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A Note on the Stability of the Swedish Phillips Curve*

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Abstract

We use Bayesian techniques to estimate bivariate VAR models for Swedish unemployment rate and inflation. Employing quarterly data from 1995Q1 to 2017Q3 and new tools for model selection, we compare a model with time-varying parameters and stochastic volatility to a specification with constant parameters and covariance matrix. We find strong evidence in favour of the specification with time-varying parameters and stochastic volatility. Our results indicate that the Swedish Phillips curve has not been stable over time. However, our findings do not suggest that the Phillips curve has been flatter in more recent years.

JEL Classification: C11, C32, E32
Keywords: Inflation, Unemployment, Time-varying parameters, Stochastic volatility

1. Introduction

Inflation in Sweden has been stubbornly low over the last years. This development is similar to that in several other inflation-targeting countries where inflation has been moderate, and increasing slowly, despite historically low policy-interest rates and developments in the real economy which many argue should have generated a stronger inflationary pressure; see e.g. Jansson (2017) and Yellen (2017). One explanation for this low inflationary pressure which has been put forward is that the Phillips curve has become flatter.[1]

In this paper we contribute to the discussion regarding the properties of the Phillips curve by providing evidence based on Swedish data. Employing a Bayesian VAR (BVAR) framework, we estimate bivariate models using quarterly data on unemployment rate and inflation. The models are estimated under two different assumptions concerning the dynamics and covariance matrix. As noted by a growing literature, time variation

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[1] See e.g. Coibion and Gorodnichenko (2015). Another argument in favour of a flattened Phillips curve is the “missing disinflation” in the aftermath of the global financial crisis of 2008; see IMF (2013).

in both dynamics and volatility appears to be important features of macroeconomic relationships.[2] We therefore estimate a model with time-varying parameters and stochastic volatility and compare this model to a traditional specification with constant parameters and covariance matrix. Relying on new tools for model selection developed by Chan and Eisenstat (2018), we formally assess which model is preferred by the data. This constitutes a step forward relative to the vast majority of previous related research. Since model selection is a non-trivial issue when models with time-varying parameters and stochastic volatility are involved, it has typically simply been assumed that it is reasonable to employ a model with such features.[3] In this paper we instead evaluate this assumption using marginal likelihoods and Bayes factors and can provide statistical evidence on the stability of the Swedish Phillips curve.

2. The Bayesian VAR models

We rely on BVARs for our analysis since the inflation equation of the BVAR can be seen as a "*dynamic generalization of the Phillips curve*" (King and Watson, 1994, p. 172). While we pay special attention to the inflation equation, our analysis is mainly based on the full bivariate system since important aspects of the dynamic relation between the variables otherwise could be lost.

With the vector of dependent variables $\boldsymbol{y}_t = (u_t \quad \pi_t)'$ – where u_t is the unemployment rate and π_t is inflation – we specify the BVAR with time-varying parameters and stochastic volatility (TVP-SV) in "structural" form as

$$\boldsymbol{B}_{0t}\boldsymbol{y}_t = \boldsymbol{\delta}_t + \boldsymbol{B}_{1t}\boldsymbol{y}_{t-1} + \cdots + \boldsymbol{B}_{pt}\boldsymbol{y}_{t-p} + \boldsymbol{\varepsilon}_t \quad (1)$$

where $\boldsymbol{B}_{0t}$ is a 2x2 lower triangular matrix with ones on the diagonal, $\boldsymbol{\delta}_t$ contains the time-varying intercepts and the matrices $\boldsymbol{B}_{1t}, \dots, \boldsymbol{B}_{pt}$ describe the dynamics. The vector of disturbances, $\boldsymbol{\varepsilon}_t$, follows $\boldsymbol{\varepsilon}_t \sim N(\boldsymbol{0}, \boldsymbol{\Sigma}_t)$, where $\boldsymbol{\Sigma}_t = diag\big(exp(h_{1t}), exp(h_{2t})\big)$. Lag length is set to $p = 4$. Collecting the free parameters of $\boldsymbol{\delta}_t$ and $\boldsymbol{B}_{it}$ in the 19x1 parameter vector $\boldsymbol{\theta}_t$, we specify the processes for the time-varying parameters and log-volatilities as random walks:

