



WP/15/233

IMF Working Paper

Steady as She Goes—
Estimating Potential Output
During Financial “Booms and Busts”

by Helge Berger, Thomas Dowling, Sergi Lanau, Weicheng Lian, Mico Mrkaic,
Pau Rabanal, and Marzie Taheri Sanjani

I N T E R N A T I O N A L M O N E T A R Y F U N D

IMF Working Paper

European Department

Steady as She Goes—Estimating Potential Output During Financial “Booms and Busts”

**Prepared by Helge Berger, Thomas Dowling, Sergi Lanau, Weicheng Lian,
Mico Mrkaic, Pau Rabanal, and Marzie Taheri Sanjani¹**

November 2015

***IMF Working Papers* describe research in progress by the author(s) and are published to elicit comments and to encourage debate.** The views expressed in IMF Working Papers are those of the author(s) and do not necessarily represent the views of the IMF, its Executive Board, or IMF management.

Abstract

Potential output—in the sense of the GDP level or path an economy can sustain over the medium term—is a crucial benchmark for policymakers. However, it is difficult to estimate when financial “booms and busts” are driving the real economy. This paper uses a simple multivariate filtering approach to illustrate the role financial variables play in driving potential or sustainable output. The results suggest that it moves more steadily during financial “boom and bust” periods than implied by conventional HP filter estimates, which tend to more closely follow actual GDP. A two-region, multisector New Keynesian DSGE model with financial frictions sheds light on the economic forces that could be behind the results obtained from the filter. This has important implications for policymakers.

JEL Classification Numbers: E32, E44, C51, C13.

Keywords: Potential output, Output gap, Credit.

Author’s E-Mail Address: hberger@imf.org; tdowling@imf.org; slanau@imf.org; wlian@imf.org; mmrkaic@imf.org; mtaherisanjani@imf.org; prabanal@imf.org

¹ We thank Derek Mason for his help in constructing the dataset. Olivier Blanchard, Lars Svensson, Jörg Decressin, Davide Furceri, and EUR country teams provided many helpful comments and suggestions.

Contents	Page
I. Introduction	3
II. An Empirical Approach Using Multivariate Filtering	8
III. A Structural Approach to Estimating Potential Output	14
IV. Conclusions.....	20
 REFERENCES	 23
 FIGURES	
1. Euro Area: Output Gaps from a MVF Model.....	11
2. Euro Area: Greece/Ireland/Italy/Portugal/Spain—Output Gaps Estimates at Different Years.....	14
3. Euro Area: Shock Decomposition	17
4. Euro Area: Output Gaps with and without Financial Friction.....	18
5. Euro Area: Financial Wedge.....	19
 APPENDICES	
I. MVF Estimate and Comparison with HP Filter	26
II. DSGE Model and Estimation—An Overview	29

I. INTRODUCTION

A reliable measure of “potential output” is a critical benchmark for economic policy. Potential output is often defined as the level of output (or GDP) compatible with stable inflation or, equivalently, the absence of price rigidities. Another definition is sustainable output, the level of GDP that an economy can sustainably produce over the medium term in the absence of imbalances.² Both concepts are closely related. For example, GDP can be at potential (that is, without generating inflationary or deflationary pressure) but still not be sustainable because a “credit boom” has temporarily lifted growth but not yet inflation. This could mean that the level of potential output might fall subsequently in the direction of the level of sustainable output, for instance as the credit boom “busts.” Variants of both measures are used, sometimes in parallel, to measure the amount of slack in the economy, help identify the fiscal stance, or gauge the impact of structural reforms.

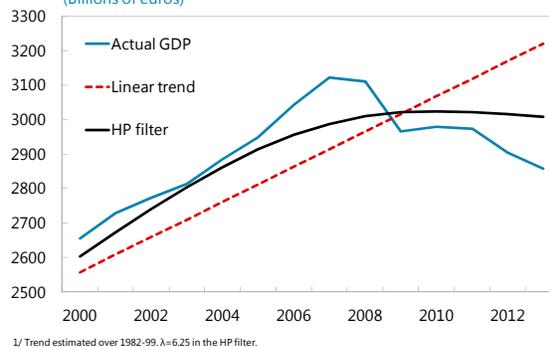
However, any such measure is an economic construct, not an “observable,” and will have to serve different purposes. Economies rarely operate at normal capacity and undistorted for long, which makes it

difficult to gauge the level of potential or sustainable output or the output gap (i.e., the distance of actual to the benchmark output). In reality, a barrage of overlapping shocks tends to move GDP one way or the other, leaving policymakers to decide whether these changes are due to lasting capacity shifts, transitory demand jitters, or simply statistical noise. Moreover, different policymakers will pay attention to

different aspects. For example, fiscal and macroprudential policy will be mostly interested in the sustainability of a given GDP path. However, a central bank targeting (only) inflation will be mostly interested in the information potential contains with regard to inflationary pressures.

Identifying potential or sustainable output is particularly difficult during financial “boom and bust” periods. The recent crisis has shown that imbalances can build up without triggering immediate price pressures and that large fluctuations in housing and credit markets, if left unaddressed, can lead to large cycles in real GDP. With hindsight, such patterns suggest actual GDP growth can significantly outpace what is sustainable during the boom years. However, in real time the degree of overheating is much more difficult to determine.

Greece, Ireland, Italy, Portugal, and Spain:
Potential GDP 1/
(Billions of euros)



² See IMF (2015) and Section III for further discussion of the alternative definitions of potential or sustainable output. The terms “output” and “GDP” are used synonymously throughout.

The experience of some countries in the Economic Monetary Union (EMU), are a case in point. For a number of countries, the new currency came with significantly improved credit access and rapidly falling interest rates and country risk premia. In the mid-1990s, Greece, Ireland, Italy, Portugal, and Spain's faced higher borrowing costs than France and Germany, but these interest rate differentials disappeared after the decision to establish EMU. This contributed to a surge in residential investment, credit, and house prices inflation—especially in Ireland and Spain—without leading to a significant increase in inflation. After the crisis hit, borrowing costs again increased relative to France and Germany. In what follows, we will take a closer look at what this implies for the assessment of the output gap in both groups of countries.

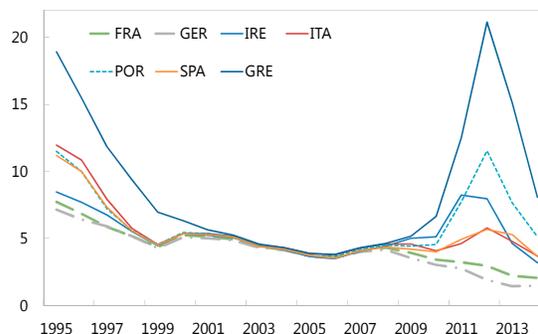
The grouping of countries also helps reduce the computational burden of multi-country modeling. However, while the

behavior of borrowing costs is broadly similar within the groups, there are also differences. Irish interest rates were relatively lower before EMU, but, after a period of falling housing prices in the early 2000s, Ireland went through a housing and credit boom and bust cycle broadly similar to Spain. Portugal saw high credit growth during the 2000s, but growth was never as high as Greece, Ireland, or Spain. Italy's credit growth and real house price appreciation was milder, and real growth was lower than the rest of the countries with high borrowing spreads.

If financial variables were to impact potential or sustainable output, what would it mean for policies? The answer depends on the policy goals and whether the instrument will impact the credit-adjusted measure of the output gap. For example, from a fiscal sustainability point of view, an improved estimate of sustainable output that is less perturbed by financial “booms and busts” will help avoid debt bias. If the revenue flows linked to a booming housing sector can be correctly identified as temporary, spending is less likely to be adjusted upward, and fiscal buffers can be built. A more robust measure of potential or sustainable output will also make it easier to assess the impact of structural reform on medium- and long-term growth.

The impact on macroeconomic policies requires more careful consideration. If taking into account financial variables would lead policymakers to believe that an ongoing episode of credit and house price growth was associated with a higher degree of overheating than suggested by conventional measures, the implications for monetary policy will depend on its effectiveness addressing the boom. For instance, while higher interest rates might help, more stringent macroprudential policy measures might be even more useful and should, therefore, be launched first.

Selected Euro Area Countries: 10 Year Bond Yields
(Percent)



Sources: Eurostat and Fund staff calculations.

Standard approaches to estimate potential or sustainable output deal with the difficulties posed by “boom and busts” to different degrees.

- ***Aggregate univariate filtering*** methods, such as the widely-used Hodrick-Prescott (HP) filter, operate under the broad assumption that potential or sustainable output is equal to a to-be-identified smooth trend around which GDP fluctuates.³ Their advantage is simplicity. Unfortunately, depending on the particular approach, they also can be sensitive to statistical choices (e.g., the degree of smoothing), suffer from the problem of reverting to actual GDP at the start and end of the sample, and, by construction, do little to foster our understanding of what actually drives potential or sustainable output. This can make it difficult to differentiate between temporary but large and persistent shocks to GDP on the one hand, and sustained shifts on the other. For example, for the group of euro area countries that faced particular financial stress during the crisis—Greece, Ireland, Italy, Portugal, and Spain—a standard HP filter approach would have suggested a level of potential output closer to actual GDP than a much less flexible linear trend during the pre-crisis period 2000–07 (see text figure).
- ***Production function models*** construct potential or sustainable output bottom-up from the supply side of GDP based on available labor and capital inputs, as well as measures of total factor productivity and utilization rates of labor and capital.⁴ This is the method applied by the European Commission and the Congressional Budget Office, among others.⁵ However, the approach requires timely access to micro-level data as well as filtering to eliminate short-term fluctuations from these variables—for example, to determine the level of labor available for production—creating problems very similar to the univariate filtering approach.
- ***Structural multivariate approaches***, while remaining focused on the supply side, use economic theory to help identify potential output through its implied relationship to selected observable variables such as inflation (Phillips curve) or employment (Okun’s law).⁶ They also narrow down the definition of potential to the output level that would be available if the economy could operate in the absence of price and wage rigidities but taking into account the reality of real frictions that demand

³ See Mishkin (2007) for a helpful categorization of approaches to potential output. Well known examples for aggregate filtering techniques other than Hodrick and Prescott (1997) include Beveridge and Nelson (1981), Clark (1987), and Christiano and Fitzgerald (2003).

⁴ See, e.g., Fernald (2014).

⁵ The production function approach can also be used to explore the heterogeneity of sectoral output gaps. For example, Lian (2015) constructs sector-level potential output accounting for inter-sector linkages.

