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Abstract: The paper estimates a Phillips curve type relationship for the Bulgarian economy in a setup that takes into account the simultaneous interaction between inflation, output and unemployment. Using a state space model estimated with Bayesian methods on quarterly data from 1999 to 2015, we assess the cyclical developments in unemployment and output, and identify the main drivers of inflation over the period. Compared to other methods such as univariate filtering or production function approaches, our methodology enables the combination of information from different time series and admits a structural interpretation of the results in terms of the underlying shocks.

JEL classification: C32, C53, E10, E20, E31, E32

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Introduction

The historical analysis of cyclical developments in the Bulgarian economy faces challenges if traditional methods like univariate filters or a production function approach are used. Due to country-specific factors like the transition to a market economy and the consequences of bad economic policies in the mid-1990s, Bulgaria went through a period of relatively high inflation coupled with high unemployment and, likely, an increase in structural unemployment in the period 1999–2003. This suggests that at the time there was a slowdown in potential output growth and a significant negative output gap. However, results from conventional univariate filters contradict this view and simple Phillips curve models focused solely on the relationship between output and inflation cannot explain the developments in this period and fit them with the more recent history. This underscores the importance of modelling the interaction between inflation, output and unemployment simultaneously to obtain a unified picture of the observed developments.

This paper aims to contribute to filling the above gap by analysing the factors that influence inflation dynamics for the Bulgarian economy and model the relationship between inflation and measures of business cycle fluctuations in the framework of a Phillips curve type relationship. This in effect allows us to obtain estimates for the output gap and the natural level of unemployment, using other relevant economic information. For that purpose we use a state space model with Kalman filter, based on the methodology of Benes et al. (2004, 2010). The model is estimated using Bayesian methods to allow for the inclusion of prior information and to alleviate the potential drawbacks from using a relatively short sample. The inclusion of external supply-side shocks to affect directly inflation and the use of model-consistent inflation expectations and hard anchoring are important features of the model. More generally, our methodology enables a structural interpretation of the results in terms of the underlying shocks.

The model results are compared to the output of the simple HP filter. It is expected that the state space model will give more reliable estimates of the output gap, especially in regards to the period of 2000–2003, when high inflation is coupled with high unemployment in the context of a post-recession recovery. Furthermore, the state space model can be employed in medium and long-term growth forecasting, in addition to uses related to the analysis of the cyclical position of the economy. Results from such forecasting exercises can also be used in order to formulate appropriate expectations about indicators relevant to economic policy like the cyclically-adjusted budget deficit and the gross government debt.

We find a significant negative output gap during the period 2000–2003, in line with the high unemployment at the time, but despite high inflation, which would traditionally be associated with an overheating phase of the business cycle. In contrast, HP filter estimates point to a negative output gap close to zero during the same period. During the period 2003–2008, as well as during the recession period after 2009, estimates of the output gap are similar to the ones obtained using the HP filter. In regards to the characteristics of the Phillips curve relationship, we obtain a low estimate of the elasticity of inflation to demand. According to our results, shocks in oil prices and other international commodity prices are more important for inflation dynamics than demand. The historical decomposition of inflation dynamics reveals that other cost push shocks, not explicitly included in the model, matter the most for inflation dynamics during periods of high inflation. Such cost push shocks are difficult to specify precisely but they probably combine spill-overs from administrative price changes to core inflation, the dynamics of labour costs and dynamics of housing prices and their effects on consumer price inflation. Our results seem to be consistent with other empirical studies on the drivers of inflation done in the recent years (IMF (2015), Iossifov and Podpiera (2014)).

The paper is structured as follows. In the next section we provide a concise overview of the literature and recently used empirical methods. Following that, we justify the selection of a specific approach and describe the details of the methodology and the dataset used for the estimation. The subsequent section presents and discusses the results obtained. Finally, conclusions arising from the work are formulated.

Literature Overview

The relationship between measures of inflation and real variables at the macroeconomic level has always been of special interest in economics. While traditionally such relationships are referred to as *Phillips curves,* the notion has long surpassed the original Phillips (1958) study of money wages and unemployment to include real marginal costs, output gaps or unemployment gaps on the real side and various inflation indicators on the price side.

Starting from the seminal Phillips (1958) paper, the thinking on the Phillips curve-type mechanisms has undergone several transformations (see Fuhrer et al. (2009) for a more detailed account of this evolution). The initial interpretation of the Phillips curve as embodying a permanent trade-off between inflation and unemployment and hence implying that monetary policy could have long-term effects was criticized in the 1960s. In several influential papers Samuelson, Solow, Friedman and Phelps (Samuelson and Solow (1960), Friedman (1968), Phelps (1978)) argued that such a trade-off was valid only in the short run, thus limiting the usefulness of monetary policy measures to the near term only.

The advent of the rational expectations paradigm in the 1970s brought about a further strengthening of the initial criticism. A classical rational expectations model would imply not only a short-term role for monetary policy but would additionally require policy actions to surprise economic agents in order to have any effect at all. Results of this type are discouraging when taken at face value but they critically hinge on the assumption of price level flexibility, which is dubious from an empirical standpoint.

The need to square the assumptions of rational expectations models with empirical evidence spawned a body of literature trying to incorporate various forms of price inertia in a rational expectations framework. Introducing such rigidities ultimately makes the models more plausible and also reasserts a (temporary) role for monetary policy. The contributions in this strand of the literature are too numerous to review here but two studies are noteworthy as they play an important part in microfounded models with a Phillips curve to date. Calvo (1983) introduced a mechanism of time-dependent pricing under which firms in each period are constrained to stick to their current price with a certain probability. Rotemberg (1982, 1983) pursued the idea of state-dependent pricing and developed a mechanism under which firms pay an adjustment cost dependent on the extent of price change whenever they update prices. Both models have practically identical implications at the macro level and in a sense may be seen as only differing in the interpretability of their microfoundations by virtue of the different choice of modelling the price rigidities.

Starting from the second half of the 1980s and continuing through the 1990s, the literature on the Phillips curve took essentially its modern-day form by branching out in two directions. Gordon (2009) provides an excellent account of these developments and colourfully refers to the two branches of the bifurcation as the “left and right fork in the road”.

One branch followed up on the rational expectations construct with rigidities and strove to deepen further its microfoundations, ultimately incorporating the Phillips curve into a full-fledged DSGE-type model. The resulting Phillips curve specification – whether embedded in a DSGE model or taken as a standalone object for estimation – is commonly referred to as the New Keynesian Phillips Curve (NKPC). This is Gordon's "right fork in the road".

The other branch ("the left fork in the road") took a more empirical lean from the start and postulated a Phillips curve formulation comprising three sets of factors: inertia, demand factors and supply factors. Inertia is traditionally captured by lagged values of the inflation rate, demand factors are taken on board by means of current and lagged values of a gap-type measure (the deviation of unemployment from its "natural" level) and supply factors include current and lagged values of variables such as oil and food prices, real exchange rates or price control dummies. This approach is typically referred to as "the triangle model" (see Gordon (1998) for a typical implementation).

There is no consensus on the issue of which branch provides a more appropriate specification in terms of empirical performance. Indeed, the literature seems to have settled on the view that the NKPC and the triangle model perform differently in different historical episodes and hence both have their place in empirical applications. As a general guideline, however, the NKPC can be viewed as an appropriately restricted version of the triangle model and hence can be employed when there is evidence that these restrictions are plausible for the particular case in point or when the ultimate goal is to develop a larger microfounded model. In contrast, the triangle model seems more appropriate for situations where there is no convincing prior information justifying the imposition of particular restrictions and hence a more flexible specification is warranted.