$$\boldsymbol{\theta}_t = \boldsymbol{\theta}_{t-1} + \boldsymbol{\eta}_t \quad (2)$$

$$\boldsymbol{h}_t = \boldsymbol{h}_{t-1} + \boldsymbol{\zeta}_t \quad (3)$$

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[2] See e.g. Cogley and Sargent (2005).

[3] Exceptions do exist; see e.g. Koop *et al*. (2009) and Karlsson and Österholm (2018).

where $\boldsymbol{\eta}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma}_{\boldsymbol{\theta}})$ and $\boldsymbol{\zeta}_t \sim N(\mathbf{0}, \boldsymbol{\Sigma}_{\boldsymbol{h}})$. When estimating the BVAR with constant parameters and covariance matrix, the variances $\boldsymbol{\Sigma}_{\boldsymbol{\theta}}$ and $\boldsymbol{\Sigma}_{\boldsymbol{h}}$ are restricted to be zero.

We carefully tailor the prior to match the scale and variation of the data as this is crucial for the model comparison with marginal likelihoods. For the constant parameter BVAR we use a diffuse prior for the regression parameters, $\boldsymbol{\theta} \sim N(\mathbf{0}, \mathbf{10}\boldsymbol{I})$, and inverse Gamma priors for the diagonal elements of $\boldsymbol{\Sigma}$, $\sigma_i^2 \sim iG(v_{0i}, S_{0i})$, with $v_{0i} = 5$ and S_{0i} selected to match the prior mean with the residual variance from univariate AR-models.

For the TVP-SV BVAR the same diffuse normal prior is used for the initial condition, $\boldsymbol{\theta}_0$. The diagonal elements of $\boldsymbol{\Sigma}_{\boldsymbol{\theta}}$ have inverse Gamma priors, $\sigma_{\theta i}^2 \sim iG(v_{\theta i}, S_{\theta i})$, with $v_{\theta i} = 5$ and prior means of 0.01 for the intercepts and 0.0001 for the other regression parameters. For the time-varying variances, the prior for the initial condition is selected to closely resemble the prior for the constant variance case. The initial condition for the log-variances has a normal prior, $\boldsymbol{h}_0 \sim N(\boldsymbol{\mu}_h, 0.25\boldsymbol{I})$, that is the variance is log-normal and the elements of $\boldsymbol{\mu}_h$ are selected so that the prior means of $exp(h_{i0})$ coincides with the constant variance case. Finally, the prior for the diagonal elements of $\boldsymbol{\Sigma}_{\boldsymbol{h}}$ is inverse Gamma with shape parameter 5 and mean 0.005.

For posterior inference, we rely on the Markov Chain Monte Carlo-sampler employed by Chan and Eisenstat (2018).

3. Empirical findings

We use data on seasonally adjusted unemployment rate and CPIF[4] ranging from 1995Q1 to 2017Q3. CPIF inflation is calculated as $\pi_t = 100(P_t/P_{t-4} - 1)$, where P_t is the CPIF index at time *t*. Data are shown in Figure 1.

Estimating the two models, we find that the log marginal likelihood is -124.0 for the model with constant parameters and covariance matrix and -117.7 for the model with time-varying parameters and stochastic volatility.[5] The evidence in favour of the latter model is "decisive" using the terminology of Kass and Raftery (1995). We accordingly conclude that the Phillips curve has not been stable.

