BRUEGEL WORKING PAPER 2015/11

FILLING THE GAP: OPEN ECONOMY CONSIDERATIONS FOR MORE RELIABLE POTENTIAL OUTPUT ESTIMATES

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Highlights

- This paper argues that the Phillips curve relationship is not sufficient to trace back the output gap, because the effect of excess demand is not symmetric across tradeable and non-tradeable sectors. In the non-tradeable sector, excess demand creates excess employment and inflation via the Phillips curve, while in the tradeable sector much of the excess demand is absorbed by the trade balance.
- We set up an unobserved-components model including both a Phillips curve and a current account equation to estimate 'sustainable output' for 45 countries. Our estimates for many countries differ substantially from the potential output estimates of the European Commission, IMF and OECD.
- We assemble a comprehensive real-time dataset to estimate our model on data which was available in each year from 2004-15. Our model was able to identify correctly the sign of pre-crisis output gaps using real time data for countries such as the United States, Spain and Ireland, in contrast to the estimates of the three institutions, which estimated negative output gaps real-time, while their current estimates for the pre-crisis period suggest positive gaps.
- In the past five years the annual output gap estimate revisions of our model, the European Commission, IMF, OECD and the Hodrick-Prescott filter were broadly similar in the range of 0.5-1.0 percent of GDP for advanced countries. Such large revisions are worrisome, because the European fiscal framework can translate the imprecision in output gap estimates into poorly grounded fiscal policymaking in the EU.

JEL classification: C32; E32; F41
Keywords: equilibrium current account; international trade; Kalman-filter; open economy; Phillips-curve; potential output; real-time data; sustainable output; state-space models.

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OCTOBER 2015

Acknowledgements

We are grateful to conference participants at the Project Link Fall Meetings 2000 and 2013, European Economic Association Congress 2001, European Meeting of the Econometric Society 2013, The Society for Economic Measurement conference 2014, CESifo-Delphi conference on 'Current Account Adjustments' 2015, EcoMod2015 and EPC-ECFIN-JRC workshop 'Assessment of the real time reliability of different output gap calculation methods', as well as seminar participants at Cardiff Business School, University of Pécs, Institute of Economics of the Hungarian Academy of Sciences and Bruegel, and at an internal discussion at the European Central Bank, for helpful comments and suggestions. Pia Hüttl, Alvaro Leandro and Allison Mandra provided excellent research assistance. This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 320278 (RAStaNEWS).

1 Introduction

Potential output in an important unobserved variable for macroeconomic modelling, policy analysis and policymaking. Theoretical and empirical macroeconomic models assign a major role to the output gap (the difference between actual and potential output) in modelling monetary policy or fiscal stabilisation. The reformed fiscal governance of the European Union reinforces the role of the structural budget balance, which depends on an estimate of the output gap[1]. Breaching the EU's fiscal rules could lead to financial sanctions. Consequently, the way potential output is estimated has implications for fiscal policy and financial sanctions in the EU.

The origin of the concept of potential output goes back to the traditional theory of business cycles that decomposed output into a deterministic trend and a stationary cycle component. With the development of theory and econometrics, the decomposition was refined and permanent and transitory stochastic components were distinguished. The permanent component has been called potential output.

The decomposition cannot be accomplished without some assumptions about the structure of the economy and/or the stochastic properties of the unobserved time series. These assumptions may differ depending on the purpose of the decomposition, implying that any decomposition is model-dependent. Models of potential output range across a wide spectrum. There are simple univariate models that use some assumed properties of the data-generating process[2]. Several structural models include information on inflation and unemployment, such as a Phillips curve and/or the non-accelerating inflation/wage rate of unemployment (NAIRU/NAWRU)[3]. The production function approach analyses factor inputs to production, like the OECD methodology (see Giorno *et al,* 1995, and Johansson *et al*, 2013).

The current method used in the European Union's fiscal framework by the European Commission (EC) combines the production function with the NAWRU (Havik *et al,* 2014). Unfortunately, this methodology has major conceptual weaknesses related to the incorporation of labour, capital and total factor productivity, and disregards the open economy implications of output gaps[4]. Like the estimates of the IMF and OECD and several other models (Orphanides and van Norden, 2002), it is also subject to major revisions.

In this paper we contribute to the structural approach by proposing and estimating a novel model that is conceptually more suitable than existing models in the literature. As it turns out, our sustainable output estimates are much more reliable real-time than the estimates of the European Commission, IMF and OECD.

The motivation for our model is straightforward and supported by economic theory. We argue that the Phillips curve relationship is not sufficient to trace back the output gap, because the effect of excess demand is not symmetric across the tradeable and non-tradeable sectors. In the non-tradeable sector excess demand creates excess employment and inflation via the Phillips curve, while in the tradeable sector much of the excess demand is absorbed by the trade balance. The cyclical position of the rest of the world has implications for domestic inflation and trade balances. These effects work in any economy in which foreign trade is not completely restricted, be it large or small. Our model utilises open economy considerations: as well as a Phillips curve relationship augmented with global variables, we add a parallel behavioural relationship for the deviation of the actual current account from its estimated

[1] See the so-called 'Six-Pack' (five Regulations and one Directive adopted by all EU countries in 2011) and the 'Fiscal Compact' ('Treaty on Stability, Coordination and Governance in the Economic and Monetary Union', which was signed by 25 EU members in 2012). Kiss and Vadas (2005) compare methodologies for the cyclical adjustment of the budget.

[2] See Canova (1998) for a comparison of several such methods.

[3] See Laxton and Tetlow (1992), Kuttner (1994), Gerlach and Smets (1999), Doménech and Gómez (2006), Basistha and Nelson (2007), Gali (2011), Blagrave *et al* (2015).

[4] See Darvas (2013).

equilibrium value. We let the data determine the relative importance of the two relationships. Given that the term 'potential output' is occupied by the group of standard models, we try to discriminate our concept by calling our estimates 'sustainable output'.

The idea we exploit is well supported by economic theory. For example, the simulation results from the European Central Bank's EAGLE (Euro Area and Global Economy model) model (see Gomes, Jacquinot and Pisani, 2012), which is a micro-founded 4-region macroeconomic model of the euro area and the world economy, are fully in line with our assumptions. According to this model, a foreign consumption shock (temporarily) boosts domestic inflation and improves the domestic trade balance. A domestic public expenditure shock deteriorates the domestic trade balance and increases domestic inflation, while it improves the trade balance of the rest of the euro area and increases inflation there too. The same results appear in many other models.

Therefore it is rather surprising that international organisations calculating output gaps regularly (European Commission, IMF, OECD) do not utilise open economy considerations. We hope that our efforts can help these institutions realise the importance of open economy considerations for potential output estimation.

We estimate our model for 45 countries using an unobserved component (UC) model. In order to assess the revisions of our estimates, we assemble a comprehensive real-time dataset to estimate our model predictions on the basis of data that was available in each year from 2004-15. We use annual data, because historical vintages of annual data are readily available and it allows the comparison of the revisions in real-time estimates of our model with that of the estimates of the European Commission, IMF, OECD and the filter of Hodrick and Prescott (1997)[5].

There is some research in the literature to which our work is related. In fact, we put forward the main idea behind our model in Darvas and Simon (2000) and estimated sustainable output for Hungary, Mexico and Poland in a model that included export and import equations. However, in that early version of our model we did not address the notion of external equilibrium to which potential or sustainable output should correspond. To correct this problem, we now build on the literature estimating medium-term equilibrium current account balances and we consider the deviation of the actual current account balance from this estimated (time-varying) equilibrium as an indicator[6].

Independently from our work, other researchers developed models that are based on related considerations. The starting point of Dobrescu (2006), Alberola, Estrada and Santabárbara (2014) and Borio, Disyatat and Juselius (2013, 2014) is the same as ours: a Phillips-curve is not sufficient for identifying potential or sustainable output. Yet their conceptual frameworks and methodologies differ from our work.

Dobrescu (2006) defines potential output as the output level that is associated with constant inflation and constant net export-to-GDP ratio. He uses regressions to calculate potential output for Romania. A problem with this definition is that the equilibrium level of the trade balance can change over time and our estimations for the equilibrium current account balance (which is closely related to the trade balance) indeed confirmed sizeable time-variability for most countries. Also, his regression methodology seems to have major weaknesses.

Alberola, Estrada and Santabárbara (2014) define sustainable growth as the output growth that does not widen macroeconomic imbalances and present estimates for Spain. They use a production function approach, for which they estimate the sustainable level labour input, capital input and total factor productivity by relating their cyclical components to indicators of domestic and external imbalances. Borio, Disyatat and Juselius (2013, 2014) estimate a 'finance-neutral measure of sustainable output'

[5] Our model could be estimated on quarterly data too.
[6] See Darvas (2015) for an overview of the literature estimating equilibrium current account balances.

for the United States, United Kingdom and Spain. They incorporate financial variables such as credit growth, real interest rates, housing prices, but also the inflation rate, the unemployment rate and capacity utilisation, into a multivariate filter estimated with Bayesian techniques. Neither Alberola, Estrada and Santabárbara (2014), nor Borio, Disyatat and Juselius (2013, 2014) define what equilibrium is, while we define it for the current account balance. Therefore, our model has a better theoretical foundation. We do not use a production function, but adopt an unobserved components model in which the two behavioural equations are a Phillips curve and a current account equation. Thereby, we consider only inflation and the current account balance as indicators of imbalances, while Alberola, Estrada and Santabárbara (2014) used seven indicators[7] and Borio, Disyatat and Juselius (2014) used six indicators.

Blagrave *et al* (2015) and Box 3.1 in IMF (2015) express several criticisms of the finance-neutral concept of sustainable output. A key issue is whether financial imbalances can be identified in real-time. For example, while fast credit expansion used to precede financial crisis, not all fast credit expansion leads to financial crisis, as it might be accompanied by sound economic fundamentals. In fact, Borio, Disyatat and Juselius (2013, 2014) already recognised that those financial variables are useful in identifying finance-neutral sustainable output which have stable means.

The problem of real-time identification of imbalances is less relevant for our model of sustainable output. Theory predicts that the current account balance deviates from its equilibrium when demand at home deviates from supply, *ceteris paribus*. While it can always be discussed whether a large current account deficit or surplus is justified, several empirical models were developed to estimate equilibrium current account balances in a panel-econometric framework, which we found robust. Our current account gap estimates based on real-time pre-crisis data are quite similar to estimates based on the currently available data, suggesting that excess deficits and surpluses could have been identified in real time. While our current account model largely follows Lane and Milesi-Ferretti (2012), an article published after the global financial and economic crisis, many similar models were used earlier too, such as Chinn and Prasad (2003).

Another issue is making numerous practical assumptions for estimations, which may affect the findings. Borio, Disyatat and Juselius (2014) argue that conventional approaches, and in particular models including a Phillips-curve, are in fact opaque and highly vulnerable to specification errors, a critique that applies to the model of Blagrave *et al* (2015). In turn, Blagrave *et al* (2015) and Box 3.1 in IMF (2015) echo the same criticism with regard the finance-neutral measures of sustainable output.

We regard this problem as less serious for our model than for other structural models. Our choice for the observation and state equations of our model is simple and transparent. Perhaps the biggest unknown for our model is the equilibrium value of the current account balance. Yet we experimented with different versions of the equilibrium current account model and found minor sensitivity of our sustainable output results to the alterations in the current account model. We use the Kalman-filter and maximum likelihood estimation and therefore no priors should be defined as in a Bayesian framework, as for example in Blagrave *et al* (2015) and Borio, Disyatat and Juselius (2014).

Yet our model is not without practical difficulties. For example, we cannot estimate sensible Phillips curves for countries undergoing hyperinflation periods, including several Latin-American countries. Estimating a Phillips curve is also challenging for countries with moderate inflation rates and for catching-up economies undergoing a price-convergence process as described by the Balassa-Samuelson hypothesis. Yet this difficulty is not specific to our model, but applies to all existing models of the literature using a Phillips curve, which may explain why potential output estimates for emerging

[7] Alberola, Estrada and Santabárbara (2014) considered fifteen possible indicators of domestic and external imbalances (see Table 1 of other paper), but they actually used seven of them (see Table 5 of their paper): the current account balance, public balance, private balance, private savings, private investment, public investment and residential investment.

economies are scarce. Another issue is the length of the sample period. For advanced countries that have about four decades of data, the actual start of the sample period does not seem to matter. In contrast, for some emerging countries with only about two decades of available data, the actual start of the sample period alters the results in some cases. A further issue is the possibility of multiple optimums for the maximum likelihood estimation. While for most countries the starting values of the parameters do not seem to influence the estimation results, for a few countries two different optimums were reached, depending on the starting values. Yet keeping all these caveats in mind, we believe that our model is not just theoretically intuitive and has much better real-time reliability than other models of the literature, but its practical implementation is also straightforward.

The rest of the paper is organised as follows. Section 2 presents our model for calculating a newly defined measure of sustainable output as a latent variable. The real-time dataset we assemble is described in Section 3. Section 4 presents our empirical results and compares our estimates based on real-time data with the actual real-time estimates of the European Commission, IMF and OECD. Section 5 concludes.

2 A model of sustainable output

Our new model for measuring the equilibrium level of output is based on the following main observations, which are well supported by economic theories[8]:

- The effects of excess domestic demand are not symmetric across the tradeable and non-tradeable sectors, because foreign supply can fill the gap between demand and supply in the tradeable sector, but not in the non-tradeable sector;
- Excess domestic demand may manifest itself in the deterioration of the trade balance, parallel to, or even without, the increase of inflation of tradeables;
- Excess domestic demand may increase inflation of non-tradeables;
- Excess demand of the rest of the world (relative to the supply of the rest of the world) has implications for domestic inflation and trade balance.

As a consequence, beside the standard Phillips curve relationship, which describes the behaviour of the non-traded sector, there is a parallel relationship in the traded goods sector. In this second relationship, excess demand at home will create an 'excess trade deficit', ie a deficit in excess of its intertemporal optimum, while excess world demand works the opposite way. Similarly, a shortage of domestic demand would lead to an 'excess trade surplus,' *ceteris paribus*.

In principle we should distinguish between the tradeable and non-tradeable sectors and use the non-tradeable output in the Phillips curve and the tradeable output in the trade model. But specifying and estimating a two-sector model is beyond the ambition of this paper. It would raise too many conceptual and statistical difficulties: how to define the tradeable sector and how to define its specific cyclical features that distinguish it from the non-tradeable sector? Since the production of non-tradeable goods and services uses tradeable inputs, while tradeable goods are sold via a non-tradeable distribution sector, a clear decomposition between the two sectors is not possible. Instead, we substitute total output for sectoral outputs both in the Phillips curve and in the trade model. This assumption neglects important details, as investment and consumption shocks have probably different impacts on tradeables and non-tradeables. Similarly, external demand is biased towards tradeables. But this assumption is in line with general practice, where the Phillips curve equation is estimated for total (domestic) supply instead of non-traded supply.

[8] See eg the Gomes, Jacquinot and Pisani (2012).

Since we consider the trade balance implications of domestic and rest of the world output gaps, we call our estimates 'sustainable output', in order to discriminate our concept from the concepts used in the literature to estimate potential output.

2.1 The Phillips curve

The idea behind the notion of output potential is sustainability. Output can be boosted by demand, but this surge will be temporary because of inflation – as captured by a formulation of the Phillips curve. The hybrid New Keynesian Phillips Curve (NKPC), a widely-used model (Gali and Gertler, 1999), describes the dynamics of the inflation rate as a function of the expected inflation rate, the lagged inflation rate, and the output gap:

$$(1) \qquad \pi_t = \theta_1 E_t(\pi_{t+1}) + \theta_2 \pi_{t-1} + \theta_3 (y_t - \bar{y}_t) + \varepsilon_t^{(\pi^*)} ,$$

where π_t is the inflation rate, y_t is the log actual output, $\bar{y}_t$ is the log of potential output, $\theta_1, \theta_2, \theta_3$ are parameters and $\varepsilon_t^{(\pi^*)}$ is the error term.

Solving for $E_t(\pi_{t+1})$, as in Nason and Smith (2008) and Harvey (2011), inflation depends on past inflation and the discounted sequence of expected future output gaps. By assuming that the output gap is a stationary process and an autoregressive model represents its expectation formation (possibly, with some other stationary determinants that are also supposed to follow an autoregression), the reduced form representation of the model can be written as:

$$(2) \qquad \pi_t = \beta_\pi \pi_{t-1} + \beta_{gap}(y_t - \bar{y}_t) + \beta_x x_t + \varepsilon_t^{(\pi)} ,$$

where $\beta_\pi, \beta_{gap}, \beta_x$ are the reduced form parameters, with the latest one denoting the reduced form parameter(s) of x_t a vector of other variables determining the output gap, and $\varepsilon_t^{(\pi)}$ is the error term with variance σ_π^2.

We assume that the output gap follows a simple first order autoregressive process and therefore we do not consider x_t. However, Borio and Filardo (2007) argued that global factors, including the global output gap, are important determinants of domestic inflationary developments. Furthermore, simulations results of Gomes, Jacquinot and Pisani (2012) show that a foreign consumption shock, which increases the foreign output gap, boosts domestic inflation too. To test the relevance of the global influences on domestic inflation empirically, we incorporate three additional variables to the Phillips curve we estimate: global inflation, global output gap and the deviation of the real exchange rate from its equilibrium. Thereby, the Phillips curve we estimate is the following:

$$(3) \qquad \pi_t = \beta_0 + \beta_\pi \pi_{t-1} + \beta_{gap}(y_t - \bar{y}_t) + \beta_{w\pi} \pi_t^{(w)} + \beta_{wgap}\left(y_t^{(w)} - \bar{y}_t^{(w)}\right) + \beta_r(r_t - \bar{r}_t) + \varepsilon_t^{(\pi)} ,$$

where $\pi_t^{(w)}$ is world inflation rate, $y_t^{(w)}$ is the logarithm of the actual output of the rest of the world, $\bar{y}_t^{(w)}$ is the logarithm of the potential output of the rest of the world, r_t is the logarithm of the real exchange rate, $\bar{r}_t$ is the logarithm of the equilibrium real exchange rate, and β with different subscripts are the reduced form parameters.

Similarly to Borio and Filardo (2007), we tried a specification in which the dependent variable is the deviation of the inflation rate from its Hodrick-Prescott filtered trend (and consequently, its lag on the right hand side is also measured as the deviation from the Hodrick-Prescott filtered trend and global inflation is included as the deviation from its Hodrick-Prescott filtered trend). However, results were not much affected: for those countries for which the output gap was significant in (3), it remained significant in the Hodrick-Prescott filtered version of the equation too, but for countries for which the output gap were not significant in (3), it was typically not significant in the Hodrick-Prescott filtered version either. Moreover, Hodrick-Prescott gives really bizarre inflation gap estimates for countries undergoing hyperinflation periods. We also tried to use the difference between home and world inflation as the dependent variable in the Phillips curve, but for some countries the results did not differ much from the standard formulation in (3), while for other countries the results became rather strange. Therefore, we decided to stay with the standard specification of (3), in which the inflation rate itself is included[9].

2.2 Incorporating foreign trade

The Phillips curve describes just one implication of a deviation of actual output from potential. Our main conceptual innovation in relation to the estimation of potential or sustainable output is that we add the other main consequence of excess demand to the model. The answer to whether an economy is able to sustain a high level of domestic demand (and output) depends on how the country is able to cope with international competition. We can say that sustainability, or potential output, are alternative formulations of competitiveness. If output follows an increase in demand without improving its competitiveness, its supply will be crowded out by import- and export-competitors and its balance of trade goes toward non-sustainability. This may necessitate a deep contraction later, as the recent examples of the southern members of the euro area and the Baltic countries show.

A strong competitive potential shows up in a better trade balance, which is true both for bigger countries, like Germany, and smaller countries, like Slovakia[10]. While our intuition suggests implications for the trade balance, we formulate our model in terms of the current account balance. The reason for this choice is twofold. First, both theoretical and empirical research focuses much more on the current account balance. Second, the trade balance typically accounts for a large share of the current account balance and variations in the trade balance used to be the dominant factor behind the variations in the current account balance.

Various theoretical models built on the conceptual framework of the intertemporal approach to the current account. (Obstfeld and Rogoff, 1995) suggest that current account has an equilibrium value. But it is a difficult task in international economics to estimate this equilibrium. Theoretical models do not provide numerical benchmarks, which lead some researchers to use empirical methods for estimating the equilibrium current account balance. We follow this route and estimate a model for the medium-term determinants of current account balances in a panel-econometric framework. We adopt the model of Lane and Milesi-Ferretti (2012), with some minor changes, as described in Darvas (2015).

Having an estimate for the equilibrium current account balance, we postulate an equation describing the behaviour of the actual balance relative to its estimated equilibrium:

$$(4) \qquad \tau_t - \bar{\tau}_t = \gamma_0 + \gamma_{gap}(y_t - \bar{y}_t) + \gamma_{wgap}\left(y_t^{(w)} - \bar{y}_t^{(w)}\right) + \gamma_{r0}(r_t - \bar{r}_t) + \gamma_{r1}(r_{t-1} - \bar{r}_{t-1}) + \varepsilon_t^{(\tau)},$$

[9] Instead of the all-items inflation rate, we could use the core inflation rate (the inflation rate excluding items with volatile price developments such as food and energy), which is left for future research.

[10] Trade models usually assume that most goods in trade are differentiated and therefore exporting more is possible only by cutting prices. Adding the assumption of decreasing returns this could be augmented by an expansion with increasing costs. This was the basis of the macro-econometric models originating from the idea of Armington (1969). However, seminal papers of Dixit and Stiglitz (1977), Lancaster (1979), and Salop (1979) opened up the literature on economies of scope. Interpreting the definition of varieties as goods in different geographical regions and assuming the number of these regions to be infinite, the market behaves as a classical market in which the sales volume of the individual supplier depends only on its costs. If we add economies of scale to the picture the expanding supplier does not even have to undertake higher costs. Simon (1995) estimated an international trade-model along this line.

where τ_t is the actual current account balance (% GDP), $\bar{\tau}_t$ is the equilibrium current account balance (% GDP), ε_t^{τ} is the error term with variance σ_{τ}^2, while γ with different superscripts denote the estimated parameters. We include the contemporaneous and one-year lagged value of the real exchange rate, given that empirical works typically find a delayed impact of the real exchange rate on trade flows and current account balances. Further lags of the real exchange rate could be considered too, yet our empirical results support well our simple choice.

2.3 The state-space specification and further research avenues

We adopt a state-space model to estimate the parameters and the unobserved variables, for which the observation equations are described by (3), (4) and an identity linking actual and potential output:

(5) $$y_t = \bar{y}_t + \bar{c}_t,$$

where $\bar{c}_t$ is the unobserved output gap. There is no error term to equation (5) as it describes an identity.

We assume that potential output follows a simple I(1) process, a random walk with drift:

(6) $$\bar{y}_t = \bar{y}_{t-1} + \delta + \varepsilon_t^{(\bar{y})}$$

where $\varepsilon_t^{(\bar{y})}$ is the error term with variance $\sigma_{\bar{y}}^2$.

The output gap is described by a first order autoregressive model:

(7) $$\bar{c}_t = \rho\bar{c}_{t-1} + \varepsilon_t^{(\bar{c})}.$$

where $\varepsilon_t^{(\bar{c})}$ is the error term with variance $\sigma_{\bar{c}}^2$.

Equations (6) and (7) describe a very simple structure for the two key unobserved variables. More sophisticated processes could be also employed, like the I(2) specification of Darvas and Simon (2000), or the I(1) with slowly changing drift specification of Blagrave *et al* (2015). Also, the simple first order autoregressive specification for the output gap in equation (7) could be enriched with the trigonometric cycle specification of Harvey (1990, 2011), similarly to Darvas and Simon (2000). Yet our results shows that our simple setup is able to generate a wide range of potential output and output gap movements, so we leave the incorporation of more sophisticated state equation specifications for future research.

Beyond the domestic potential output and the output gap, three other unobserved variables enter the equations above:

- Equilibrium current account ($\bar{\tau}_t$): we adopt the model of Lane and Milesi-Ferretti (2012), with some minor changes, as described in Darvas (2015).
- Equilibrium real exchange rate ($\bar{r}_t$): we approximate it as the deviation from a Hodrick-Prescott-filtered trend, using the standard λ=100 smoothing parameter. This approximation could certainly be improved by, for example, estimating a structural model for the equilibrium real exchange rate. Yet our current result look sensible and we did not want to burden our model with a structural estimation of the equilibrium real exchange rate. Further research could explore the incorporation of a structural estimate for the real exchange rate in our sustainable output model.
- World potential output ($\bar{y}_t^{(w)}$): we approximate it as the deviation from a Hodrick-Prescott-filtered trend, using the standard λ=100 smoothing parameter. This approximation could be improved too. For example, an iterative process could be adopted in which the first step could

be an estimation based on the Hodrick-Prescott filter. Then we could start an iteration, in which we use the weighted average of country-specific output gaps we estimated in the previous step to estimate a new series for the domestic output gap. We could continue this iteration until convergence. We leave the consideration of these iterative calculations for future research.

A further avenue to extend our work could be a joint estimation of all unobserved variables: instead of relying on external estimates for the equilibrium current account, the equilibrium real exchange rate and the rest of the world potential output, we may develop a single system for jointly estimating all latent variables along with domestic potential output. For example, the equilibrium current account and the equilibrium real exchange rate could be specified as reduced from equations based on their determinants, like the Lane and Milesi-Feretti (2012) model for the current account and a BEER (Behavioural Equilibrium Exchange Rate) model for the real exchange rate. The advantage of this system estimation would be to estimate all unobserved variables in a single-step, while its drawback could be practical: estimating a rather large model with many parameters and unobserved variables may prove to be difficult. We leave the development of such a large model for further research.

3 The real-time dataset

Using annual data for 1970-2015, we estimate the model for 45 countries. In order to test the revision properties of our output gap estimates, we assemble a comprehensive real-time dataset to include data which was available in the spring of each year between 2004 and 2015. For example, for the 2004 vintage of our dataset we collected data which was available in the spring 2004 for 1970-2004. Thus the last observation of each vintage of our dataset is the forecast made in spring of the year, while earlier data corresponds to what was available at the time of the spring forecast.

Our main source is the spring versions of the IMF World Economic Outlook (WEO) databases between 2004 and 2015, which were typically published in April (in some years it was published in May). Unfortunately, the publicly available versions of pre-2004 WEO include much less data and therefore we cannot create a good approximation of the real-time dataset for vintages before 2004. The 2004-15 vintages of the WEO include data from 1980 (when available). The other main data source is the April versions of the World Bank World Development Indicators (WDI) dataset, for which we could collect historical versions published between 2005 and 2015 (not 2004 unfortunately). Data in the WDI starts in 1960 (when available). When data was missing in these datasets, we used some additional sources, like the historical spring versions of the European Commission's annual AMECO dataset. We detail below how various datasets were combined.

Variables which directly enter the sustainable output model are the following:

- Constant price GDP level and growth: real-time data from the IMF WEOs, which are available from 1980 (for some countries data starts later). For 1970-79 we used the real-time WDI data that we chained backwards to IMF data on GDP level. The 2004 vintage of the real-time WDI dataset is not available: we used instead the actual 2005 vintage for the 2004 vintage of our dataset. Since the 1970-79 growth rates reported by the WDI in all years from 2005-10 are unchanged, it is safe to assume that the 2004 vintage for 1970-79 was also identical to the 2005 vintage for 1970-79.
- Consumer price level and inflation: real-time data from the IMF WEOs, which are available from 1980 (for some countries data starts later). For 1970-79 we used real-time WDI data that we chained backwards to IMF data in the case of CPI level. Similarly to the GDP, we used the 2005 WDI vintage for 1970-79 as the 2004 vintage too in our dataset.
- Current account (% GDP): real-time data from the IMF WEOs for the years from 1980 till the year of the real-time data. For 1970-79 we used WDI data.

- CPI-based real effective exchange rate: to create real-time vintages simulating the data available in the spring of each year, we followed the following procedure:
  - o The CPI index was taken from the spring version of the World Economic Outlook of the given year and extended backward before 1980 using DWI data as described above.
  - o While yearly vintages of exchange rates against the US dollar are not available, exchange rates are typically known well and not revised. To approximate exchange rate data available in the spring of each year, we use actual monthly data for January-April of the given year and assume that the nominal exchange rate will remain unchanged at its April level for May-December. Then we calculate the average 'real-time expected' exchange rate of the given year, while for earlier years we use the actual annual average exchange rate data.
  - o Using the standard methodology for calculating real effective exchange rates (see eg Darvas, 2012), we calculate, for each vintage of data which was available between 2004 and 2015, the country-specific weighted average foreign CPI, the nominal effective exchange rate and the real effective exchange rate against 67 trading partners. Weights are derived on the basis of Bayoumi *et al* (2006).
- World inflation: weighted average of the inflation rates of 67 trading partners (the same countries which are considered for the real effective exchange rate), using country-specific weights on the basis of Bayoumi *et al* (2006). Real-time inflation rates were used to calculate the real-time world inflation rate.
- World output gap: weighted average of output gaps calculated by us for 34 countries using the iterative procedure described in the previous section. For deriving the country-specific weights, we used again the weight matrix of Bayoumi *et al* (2006).

Variables which enter the panel econometric model estimating the determinants of current accounts are the following:

- Current account (% GDP): real-time data as described above.
- Fiscal balance: real-time data from the IMF WEOs, which are available from 1980 (for some countries data starts later). Pre-1980 values and some missing values were added from Mauro *et al* (2013), but these additions are not real-time data. For a few central European countries, we the European Commission's AMECO database.
- GDP growth: real-time data as described above.
- GDP per capita at PPP: real-time data from the IMF WEOs, which is available from 1980 onwards (for some countries data starts later). Pre-1980 values and some missing values were chained backwards using data from World Bank World Development Indicators, European Commission's AMECO database, EBRD's Selected Economic Indicators database and the Maddison Project and thus some of these additions are not based on real-time data.
- Old-age dependency ratio: real-time data is available from World Bank World Development Indicators for vintages between 2009-15, starting in 1960 (when available) and ending two years before the vintage of the dataset. For our dataset, the 2004-08 vintages are approximated by the 2009 vintage and we disregarded the data for the year of the data vintage and one year earlier, similarly to the availability of the data in the 2009-2015 vintages.

- Aging speed (20-year forward-looking change in the old age dependency ratio): calculated using data on old-age dependency ratio and United Nation's population projections (United Nations, Department of Economic and Social Affairs, Population Division (2013), World Population Prospects: The 2012 Revision, DVD Edition). Unfortunately, we did not get access to earlier versions of the UN projections and so our aging speed variable is not real time.

- Oil rents (percent of GDP): real-time data from World Bank World Development Indicators. The data available in April of each year always lags two years: for example, in the April 2015 version of the WDI the most recent data point is for 2013. However, there were major oil prices changes since then, so we approximated 2014-15 values by assuming that oil rents as a share of GDP evolved proportionally with the evolution of oil prices. We do not have real-time data on oil prices, but they are well known in real time and not really revised. We follow the same approach as we do for the nominal exchange rate against the US dollar: we use actual monthly data for January-April of the given year and assume that the oil price will remain unchanged at its April level for May-December. Then we calculate the average 'real-time expected' oil price of the given year, while for the previous years we use the actual annual average oil price. The WDI includes the oil rents indicator from its 2011 vintage, while for earlier vintages of the WDI dataset this indicator is not available. We compared the data in the 2011-15 vintages and found that historical data are hardly revised. Therefore, for pre-2011 vintages we use the 2011 vintage but disregard data for latest two years of the given vintage and approximate them with oil prices, as we do for the 2011-15 vintages. For example, the April 2007 vintage of our oil rents indicator is composed as follows: for 1970-2005 we use the April 2011 vintage of the data; for 2006 we multiply the 2005 value with the ratio of the 2006 oil price to the 2005 oil price, while we calculate a 'real-time expected' oil price for 2007 by using the actual January-April 2007 prices and assume that for May-December 2007 the April 2007 prices will prevail, calculate the 2007 average as the 'real-time expected' oil price for 2007 and extrapolate the 2006 annual oil rents figures to 2007.

- Net foreign assets: the updated dataset of Lane and Milesi-Ferretti (2007).

Therefore, the variables that enter the sustainable model directly are fully real-time, as well as the depended variable in the panel model estimating equilibrium current account balances, while the bulk of the explanatory variables in the panel model are also real-time.

We also note that we carefully checked the data we use and corrected when we spotted data reporting errors. For example, for the 1980 GDP growth rate of Italy, the 2000-05 vintages of the IMF World Economic Outlook suggested plus 4.2 percent growth, while the 2006-15 vintages include a -1.4 percent GDP fall in 1980. In contrast, 2005-15 vintages of the World Bank's World Development Indicators include plus 3.4 percent growth for 1980, similarly to the European Commission's AMECO database. There was a smaller difference in 1981 GDP growth too. Therefore, for the 1980-81 GDP growth for Italy we use World Bank WDI data. Another example is the Belgian CPI inflation in 1981, for which the 2000-07 and 2010-15 vintages of the IMF WEO includes plus 7.6 percent, but the 2008-09 vintages of the WEO includes -11.3 percent, which is again a data error that we corrected.

We compare our output gap estimates based on real-time data with the actual real-time estimates of the European Commission, IMF and OECD. Similarly to our dataset, we use the versions published in the spring of each year. Typically, the IMF publishes its spring World Economic Outlook in April, the European

Commission publishes its spring European Economic Forecast in May, and the OECD publishes its Issue 1 of its Economic Outlook in June.

- The IMF offers the most user-friendly access to its historical output gap estimates among the three institutions. It makes available all vintages of its World Economic Outlook databases (which include output gap estimations) in excel files, containing long time series, starting with the Spring 1999 WEO at:

  https://www.imf.org/external/ns/cs.aspx?id=28

- The European Commission makes available its most recent version of the AMECO dataset (which includes the output gap estimations):

  http://ec.europa.eu/economy_finance/db_indicators/ameco/index_en.htm

  Unfortunately, earlier vintages of the AMECO datasets are not available for download. Yet output gap estimations are available at the CIRCABC (Communication and Information Resource Centre for Administrations, Businesses and Citizens) website:

  https://circabc.europa.eu/faces/jsp/extension/wai/navigation/container.jsp

  One has to click "Browse categories", then "European Commission", then "Economic and Financial Affairs", then "Output Gaps", then "Library" and finally "99. ARCHIVES", where time series of output gap estimations are available starting with Autumn 2002 estimation. Earlier versions (staring with Autumn 1998) of the European Economic Forecast are available as pdf reports, which include output gap estimates for a few years (typically forecast for the current year, forecast one year ahead, and four earlier years) at:

  http://ec.europa.eu/economy_finance/publications/european_economy/forecasts_en.htm

- The OECD does not make available for download its historical output gap estimates for non-subscribers. Yet historical versions of its Economic Outlook (starting in 1967) are available for on-line reading (not for download) at:

  http://www.oecd-ilibrary.org/economics/oecd-economic-outlook_16097408One can type from the screen earlier vintages of OECD output gap estimates, which are typically in Table 10 of the Annex and cover 20 years (typically forecast for the current year, forecast one year ahead, and 18 earlier years). For example, the direct weblink for the 2007 Issue 1 output gap estimates is the following:

  http://www.keepeek.com/Digital-Asset-Management/oecd/economics/oecd-economic-outlook-volume-2007-issue-1_eco_outlook-v2007-1-en#page249

4 Estimation results

We use a state-space representation of our sustainable output model, the Kalman-filter and maximum likelihood estimation to estimate the parameters of the model and the latent variables: before reporting the results for the sustainable output model, the first step is the estimation of a panel-econometric model for the equilibrium current account balance, which will be used to calculate the current account gap appearing on the left hand side of equation (4).

4.1 First step: the current account model

We approximate the equilibrium current account balance with the predictions of a standard panel-econometric model widely used in the literature. We largely follow Lane and Milesi-Ferretti (2012) with some small alterations, as detailed in Darvas (2015). After estimating the equilibrium current account position as a first step, we will include the deviation of the actual current account from this estimate as a measure of "excess current account balance" as described in equation (4).

The estimated current account model is the following:

$$(8) \qquad \tau_{i,t} = \omega_0 + \omega_1 z_{i,t}^{(1)} + \omega_2 z_{i,t}^{(2)} + \cdots + \omega_k z_{i,t}^{(k)} + \varepsilon_{i,t}\,,$$

where $\tau_{i,t}$ is the current account balance (% of GDP) of country i in period t, $z_{i,t}^{(j)}$ is the j-th explanatory variable of country i in period t, ω_j is the parameter of the j-th explanatory variable and $\varepsilon_{i,t}$ is the error term. We do not add any country-specific or time fixed effects, because we are interested in studying the impacts of the fundamental determinants only.

The model includes seven explanatory variables:

- Fiscal balance (expected sign: positive): a deviation from Ricardian Equivalence will imply that an increased fiscal deficit will reduce national savings and thereby deteriorate the current account balance. Similarly to Lane and Milesi-Ferretti (2012), we measure fiscal balance relative to the weighted average of trading partners (as a percent of GDP). In order to have a full sample from 1971 onwards, we are bound to use only 41 trading parents for which data is available from 1971 as the reference group.

- Economic growth (expected sign: negative): faster economic growth can indicate faster productivity growth, which could attract capital inflows and thereby worsen the current account balance. We measure economic growth with real GDP growth relative to the weighted average of 67 trading partners.

- Stage of economic development (expected sign: positive): lower level of development offers a higher rate of return on capital according to neoclassical theory, which implies that capital should flow from rich to poor countries, thus poor countries are expected to have current account deficits. We measure the stage of economic development with GDP per capita relative to the weighted average of 59 trading partners.

