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An intuitive method to improve the estimation of output gaps

Joscha Beckmann and Wolfram Wilde¹

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Abstract

Standard procedures for output gap estimates, such as the Hodrick-Prescott Filter or the Production Function Method, suffer from the sample phase shift issue at the end of the sample. This often provides unstable and unreliable estimates for the current output gap. However the current estimate of output gaps is the most relevant one for monetary and fiscal policymakers. The results from time series filters lack an economic founding and tend to produce economic implausible results for the output gap. This paper introduces and evaluates a new method which is able to reduce the uncertainty of output gaps at the end of a sample while allowing for an economic interpretation of the obtained estimate. Our estimates for 12 economies show that we are able to outperform the popular production function methodology (PF) when nowcasting the current output gap.

Keywords: Output Gap, Policy Evaluation,

JEL codes: E52; E58

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1. Introduction

Understanding and estimating output gap dynamics is of great importance for academics and policymakers. Conventional monetary policy rules rely on output gap estimates which are also important for decision about fiscal policy, in particular around turning points of the business cycle. The output gap is of crucial importance in the European Union where fiscal deficit rules are based on output gap estimates according to the fiscal surveillance of the Stability and Growth Pact.

The uncertainty surrounding output gap estimates has long been recognized in the literature with the unreliability of end –of sample estimates acknowledged as the most important issue (Orphanides and van Norden, 2002). This problem results from the fact that standard procedures, such as the Hodrick-Prescott (HP) Filter are two sided filters. This necessarily requires future information which is usually obtained via averaging historical growth rates or autoregressive forecast models. Multivariate methods, which for example include inflation dynamics have so far failed to outperform their univariate counterparts (Orphanides and van Norden, 2002). This discussion has recently been revitalized by Hamilton (2017) who is highly critical of the HP filter, highlighting the generation of spurious dynamic relations at the end of the sample as a major issues.

Univariate methods to determine the output gap usually do not allow for an economic interpretation of the cyclical behavior of the economy. Therefore the European-Commission, the IMF and the OECD usually adopt Production Function Methods which disentangle potential growth into labour, capital and total factor productivity components. The cyclical adjusted production factors are estimated via multivariate filtering. However, these methods also face the notorious end point problem. This often results in substantial revisions when recent and forecasted values of the production factors are replaced with actual observations. Due to the

strong reliance of the current output gap estimate on forecasts, the production function method also often generates output gaps which are at odds with other observable cyclical variables such as survey data or labor market variables. This leaves the impression that current output gap estimates are generated inside a black box. Unsurprisingly, the impact of output estimates and the underlying uncertainty on policy decisions has resulted in controversial discussions among economist and policymakers which also attracted media attention (Financial Times and Bundesbank (2014)).

Against this background, this paper contributes to the literature by introducing an economic intuitive method which reduces the uncertainty of output gap estimates at the end of the sample. We compare our results with those obtained from a standard structural models for 12 european economies.² We rely on the production function methodology (PF) approach adopted by the European Commission as a main benchmark. The reason is that this ‘state of the art’ multivariate structural model has been found to perform best in real time compared to the methods applied from the IMF, the OECD and also the HP Filter (Mc Morrow et al., 2015). Our results show some improvement in terms of mean squared errors when nowcasting the output gap for the current year. A further major advantage is that it is generated by observable cyclical variables and thus improves the economic plausibility of the output-gap. It doesn’t rely on any a-priori assumptions once a set of cyclical indicators is chosen. Our approach also allows the construction of confidence bounds for the obtained estimates.

The reminder of this paper is organized as follows. The following section introduces our intuitive output gap method and provides a brief summarization of alternative approaches. Section 3 describes our data set and the empirical findings. Section 5 concludes.

² The method we introduce has recently also been partly adopted by the European Commission. Their work explicitly cite the original work of Wolfram Wilde. See Hristov et al (2017) Page 11.

2. Theoretical background and Empirical Framework

2.1 Definitions and alternative methods

The literature has produced several methods for output gap estimates and is rich in controversy. This section briefly recaptures the underlying definitions and most common methods. In all cases, the output gap is defined as the difference between actual and potential output:

$$gap_t = y_t - y_t^p$$

The Hodrick and Prescott Filter

The Hodrick and Prescott filter determines the growth component g_t such that the following expression is minimized:

$$HP = \sum_{t=1}^T (y_t - y_t^p)^2 + \sum_{t=1}^T (g_{t+1} - g_t) - (g_t - g_{t-1})^2 \quad (1)$$

where $(g_{t+1} - g_t)$ denotes the percentage growth rate of the trend value of GDP between period t and $t+1$.

The underlying idea is to minimize a weighted sum of squares of cyclical components and of changes in the estimated trend growth rate. The parameter λ determines the relative weight given with $\lambda = 0$ corresponding to no fluctuations. The underlying idea of the procedure is to use smoothed and weighted averages of past and future values of fourth-differences of the original data. Hamilton (2017) adopts points out that the underlying assumptions are not realistic for random walk series which contain stochastic trends. He suggests to remove cyclical fluctuations based on simple forecasts with a smoothed estimate of Y obtained via a regression of Y on 4 lags shifted by two years:

Unobserved-Components Models and Stochastic Methods

Unobserved-Components frameworks also start by decomposing output into unobserved trend and cycle components.

$$y_t = y_t^{pE} + z_t \quad (2)$$

Where the permanent component y_t^{pE} reflects the permanent component and z_t denotes the transitory component. Permanent, or potential, output is assumed to follow a random walk with drift:

$$y_t^{pE} = \mu + y_{t-1}^{pE} + \epsilon_t \quad (3)$$

Unobserved state variables are for example estimated via Kalman filter. Kuttner (1994) and Gerlach and Smets (1997) use modified versions of these models to improve conventional estimates. Other authors apply Markov-Switching models, where the regime is determined by an unobservable stochastic process. While this accounts for the fact that the output gaps is an unobservable variable, such methods do not allow for an economic interpretation of the obtained findings.