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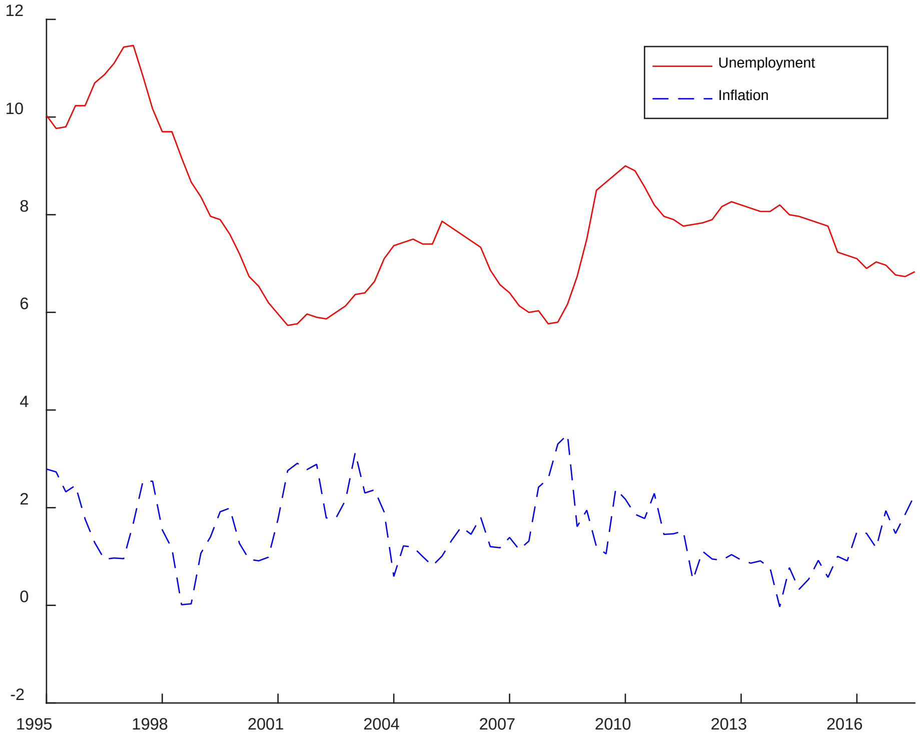
[4] CPIF is the consumer price index with a fixed interest rate.

[5] For details regarding the marginal likelihood calculations, see Chan and Eisentstat (2018).

Figure 1. Data.



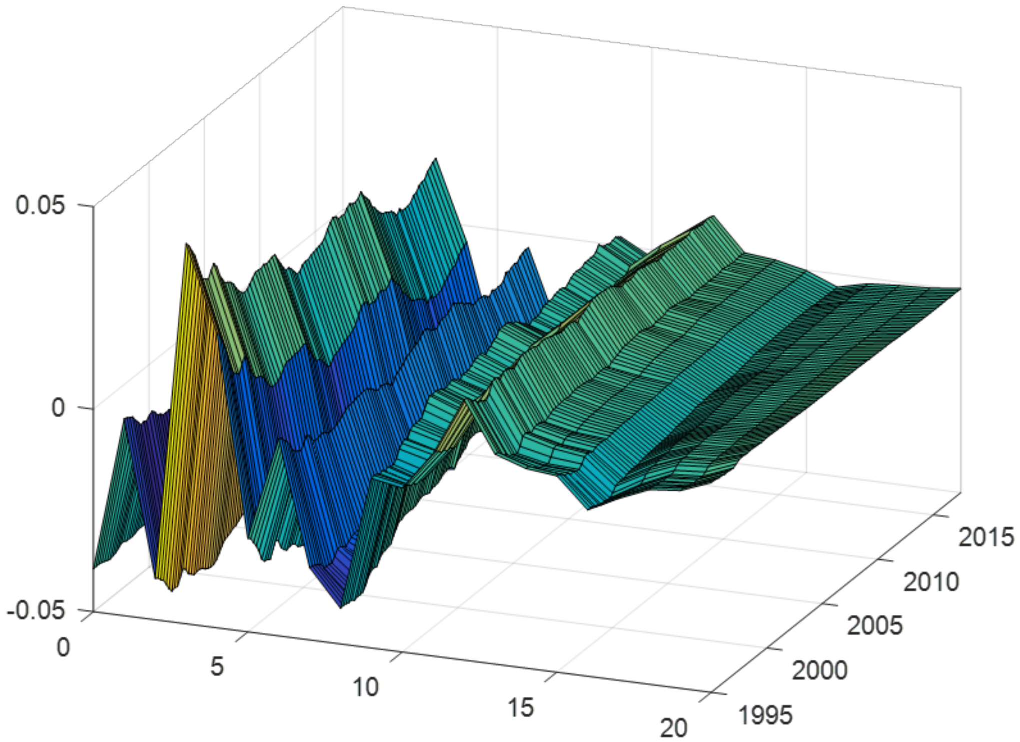
Note: Variables measured in percent.
Source: Macrobond