More recent empirical work based on the "right fork" approach uses several extensions of the specification of the NKPC to bridge the gap between the theory and the data. In their influential paper, Gali and Gertler (1999) extend the theoretical framework by allowing for a fraction of firms to use a backward-looking rule of thumb to set prices. In this way they developed a "hybrid" NKPC model that accounts for inflation persistence, which is observed empirically. Other studies, including Gali and López-Salido (2001), Balakrishnan and López-Salido (2002) and Batini, Brian and Stephen (2005) augment the production function by including an imported intermediate goods input, which takes into account supply-side shocks related to international prices of commodities.

Due to the assumption of rational expectations in microfounded models, estimating the NKPC poses the problem of endogeneity, which arises from possible correlation of the errors from the model with the regressors. Since in this case the ordinary least squares (OLS) estimates of the parameters in the estimated equation might be inconsistent, the standard approach is to use instrumental variables to eliminate the correlation. There are many different approaches to using instruments to eliminate the effect of variable and residual correlation. A common practice in empirical research, including Gali and Gertler, is to estimate the NKPC model with the General Method of Moments (GMM) estimator.

When following the "left fork" approach a crucial step in modelling a Phillips curve relationship is estimating the unobservable variables that capture the state of the business cycle like the output gap or the unemployment gap. The most common method for estimation that has been used in the past decade is the univariate Hodrick-Prescott filter, which however has some significant limitations like the end-point bias and the fact that the estimation in the long-run is not robust to the introduction of new observations. Additionally, univariate filters do not take into account other relevant information, except the one contained in the series that is being filtered, which is another considerable setback.

In order to overcome these disadvantages, Benes et al. (2004, 2010) employed a methodology of measuring potential output and the output gap that makes use of the empirical relationships between relevant variables like the actual and potential GDP, unemployment, inflation and capacity utilization in the industry within the framework of a simple macroeconomic model. The model provides a multivariate filter, which can be adapted to many countries and is flexible in a way that it allows for the framework to be refined and more information added.

The most basic version of the model (Benes et al. 2010) is described and discussed below. The model equations are presented in two groups: Identifying relationships and laws of motion for equilibrium variables.

Identifying Relationships

$$\pi 4_t = \pi 4_{t-1} + \beta y_t + \Omega(y_t - y_{t-1}) + \varepsilon_t^{\pi 4} \tag{1}$$

$$u_t = \phi_1 u_{t-1} + \phi_2 y_t + \varepsilon_t^u \tag{2}$$

$$c_t = \mathrm{k}_1 c_{t-1} + \mathrm{k}_2 y_t + \varepsilon_t^c \tag{3}$$

Laws of Motion for Equilibrium Variables

Equilibrium unemployment or NAIRU

$$\bar{U}_t = \bar{U}_{t-1} + G_t^{\bar{U}} - \frac{\omega}{100} y_{t-1} - \frac{\lambda}{100}(\bar{U}_t - \bar{U}^{ss}) + \varepsilon_t^{\bar{U}} \tag{4}$$

where0 $G_t^{\bar{U}} = (1-\alpha)G_{t-1}^{\bar{U}} + \varepsilon_t^{G^{\bar{U}}}$ (5)

Potential output

$$\bar{Y}_t = \bar{Y}_{t-1} - \theta(\bar{U}_t - \bar{U}_{t-1}) - \frac{(1-\theta)(\bar{U}_{t-1} - \bar{U}_{t-20})}{19} + \frac{G_t^{\bar{Y}}}{4} + \varepsilon_t^{\bar{Y}} \tag{6}$$

where $G_t^{\bar{Y}} = \tau G_{ss}^{\bar{Y}} + (1-\tau)G_{t-1}^{\bar{Y}} + \varepsilon_t^{G^{\bar{Y}}}$ (7)

Equilibrium capacity utilization

$$\bar{C}_t = \bar{C}_{t-1} + G_t^{\bar{C}} + \varepsilon_t^{\bar{C}} \tag{8}$$

where $G_t^{\bar{C}} = (1-\delta)G_{t-1}^{\bar{C}} + \varepsilon_t^{G^{\bar{C}}}$ (9)

Perceived long-term inflation objectives

$$\pi 4_t^{LTE} = \pi 4_{t-1}^{LTE} + \varepsilon_t^{\pi 4^{LTE}} \tag{10}$$

Output gap equation

$$y_t = \rho_1 y_{t-1} - \frac{\rho_2}{100}(\pi 4_{t-1} - \pi 4_{t-1}^{LTE}) + \varepsilon_t^{y} \tag{11}$$

The group of identifying relationships comprises three equations: a simplified Phillips curve type relationship describing the short-run trade-off between the output gap (y_t) and inflation ($\pi 4_t$), adjusted for staggered prices and speed limit effects – equation (1), Okun's law type equation describing the interplay between unemployment gap (u_t) and the output gap – equation (2) and a similar link between the capacity utilization in manufacturing gap (c_t) and the output gap – equation (3). The three gaps are defined as deviation of the actual from its equilibrium level.

The laws of motion for the equilibrium variables are presented in equations (4) through (11). The equilibrium unemployment rate ($\bar{U}_t$), which corresponds to the notion of NAIRU, is allowed to deviate from its fixed steady-state level ($\bar{U}^{ss}$) and follows a stochastic process with both transitory ($\varepsilon_t^{\bar{U}}$) and more persistent shocks ($G_t^{\bar{U}}$) and it also depends on the output gap, which introduces a partial hysteresis effect, as captured in equation (4). In equilibrium the potential output ($\bar{Y}_t$) depends on changes in the underlying trend growth of potential ($G_t^{\bar{Y}}$) and on changes in the NAIRU – see equation (6). The inclusion of the latter causes short-term and medium-term potential growth to vary from the underlying trend growth of potential in order to capture the impact of changes in the equilibrium level of employment and the effect of the induced changes in the capital stock via a Cobb-Douglas production function, in which θ is the labour share. On the other hand the equilibrium trend growth of potential output is not constant and follows serially correlated deviations from its steady-state growth rate ($G_{ss}^{\bar{Y}}$) – equation (7). Equilibrium capacity utilization ($\bar{C}_t$), similarly to the unemployment equation, includes both transitory level shocks ($\varepsilon_t^{\bar{C}}$) as well as more persistent shocks in the growth rate ($G_t^{\bar{C}}$), see equation (8). Perceived long-term inflation expectations ($\pi 4_t^{LTE}$), which follow an adaptive process with revisions to their level of the previous period – equation (10), enter the equilibrium output gap equation so that there is a negative effect on demand from inflation deviating from its target, as presented in equation (11). This recognizes the idea that monetary policy exerts influence on core inflation through control over the output gap, which is generally consistent with a variety of monetary regimes.

To estimate the model Benes et al. employ a combination of the Kalman filter and the regularized maximum likelihood method following Ljung (1999). This allows for the definition of prior distributions, which can prevent parameters from wandering into illogical directions, but is also important for the estimation of parameters for which actual data can give little insight. The prior constraints imposed by the method are useful in the cases where the data set is too limited to provide enough information for the estimation of the particular variables.