Production Function Method

Approaches of the European Commission, the IMF and the OECD estimate an aggregate production function (Laxton and Tetlow 1992; OECD 1994; Fisher et al. 1997). The difference between the current level of GDP and the potential GDP generated from the production function is the output gap. Suppose for example that output can be characterised as a Cobb-Douglas production function in logarithmic form

$$y_t = tfp_t + \alpha l_t + (1 - \alpha)k_t \quad (4)$$

where tfp_t is total factor productivity, l denotes effective labour and k represents the capital stock. α is the labour share of income. If the inputs are equilibrium values, then the production

function provides an estimate of potential output and hence the output gap. First, using historical values of the labour share of income ($\alpha = 0.57$), total factor productivity is estimated as output less the weighted sum of effective labour and physical capital inputs:

$$tfp_t = y_t - \alpha l_t - (1 - \alpha)k_t \quad (5)$$

Effective labour is defined as full-time-equivalent employment multiplied by the ratio of the trend participation rate to the actual participation rate. A trend is then fitted to the residual, total factor productivity, in order to obtain an estimate of trend productivity to be used in calculating potential output. Potential drawback are the partly restrictive assumptions regarding the underlying production function and the fact that the obtained measures of potential output are inherently cyclical (Fernald, 2014).

2.2 Intuitive output gap approach

The output gap is a latent variable. Unlike other economic variables for instance GDP and inflation there is no official release of the “true output gap” in a certain year. Instead each different method described in section 2.1 produces a distinct estimate of the output gap for a certain year. Figure 1 shows the output gap estimates from the IMF, the OECD, the EU-Commission and the HP Filter with a Lambda of 100 for 12 countries. It is obvious that the different methods tend to produce very similar data for past periods but diverge at the end of the sample. When forecasted values for GDP or the production factors are replaced by observations or in-sample estimates, the data input for different filter techniques becomes more stable and the different methods tend to produce very similar results. Once the distance between the current estimate for the output gap and the end of the observed data increases, the endpoint problem of the different filters therefore diminishes rapidly. As illustrated in Figure 2, revisions to output gaps are rather small after a few years and these past observations can thus be treated

as “final data”. Previous research has already illustrated that modeling the output process alongside the revision process via autoregressive dynamics reduces some of the underlying estimation uncertainty (Garratt et al.,2005).

Figure 3 shows the difference between the most recent estimate according to the EU-COM methodology and the first estimate in the respective year. The original output gap estimates for the year 2007 produced in autumn 2007 showed just a small or even negative estimate for the output gap. Substituting the forecasted values with the true realizations changed the picture completely. The output gap of the year 2007 from today’s perspective is positive and much higher for all 12 countries than originally estimated. The forecast errors of GDP and the production factors are the major source of these substantial output gap revisions. Figure 4 shows the change in GDP forecast from period $t+1$ to t together with the change in output gap estimates. There is a strong significant relationship between GDP growth and output gap revision. This shows the strong influence of the forecasts on the current output gap estimate. But the use of forecasts is necessary for the proper working of the statistical filters.

The intuitive starting point of our approach is therefore to avoid the influence of possibly flawed forecasts on the estimate of the output gap in the current year t . As a basic assumption we treat the past data of output gaps as “final data” which can be used to assess how the output gap behaves in relation to certain observable cyclical variables in a broader context. This enables us for example to analyze how deviations of capacity utilization from its historical mean has been related to output gap fluctuations in the past. As a first step, this set of potential indicators has to be identified. Despite the importance of potential country-specific indicators, the literature usually agrees on a set of variables which correlates with the business cycle and output gap fluctuations. Capacity utilization is an obvious candidate which has been found to be useful in various studies (Alichi, 2017). Also the graphical inspection in Figure 5 shows a strong positive correlation between the capacity utilization and the output gap. The inverse relationship

between unemployment and production reflected in Okun's law suggests unemployment as another indicator. The graphical comparison in Figure 6 confirms this impression. We use short term unemployment rates (less than one year duration of unemployment) to disentangle the cyclical effect on unemployment. Another substantial part of the output gap literature focuses on the link between inflation and output gap with potential two-way causalities. See for example the long lasting Phillips Curve Debate (Atkeson, A and L E Ohanian, 2001; Orphanides and van Norden, 2004). As a price measure, we prefer wage inflation rather than consumer price inflation. During the estimation period consumer prices have been heavily influenced by changes in administrative prices and value added tax rates. Because of this and further reasons the relationship between consumer price inflation and the output gap weakens. We neglect survey data recently proposed by Alivi et al. (2016) given that this data is not available to the public and only available for a limited time span.

Besides capacity utilizations, our starting set of common indicators therefore includes lagged GDP growth, the short term unemployment rate and wage inflation. A set of common indicators is also useful since our aim is to provide comparable output gap estimates for most countries of the European Union. This obtained historical relationship between the different indicators and the estimated output gap from the European-Commission is then consulted to calculate an estimate for the current output gap. To do this, the difference between the current realization of the different indicators and its long term mean value is calculated and multiplied by the corresponding coefficient. The result is a fitted output gap series. As it is based on actual observations of cyclical variables, which would be the first variables to get an impression of the cyclical position of the economy, we call it “intuitive output gap”.