We next turn our attention to the properties of the Phillips curve given the established presence of time variation; that is, we look at the TVP-SV model. An issue of key interest in a Phillips curve framework is the effect that shocks to the unemployment rate has on inflation. This impulse-response function is given in Figure 2.[6] (The other impulse-response functions are shown in Figures A1 to A3 in the appendix.) An unexpectedly high unemployment rate tends – in line with our expectations – to decrease inflation at short horizons (apart from the three-quarter horizon).

While this impulse-response function looks stable over time, this does not imply that the parameters of the model have been constant. In Figure 3 we present the parameters of the inflation equation when the model has been expressed in the more commonly used "reduced form"

[6] The shock size is one standard deviation. This varies between 0.11 and 0.15 percentage points; see Figure A1.

Figure 2. Impulse-response function: Effect of shocks to the unemployment rate on inflation.



Note: Size of impulse is one standard deviation. Effect in percentage points on vertical axis. Horizon in quarters and time on horizontal axes.

$$\boldsymbol{y}_t = \boldsymbol{\gamma}_t + \boldsymbol{A}_{1t}\boldsymbol{y}_{t-1} + \cdots + \boldsymbol{A}_{pt}\boldsymbol{y}_{t-p} + \boldsymbol{e}_t \tag{4}$$

where $\boldsymbol{\gamma}_t = \boldsymbol{B}_{0t}^{-1}\boldsymbol{\delta}_t$, $\boldsymbol{A}_{it} = \boldsymbol{B}_{0t}^{-1}\boldsymbol{B}_{it}$ and $\boldsymbol{e}_t = \boldsymbol{B}_{0t}^{-1}\boldsymbol{\varepsilon}_t$. As can be seen, there has been a fair bit of variation in the parameters.

The sum of the coefficients of lagged unemployment in Figure 3 provides a measure of the "slope" of the Phillips curve.[7] This is plotted in Figure 4. Judging by the 68 percent credible interval, the slope of the Phillips curve has not changed dramatically during the sample. Looking at the point estimate, the story is somewhat different as it ranges from -0.11 to -0.37. Interestingly, the slope has not been unusually low between 2011 and 2016 indicating that Sweden's low inflation in this period cannot be explained by a flat Phillips curve.

[7] This is a common definition of the slope of the Phillips curve; see e.g.Knotek and Zaman (2017).

Figure 3. Estimated coefficients of the inflation equation from the BVAR in equation (4).