Benes et al. apply their method to a number of countries and conclude that the multivariate filter estimates of the output gap are much more robust to introduction of a newer data set with longer time series, as compared to the univariate Hodrick-Prescott filter. Moreover, the multivariate filter estimates confirm that the growth rate of potential output can vary substantially over time, in contrast to the more conventional production approach, which assumes smoothly changing productivity growth. Several studies have followed the approach proposed by Benes et al., among which Fabiani and Mestre (2001), Sramkova (2010), Bokan and Ravnik (2012), where the abovementioned conclusions were confirmed.

Methodology and Data

Since the aims of our study are not only to analyse the factors that influence inflation dynamics and model the relationship between inflation and measures of business cycle fluctuations, but also to obtain reliable estimates for the output gap and the natural level of unemployment, using other relevant economic information, we believe the Benes et al. approach is preferable and more appropriate. Specifically, one of the useful outcomes of the model is a potential output estimate alternative to the ones derived by a Hodrick-Prescott filter or the production function approach, which are considered somewhat inferior and lacking in the literature on the topic (Benes and N'Diaye (2004)).

Model Specification

Several adjustments to the methodology of Benes et al. were made in order to fit the case of a small open economy with a currency board arrangement, without independent monetary policy, in this framework. The effort was directed towards arriving at a parsimonious specification, which, however, would not disregard any important prior theoretical considerations. First, we introduce external supply-side shocks to directly affect inflation. The ones that we identify as the most important for Bulgarian inflation dynamics are the international oil and other import prices and the real effective exchange rate. These are incorporated in the model similarly to Apel et al. (1999) by transforming them into shocks relative to inflation by deflating and standardizing them. In order to accommodate this addition we reformulate the Phillips curve equation in terms of quarterly annualized changes instead of annual changes as it is done in the original model by Benes et al. Secondly we introduce model-consistent inflation expectations and a hard anchoring element to the Phillips curve relationship. Using only model consistent expectations resulted in an explosive behaviour of the model, despite any combination of priors on parameters or residuals. Adding hard anchoring improved the model stability significantly and allowed to keep the model-consistent expectations. This improved the characteristics of the model compared to a version where some combination between consumer survey-based expectations and hard anchoring was used. With these modifications our Phillips curve relationship took this form:

$$\pi_t = \eta_1 \pi_{t-1} + \eta_2 \pi^E_{t+1} + (1 - \eta_1 - \eta_2)\pi_{ss} + \beta y_t + \Omega(y_{t-1} - y_{t-2}) + \sum_{k=0}^{2} \gamma_k z_{t-k} + \varepsilon^{\pi}_t, \quad (12)$$

where $z_t = (z_t^l, z_t^m, z_t^s)'$ is the vector of the supply side shocks of respectively the oil price, import prices and the real effective exchange rate, and the corresponding coefficients are given by $\gamma_k = (\gamma_k^l, \gamma_k^m, \gamma_k^s)$ for k = 0 to 2. The variables π_{t+1}^E and π_{ss} are respectively model-consistent expectation for one period ahead and the long-run steady state for inflation.

The effect of monetary policy on output gap through the difference between actual and expected inflation was taken out, since Bulgaria does not have independent monetary policy and it is rather the ECB monetary policy and policies of other non-Euro area central banks that (indirectly) affect the economy of Bulgaria. Thus, the block of equations for the potential and actual output and output gap was formulated in the following way, broadly following the Benes et al. construct:

Output gap identity:

$$y_t = Y_t - \overline{Y}_t \tag{13}$$

Potential output:

$$\overline{Y}_t = \frac{G_t^{\overline{Y}}}{4} + \overline{Y}_{t-1} + \varepsilon_t^{\overline{Y}} \tag{14}$$

Growth of potential output:

$$G_t^{\overline{Y}} = \tau G_{ss}^{\overline{Y}} + (1-\tau)G_{t-1}^{\overline{Y}} + \varepsilon_t^{G^{\overline{Y}}} \tag{15}$$

Output gap:

$$y_t = \rho y_{t-1} + \varepsilon_t^y \tag{16}$$

The unemployment block of the model is formulated in the following way:

Unemployment gap identity:

$$u_t = \overline{U}_t - U_t \tag{17}$$

Equilibrium unemployment:

$$\overline{U}_t = \overline{U}_{t-1} + G_t^{\overline{U}} - \frac{\omega}{100} y_{t-1} - \frac{\lambda}{100}(\overline{U}_{t-1} - \overline{U}^{ss}) + \varepsilon_t^{\overline{U}} \tag{18}$$

Growth of equilibrium unemployment:

$$G_t^{\overline{U}} = (1-\alpha)G_{t-1}^{\overline{U}} + \varepsilon_t^{G^{\overline{U}}} \tag{19}$$

No capacity utilization block was included in our model. Our experiments showed that the capacity utilization series introduced more noise than valuable information for the estimation of the unobservables, probably because of its survey-based nature.

Additional modifications were tested like the inclusion of industrial production, instead of capacity utilization and the current account balance, similarly to Bokan and Ravnik (2012). However, the benefit of complicating the model further in this direction seemed little to none in terms of model stability and quality of the estimates of the unobservable variables. Therefore, similarly to the capacity utilization, these indicators were not included in the system.

Parameter Calibration

The properties of the model depend on the values of the parameters representing the long-run steady states for inflation (π_{ss}), growth rate of potential output ($G_{ss}^{\overline{Y}}$) and the equilibrium unemployment rate ($\overline{U}^{ss}$), which are typically calibrated. The challenge in setting these values lies in striking the right balance between empirical performance, which implies reliance on historical data, and theoretical consistency, which requires an assessment of the expected future development of the economy.

The calibration of the steady state for inflation is direct. Based on the premise that inflation is ultimately a monetary phenomenon, and taking into account both the present currency board framework in Bulgaria and the obligation to join the euro area in the future, we set the steady state inflation rate to equal 2%. The primary objective of the ECB is to maintain price stability which is defined in quantitative terms as 'inflation rates below, but close to, 2% over the medium term'. Although the inflation objective of ECB is defined in terms of a narrow range, solving the model requires a precise parameter value of the steady-state. Therefore, the choice of 2% for the steady state inflation rate is considered to be appropriate as any other value would be arbitrary and not necessarily in line with the perception of the ECB. This approach is often adopted in empirical research (Bulíř et al 2008).

To calibrate the value of the steady state growth of potential output, we took annual World Bank data on real GDP growth rates for a set of countries and country groups[1] over the period 1960–2015. For this sample, we computed the average annual GDP growth for each country or country group. Assuming that business cycle fluctuations cancel out sufficiently well over a long period of time, average GDP growth should provide a reasonable approximation to long-run potential output growth. Additionally, one would be interested in economies that are expected to be at or rela-

[1] The precise country and country group coverage can be retrieved from the metadata for the series NY.GDP.MKTP.KD.ZG from the World Bank Databank.

tively close to the steady state to avoid picking up the effects of transition dynamics for less developed economies. For this reason we concentrated on economies at an advanced stage of economic development, as defined below.