- Old-age dependency ratios (expected sign: negative): the life-cycle hypothesis suggests that young and old people save less, thus countries with high young-age and old-age dependency ratios tend to have larger current account deficits[11].
- Aging speed (expected sign: positive): countries in which the population is getting old more rapidly should save more and thereby have a larger current account surplus. This variable was introduced by Lane (2010) and popularised by Lane and Milesi-Ferretti (2012) and is measured as the 20-year forward-looking change in the old-age dependency ratio. For earlier years we use the actual future change (eg for 1980 we use the actual change from 1980 to 2000), while for more recent years we use the United Nations 2012 population projection (eg for 2005 we use expected change from 2005 to 2025, where the 2025 data is from the UN projection).
- Oil rents as a percent of GDP (expected sign: positive): various indicators have been used in the literature to isolate the impact of oil prices, production, consumption and trade on current account balances. We use oil rents (percent of GDP), which is influenced by oil price swings, as large oil rents typically lead increased exports which are not matched by corresponding imports.
- Net foreign assets as a percent of GDP (expected sign: positive): if the steady-state NFA/GDP ratio is stable, in a growing economy a positive NFA position must be accompanied by a positive current account balance. The NFA/GDP ratio is lagged (eg the end-2011 value is used for the 2012-15 time period), as the NFA is determined by the past current account balances (and valuation changes) and it provides an initial condition for future current account balance.

We experimented with other variables considered in the literature, but did not find them statistically significant and therefore we do not include them.

After selecting the appropriate model, we use the estimated model to calculate the fitted current account values, which may correspond to a medium-term current account 'equilibrium' or 'norm'. However, there are two issues suggesting that one should assess such fitted values with caution.

First, our models might be imperfect and miss important variables – in which case the fitted value might not correspond to an equilibrium notion. However, as reported by Darvas (2015), the estimated gap between the actual and fitted current account has a strong predictive power for future changes in the current account and for most countries the actual current account balance fluctuates around the fitted value, which can be consistent with an equilibrium notion. However, for a few countries such as Australia or the United States, there are persistent gaps between the actual and fitted values, suggesting that certain information for such countries is missing from the model.

Second, we use the actual values of the explanatory variables to calculate fitted values for the current account, but the actual explanatory variables do not always correspond to medium-term sustainable values, even though we use time-averaged data over four-year non-overlapping periods to eliminate fluctuations related to the business cycle. For example, the actual fiscal position over a four-year period may not correspond to a medium-term sustainable position.

The fitted values from our estimated models should be therefore assessed with caution, yet the above-mentioned strong predictability result and the fluctuation of actual current account balances around the predicted values for most countries suggest that our models have useful informational content.

[11] We therefore also considered the young-age dependency ratio, but it did not lead to significant estimates.

We estimate the model on the basis of real-time available data in each year between 2004 and 2015. The sample period starts in the early 1970s and lasts till the year for which real-time data is available. The sample period includes 4-year non-overlapping averages (except for the net foreign asset position, for which the last year of the previous 4-year long period is used, eg the 2011 value of the net foreign asset position is used for the 2012-15 period). The reason for using 4-year averages is to smooth out the impacts of the business cycle. This formulation is particularly advantageous for us, because there is no need to incorporate the cyclical position of the economy in the estimation of the equilibrium current account balance. By contrast, the IMF's External Balance Assessment (EBA) methodology for estimating 'current account norms' uses the cyclically adjusted fiscal balance as an explanatory variable in the regression (Phillips *et al*, 2013). This cyclically adjusted variable is derived on the basis of the IMF's potential output estimate. Since our goal is to measure the cyclical position of the economy, we cannot use variables which are based on another measure of potential output.

We include 65 advanced and emerging countries in the panel estimation, not including main oil exporters, poor and small countries[12].

For the different annual vintages of our dataset we estimate the model recursively on 4-year non-overlapping averages. We move forward the 4-year samples by one year when we estimate the model for the next data vintage. For example, for our 2004 vintage estimation the eight 4-year periods are: 1973-1976, 1977-1980, … and 2001-2004, while for the 2005 vintage estimation the eight 4-year periods are: 1974-1977, 1978-1981, … and 2002-2005. We aim for recursive sample estimation and not rolling window estimation, so whenever possible, we add an earlier 4-year period from the 1970s. Since the NFA is available from 1970 onwards and NFA is lagged, the first year for which we can estimate the model is 1971. Consequently, for the 2006 vintage estimation we have nine 4-year periods: 1971-1974, 1975-1978, 1979-1982, … and 2003-2006, and so on.

Table 1 shows the parameter estimates for different vintages of our real-time dataset. All parameter estimates have the correct sign and their estimated values change little from one vintage to the next. Six of the seven variables have significant parameter estimates throughout, while relative GDP growth is highly significant for early vintages of our data, but not significant for more recent vintages. Yet the sign of the point estimate remains correct and therefore we keep the same specification throughout.

[12] Compared to Darvas (2015) in which 66 countries were used, we do not include Serbia, because of the difficulties in obtaining the historical vintages of real-time data for this country.

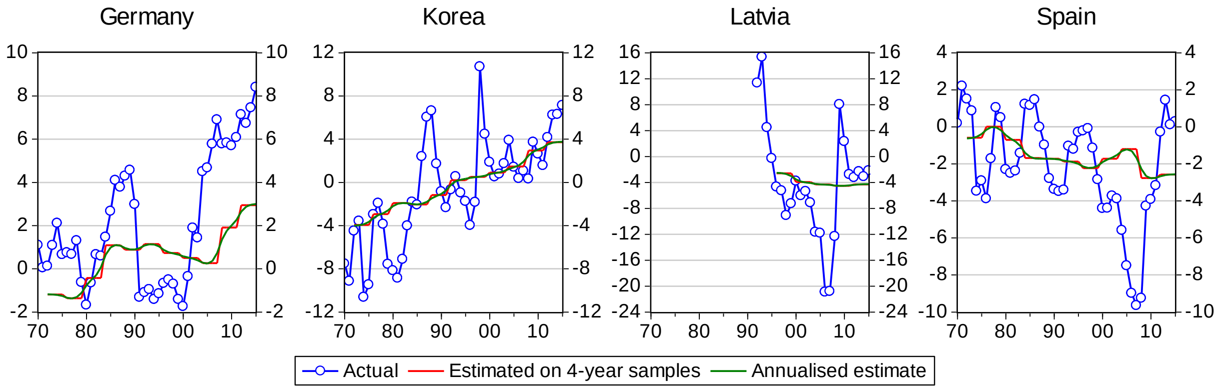
Table 1: Medium term determinants of the current account balance: estimated parameters for different vintages of our real-time dataset

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Fiscal balance (+)	0.238***	0.228***	0.178***	0.224***	0.207***	0.193***	0.155***	0.206***	0.220***	0.193***	0.197***	0.207***
	(0.061)	(0.064)	(0.059)	(0.060)	(0.058)	(0.058)	(0.052)	(0.052)	(0.052)	(0.053)	(0.051)	(0.048)
Growth differential (-)	-0.226**	-0.211**	-0.158*	-0.191**	-0.198**	-0.157*	-0.098	-0.173**	-0.157*	-0.087	-0.069	-0.119
	(0.095)	(0.105)	(0.084)	(0.090)	(0.095)	(0.095)	(0.084)	(0.088)	(0.091)	(0.087)	(0.082)	(0.083)
GDP per capita (+)	0.027***	0.025**	0.029***	0.033***	0.028***	0.029***	0.031***	0.028***	0.032***	0.040***	0.041***	0.040***
	(0.009)	(0.01)	(0.009)	(0.011)	(0.010)	(0.011)	(0.010)	(0.010)	(0.011)	(0.012)	(0.012)	(0.011)
Old dependency ratio (-)	-0.097**	-0.094*	-0.105**	-0.116**	-0.124**	-0.126**	-0.112**	-0.095**	-0.101**	-0.104**	-0.087*	-0.081*
	(0.046)	(0.049)	(0.045)	(0.047)	(0.049)	(0.050)	(0.045)	(0.045)	(0.048)	(0.049)	(0.045)	(0.042)
Aging speed (+)	0.260***	0.248***	0.227***	0.200***	0.185***	0.154***	0.169***	0.145***	0.150***	0.162***	0.165***	0.178***
	(0.052)	(0.050)	(0.049)	(0.052)	(0.047)	(0.045)	(0.041)	(0.041)	(0.045)	(0.045)	(0.042)	(0.041)
Lagged NFA (+)	0.036***	0.038***	0.038***	0.037***	0.046***	0.047***	0.042***	0.040***	0.037***	0.029***	0.026***	0.025***
	(0.009)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
Oil rents (+)	0.317***	0.353***	0.416***	0.425***	0.401***	0.418***	0.455***	0.434***	0.394***	0.400***	0.402***	0.376***
	(0.082)	(0.080)	(0.092)	(0.091)	(0.075)	(0.081)	(0.094)	(0.084)	(0.076)	(0.076)	(0.084)	(0.079)
Constant	0.048	-0.022	0.172	0.526	0.719	0.854	0.561	0.429	0.553	0.538	0.223	0.120
	(0.893)	(0.946)	(0.851)	(0.878)	(0.911)	(0.932)	(0.854)	(0.843)	(0.868)	(0.864)	(0.815)	(0.762)
Observations	399	408	440	454	466	475	501	516	525	534	566	581
Time periods	8	8	9	9	9	9	10	10	10	10	11	11
Number of countries	65	65	65	65	65	65	65	65	65	65	65	65
R2	0.32	0.32	0.34	0.35	0.38	0.38	0.39	0.39	0.37	0.36	0.36	0.38

Note: Panel estimation, non-overlapping 4-year averages (except for the lagged NFA, which refers to the last year of the previous 4-year period) between the early 1970s till the year of the real-time dataset indicated in the first row. The dependent variable is the average current account balance during the 4-year period. The expected sign of the parameter is indicated in brackets after the variable name.,**, *** denote significance at 10, 5 and 1% levels respectively. OLS estimation with robust standard errors.*

While we estimate the current account model on non-overlapping 4-year long periods, our potential output model is based on annual data. We therefore have to annualise the fitted values. To do that, we first make equal each year during the 4-year long period with the estimated value for that period and then use a simple Hodrick-Prescott filter with the standard smoothing parameter =100. As an example, Figure 1 illustrates this transformation for Germany, Korea, Latvia and Spain, using the most recent 2015 vintage of the data. The same chart for all countries is reported in the annex.

Figure 1: Actual and estimated equilibrium current account balances (% GDP), 1970-2015

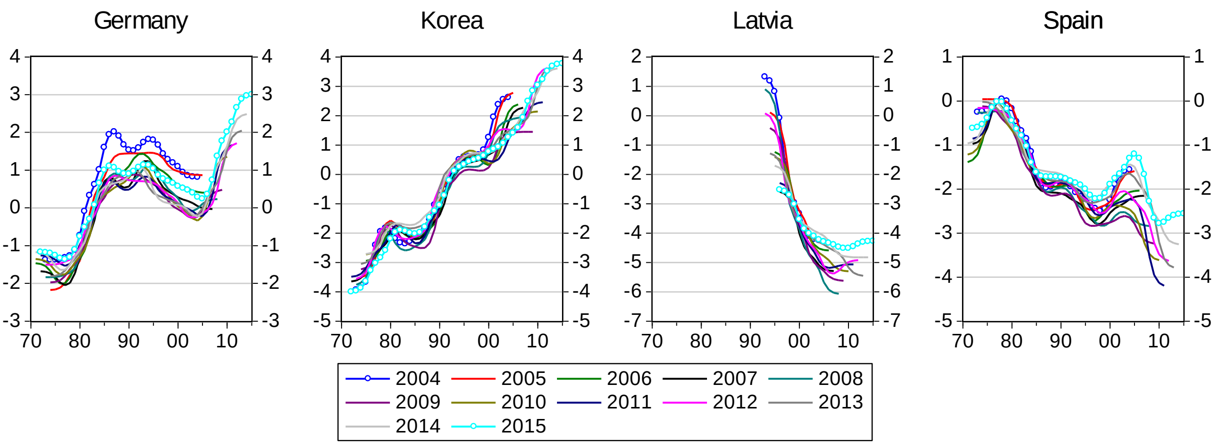


Sources: Bruegel using data described in Section 3.

It is interesting to check the revisions in the annualised fitted values ($\bar{\tau}_t$) and in the current account gaps (ie $\tau_t - \bar{\tau}_t$, which is one of the two indicators we use to identify the consequences of non-zero output gaps, see equation (4)). We expect revisions for three reasons: changes in the estimated parameter values (Table 1), revisions of the data (both the current account balance data and the explanatory variables used in model (8) can be revised) and the transformation from the 4-year frequency to the annual frequency can also lead to revisions.

Figure 2 reports that revisions in our annualised equilibrium current account estimates are not always negligible. For example, for Germany, the range of the different estimates in the period starting in the late 1980s up to the early 2000s is about 1.5 percent of GDP, which is not excessively large in our assessment, but not small either. For Korea and Spain the range is narrower before 2000, about half percent of GDP, but the range widens for these countries too in the 2000s. For Latvia, the range widens to about 2 percent of GDP.

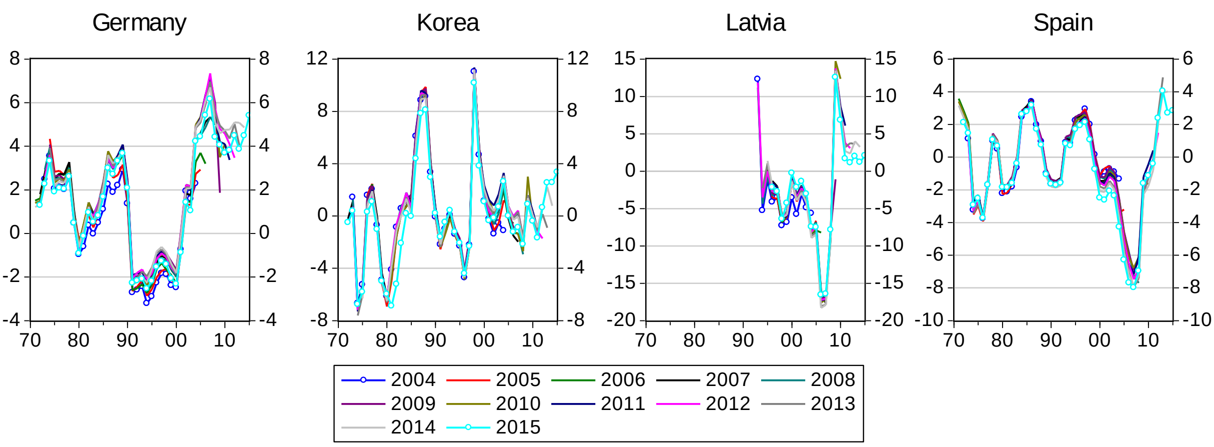
Figure 2: Estimated annual equilibrium current account balances (% GDP) using different data vintages, 1970-2015



Source: Bruegel.

While the non-negligible revisions in the estimated annual equilibrium current account balances translate into the estimated current account gaps, Figure 3 indicates quite clearly that the revisions in the current account gap estimates are minor relative to the value of the current account gap itself. Quite importantly, the sign of current account gap is estimated correctly in real time (including in 2007, the last boom year before the global financial and economic crisis), which suggests that the estimated current account gap variable can be a useful indicator for identifying the output gap in real time too.

Figure 3: Estimated annual current account gaps (% GDP) using different data vintages, 1970-2015

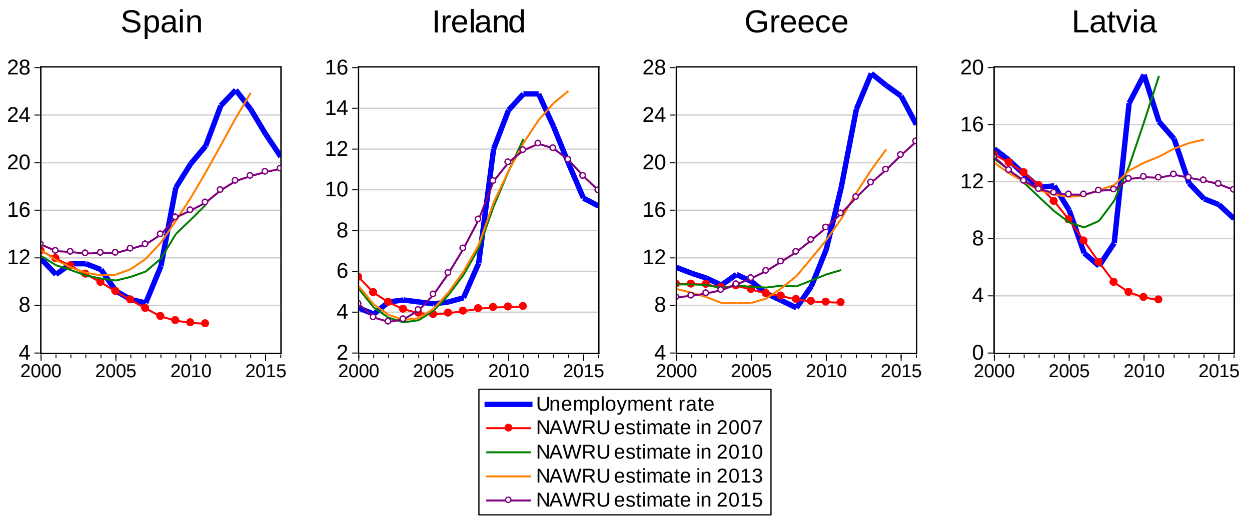


Source: Bruegel. Note: the charts shows the difference between the actual current account balance and the estimated equilibrium value, ie $\tau_t - \bar{\tau}_t$*, which appear on the left hand side of equation (4).*

In contrast, we note that one of the main ingredients of the European Commission's production function methodology, the NAWRU, is subject to much larger revisions for countries undergoing major fluctuations in their unemployment rate. As an illustration, Figure 4 shows the NAWRU estimates and forecasts by the European Commission made in 2007, 2010, 2013 and 2015, along with the actual unemployment rate, for four countries.

The most striking miscalculations were made for Latvia. In 2007, the European Commission estimated that NAWRU was about 6 percent and equal to the actual unemployment rate and forecast that it will decline further to 4 percent. In 2010, when actual unemployment skyrocketed, the NAWRU estimate for 2007 was revised upwards to about 9 percent and it was forecast that NAWRU would continue to increase in later years. Yet in 2013, by when actual unemployment fell, the estimate for 2007 was again revised upwards to about 11 percent and the 2010 estimate was revised downward very significantly. The current estimate for 2015 suggests that there is excess employment in Latvia, because the actual unemployment rate (10 percent) is below the NAWRU (12 percent). Yet it is not very plausible that there is excess employment in Latvia, given the still rather high unemployment rate. Figure 4 suggests that the revisions for the other countries undergoing wide fluctuations in the unemployment rates reflect similar tendencies to revisions in Latvian NAWRU estimates.

Figure 4: NAWRU estimates and forecasts by the European Commission at different dates and the actual unemployment rate, 1995-2016



Source: Bruegel based on European Commission forecasts made in spring of the years indicated. Note: the revisions to the actual unemployment rates are minor and therefore the failures of the real-time NAWRU estimate is not due to later revisions in the actual unemployment rate.

Therefore, we conclude that it is possible to estimate the current account gap reliably in real time even for countries that witnessed dramatic fluctuations in their current account balances, but the European Commission was unable to estimate the NAWRU reliably for those countries which experienced major changes in their unemployment rate. One reason for the difference in real-time performance is likely related to the econometric model setup: we use panel-econometric models for estimating the current account equilibrium gap with several explanatory variables, which enables to incorporate information from four decades of data for 65 countries. Thereby our estimate is not much influenced by a possibly unsustainable development in a particular country towards the end of the sample. By contrast, the European Commission estimates the NAWRU for a single country in a simple statistical framework, which can be significantly influenced by developments in the last few years of the sample period. While the European Commission's NAWRU methodology was revised somewhat in recent years, we remain sceptical whether a real-time reliable NAWRU methodology could be developed for countries which experienced major changes in their unemployment rate.

4.2 Parameter estimates of the potential output model

The estimated parameters of the sustainable output model are reported in Table 2 for the most recent (2015) vintage of our data.

The parameter estimate for γ_{gap}, the parameter of output gap in the current account equation, has negative estimates sign and for all 45 countries and almost all estimates are statistically significant. The absolute value of the parameter ranges from about half (United States, Japan, Argentina) to somewhat above two (Belgium, Malaysia, Sweden, Poland). A value of minus one would indicate that a one percent of GDP domestic output gap is associated with a one percent of GDP lower current account than what is predicted by our current account model.

In contrast, the estimates for β_{gap} , the parameter of output gap in the Phillips curve, are much more variable. For 15 of the 45 countries the estimated sign of the parameter is incorrectly negative, while among the other 30 countries the parameter is significant for only nine. Not surprisingly, the estimated parameter values are strange for countries that had hyperinflation, such as for Argentina and Brazil.

Therefore, our dataset suggests that the current account equation is more important than the Phillips curve in identifying the output gap. In fact, if we constrain β_{gap} to zero even for those countries for which Table 2 indicates a significantly positive parameter, the resulting sustainable output estimates do not change much.

In the Phillips curve, the estimated coefficient of word inflation ($\beta_{w\pi}$) is positive for 44 of the 45 countries, as expected, and statistically significant in most cases. The estimated coefficient of world output gap in the Phillips curve (β_{wgap}) is correctly positive for 32 countries, the exceptions are mainly emerging countries. The estimated coefficient of the real exchange rate (β_{π}) is correctly negative for 38 countries, suggesting that a real exchange rate appreciation reduces domestic inflation.

Real exchange rates also seem to matter for current account developments, as the estimated coefficients of the contemporaneous (γ_{r0}) and lagged (γ_{r1}) real exchange rate tend to be negative. The world output gap has the expected positive coefficient (γ_{wgap}) for about 2/3 of the countries, suggesting that it matters for current account developments. It is also noteworthy that the standard error of the current account equation (σ_{τ}) is estimated to be (almost) zero for about half of the countries, suggesting that our estimated output gaps incorporate much of the volatility of the current account gap.

As regards the parameters of the state equation, the estimated autoregressive parameters (ρ) suggest that persistence of the output gap is moderate for most countries. For several countries the estimate is about around 0.7-0.9, which implies that the half-life of a shock to the output gaps is about 4-6 years. However, for three countries (Denmark, Hong Kong and Slovenia) the estimate is close to one, implying random walk behaviour, and for two countries (Hungary and Sweden) it is even larger than one, implying that the cycle has a tendency to explode. Both a random walk and an exploding process is contrary to the notion of an output gap and therefore our model should be amended for these five countries.

Table 2: Estimated parameters of the sustainable output model

		Argentina	Australia	Austria	Belgium	Brazil	Bulgaria	Canada	China	Cyprus	Denmark	Dominican Rep.
						State equations						
(+)	ρ	0.64	0.71	0.68	0.94	0.81	0.83	0.87	0.80	0.77	0.99	0.82
	se	0.13	0.16	0.19	0.08	0.11	0.12	0.10	0.14	0.17	0.07	0.17
	$\sigma_{\bar{c}}$	0.038	0.011	0.007	0.006	0.019	0.015	0.007	0.010	0.012	0.015	0.017
	se	0.007	0.003	0.003	0.003	0.004	0.008	0.003	0.003	0.006	0.003	0.005
	δ	0.023	0.031	0.020	0.018	0.027	0.021	0.027	0.093	0.021	0.020	0.052
	se	0.006	0.002	0.002	0.002	0.004	0.008	0.003	0.004	0.006	0.002	0.004
	$\sigma_{\bar{y}}$	0.037	0.010	0.015	0.016	0.024	0.038	0.019	0.023	0.026	0.014	0.021
	se	0.005	0.002	0.002	0.002	0.003	0.006	0.002	0.003	0.004	0.002	0.004
						Phillips-curve						
(+)	β_{gap}	8.74	0.40	-0.04	0.17	-44.39	-21.29	0.28	1.23	0.33	0.11	-1.05
	se	13.35	0.20	0.18	0.18	27.75	28.76	0.19	0.69	0.21	0.09	0.57
(+)	β_{π}	0.26	0.61	0.66	0.60	0.42	-0.14	0.59	0.47	-0.10	0.65	0.00
	se	0.12	0.09	0.09	0.10	0.13	0.24	0.10	0.13	0.20	0.10	0.16
(-)	β_{r}	-12.39	-0.10	-0.06	-0.09	0.61	5.93	-0.05	-0.11	-0.11	0.00	-0.89
	se	2.76	0.04	0.04	0.04	5.56	8.76	0.03	0.09	0.09	0.05	0.15
(+)	β_{wgap}	87.64	-0.22	0.28	0.34	33.35	12.70	0.15	0.46	0.05	0.24	1.75
	se	39.37	0.22	0.12	0.18	57.39	48.37	0.13	0.67	0.18	0.17	0.83
(+)	$\beta_{w\pi}$	7.22	0.32	0.19	0.27	20.10	38.55	0.37	0.29	0.80	0.13	0.09
	se	2.07	0.10	0.06	0.07	6.14	32.17	0.09	0.37	0.20	0.08	0.63
	σ_{π}	3.626	0.014	0.009	0.013	4.632	2.052	0.012	0.040	0.010	0.013	0.055
	se	0.416	0.002	0.001	0.001	0.518	0.320	0.001	0.005	0.002	0.001	0.008
						Current account equation						
(-)	γ_{gap}	-0.48	-0.76	-1.72	-2.02	-0.84	-2.10	-1.68	-1.65	-2.09	-0.71	-1.18
	se	0.07	0.26	0.98	1.11	0.16	0.96	0.81	0.53	0.95	0.20	0.37
(+)	γ_{wgap}	0.33	0.13	0.26	0.21	0.48	-1.96	0.35	0.84	-0.76	0.11	0.01
	se	0.17	0.14	0.21	0.26	0.17	0.55	0.17	0.23	0.49	0.18	0.12
(-)	γ_{r0}	-0.01	-0.02	-0.04	-0.03	-0.02	-0.01	0.04	-0.08	0.26	0.00	-0.13
	se	0.01	0.03	0.08	0.08	0.02	0.11	0.05	0.03	0.21	0.05	0.04
(-)	γ_{r1}	-0.02	-0.02	-0.16	-0.02	-0.06	-0.16	-0.03	-0.01	-0.72	0.05	0.03
	se	0.01	0.03	0.09	0.07	0.02	0.11	0.05	0.04	0.23	0.06	0.05
	σ_{τ}	0.000	0.006	0.006	0.009	0.000	0.000	0.004	0.000	0.000	0.006	0.005
	se	0.007	0.002	0.004	0.002	0.002	0.019	0.003	0.004	0.008	0.002	0.006

Note: cells with light-red background indicate estimated coefficients with incorrect sign.

Table 2: **Estimated parameters of the sustainable output model, continued**

		Estonia	Finland	France	Germany	Greece	Hong Kong, China	Hungary	India	Indonesia	Ireland	Italy
							State equations					
(+)	ρ	0.77	0.91	0.89	0.87	0.91	0.98	1.04	0.83	0.84	0.93	0.49
	se	0.17	0.06	0.07	0.09	0.08	0.08	0.09	0.15	0.00	0.06	0.14
	$\sigma_{\bar{c}}$	0.049	0.012	0.007	0.018	0.015	0.019	0.015	0.009	0.032	0.020	0.011
	se	0.012	0.005	0.003	0.003	0.005	0.008	0.006	0.003	0.000	0.006	0.003
	δ	0.047	0.022	0.021	0.019	0.013	0.042	0.026	0.057	0.048	0.040	0.016
	se	0.007	0.004	0.002	0.001	0.005	0.006	0.005	0.004	0.000	0.005	0.003
	$\sigma_{\bar{y}}$	0.031	0.028	0.015	0.009	0.032	0.031	0.022	0.027	0.022	0.029	0.018
	se	0.010	0.003	0.002	0.002	0.004	0.005	0.004	0.003	0.000	0.004	0.002
							Phillips-curve					
(+)	β_{gap}	-0.02	0.10	0.23	0.03	0.13	0.37	-0.01	0.87	0.01	0.28	0.71
	se	0.08	0.12	0.24	0.04	0.12	0.15	0.15	0.45	0.00	0.12	0.26
(+)	β_{π}	0.63	0.81	0.67	0.74	0.70	0.46	0.63	0.11	0.09	0.38	0.74
	se	0.12	0.08	0.12	0.10	0.08	0.09	0.13	0.16	0.00	0.10	0.08
(-)	β_{r}	-0.11	-0.07	-0.07	-0.03	-0.12	-0.14	-0.14	-0.05	-0.51	-0.14	-0.13
	se	0.13	0.04	0.07	0.03	0.09	0.05	0.16	0.07	0.00	0.07	0.06
(+)	β_{wgap}	0.60	0.56	0.31	0.32	0.28	-0.23	-0.47	-0.32	0.09	-0.22	0.55
	se	0.46	0.18	0.21	0.10	0.28	0.24	0.57	0.35	0.00	0.26	0.24
(+)	$\beta_{w\pi}$	2.26	0.17	0.25	0.07	0.70	0.60	3.32	0.19	-0.39	0.81	0.34
	se	0.75	0.10	0.11	0.04	0.16	0.13	1.07	0.10	0.00	0.14	0.10
	σ_{π}	0.018	0.015	0.016	0.007	0.020	0.012	0.026	0.023	0.069	0.017	0.017
	se	0.003	0.002	0.002	0.001	0.002	0.001	0.004	0.003	0.000	0.002	0.002
							Current account equation					
(-)	γ_{gap}	-0.75	-1.50	-1.05	-0.73	-1.11	-1.68	-0.92	-0.91	-0.55	-0.90	-1.26
	se	0.21	0.59	0.39	0.11	0.35	0.63	0.33	0.38	0.00	0.32	0.26
(+)	γ_{wgap}	0.33	0.58	0.13	1.01	-0.55	1.00	-0.52	-0.09	-0.32	-0.27	0.22
	se	0.48	0.26	0.11	0.14	0.23	0.59	0.26	0.13	0.00	0.26	0.19
(-)	γ_{r0}	-0.02	-0.05	0.03	0.03	-0.06	-0.05	-0.03	-0.01	0.05	0.00	-0.06
	se	0.18	0.06	0.03	0.03	0.08	0.14	0.06	0.03	0.00	0.08	0.04
(-)	γ_{r1}	0.06	-0.06	-0.07	-0.11	0.05	-0.20	-0.10	0.00	0.04	-0.02	-0.11
	se	0.18	0.06	0.03	0.03	0.09	0.12	0.07	0.04	0.00	0.07	0.04
	σ_{τ}	0.008	0.000	0.000	0.004	0.000	0.005	0.000	0.004	0.000	0.008	0.000
	se	0.011	0.003	0.003	0.002	0.007	0.011	0.004	0.002	0.000	0.003	0.003

Note: cells with light-red background indicate estimated coefficients with incorrect sign.

Table 2: **Estimated parameters of the sustainable output model, continued**

		Japan	Korea	Latvia	Lithuania	Luxembourg	Malaysia	Mexico	Nether-lands	New Zealand	Pakistan	Poland
		State equations										
(+)	ρ	0.93	0.43	0.72	0.68	0.26	0.80	0.55	0.77	0.52	0.73	0.56
	se	0.07	0.22	0.20	0.22	0.22	0.12	0.21	0.12	0.13	0.15	0.31
	$\sigma_{\bar{c}}$	0.009	0.018	0.041	0.043	0.012	0.022	0.014	0.012	0.011	0.006	0.007
	se	0.005	0.005	0.012	0.009	0.008	0.007	0.008	0.003	0.002	0.004	0.004
	δ	0.023	0.054	0.046	0.046	0.024	0.058	0.022	0.021	0.023	0.049	0.042
	se	0.004	0.004	0.009	0.007	0.006	0.006	0.004	0.002	0.002	0.003	0.003
	$\sigma_{\bar{y}}$	0.023	0.024	0.038	0.028	0.022	0.029	0.025	0.014	0.015	0.018	0.015
	se	0.003	0.004	0.009	0.005	0.007	0.005	0.005	0.002	0.002	0.002	0.003
		Phillips-curve										
(+)	β_{gap}	-0.14	0.01	0.04	0.08	-0.40	0.02	0.00	-0.01	1.04	2.48	-0.49
	se	0.13	0.13	0.14	0.08	0.20	0.09	0.00	0.09	0.36	1.77	0.78
(+)	β_{π}	0.61	0.12	0.60	0.58	-0.29	0.28	0.67	0.82	0.57	0.07	0.49
	se	0.06	0.15	0.12	0.05	0.09	0.17	0.11	0.08	0.11	0.16	0.06
(-)	β_{r}	-0.04	-0.07	-0.16	-0.39	0.06	0.01	-1.17	-0.09	-0.09	-0.09	-0.03
	se	0.02	0.03	0.09	0.07	0.05	0.05	0.30	0.04	0.06	0.11	0.10
(+)	β_{wgap}	0.21	0.14	0.95	-1.09	0.12	0.21	-3.28	0.38	0.15	-0.42	-0.44
	se	0.12	0.27	0.46	0.48	0.18	0.20	1.81	0.13	0.36	0.45	0.44
(+)	$\beta_{w\pi}$	0.25	0.52	2.11	1.93	1.40	0.13	1.16	0.11	0.54	0.04	2.39
	se	0.08	0.10	0.71	0.55	0.16	0.17	1.45	0.05	0.18	0.09	0.56
	σ_{π}	0.009	0.013	0.018	0.014	0.000	0.011	0.165	0.010	0.022	0.023	0.021
	se	0.001	0.002	0.003	0.002	0.004	0.002	0.020	0.001	0.003	0.004	0.003
		Current account equation										
(-)	γ_{gap}	-0.53	-1.21	-0.85	-0.88	-1.28	-2.04	-0.66	-1.13	-1.70	-2.29	-2.44
	se	0.37	0.26	0.27	0.13	0.85	0.47	0.43	0.30	0.33	1.83	2.06
(+)	γ_{wgap}	0.15	0.88	-1.99	0.61	1.16	0.63	0.20	0.42	0.01	-0.24	-0.18
	se	0.10	0.39	0.55	0.68	0.62	0.71	0.16	0.23	0.16	0.25	0.43
(-)	γ_{r0}	0.03	-0.17	0.32	0.07	-0.16	-0.17	-0.04	-0.16	0.09	0.04	0.04
	se	0.01	0.06	0.17	0.15	0.37	0.18	0.02	0.06	0.04	0.06	0.09
(-)	γ_{r1}	-0.05	-0.10	-0.21	-0.08	-0.77	-0.01	-0.07	0.04	-0.10	-0.04	0.04
	se	0.02	0.05	0.20	0.13	0.35	0.20	0.02	0.06	0.04	0.07	0.07
	σ_{τ}	0.005	0.000	0.009	0.000	0.021	0.000	0.005	0.007	0.000	0.007	0.009
	se	0.001	0.007	0.010	0.050	0.004	0.018	0.003	0.002	0.006	0.005	0.009

Note: cells with light-red background indicate estimated coefficients with incorrect sign.