⁶ See, among others Kuttner (1994), Laubach and Williams (2003), and Benes et al. (2010).

policies (e.g., monetary or fiscal policy) cannot overcome. This generally adds to the usefulness of estimates of potential output for guiding policy decisions. At the same time, the results are often sensitive to the specification and estimation of the underlying partial-equilibrium relationships and not all imbalances that will impact the sustainability of output in the medium term will be reflected in inflation.⁷ In addition, the necessary assumptions about the smoothness of potential output require judgment quite similar to the selection of the smoothness of univariate filters.

- ***Dynamic stochastic equilibrium (DSGE) models***, overcome some of these shortcomings by modeling both the demand and the supply side of the economy to identify GDP fluctuations driven by supply shocks that matter for potential output over the longer term (e.g., Smets and Wouters, 2003, Andrés, López-Salido, and Nelson, 2005). The latest generation of estimated DSGE models also incorporates financial frictions, including the role of credit and asset markets, banks, and the housing market (see, for instance, Christiano, Motto, and Rostagno, 2014). Furlanetto, Gelain and Taheri Sanjani (2014) explicitly measure the effect of financial frictions on estimated potential output.⁸ Among other things, this new model class can, in principle, provide additional insights on how the concepts of potential and sustainable output are linked—for example by helping to distinguish between sustainable changes in output linked to a reduction in financial frictions from credit-fueled growth.

This paper uses a combination of approaches to illustrate how financial variables can inform the estimation of sustainable and potential output. First, a multivariate filter (MVF) in the spirit of Borio, Disyatat, and Juselius (2013) is used to show under which circumstances credit growth, house prices, and other additional information will usefully inform sustainable output estimates for the euro area and other European economies. Second, an estimated DSGE model with financial frictions complements the filtering approach by providing theoretical foundations for the link between financial cycles and potential output. The results are encouraging in the sense that these completely different modeling strategies suggest that taking into account financial variables can impact our view on the level of potential or sustainable output in a similar fashion for different country groups in the euro area.

More specifically, the MVF incorporates fluctuations in financial variables to improve estimates of the non-cyclical component of GDP. The MVF identifies episodes of

⁷ See, among others, Staiger, Stock, and Watson (1997a, b) and Orphanides and van Norden (2002).

⁸ More specifically, they show that the financial wedge, defined as the difference between potential output derived from a model with and without financial friction, is highly correlated with the default risk spread, pointing to the relevance of financial frictions in computing the output gap. This allows distinguishing sustainable changes in potential output linked to a reduction in financial frictions from credit-fueled growth triggered by temporary surges in demand in the same coherent DSGE framework. See also Section III.

particularly high or low GDP growth as cyclical deviations from the level of sustainable output based on deviations of credit and house prices, inflation, and capacity utilization from their own longer-term trends. For example, if wide swings in output tend to occur along with wide swings in credit, the approach will ignore the former when determining the level of sustainable output. A critical element is to restrict the information from financial variables to higher frequencies so as to avoid a misinterpretation of permanent shifts (say, a higher level of credit due to financial deepening) as transitory.

The MVF results suggest that conventional estimates might overestimate sustainable output during credit booms and underestimate it during busts.⁹ The MVF tends to deviate markedly from univariate HP filters in countries that experienced a “financial cycle,” providing a sensible distinction between sustainable and transitory movements in GDP driven mostly by credit and housing price movements. This means that sustainable output moves more steadily during such periods than implied by conventional estimates. As a consequence, MVF output gaps tend to suggest more severe overheating (i.e., a larger positive output gap) before the crisis and more excess capacity afterwards (a more negative gap) than the univariate HP filter. These results come with an element of hindsight, as MVF models have to “learn” how financial data impacts the estimate of sustainable output. Where the use of time series data does not allow this, cross-country approaches could be helpful. Alternatively, a structural DSGE model can be used.

A two-region DSGE model with financial frictions and housing backs the findings of the MVF for the euro area.¹⁰ Similarly to Furlanetto, Gelain and Taheri Sanjani (2014), the model has an explicit role for leverage and credit risk. In this setting, it is possible to distinguish sustainable changes in potential output linked to a reduction in financial frictions from credit-fueled growth triggered by temporary surges in demand. Take the example of Greece, Ireland, Italy, Portugal, and Spain, all of which saw significant drops in interest rates after the introduction of the euro. Seen through the lens of the model, this signals a persistent decline of risk premia, which reduced financial frictions and lifted both GDP and potential (as well as, arguably, sustainable) output. However, by the mid-2000s, a housing and credit boom had taken hold in some of these countries—a development large enough to open a significant output gap for the aggregate. The crisis after 2007 reversed most of these gains, leading to an increase of country and housing risk premia, a credit bust, and a large negative

⁹ See Alberola, Estrada, and Santabàrbara (2014) for a similar result for Spain. They find that sustainable growth, defined as output growth that does not widen macroeconomic imbalances, is more stable than conventional measures of potential growth, resulting in an output gap that is substantially larger (in absolute value) both before and after the crisis.

¹⁰ See Section III. The model is described in greater detail in Rabanal and Taheri Sanjani (2015).

output gap. While some of these gyrations spilled over into the rest of currency area, the output gap remained relatively flat in the rest of the euro area after the turmoil of 2008–09.

Overall, the evidence discussed here suggests that financial variables can inform estimates of sustainable or potential output—but more work is needed. The MVF approach lets the data speak but still requires numerous practical decisions that impact findings and deserve further scrutiny. DSGE models help identify the drivers of potential and sustainable output in a coherent way but their underlying structural assumptions also impact the results. The relevant literature is still growing and future research will help refine the results discussed here.

The rest of the paper is organized as follows. Section II describes the MVF approach. Section III discusses the structural model, emphasizing the importance of financial frictions to understand output gaps in the euro area and the consistency with the MVF. Finally, Section IV briefly points out preliminary implications of these findings for policymakers.

II. AN EMPIRICAL APPROACH USING MULTIVARIATE FILTERING

MVF models offer a reduced-form approach to capturing the link between financial cycles and output gaps. The general idea is to augment traditional aggregate univariate filtering methods by using additional information to help identify transitory movements in economic activity. As discussed below, the approach taken in this paper goes beyond the existing literature, including by carefully filtering all additional variables to ensure that any longer-term trend will ultimately be captured by the estimate of potential.

Specifically, sustainable GDP is estimated by decomposing observed GDP time series into two unobservable components, the cycle (in the broadest possible sense capturing all transitory movements of GDP) and the trend (or sustainable) GDP:

$$y_t = y_t^* + c_t \tag{1}$$

$$\Delta^2 y_t^* = \varepsilon_t^* \tag{2}$$

$$\lambda \equiv \frac{\text{Var}(c_t)}{\text{Var}(\varepsilon_t^*)} \tag{3}$$

where y_t and y_t^* represent observed and sustainable output (or GDP), respectively, and c_t is the business cycle. Mirroring the HP filter, the model is estimated with a constraint on the variance ratio λ to ensure the desired spectral properties of the filtered series. With quarterly

data, the conventional value for λ is 1600, which implies that potential output will capture output movement at frequencies above 8 years.¹¹

In addition, the model takes into account information from a set of observable variables, x_t , which could be correlated with the output gap. To match the dynamic properties of the latter, the approach allows for the current output gap to depend on its lagged values.

$$y_t - y_t^* = \rho(y_{t-1} - y_{t-1}^*) + x_t\beta + \varepsilon_t^o, \quad (4)$$

where the variance ratio $\frac{\text{Var}(y - y^*)}{\text{Var}(\Delta^2 y^*)}$ is constrained to match the one implied by equations

(1)-(3) and implicitly the frequency characteristics of the HP filter. In the empirical application, x_t will include up to four variables: credit growth, house price inflation, consumer price inflation, and, where available, a survey-based measure of capacity utilization.

The estimation procedure differs from the one in Borio, Disyatat, and Juselius (2013) in three ways. (See Appendix I.A for further details.)

- First, instead of a Bayesian approach to estimating model parameters, maximum likelihood estimation (MLE) is used. This data-driven approach avoids the selection of priors, which make it difficult to apply to a large number of countries of potentially very different characteristics.
- Second, along similar lines, the parameters driving the persistence of the output gap, ρ and β , are estimated in a two-step procedure and not simultaneously. The autoregressive parameter of the output gap, ρ , is estimated from the output gap obtained from the original HP filter and then substituted into equation (4), which is estimated using MLE.¹² This approach bypasses the potentially problematic numerical joint estimation of ρ and β and allows the data to determine the persistence of the gap.¹³ In practice, the results are not very sensitive to moderate changes in ρ .
- Third, as indicated earlier, to prevent possible longer-term trends in the additional variables x_t from being misinterpreted as cyclical, these variables are pre-filtered to

¹¹ Ravn and Uhlig (2002) discuss the mapping of λ into HP filter cutoff frequencies.

¹² While the endpoint problem in the HP filter can affect the estimates of the potential GDP, the estimates of the autocorrelation parameter are more robust because they depend upon the entire history of the sample.

¹³ Borio, Disyatat, and Juselius (2013) solve the problem of numerical instability by imposing a tight prior on ρ with a peak at 0.8.

exclude movements at frequencies of 20 years or longer.¹⁴ In other words, the approach uses history as a guide to help the model associate longer-term phenomena such as credit deepening or a lasting reduction in financial frictions with the development of potential output. To illustrate the importance of this additional step, the findings below will report not only these filtered results but also results where the additional variables x_t are simply demeaned before running the multivariate filtering procedure (as in Borio, Disyatat, and Juselius, 2013).

The results suggest that sustainable output might move more steadily during financial “boom and bust” periods than implied by conventional HP filter estimates.

Applying the MVF approach to the group of countries that saw their interest rates drop significantly following the introduction of the euro and later faced particular financial stress during the crisis—Greece, Ireland, Italy, Portugal, and Spain—indicates that actual output started to exceed estimated sustainable output prior to the crisis, resulting in a large positive output gap (see Figure 1).¹⁵ However, the gap measure peaks earlier, in 2005, and stays at a high level until about 2007. After the crisis, with actual output falling fast, the output gap turned significantly negative.¹⁶ The difference between the MVF and HP filter results are predominantly driven by the contributions of the deviations of house price and credit growth from their longer-term trends, which help the MVF approach to avoid misinterpreting the output effects of the “boom and bust” cycle as lasting movements of sustainable output. In this context, ensuring the longer-term stationarity of the additional variables entering the MVF approach is very important. A reliance on simple de-meaning produces results much closer to the HP filter. Conversely, reflecting the lack of a financial cycle, the MVF output gap estimated for the rest of the euro area—here approximated by Germany and France—is fairly similar to the conventional HP filter. Note that compared to the information in house prices and credit growth, the MVF models attaches relatively little weight to movements in CPI inflation when estimating sustainable output.