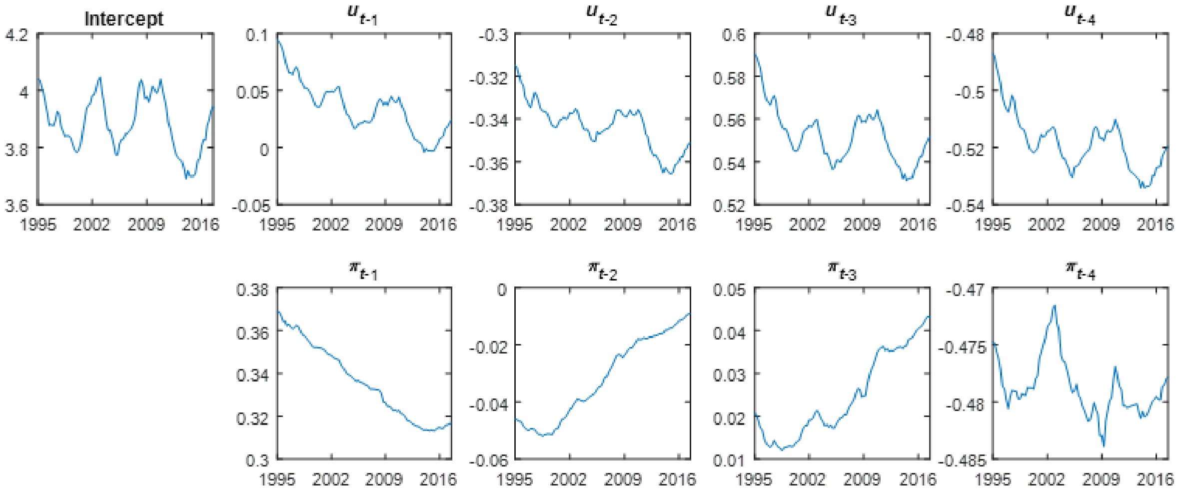
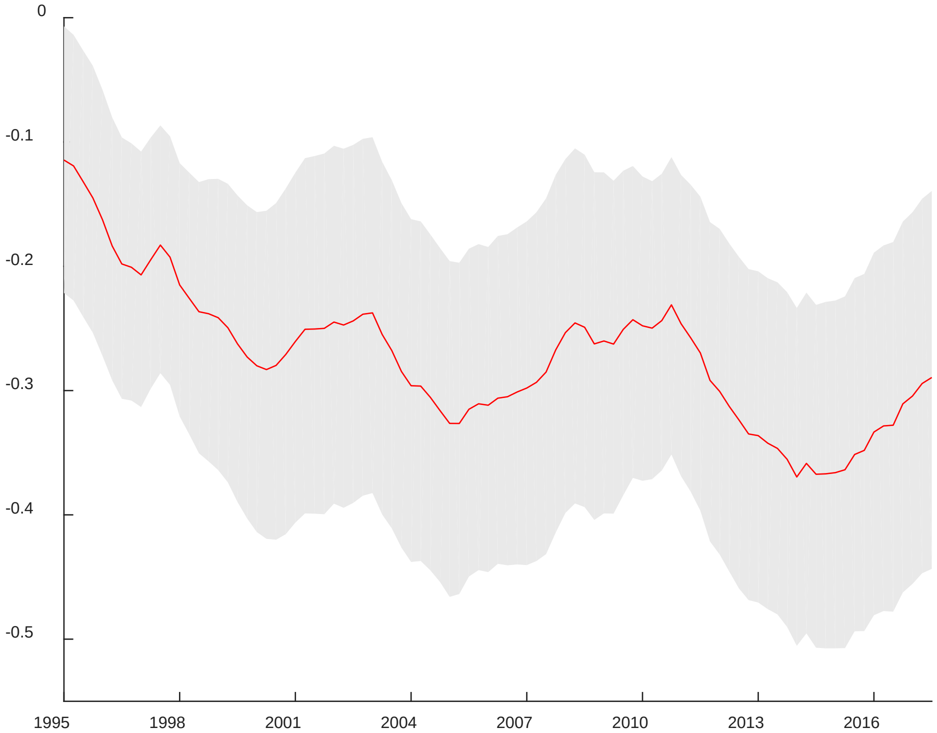


Figure 4. Estimated "slope" of the Phillips curve.