Table 2: **Estimated parameters of the sustainable output model, continued**

		Portugal	Romania	Slovakia	Slovenia	South Africa	Spain	Sweden	Switzerland	Thailand	Turkey	United Kingdom	United States
		State equations											
(+)	ρ	0.85	0.81	0.91	0.97	0.78	0.89	1.01	0.71	0.69	0.80	0.92	0.95
	se	0.09	0.00	0.12	0.14	0.17	0.08	0.02	0.22	0.12	0.13	0.23	0.06
	$\sigma_{\bar{c}}$	0.013	0.021	0.008	0.030	0.013	0.013	0.004	0.012	0.021	0.023	0.011	0.012
	se	0.004	0.000	0.007	0.006	0.003	0.003	0.003	0.004	0.006	0.006	0.004	0.003
	δ	0.024	0.024	0.038	0.029	0.023	0.023	0.022	0.018	0.052	0.037	0.020	0.027
	se	0.004	0.000	0.008	0.004	0.003	0.003	0.003	0.002	0.006	0.005	0.003	0.002
	$\sigma_{\bar{y}}$	0.024	0.039	0.033	0.014	0.016	0.016	0.021	0.011	0.034	0.032	0.017	0.015
	se	0.003	0.000	0.006	0.002	0.002	0.002	0.002	0.004	0.004	0.004	0.003	0.002
		Phillips-curve											
(+)	β_{gap}	0.60	-0.02	0.20	0.01	-0.02	0.28	-0.11	0.00	0.06	-1.85	-0.01	0.15
	se	0.33	0.00	0.57	0.05	0.19	0.13	0.55	0.24	0.16	1.07	0.16	0.10
(+)	β_{π}	0.56	0.07	0.46	0.71	0.67	0.79	0.30	0.28	0.38	0.60	0.76	0.64
	se	0.13	0.00	0.23	0.07	0.11	0.07	0.12	0.12	0.12	0.12	0.13	0.08
(-)	β_{r}	0.04	0.40	-0.14	-0.22	-0.10	-0.06	-0.02	-0.07	-0.08	-0.48	-0.09	-0.09
	se	0.15	0.00	0.14	0.10	0.03	0.06	0.05	0.03	0.07	0.33	0.05	0.04
(+)	β_{wgap}	-0.71	-4.84	-0.35	-0.66	0.30	0.16	0.34	0.23	0.71	2.70	0.81	0.53
	se	0.45	0.00	0.55	0.25	0.22	0.26	0.24	0.14	0.28	2.65	0.22	0.20
(+)	$\beta_{w\pi}$	0.89	12.13	1.83	1.54	0.30	0.30	0.73	0.29	0.54	1.55	0.25	0.14
	se	0.28	0.00	1.15	0.34	0.08	0.10	0.18	0.10	0.16	0.70	0.12	0.05
	σ_{π}	0.037	0.284	0.024	0.008	0.016	0.017	0.017	0.009	0.021	0.156	0.013	0.011
	se	0.004	0.000	0.004	0.001	0.002	0.002	0.002	0.001	0.002	0.018	0.002	0.001
		Current account equation											
(-)	γ_{gap}	-2.17	-0.83	-1.76	-0.63	-1.75	-1.02	-2.28	-2.06	-1.70	-0.87	-0.82	-0.53
	se	0.57	0.00	1.59	0.07	0.31	0.21	1.79	1.54	0.43	0.19	0.30	0.11
(+)	γ_{wgap}	0.48	-0.65	-0.39	0.19	0.73	-0.30	0.32	0.57	-0.19	-0.01	0.05	-0.02
	se	0.37	0.00	0.33	0.31	0.26	0.15	0.17	0.51	0.50	0.68	0.21	0.09
(-)	γ_{r0}	-0.17	-0.05	0.15	-0.16	-0.03	0.01	-0.03	-0.21	-0.12	-0.05	0.02	-0.01
	se	0.12	0.00	0.12	0.09	0.03	0.04	0.04	0.11	0.13	0.03	0.03	0.02
(-)	γ_{r1}	0.10	-0.03	-0.29	-0.52	-0.06	-0.12	-0.06	-0.03	0.00	-0.04	-0.04	-0.05
	se	0.12	0.00	0.12	0.11	0.04	0.04	0.04	0.13	0.09	0.03	0.03	0.02
	σ_{τ}	0.000	0.000	0.008	0.000	0.000	0.000	0.005	0.015	0.000	0.000	0.002	0.000
	se	0.007	0.000	0.005	0.003	0.007	0.002	0.002	0.011	0.025	0.026	0.002	0.002

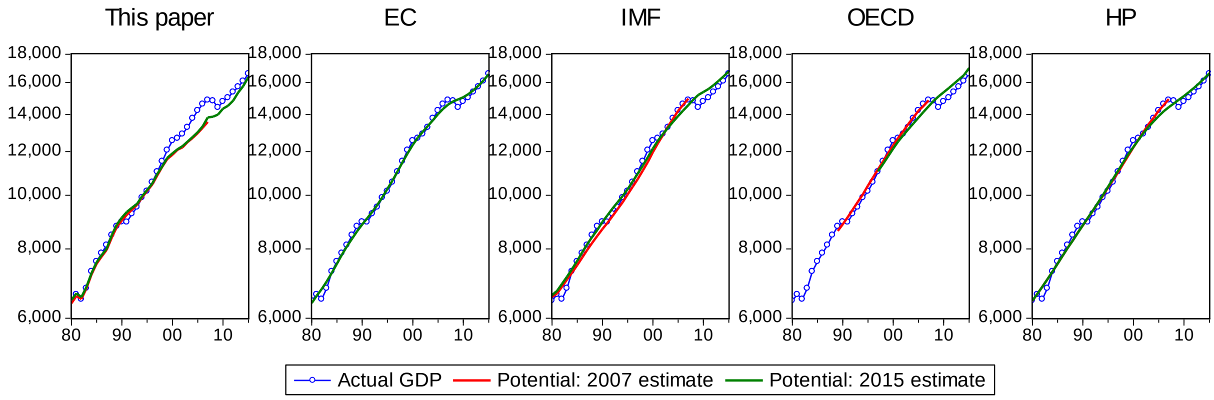
Note: cells with light-red background indicate estimated coefficients with incorrect sign.

4.3 Sustainable output levels

We highlight our sustainable output estimates for five countries – United States of America, Germany, Greece, Spain and Italy – for which our results are profoundly different from the potential output estimates of the three institutions (our estimates for other countries are reported in the annex). We compare the estimates made in 2007 and 2015 to see the real-time properties of the different estimates.

For the United States of America our results suggest a growing positive output gap from the late 1990s, reflecting a slight slow-down in sustainable output growth (Figure 5). The output gap reached about 9 percent in 2006 according to our estimates and the subsequent fall in actual output only closed this positive output gap. In contrast, potential output estimates of the institutions largely "smooth out" actual GDP developments around 2008 and visually these estimates do not differ much from the result of a simple Hodrick-Prescott filter. Another notable difference is that our estimates were hardly revised between 2007-15, while there were major revisions in the estimates of the three institutions (unfortunately European Commission estimates for the US were not published in 2007) and the Hodrick-Prescott filter.

Figure 5: United States of America: real-time sustainable and potential output estimates, 1980-2015 (constant prices)



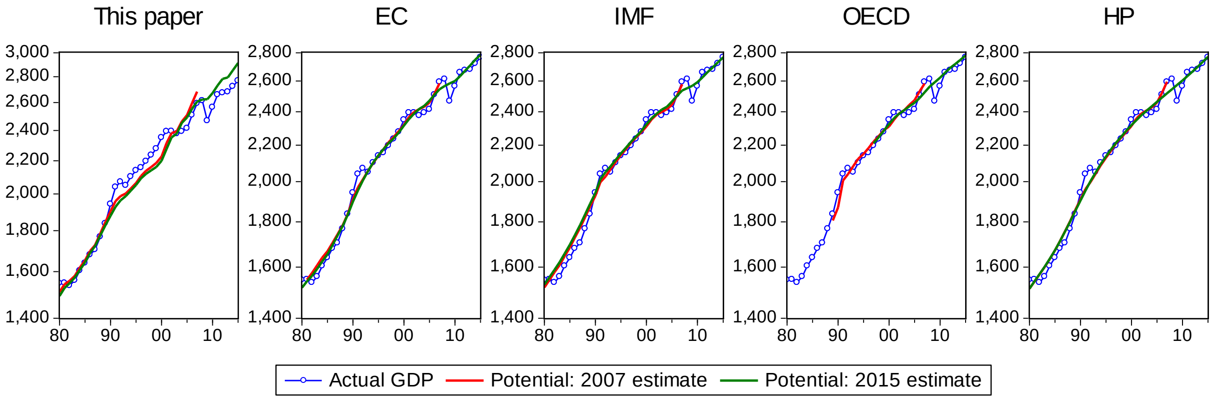
Source: Bruegel. Note: since actual GDP data was somewhat revised between 2007-2015 and the real-time GDP data used by the three institutions also differed to some extent (at least for the last observation in each vintage, which is a forecast made in spring of the given year), for better comparability of the real-time estimates, for sustainable and potential output estimates we relate the real-time output gap estimates made in 2007 and 2015 to the actual GDP as it is available in the April 2015 IMF World Economic Outlook. The European Commission did not publish its potential output estimate for the United States in its Spring 2007 forecast.

Our results for Germany are also strikingly different from the estimates of the three institutors (Figure 6). Our sustainable output estimates indicate that the re-unification boom led to a positive output gap of about 5 percent in the early 1990s. A positive output gap at that time was in line with the actions of the Bundesbank, which tightened monetary policy and thus triggering the 1992-93 ERM crisis. In contrast, potential output estimates of the three institutions smooth out again this period and do not suggest a large positive output gap for the 1990s.

Our results for the post-2008 period are also strikingly different from the estimates of the institutions and suggest that the growth rate of sustainable output did not really decline. Therefore, weak GDP growth has led to the opening of a sizeable negative output gap, reaching 5 percent in 2015.

As regards revisions between the 2007 and 2015 estimates, there does not seem to be a big difference between the five methods indicated in Figure 6.

Figure 6: Germany: real-time sustainable and potential output estimates, 1980-2015 (constant prices, in logarithm)



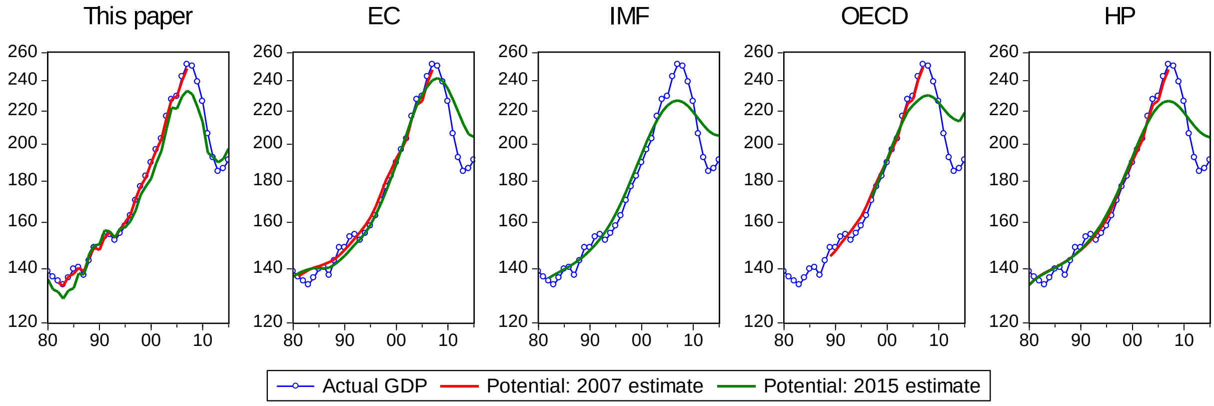
Source: Bruegel. Note: see notes to Figure 5.

For Greece, our results are also notably different from the estimates of the institutions and the Hodrick-Prescott filter (Figure 7). According to our findings, the fall in sustainable output preceded the fall in actual output in 2009-13 and not followed it, as a smoothing algorithm and the results of the three institutions suggest. Consequently, there was almost no negative output gap in 2013 according to our estimates, while the estimates of the institutions suggest large negative output gaps (eg 13 percent in 2013 according to the estimates of the European Commission). Such differences have major policy implications concerning the prospect of economic growth (whether closing the output offers a short-term prospect for growth) and the structural budget balance and thereby the fiscal adjustment need according to the European fiscal framework (as the structural balance is much better than the actual budget balance when there is a large negative output gap). Note that for actual GDP we use the April 2015 IMF WEO projection, which suggested a 3 percent increase in 2015, while the October 2015 WEO suggests a 2 percent fall in 2015.

In terms of real-time reliability, our 2007 estimate for Greece was not much different from the estimates of the three institutions.

It is also noteworthy that for Greece, the IMF's potential output estimate is practically identical to the results of the Hodrick-Prescott filter. In the annex chart, we plot the IMF and Hodrick-Prescott results on the same chart and they practically overlap each other.

Figure 7: Greece: real-time sustainable and potential output estimates, 1980-2015 (constant prices, in logarithm)



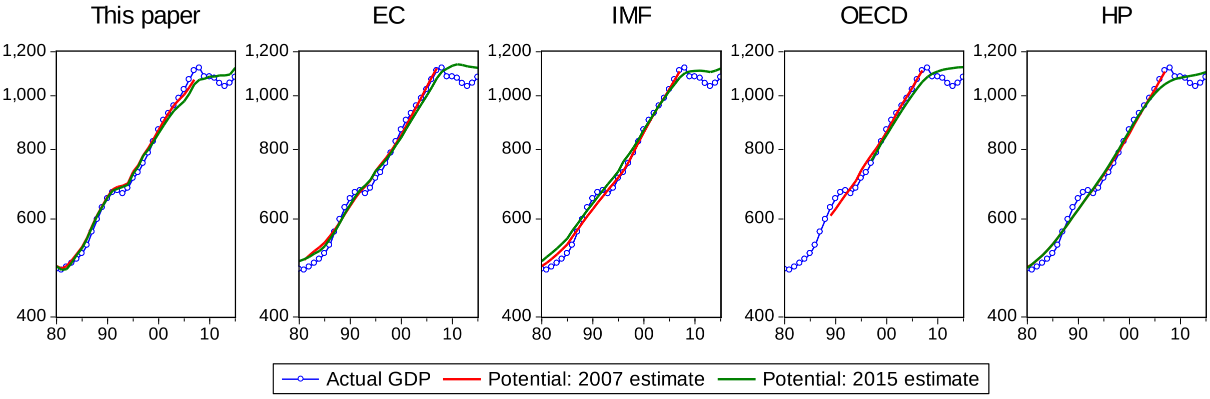
Source: Bruegel. Note: see notes to Figure 5. The IMF did not publish its potential output estimate for Greece in its April 2007 WEO. Note that for actual GDP we use the April 2015 IMF WEO projection, which suggested a 3 percent increase in 2015. The stalemate in negotiations between the Greek government and its official lenders and the introduction of capital controls had major negative impacts on the Greek GDP and the October 2015 WEO of the IMF suggest a 2 percent fall in GDP in 2015. Yet for consistency with our other estimates, we continue to use the April 2015 WEO projection for actual GDP.

Our sustainable output estimates for Spain are again different from the estimates of the institutions and the Hodrick-Prescott filter. Before the crisis, sustainable output increased less according to our estimates than according to three institutions. Sustainable output growth slowed down considerably in 2009-14, but there was no decline in the level of sustainable output, in contrast to the estimates of the institutions. Our more recent estimates suggest a pick-up in sustainable output growth, which is in line with fast-growing Spanish export performance. In contrast, the Commission's estimate of potential output follows an inverted U-shape because of the various soothing algorithms that it includes and potential output continues to fall in 2015 too. (The inverted U-shape was even more pronounced in the European Commission's 2013 estimate). Although the estimation of unobserved variables is by definition model dependent, we regard our results as more plausible from an economic perspective than the Commission's estimates.

The real-time performance of our estimates is much better than that of the institutions and the Hodrick-Prescott filter: our model was able to identify in 2007 that Spain was above potential in this year, while the 2007 estimates of the institutions suggested that Spain was practically at its potential or even below in 2007. In contrast, in 2015 the institutions' estimates, as well as the Hordrick-Prescott filter, suggest that Spain had a sizeable positive output gap in 2007.

Our sustainable output estimates for Ireland and Portugal follow a similar pattern to our estimates for Spain (see annex) and the real-time reliability of our estimates is markedly better than that of the three institutions and the Hodrick-Prescott filter.

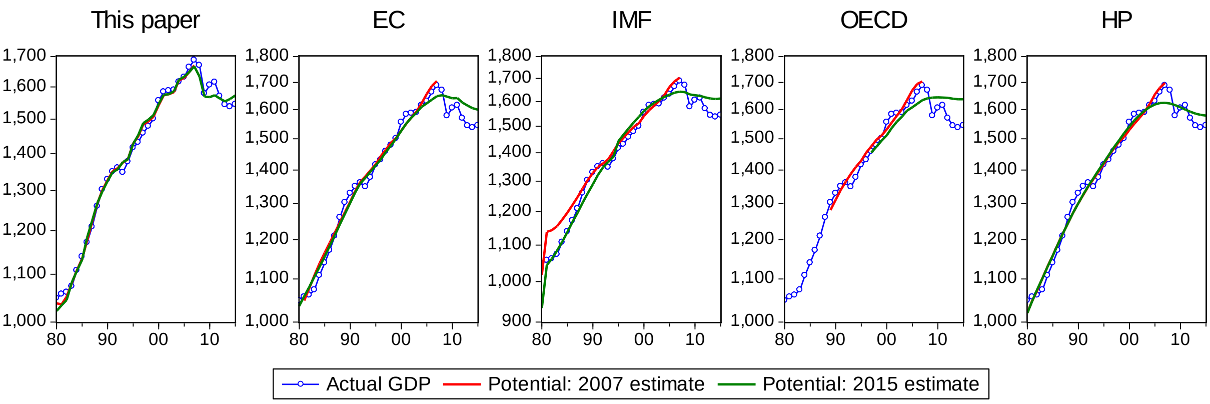
Figure 8: Spain: real-time sustainable and potential output estimates, 1980-2015 (constant prices, in logarithm)



Source: Bruegel. Note: see notes to Figure 5.

We also highlight our results for Italy (Figure 9). Our findings suggest that there was a sudden drop in potential output in 2009 and thereby the recent global and European economic crises did not lead to a large negative output gap, in contrast to the estimates of the institutions and the Hodrick-Prescott filter. Perhaps this is the consequence of the weak export performance of Italy. Our results suggest a similar sudden drop in sustainable output for some other countries too (eg Austria, Belgium, Canada and France).

Figure 9: Italy: real-time sustainable and potential output estimates, 1980-2015 (constant prices, in logarithm)



Source: Bruegel. Note: see notes to Figure 5.

Results for other countries are reported in the annex. There are several notable results. Some examples:

- Argentina: sustainable output remained stable from the mid-1990s till the crash in 2001, but after that, it increased despite the collapse of actual output, which again may be explained by the export performance of the country.
- Brazil: sustainable output stopped growing in about 2010 and has even fallen slightly in recent years. Therefore, while actual GDP growth slowed down, a sizeable positive output gap (about 4 percent) emerged.

- Canada: the recent current account deficit (despite the surplus prediction of our equilibrium current account mode) translated into a positive output gap of about 2 percent in the past five years.
- China (mainland): the large current account surplus led our model to conclude that China had a negative output gap in most of the 1990s and2000s, while recent years the economy has returned to sustainable output according to our calculations.
- Denmark and Sweden: results are similar for our German result of the past decade, whereby the increased current account surplus makes our model to conclude that the output gap is negative.
- Estonia, Latvia and Lithuania: our model suggests that in the three Baltic countries sustainable output grew significantly recent years and thereby these countries have a sizeable negative output gaps (about 5-10 percent), which is reflected in their current account surpluses.
- Hungary: our results for Hungary are similar to the results for the Baltic countries and suggest an 8 percent negative output gap in 2015.
- Ireland: our model suggests a stronger growth in sustainable output than potential growth estimates of the three institutions recent years. Thereby we estimate a sizeable negative output gap for 2015, about 4 percent, while the IMF's, OECD's and Hodrick-Prescott's estimate is about 2 percent negative gap and the European Commission suggests that the Irish economy is even above its potential.
- Korea: the recently increased current account surplus, well over the equilibrium current account model prediction, makes our model to conclude that the country has a negative output gap of about 3 percent.
- Malaysia: the sudden emergence of large excess current account surplus in the late 1990s led to similar results as for China, while the recent convergence of the current account surplus to its estimated equilibrium makes our mode to conclude that the economy has returned to its sustainable output.
- Netherlands: interestingly, despite the country's large excess current account surplus, our findings for the Netherlands are different from the results for Germany, Denmark and Sweden. The likely reasons for this discrepancy is that the Dutch current account surplus was persistently larger than the prediction of the current account model for almost four decades, while for Germany, Denmark and Sweden there were alterations in the sign of the current account gap.
- Portugal: our findings are similar to our Spanish results and suggest that potential output started to increase recent years, which is in line with the good export performance of the country.
- Slovenia: results are similar for Hungary and the Baltics, with an even larger negative output gap of about 12 percent.
- Turkey: the large current account deficit of the past five years translated into a large positive output gap over 7 percent, while the 2015 expected narrowing of the current account deficit signals that the output gap narrowed to about 3 percent.
- United Kingdom: similarly to Turkey, the recently emerged current account deficit makes our model to conclude that the UK economy is currently performing above its sustainable level by about 4 percent.

4.4 The 2007 output gap as estimated in different years

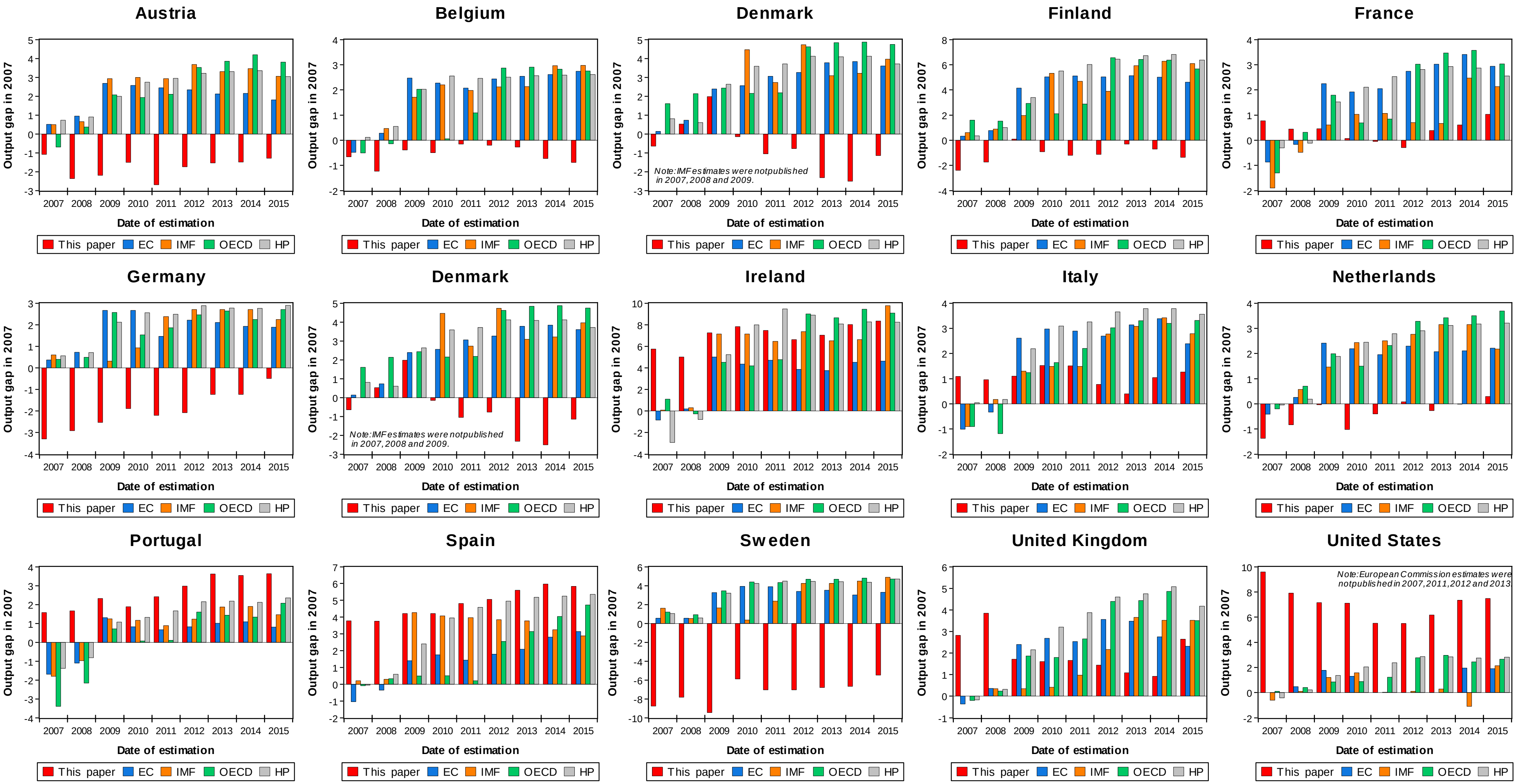
The figures reported in the previous section suggest that there were major revisions in output gap estimates when new data became available. It is interesting to highlight the revisions in the 2007 output gap, which is the last 'boom year' before the financial and economic crisis became global. Figure 10 compares our output gap estimates based on real-time data with the actual real-time estimates of three institutions. For comparison, we also report the Hodrick-Prescott filtered estimates based on real-time data.

Our model could identify the sign of the output gap correctly for all countries but one, which is a notable result[13]. In contrast, for several countries (Belgium, France, Ireland, Italy, Netherlands, Portugal, Spain, United Kingdom and the United States) the institutions incorrectly identified the sign of the 2007 output gap in 2007: they estimated that the output gap was negative (or very close to zero) for these countries, while in later years the institutions estimate that these countries had a positive output gap in 2007. Given that some of these countries experienced large current account deficits and huge credit and construction booms before the crisis, the real-time negative output gap estimates of the institutions is quite bizarre. In fact, the estimates of the institutions do not differ that much from the result of a simple Hodrick-Prescott filter.

To sum up, while our 2007 output gap estimates are also subject to revisions, but to a smaller extent than the revisions of the three institutions' and the Hodrick-Prescott filter's estimate. Our estimates were successful in identifying the sign of the output gap in real time for almost all countries, in contrast to the estimates of the three institutions and the Hodrick-Prescott filter.

[13] The single exception is the Netherlands, for which our real-time estimate suggested that the output gap was -1.4 percent of potential output in 2007, while our estimate based on 2015 data suggest 0.3 percent positive gap for 2007. Yet the 1.7 percent upward revision is smaller than the revisions by the three institutions: the European Commission revised its -0.4 percent real time estimate to 2.2 percent, the IMF revised its 0.0 percent real-time estimate to 2.2 percent, and the OECD revies its -0.2 percent estimate to 3.7 percent.

Figure 10: Estimates for the 2007 output gap at different dates



4.5 A systematic analysis of output gap revisions

In order to systematically analyse the revision properties of the different estimates, we focus on end-point stability. End-point stability is especially important for EU countries, because the European fiscal framework formulates targets for both the level and the change of the structural budget balance, which is determined on the basis of output gap estimates.

To assess end-point stability, we focus on the previous year and current year output gap estimates and the expected change between them. For these three indicators we define two formal measures of revisions: 'short-term' and 'long-term' revisions. The short-term measure indicates the revision one year later, while the long-term revision is defined as the difference between the most recent (ie 2015) and the real-time estimates. By definition, for the last observation we assess, the 'short-term' and 'long-term' revisions are equal. Our long-term measure will change in the future with new estimates.

The following example helps to illustrate the revision indicators that we consider:

Table 3: Short-term and long-term revision measures: an example using the European Commission's May 2012, May 2013 and May 2015 estimates for the German output gap in 2011-12 (% of potential GDP)

	(1)	(2)	(3)	(2)-(1)		(3)-(1)	
	Date of publishing the estimation			**Short-term revision**		**Long-term revision**	
Output gap in:	May 2012	May 2013	May 2015				
2011	0.02	0.69	0.97	**0.67**	= Revision of previous year estimate a year later	**0.95**	= Revision of previous year estimate by 2015
2012	-0.87	-0.05	0.12	**0.82**	= Revision of current year estimate a year later	**0.99**	= Revision of current year estimate by 2015
change from 2011 to 2012	-0.89	-0.74	-0.85	**0.15**	= Revision of the change from previous year to current year estimate a year later	**0.04**	= Revision of the change from previous year to current year estimate by 2015

Source: Bruegel.

In May 2012, the European Commission estimated that Germany was 0.02 percent above its potential output level in 2011. A year later in May 2013 the estimate for the 2011 output gap was revised to 0.69 percent of potential GDP. The difference between the May 2013 and the May 2012 estimates for 2011 is therefore 0.67 percent of potential GDP, and this is what we call *"short-term revision of previous year output gap a year later"*. In May 2015, the commission estimated that the 2011 output gap was 0.97 percent, so the difference between the May 2015 and May 2012 estimates for 2011 is 0.95 which we call *"long-term revision of previous year output gap by 2015"*.

Our indicator *"revision of the current year output gap a year later"* is the difference between the May 2013 and the May 2012 estimates for 2012, which is 0.82 percent of potential GDP, while its long-term value is 0.99 percent, as indicated in the table. In the example above, both the previous year (2011) and the current year (2012) output gap estimate were revised upwards in the 2013 and 2015 estimates, so both the short-term and long-term revisions in the change in the output gap from 2011 to 2012 are smaller, 0.15 percent (short-term) and 0.04 percent (long-term).

The key reasons behind revisions have to be kept in mind when assessing these revision measures:

- **Methodology**: Certain aspects of the methodology may increase revisions. For example, a smoothing algorithm (like the Hodrick-Prescott filter or the EU's methodology to calculate NAWRU and trend total factor productivity) works best when the underlying trend does not change much. It is not surprising therefore, for example, that the EU's methodology and the Hodrick-Prescott filter revisions for Austria are rather small, because the country did not experience major changes in economic developments. But when previous trends change substantially, revisions of methodologies involving smoothing algorithms became substantial, as in the case of Latvia. On the other hand, methods which do not assume the smooth development of potential or sustainable output (as our model) may lead to more volatile estimates even for countries for which the trend does not change much, depending on the estimates.
- **Changes to the methodology**: In this paper we report the revisions of EC, IMF and OECD output gap estimates made in each consecutive year between 2001 and 2015. During this period, there were certain changes to the methodology. Therefore, the revisions in the output gap estimates also reflect changes to the methodology in those years when there was such a change. In the case of the EU methodology, methodological changes impacted only certain technical features of the production function method, like the 2010 change in the filter used to smooth TFP or the 2014 change in the NAWRU model. None of the methodology reviews changed the basic characteristics of the methodology and small technical changes will likely also be implemented in the future. Thus, past revisions may be indicative for future revisions. We do not have information about the changes in the IMF and OECD output gap estimates. We also note that our model (both for the equilibrium current account and for the sustainable output) is unchanged, as described in the previous sections.
- **Forecasts:** Forecasts obviously matter in the revision of current-year estimates. For example, the estimate for 2015 made in spring 2015 depends on the forecasts for 2015. Therefore, revisions of current year estimates might signal that the forecasts for that year were incorrect. This obvious dependence on forecasts is less important for the revision of previous year output gap estimates. For example, in spring 2015 most of the 2014 data was available and therefore the forecast component in the 2014 actual GDP data is smaller. However, forecasts may also matter for output gap revisions as a result of the methodology of the institutions: potential output is calculated by the three institutions for a couple of future years too, and since the methodology uses various data smoothing techniques, longer term forecasts also matter even for the revision of previous year output gap estimates. The use of forecasts partly aims at reducing the end-point uncertainty of the estimates, but if forecasts actually turn out to be highly incorrect, this will also have an impact on the estimates for the past. For example, if the May 2015 forecasts for 2015-16 and the additional projections for 2017-24 by the European Commission prove to be wrong, the Commission output gap estimates for 2014 (and to a lesser extent even for earlier years) will be revised too.
- **Data revisions**. GDP data and certain other data, which are used in the models, may be revised from time to time. Such data revisions certainly impact the estimated level of potential output, and may also impact (though likely to a lesser extent) the output gap estimate. Since we use real-time data, data revisions impact all methodologies we compare, yet likely to different degrees given the differences in data inputs.

Given the large dependence on forecasts of the current year estimates, our preferred indicator is the revision in the previous year estimate. We also highlight that our dataset is based on IMF spring WEO data, which are typically published in April each year. Our dataset therefore has an informational disadvantage over the European Commission's estimates, which are typically published in May each year, and the OECD estimates, which are typically published in June each year.

There are twelve EU countries for which the estimates of all three institutions are available for each year from 2003-15 and therefore Panel A of Table 4 compares our results for these twelve countries. For comparison, the revisions of the Hodrick-Prescott filter results are also indicated: we use the standard λ=100 smoothing parameter and consider two versions depending on the use of forecasts: the first version uses data up to the year of the data vintage, but no further forecasts, while the second version uses forecasts five years ahead[14]. Of these two versions, the first corresponds to the data use of our model (data up to the year of the vintage), while the second corresponds to the data use of the institutions (which extend the sample period with forecasts several years ahead and calculate potential output for this extended sample period). Panel B reports results for five non-EU countries (European Commission estimates are not available for these countries). Since revisions can be both positive and negative, we calculate the absolute value of revisions for each country and then calculate the average for the twelve countries during the past twelve years[15].

[14] The regular IMF WEO database includes forecasts five years ahead from staring with 2008 publication of the WEO, while earlier vintages of the WEO includes forecasts only two years ahead. Yet the IMF published a separate historical dataset, which includes 5-year ahead forecasts for three indicators (GDP growth, inflation and the current account balance) and thereby we could extend WEO GDP level data of the 2004-2007 vintages to include forecasts five years ahead. The historical dataset is available here: http://www.imf.org/external/pubs/ft/weo/data/WEOhistorical.xlsx
[15] The first vintage of our real-time dataset is from the year 2004 and therefore the first year for which we can calculate the revision in previous year output gap estimate is 2003 and the first year for which we can calculate the revision in the current year output gap estimate is 2004.

Table 4: Short-term and long-term revisions in real-time output gap estimates for 2003-2014 (absolute value, % of potential GDP)

(A) Twelve EU countries

	Short-term revision			**Long-term revision**		
	Previous year	Current year	Change from previous year to current year	Previous year	Current year	Change from previous year to current year
This paper	0.70	0.95	0.57	1.15	1.38	0.72
EC	0.80	0.72	0.57	1.23	1.52	0.83
IMF	0.76	0.91	0.53	1.61	2.03	0.86
OECD	0.87	0.90	0.63	2.26	2.66	0.85
HP (without forecasts)	0.75	0.89	0.61	1.56	2.24	1.05
HP (with forecasts)	0.79	0.80	0.57	1.31	1.81	0.96

(B) Five non-EU advanced countries

	Short-term revision			Long-term revision		
	Previous year	Current year	Change from previous year to current year	Previous year	Current year	Change from previous year to current year
This paper	0.57	0.76	0.51	0.76	0.93	0.57
EC	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*
IMF	0.66	0.72	0.53	1.03	1.16	0.61
OECD	0.66	0.70	0.52	1.19	1.42	0.71
HP (without forecasts)	0.51	0.66	0.57	0.94	1.39	0.77
HP (with forecasts)	0.67	0.64	0.50	0.93	1.18	0.72

Source: Bruegel. Note: the IMF spring WEOs are typically published in April, the European Commission's forecasts in May and the OECD Economic Outlooks in June of each year, and therefore they are not based on the same information set. Our model and the Hodrick-Prescott filter use IMF data and thereby our model has a slight informational disadvantage over the Commission's and OECD's estimates. Data in line "HP (without forecasts)" was calculated by estimating the Hodrick-Prescott filter up to the year of the data vintage (eg up to 2015 for the 2015 data vintage) and thereby includes a forecast only for the year of the data vintage made in spring. Data in line "HP (with forecasts)" was calculated by estimating the Hodrick-Prescott filter on data including forecasts five years ahead (eg up to 2020 for the 2015 data vintage) and thereby includes medium-term forecasts too. Unweighted averages are shown for twelve EU countries in panel A (Austria, Belgium, France, Finland, Germany, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and the United Kingdom) for 2003-2013 (previous year and the change from previous year to current year) and 2014-2014 (current year). The five non-EU countries considered in panel B are: Australia, Canada, Japan, New Zealand and the United States of America.

Panel A of Table 4 suggests that our model has better revision properties than the estimates of the three institutions and the Hodrick-Prescott filter, yet the improvement over the European Commission's estimates are relatively small, about 0.1 percentage point of GDP for the previous year estimates (our preferred indicator). The difference is broadly the same for the other two long-term revision measures (current year and the change from previous to current year), while the Commission estimates have the smallest revision in short-term current year output gaps, possibly suggesting that the Commission's current year forecasts are better than the forecasts of the IMF and the OECD.

Among the three institutions, the OECD estimates suffered from the greatest revisions. The IMF was slightly better than the Commission in the short-term revisions of previous year output gap and somewhat worse than the Commission in long-tern revisions in previous year estimates (our preferred measures).

It is also noteworthy that the Hodrick-Prescott (HP) filter revisions were quite similar to the revisions by the three institutions concerning the short-term revision of previous year output gap (in fact, both version of the HP filter lead to slightly lower revisions than the EC and OECD estimates). For long-term revisions the Commission's methodology is only marginally better than the HP filter (0.08 percent) considering the version which utilises forecasts, while the IMF is slightly worse and the OECD is significantly worse than the HP filter.

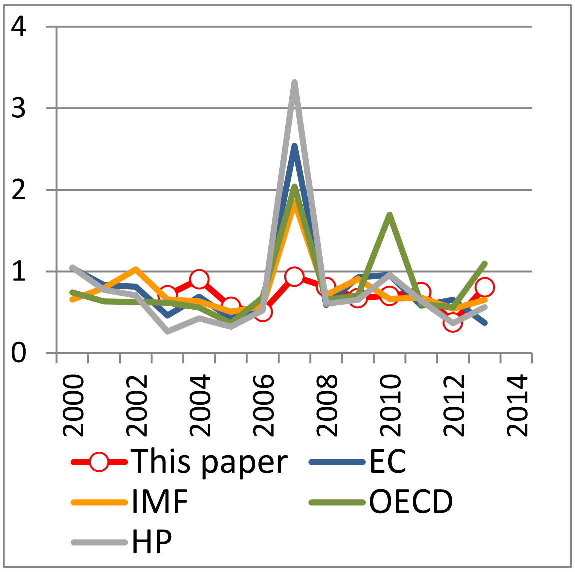
Results for five non-EU advanced countries are similar (Panel B of Table 4): the revision in previous year output gaps from our model is smaller than the IMF and OECD revisions. Interestingly, the Hodrick-Prescott filter has led to smaller short-term and long-term revision in previous year output gaps (our preferred indicators) than the IMF and OECD estimates, though the differences between the four models in terms of short-term revisions are minor. As regards the long-term revision indicators, our model has led to the smallest revisions.

While Table 4 compares the average results in 2003-14, Figure 11 shows revisions of each year's output gap for the average of the twelve countries.