In order to define more precisely the set of advanced economies, we proxied the state of development by using World Bank data on GDP per capita in PPP, measured in constant 2011 international dollars, for a set of countries and country groups[2] over the period 1960–2015. Both the dataset on GDP per capita in PPP and the dataset on real GDP growth include approximately 240 countries and country groups each. Thus, the two datasets are virtually identical in terms of country coverage. As the aim was to obtain an up-to-date picture, we computed the average GDP per capita for the period from 2010 to the end of the sample for each country. This approach allows the use of the most recent information while reducing the risk of arbitrary fluctuations in the outcomes that might exist if one were to use only the most recent observation for each country or region. We then sorted the data according to the computed period-average GDP per capita and took the subsample covering the top 85 to 95 percent. This procedure was applied in order to exclude some outliers in the sample, while capturing the relevant subset of advanced countries. The results include a subset of 24 countries and country groups, containing countries like the Netherlands, Austria, Germany and the UK, as well as groups like North America and the *High income* countries. Upon comparing the respective average real GDP growth rates, we chose to use the growth rate for the *High income* group as representative of what potential output growth for Bulgaria might eventually be. Thus, we calibrated the steady state growth of potential output at 3.1%.

The calibration of the steady state value for equilibrium unemployment is the most complicated one, as labour market outcomes are substantially affected by a number of factors, including demographic developments, institutional arrangements and the structure of the economy in general. While a detailed and comprehensive analysis of such issues is obviously beyond the scope of a calibration exercise, the preceding considerations suggest that an approach transcending a standalone analysis of unemployment rates is called for. Our implementation of such an approach is based on a combination of two elements – a "historical" and a "forward-looking" estimate – to produce a final calibrated value for steady state equilibrium

[2] The precise country and country group coverage can be retrieved from the metadata for the series NY.GDP.PCAP.PP.KD from the World Bank Databank.

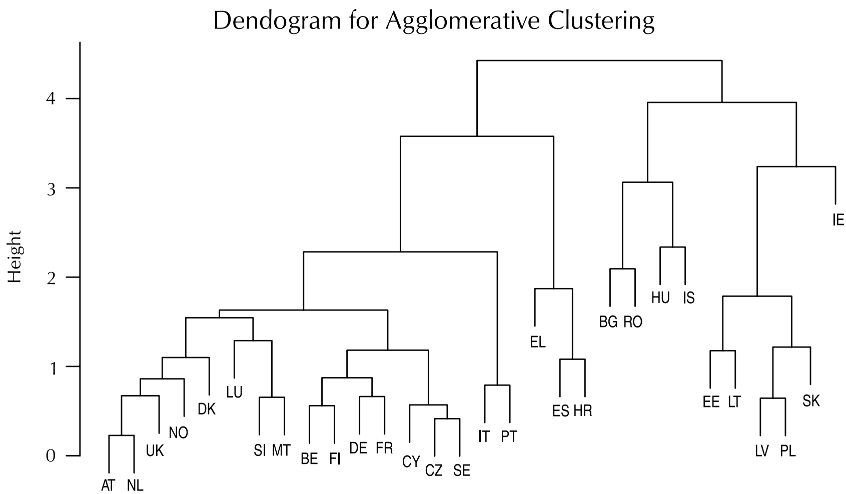
unemployment. Both estimates are constructed using data for the European economies.

The choice of the European economies as the starting set for computing the estimate of steady state unemployment can be questioned on grounds of consistency with the data used to calibrate the steady state growth of potential output. The most straightforward approach would be to use unemployment data for the same economies that formed the potential output group. We chose to depart from that option in our implementation. The motivation for that choice is grounded in the view that, even though the evolution of many macroeconomic variables is history-dependent and institution-specific, this is particularly true for labour market outcomes. Whereas long-term growth will at best be constrained by the expansion of the technology frontier, hence the choice of a group which is arguably on or close to that frontier, this can be achieved under a variety of modes of functioning of the labour market. For this reason, we find it preferable to benchmark possible unemployment outcomes against economies that are – to the extent possible – historically and institutionally similar to Bulgaria. While this goal inevitably entails a trade-off between a larger but more heterogeneous sample and a smaller sample of close counterparts, we believe the European economies provide an acceptable compromise in that respect.

To implement the first part of our approach, we identified a set of European economies that are similar to Bulgaria in terms of historical developments in inflation, growth and unemployment. To this end, we applied clustering procedures to data for average growth, inflation (based on the overall harmonized index of consumer prices excluding energy, food, alcohol and tobacco) and unemployment for the European economies over the period 1996–2015. Clustering refers to a rich set of unsupervised learning procedures that aim to discover groups in a dataset. Groups should include "similar" data points where similarity (or, equivalently, dissimilarity) can be formally defined on the basis of a chosen metric. Such metrics commonly include proximity and distance measures. An accessible overview of the main ideas can be found in James et al. (2013), chapter 10, while Gan et al. (2007) and Kaufman and Rousseeuw (2005) offer specialized treatments of the subject.

Proximity in our case was defined via the Euclidean distance without weighting, on standardised data. To test the robustness of our results, we used both an agglomerative[3] procedure and a divisive[4] one. Both procedures are representatives of the class of hierarchical clustering methods. In essence, hierarchical clustering methods do not produce a single partition of the data into groups but instead yield a set of nested partitions constructed for varying degrees of strictness in the application of the similarity criterion. Depending on whether the partitioning is carried out bottom-up (starting from individual observations and successively binding them together in larger groups) or top-down (starting from one group and successively subdividing it into smaller groups) we speak of agglomerative or divisive procedures, respectively. The results of both methods indicate that Bulgaria can be grouped together mostly with Eastern European countries. These results can be presented graphically via a tree-like structure called a dendrogram (see Figure 1 for the results of the agglomerative procedure and Figure 2 for the results of the divisive one), which shows the various groups as a function of the similarity criterion. The coverage of the group obviously depends on the strictness of the similarity definition and in this case we opted for a broader one comprising 10 countries[5] in order to get more representative results.

Figure 1: **Cluster Analysis Results for Agglomerative Clustering**

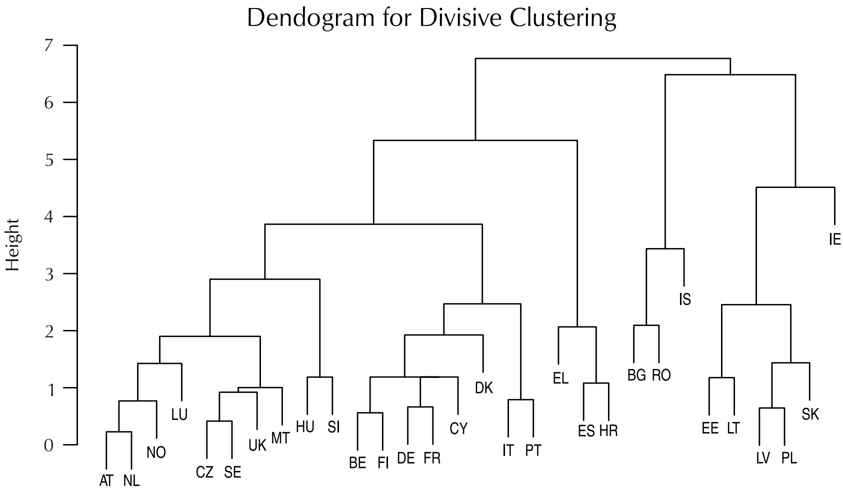


[3] Algorithm AGNES as implemented in R package *cluster*. See also Kaufman and Rousseeuw (2005), chapter 5.