The results are fairly robust to a number of alternative specifications, but the treatment of non-stationary additional variables matters. As discussed, small to moderate variations of the persistence of output gap in the MVF do not change the results significantly. The inclusion of individual credit-boom related explanatory variables gives broadly similar

¹⁴ For example, if not corrected, the presence of a strong upward trend in credit growth on the right-hand-side of the dynamic output gap equation (4) can lead to a misinterpretation of a long-term trend of financial deepening as cyclical. As a consequence, the resulting potential output estimate is higher and the output gap lower than it would otherwise be. As a pragmatic remedy, a HP filter is used with λ equal to 63,500, reflecting the fact that financial cycles are conventionally thought to last longer than “standard” business cycles. To mitigate the endpoint problem, the variables are extended beyond the observed sample using standard AR models.

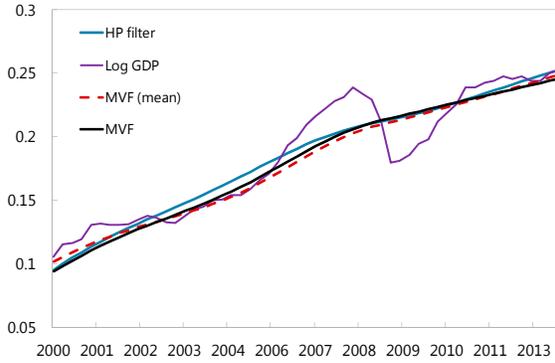
¹⁵ As mentioned, while all of these countries were subject to the same negative interest rate shock, not all of them experienced a “boom and bust” period afterwards. Note that this introduces a bias *against* finding a significant role for financial variables such as credit on sustainable or potential output.

¹⁶ The MVF-implied output gap is also statistically different from the HP result (see Appendix I.B).

**Figure 1. Euro Area: Germany/France
Output Gaps from a MVF Model**

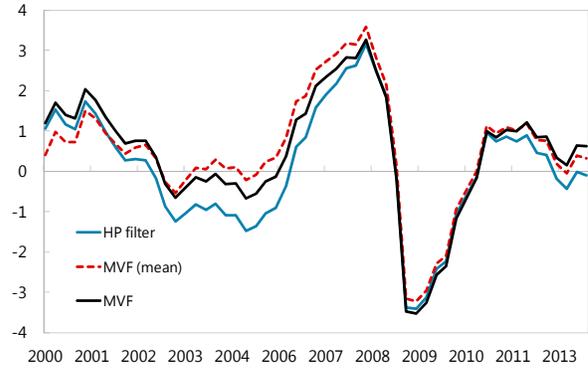
GDP Trend with Combined Information

(Logs)



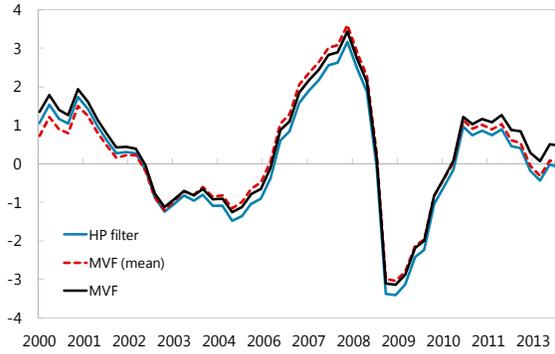
GDP Gap with Combined Information

(Percent of potential GDP)



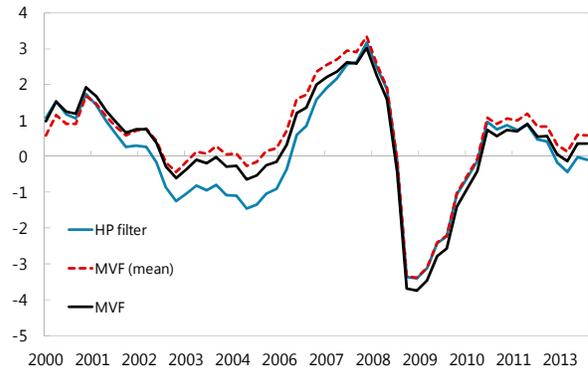
GDP Gap and Inflation

(Percent of potential GDP)



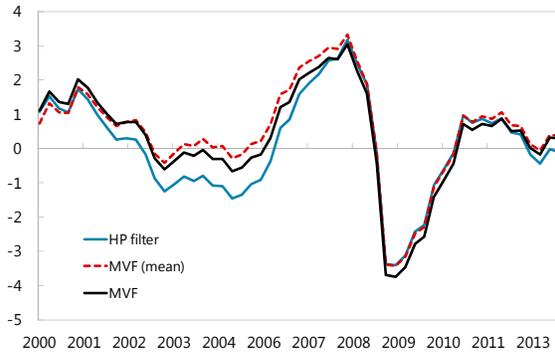
GDP Gap and House Prices

(Percent of potential GDP)



GDP Gap and Credit Cycle

(Percent of potential GDP)

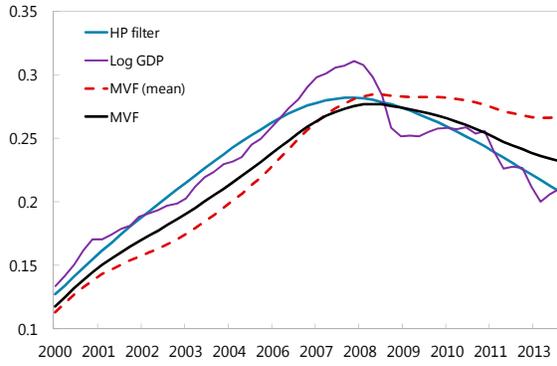


Sources: IMF Staff estimates and EUROSTAT.

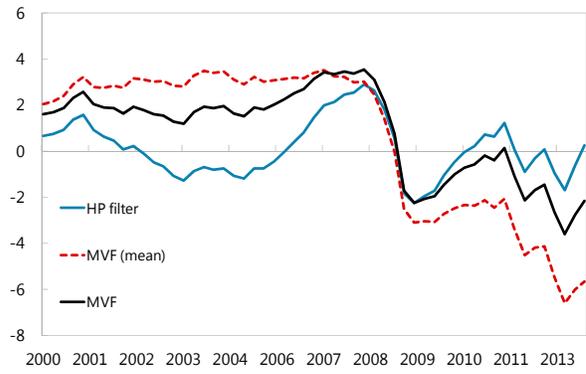
Note: Units are percent/100.

**Figure 1. Euro Area: Greece/Ireland/Italy/Portugal/Spain
Output Gaps from a MVF Model (continued)**

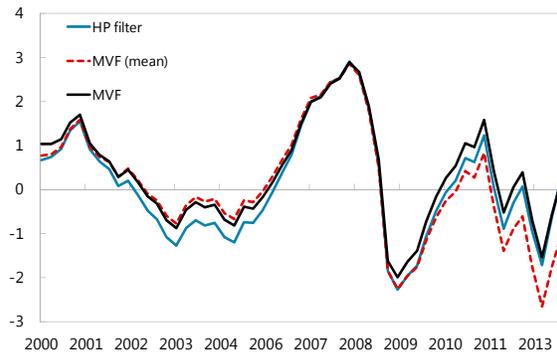
GDP Trend with Combined Information
(Logs)



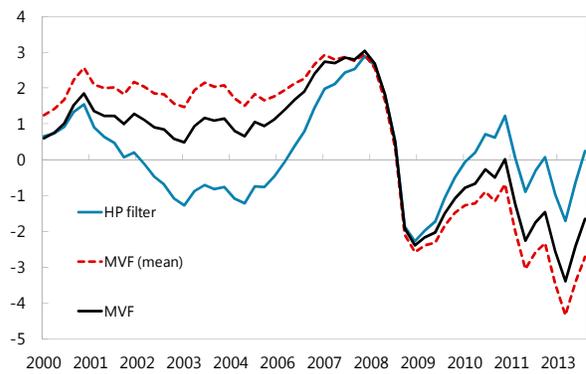
GDP Gap with Combined Information
(Percent of potential GDP)



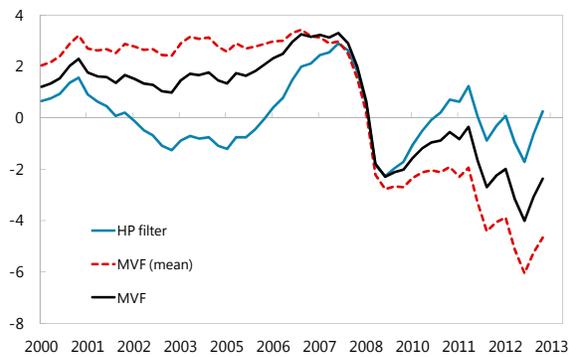
GDP Gap and Inflation
(Percent of potential GDP)



GDP Gap and House Prices
(Percent of potential GDP)



GDP Gap and Credit Cycle
(Percent of potential GDP)



Sources: IMF Staff estimates and EUROSTAT.

Note: Units are percent/100.