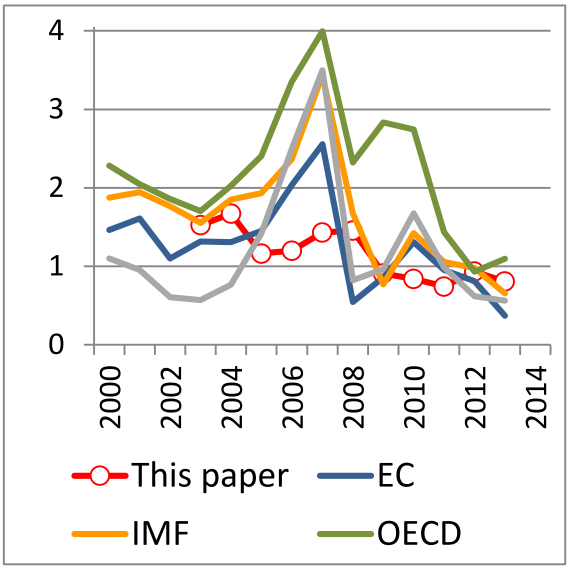
Figure 11: Short-term and long-term revisions in previous year output gap estimates (absolute value, % of potential GDP)

(A) Twelve EU countries

(A) Short-term: revision of previous year's output gap one year later

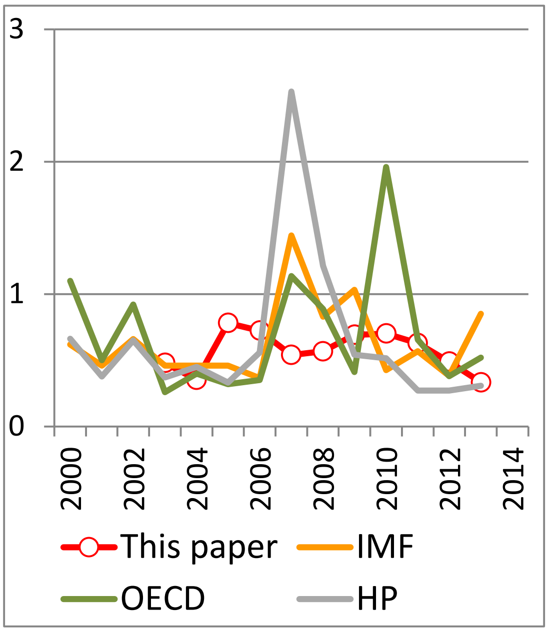


(B) Long-term: revision of previous year's output gap by spring 2015

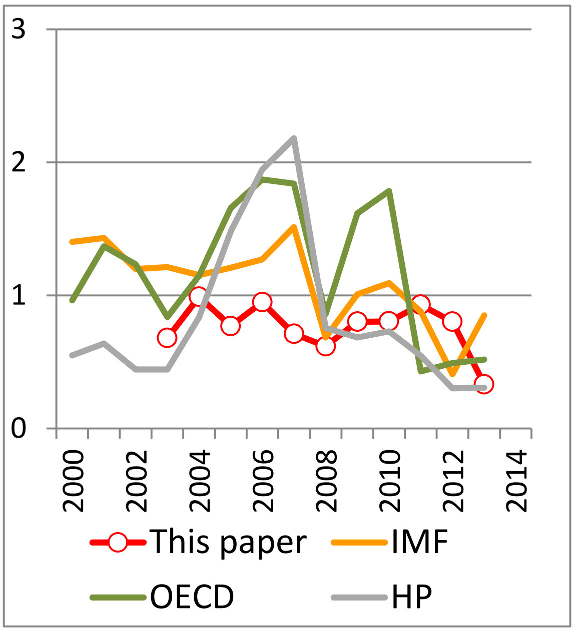


(B) Five non-EU advanced countries

(A) Short-term: revision of previous year's output gap one year later



(B) Long-term: revision of previous year's output gap by spring 2015



Source: Bruegel. Note: the IMF spring WEOs are typically published in April, the European Commission's forecasts in May and the OECD Economic Outlooks in June of each year, and therefore they are not based on the same information set. Our model and the Hodrick-Prescott filter use IMF data and thereby our model has a slight informational disadvantage over the Commission's and OECD's estimates. Unweighted country averages are shown for twelve EU countries on Panel A: Austria, Belgium, France, Finland, Germany, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and the United Kingdom. The five non-EU countries considered in panel B are: Australia, Canada, Japan, New Zealand and the United States of America.

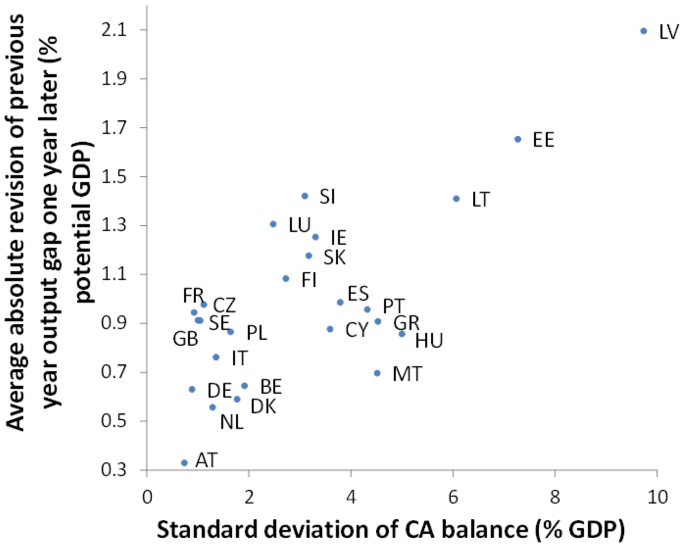
The most striking feature of Figure 11 is the large revisions by the three institutions' and the Hodrick-Prescott filter's estimates for 2007, while the revisions in our estimates around the crisis years were broadly similar to other years. This finding provides further support for our model.

Leaving aside the extraordinary years around 2008, there were still major revisions in both earlier and later years for all models. The typical short-term revision in previous year output gap is around 0.5-1.0 percent of potential output for all five estimates indicated in Figure 11, which is quite large in our view. Within this range, pre-crisis, the Hodrick-Prescott filter tended to result in the smallest revisions and our model the largest, while post-2008 the ranking of the methods vary from year to year.

These findings suggest that in 'normal' years, our model performs similarly to the methods of the three institutions in terms of short-term revisions, while our model is clearly superior around the crisis years.

Since the methodologies of the institutions consider each country as a closed economy, we also check if the size of output gap revisions is related to the variability of the current account balance. Figure 12 shows quite a strong association for European Commission estimates. For example, Austria (denoted by AT in the chart) had the smallest volatility of current account balance from 2004-13 and the revision of EC output gap estimates was also the smallest in this period. The largest volatility of the current account balance and the largest revision of the European Commission output gap estimate were observed for Latvia (denoted by LV).

Figure 11: Cross-country correlation between the variability of current account balance and the revisions of the previous year European Commission output gap estimates a year later, 2004-13



Source: Bruegel.

The correlation coefficient for the 25 countries included in Figure 12 is 0.75. The coefficient is the same 0.75 for the sub-group of the 10 newer member states that joined the EU in 2004, while it is 0.52 for the EU15 countries (EU members before 2004). The correlation coefficients are similar when considering the IMF, OECD and Hodrick-Prescott filter output gap revisions, as indicated in Table 5. In contrast, the correlation coefficient is close to zero for our model.

Table 5: Correlation coefficient between short-term output gap revisions and the variability of the current account balance (twelve EU countries, 2004-13)

	Previous year	Current year
This paper	0.13	0.06
EC	0.59	0.74
IMF	0.69	0.70
OECD	0.54	0.84
HP (without forecasts)	0.57	0.71
HP (with forecasts)	0.50	0.72

Note: Data in line "HP (without forecasts)" was calculated by estimating the Hodrick-Prescott filter up to the year of the data vintage (eg up to 2015 for the 2015 data vintage) and thereby includes a forecast only for the year of the data vintage made in spring. Data in line "HP (with forecasts)" was calculated by estimating the Hodrick-Prescott filter on data including forecasts five years ahead (eg up to 2020 for the 2015 data vintage) and thereby includes medium-term forecasts too.

This correlation underlines that our main conceptual innovation in relation to the definition of potential or sustainable output, contains in practice relevant information which is completely missing from the methodologies of the European Commission, IMF and OECD. This simple finding lends further support to our model.

5 Summary

This paper proposes a novel structural model to estimate the equilibrium level of output and reports results for 45 countries. The model is conceptually more appropriate than existing methods by incorporating open economy considerations, which are completely missing from the models of the European Commission, IMF and OECD.

In line with various theoretical models, our model recognises that the effect of excess demand is not symmetric across the tradeable and non-tradeable sectors, because foreign supply can fill the gap between demand and supply in the tradeable sector, but not in the non-tradeable sector. Excess domestic demand may manifest itself in the deterioration of the trade balance, parallel to, or even without, the increase in inflation. A shortage of domestic demand would lead to an 'excess trade surplus', *ceteris paribus*. Excess demand of the rest of the world (relative to the supply of the rest of the world) has implications for domestic inflation and trade balance. These effects work in any economy in which foreign trade is not completely restricted, be it large or small. However, a standard Phillips curve (or a NAIRU/NAWRU) formulation cannot capture these effects and therefore we use a model incorporating both a Phillips curve and a current account equation.

Using an unobserved components model and the classical maximum likelihood estimation technique, we estimate our model for 45 countries. We find that the current account equation is more important in determining the sustainable level of output than the Phillips curve. The key coefficient of the output gap in the current account equation has the correct estimated sign for all 45 countries in our sample and is statistically significant for almost all of them, while the output gap parameter in the Phillips curve has an incorrect sign for one-third of the countries and is hardly significant.

Our output gap estimates are markedly different from the estimates of European Commission, IMF, OECD and the results of the Hodrick-Prescott filter. For example, we find that the United States had a growing positive output gap before 2007 and the output fall during the global financial and economic crisis just brought the US economy back to potential, but did not lead to a negative output gap. For Germany we find a persistent positive output gap after reunification and a growing negative output gap from the mid-2000s. The latter development also characterises Denmark and Sweden, in contrast to the output gap estimates of the institutions. For Greece we find that the contraction of sustainable output preceded the fall in actual and did not follow it, as the intuitions and the Hodrick-Prescott filter estimate. We also find that the Greek output gap was small in recent years, in contrast to the large negative output gap results of the three institutions and the Hodrick-Prescott filter. For Ireland, Portugal and Spain, our estimates of sustainable output suggest a broadly stable potential output during the crisis years and an increase more recently, which is in line with the fast-growing export performance of these countries. In contrast, the European Commission's potential output estimates follow an inverted U-shape, with potential output continuing to increase during the crisis years, then gradually turning into a decline. While by definition potential or sustainable output is not known, we regard most of our estimates as more sensible from an economic perspective than the estimates of the European Commission, IMF and OECD.

We assemble a comprehensive real-time dataset in order to test our model on data that was available in each year from 2004-15. We find that our model was able to identify correctly the sign of the output gap in the pre-crisis period in real time for countries including the United States, Spain and Ireland, in contrast to the estimates of the European Commission, IMF and OECD, which estimated negative output gaps real-time, while their current estimates for the pre-crisis period suggest positive output gaps.

By systematically analysing the revisions of output gap estimates, we find that our model was clearly superior to the estimates of the three institutions and the Hodrick-Prescott filter around the crisis years. A likely reason for that is that our current account gap indicator can be estimated reliably real-time, meaning that the real-time estimated sign is correct and the estimate was subject to minor revisions when new data became available. But this is not the case with the NAWRU, a key ingredient of the

European Commission's model. We estimate the equilibrium current account balance in a panel-regression framework using four decades of data for 65 countries and thereby our estimates are not much affected by possible unsustainable developments in some countries towards the end of the sample period. In contrast, the European Commission estimates the NAWRU for each country separately in a simple statistical framework, which can be significantly influenced by developments in the last few years of the sample period. We remain sceptical whether a more robust NAWRU methodology could be developed. Furthermore, the European Commission, and most likely the IMF and OECD too, use various smoothing algorithms: the results of such algorithms are bound to be revised when the trends in the data change substantially.

Putting aside the crisis years, the annual revision of our output gap estimates is broadly similar to the revisions in the estimates of the European Commission, IMF, OECD and Hodrick-Prescott filter for advanced countries: the typical yearly revision in the output gap estimate is in the range of 0.5-1.0 percent of GDP for all five methods, which is large in our view.

We also find that the size of European Commission, IMF, OECD and Hodrick-Prescott output gap revisions are significantly correlated with the variability of the current account balance, while the revisions in our model estimates do not correlate. This suggests that important information is not utilised by the institutions when they estimate potential output.

Certainly, revision of an estimate when new data becomes available is quite natural and small revisions do not necessarily mean that an estimate is 'reliable' in an economic sense. For example, very small revision can be achieved when the potential output estimate is very close to actual output and thereby the variance of the output gap is very small (eg the Hodrick-Prescott filter with a very low smoothing parameter would lead to such results). Being subject to small revisions, such an estimate would not be informative about the cyclical state of the economy. Yet the major revisions of output gap estimates is a major cause for concern, because output gap estimates are used for real-time fiscal and monetary policymaking. In particular, in the European Union fiscal adjustment requirements are expressed in terms of the structural budget balance estimate, which in turn depends on the output gap estimates. Therefore, imprecision in output gap estimates can translate into poorly grounded fiscal policy recommendations.

We hope that our work will help the European Commission, IMF and OECD to realise the importance of the open economy considerations, and will encourage them to incorporate such considerations into their potential output models.

Our model could also be developed further. For example, more sophisticated state equations could be tried. A structural model for the equilibrium real exchange rate could be incorporated instead of the Hodrick-Prescott filter that we currently use. Our model for the equilibrium current account balance could be refined. World potential output could be calculated by weighting our country-specific estimates and then iterating the model. The Phillips curve could be improved by using the core inflation rate instead of the all-items inflation rate and by the incorporation of the Balassa-Samuelson effect. Our sustainable output model could be estimated in a panel framework by assuming some parameters to be the same for certain countries. And instead of relying on external estimates for the current account equilibrium and the equilibrium real exchange rate, a larger model could be set up to estimate all unobserved variables jointly. These issues are left for future research.

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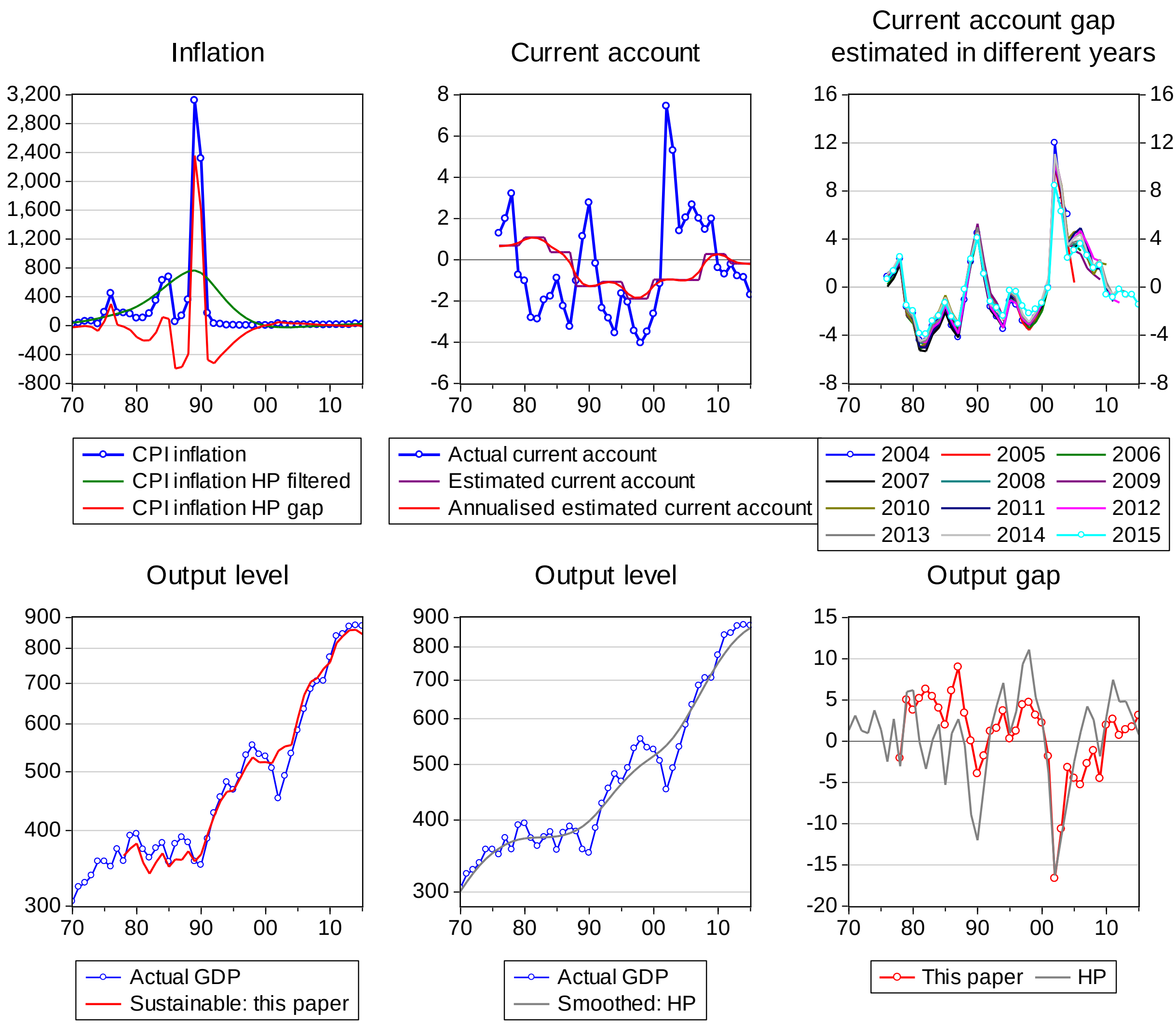
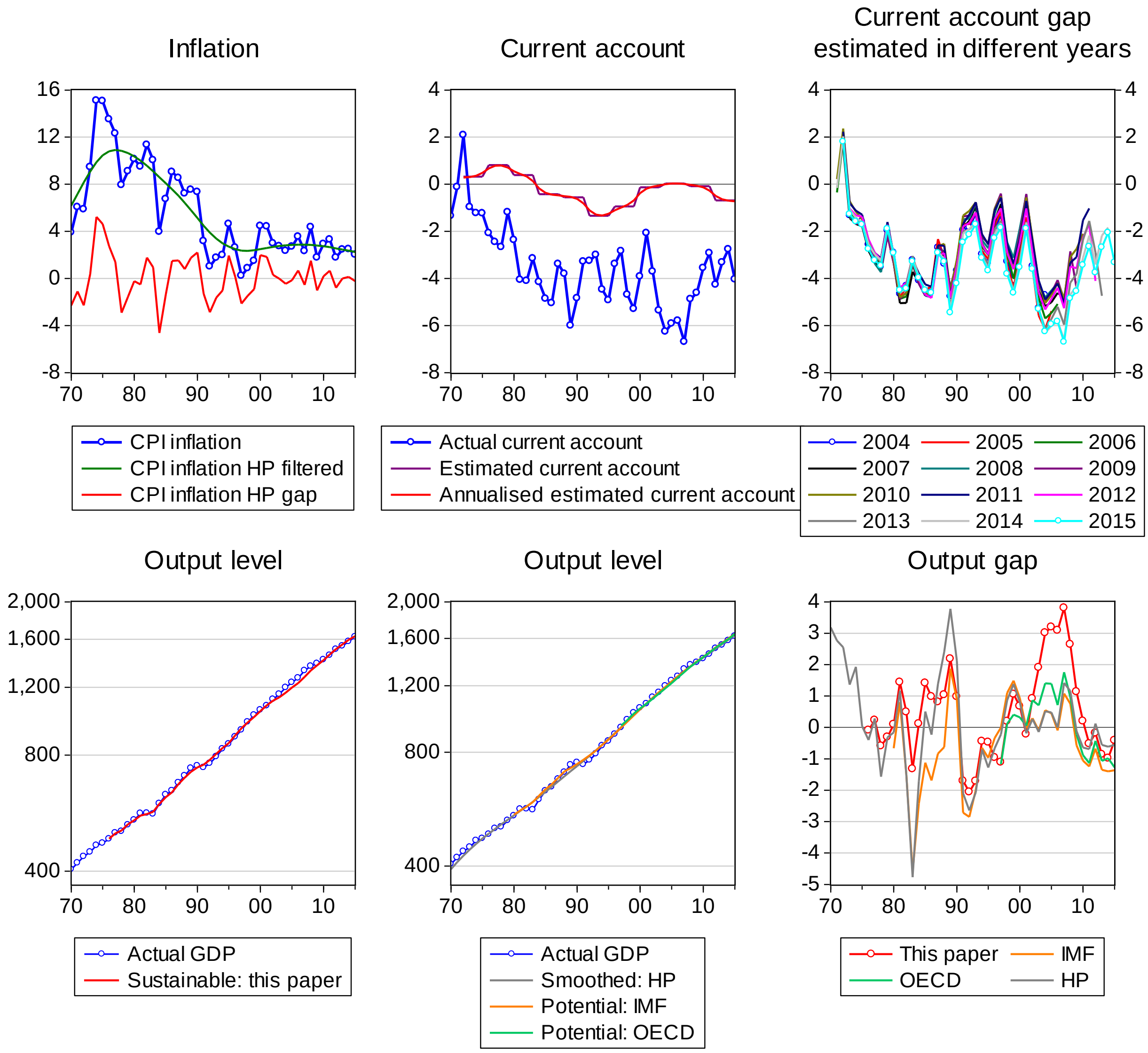
Annex: Results for 45 countries

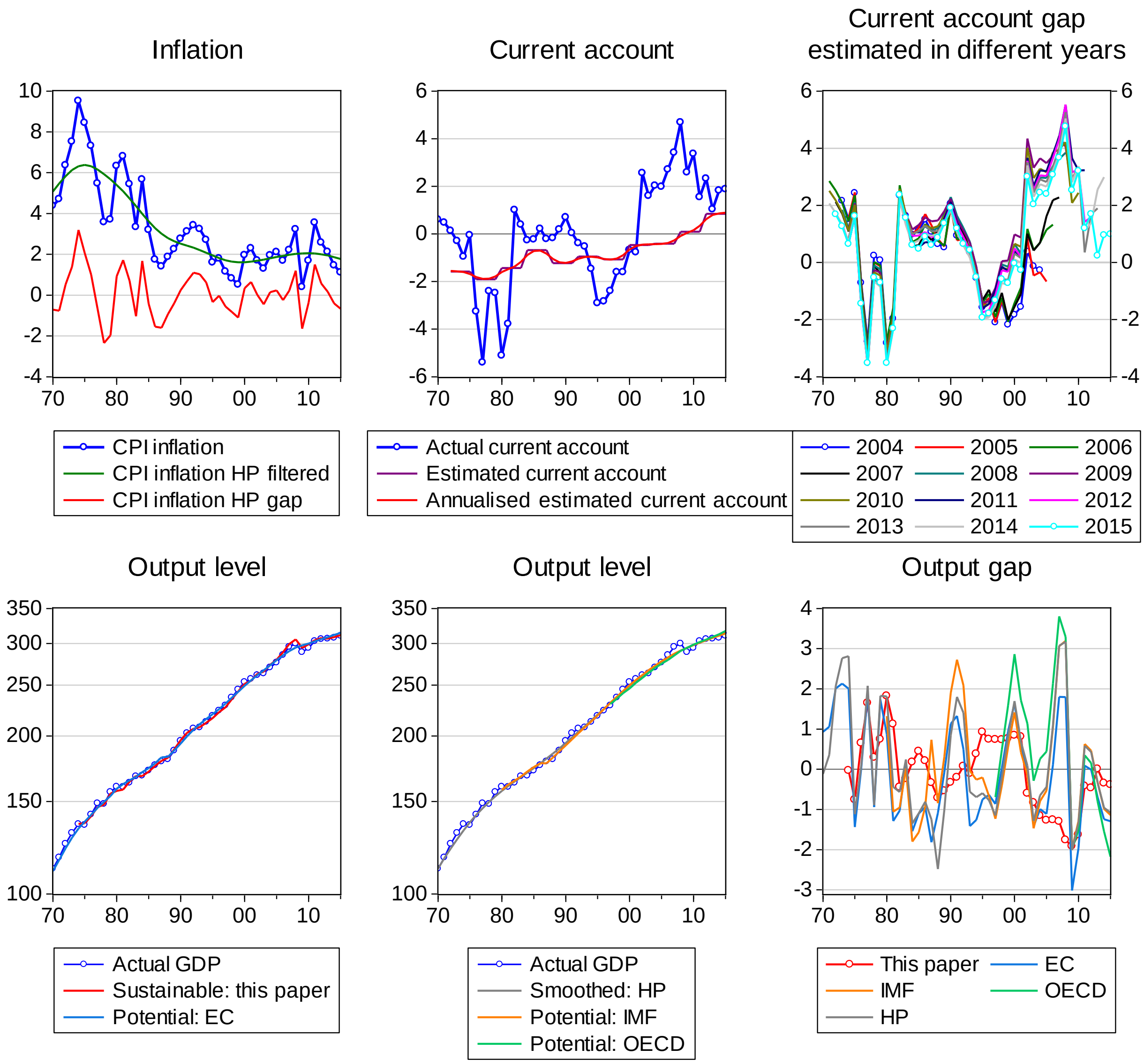
Argentina



Australia


Inflation
Current account
Current account gap estimated in different years
16
12
8
4
0
-4
-8
70
80
90
00
10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Output level
Output gap
2,000
1,600
1,200
800
400
Actual GDP
Sustainable: this paper
Smoothed: HP
Potential: IMF
Potential: OECD
This paper
IMF
OECD
HP

Austria


Inflation
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Current account gap
estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004
2005
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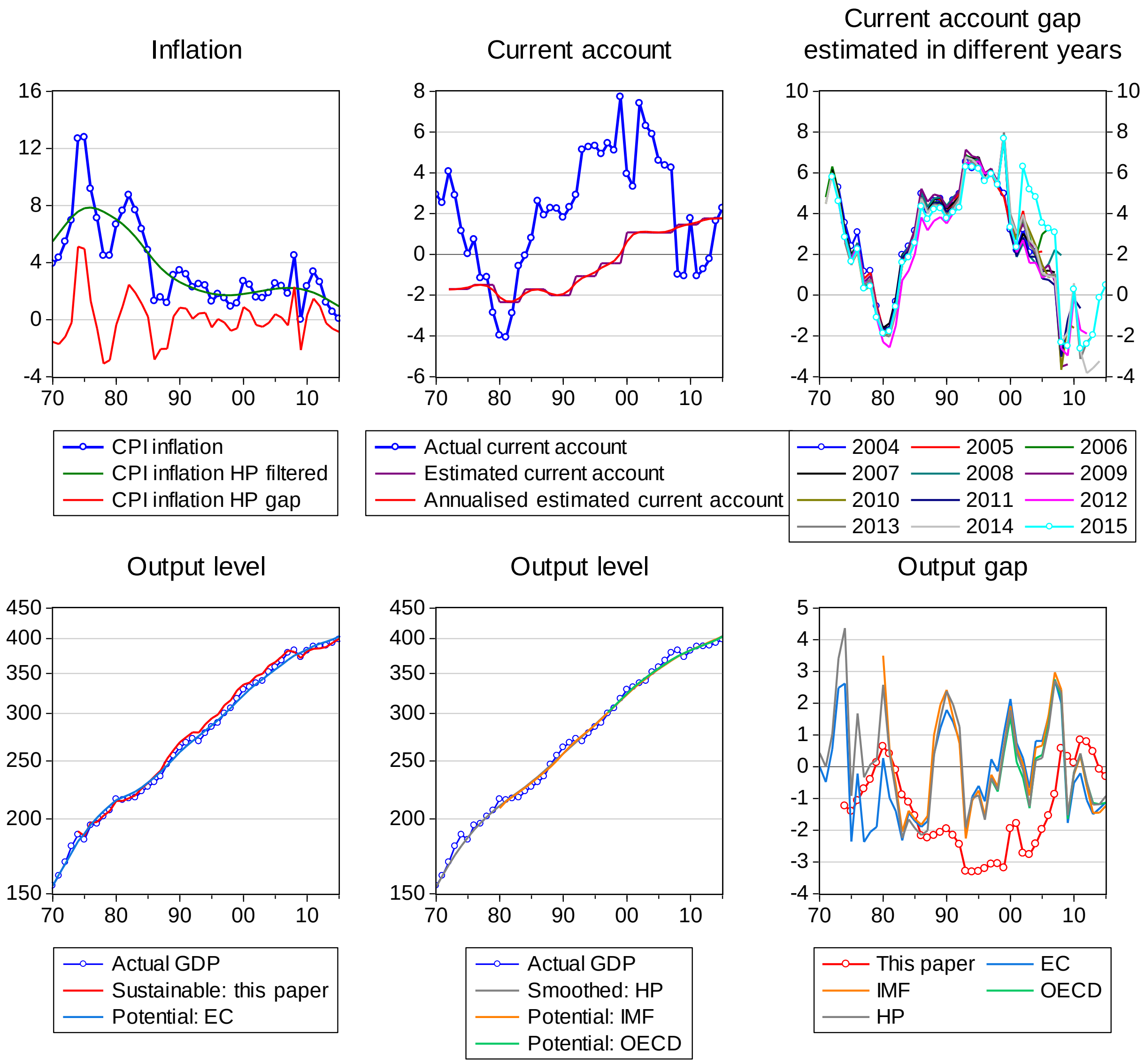
2007
2008
2009
2010
2011
2012
2013
2014
2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
This paper
EC
IMF
OECD
HP
70
80
90
00
10

Belgium



Inflation
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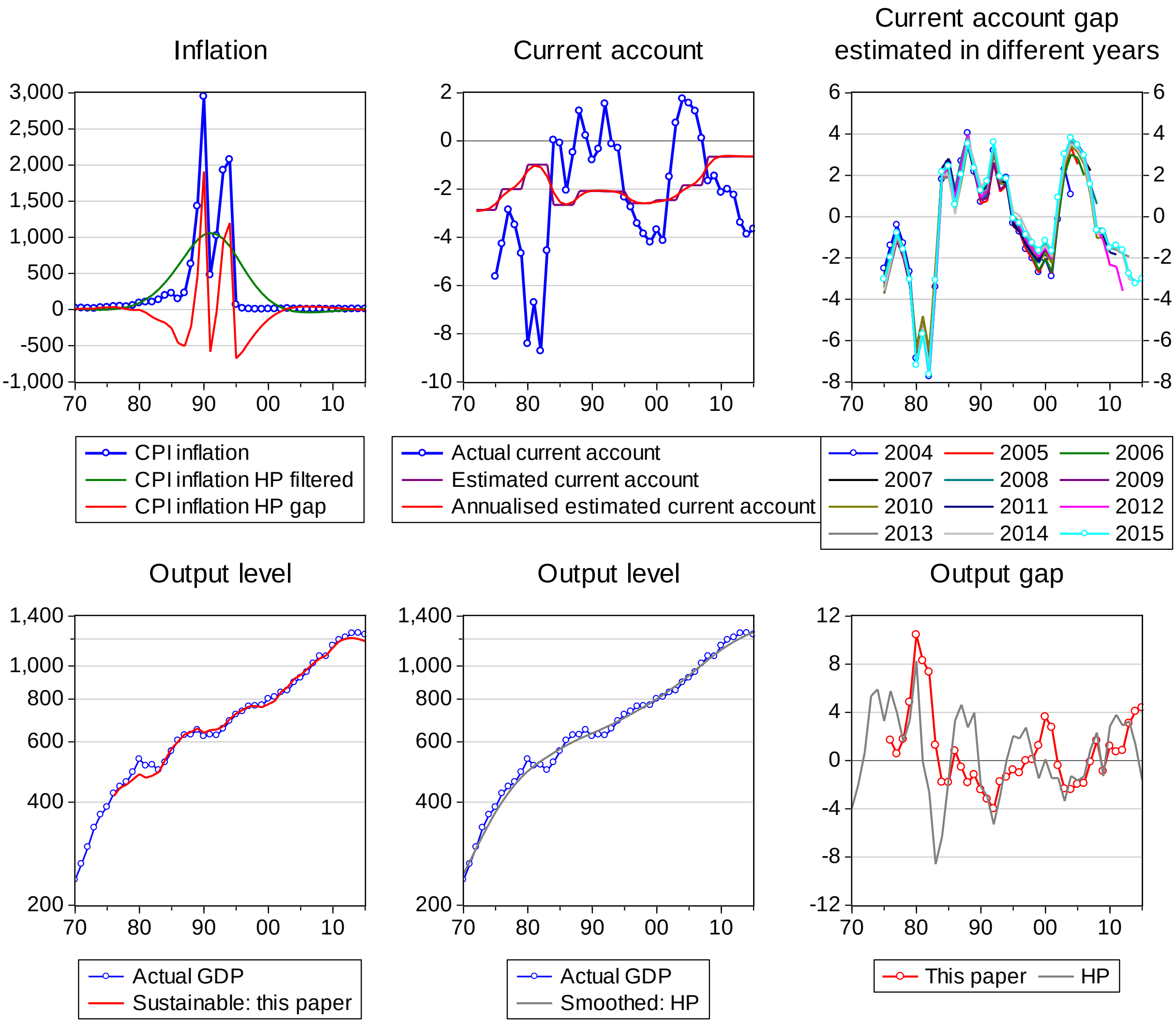
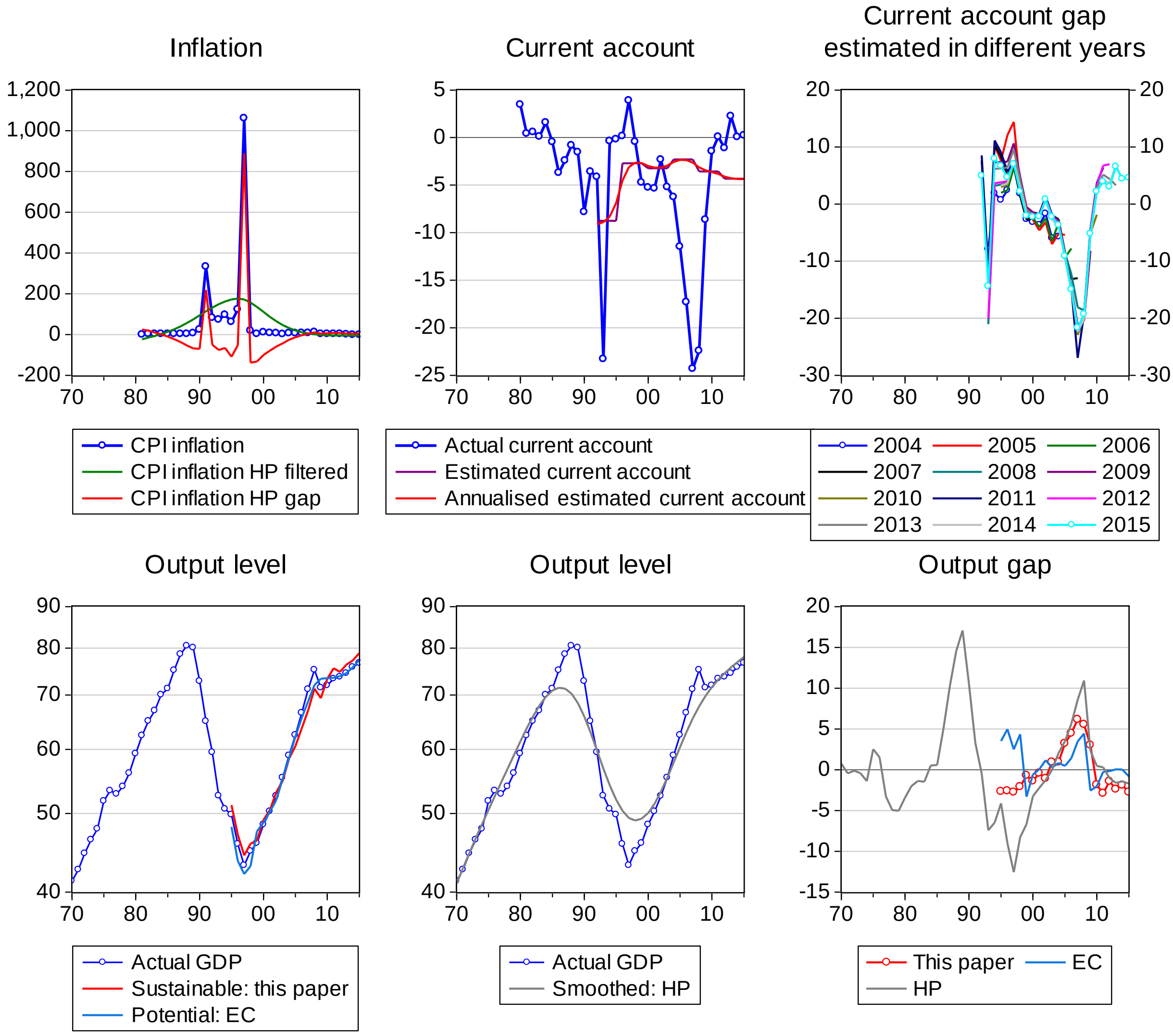
Current account gap estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
This paper
EC
IMF
OECD
HP

Brazil


Inflation
3,000
2,500
2,000
1,500
1,000
500
0
-500
-1,000
70 80 90 00 10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
2
0
-2
-4
-6
-8
-10
70 80 90 00 10
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
6
4
2
0
-2
-4
-6
-8
70 80 90 00 10
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
1,400
1,000
800
600
400
200
70 80 90 00 10
Actual GDP
Sustainable: this paper
Output level
1,400
1,000
800
600
400
200
70 80 90 00 10
Actual GDP
Smoothed: HP
Output gap
12
8
4
0
-4
-8
-12
70 80 90 00 10
This paper
HP