As a first step, output gaps estimates from the EU-Commission for each country are regressed on the set of potential cyclical indicators.

$$gap_{i,t} = c + \sum_k \beta_k X_{kit} + v_i + \mu_t + u_{it} \quad (7)$$

Where i denotes the country, k the corresponding indicator and t the time period. Estimation via fixed effects leads to a demeaning of all variables. This transformation allows to estimate how the output gap estimate (which is zero on average) behaves if the structural indicators deviate from their long-term trend. Based on these obtained estimates, in-sample forecasts are estimated according to formula 8.

$$\widehat{gap}_{i,t} = \hat{c} + \sum_k \hat{\beta}_k X_{kit} + v_i + \hat{v}_i + \hat{\mu}_t \quad (8)$$

It seems at odds to include GDP growth into the regression as GDP growth is directly used to compute the output gap, suggesting a potential endogeneity problems. However endogeneity occurs when the causality is at question. In the present cases, GDP growth causes the output gap by construction and not vice versa. An intuitive reason to include lagged GDP growth is that highly positive or negative output gaps usually do not arise within one year but rather tend to build up over a number of years.

3. Data

Data for the output gap estimates are based on the EU-Commission autumn forecasts from 2005 until 2014, comprising ten years of data. Our sample ends in 2014 since output gap estimates tend to be revised strongly up to three years from the latest observation. The countries we analyze include Belgium, Denmark, Finland, France, Italy, Netherlands, Austria, Portugal, Sweden, Spain, the UK and Germany. These are the largest countries from the EU-15. Restricting the sample to countries from the former EU-15 ensures data coverage also prior to 1990. Data for GDP growth and consumer price inflation are taken from the respective Autumn projection. Wage inflation is measured by nominal compensation per employee. Realized consumer price inflation is measured via the harmonized consumer price index published by Eurostat. Data on GDP growth is not seasonally adjusted. Data for the capacity utilization in

manufacturing is mainly obtained from Eurostat with OECD data adopted in cases where Eurostat does not provide data before 2005. The short term unemployment rate is calculated as the difference between the long term and the total unemployment rate. Data on long term unemployment is taken from Eurostat after 2005 with World Bank data adopted previously in cases where Eurostat data is not available.

Unlike GDP, data on capacity utilization and long term unemployment rates are usually not revised with later releases. Hence, the actual series can be treated as real time-observation. To reflect the real-time problem of policymakers, we ensure that the used data was available at the time the EU-Commission produced the respective autumn projection.

4. Empirical Findings

4.1 Structural factors

As outlined in Section 2.2, relevant structural indicators and their contribution to explaining output gap dynamics are identified by regressing the output gap estimate from the autumn projection 2017 on all candidate variables using fixed effects. Figure 5 to 7 provide graphs of the three proposed indicators and their relationship to the output gap. The main regression uses data from the last 20 years from 1987 until 2016. The findings for the different specifications are summarized in Table 1.

Model 1 provides the basic setup. All variables turn out to be considered significant and show the expected sign. The rather high adjusted R^2 of around 0.7 shows that the behavior of the output gap is adequately described by this simple setup. Model 2 omits lagged GDP growth in order to disentangle the influence of the other candidate variables which are not per definition related to the output gap. The adjusted R^2 essentially remains unchanged and confirms the importance of other indicators. Model 3 resembles Model 1 for a sample ending in 2014 in order to reduce the influence of possibly wrong output gap estimates at the end of the sample.

However, neither coefficient estimates nor the R^2 do display remarkable changes. The final Model 4 adopts consumer price inflation as price measure instead of wage inflation. Consumer price inflation turn out to be only weakly significant and the R^2 drops from 0.73 to 0.71. Therefore and according to the reasons described in the previous section, we use wage inflation as our price measure.

A comparison across the different models for the past history overall suggest that capacity utilization and unemployment are strongly related to the output gap while GDP growth and inflation are somehow less important.

4.2 Output Gap Estimates

The sample for the regression in Table 1 uses final data which was not known at the time the EU-Commission produced the various autumn projections. For the following nowcasting exercise, we therefore rely on data available in real time at the time of the projection. We include all regressors even if they appear to be insignificant or wrongly signed. According to the described procedure in Section 2, we produce nowcast estimates for the output gap in period t . By treating the last available data as final, we are able to compare the distinct estimates of the current output gap in year t . Thus output gap estimates are compared to the actual results from the autumn projection 2017. We calculate the Root Mean Squared Errors (RMSE) for each estimate from model 1 to 3 between 2005 and 2014 and compare those to the RMSE of the EU-Commission output gap estimate.

For the nowcast in period t , the three intuitive output gap measures produce lower RMSE than the commission estimate in absolute terms. Within the different models for the intuitive output gap the omission of GDP growth as regressor in Model 2 produces the lowest RMSE. However based on a Diebold Mariano test, the differences in RMSE are rather small and are not significantly superior to the estimates from the commission. Even though the reduction in the

RMSE is not significant the lower RMSE is still astonishing. The setup of the intuitive output gap aims to replicate the results of the Production Function Method. Essentially, we compare a linear approximation based on three or four variables with a nonlinear method relying on dozens of exogenous time series like population data and development of the capital stock. Thus, the EU-Commission estimate for the current output gap has a strong advantage in the “horse race” with the intuitive output gap.

It is also important to keep in mind that the later final values of the output gap are produced with the same method like the EU-commission output gap estimate in the respective year.³ Consequently, the intuitive output gap is just an approximation of the EU-Commission methodology. Thus, any in-sample error of the approximation is added to the RMSE of the intuitive output gap. The source of the reduction in RMSE relative to the results of the EU-Commission is visible in Figure 3. The intuitive output gap indicated in most cases that the output gap before the financial crisis was significantly positive. Whereas the filtering approach of the EU-Commission signaled just a small positive or even negative output gap. The graphical inspection in Figure 3 reveals that the differences are largest at upper turning points of the business cycle. This is the situation where the use of forecasts, which is necessary to reduce the endpoint problem, produces the largest errors.