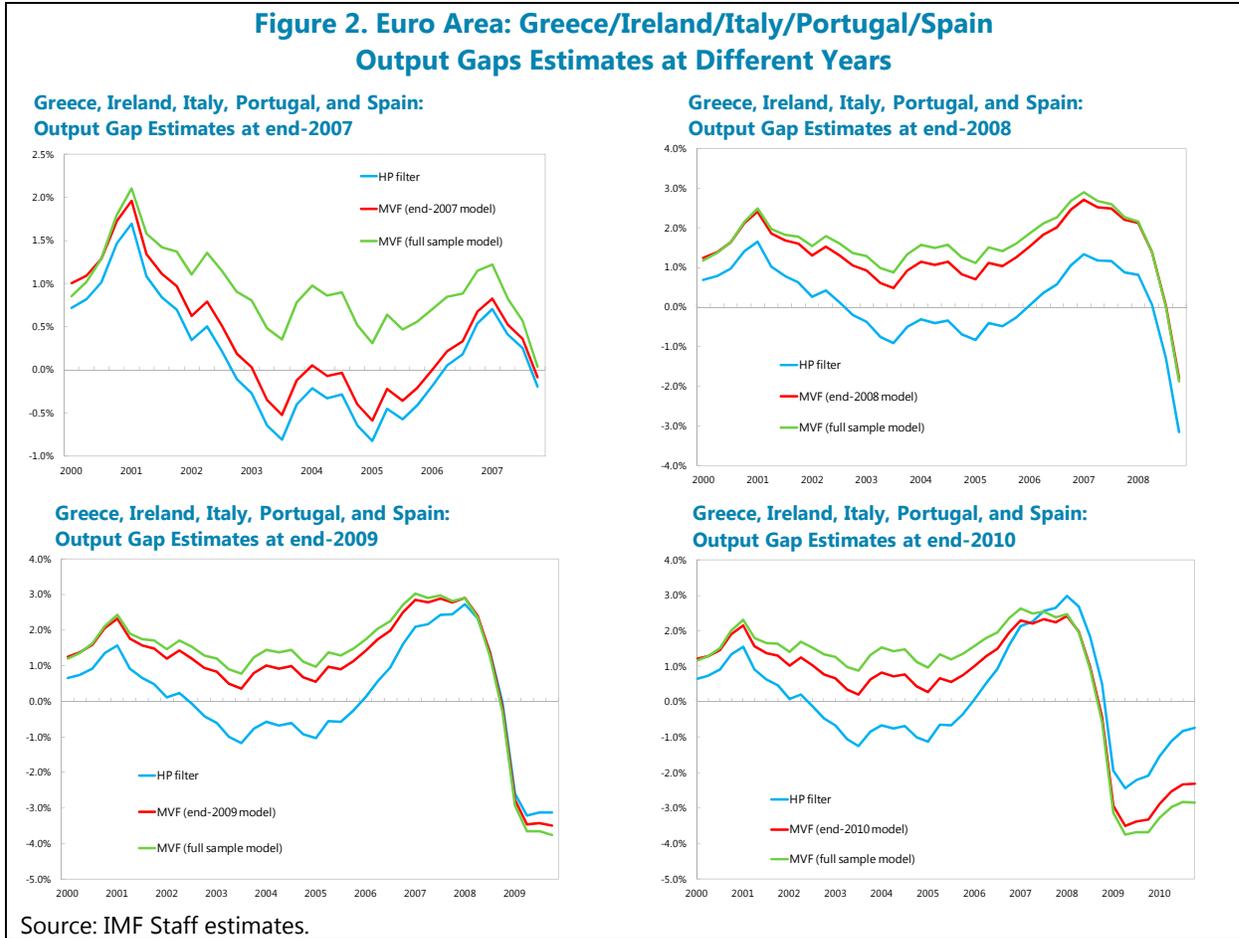
results to the estimation where they are included jointly (e.g., house prices and various credit cycle variables). Where the inclusion of additional variables makes a difference for the estimated level of sustainable output, the approach to pre-treatment can be important as well. Finally, the estimation requires time series that are long enough to capture the pre-crisis state of the economy, which could be a limiting factor in some cases (see below).

The MVF approach works best if the model can be estimated across a complete “boom and bust” episode. As the model relies on exploiting the variation of financial and other variables around their longer-term trend to identify transitory movements in GDP, the coefficients linking the output gap to these movements are more difficult to identify in the absence of full financial cycles in the data. The results for the group of Greece, Ireland, Italy, Portugal, and Spain is a case in point. Using only data until 2007, the HP and MVF models estimate fairly similar output gaps that turn negative around 2005 (see Figure 2).

However, applying the MVF model estimated from the full sample to the data available in 2007 points to a significantly positive output gap. This suggests that this class of models can be an effective tool to inform policymakers in “real time” when estimated based on long enough time series. Indeed, in the case of the group of Greece, Ireland, Italy, Portugal, and Spain, the weight given to financial variables in the explanation of the dynamics of the implied output gap significantly increases after 2007. Alternatives less sensitive to sample-length include taking advantage of cross-country variation in estimating MVF models or turning to structural modeling (see Section III).

The MVF approach can, of course, also be applied at the country level. Among the countries in the group shown in the second panel of Figure 1, including financial variables in the estimate of the output gap makes a notable difference for Spain, Portugal, and Greece for the full sample period, broadly resembling the aggregate results shown above (see Appendix I.C). For Ireland, the difference becomes more pronounced only after 2005, reflecting the temporary negative turn of house price inflation in the early 2000s and the fact that credit growth truly accelerated only in the second half of the decade. Somewhat counterintuitively, for Italy the MVF-implied output gap exceeds the one suggested by the simple HP filter until about 2005, likely in response to the moderate but uninterrupted house price growth relative to long-term trends during this period.¹⁷ This last finding suggests that a mechanistic application of the MVF approach can be misleading—a broader point taken up again in Section IV.

¹⁷ The general pattern is broadly similar for other advanced European countries (not shown). The difference between the MVF and simple HP approach tends to be larger for economies that experienced a fully developed credit and housing boom before the crisis, including, for example, in Denmark, the Netherlands, and the United Kingdom, while it is small in Austria, Belgium, and Switzerland.



III. A STRUCTURAL APPROACH TO ESTIMATING POTENTIAL OUTPUT

A DSGE approach can shed light on the economic forces illuminated by the MVF. The modeling approach combines two strands of the recent literature—a new generation of DSGE models, which incorporate financial frictions into the standard New Keynesian model with price and wage rigidities (e.g., Christiano, Motto, and Rostagno, 2013; Furlanetto, Gelain, and Taheri Sanjani, 2014), and two-country models with housing that improve our understanding of monetary and macroprudential policy tradeoffs in the euro area (Aspachs-Bracons and Rabanal, 2011; Quint and Rabanal, 2014).¹⁸

The framework focuses on the euro area, representing it as a highly stylized two-region, two-sector, two-agent general equilibrium model. Two types of goods, housing and non-durable consumption, are produced under monopolistic competition and nominal rigidities. While non-durables are traded across regions, housing is non-tradable. In each region, there are two types of agents, savers and borrowers. Borrowers prefer to consume early, which

¹⁸ See Appendix II and Rabanal and Taheri Sanjani (2015) for details.

creates the condition for credit to occur in equilibrium. The single monetary policy is conducted by a central bank with a standard flexible inflation targeting regime, seeking to stabilize union-wide consumer inflation and real GDP growth. This means that monetary policy alone cannot address sector- or region-specific shocks.

Borrowing households face financial frictions. Applying the approach of Bernanke, Gertler and Gilchrist (BGG) (1999) to households, those seeking credit for residential investment have to provide their house as collateral, but house values are subject to idiosyncratic valuation shocks. As a consequence, house price shocks affect the balance sheet of borrowers, which in turn affect the default rate on mortgages and the lending-deposit spread. The variance of valuation shocks varies across time subject to what are labeled as housing “risk” shocks, with periods of elevated risk implying more volatile house prices, mortgage default risk and higher lending-deposit spreads.

Financial frictions, in turn, impact actual and potential output. Financial frictions drive a spread between the mortgage lending rate and the risk-free deposit rate. Shocks to this spread, such as “risk” shocks, will influence aggregate output through households’ residential investment decisions. The feedback effects introduced by the housing accelerator mechanism imply that the impact of such shocks could be large, depending on aggregate financial conditions (such as loan-to-value ratios and leverage). This ultimately determines the efficient frontier of the overall economy and the sustainable level of economic activity.

In this context, potential output is defined as the counterfactual level of output attained under fully flexible prices and wages and in the absence of mark-up shocks. Following the literature, nominal rigidities and “inefficient” mark-up shocks are removed from the definition of potential. Real and financial frictions are kept in the definition, as well as all technology, preference, demand and financial shocks. Moreover, firms maintain constant monopoly power in the goods and labor markets and mark-ups are constant at their steady state level. Potential output in this sense is still close to the conventional definition as the level of output that can be sustainably produced at normal capacity—with normal capacity understood as the output available without the restrictions imposed on labor and product markets by sluggish price and wage adjustment.¹⁹

The model is estimated for the euro area regions using Bayesian methods. As before, the regions or country groups of interest are, on the one hand, Greece, Ireland, Italy, Portugal, and Spain, and Germany and France, on the other. Most parameters related to household

¹⁹ This constitutes a third best equilibrium. The first-best (or efficient) allocation assumes perfect competition in goods and labor markets, with no nominal rigidities, and no financial frictions or shocks. The second best equilibrium allows for constant but non-zero mark-ups. The third best lifts the assumption of perfect financial markets (no financial frictions). Note that, while first- and second-best outputs may vary over time, the gap between these two remains constant. However, the gap to the third-best equilibrium is time-varying and depends on the leverage ratio of households.

preferences, nominal and real rigidities, and the stochastic properties of the shocks are estimated using Bayesian methods, as described in An and Schorfheide (2007), with quarterly data between 2000:Q1 and 2013:Q4.²⁰ Some model parameters are calibrated because they cannot be directly identified from the data, including the probability of credit defaults. This allows backing out the level of risk in the economy.