Bulgaria


Inflation
Current account
Current account gap
estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
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2014
2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
This paper
EC
HP
1,200
1,000
800
600
400
200
0
-200
70
80
90
00
10
5
0
-5
-10
-15
-20
-25
20
10
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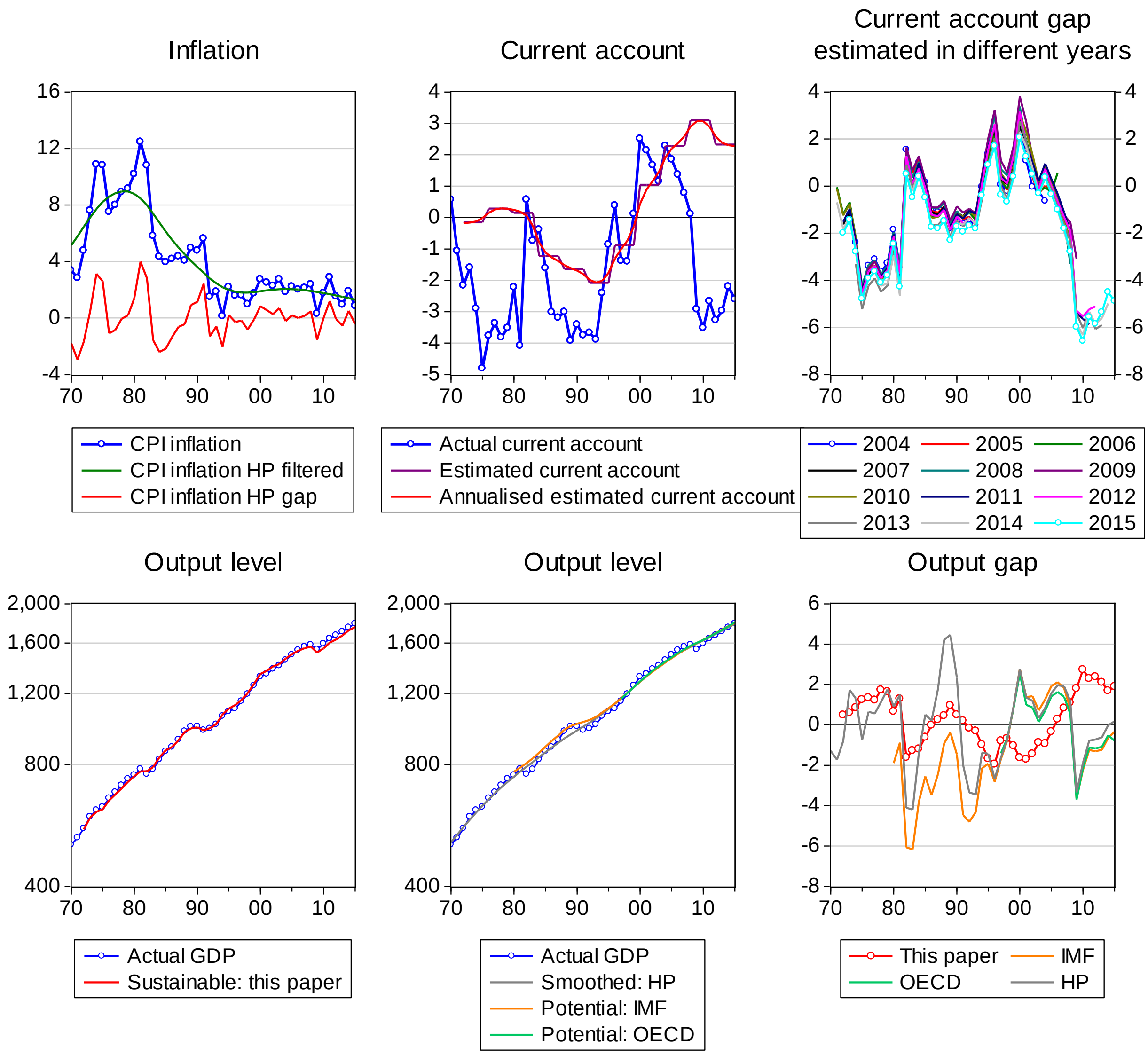
-10
-20
-30
90
80
70
60
50
40
15
5
-5
-15

Canada



Inflation
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-4
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80
90
00
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CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
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3
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1
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-1
-2
-3
-4
-5
Actual current account
Estimated current account
Annualised estimated current account
Current account gap
estimated in different years
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2004
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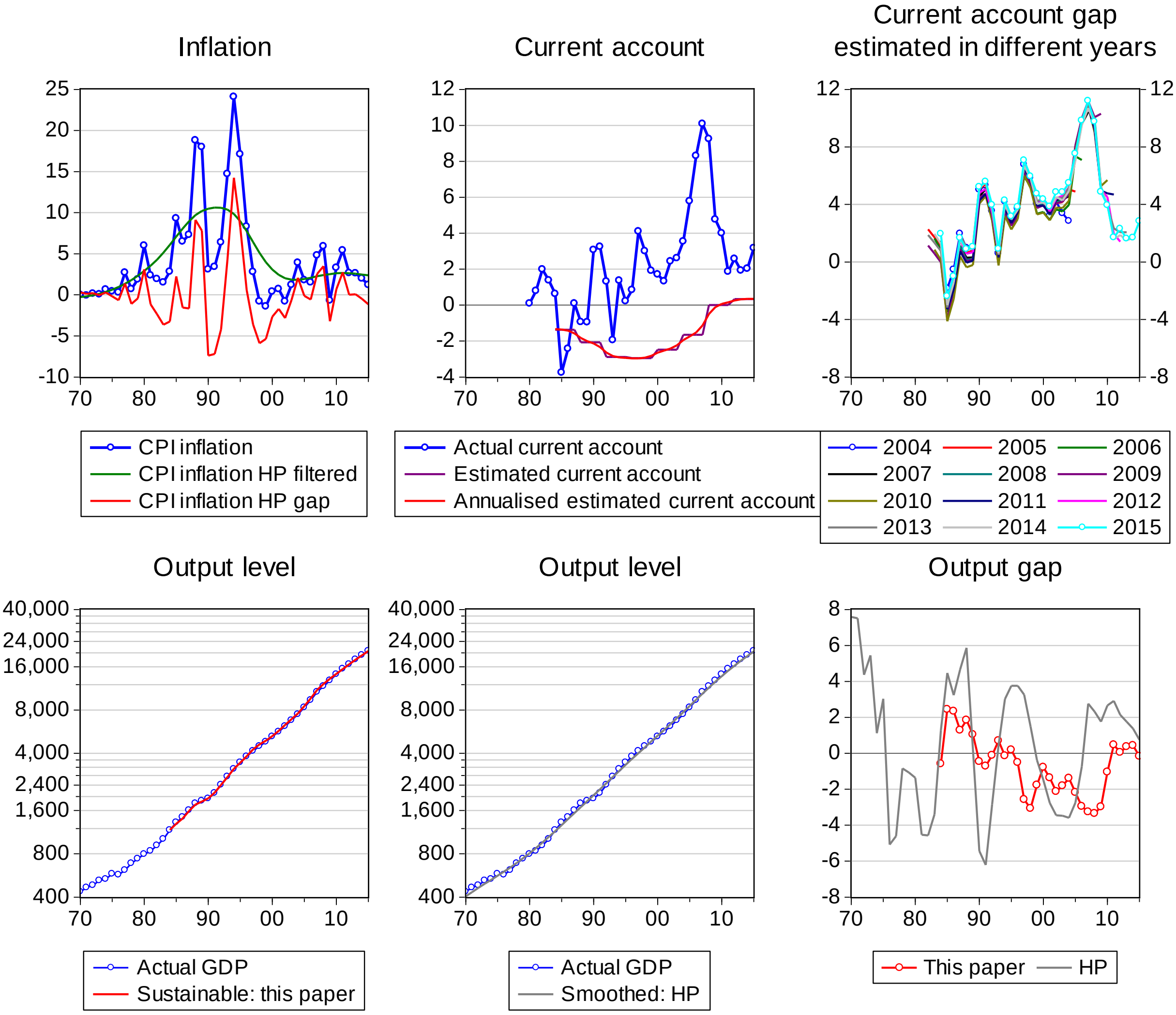
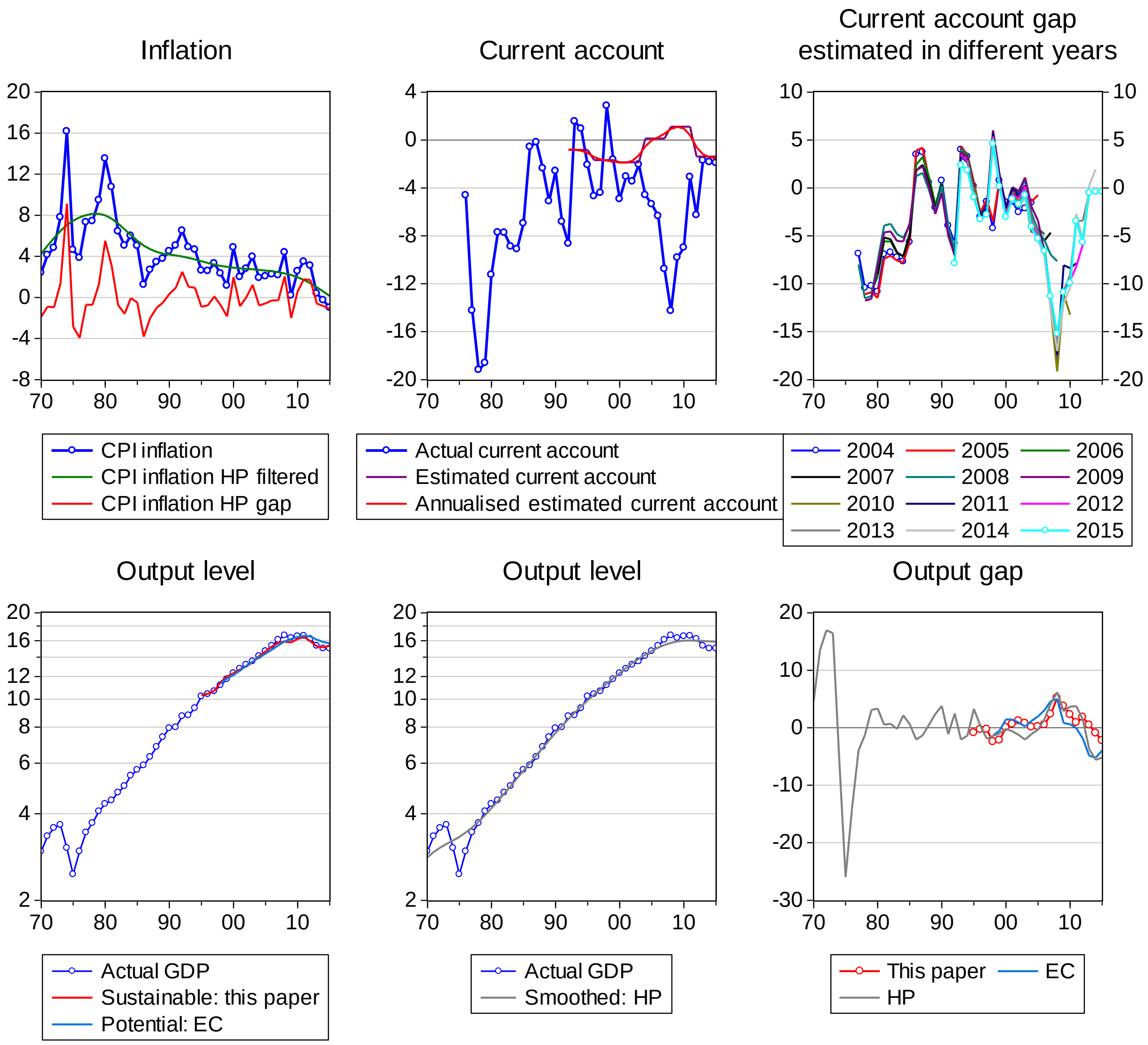
2015
Output level
2,000
1,600
1,200
800
400
Actual GDP
Sustainable: this paper
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
6
This paper
IMF
OECD
HP

China, P.R.: Mainland



Cyprus


Inflation
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70 80 90 00 10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
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-4
-8
-12
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-20
70 80 90 00 10
Actual current account
Estimated current account
Annualised estimated current account
Current account gap
estimated in different years
10
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-5
-10
-15
-20
70 80 90 00 10
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
20
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12
10
8
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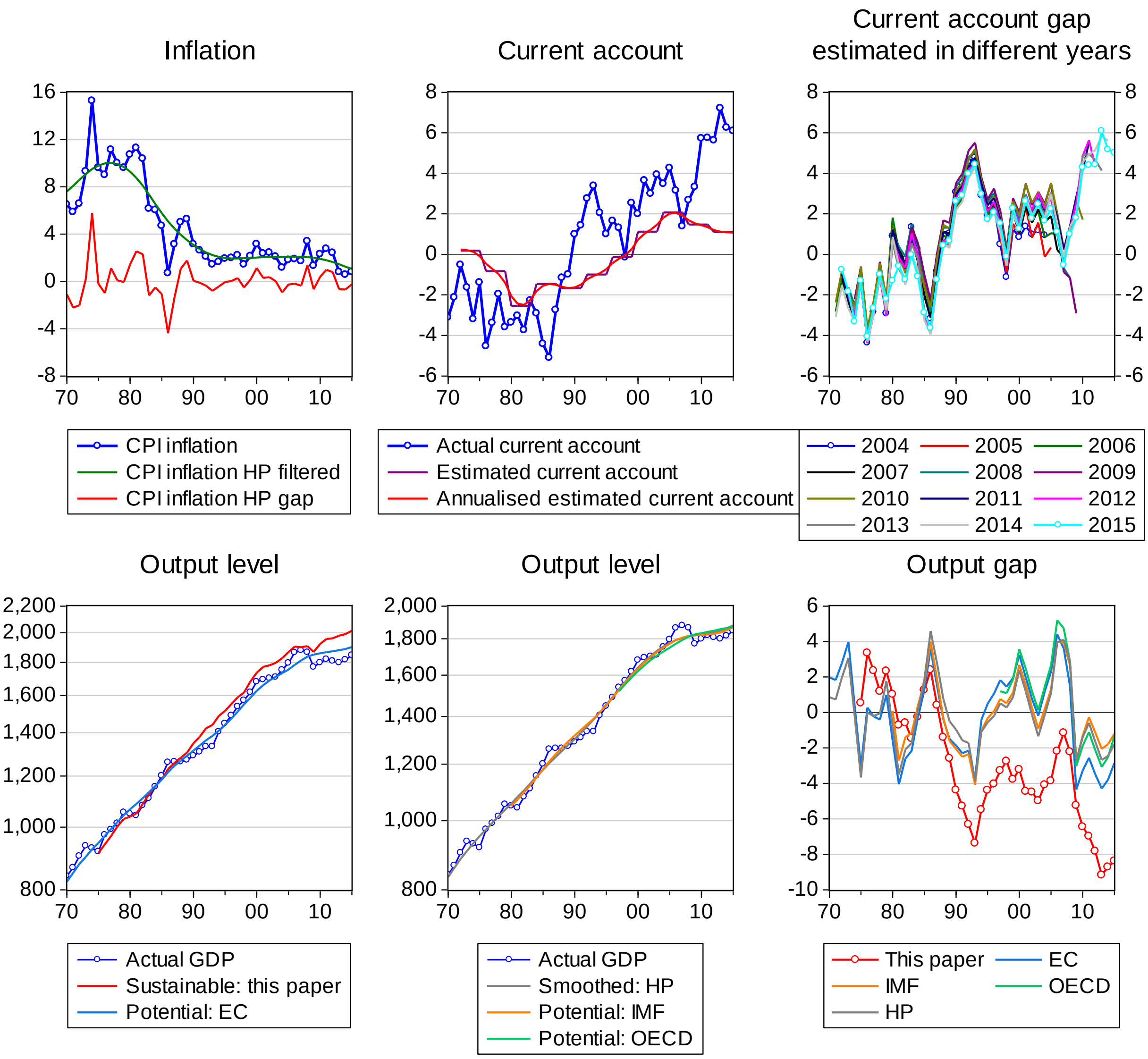
2
70 80 90 00 10
Actual GDP
Sustainable: this paper
Potential: EC
Output level
20
16
12
10
8
6
4
2
70 80 90 00 10
Actual GDP
Smoothed: HP
Output gap
20
10
0
-10
-20
-30
70 80 90 00 10
This paper
EC
HP

Denmark


Inflation
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
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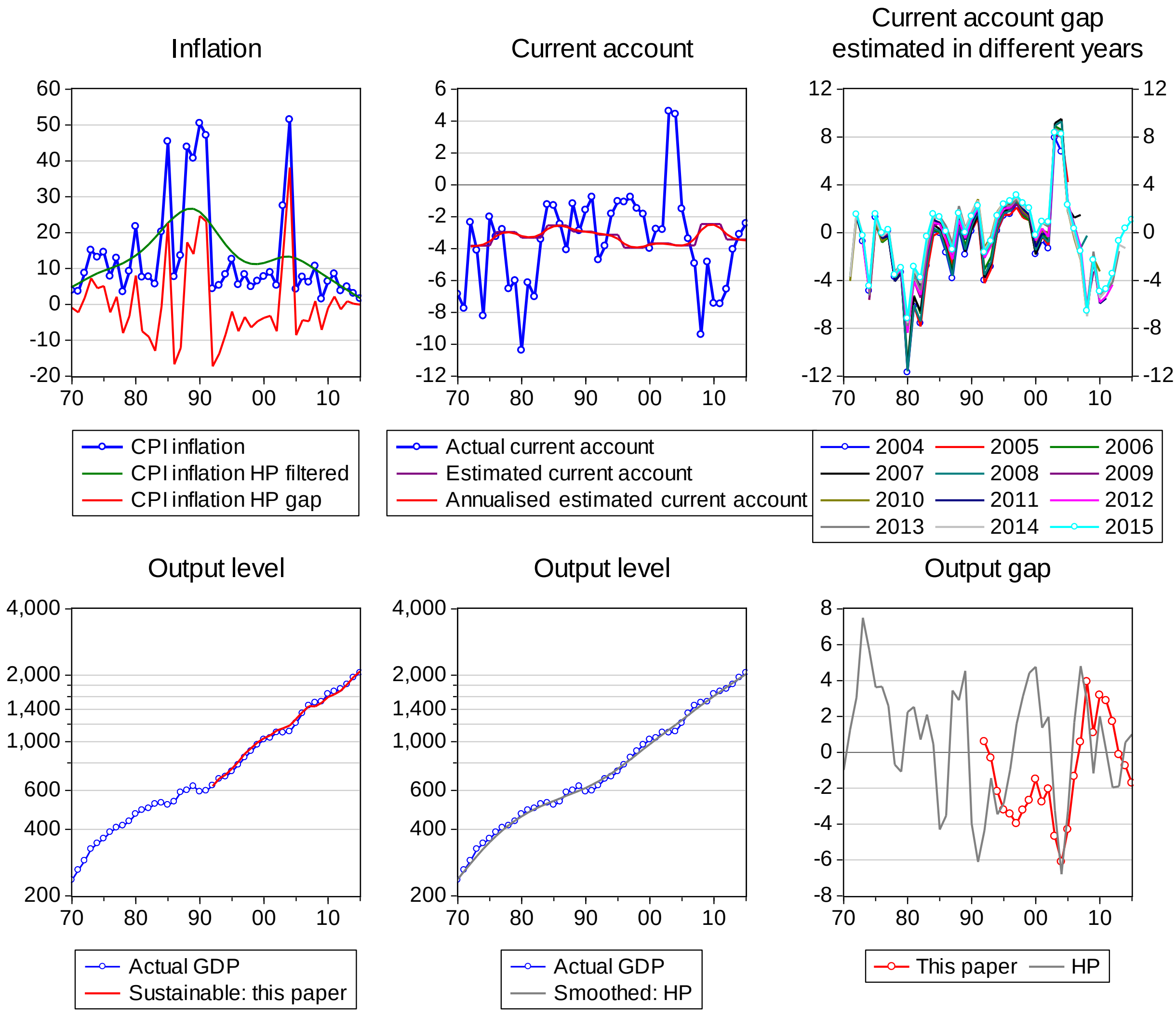
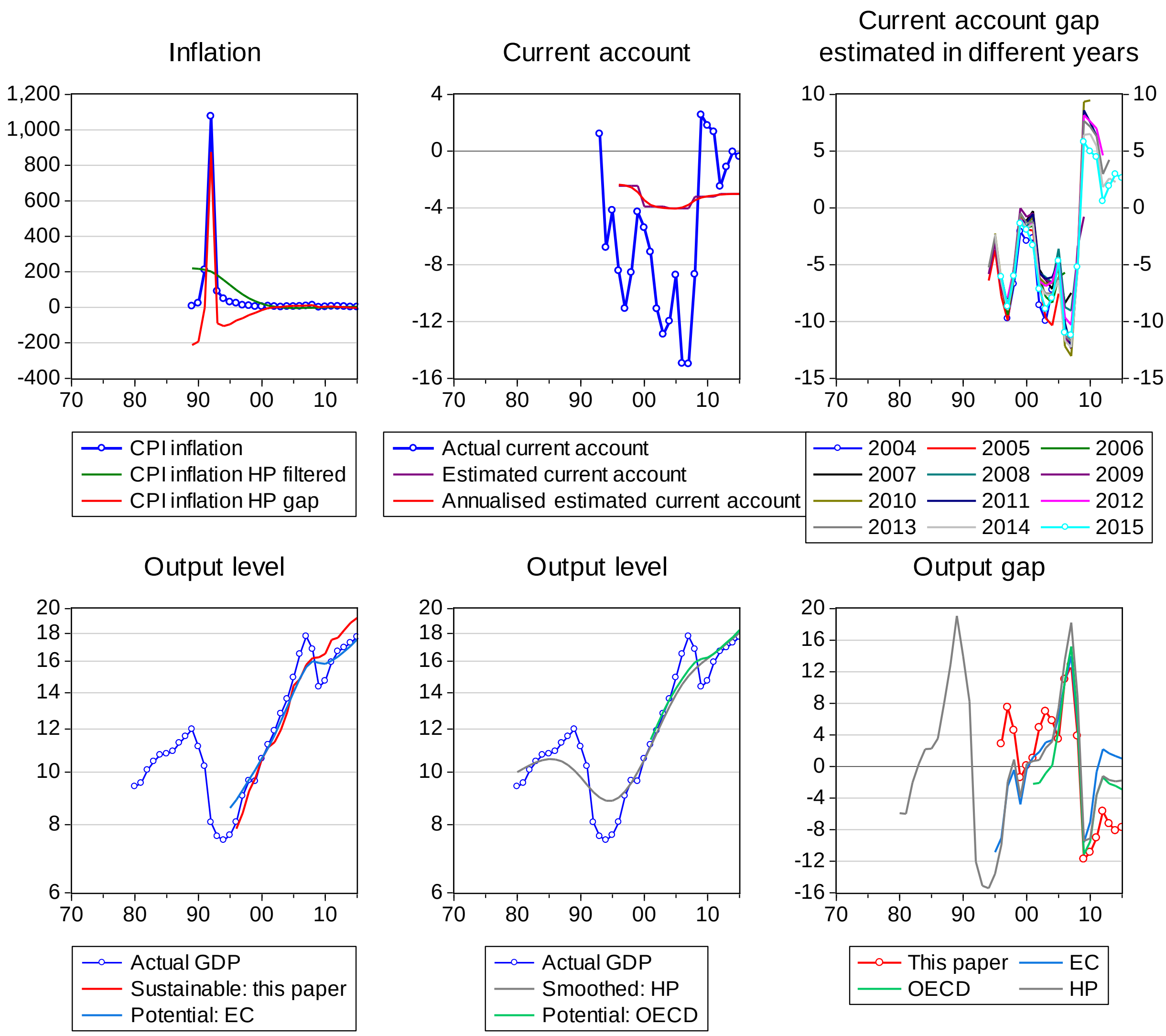
2015
Output level
Actual GDP
Sustainable: this paper
Potential: EC
Output level
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
This paper
EC
IMF
OECD
HP

Dominican Republic



Estonia


Inflation
Current account
Current account gap estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
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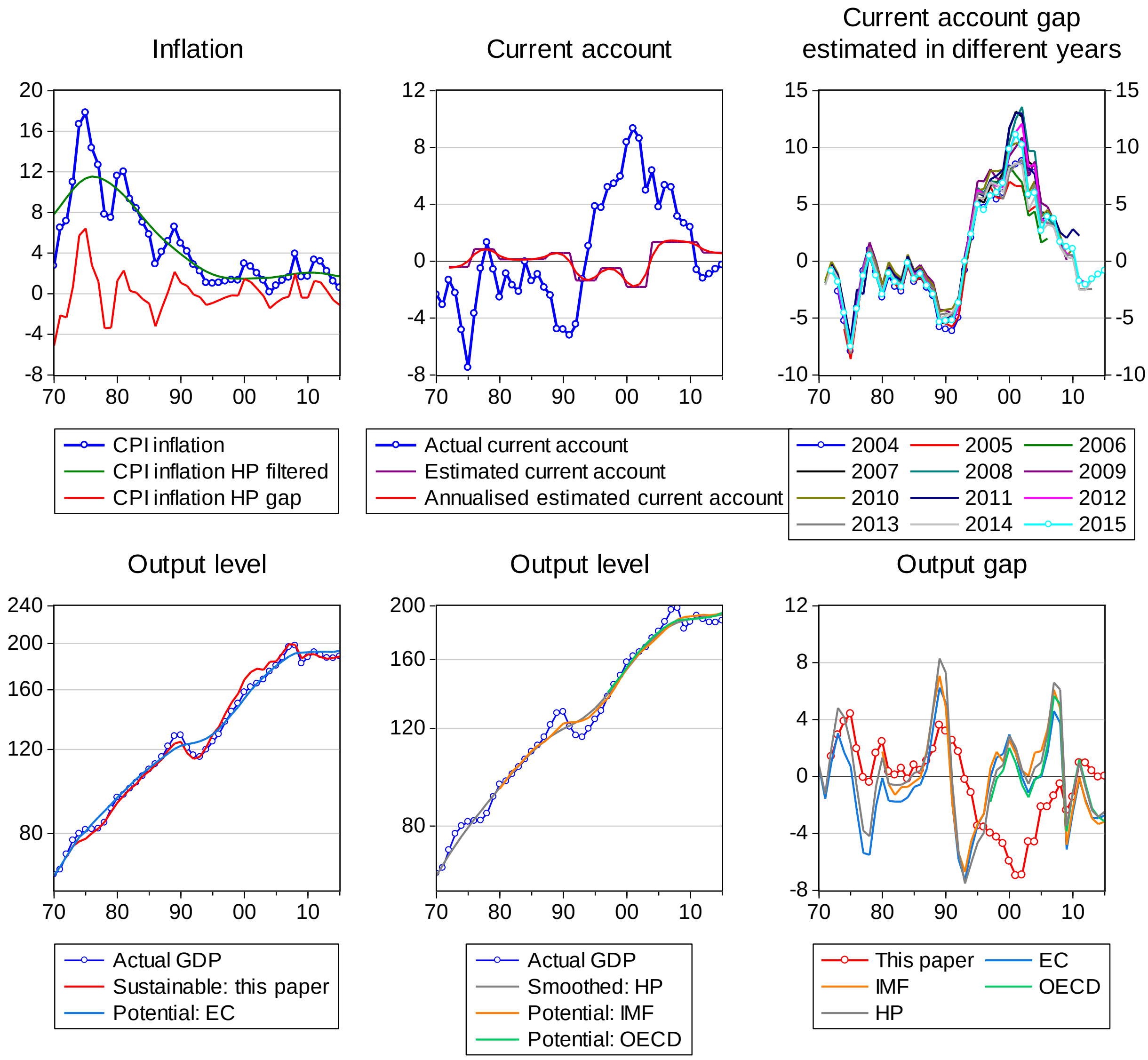
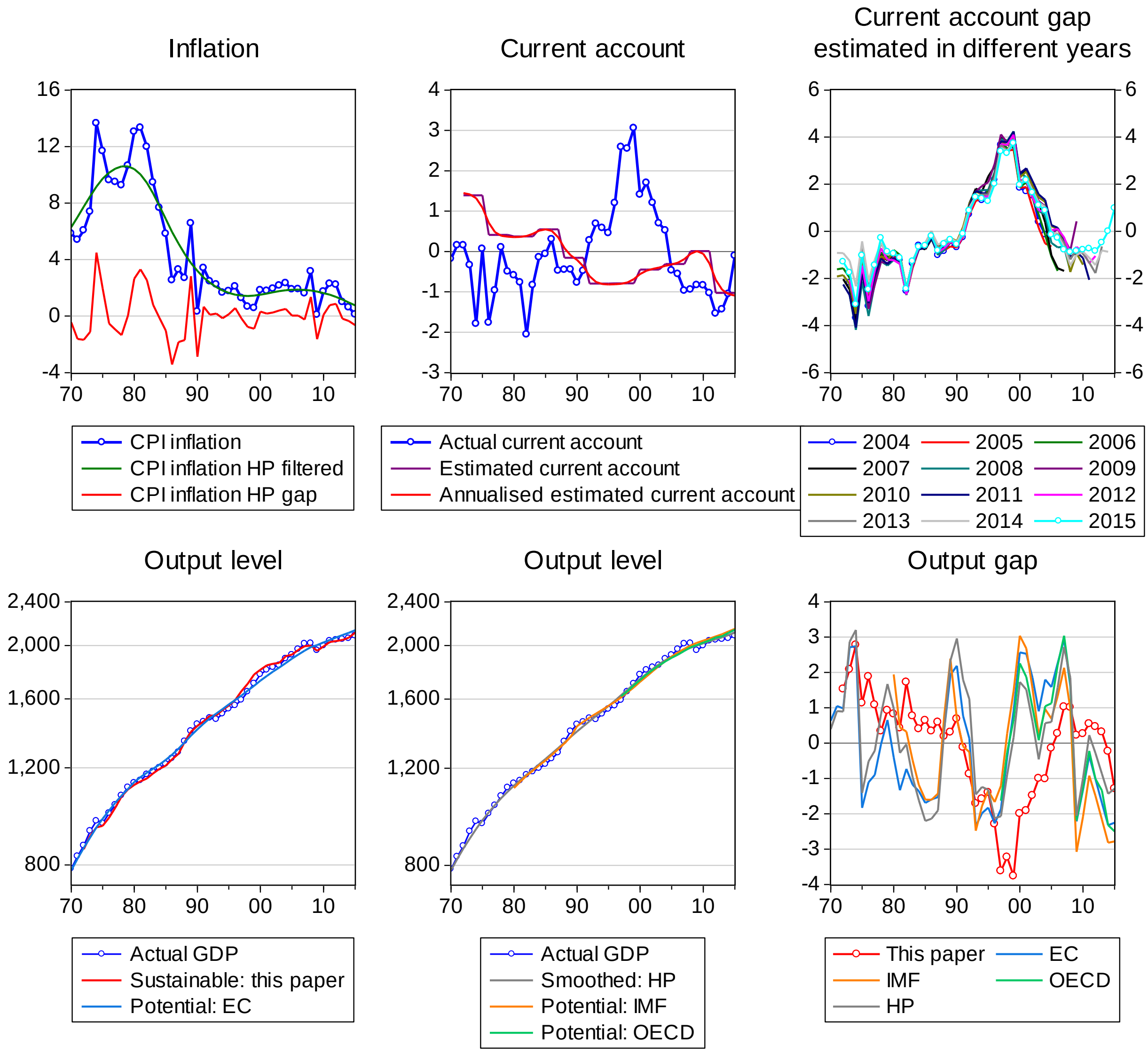
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
Potential: OECD
This paper
EC
OECD
HP

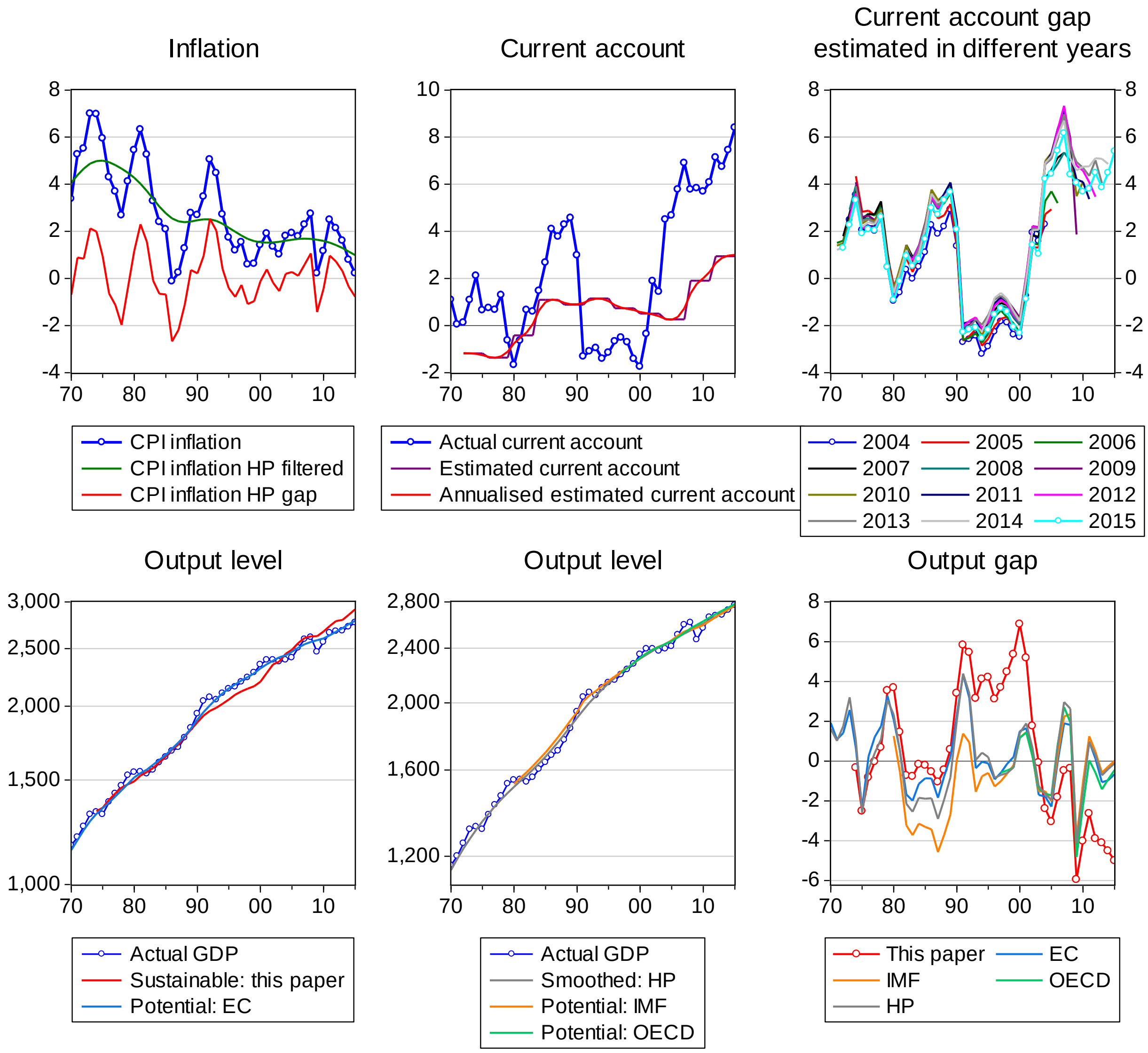
Finland


Inflation
Current account
Current account gap estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
This paper
EC
IMF
OECD
HP

France


Inflation
Current account
Current account gap estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
This paper
EC
IMF
OECD
HP