Another way to judge the ability of the intuitive output gap in comparison to the EU-Commission approach is to signal a potential inadequate estimate of the current output gap. This is the case if the output gap estimates in t falls outside the range defined by the intuitive approach plus the RMSE from the respective regression. Table 3 shows that the type one error for t ranges from 17% to 26 %: This illustrates that the output gap is indeed later revised in the

³ There have been multiple changes in the EU-Methodology to construct the output gap. However these changes tend to produce rather small revisions to the output gaps. Despite these methodological changes, the results from the intuitive and the EU-Commission output gap can still be compared to each other as the disadvantage of not accounting for future changes in methodology is common to both approaches.

suggested direction in 70 % to 85 % of all cases where the signal occurs. The rather high type 2 error which ranges from 54% to 69% implies that the differences between the intuitive output gap and the commissions estimate are often too small to generate a signal.

5. Conclusion

This paper has provided an intuitive procedure to produce output gap estimates which are in line with observable cyclical variables. It further avoids the use of forecasts and by this eludes the endpoint problem of statistical filters. Our estimates for 12 economies show that we are able to outperform the production function methodology (PF) adopted by the European Commission when nowcasting the output gap. It especially performs better than the PF approach at upper turning points of the business cycle.

A major advantage is that our procedure is intuitive and only requires a small set of easily in real time observable indicators which are then evaluated via a first stage regression. The embedded evaluation also provides an economic guideline for policymakers, supporting derivations and discussion of policy recommendations.

Our analysis also provides a starting point for several possible extensions, such as estimating country-specific output gap dynamics in real time.

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Results:

Table 1: Identification of structural variables

| Model | 1 | 2 | 3 | 4 |
|------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| | Coef./t-stat | | | |
| Capacity utilization | 0.295*** (10.72) | 0.356*** (14.71) | 0.298*** (10.59) | 0.290*** (10.48) |
| Short term unemployment rate | -0.784*** (-12.21) | -0.865*** (-13.72) | -0.798*** (-12.01) | -0.806*** (-12.60) |
| Change in consumer price inflation | | | | 0.072* (1.75) |
| Change in wage inflation | 0.081*** (2.90) | 0.117*** (4.32) | 0.067** (2.28) | |
| Growth in GDP (lagged) | 0.180*** (4.32) | | 0.174*** (4.09) | 0.198*** (4.81) |
| adjusted R ² | 72% | 71% | 73% | 71% |
| R ² | 74% | 72% | 74% | 73% |
| N | 334 | 334 | 310 | 334 |

* p<0.10, ** p<0.05, *** p<0.01

Note: This Table shows the estimates from regression of the respective output gap from autumn projection 2017 produced by EU-Commission on variables to explain the observed output gap.

Table 2: RMSE of EU-Commissions and model based output gaps

| EU-Commission | Model 1 | Model 2 | Model 3 |
|---------------|----------------|----------------|----------------|
| 1,72 | 1,64 (0,44) | 1,56 (0,20) | 1,70 (0,87) |

Note: This Table shows the RMSE of the EU-Commission and the intuitive output gap estimates for nowcasts in Period t.

Table 3: Type I and Type II error for intuitive output gap estimates

| Model 1 | | Model 2 | | Model 3 | |
|---------|---------|---------|---------|---------|---------|
| type I | type II | type I | type II | type I | type II |
| 25,5% | 69,2% | 17,3% | 54,1% | 23,5% | 62,5% |

Note: This Table shows the type I and type II error for the intuitive output gap. A significant revision is signaled when the the estimate from the EU-Commission falls outside the range from the intuitive output gap plus RMSE from the regression. A significant revision occurs when the difference between the EU-Commission estimate in real time and the estimate from autumn projection 2017 is greater than the RMSE from Regression in formula xxx.