[4] Algorithm DIANA as implemented in R package *cluster*. See also Kaufman and Rousseeuw (2005), chapter 6.

[5] These are BG, RO, IS, EE, LT, LV, PL, SK, IE and HU.

Figure 2: **Cluster Analysis Results for Divisive Clustering**



The direct computation of the mean unemployment rate for the selected set of economies has the potential drawback that the average unemployment rate for each economy may reflect an out-of-equilibrium position due to cyclical developments. To control for that possibility, we computed estimates of the output gap on quarterly data for these economies using a simple HP filtering procedure and isolated the episodes when output was sufficiently close to its potential (defined as an absolute value of the estimated output gap less than or equal to 0.2%[6]). We then averaged the corresponding unemployment rates over the identified subsamples. In this procedure all countries and observations were treated symmetrically and, in particular, no weighting scheme of any kind was applied. The resulting mean unemployment rate is a measure providing a picture of the typical historical state of unemployment when the output was close to equilibrium.

It can also be argued that the calibration of equilibrium unemployment should not be entirely backward looking but should also reflect what may be considered achievable in the future. This consideration motivates the second part of our overall approach. To this end, we introduced a measure of what the "best" outcome in terms of unemployment might be. In order to keep this approach empirically grounded, we computed the lowest historical unemployment rates for the full sample of EU countries over the

[6] While the choice of the specific threshold value is essentially arbitrary, we experimented with other values in the range 0.1–0.5% to confirm the robustness of the results.

period 1996–2015 and averaged them. While the observed minima may have been attained under specific circumstances and, in particular, at a time when the respective economy was overheating, a computation of this kind shows the historical limits reached by the respective labour markets.

To construct an estimate of equilibrium unemployment that combines a historically representative quantity with the potential "best" outcome, we obtained the final calibration value by taking the mean of the average unemployment rate computed for small output gaps and the average of the historical unemployment minima. The equilibrium unemployment rate was thus calibrated at 7.4%.

Estimation Strategy and Data

For the estimation of the model we use a more general methodology than the one used by Benes et al. Once we set up the priors of the individual parameters and locate the posterior mode, we use an adaptive random-walk Metropolis-Hastings algorithm to obtain the whole distributions of the parameters.[7] For most parameters we use the lognormal distribution and only for a few shocks in the unemployment block the inverse gamma distribution.

We estimate the model over the sample of 1999Q1–2015Q4. The series of GDP used in the model are the ones provided by the National Statistical Institute (as of March 2016) and seasonally adjusted using Bayesian methods by the Bulgarian National Bank. The measure of inflation used in the model is the HICP excluding energy goods, unprocessed food, tobacco and administrative prices. For the measure of import price, we use competitors' prices on the import side relevant for Bulgaria's main trading partners and for the international oil price we take the Brent crude oil price. The real effective exchange rate is taken from the ECB database[8]. Unemployment is taken from the Labour Force Survey and the measure used is for persons over the age of 15, seasonally adjusted by the Eurostat. Alternative versions of the model were tested with core inflation excluding energy, food, tobacco and administrative prices as well as international food prices instead of the competitors' prices on the import side. However, these alternative specifications did not yield satisfying results.

[7] Estimation was done with the Matlab toolbox IRIS.

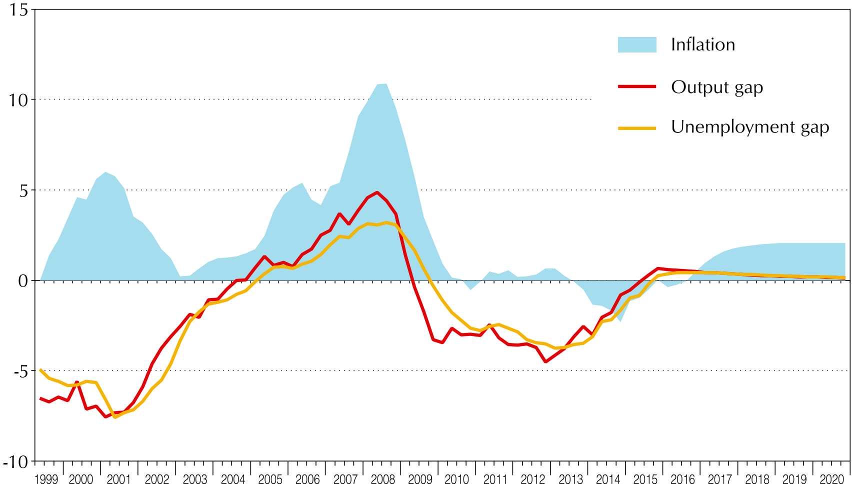
[8] The series used in the paper is the GDP-deflators deflated effective exchange rate (EER) of the Bulgarian lev against the currencies of 19 countries.

Results

The estimates show that the trade-off between economic activity and inflation is not as clear-cut as theory suggests which is mainly due to one-off and country-specific factors. There is a large negative output gap in the period 1999Q1–2003Q1, which corresponds to the high unemployment in this period. During the same period there is also high inflation, which on the one hand can be related to the transition to market economy the country went through in terms of opening up borders to trade and privatization and on the other the period of hyperinflation the country emerged from in the end of the 90s with the introduction of the currency board. In the period 2003Q2–2008Q4 the output gap is positive and increasing and peaks in 2008Q1 (4.5%), which coincides with the peak in inflation. Throughout that period unemployment is also steadily decreasing. With the global financial crisis and the negative shock in demand, output gap turns negative in 2009Q1 and reaches a local trough in 2009Q4 (-4.5%). Coinciding with the European sovereign debt crisis there is another local trough in 2012Q4 (-4.6%). The negative output gap observed after 2009 is estimated to close in 2014Q4. Afterwards the output gap is estimated and projected to fluctuate close to zero as inflation goes up to the hard anchor of 2% annually. In general, inflation tends to exhibit stronger persistence and lag behind the output gap historically.

Figure 3: **Output Gap, Inflation and Unemploymen Gap**

(in percent)

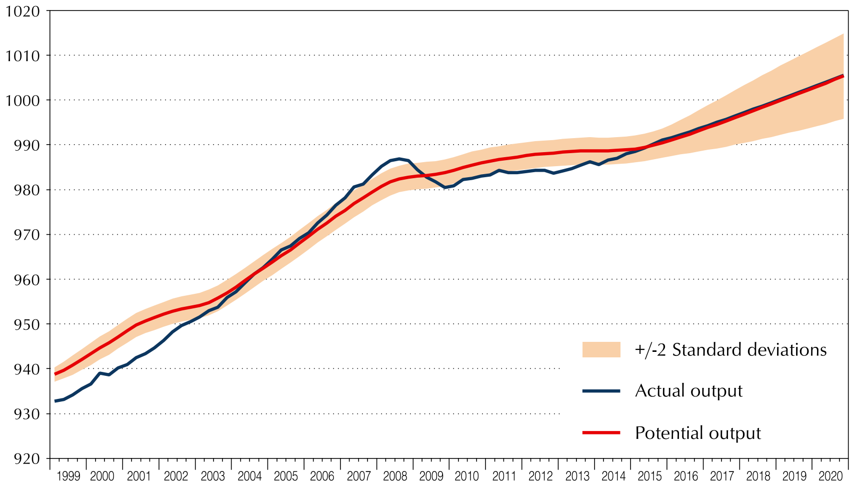


Source: Authors' calculations.