Germany


Inflation
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
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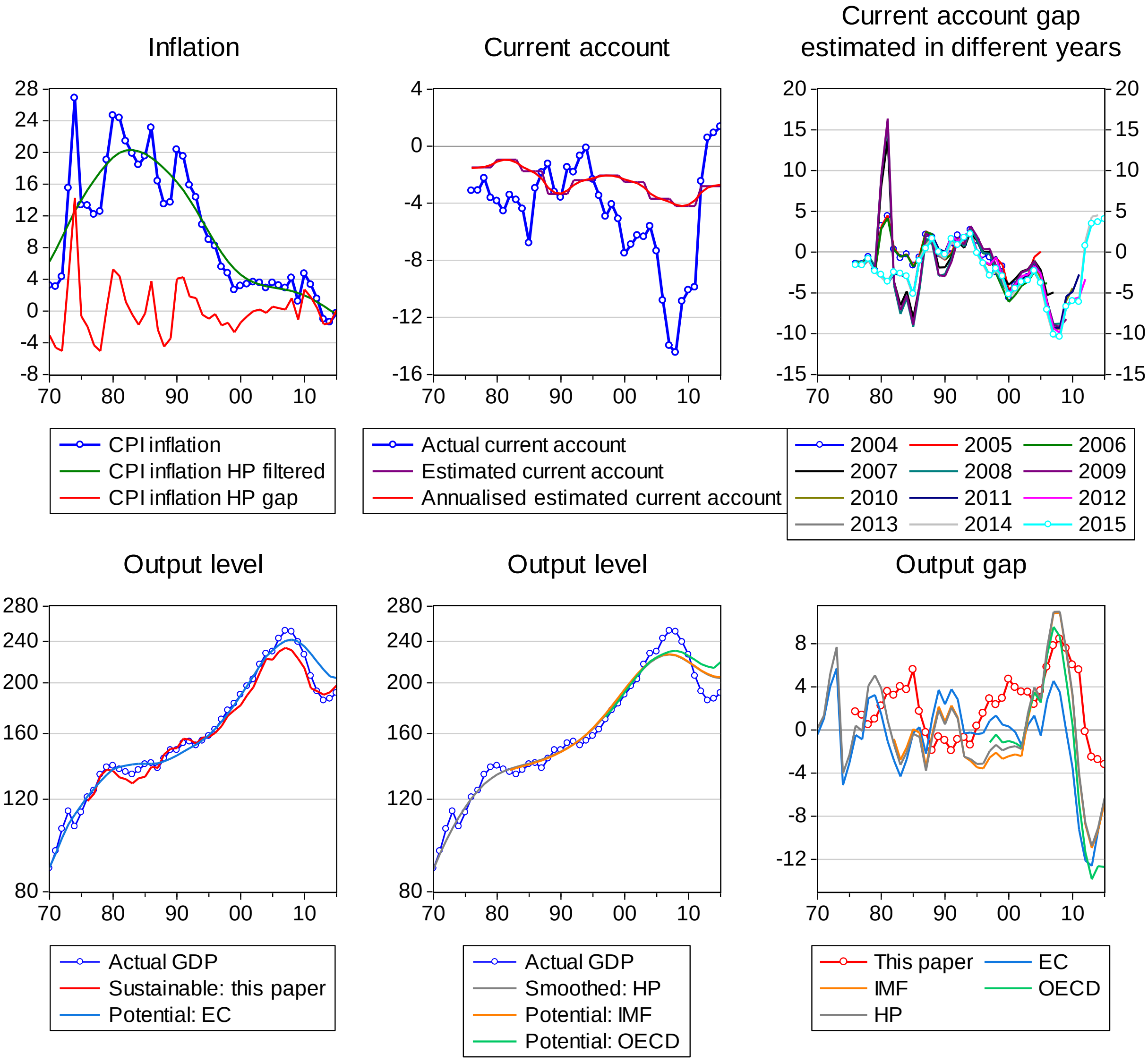
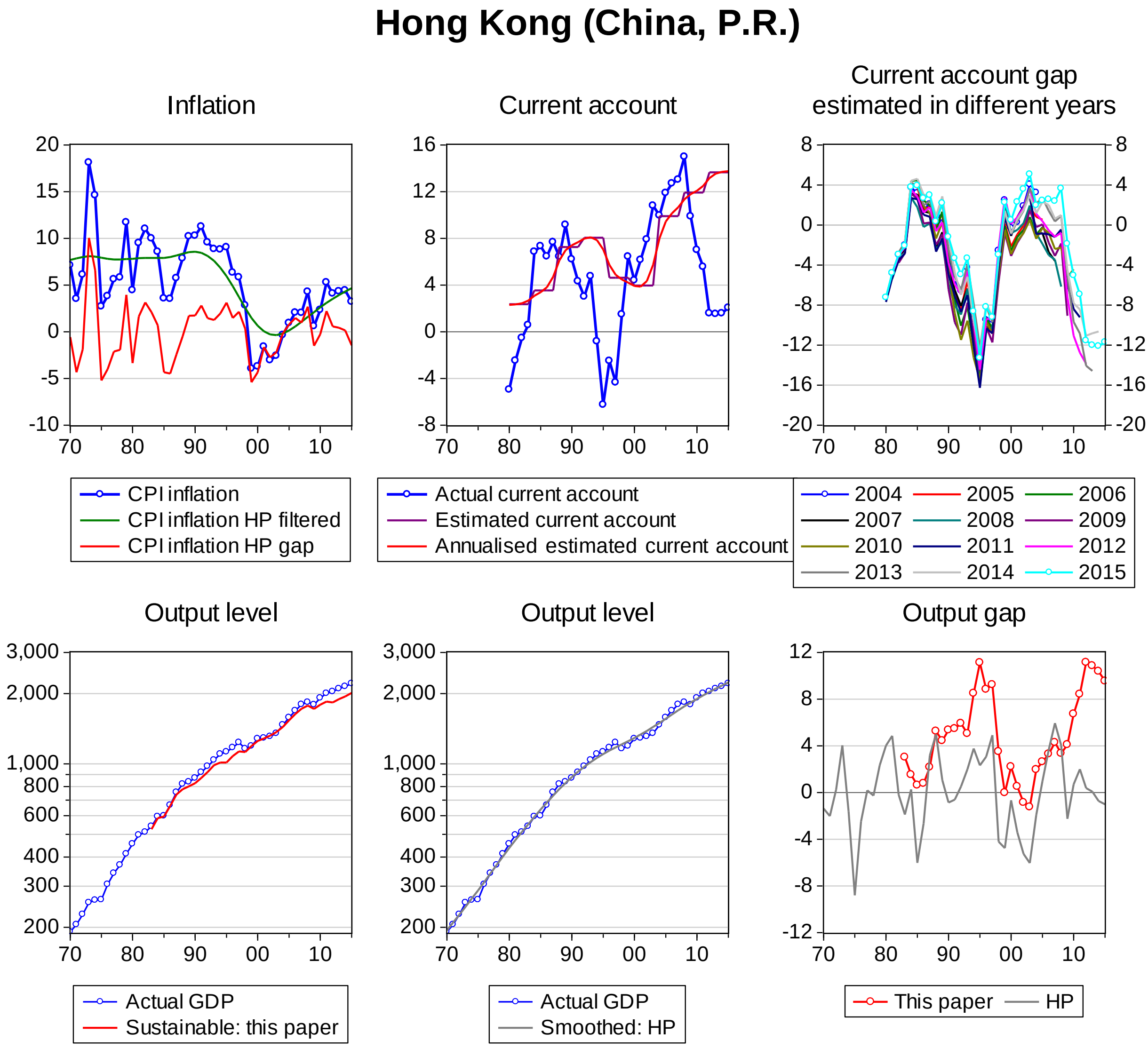
Output level
Actual GDP
Sustainable: this paper
Potential: EC
Output level
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
This paper
EC
IMF
OECD
HP
70
80
90
00
10

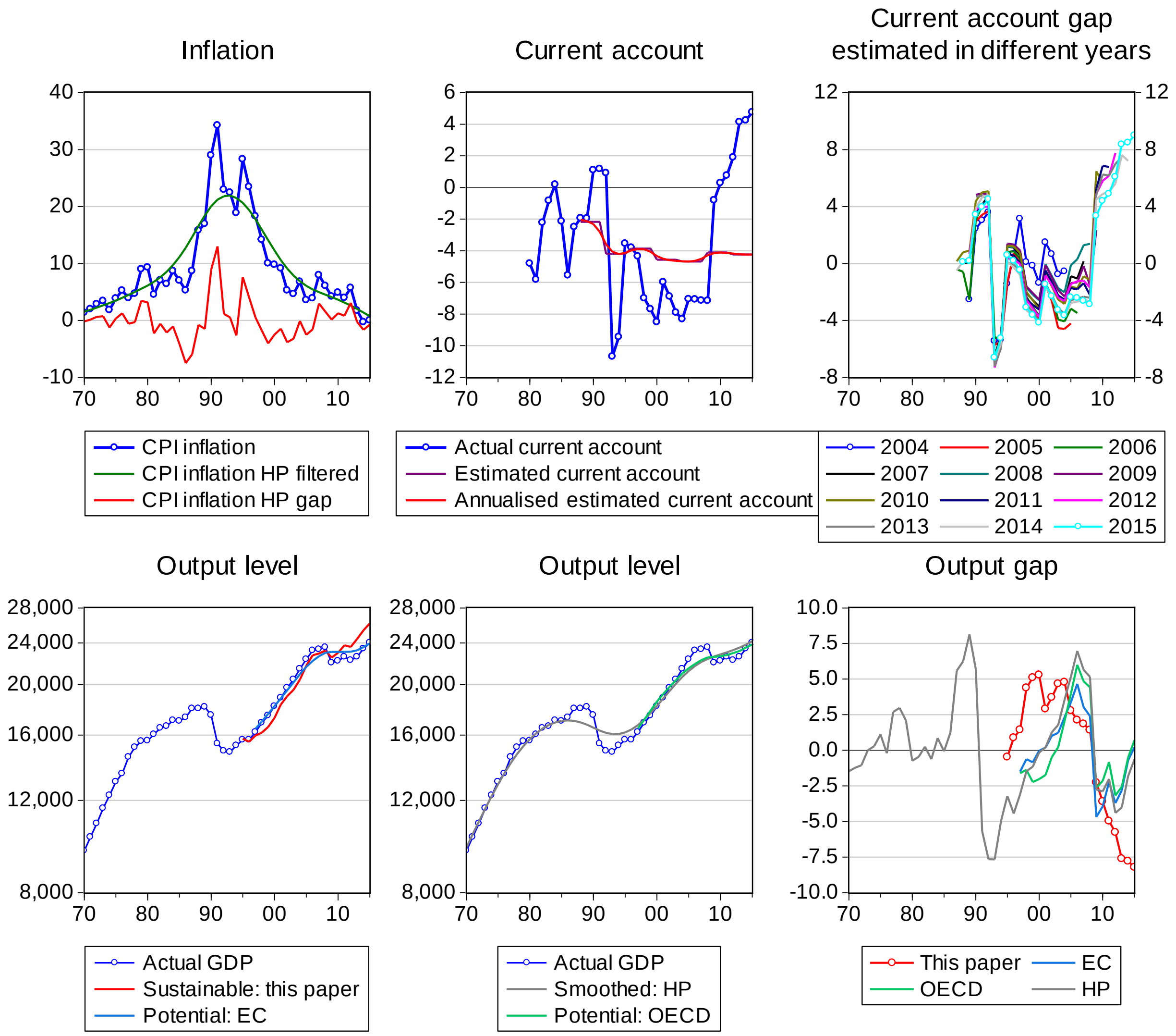
Greece


Inflation
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
Actual current account
Estimated current account
Annualised estimated current account
Current account gap
estimated in different years
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
Actual GDP
Sustainable: this paper
Potential: EC
Output level
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
This paper
EC
IMF
OECD
HP



Hong Kong (China, P.R.)
Inflation
Current account
Current account gap estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Actual GDP
Smoothed: HP
This paper
HP

Hungary



Inflation
40
30
20
10
0
-10
70
80
90
00
10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
6
4
2
0
-2
-4
-6
-8
-10
-12
Actual current account
Estimated current account
Annualised estimated current account
Current account gap
estimated in different years
12
8
4
0
-4
-8
2004
2005
2006
2007
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2009
2010
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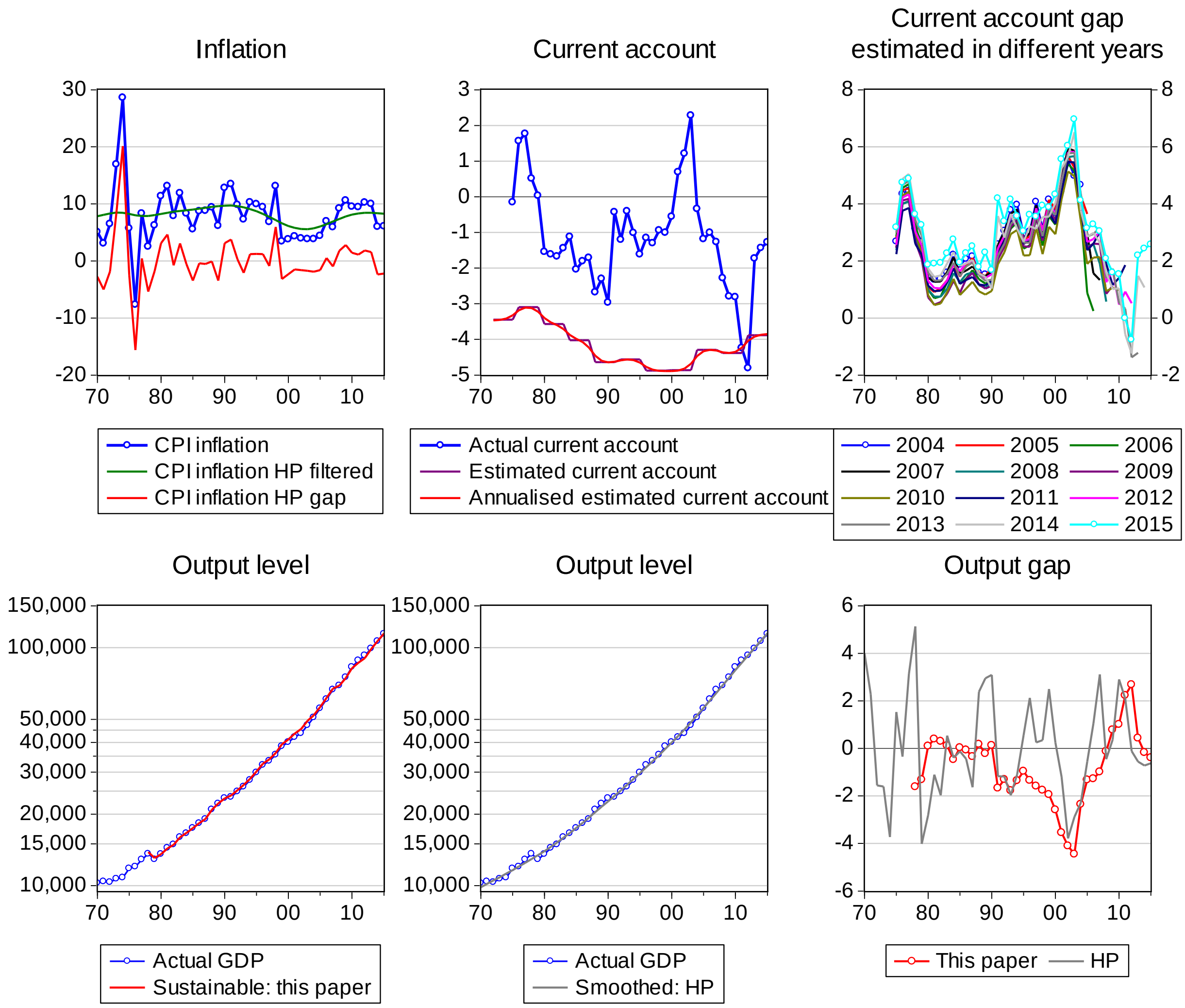
2014
2015
Output level
28,000
24,000
20,000
16,000
12,000
8,000
Actual GDP
Sustainable: this paper
Potential: EC
Output level
Actual GDP
Smoothed: HP
Potential: OECD
Output gap
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
This paper
EC
OECD
HP

India


Inflation
Current account
Current account gap estimated in different years
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CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004
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2014
2015
Output level
Output level
Output gap
150,000
100,000
50,000
40,000
30,000
20,000
15,000
10,000
6
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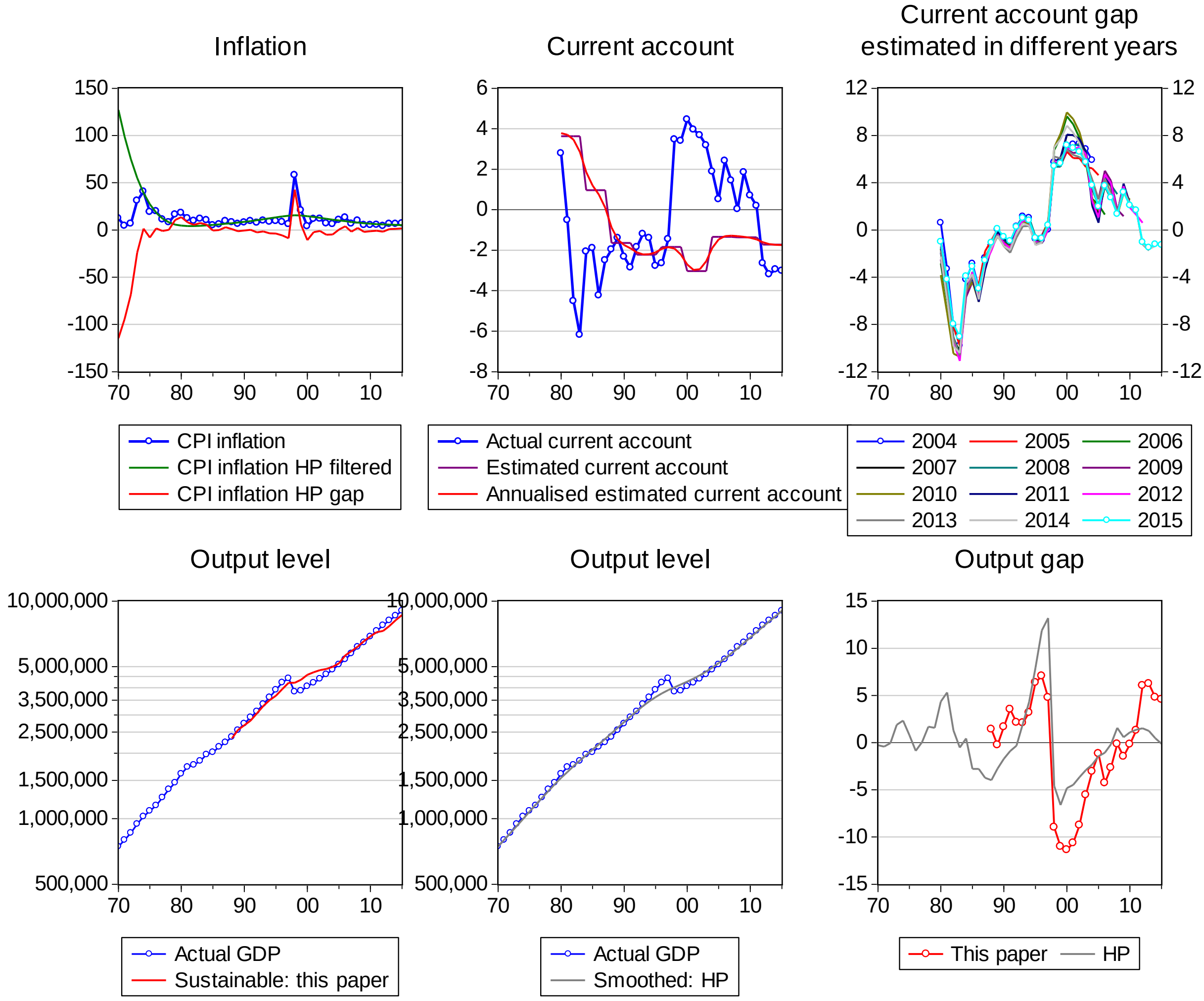
-2
-4
-6
Actual GDP
Sustainable: this paper
Actual GDP
Smoothed: HP
This paper
HP

Indonesia



Inflation
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-150
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CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
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Actual current account
Estimated current account
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Current account gap
estimated in different years
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Output level
10,000,000
5,000,000
3,500,000
2,500,000
1,500,000
1,000,000
500,000
Actual GDP
Sustainable: this paper
Smoothed: HP
Output gap
15
10
5
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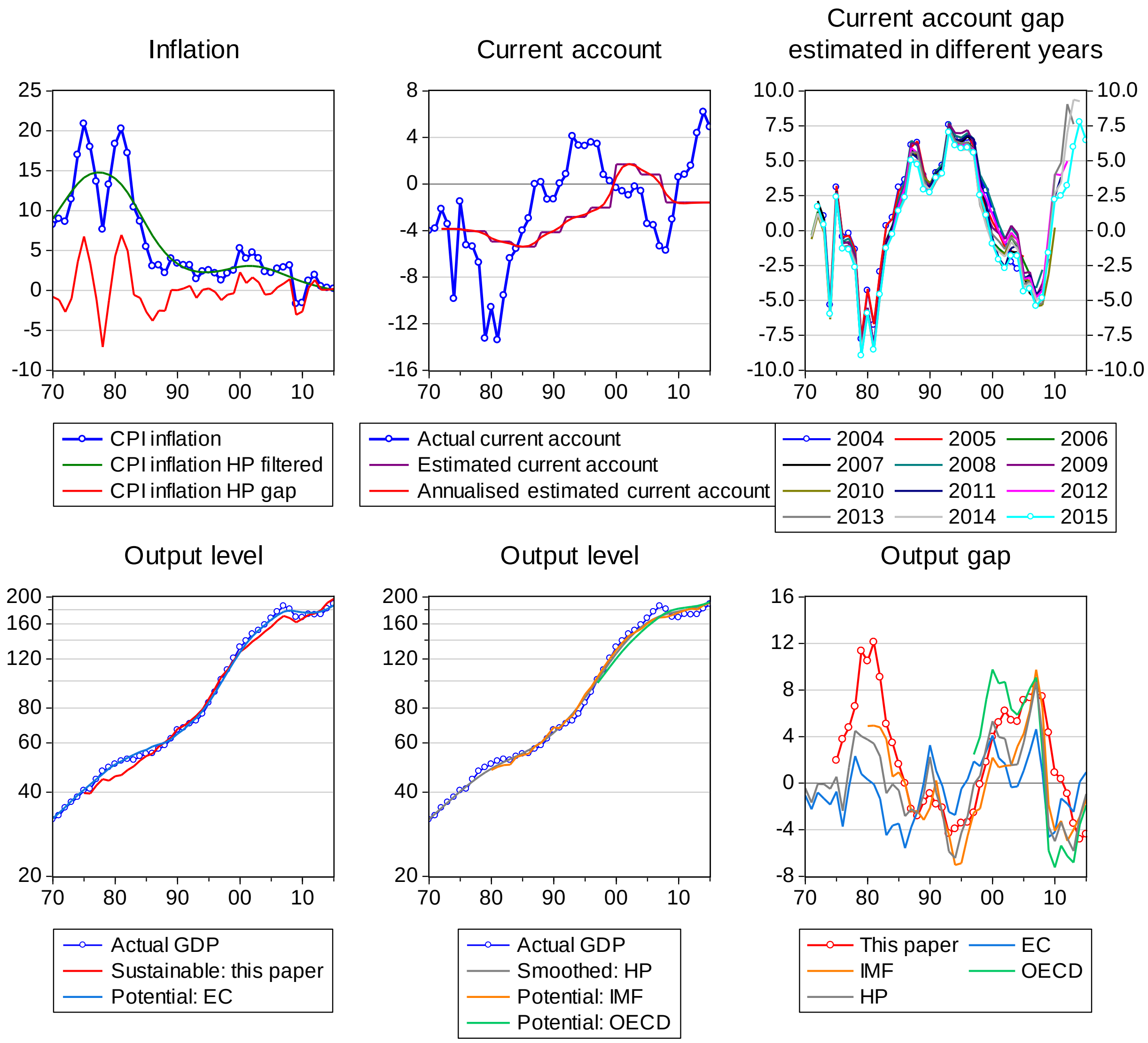
-5
-10
-15
This paper
HP

Ireland


Inflation
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CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
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Actual current account
Estimated current account
Annualised estimated current account
Current account gap
estimated in different years
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
2004
2005
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2015
Output level
200
160
120
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60
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Actual GDP
Sustainable: this paper
Potential: EC
Output level
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
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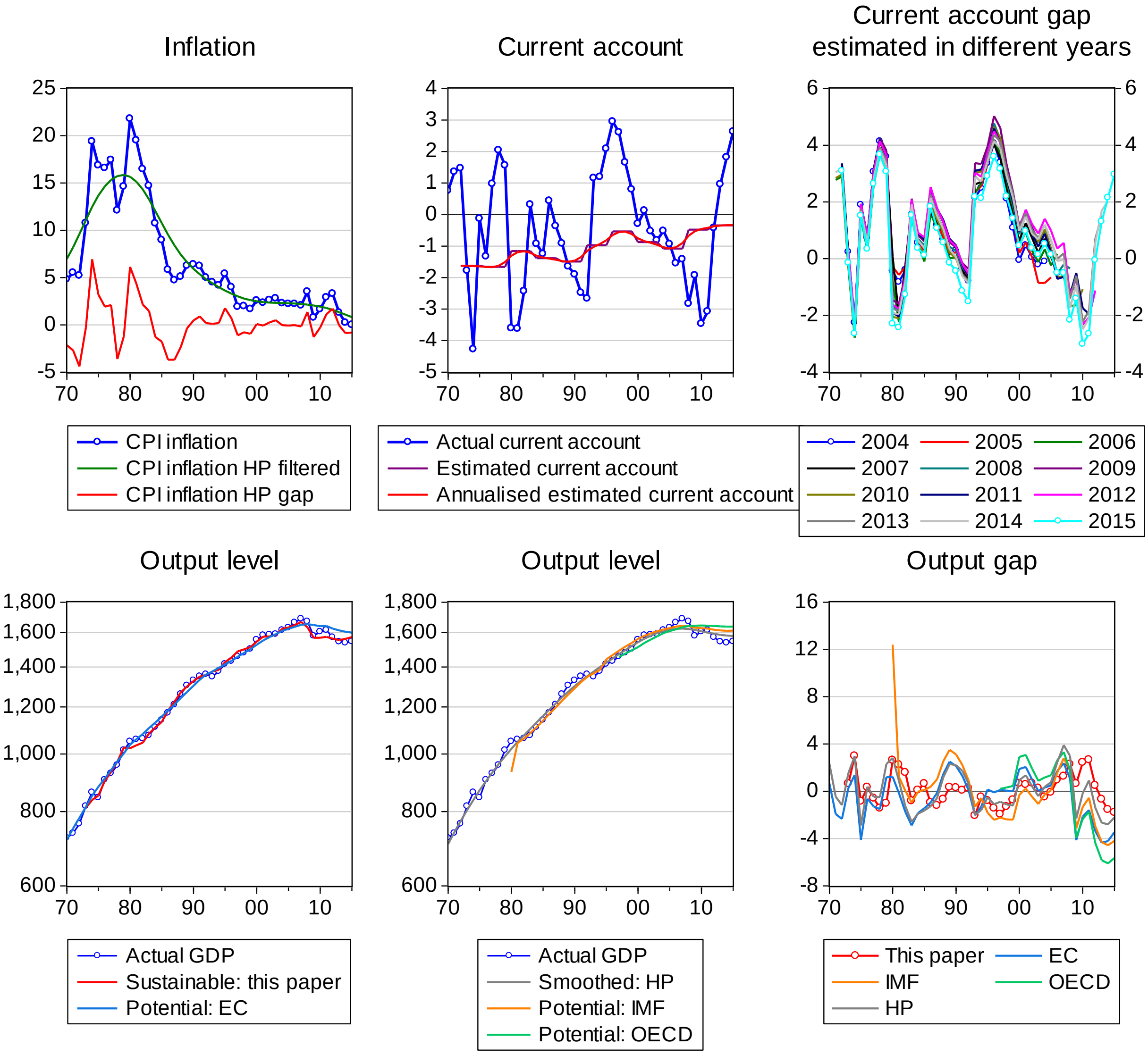
This paper
EC
IMF
OECD
HP

Italy


Inflation
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Annualised estimated current account
Current account gap estimated in different years
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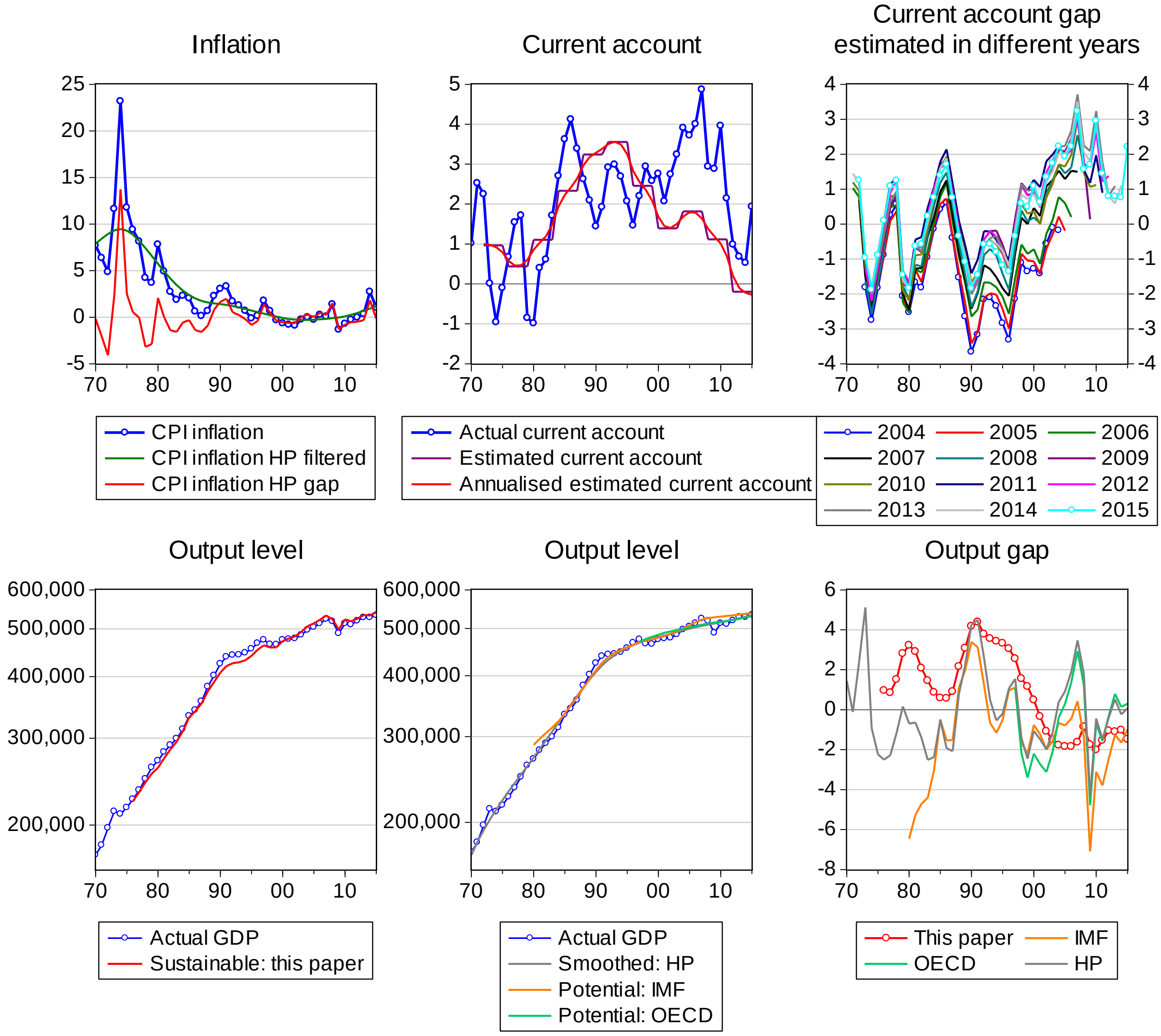
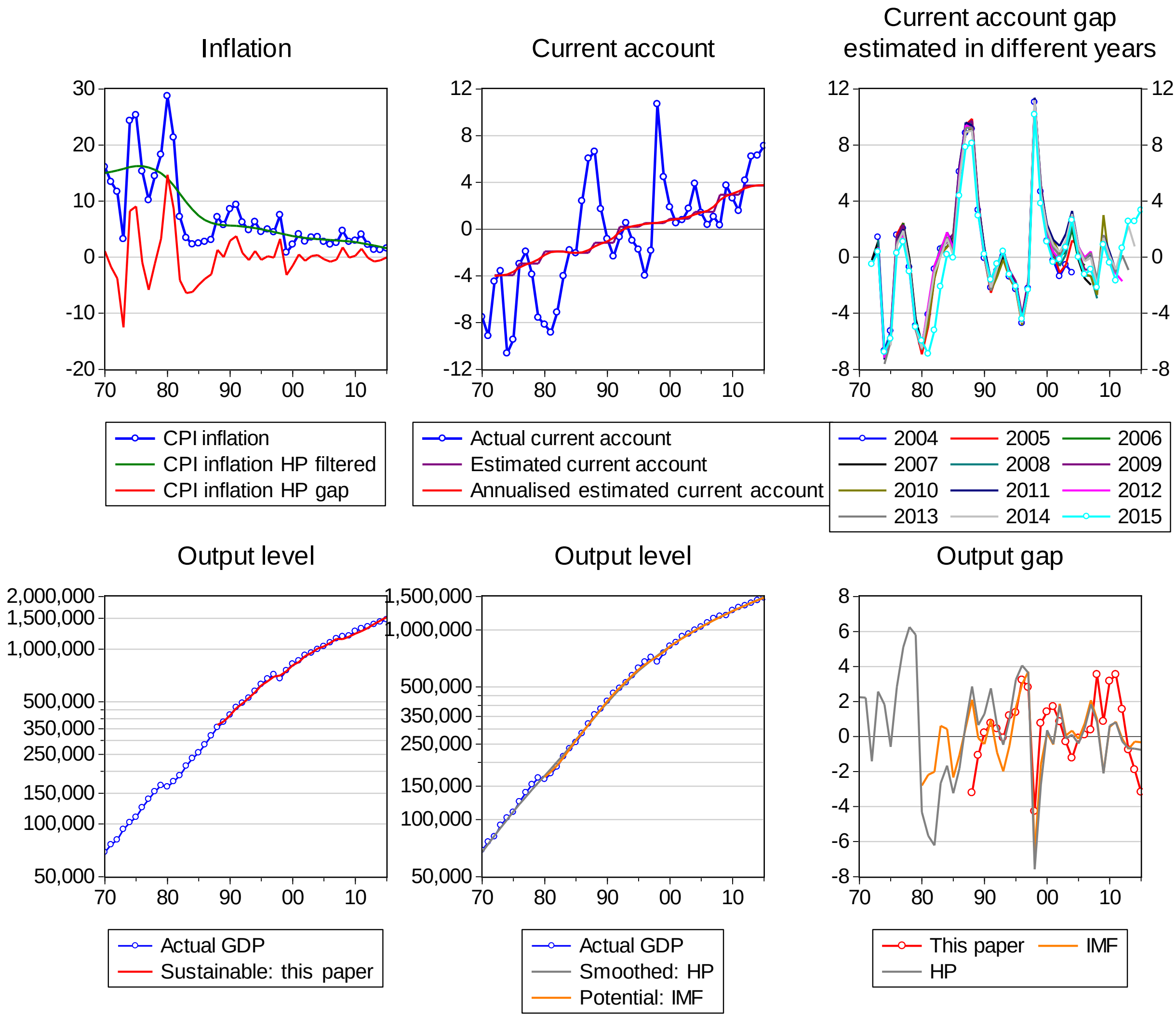
Output level
Actual GDP
Sustainable: this paper
Potential: EC
Output level
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
This paper
EC
IMF
OECD
HP

Japan

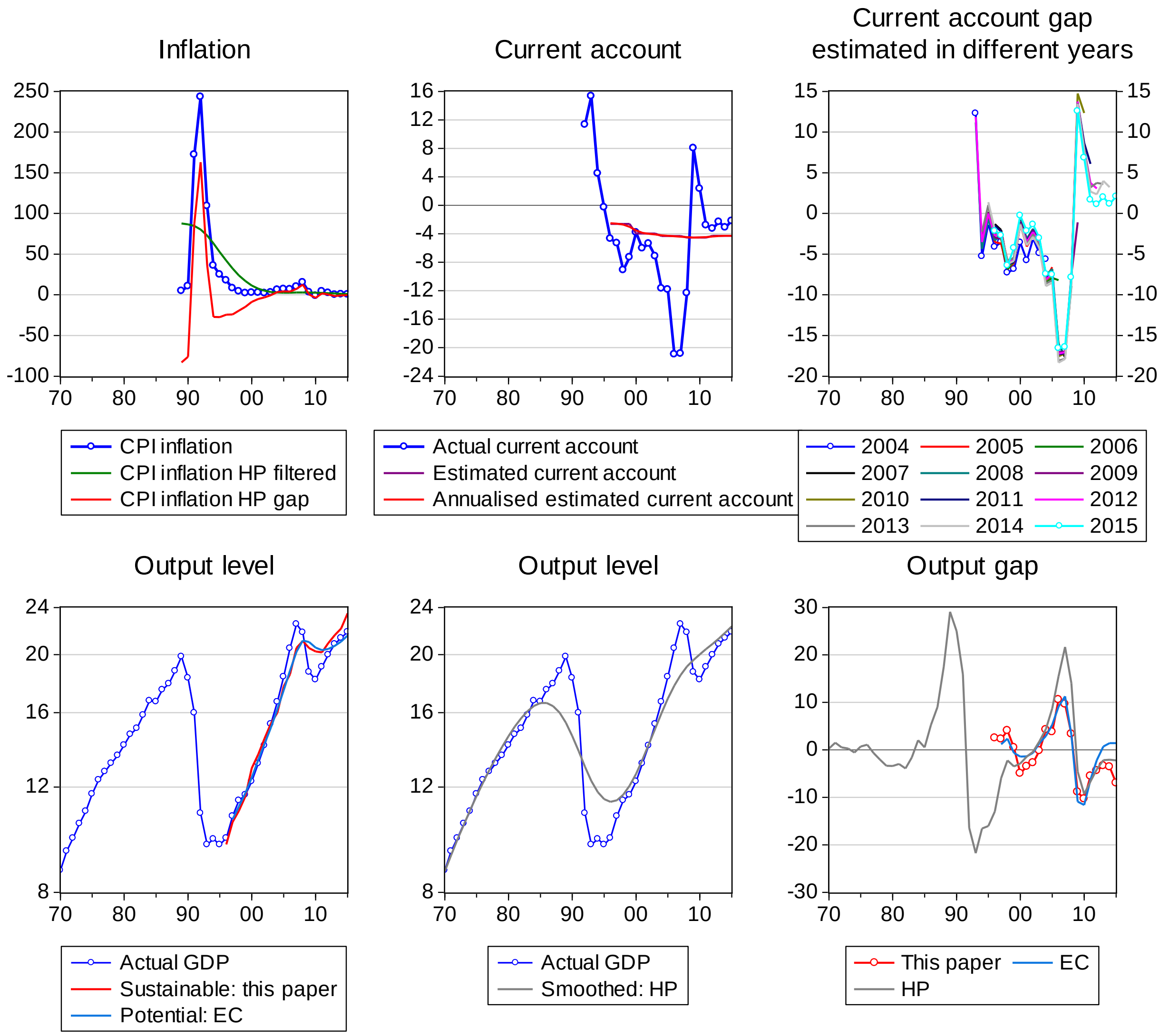


Inflation
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
Actual GDP
Sustainable: this paper
Output level
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
This paper IMF
OECD HP