Figures

Figure 1: Country specific output gap estimates with different methods

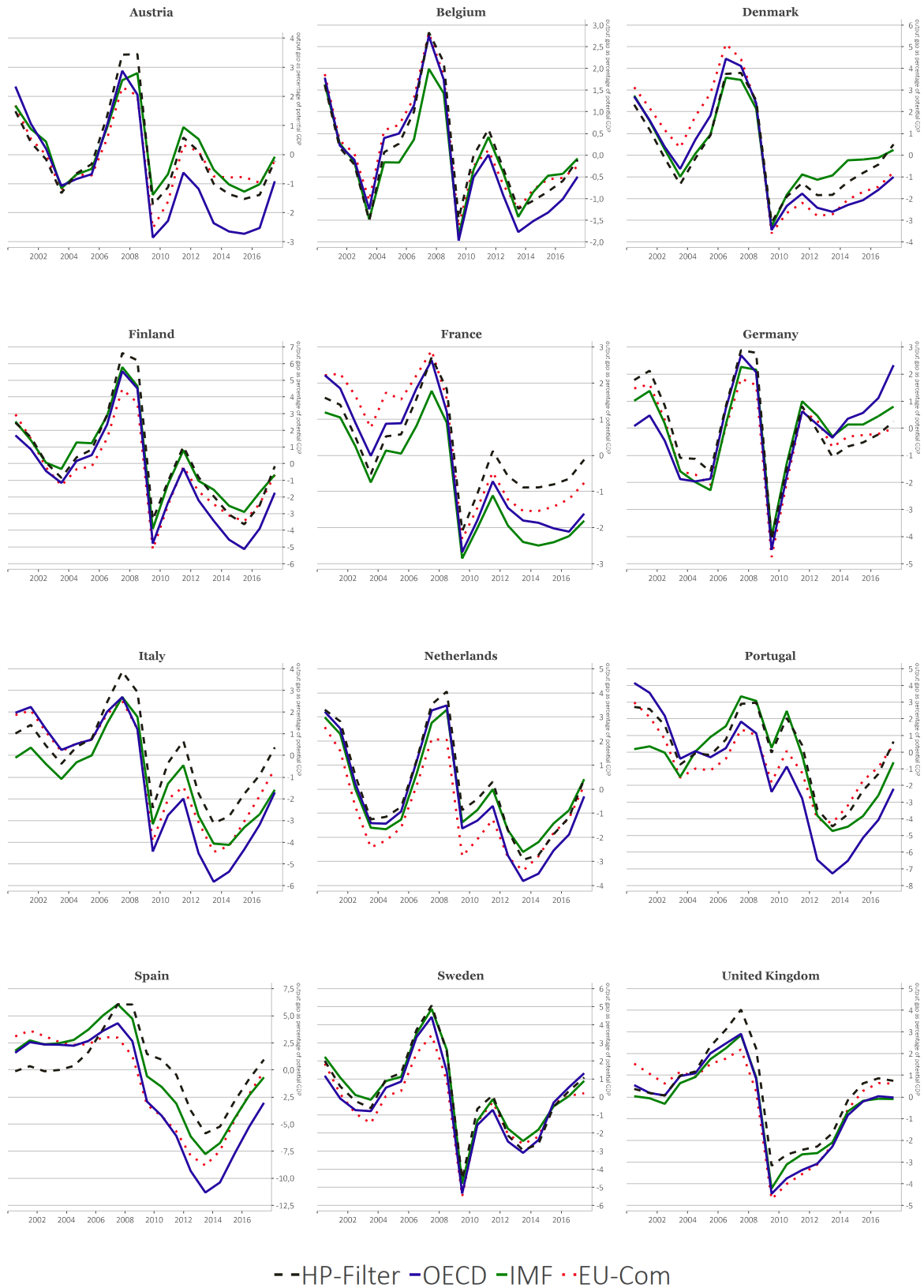
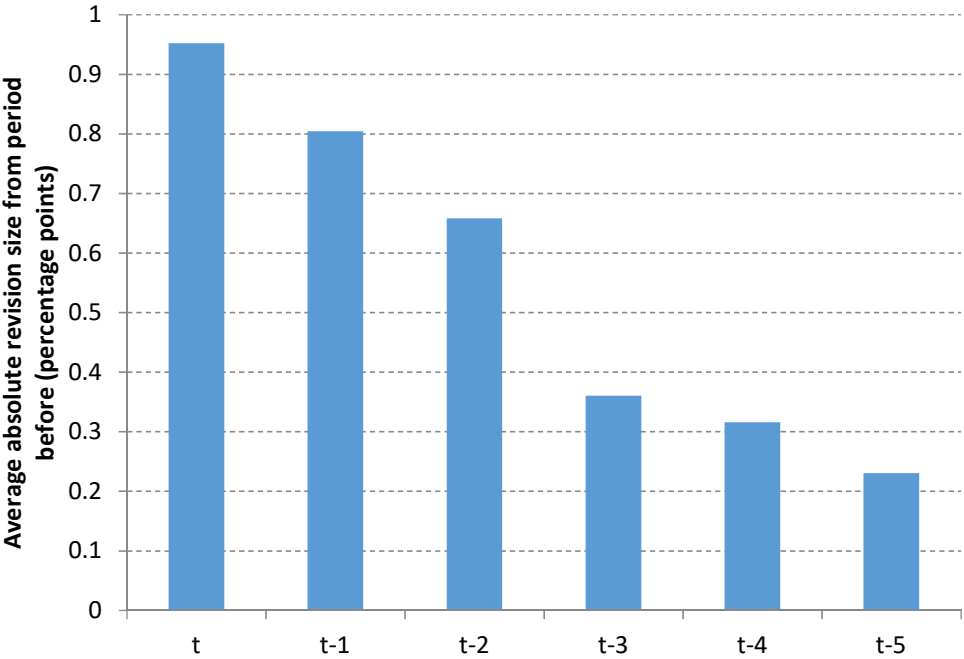
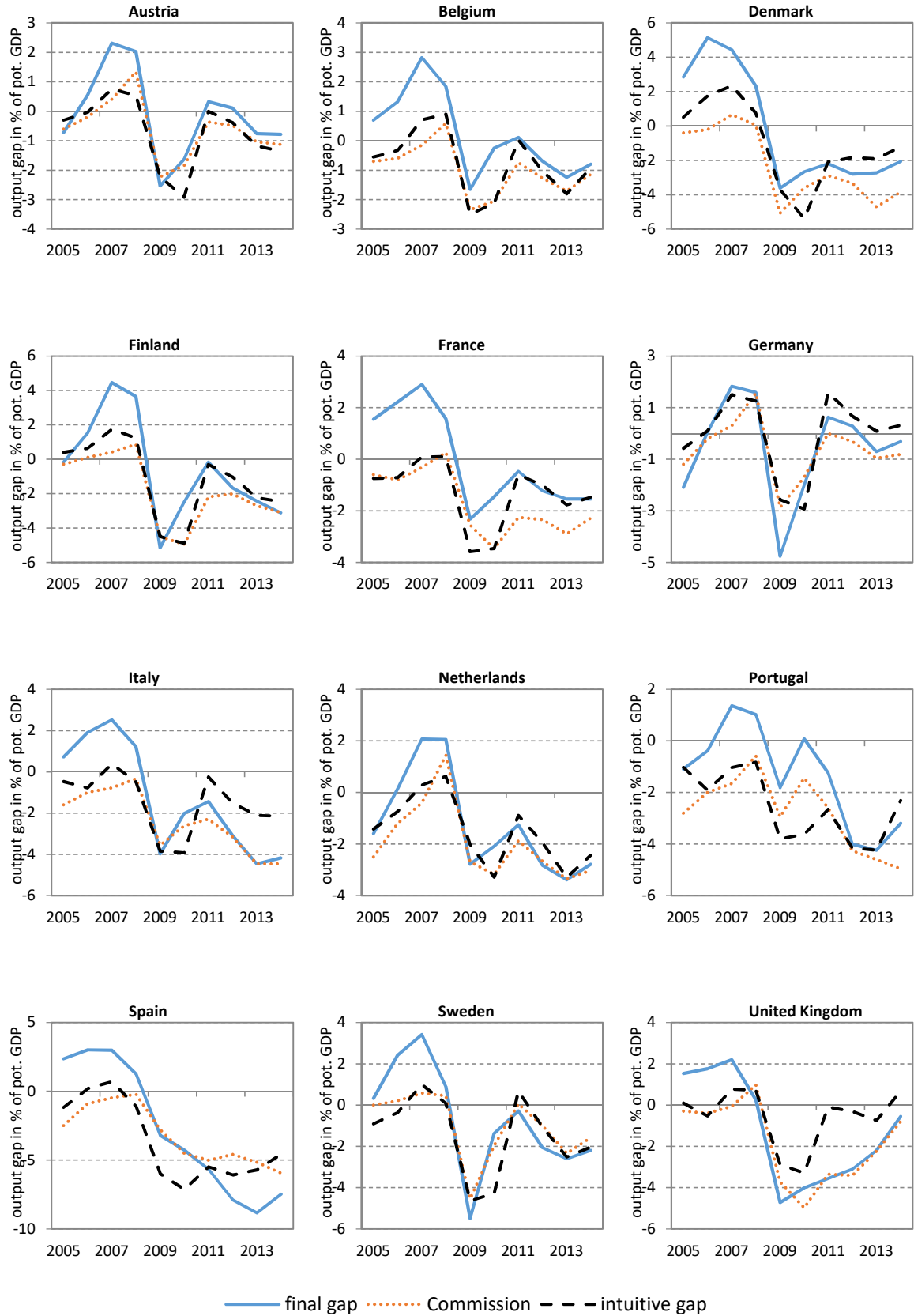