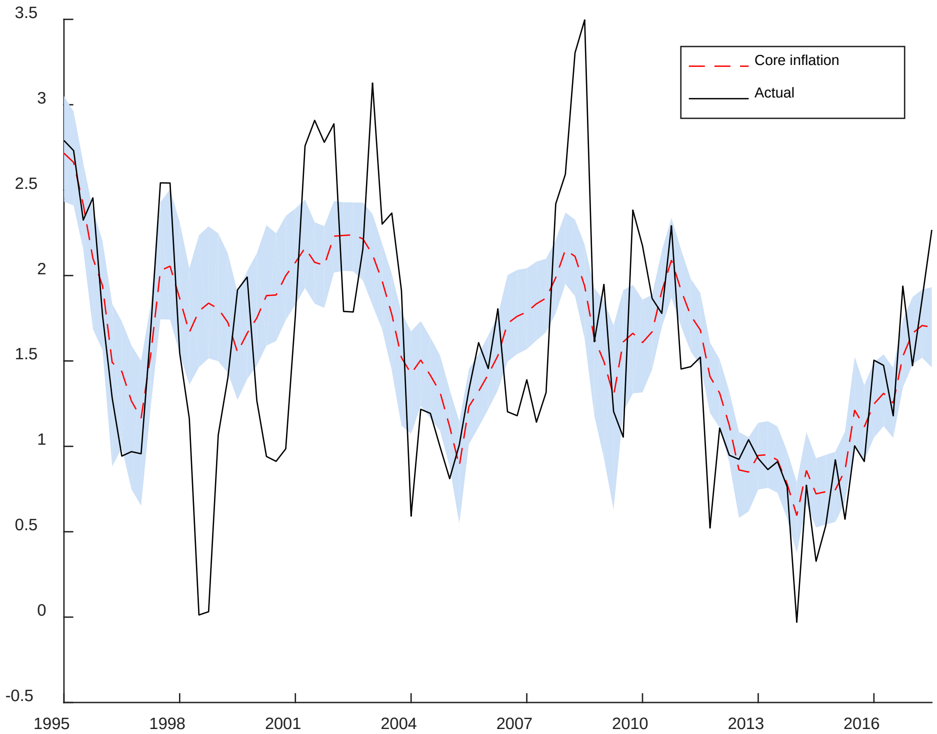


Note: Coloured band is 68% equal tail credible interval.

The final aspect of the evolving dynamics of the model which we consider can also be related to the Swedish monetary policy discussion. Around 2010 to 2014, the Riksbank was "leaning against the wind" in order to dissuade households from taking on housing-related debt. This contributed to the low inflation outcomes and sparked an intense debate regarding whether the Riksbank's policy was expansive enough (e.g. Svensson, 2014). In 2014, the Riksbank abandoned this policy and declared that its focus was on achieving the inflation target. In line with this the Riksbank lowered the repo rate to zero in October 2014 and has kept it at -0.5 percent since February 2016.

In our BVAR, we can – using the terminology of Cogley and Sargent (2005) – define "core inflation" as the value to which the inflation forecasts from the model converges. Estimated core inflation at each point in time is shown in Figure 5. As can be seen, core inflation fell while the Riksbank was leaning against the wind. By 2014 core inflation was between 0.6 and 1 percent. The model hence suggests that the low inflation outcomes had become problematic since its long-run inflation forecasts were not consistent with the inflation target. As the Riksbank changed its policy and focused on the inflation target, inflation increased slowly but surely and core inflation with it.

Figure 5. Estimated "core inflation".



Note: Coloured band is 68% equal tail credible interval.

4. Conclusions

In this paper we have assessed the stability of the Swedish Phillips curve. Conducting model selection using new methods, we found strong evidence for time-varying parameters and stochastic volatility. Based on this finding, we conclude that the Phillips curve has not been stable over time. However, while time-varying relations (and stochastic volatility) are preferred by the data, it can also be noted that *i)* the effect of an unexpectedly low unemployment rate on inflation is fairly stable over time and *ii)* our results do not suggest that the low inflation in recent years is due to a flatter Phillips curve.