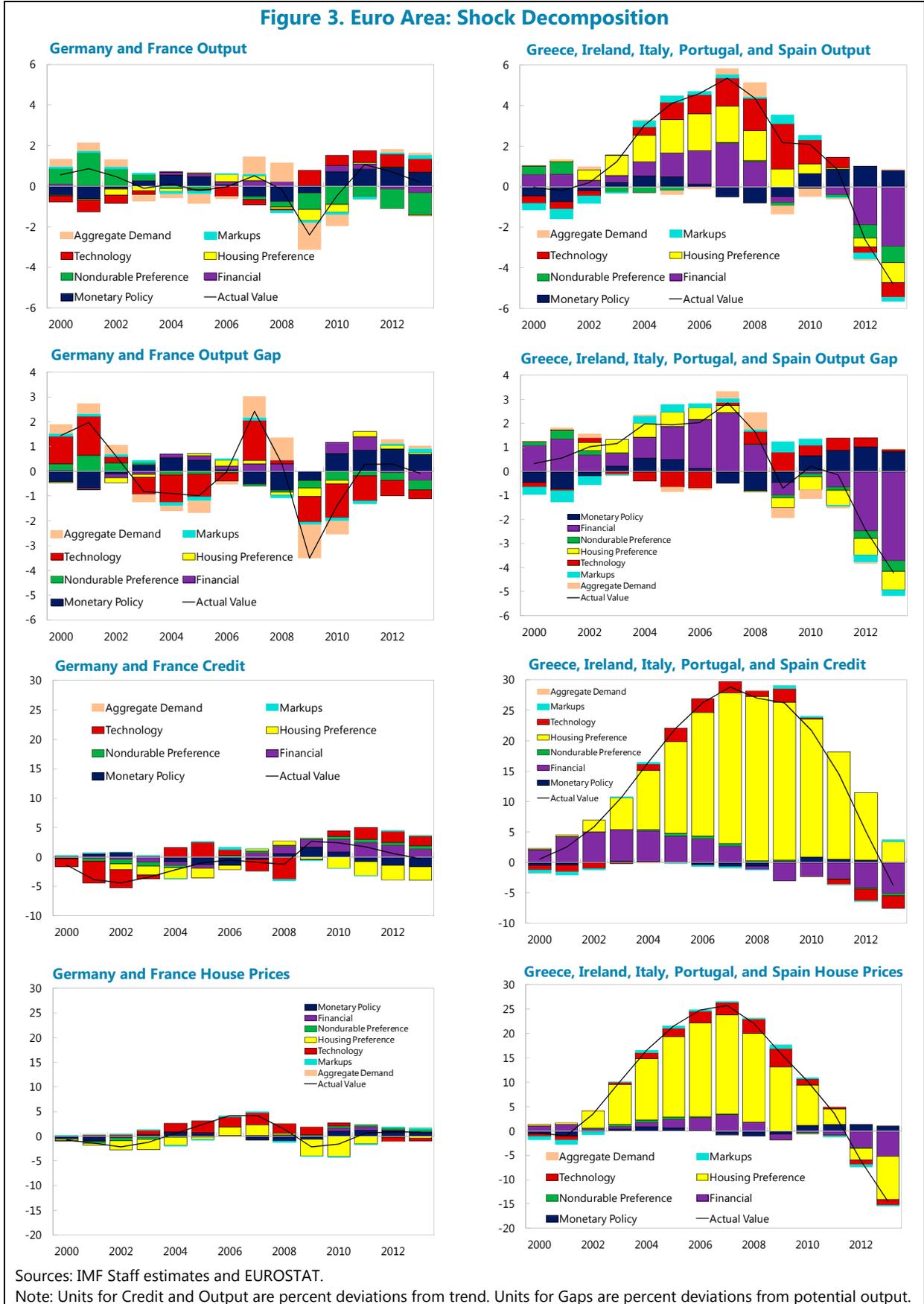
Consistent with the MVF, the results show that a credit-fueled surge in housing demand opened a large positive output gap before reversing after the crisis. The model allows for a structural decomposition of credit, output, and the output gap between 2000 and 2013 and their determinants (see Figure 3).²¹ In particular:

- **Credit:** In the group of Greece, Ireland, Italy, Portugal, and Spain, favorable financial shocks helped reduce financial frictions and improve access to credit (see the discussion below) after the introduction of the euro. The credit surge observed for the aggregate of these economies around 2003 was quantitatively much larger and mostly driven by rapidly increasing housing demand and the resulting positive housing-accelerator feedback loop: as demand for housing services surged, house prices increased and the resulting improvement in household net worth improved credit availability and residential investment. This, in turn, fueled house price increases further. However, the same factors in reverse then explain much of the drop in credit after 2008. Conversely, credit in Germany and France was an order of magnitude less volatile (note the difference in scale) and driven by several factors. In fact, falling housing demand reduced credit volumes for most of the sample.
- **Output:** Not surprisingly, financial shocks (such as country risk premia and housing market risk) and housing demand were also the main driver of output in the group of Greece, Ireland, Italy, Portugal, and Spain, while other aggregate demand shocks (such as household consumption, government spending, and net-exports) and supply-side shocks (technology and mark-ups) played a comparatively minor role, except in 2008–09. The single monetary policy impacted output in this group of countries in a countercyclical fashion, but not enough by far to offset the housing-driven “boom and bust” cycle. However, in 2002–05, monetary policy was mildly pro-cyclical. In Germany and France, output fluctuations were generally much milder and more closely linked to aggregate demand shocks, and the common monetary policy had a countercyclical effect.

²⁰ The aggregation into country groups is using HICP weights. See Appendix II and Rabanal and Taheri Sanjani (2015) for further details on the estimation and calibration of the model.

²¹ In order to make Figure 3 (and following the model-based figures) more readable, the series have been aggregated to annual frequency, and shocks across countries have been aggregated under the same category.

Figure 3. Euro Area: Shock Decomposition

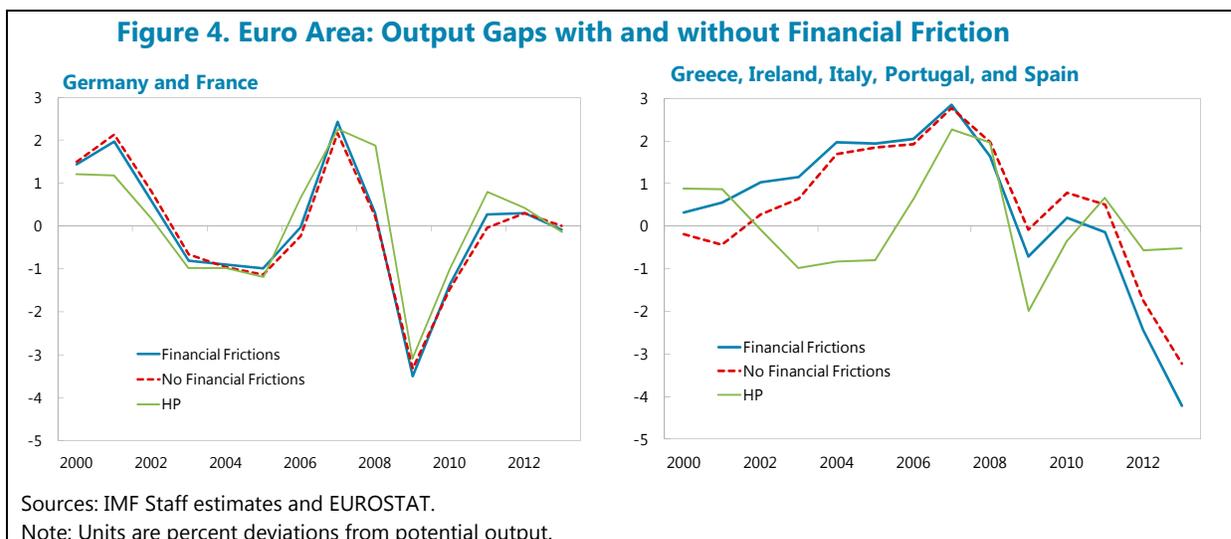


Sources: IMF Staff estimates and EUROSTAT.

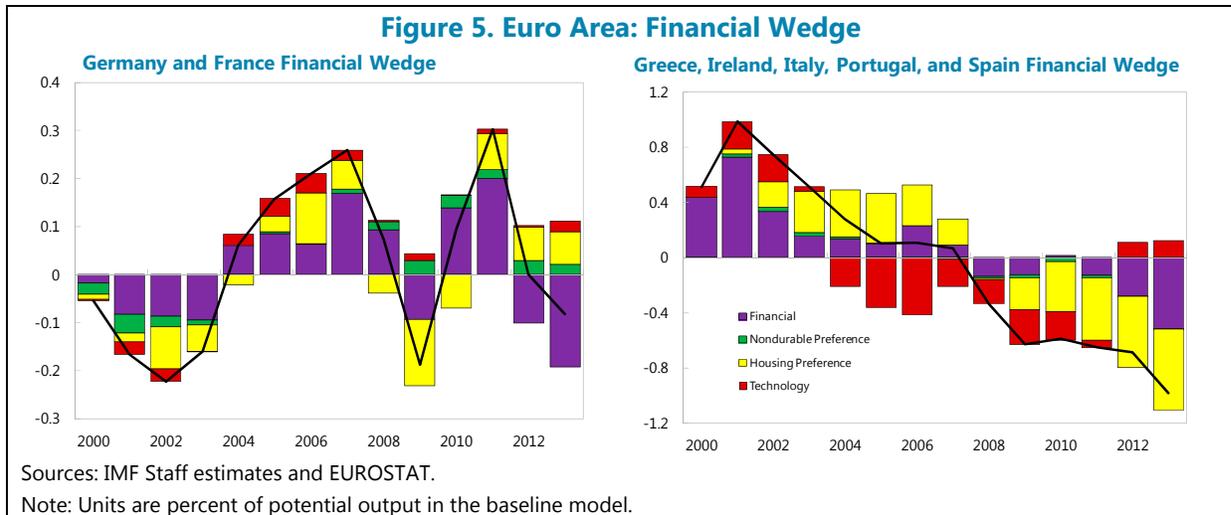
Note: Units for Credit and Output are percent deviations from trend. Units for Gaps are percent deviations from potential output.

- Output gap:** In the group of Greece, Ireland, Italy, Portugal, and Spain, actual output consistently exceeded potential prior to the crisis. Until 2002, this seems to reflect mostly improving financial conditions after the introduction of the euro, which for a time lowered interest rate spreads and increased credit and output. However, later on housing demand also contributed to the output gap. Fiscal policy (captured in the aggregate demand shock) supported growth in 2008, but faltering housing demand and the reversal of financial conditions pushed the output gap into negative territory afterwards. Meanwhile, in Germany and France, the estimated output gap oscillated around zero, driven mostly by external demand (in particular, in the aftermath of the global financial crisis) and productivity shocks. Monetary policy had an increasingly expansionary effect in both regions towards the end of the sample, but given the difference in headwinds had a proportionally stronger impact in the Germany and France.

The results confirm the MVF intuition that financial frictions can matter for potential output. One way to illustrate their relevance is to compare the output gap derived from a counterfactual baseline model without financial frictions to the one including financial frictions (Figure 4). For the group of Greece, Ireland, Italy, Portugal, and Spain, taking into account financial frictions results in a marked change in the assessment of the economic slack as defined in the DSGE framework: the pre-crisis output gap is between one and three times larger than estimated using a model that does not allow for a role for credit in the economy. In addition, the HP filter gap appears to deliver the wrong signals, in particular during the mid-2000s and at the end of the sample. For Germany and France, where the credit played less of a role, the difference looks much less remarkable, and the HP filter delivers the same signal.



Both financial shocks and leverage are relevant in this regard. Computing the difference between the output gap estimated with the full model with financial frictions and the benchmark model without credit frictions allows us to take a closer look at the financial wedge and its drivers (Figure 5). Leverage matters through the housing accelerator that amplifies swings in household preferences that change investment and house prices.²² Conversely, financial shocks directly affect the efficiency frontier by changing the spread between housing lending rates and risk-free lending. But how do they change over time? In the group of Greece, Ireland, Italy, Portugal, and Spain in the early 2000s, the boom was amplified by favorable financial factors as financial risks diminished. As these effects faded around 2003, the accelerator-driven housing boom lifted output and output gap. Since the crisis hit in 2008, financial and housing factors combined in a reverse financial accelerator effect that severely deepened the recession.