Figure 2: Average revision of output gap estimates



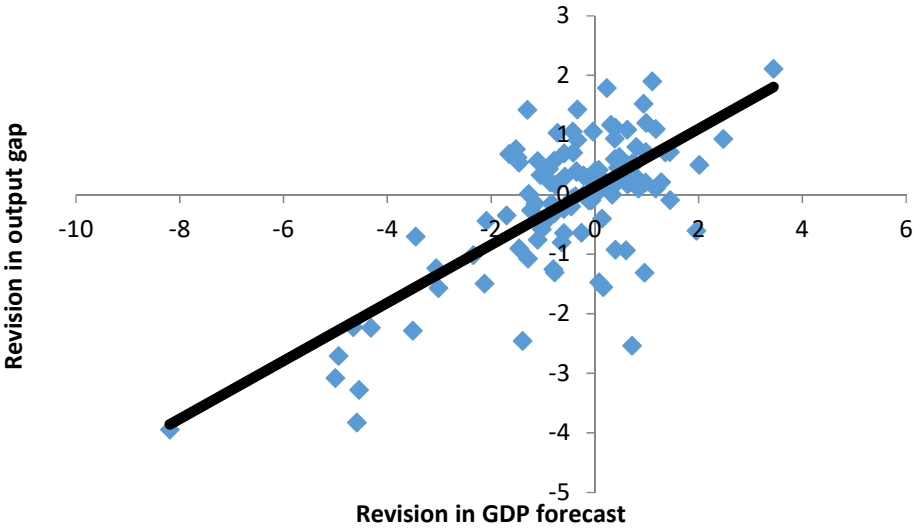
This figure shows the average revision of the output gap estimate for a specific year with respect to the value from the previous estimate. Thus the average change of the output gap estimate from $t+1$ to t is on average 0,95 percentage points for all 12 countries.

Figure 3: First output gap estimate in period t and final data



This figure shows the final estimate of the output gap from the autumn projection 2017 together with the first estimate of the Commission in period t and the estimate from the intuitive output gap in period t .

Figure 4: Revision in GDP forecast and output gap estimate



This figure shows the average revision of GDP growth by the EU-Commission from period $t+1$ to t together with the revision in output gap estimate from $t+1$ to t for all 12 countries between 2005 and 2014

Figure 5: Output gap estimates of EU-Com and capacity utilization in manufacturing