Assessing the dynamics of potential output, we see that there is a significant deceleration in potential output growth in the period 2000Q4–2003Q1, which has the main contribution for the closing of the output gap in 2003. This significant deceleration can be associated with the significant increase in equilibrium unemployment. Until 2009 and the global financial crisis potential output growth is steady of around 5%. Afterwards another deceleration takes place, but much smoother than the one in the beginning of the sample. Again, this deceleration contributes to the faster closing of the negative output gap in the end of 2014. Assessing the relative variance of changes in the output gap to changes in actual output, we see that changes in the output gap dominate short-term changes in GDP (see Appendix 2). This confirms the view, which is taken as conventional for industrialized countries that output gap is more important for short-term actual output movements than the potential output.

Figure 4: **Actual and Potential Output**

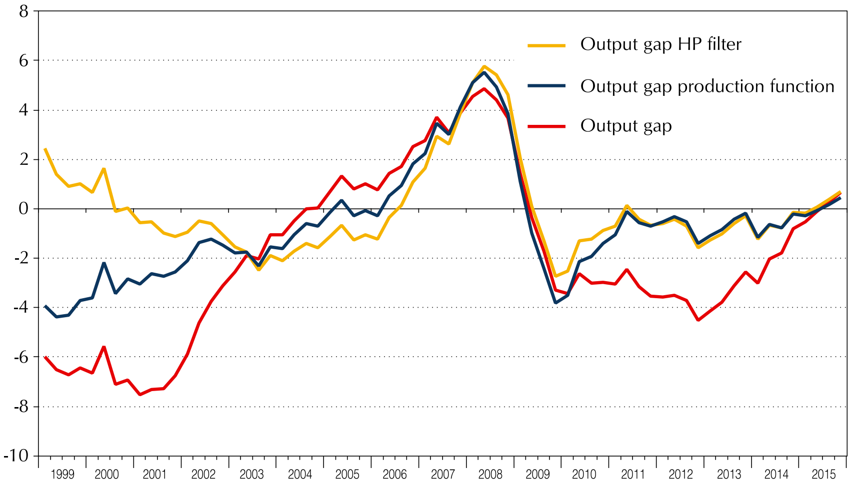
(in logarithm)



Source: Authors' calculations.

Comparing the estimated output gap with other measures obtained from alternative methods like a simple Hodrick-Prescott filter and a production function approach, we find some significant differences. The two alternative measures of output gap fluctuates much closer to zero than the one estimated by the multivariate filter model, where most of the movement is in negative territory. In the period 1999Q1–2003Q1, the output gap estimated by the production function approach is much less negative and positive in one quarter, while the one obtained from the HP filter is positive most of the time. In the period 2003Q2–2008Q4 the three estimates are quite close to each other, even though the HP filter and the production function approach show the output gap turning positive much later than the multivariate filter estimate around 2006. During the crisis, the two alternative measures estimate a closing of the negative output gap in 2011Q1, when actual output growth accelerates, which is much sooner than the results from the multivariate filter. The results from the multivariate approach are more consistent with the undergoing structural change of the economy in 1999–2003 and macroeconomic developments in the aftermath of the global financial crisis. This comparison shows that the use of additional information about inflation and labour market developments improves on univariate methods as the Hodrick-Prescott (HP) filter.

Figure 5: **Various Measures of Output Gap**
(in percent)



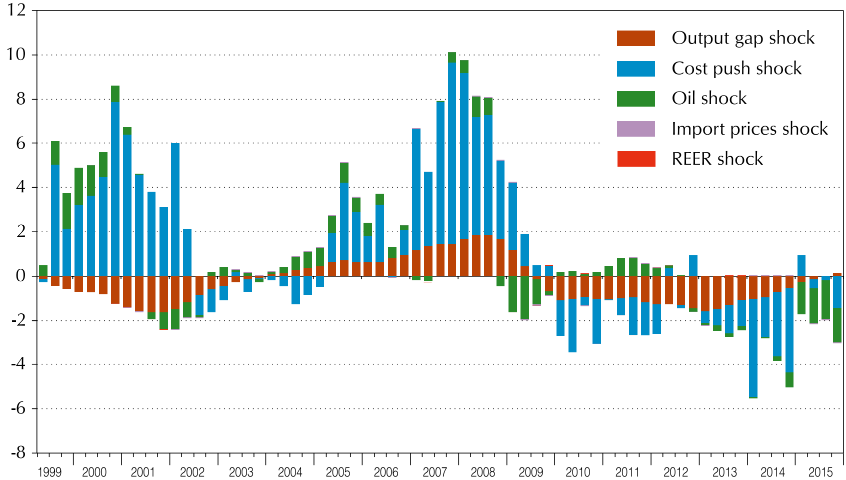
Source: Authors' calculations.

The estimated Phillips curve displayed a low sensitivity of core inflation to changes in the output gap, but a relatively higher sensitivity to speed-limit effects (see Appendix 1). Lagged inflation has a high coefficient in the Phillips curve equation, while expectations have a relatively low impact on inflation. Oil price shocks affect inflation mostly contemporaneously, while other import prices shocks have an effect with a lag. The effect of real exchange rate shocks on inflation is rather small. The coefficients remain stable when the model is estimated over different sub-samples. The core parameters of the model, like the steady-state growth rate, were estimated within the model and the results were close to the initial calibrations. More graphs of the estimated potential output and NAIRU are given in Appendix 2.

The contribution of shocks to inflation dynamics reveals that in the periods of very high inflation, the factors incorporated in the Phillips curve do not explain most of the variation in inflation. Therefore, factors not explicitly included in the model should account for that. We see the output gap shock has been systematically important for inflation dynamics throughout the sample, matching the sign of the output gap. However, the size of the contribution corresponds to the low sensitivity of inflation to economic slack. The cost push shock, which is the shock in the Phillips curve equation, has the main contribution in the three periods of very high inflation: 1999Q2–2002Q2, 2003Q2–2004Q3 and 2005Q1–2009Q2. As it was mentioned above the earliest spell of high inflation in the sample can probably be associated with the process of transition to a market economy and opening up to trade. However, the most important factors that we believe stand behind the spikes in inflation and especially the one during the pre-2009 period are administrative price changes, strong growth in unit labour costs and possibly the appreciation of housing prices (see Figure 7). It is evident that for a prolonged period between 1999Q1 and 2003Q3 administered prices grow by a double digit growth. Some of these administered prices are the prices of utilities like electricity and gas, while others are related to public services and healthcare. On the other hand, unit labour costs growth accelerates roughly in the period 2007Q1–2009Q3. During the pre-crisis period of strong demand growth, producers were able to pass on increased production costs to final consumers.