Korea

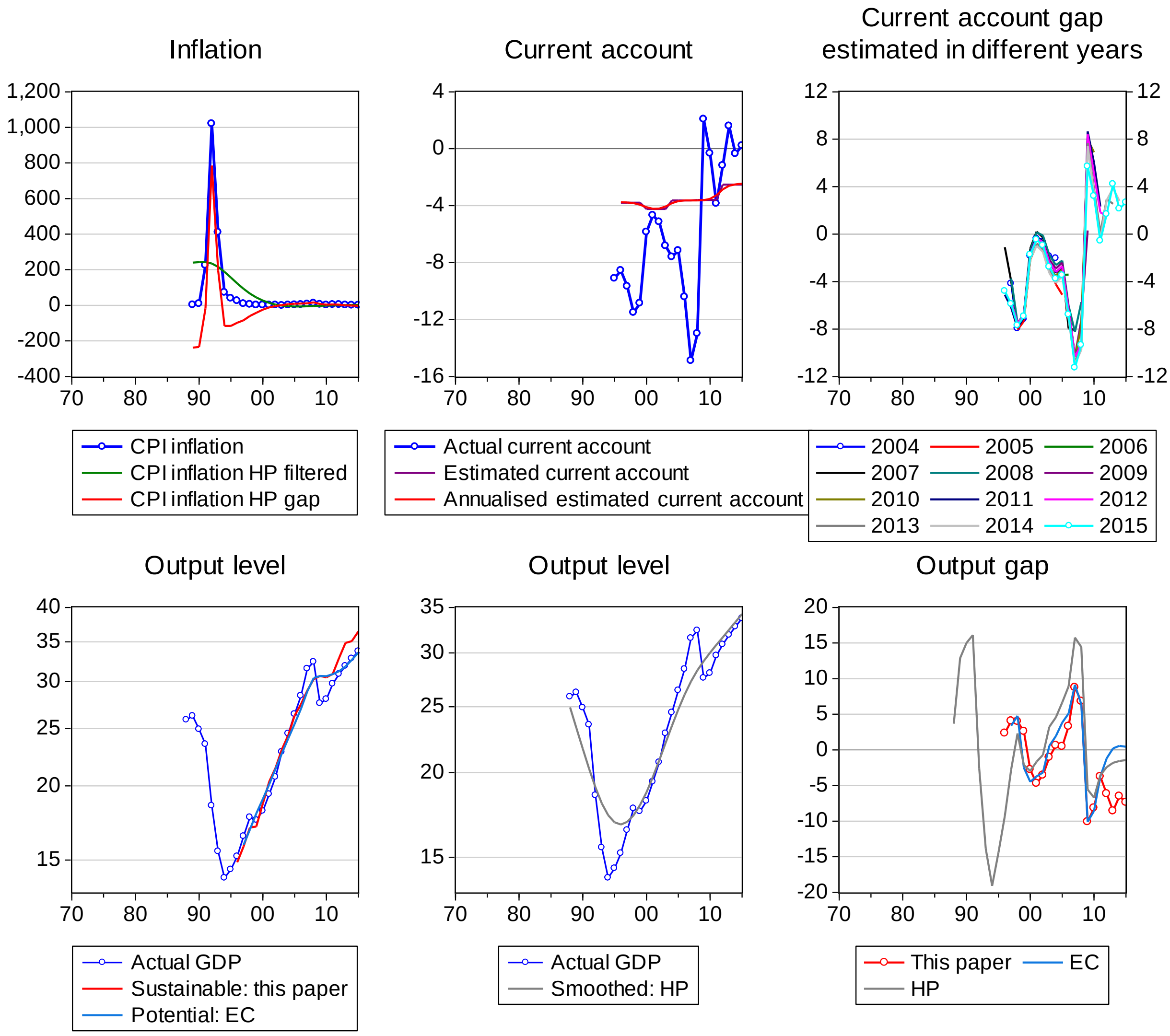

Inflation
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Output level
Actual GDP
Sustainable: this paper
Output level
Actual GDP
Smoothed: HP
Potential: IMF
Output gap
This paper
IMF
HP

Latvia



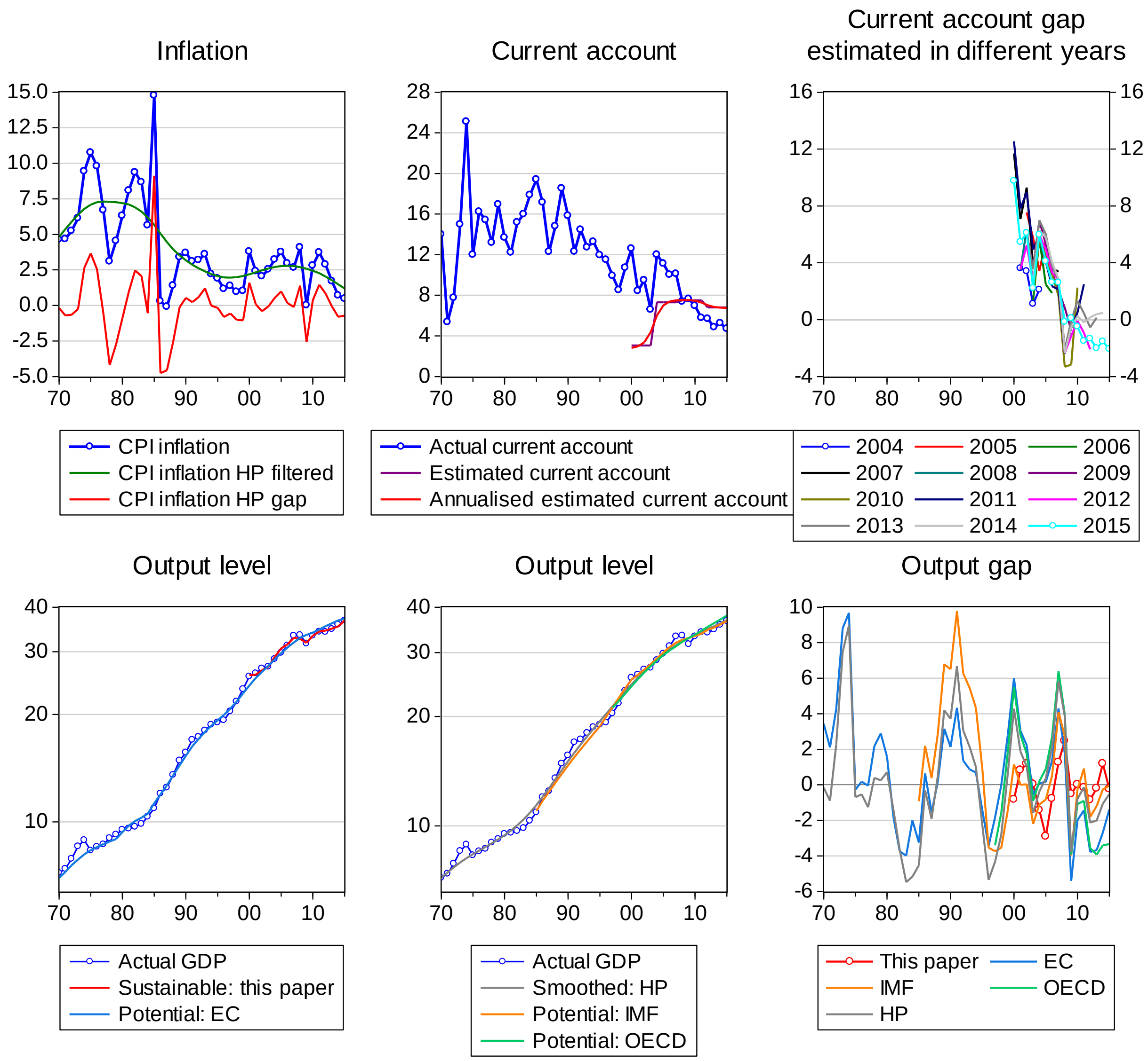
Inflation
Current account
Current account gap estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
This paper
EC
HP

Lithuania



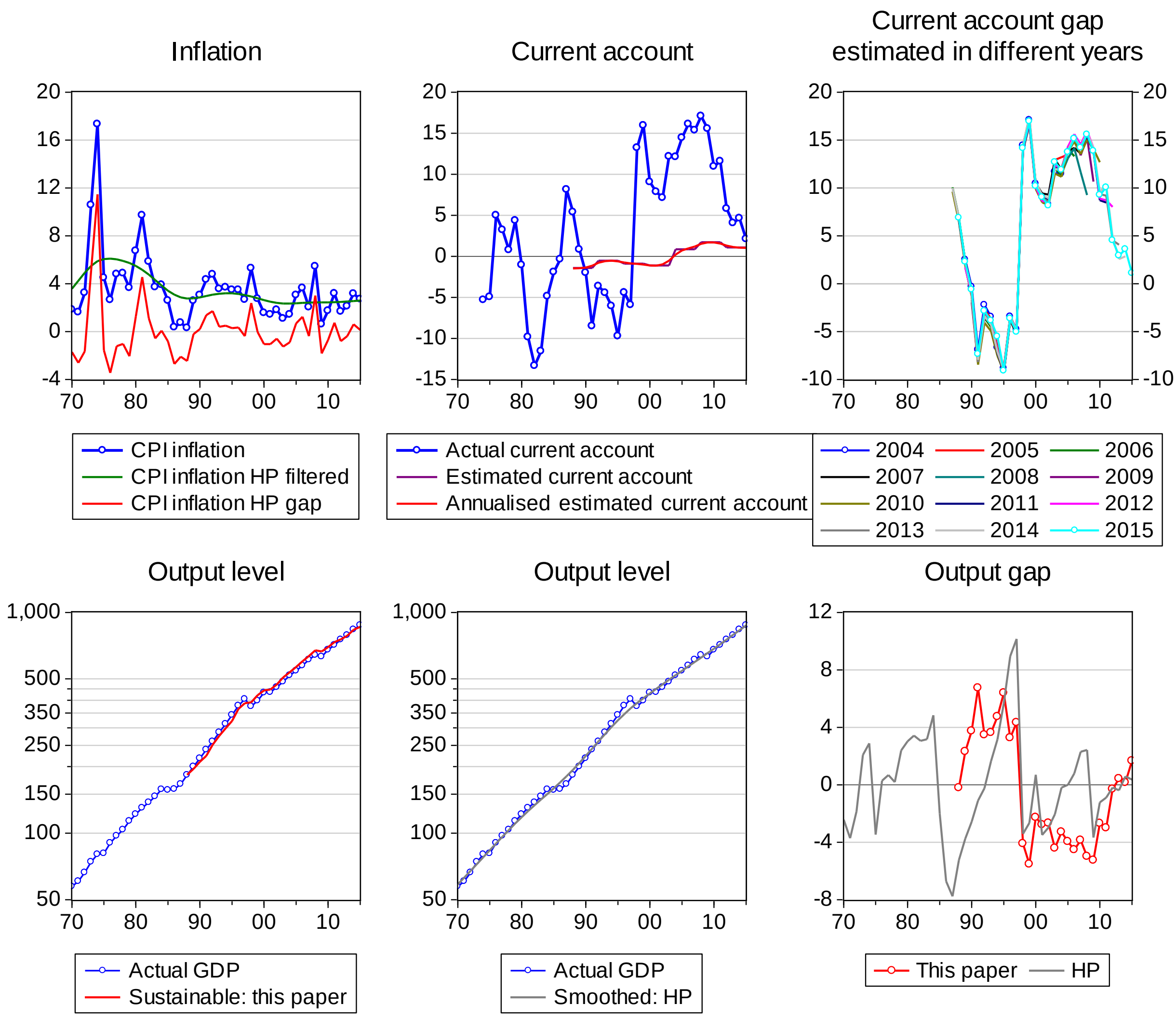
Inflation
1,200
1,000
800
600
400
200
0
-200
-400
70
80
90
00
10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
4
0
-4
-8
-12
-16
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
12
8
4
0
-4
-8
-12
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Output level
40
35
30
25
20
15
Actual GDP
Sustainable: this paper
Potential: EC
Output level
35
30
25
20
15
Actual GDP
Smoothed: HP
Output gap
20
15
10
5
0
-5
-10
-15
-20
This paper
EC
HP

Luxembourg

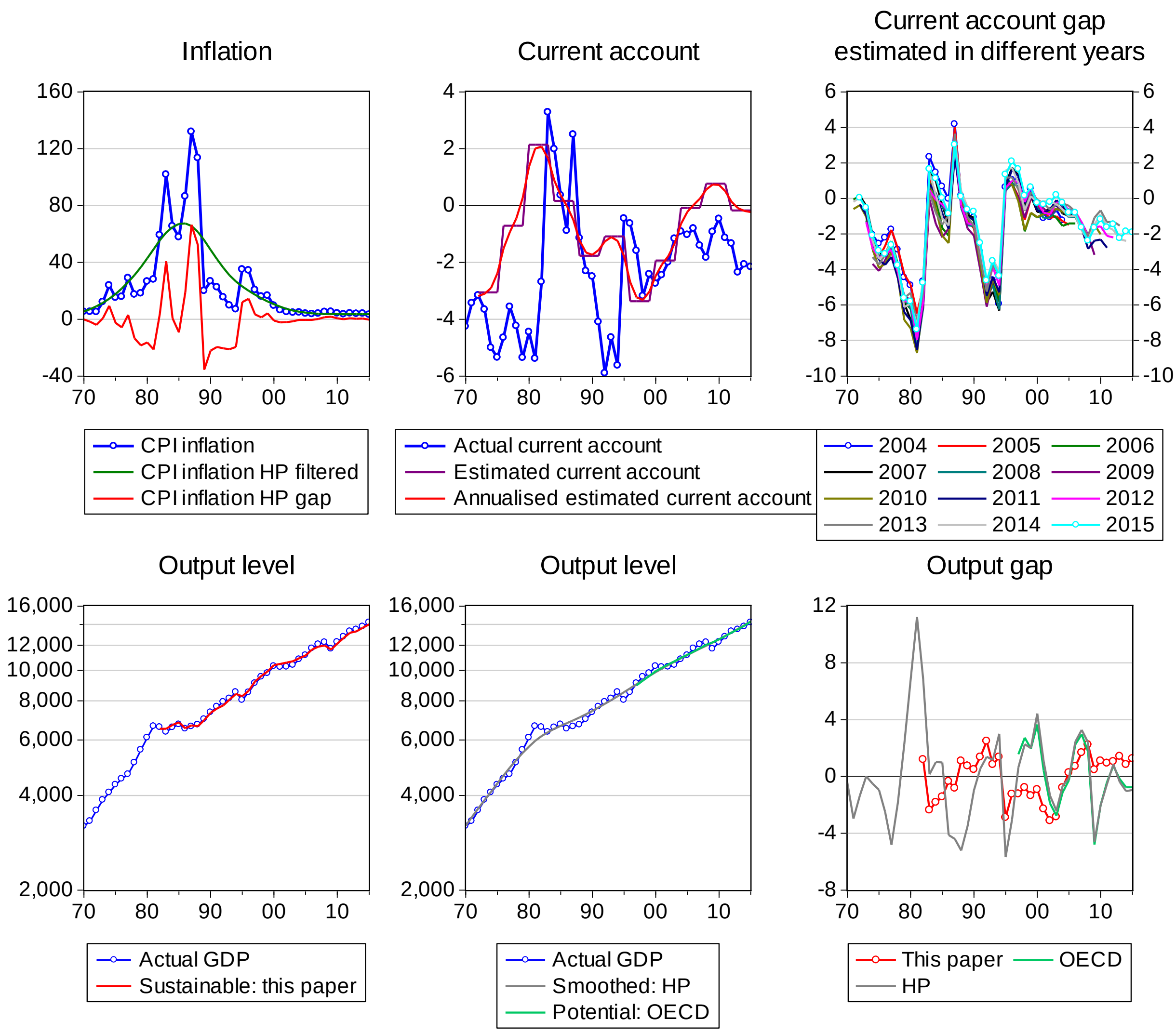


Inflation
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
70 80 90 00 10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
28
24
20
16
12
8
4
0
70 80 90 00 10
Actual current account
Estimated current account
Annualised estimated current account
Current account gap
estimated in different years
16
12
8
4
0
-4
70 80 90 00 10
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
40
30
20
10
70 80 90 00 10
Actual GDP
Sustainable: this paper
Potential: EC
Output level
40
30
20
10
70 80 90 00 10
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
10
8
6
4
2
0
-2
-4
-6
70 80 90 00 10
This paper
EC
IMF
OECD
HP

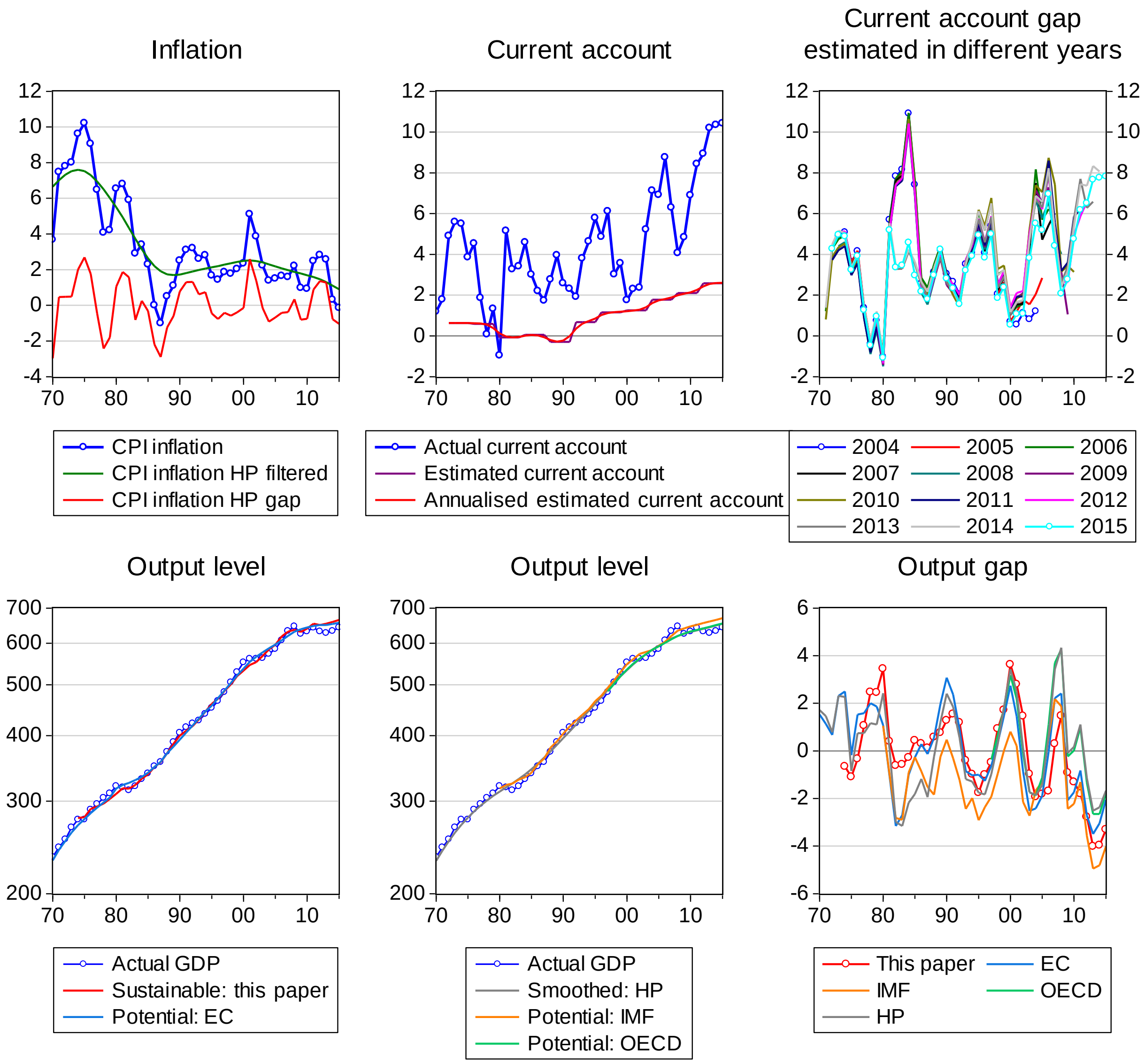
Malaysia


Inflation
20
16
12
8
4
0
-4
70 80 90 00 10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
20
15
10
5
0
-5
-10
-15
70 80 90 00 10
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
20
15
10
5
0
-5
-10
70 80 90 00 10
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
1,000
500
350
250
150
100
50
70 80 90 00 10
Actual GDP
Sustainable: this paper
Output level
1,000
500
350
250
150
100
50
70 80 90 00 10
Actual GDP
Smoothed: HP
Output gap
12
8
4
0
-4
-8
70 80 90 00 10
This paper
HP

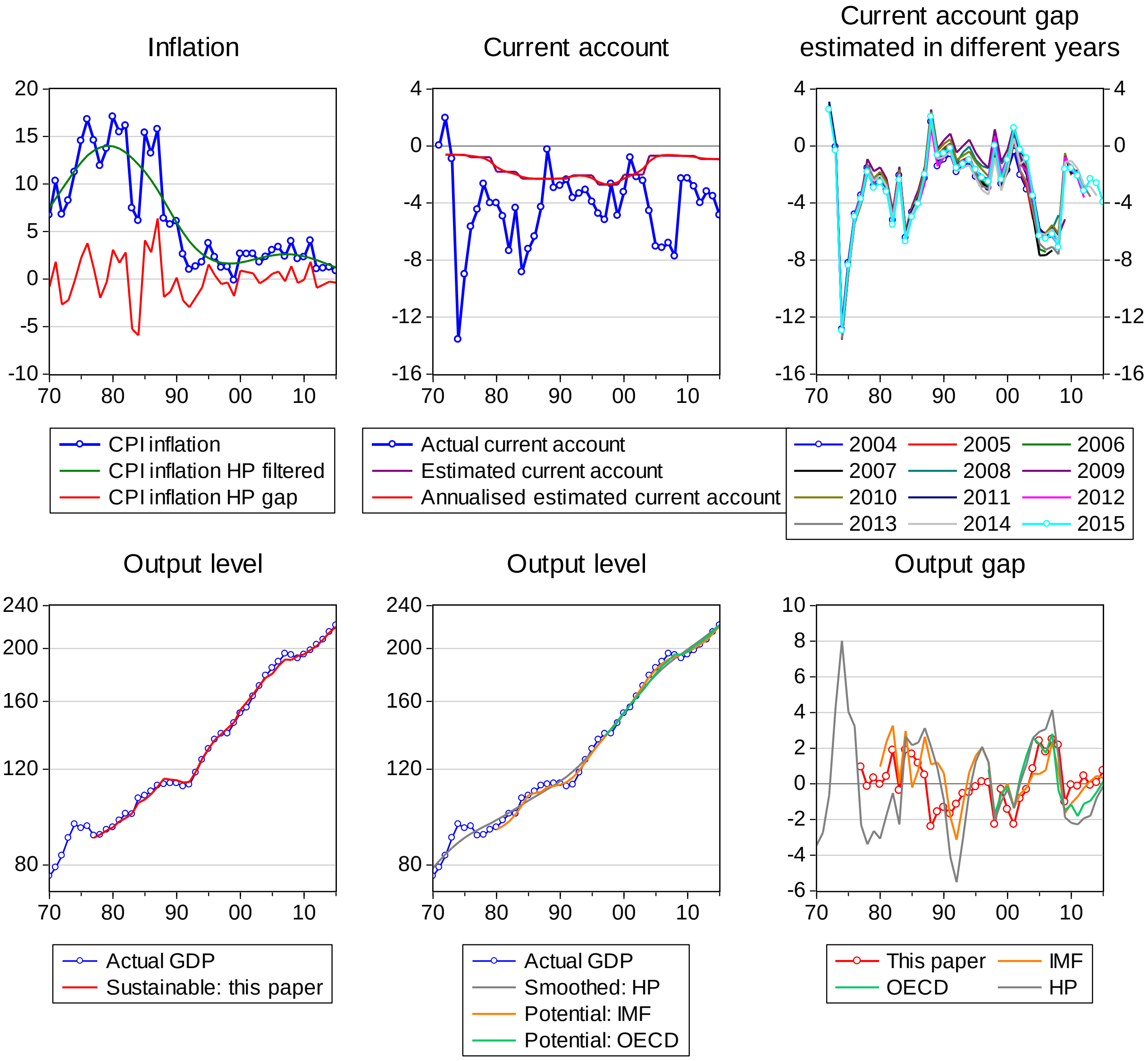
Mexico


Inflation
160
120
80
40
0
-40
70
80
90
00
10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
4
2
0
-2
-4
-6
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
6
4
2
0
-2
-4
-6
-8
-10
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Output level
16,000
12,000
10,000
8,000
6,000
4,000
2,000
Actual GDP
Sustainable: this paper
Output level
Actual GDP
Smoothed: HP
Potential: OECD
Output gap
12
8
4
0
-4
-8
This paper
OECD
HP

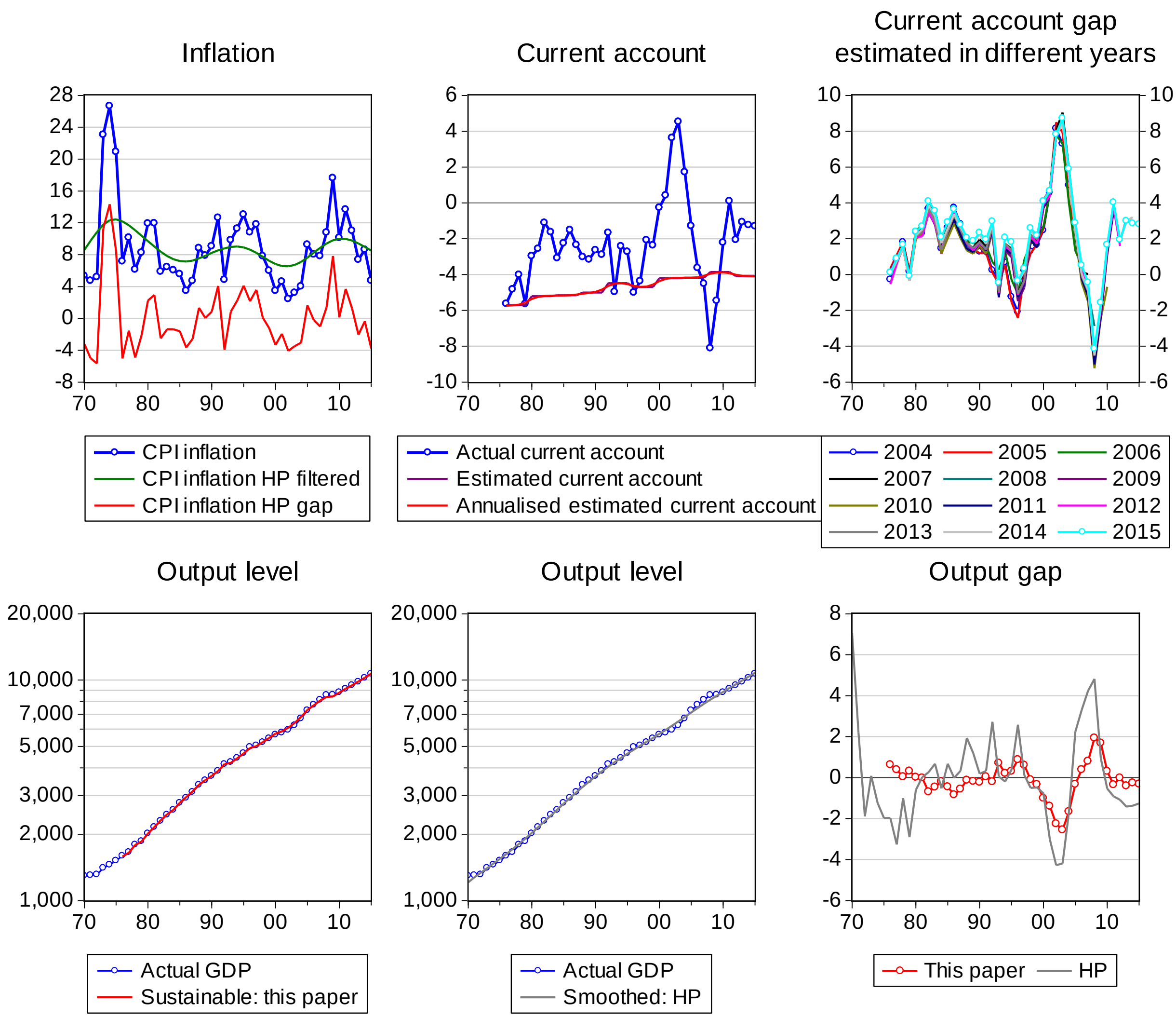
Netherlands



New Zealand

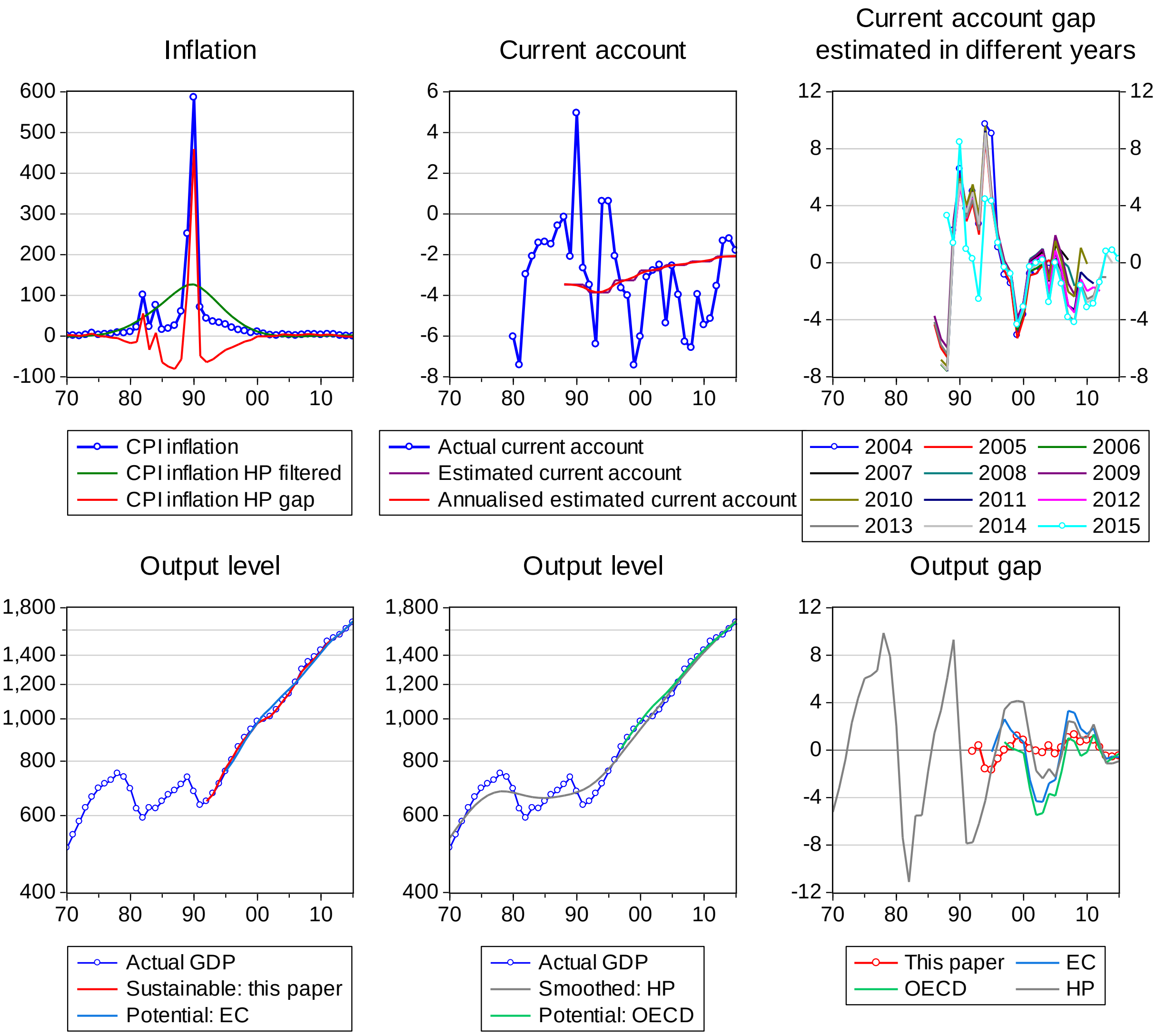

Inflation
Current account
Current account gap estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
This paper
IMF
OECD
HP

Pakistan



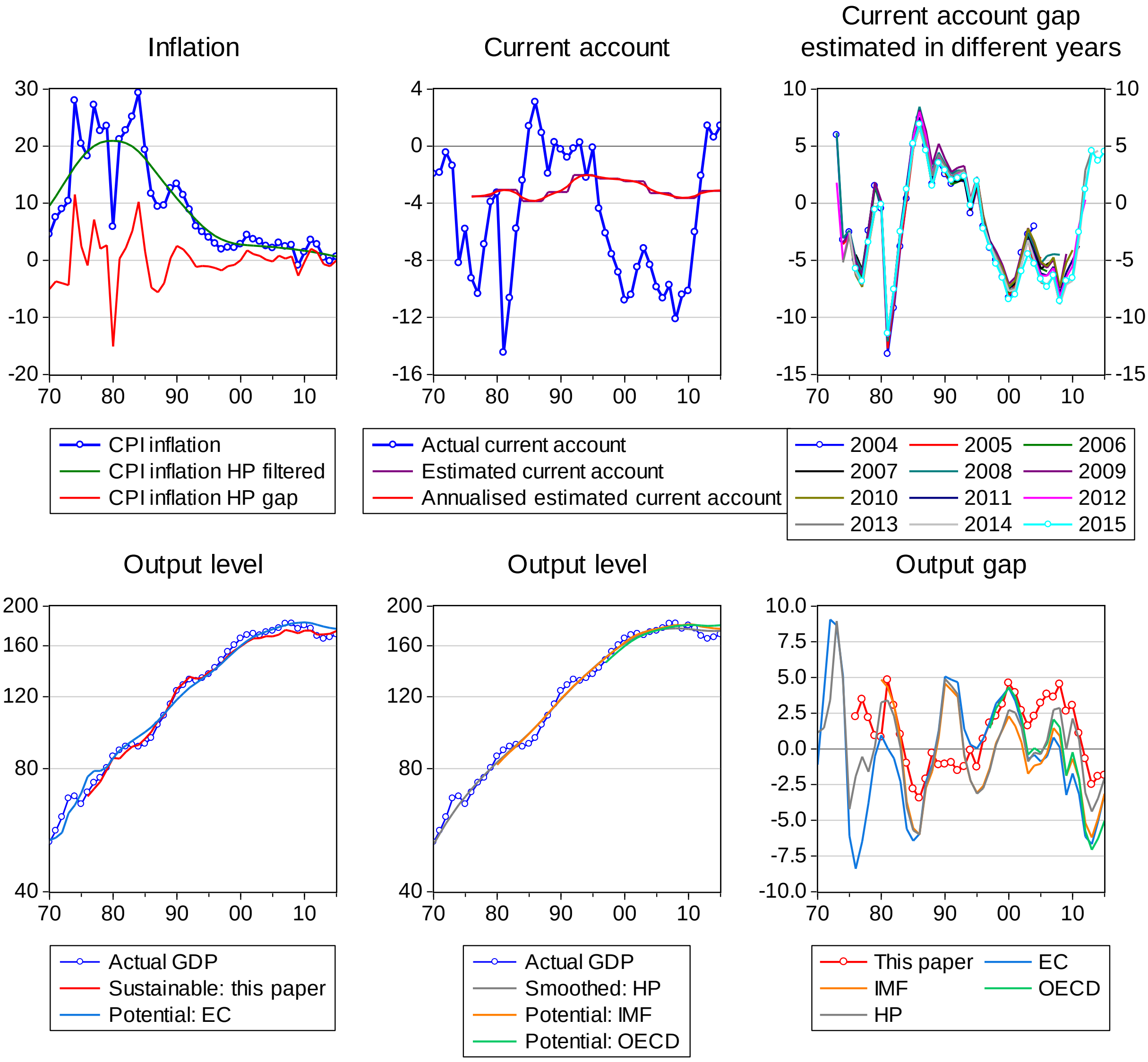
Inflation
Current account
Current account gap
estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Actual GDP
Smoothed: HP
This paper
HP

Poland

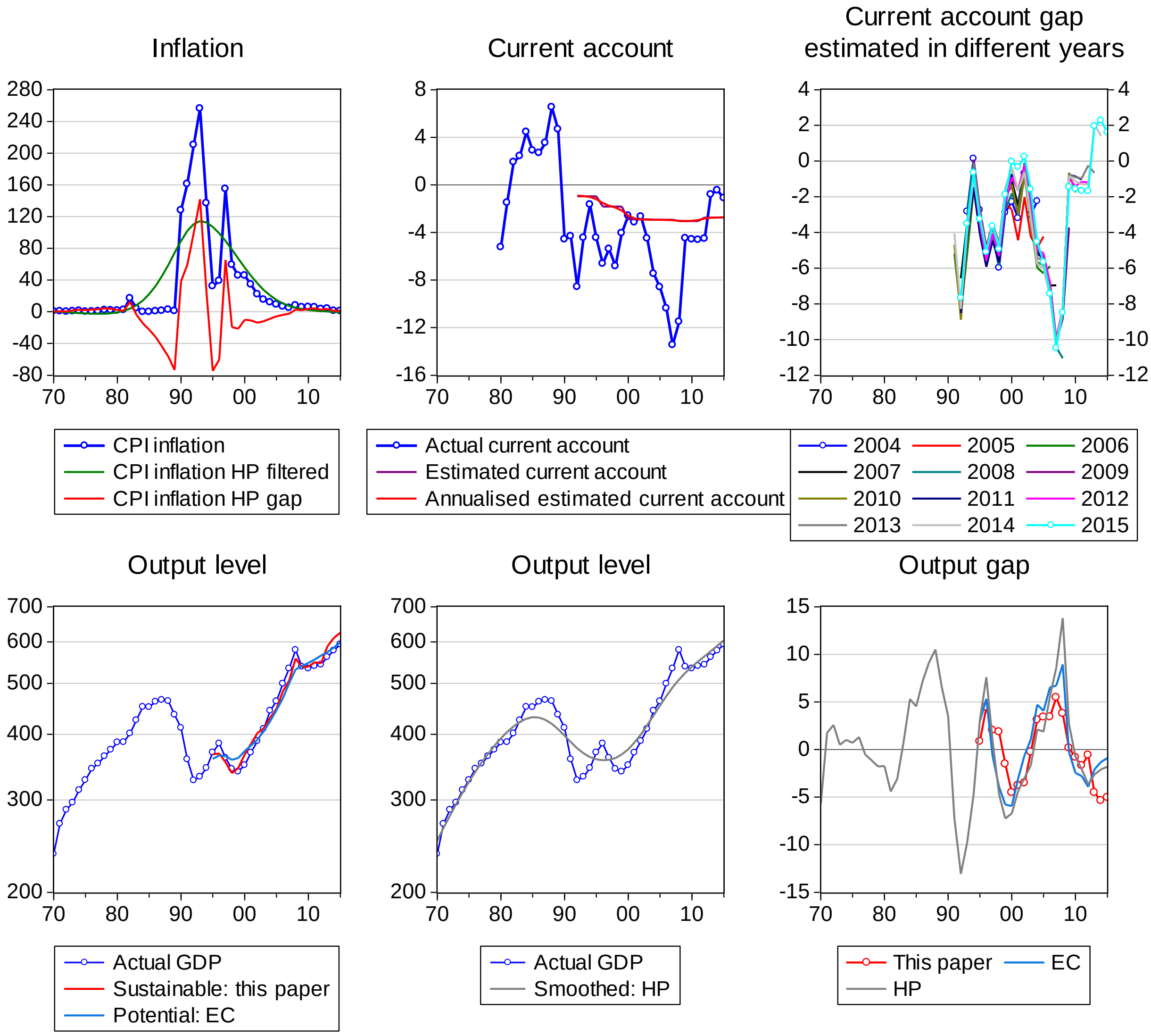


Inflation
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
Actual current account
Estimated current account
Annualised estimated current account
Current account gap
estimated in different years
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
Actual GDP
Sustainable: this paper
Potential: EC
Output level
Actual GDP
Smoothed: HP
Potential: OECD
Output gap
This paper EC
OECD HP

