BANK FOR INTERNATIONAL SETTLEMENTS

BIS Working Papers

No 404

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February 2013

JEL classification: E10, E40, E44, E47, E52, E60

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This publication is available on the BIS website (www.bis.org).

ISSN 1020-0959 (print)

ISSN 1682-7678 (online)

Rethinking potential output: Embedding information about the financial cycle*

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This version: 26 February 2013

Abstract

This paper argues that incorporating information about the financial cycle is important to improve measures of potential output and output gaps. Conceptually, identifying potential output with non-inflationary output is too restrictive. Potential output is seen as sustainable; yet experience indicates that output may be on an unsustainable path even if inflation is low and stable whenever financial imbalances are building up. More generally, as long as potential output is identified with the non-cyclical component of output fluctuations and financial factors play a key role in explaining the cyclical part, ignoring these factors leaves out valuable information. Within a simple and transparent framework, we show that including information about the financial cycle can yield measures of potential output and output gaps that are not only estimated more precisely, but also much more robust in real time. In the context of policy applications, such *"finance-neutral"* output gaps are shown to yield more reliable estimates of cyclically adjusted budget balances and to serve as complementary guides for monetary policy.

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* We would like to thank Olivier Blanchard, Fabio Canova, Stephen Cecchetti, Carlo Cottarelli, Tony Courakis, Mathias Drehmann, Jorgen Elmeskov, Steve Kamin, Doug Laxton, Marco Lombardi, Larry Schembri, Frank Smets, David Turner, Birger Vikøren and Fabrizio Zampolli for helpful comments and discussions and Magdalena Erdem and Anamaria Illes for excellent statistical assistance. All remaining errors are ours. The views expressed are those of the authors and do not necessarily represent those of the Bank for International Settlements or the Bank of Thailand.

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Introduction

Potential output is a key notion in macroeconomics and policymaking. Correspondingly, a wide range of policy decisions hinge on assessments of deviations of output from its potential – so-called output gaps. These assessments are particularly challenging since potential output is not observable, not even after the fact. As such, implicitly or explicitly, measures of potential output require assumptions about how the economy works – that is, they are inherently "model-dependent". The existing literature tends to define potential output with reference to the full (economic) utilisation of factor inputs and to inflation developments (eg Okun (1962), Mishkin (2007)). The basic idea is that, all else equal, inflation tends to rise (fall) when output is above (below) potential. Inflation, in other words, is the key symptom of unsustainability. The conceptual association between potential output and inflation is so strong that hardly anyone would question this characterisation. Partly as a result, the literature has largely ignored the role of financial factors.

On reflection, though, this omission is puzzling for at least two reasons. First, from a *conceptual* perspective, sustainability is a defining feature of potential output. If so, thinking of potential output as non-inflationary output is too restrictive. Historical evidence has shown that it is quite possible for inflation to remain low and stable and yet for output to be growing on an unsustainable path when financial imbalances build up: the recent financial crisis is just the latest reminder of this possibility. Second, from a *measurement* perspective, there is little doubt that financial developments contain information about the cyclical component of output. If so, ignoring them is bound to provide less accurate estimates of potential output whenever this is captured by the non-cyclical component of business fluctuations.

Here we take a first step in remedying this deficiency. We develop measures of potential output and output gaps in which financial factors play a central role. Our point of departure is the conviction that financial factors are critical for economic activity, for the evolution of output over time, and for which of its paths are sustainable and which are not. We pay special attention to the financial cycle, and hence to booms and busts in credit and property prices over frequencies that are lower than traditional business cycle frequencies (eg Drehmann et al (2012)). As such, our contribution can be seen as an extension of the burgeoning literature on the link between financial cycles, business cycles and banking crises (eg Aikman et al (2011), Claessens et al (2011a,b), Schularick and Taylor (2011), Drehmann et al (2012), Borio and Drehmann (2009) and Alessi and Detken (2009)).