Figure 6: **Contribution of Shocks to Inflation Dynamics**

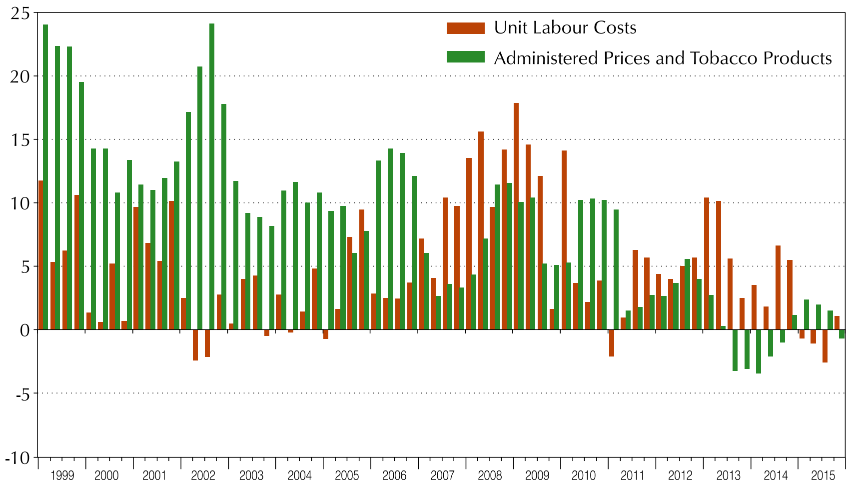
(in percentage points)



Source: Authors' calculations.

Figure 7: **Administered Prices and Unit Labour Costs**

(in annual percent changes)



Source: NSI.

On the other hand, in the period from 2009 and after it seems that the factors included in the model do manage to explain most of the inflation dynamics. In the current period of deflation demand has no contribution to the inflation dynamics as the estimated output gap closes and fluctuates around zero. On the other hand the cost push shock has a significant negative contribution, but that can be attributed to the cuts in the prices of electricity since the middle of 2013. The other major contribution to the decline in inflation is the dynamics of the international oil price since 2014Q4. In general, it seems that the Phillips curve does explain inflation better after 2009, whereas earlier a few other important factors are at play, which relate to the large portion of administered prices in the HICP basket and the processes of nominal and real convergence of the economy.

The unemployment gap seems to move close to the output gap with a lag. Its dynamics is determined by the movement of equilibrium unemployment (NAIRU), which more or less follows actual unemployment with a lag. Bigger increases in equilibrium unemployment occur roughly in the period 2001–2003, as actual unemployment spikes to almost 19% and again after 2009. Decomposing the dynamics of the equilibrium unemployment to the contribution of the shocks in the model reveals that output gap is by far the most important factor. The estimates are robust to changes in the structural unemployment parameter, which directly affects the NAIRU. Since the main focus of our model framework is the interplay between output and inflation, the results are somewhat limited in regards to unemployment. Therefore, it is hard to draw much more detailed conclusions in regards to the equilibrium unemployment and the unemployment gap. This is a reason to consider an extension of the model specification, by including indicators specific for the labour market, in order to address this issue of an undeveloped, but important part of the model.

Conclusions

The paper uses a macroeconomic model estimated with Bayesian methods and using Kalman filter to estimate a Phillips curve type relationship between output and inflation as well as produce estimates for output and unemployment gaps. The model is also used to assess the main drivers of inflation in the past decade and a half.

Modelling inflation and potential output within the theoretical framework of the New Keynesian Phillips curve yields useful results for Bulgaria. Prior views on the main drivers of inflation were confirmed in this study.

Estimates show that core inflation is highly persistent and dependent on supply-side shocks like oil prices and other import prices. Even though inflation is not very sensitive to economic slack, changes in the output gap do have a non-negligible contribution to the inflation dynamics in the sample. Before 2009, in periods of high inflation, much of the dynamics of inflation are unexplained by factors explicitly included in the Phillips curve, being driven by cost push shocks of unspecified nature. These cost push shocks are challenging to identify precisely but we conjecture that they combine the effects of spill-overs from administrative price changes to core inflation, the dynamics of labour costs and dynamics of housing prices and their effects on consumer price inflation.

However, in our view the Phillips curve does explain inflation dynamics after 2009 well, which points out that the effects of other factors like labour costs and administrative prices have been weaker lately. Also the estimates of the output and unemployment gaps seem better aligned with macroeconomic developments than the ones obtained from alternative approaches, as they incorporate information from several time series. This could be useful for medium and long-term growth forecasting, in addition to uses related to the analysis of the cyclical position of the economy. Results from such forecasting exercises can also be used in order to formulate expectations about indicators relevant to economic policy like the cyclically-adjusted budget deficit and the gross government debt. Overall, we consider the results plausible and the framework employed here merits further development both for research and for applied uses. Some further extension of the model specification and work done on parameterization is deemed necessary in order to make the model fully suitable for regular applied use and forecasting.

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Model Specification and Parameters

Model Parameters

Calibrated Parameters	Value
$G_{ss}^{\overline{Y}}$	3.1
$\overline{U}^{ss}$	7.4
π_{ss}	2.0

Bayesian Parameter Estimation

Parameter	Prior					Posterior	
	Lower Bound	Upper Bound	Log Distribution	Mean	Standard deviation	Mode	Standard deviation
α	0.1	1	normal	0.89	0.10	0.87	0.10
β	0	1	normal	0.10	0.02	0.09	0.01
Ω	0	1	normal	0.20	0.42	0.13	0.30
η_1	0	1	normal	0.80	0.40	0.63	0.00
η_2	0.01	0.15	normal	0.10	0.20	0.12	0.00
ρ	0	1	normal	0.60	0.10	0.93	0.05
ϕ_1	0	1	normal	0.57	0.06	0.66	0.06
ϕ_2	0	1	normal	0.38	0.06	0.32	0.05
τ	0	1	normal	0.50	0.09	0.28	0.08
ω	0	100	normal	3.70	1.58	4.28	1.08
λ	0.01	100	normal	5.00	0.32	4.94	0.32
γ_0^l	0	1	normal	0.30	0.32	0.20	0.48
γ_1^l	0	1	normal	0.10	0.22	0.15	0.34
γ_2^l	0	1	normal	0.10	0.32	0.19	0.02
γ_0^m	0	1	normal	0.10	0.20	0.00	0.91
γ_1^m	0	1	normal	0.16	0.20	0.00	0.38
γ_2^m	0	1	normal	0.10	0.20	0.01	0.02
γ_0^s	-1	0	normal	-0.10	0.32	0.00	1.02
γ_1^s	-1	0	normal	-0.10	0.32	-0.01	0.31
γ_2^s	-1	0	normal	-0.10	0.32	0.00	1.01

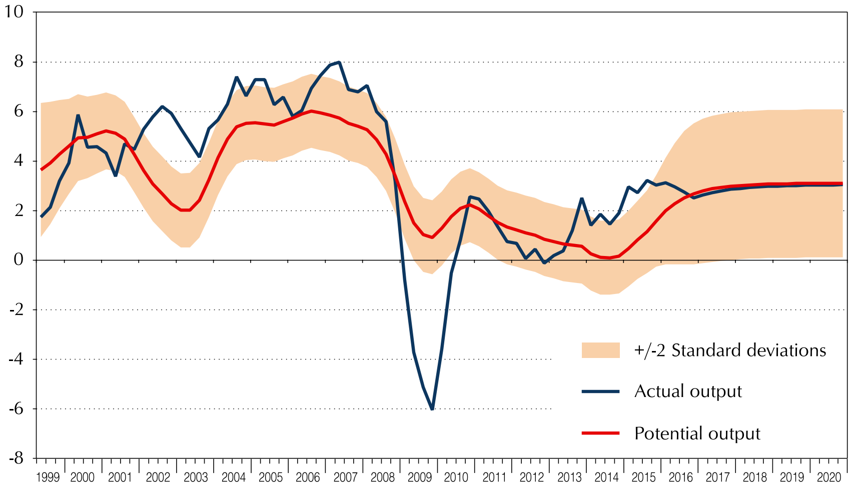
σ_{ε^y}	0.01	3	normal	0.99	0.01	1.39	0.01
$\sigma_{\varepsilon^{G\bar{Y}}}$	0.01	3	normal	0.66	0.13	1.16	0.11
σ_{ε^u}	0	3	normal	0.67	0.06	0.47	0.08
$\sigma_{\varepsilon^{\bar{U}}}$	0.01	3	invgamma	0.30	0.30	0.15	0.04
$\sigma_{\varepsilon^{G\bar{U}}}$	0	3	invgamma	0.30	0.30	0.17	0.05
σ_{ε^π}	0.01	3	normal	0.74	0.03	1.17	0.04
$\sigma_{\varepsilon^{\bar{Y}}}$	0.01	3	normal	0.21	0.08	0.26	0.08
σ_{ε^l}	0.01	3	normal	0.80	0.36	1.00	0.10
σ_{ε^m}	0.01	3	normal	0.99	0.36	1.00	0.11
σ_{ε^s}	0.01	3	normal	1.00	0.36	0.12	0.01

