepsilon_{1t}$$

Five lags of the respective explanatory variables are used. The Durbin-Watson statistic obtained for the unrestricted equation is 2,07 implying we may take it that there is no autocorrelation in the residuals. Drawing on the RSS values obtained from running the regression above an F test I carried out:

$$F = \frac{(RSS_R - RSS_{UR})/m}{RSS_{UR}/(n - k)} = \frac{(0,025 - 0,024)/5}{0,024/(97 - 2)} \approx 0,79$$

The test result entails that the null hypothesis of  $\beta_1 \dots \beta_5 = 0$  is accepted, and hence there is no evidence of inflation containing information relevant to explain part of the variation in the price gap at the five percent level where  $F_{critical} = 2,29$ . The test is carried out for the opposite direction of causality too.  $F_{obs} = 2,53$  and a Durbin-Watson statistic of 2,01, imply that the price gap does cause inflation.

## Chow's test for structural stability

The noteworthy difference in the estimation of the two periods characterized by different monetary policies induces this course of research also to include a Chow test to see whether there is a structural break in the series. The test takes the following form:

$$F = \frac{RSS_{1980-2004} - (RSS_{1980-1992} + RSS_{1993-2004})/k}{RSS_{1980-1992} + RSS_{1993-2004}/n - 2 \times k}$$

The number of explanatory variables by represented  $k$  and  $n$  the number of observations. The null hypothesis is that there is no structural break between the two series whereas the acceptance of the alternative hypothesis would imply that such a break cannot be ruled out.  $F_{critical}$  at the five percent level is 4,24 which by far falls short of the observed  $F$  value of 19,2 implying a rejection of the null hypothesis.