These results come with caveats—but overall they suggest that financial variables hold important information for the development of potential output as it happens. Like any modeling exercise, the findings are sensitive to the underlying assumptions and different models can produce different output gaps (e.g., Justiniano, Primiceri, Tambalotti, 2013). That said, the approach taken here offers a plausible economic mechanism to incorporate house prices and mortgages in a well-developed modeling structure that allows the estimation procedure to identify the shocks that are most relevant for potential output. While the DSGE decomposition of the recent euro area history finds that credit growth can be linked to a reduction in financial frictions and higher potential output, it also confirms the intuition provided by the MVF approach that very large surges in credit and house prices point to

²² The implicit assumption here is that all of the investment is actually enhancing the efficient production frontier of the economy. This goes back to the definition of potential output as the output achievable under flexible prices and wages discussed earlier in the section. Under this approach, changing household preferences affect potential.

unsustainable output growth. As discussed, while DSGE models also need to be estimated or calibrated to the data, their structural nature tends to make them relatively less dependent on the availability of very long time series including a “boom and bust” episode or incorporating cross-country evidence. Another question is whether this approach can provide a ready-to-use guidance to policymakers in practice (see below).

IV. CONCLUSIONS

Potential or sustainable output is a crucial benchmark for policymakers, but it is difficult to estimate in the presence of financial “booms and busts.” For example, a credit-fueled surge in housing demand, house prices, and residential investment can lead to a period of exceptionally strong GDP growth that—even though bound to end eventually—might be misinterpreted as a sustainable acceleration of potential output growth. As a consequence, policymakers might overestimate the strength of the public finances or underestimate the degree of overheating and inflationary pressures in the economy. Conversely, when a housing boom ends, the ensuing drop in GDP could wrongly suggest an equally steep decline in potential or sustainable output. This might mislead policymakers to underestimate the size of the output gap and, thus, the need for corrective macroeconomic stabilization measures.

This paper illustrates that financial variables can help inform estimates of potential or sustainable output. A simple multivariate filtering approach incorporating financial variables such as credit and house prices (appropriately purged of their long-term trend) suggests that, as a rule, sustainable output adjusted for the ups and downs of financial variables moves more steadily during financial “boom and bust” periods than implied by conventional estimates such as univariate HP filters. This is particularly clear in the application of the technique to a group of countries among which some were subject to wide credit and house price swings during the pre- and post-crisis period. In contrast, adding financial variables to the estimation of sustainable output for countries where this has not been the case does make less of a difference.

DSGE models with financial frictions can help shed light on some of the economic forces at work. The model featured here includes a housing market and credit frictions and is designed and estimated to distinguish unsustainable credit-fueled housing booms from changes in potential output linked to a reduction in financial frictions. The model further allows for identifying the main shocks driving macroeconomic fluctuations. Applied to a stylized euro area economy, it suggests that some of the early increase in credit volume and real activity in part of the region has been due to a reduction in financial frictions possibly linked to the introduction of the euro. However, the main driver of the boom-and-bust cycle in some countries was housing demand. The model also reinforces the result that estimates of potential output ignoring financial variables can be misleading under such circumstances.

These findings suggest that models of potential or sustainable output incorporating financial variables hold highly relevant information for policymakers. Of course, identifying these measures in real time remains a challenge. As discussed, multivariate models tend to be better at identifying the impact of credit movements on sustainable or potential output when they have been estimated over a period that includes the experience of “boom and bust” episodes or can be based on cross-country experience. And while DGSE models might be less sensitive in this regard, their much more complex structure require extensive estimation and calibration that can make them difficult to deploy for all countries. That said, when either model indicates bias in conventional estimates of potential output that do not take into account financial variables, policymakers have reason to suspect that their view of the economy’s output gap might need correction and more extensive analysis might be required.

The precise implications depend on the policy goals and whether a particular policy instrument will affect the output gap once financial variables are being taken into account. As discussed in Section I, this is particularly relevant for macroeconomic policies. The implications for fiscal sustainability and structural policies seem more straightforward.

- ***Fiscal sustainability:*** If sustainable or potential output is likely to move more steadily in the presence of financial “booms and busts” than standard measures suggest, fiscal policy will have to be careful to avoid debt bias. During upswings related to rapid credit and house price increases, conventional measures of the output gap will underreport the degree of overheating and the associated cyclically adjusted fiscal balances will paint to rosy a picture of the fiscal stance. The opposite holds during the downswing. Taking full account of the impact of the financial variables will mean policymakers should aim for less expansionary budgets during the boom and more expansionary policies afterwards.
- ***Structural reforms:*** Labor and product market reforms tend to impact the economy with a lag, and policymakers might look for estimates of medium- or long-term growth for guidance. Estimates of sustainable or potential output that avoid bias by taking into account the effects of financial variables will help in this regard.
- ***Macroeconomic stabilization:*** The implications for macroeconomic policies depend on the circumstances. For example, if policymakers had reason to believe that, once taking into account financial variables, the output gap and the degree of overheating was larger (i.e., more positive) than suggested by other measures, the question would be how to best address the issue. If monetary policy was the most effective instrument addressing the underlying credit and housing boom, interest rates should be raised to help cool it off. However, in many cases more stringent macroprudential policy measures reducing credit demand at its source might be more appropriate and should be deployed as the first line of defense. This also involves difficult real-time

decisions, such as assessing if a persistent decline in credit risk is fundamental or a market misperception.

- ***Optimal monetary policy:*** In a theoretical context, monetary policy is usually modeled as minimizing the distance of actual to potential output unimpeded by nominal price and wage rigidities. Keeping the output gap close to zero will help to keep inflation and employment steady close to a central bank's goals. However, when, as shown, potential output depends on financial frictions as much as on distortions such as mark-ups in labor and product markets, central banks have reason to re-adjust their view of the output gap taking into account financial variables. This could mean, for instance, more assertive tightening during a period of credit-fueled overheating than in the absence of strong credit growth. Moreover, the presence of financial frictions, if they cannot be addressed by other means, introduce new trade-offs for monetary policymakers (Furlanetto, Gelain, and Taheri Sanjani, 2014).

More work is needed. In particular, while the existing models can serve as a useful “fire alarm” pointing to shortcomings of conventional measures of potential output, they still require a substantial amount of judgment in practice. For example, the strength of multivariate models will improve if they can be estimated over longer time periods or across countries. Moreover, approaches such as IMF (2015) can provide useful guidance for the interpretation of multivariate models by embedding them more rigorously in a more traditional production function framework. Finally, more elaborate models that include a fuller set of policy instruments will make it easier to directly map the impact of different policy measures on the development of potential or sustainable output.

REFERENCES

- Alberola, E., Estrada, A., and D. Santabárbara, 2014, “Growth and Imbalances in Spain: A Reassessment of the Output Gap,” *Journal of the Spanish Economic Association*, Vol. 5(2–3), p. 333–356.
- An, S. and Frank Schorfheide, 2007, “Bayesian Analysis of DSGE Models,” *Econometric Reviews*, Vol. 26(2–4), p. 113–172.
- Andres, J., J. Lopez-Salido and Ed Nelson, 2005. “Sticky-price Models and the Natural Rate Hypothesis,” *Journal of Monetary Economics*, Vol. 52(5), p. 1025–1053.
- Aspachs-Bracons, O. and Pau Rabanal, 2011, “The Effects of Housing Prices and Monetary Policy in a Currency Union,” *International Journal of Central Banking*, Vol. 7(1), p. 225–274.
- Benes, Jaromir, Marianne Johnson, Kevin Clinton, Troy Matheson, Petar Manchev, Roberto Garcia-Saltos, and Douglas Laxton, 2010, “Estimating Potential Output with a Multivariate Filter,” IMF Working Paper 10/285 (Washington: International Monetary Fund).
- Bernanke, B., Gertler, M. and Simon Gilchrist, 1999, “The Financial Accelerator in a Quantitative Business Cycle Framework,” in: J. B. Taylor & M. Woodford (eds.), *Handbook of Macroeconomics*, edition 1, Vol. 1, chapter 21, p. 1341–1393.
- Beveridge, Stephen, and Charles R Nelson, 1981, “A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to Measurement of the ‘Business Cycle’,” *Journal of Monetary Economics*, Vol. 7(2), p. 151–174.
- Borio, Claudio, Piti Disyatat, and Mikael Juselius, 2013, “Rethinking Potential Output: Embedding Information About the Financial Cycle,” BIS Working Paper No. 404.
- Christiano, Lawrence J, and Terry J Fitzgerald, 2003, “The Band Pass Filter,” *International Economic Review*, Vol. 44(2), p. 435–465.
- Christiano, Lawrence J, Roberto Motto, and Massimo Rostagno, 2014, “Risk Shocks,” *American Economic Review*, Vol. 104(1), p. 27-65.
- Clark, Peter K., 1987, “The Cyclical Component of Us Economic Activity,” *The Quarterly Journal of Economics*, Vol. 102(4), p. 797–814.
- Fernald, John, 2014, “Productivity and Potential Output before, During, and after the Great Recession,” NBER Working Paper No. 20248.