APPENDIX 2

Estimates of Unobservable Variables and Additional Model Output

Actual and Potential Output Growth

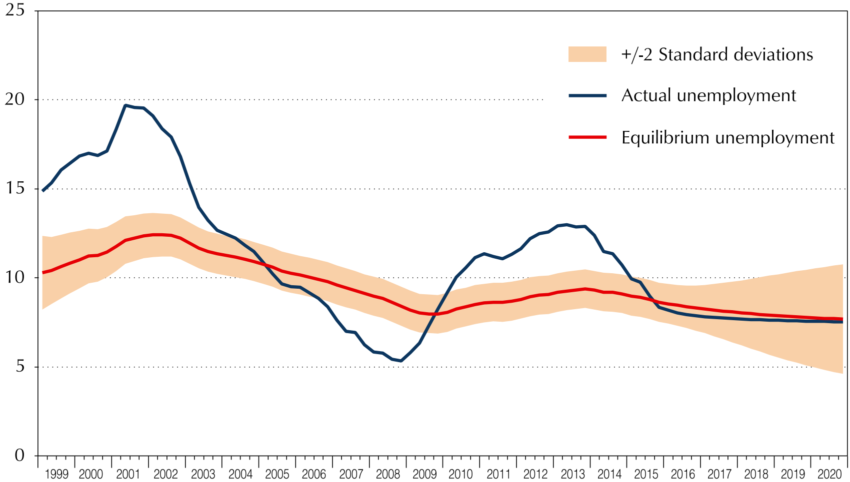
(in annual percent changes)



Source: Authors' calculations.

Actual and Equilibrium Unemployment

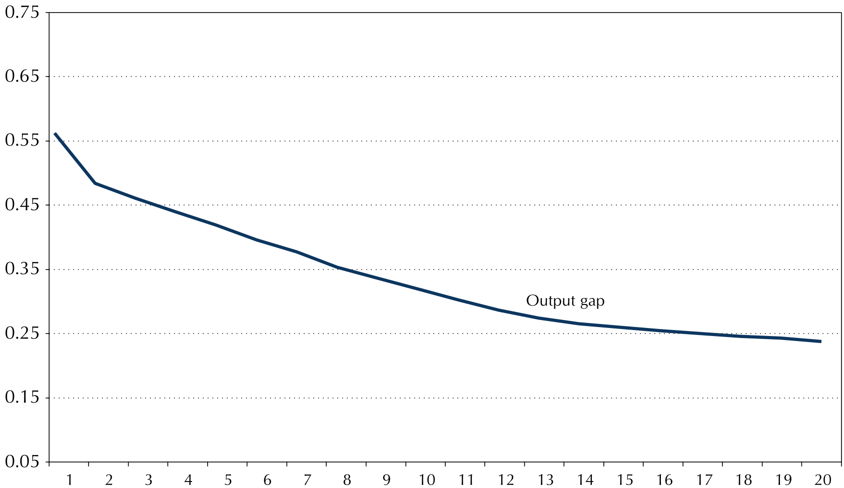
(in percent)



Source: Authors' calculations.

Variance of the Changes in Output Gap Relative to Variance of Changes in Actual Output Over One to Twenty Quarters

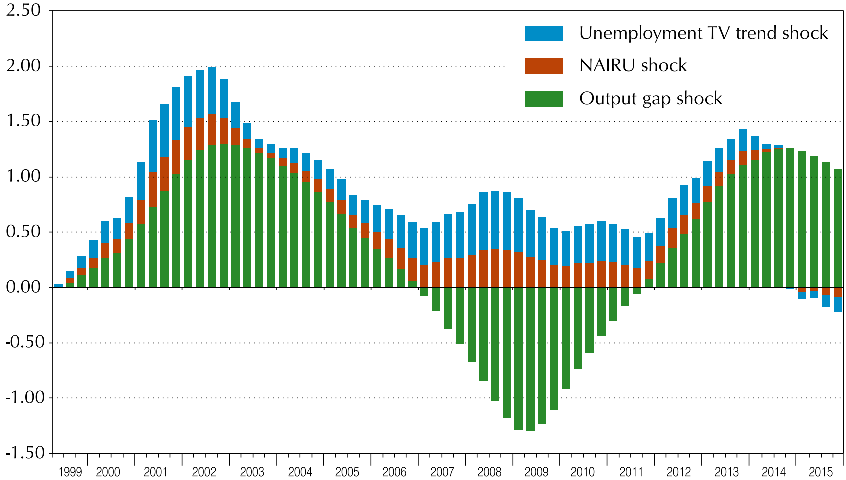
(ratio)



Source: Authors' calculations.

Contribution of Shocks to Equilibrium Unemployment Dynamics

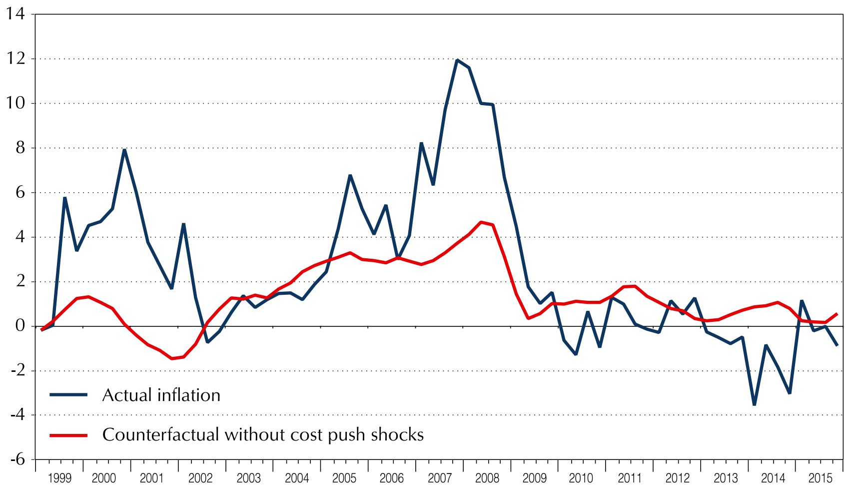
(in percentage points)



Source: Authors' calculations.

Actual and Counterfactual Inflation without the Cost Push Shocks

(in annual percent changes)



Source: Authors' calculations.