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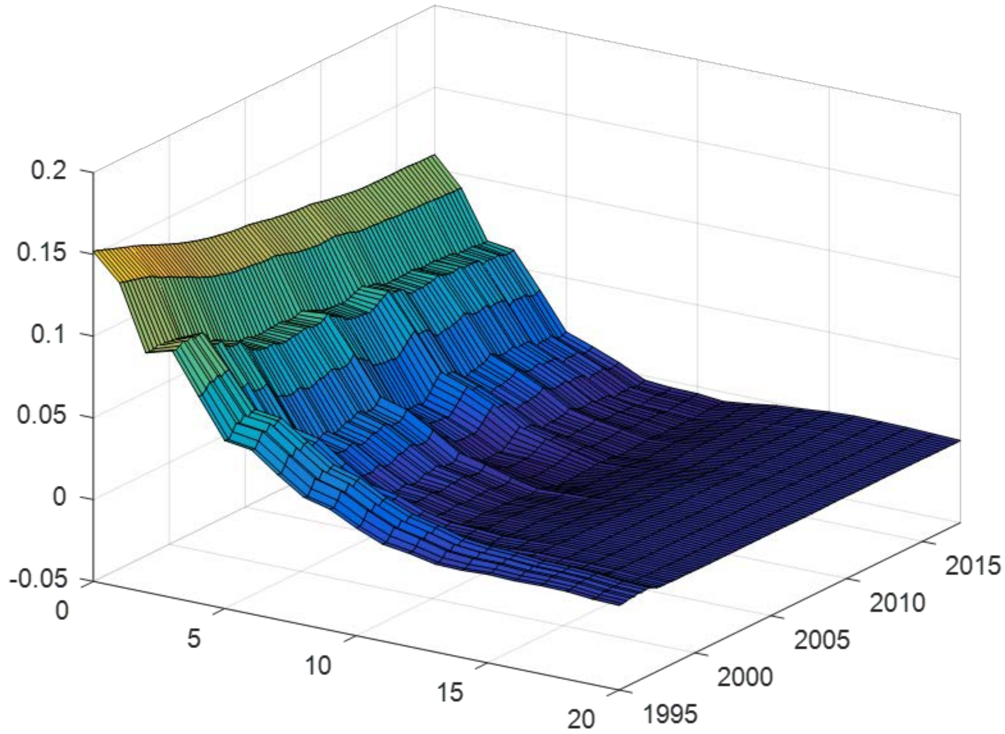
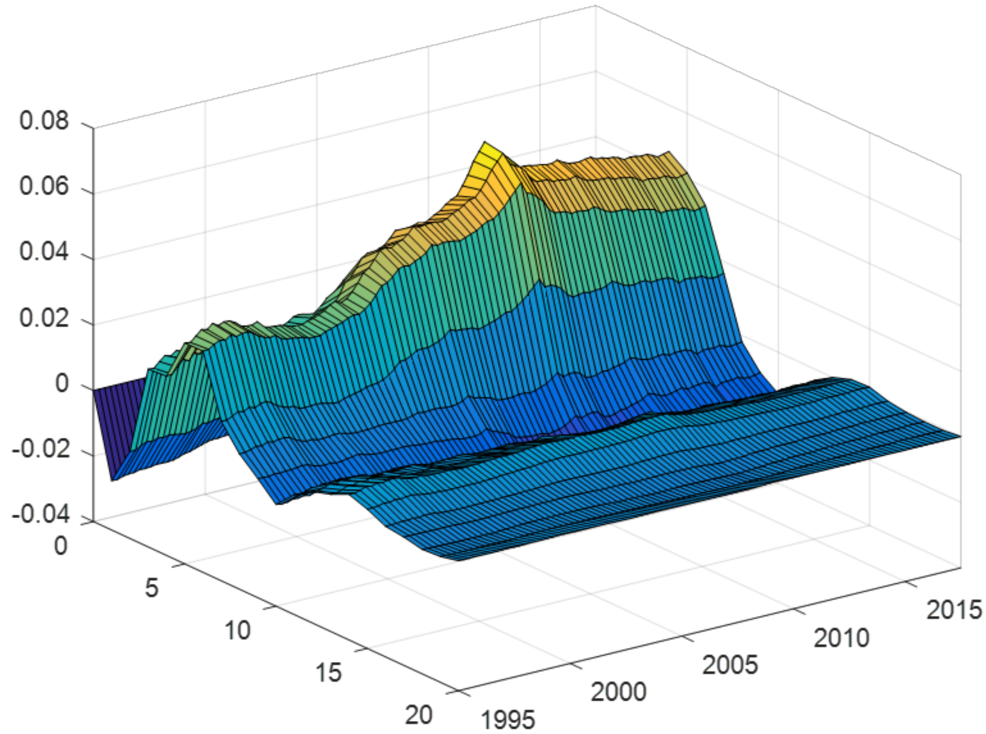
Appendix