- Furlanetto, F., Gelain, P. and Marzie Taheri Sanjani, 2014, "Output Gap in Presence of Financial Frictions and Monetary Policy Trade-offs," IMF Working Paper 14/128 (Washington: International Monetary Fund).
- Hodrick, Robert J, and Edward C Prescott, 1997, "Postwar Us Business Cycles: An Empirical Investigation," *Journal of Money, Credit, and Banking* , p. 1–16.
- International Monetary Fund (IMF), 2015, "Where Are We Headed? Perspective on Potential Output," in *World Economic Outlook*, April, Chapter 3, p. 69–110 (Washington).
- Justiniano, A., G. Primiceri, and Andrea Tambalotti, 2013, "Is There a Trade-Off Between Inflation and Output Stabilization?" *American Economic Journal: Macroeconomics*, Vol. 5(2), p. 1–31.
- Kuttner, Kenneth N, 1994, "Estimating Potential Output as a Latent Variable," *Journal of Business and Economic Statistics*, Vol. 12(3), p. 361–368.
- Laubach, Thomas, and John C. Williams, 2003, "Measuring the Natural Rate of Interest," *Review of Economics and Statistics*, Vol. 85, no. 4, p. 1063–1070.
- Lian, Weicheng, 2015, Sectoral Output Dynamics: Potential or Cyclical? IMF Working Paper, forthcoming.
- Mishkin, Frederic S, 2007, "Inflation Dynamics," *International Finance*, Vol. 10(3), p. 317–334.
- Orphanides, Athanasios and Simon Van Norden, 2002, "The Unreliability of Output-Gap Estimates in Real Time," *Review of Economics and Statistics*, Vol. 84(4), p. 569–583.
- Quint, D., and Pau Rabanal, 2014, "Monetary and Macroprudential Policy in an Estimated DSGE Model of the Euro Area," *International Journal of Central Banking*, Vol. 10(2), p. 169–236.
- Rabanal, P., and Marzie Taheri Sanjani, 2015, "Financial Factors: Implications for Output Gaps," IMF Working Paper, WP/15/153 (Washington: International Monetary Fund).
- Ravn, Morten and Harald Uhlig, 2002, "On adjusting the Hodrick-Prescott filter for the frequency of observations," *The Review of Economics and Statistics*, MIT Press, Vol. 84(2), p. 371-375.
- Staiger, Douglas, James Stock, and Mark Watson, 1997a, "The Nairu, Unemployment and Monetary Policy," *The Journal of Economic Perspectives*, p. 33–49.
- Staiger, Douglas, James Stock, and Mark Watson, 1997b, "How Precise Are Estimates of the Natural Rate of Unemployment?" in: C. Romer and D. Romer (eds.), *Reducing*

Inflation: Motivation and Strategy, p. 195–246 (University of Chicago Press:Chicago).

Smets, F., and R. Wouters, 2003, “An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area,” *Journal of the European Economic Association*, Vol. 1(5), pp. 1123–1175.

APPENDIX I. MVF ESTIMATE AND COMPARISON WITH HP FILTER

A. Output Gap Equation Parameter Estimates

The MVF model is estimated using maximum likelihood approach in the state-space context. The economically interesting parameters are included in the observation equation which determines the size of the GDP gap. Their estimates are presented in Table A1.1. Most of the estimates are significant, with the exception of the real credit growth France and Germany. This particular finding is expected, since that the boom-bust credit cycle occurred only in Greece, Ireland, Italy, Portugal, and Spain. Real house price growth has a positive and significant impact on the output gap in both groups. Surprisingly, the estimate is larger in the France and Germany than Greece, Ireland, Italy, Portugal, and Spain. However, the total impact of house price changes on the output gap is nevertheless larger in Greece, Ireland, Italy, Portugal, and Spain—house price growth in the France and Germany was much more subdued. (Also, the two estimates are statistically not distinguishable.) In both groups, the inflation coefficient estimates are significant and almost equal.

Table A1.1. Estimates of the MVF Parameters						
	France and Germany			Greece, Ireland, Italy, Portugal, and Spain		
	Estimate	Std. Error	p-value	Estimate	Std. Error	p-value
Real HPI growth	0.4202	0.1305	0.001	0.2067	0.0979	0.035
Real credit growth	0.0497	0.2604	0.849	0.1666	0.0629	0.008
CPI inflation	0.7317	0.2383	0.002	0.7285	0.1918	0.000

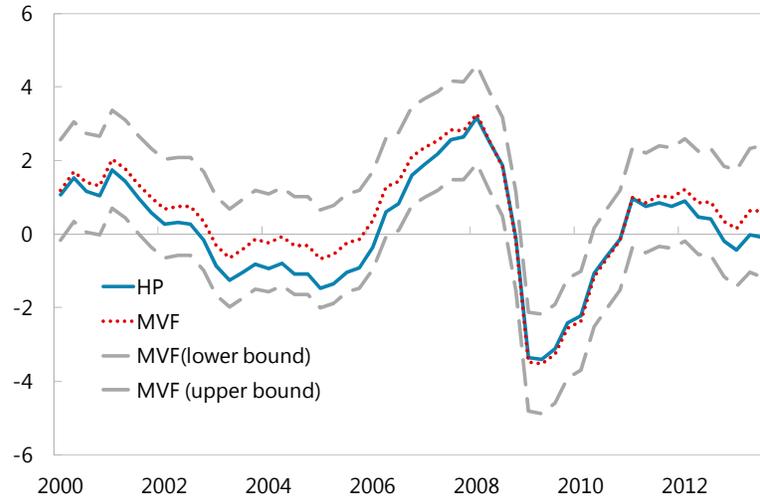
B. Statistically Significant Differences Between MVF and HP Gaps

In addition to the Statistical Significance of Potential GDP estimates, it is instructive to look at the statistical significance of estimated GDP gaps. Figure A.1 presents the point estimates and 2 standard deviation confidence intervals for the MVF output gap. An interesting difference between the France and Germany and Greece, Ireland, Italy, Portugal, and Spain is readily apparent—the HP gap for the the former is entirely contained within the MVF error band, suggesting that despite the statistical significance of individual parameters in the observation equation, the actual economic impact of credit cycle variables on the output gap is modest. The picture is different in the latter, where during the period of “the great expansion”, the HP gap estimates are well outside the MVF confidence interval. This result is supportive of the notion that the economic impact of the credit cycle was much larger in Greece, Ireland, Italy, Portugal, and Spain and that the “standard” measures of output gaps, i.e. those without credit cycle variables, are of little use in such cases. As a practical matter, it is always preferable to use the MVF—if the credit cycle is minor or nonexistent, the MVF and the HP gaps are close; if the cycle is large, only the MVF produces correct estimates.

Figure A.1. Are HP and MVF Output Gaps Significantly Different?

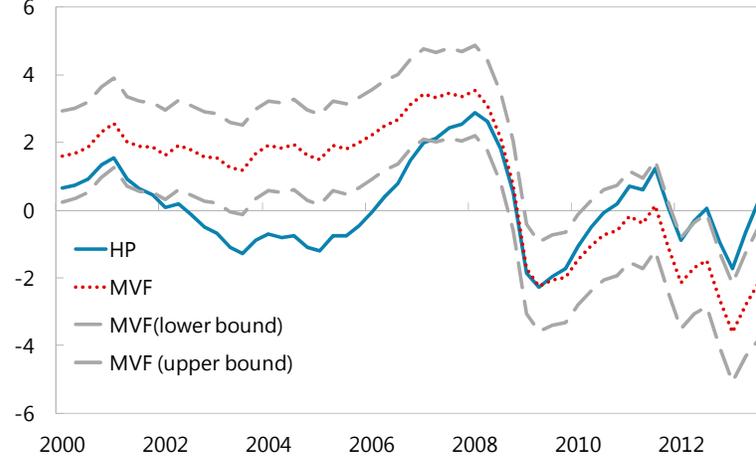
France and Germany: Comparing HP and MVF Output Gaps

(Percent of potential GDP)



Greece, Ireland, Italy, Portugal, and Spain: Comparing HP and MVF Output Gaps

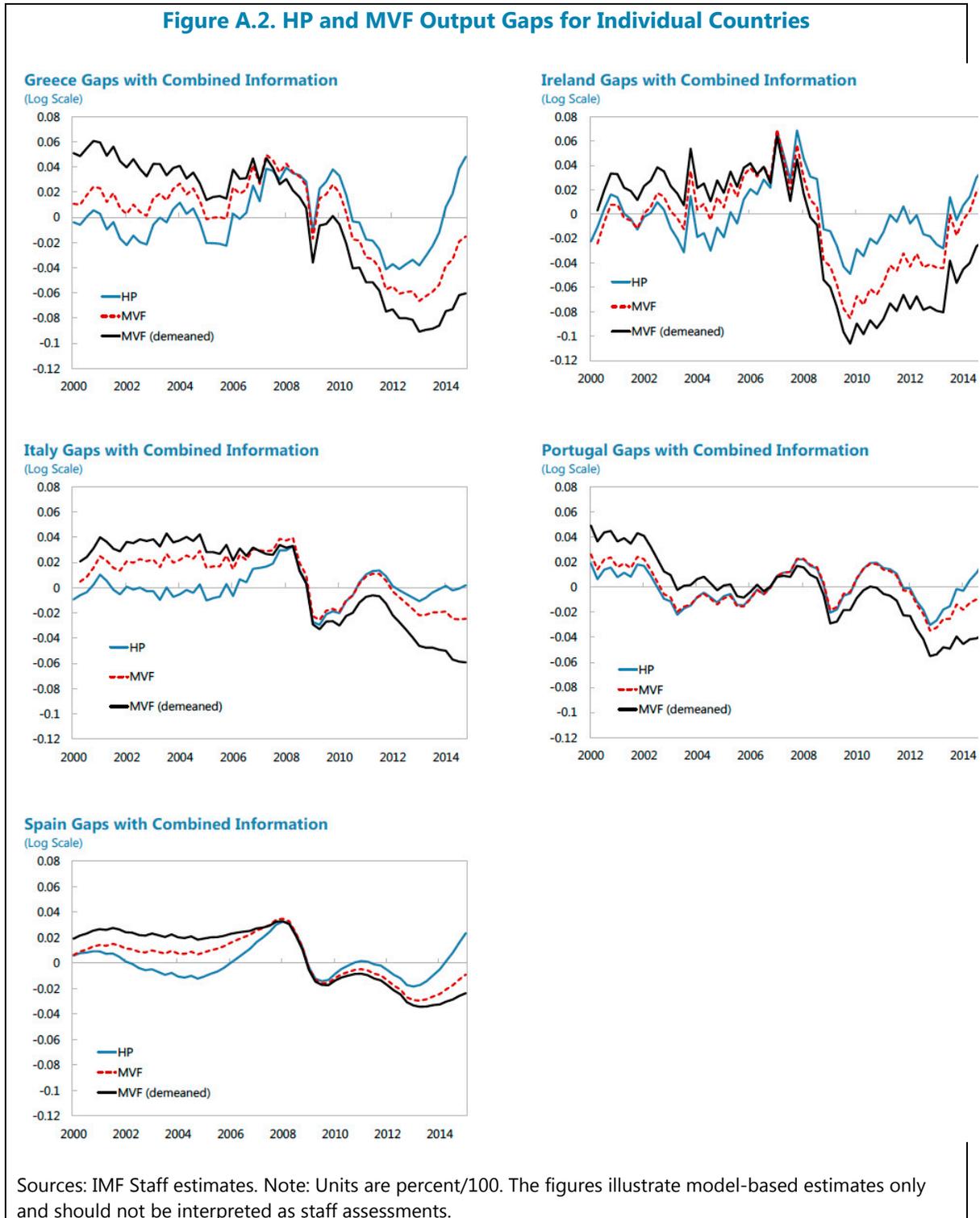
(Percent of potential GDP)



Sources: IMF Staff estimates. Note: Units are percent/100. Note: MVF estimates of the output gap are statistically significantly different from HP estimates during the run up and in the aftermath of the recession. Standard errors of the estimated GDP gap were calculated by means of the Kalman filter.