Portugal

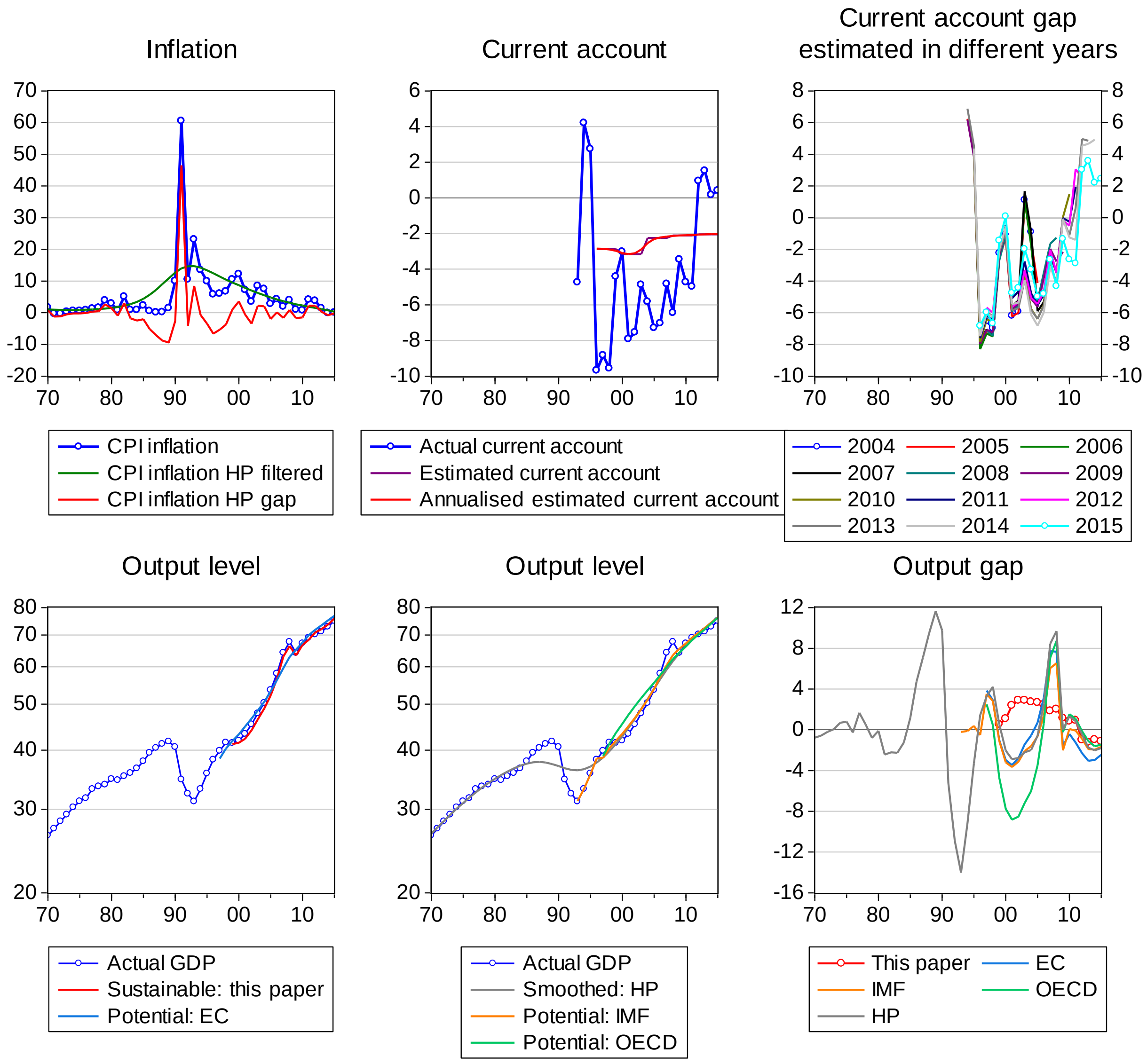

Inflation
30
20
10
0
-10
-20
70 80 90 00 10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
4
0
-4
-8
-12
-16
70 80 90 00 10
Actual current account
Estimated current account
Annualised estimated current account
Current account gap
estimated in different years
10
5
0
-5
-10
-15
70 80 90 00 10
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
200
160
120
80
40
70 80 90 00 10
Actual GDP
Sustainable: this paper
Potential: EC
Output level
200
160
120
80
40
70 80 90 00 10
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
-7.5
-10.0
70 80 90 00 10
This paper
EC
IMF
OECD
HP

Romania

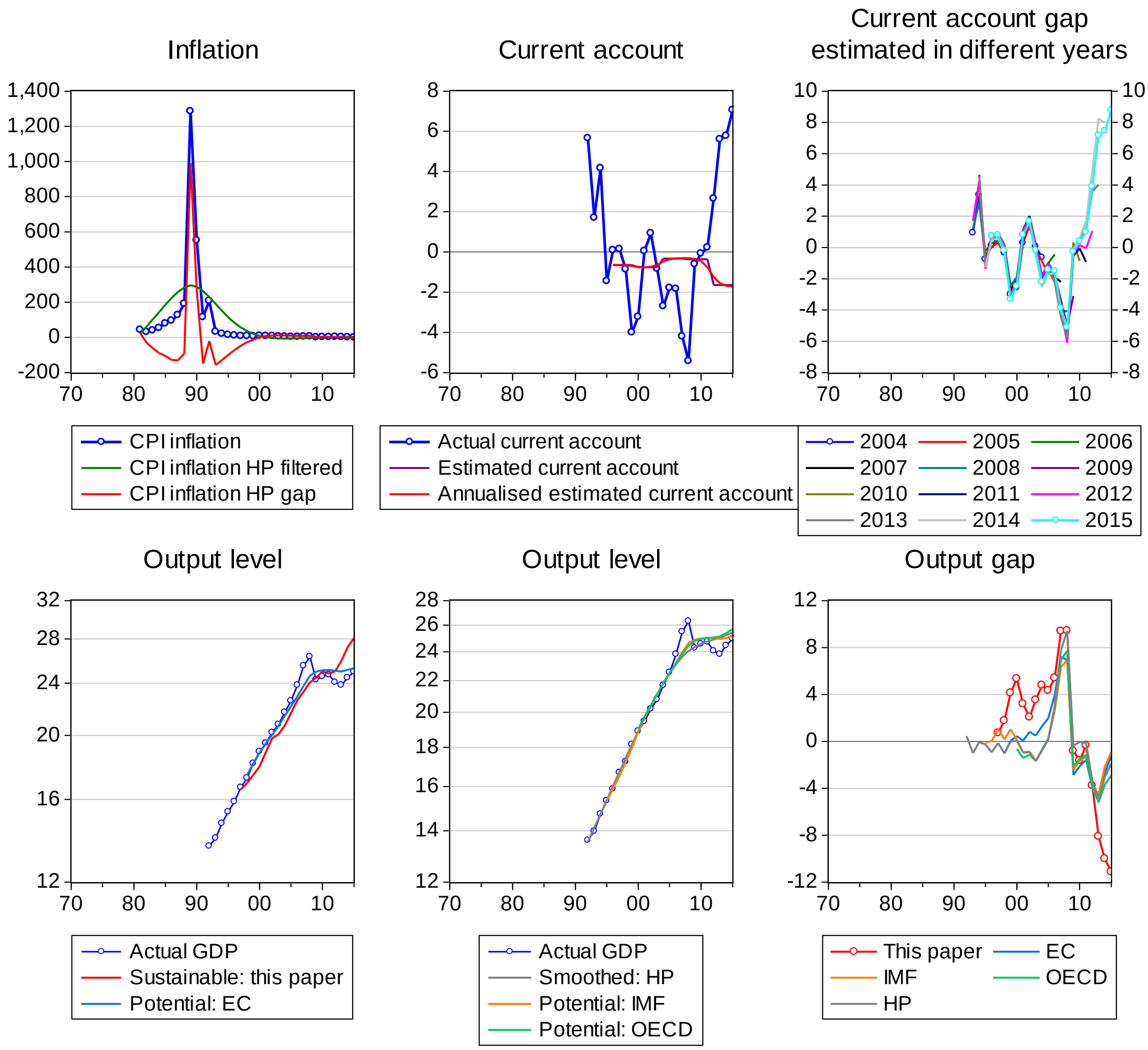


Inflation
280
240
200
160
120
80
40
0
-40
-80
70
80
90
00
10
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
8
4
0
-4
-8
-12
-16
Actual current account
Estimated current account
Annualised estimated current account
Current account gap
estimated in different years
4
2
0
-2
-4
-6
-8
-10
-12
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Output level
700
600
500
400
300
200
Actual GDP
Sustainable: this paper
Potential: EC
Output level
Actual GDP
Smoothed: HP
Output gap
15
10
5
0
-5
-10
-15
This paper
EC
HP

Slovakia


Inflation
Current account
Current account gap
estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
This paper
EC
IMF
OECD
HP

Slovenia



Inflation
Current account
Current account gap estimated in different years
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
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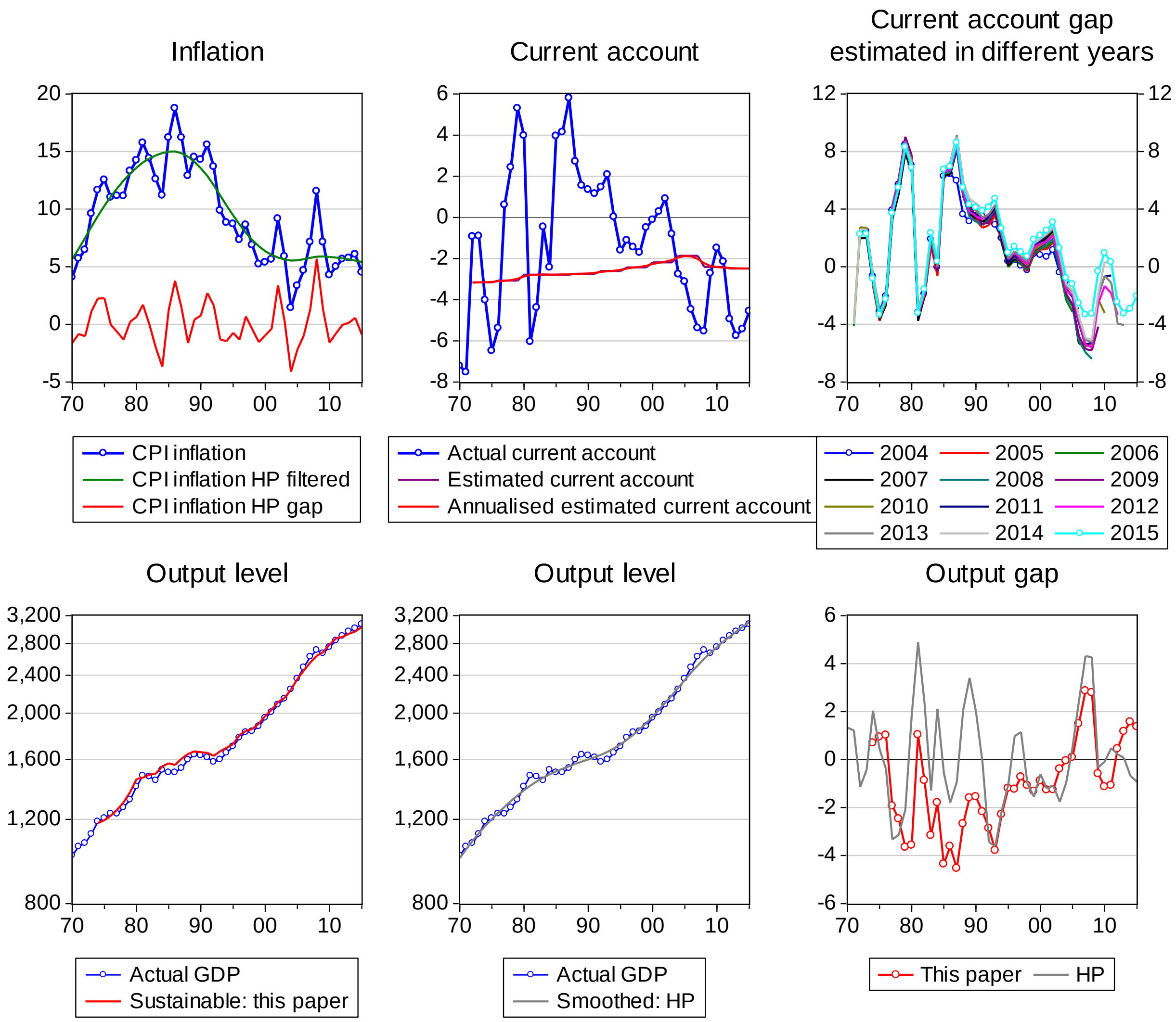
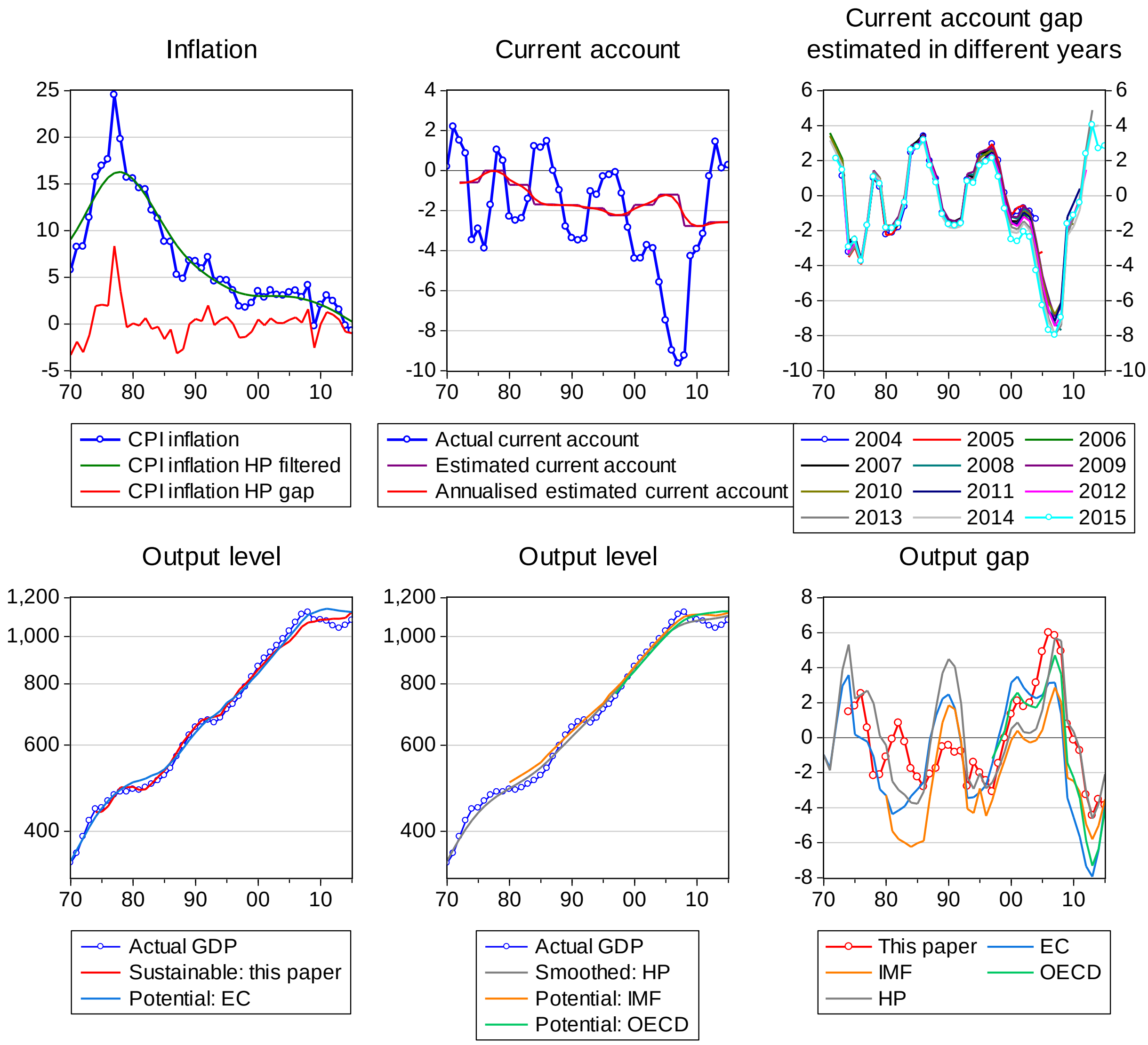
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
This paper
EC
IMF
OECD
HP

South Africa



Spain


Inflation
Current account
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CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Actual current account
Estimated current account
Annualised estimated current account
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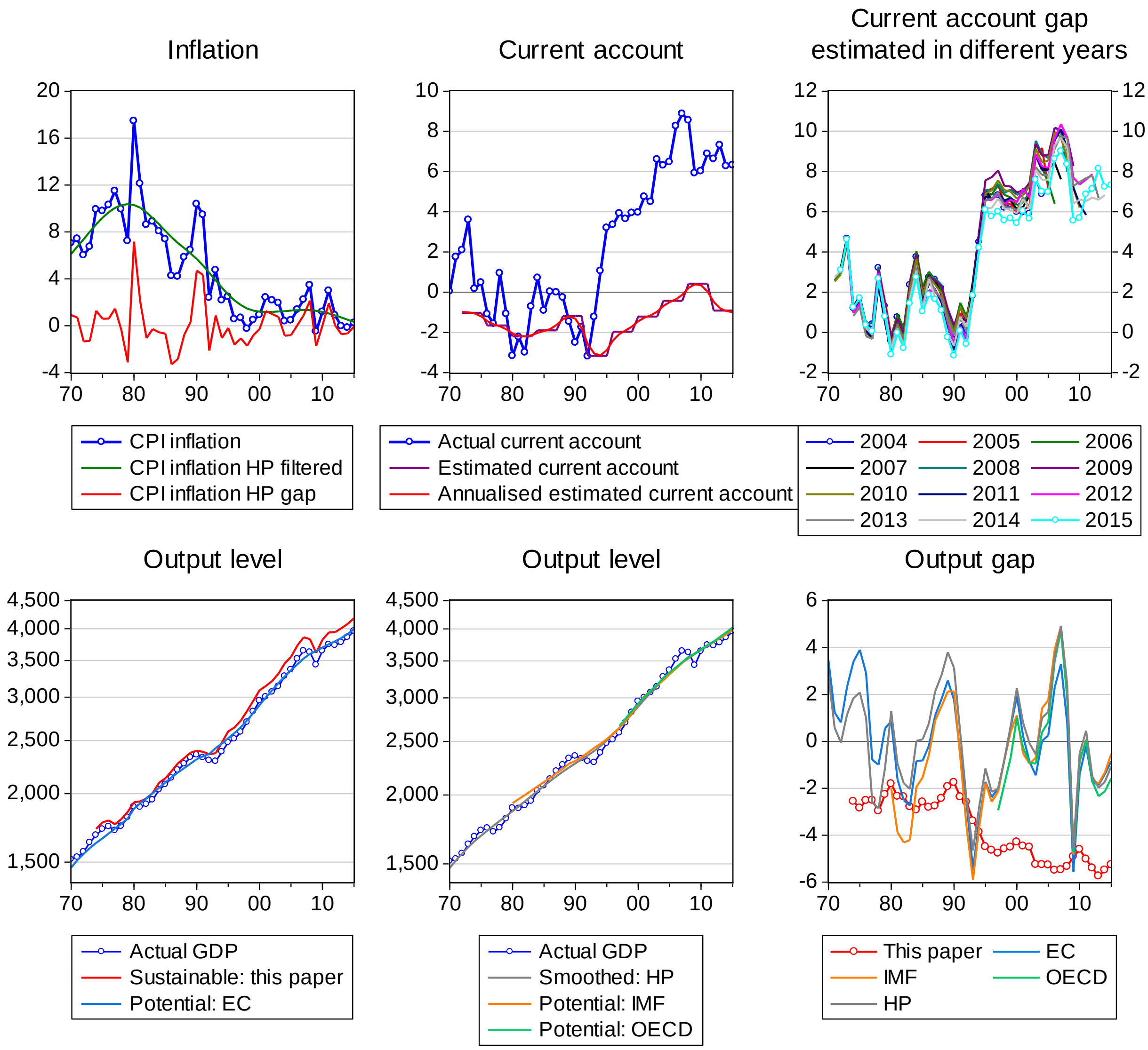
Output level
Output level
Output gap
Actual GDP
Sustainable: this paper
Potential: EC
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
This paper
EC
IMF
OECD
HP

Sweden


Inflation
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CPI inflation HP gap
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Annualised estimated current account
Current account gap estimated in different years
2004
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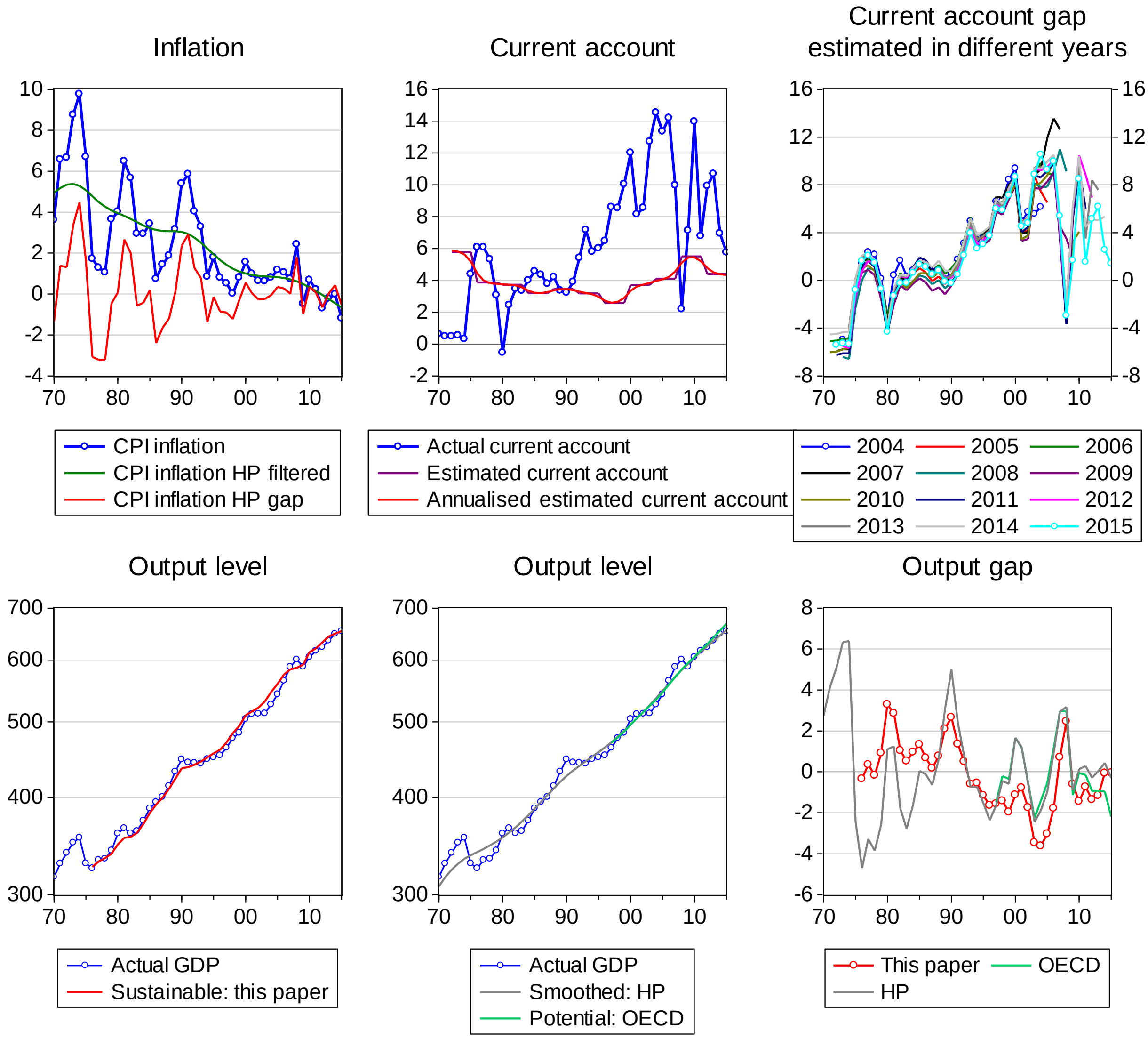
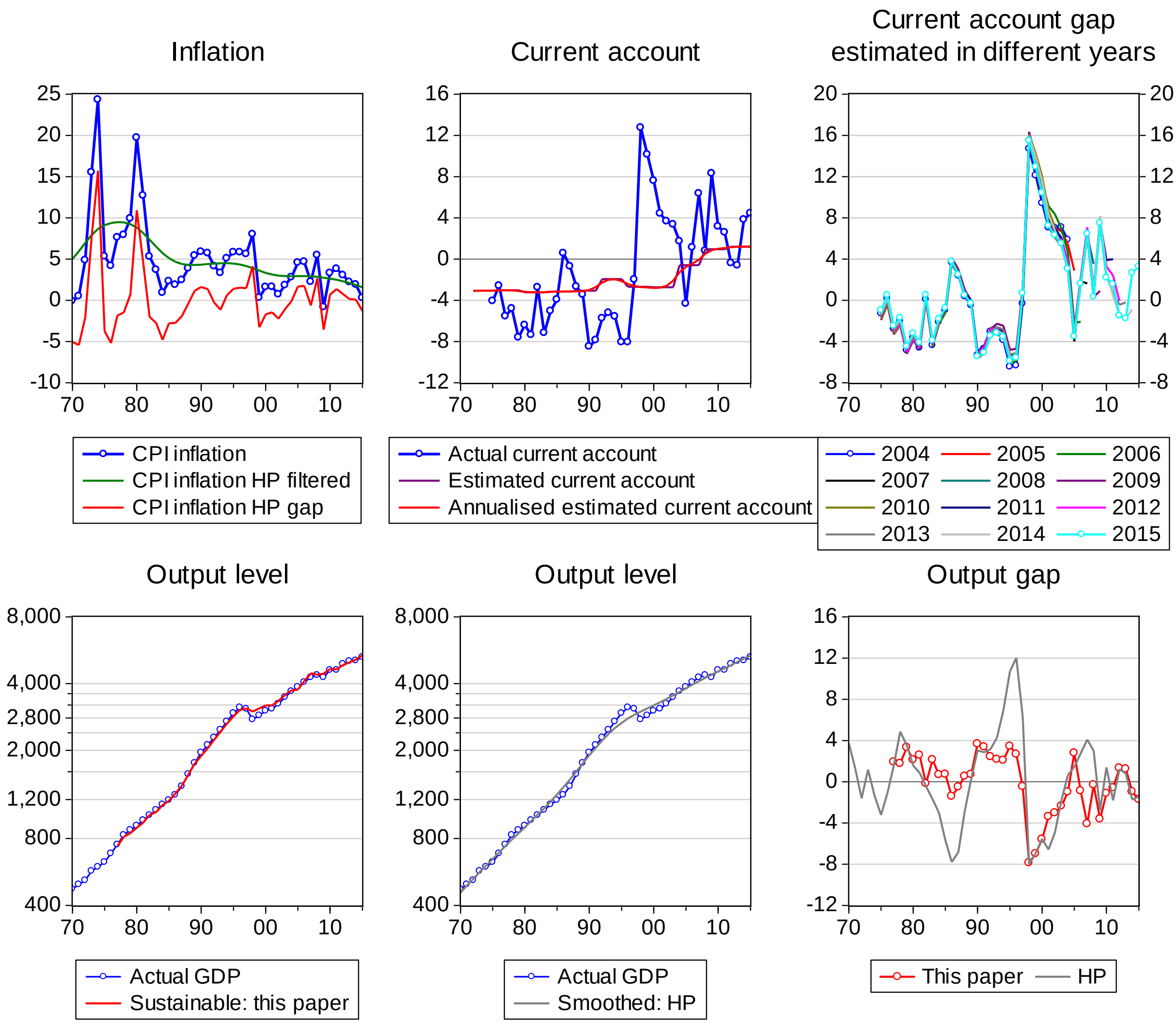
Output level
Actual GDP
Sustainable: this paper
Potential: EC
Output level
Actual GDP
Smoothed: HP
Potential: IMF
Potential: OECD
Output gap
This paper
EC
IMF
OECD
HP

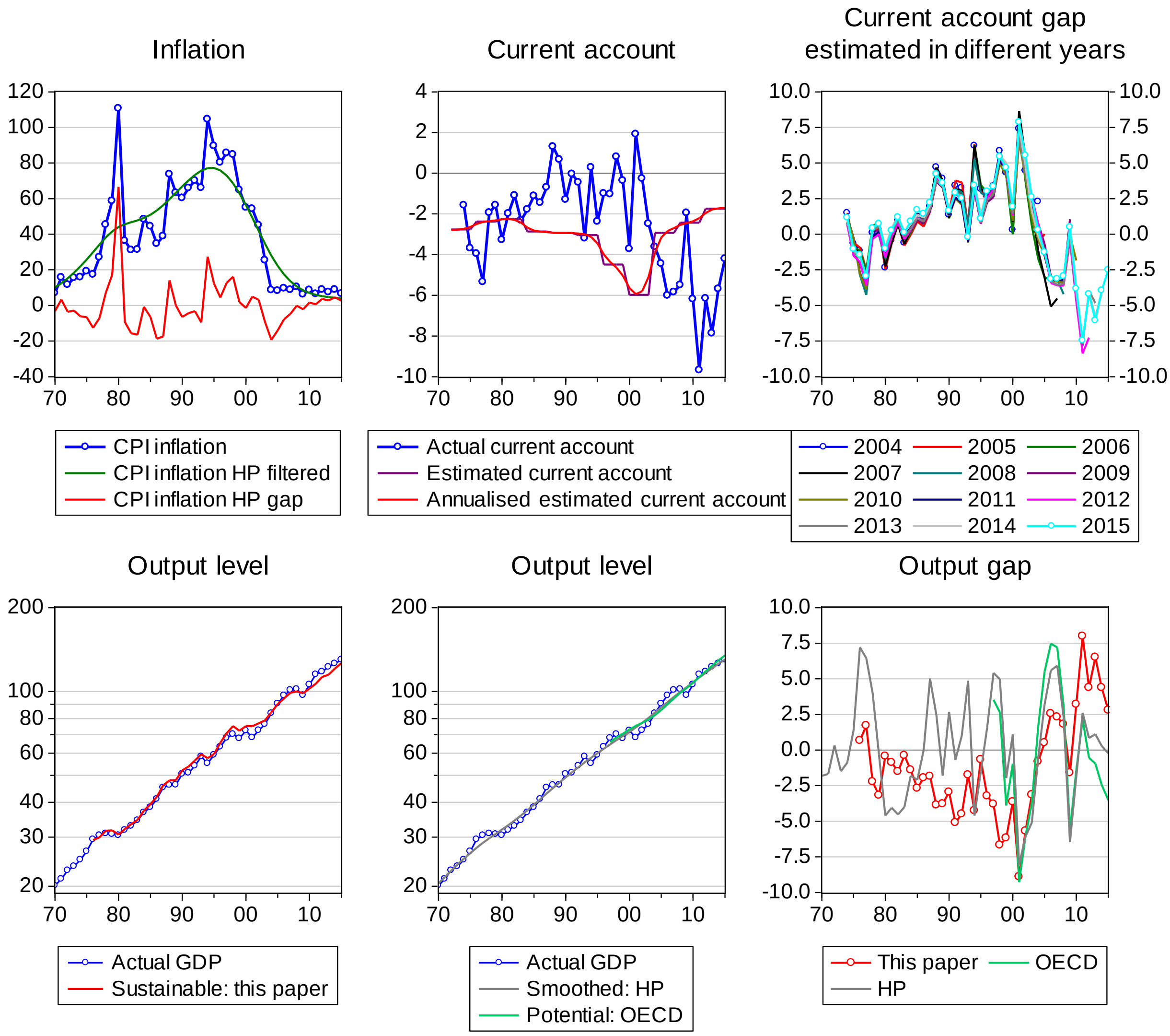
Switzerland



Thailand

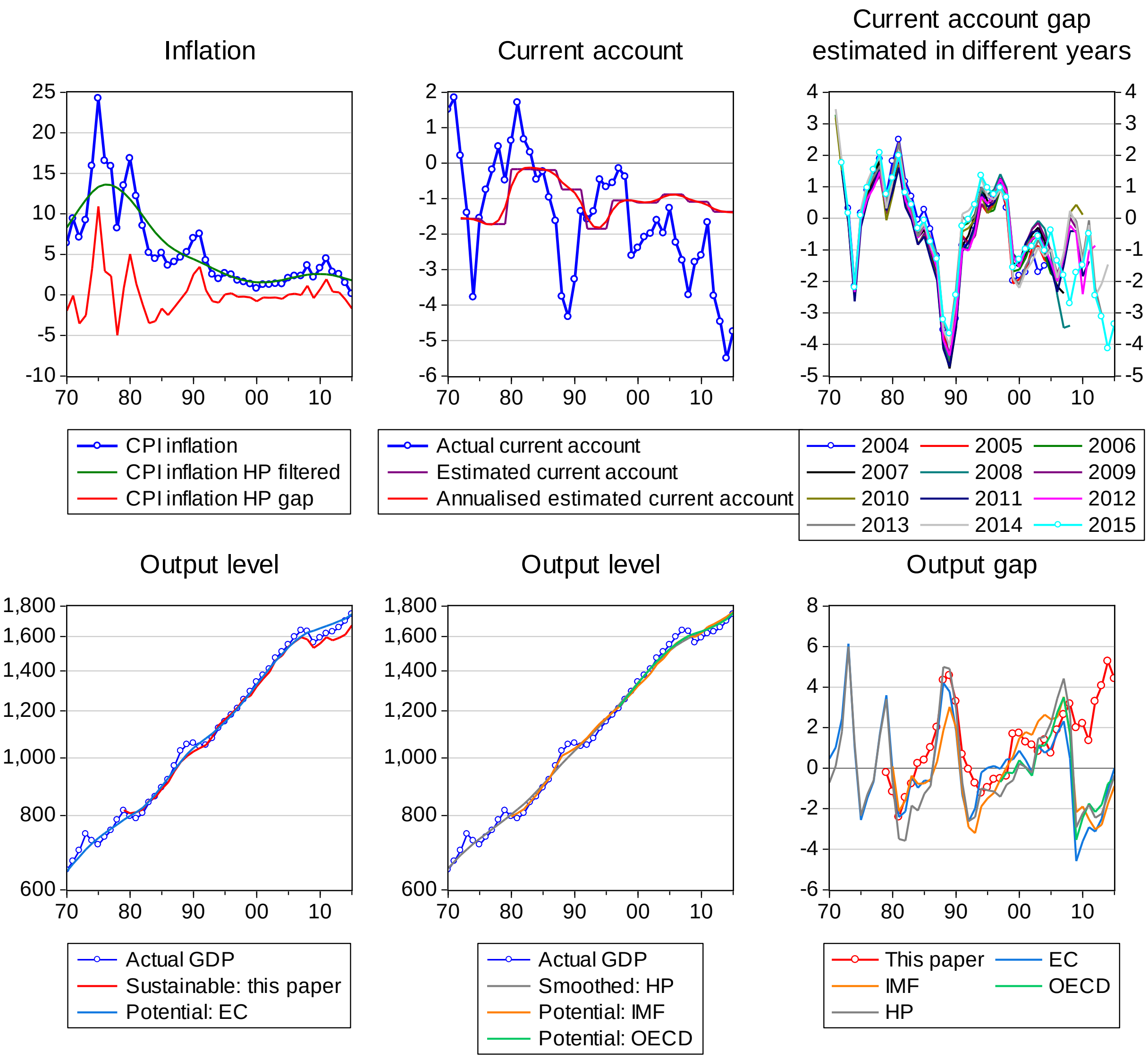

Inflation
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
Actual GDP
Sustainable: this paper
Output level
Actual GDP
Smoothed: HP
Output gap
This paper
HP

Turkey



Inflation
CPI inflation
CPI inflation HP filtered
CPI inflation HP gap
Current account
Actual current account
Estimated current account
Annualised estimated current account
Current account gap estimated in different years
2004 2005 2006
2007 2008 2009
2010 2011 2012
2013 2014 2015
Output level
Actual GDP
Sustainable: this paper
Output level
Actual GDP
Smoothed: HP
Potential: OECD
Output gap
This paper
OECD
HP

United Kingdom



United States of America