Figure A1. Impulse-response function: Effect of shocks to the unemployment rate on the unemployment rate.



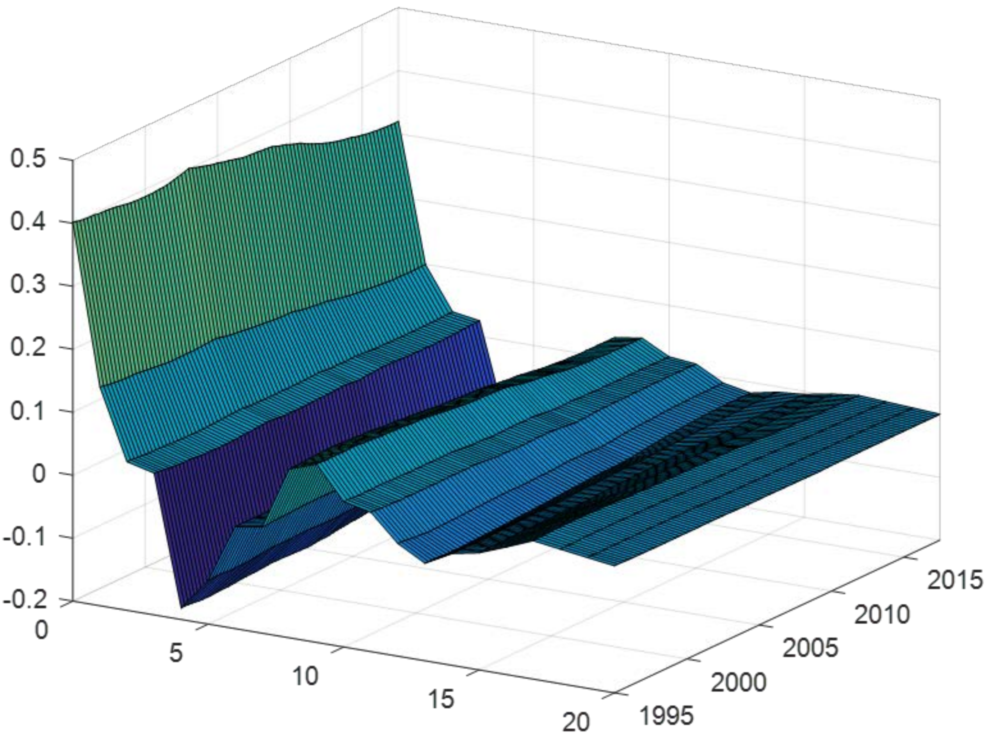
Note: See Figure 1.

Figure A2. Impulse-response function: Effect of shocks to inflation on the unemployment rate.



Note: See Figure 1.

Figure A3. Impulse-response function: Effect of shocks to inflation on inflation.



Note: See Figure 1.