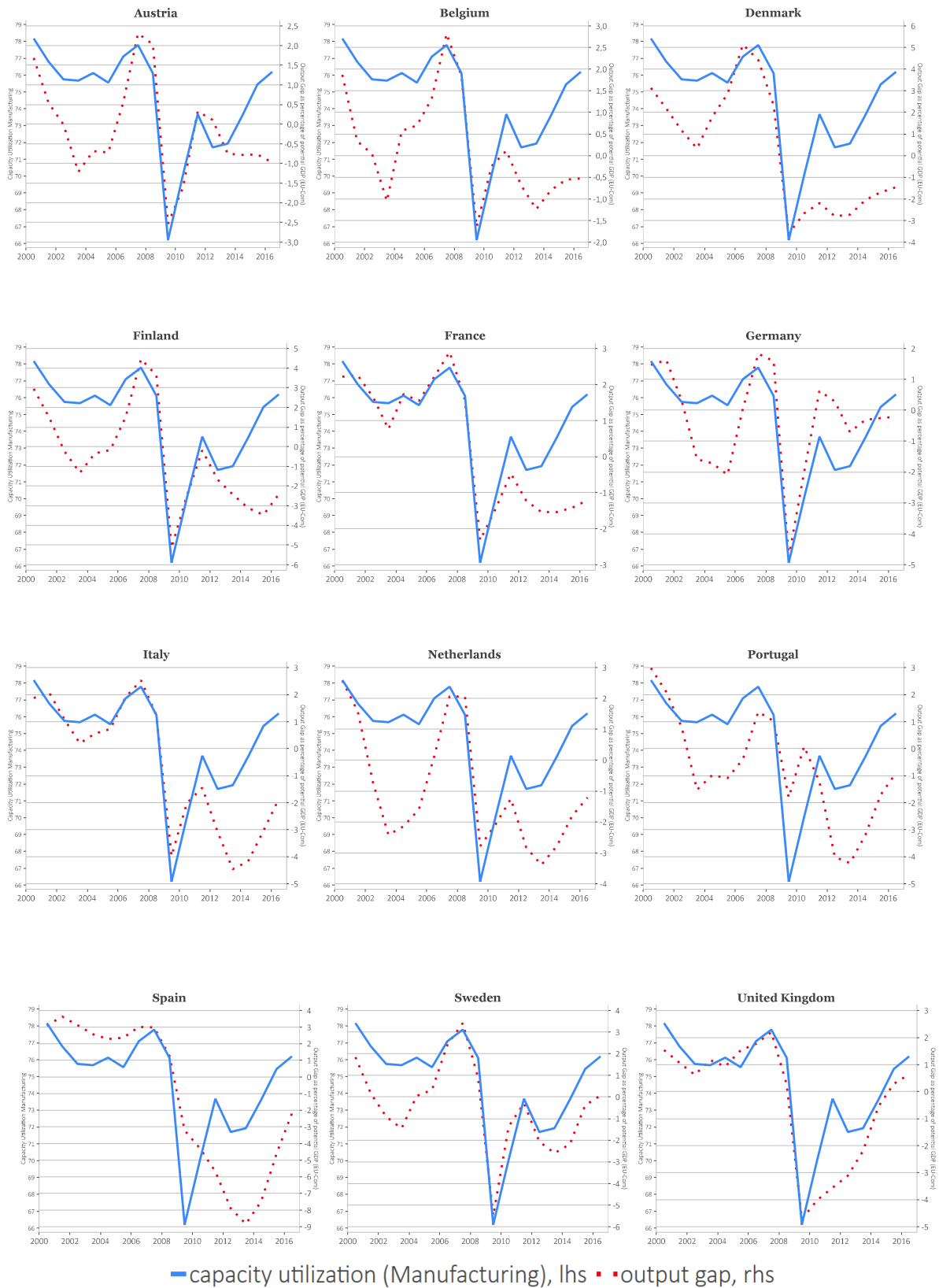
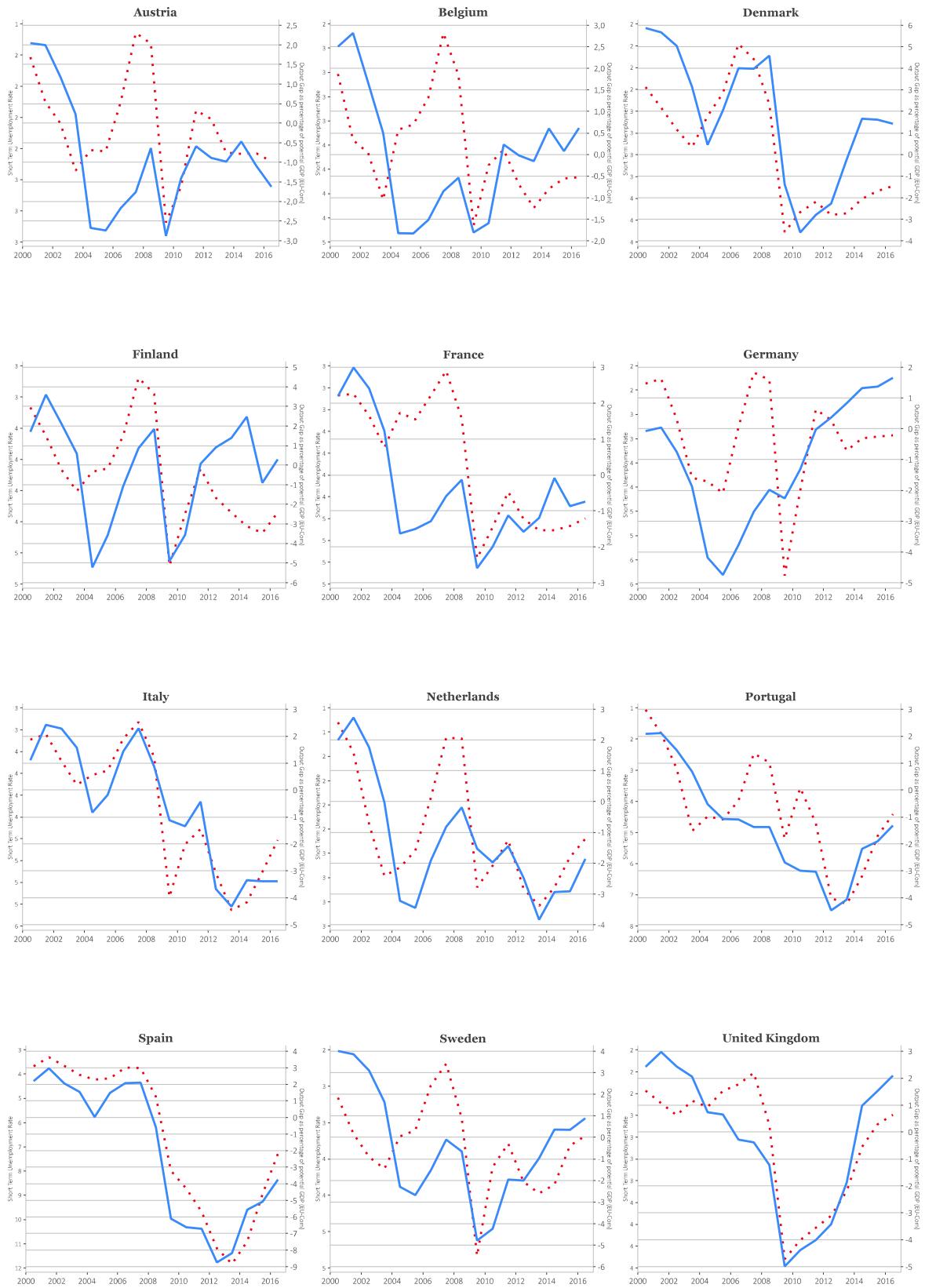
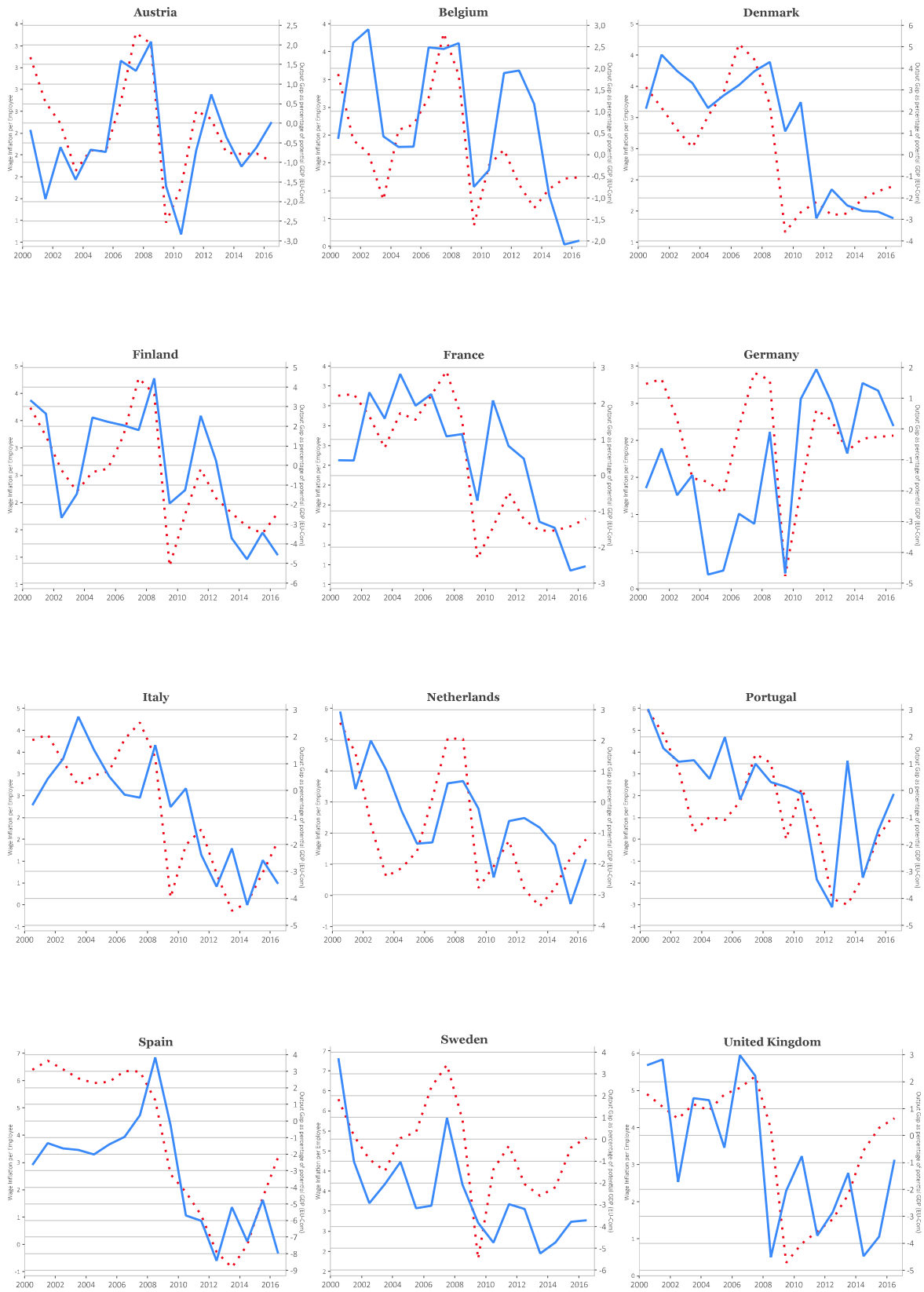


Figure 6: Output gap estimates and short term unemployment rate



— short term unemployment rate, lhs ■ output gap, rhs

Figure 7: Output gap estimates and wage inflation



— wage inflation per employee, lhs ■ output gap, rhs