C. Selected Country Results

Figure A.2 shows estimated output gaps for selected countries using same MVF approach described in Section A.



APPENDIX II. DSGE MODEL AND ESTIMATION—AN OVERVIEW

The DSGE model is a two-country, two-agent, two-sector model in a currency union.¹

The model includes two regions that share the same currency. Monetary policy is set by the common central bank that reacts to union-wide fluctuations in HICP inflation and real GDP growth. Both economies produce differentiated nondurable consumption goods, which are tradable across countries, and housing, that is non-tradable. Both goods are produced under monopolistic competition and nominal rigidities. In each country, there are two types of agents, savers and borrowers. The latter are more impatient than the former and have preference for early consumption, which creates the condition for credit to occur in equilibrium.

There are two types of financial intermediaries, domestic and international. Domestic financial intermediaries take deposits from savers, grant loans to borrowers, and issue bonds. International financial intermediaries trade these bonds across countries to channel funds from one country to the other. In compensation for this service, international financial intermediaries charge a risk premium which depends on the net foreign asset position of the country and a spread shock. Hence, deposit rates can differ between the two countries. Because of this financial arrangements, savings and (residential) investment do not have to be balanced at the country level period by period, since excess credit demand in one region can be met by funding coming from elsewhere in the monetary union.

In each, country, the lending-deposit spread depends on housing market conditions and borrowers' balance sheets. The model includes a BGG (1999)-type accelerator mechanism on the household side, as in Quint and Rabanal (2014). Households receive idiosyncratic shocks to the value of their homes, which affects the value of collateral that they can use to borrow against. When a borrower is hit by a low enough valuation shock, she will default on her loan. Highly leveraged borrowers are more likely to default. Anticipating that defaults are possible, domestic financial intermediaries will price the lending-deposit spread as an increasing function of the borrowers' loan-to-value ratios. In addition, the variance of the distribution of idiosyncratic shocks is time varying. Periods of higher uncertainty (i.e., higher variance or "risk") are associated with higher defaults and a widening of the lending-deposit spread. To summarize, in equation (A. 1), the $S(\cdot)$ function is increasing in both arguments:

$$\frac{R_t^l}{R_t} = S(\text{Loan-to-Value}_t, \sigma_t^w) \quad (\text{A.1})$$

where R_t^l is the lending rate, R_t is the deposit rate, and the risk shock σ_t^w follows an autoregressive process of order one. Everything else constant, house price increases lower loan-to-values and the default rate, which reduces the lending rate for borrowers, who will

¹The model is described in full in Rabanal and Taheri Sanjani (2015).

borrow and spend more, thereby setting in motion an accelerator effect in house prices and household debt.

The model includes several real and nominal frictions, and a rich structure of shocks to fit the data. In addition to staggered price setting by firms, the model also includes monopolistic competition on the side of workers and staggered wage setting with indexation. Other real frictions include: (i) habit formation in consumption; (ii) residential investment adjustment costs; and (iii) costly labor reallocation across sectors. As a result nondurable consumption, residential investment and sectorial employment behave smoothly in response to shocks. The model includes several types of shocks, in order to be able to capture all possible co-movements in the data: (i) productivity shocks in each country and sector; (ii) preference shocks for each type of good in each country; (iii) monetary policy shocks; (iv) financial (risk and country spread) shocks; (v) price mark-up shocks, which reflect changes in product market power; and (vi) aggregate demand shocks for the components of GDP that are not explicitly modeled (business investment, external demand and fiscal policy).²

The model is estimated using thirteen macroeconomic time series, which are aggregated according to two regions. One includes France and Germany, while the other includes Greece, Ireland, Italy, Portugal, and Spain. For each region, the following variables are used: GDP, household consumption, residential investment, HICP inflation, house prices, and household credit. All these variables are transformed taking logs and first differences (that is, quarterly growth rates).³ The ECB repo rate is also used to capture euro area common monetary policy. Ideally, one would want data on lending-deposit spreads for each region to estimate the model, but the short time series available made it not possible.

Bayesian methods are used to estimate the parameters of the model.⁴ Some model parameters are calibrated because they cannot be directly identified from the data, such as the probability of defaults (see Table A2.1). Most parameters related to household preferences, nominal and real rigidities, and the stochastic properties of the shocks are estimated using Bayesian methods, with quarterly data between 2000:Q1 and 2013:Q4. The estimated degrees of nominal and real rigidities and the coefficients of the Taylor-type interest rate rule of the ECB are similar to what has been obtained in the literature (see Table A2.2 for estimates of the structural parameters). The fraction of savers is estimated at 0.57. Prices are more sticky in the nondurable sector (average duration of roughly ten quarters in both areas)

² Note that the model does not explicitly incorporate fiscal policy, even though the aggregate demand shock includes, among other things, fiscal policy surprises. This allows the model to account for the relevant dynamics in the data.

³ The aggregation used HICP weights.

⁴ See An and Schorfheide (2007) for details on the implementation of Bayesian estimation of DSGE models.

than in the durable sector (average duration of roughly two quarters in both areas). There is less heterogeneity in wage setting, with average durations ranging from four to six quarters.⁵

Once the model is estimated, the counterfactual “potential output” can be constructed.

The steps are as follows. First, the model is solved by using the calibration at the posterior mode. Second, the solution to the model in state space form and the data are used, together with the Kalman filter, to obtain the smoothed shocks.⁶ This simply amounts to obtaining the series of shocks that through the lens of the model, explain the data. Third, the model is solved by assuming that prices and wages are fully flexible (i.e. the parameters relating to price and wage rigidities in Table A2.2 are set to zero). Finally, the smoothed shocks (except the price mark-up shocks) are fed into the newly parameterized, flexible price-wage model. The counterfactual output series is what we refer to as potential output.

Table A2.1. Calibrated Parameters		
β	Discount factor savers	0.99
$\bar{\omega}$	Steady-State loan-to-value ratio	0.7
\bar{F}	Default rate on loans	0.025
σ_{ω}	Steady state risk	0.1742
μ	Proportion of housing value paid to debt-collection agency	0.2
β^B	Discount factor borrowers	0.985
δ	Depreciation rate	0.0125
σ	Elasticity of substitution between intermediate goods	10
σ_L	Elasticity of substitution between labor types	10
n	Size of economies Germany and France	0.6
\bar{g}	Fraction of exogenous demand in GDP	0.3
$1-\tau$	Fraction of imported goods from Greece, Ireland, Italy, Portugal, and Spain to France and Germany economies	0.06
$1-\tau^*$	Fraction of imported goods from France and Germany to Greece, Ireland, Italy, Portugal, and Spain economies	0.09
α	Size of non-durable sector in GDP	0.94

⁵ See Rabanal and Taheri Sanjani (2015) for estimates of the AR(1) coefficients and standard deviations of the shock processes.

⁶ See Hamilton (1994) for a description of the Kalman smoother.

Table A2.2. Structural Parameters of the Model

Parameters	Description	Prior			Posterior	
		Distribution	Mean	SD	Mean	90% C.S.
λ	Fraction of savers	Beta	0.5	0.05	0.57	[0.50,0.64]
ϵ	Habit formation savers	Beta	0.5	0.15	0.71	[0.65,0.78]
ϵ^B	Habit formation borrowers	Beta	0.5	0.15	0.63	[0.52,0.73]
ϕ	Labor disutility	Gamma	1	0.5	1.14	[0.75,1.53]
ι_C	Elasticity of subst. between goods	Gamma	1.5	0.5	1.50	[0.86,2.17]
ι_L	Labor reallocation costs	Gamma	1	0.5	0.66	[0.42,0.83]
ψ	Investment adjustment costs	Gamma	2	1	1.94	[1.31,2.55]
γ_π	Taylor rule reaction to inflation	Normal	1.5	0.1	1.34	[1.16,1.50]
γ_y	Taylor rule reaction to real growth	Gamma	0.2	0.05	0.29	[0.19,0.41]
γ_r	Interest rate smoothing	Beta	0.66	0.15	0.84	[0.81,0.87]
κ_B	International risk premium	Gamma	0.005	0.002	0.006	[0.002,0.009]
θ_C	Calvo lottery, price non-durables	Beta	0.75	0.15	0.87	[0.82,0.92]
θ_C^*	Calvo lottery, price non-durables	Beta	0.75	0.15	0.93	[0.89,0.97]
θ_D	Calvo lottery, price durables	Beta	0.75	0.15	0.50	[0.39,0.61]
θ_D^*	Calvo lottery, price durables	Beta	0.75	0.15	0.43	[0.31,0.54]
φ_C	Indexation, price non-durables	Beta	0.33	0.15	0.16	[0.03,0.28]
φ_C^*	Indexation, price non-durables	Beta	0.33	0.15	0.30	[0.13,0.47]
φ_D	Indexation, price durables	Beta	0.33	0.15	0.14	[0.02,0.25]
φ_D^*	Indexation, price durables	Beta	0.33	0.15	0.20	[0.03,0.36]
$\theta_{W,C}$	Calvo lottery, wage non-durables	Beta	0.75	0.15	0.69	[0.62,0.77]
$\theta_{W,C}^*$	Calvo lottery, wage non-durables	Beta	0.75	0.15	0.83	[0.79,0.87]
$\theta_{W,D}$	Calvo lottery, wage durables	Beta	0.75	0.15	0.78	[0.71,0.85]
$\theta_{W,D}^*$	Calvo lottery, wage durables	Beta	0.75	0.15	0.77	[0.72,0.82]
$\varphi_{W,C}$	Indexation, wage non-durables	Beta	0.33	0.15	0.26	[0.06,0.47]
$\varphi_{W,C}^*$	Indexation, wage non-durables	Beta	0.33	0.15	0.29	[0.06,0.51]
$\varphi_{W,D}$	Indexation, wage durables	Beta	0.33	0.15	0.27	[0.06,0.47]
$\varphi_{W,D}^*$	Indexation, wage durables	Beta	0.33	0.15	0.28	[0.06,0.48]

Note: Parameters with an asterisk are for Greece, Ireland, Italy, Portugal, and Spain, without an asterisk are for France and Germany. 90 percent C.S. is the 90th percent confidence set.