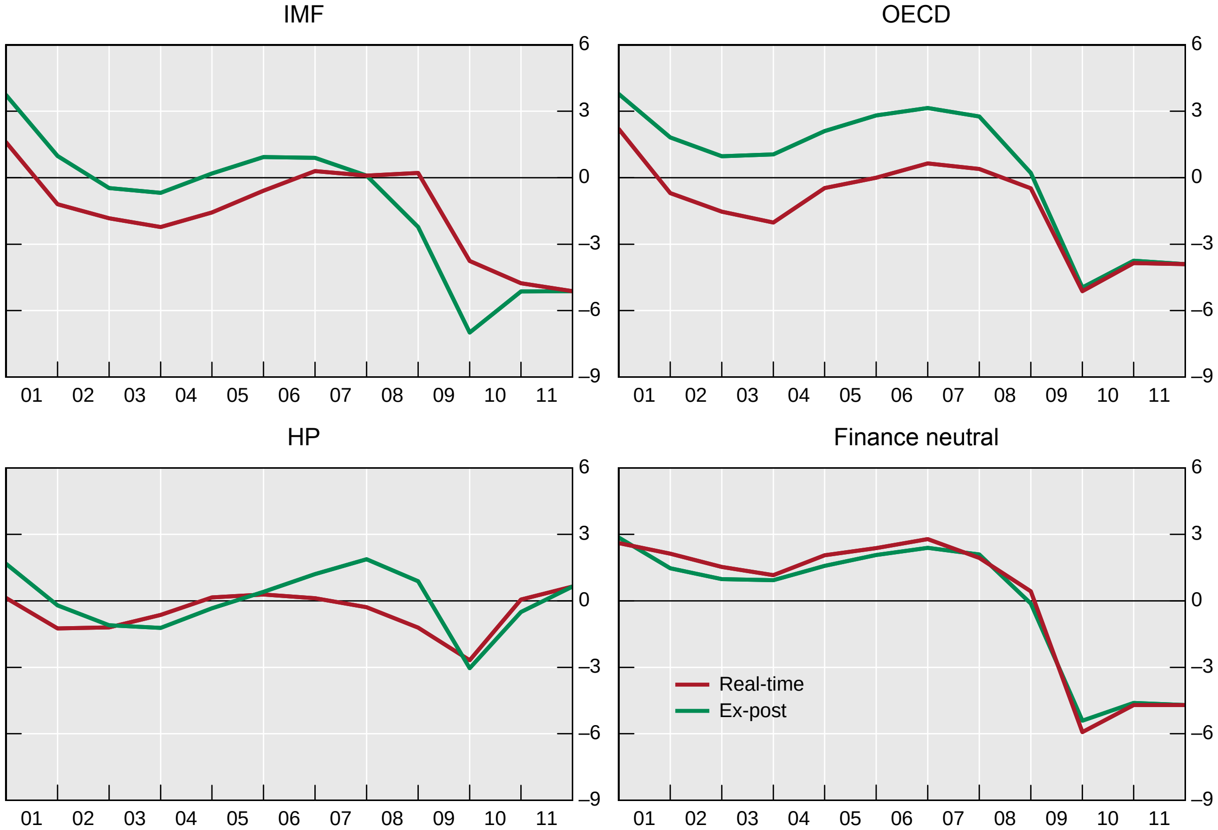
Guided by the intuition of a close relationship between financial factors and business fluctuations, our approach is largely empirical. We do not develop a fully fledged model, but rely on reduced-form relationships. To facilitate comparisons and illustrate the contribution of financial factors, we start from the most widely used purely statistical approach for estimating potential output – the Hodrick-Prescott (HP) filter – and extend it to incorporate information about the financial cycle. In doing so, we do not impose strong priors regarding the relationship between financial variables and potential output: we let the data speak. Financial factors are included only as possible explanatory variables that help filter out cyclical fluctuations in output. This contrasts sharply with the common practice of *forcing* output gaps to explain key economic variables such as inflation through the inclusion of a Phillips curve in system-based approaches. Indeed, as we show elsewhere (Borio et al (2013)), this widespread approach can lead to large biases: it does violence to the data when the information content of output gaps for inflation is limited, as is typically the case. Our approach provides a less restrictive way of incorporating economic information into statistical methods than the multivariate filters typically employed in the literature (Benes et al (2010), Boone (2000)).

We find that financial cycle information – as captured in particular by the behaviour of credit and property prices – explains a substantial portion of the cyclical movements in output, thereby helping to identify the unobservable potential output. Taking the relationship between financial developments and economic activity into account yields *"finance-neutral"* output gap measures that: (i) indicate that output is well above potential during outsize financial booms, regardless of what happens to inflation; (ii) are estimated statistically much more precisely; and, above all, (iii) are much more robust in real time. These measures are also shown to yield more reliable estimates of cyclically adjusted budget balances and potentially to serve as helpful guideposts for monetary policy. On balance, they should provide a useful complementary input for policy.

Graph 1

US output gaps: ex-post and real-time estimates

In per cent of potential output



Note: For each time *t*, the "real-time" estimates are based only the sample of data up to that point. The "ex-post" estimates are based on the full sample of data.

Sources: OECD Economic Outlook; IMF; Authors' calculations.

Take, for example, the case of the United States – the country at the epicentre of the financial crisis. Strikingly, *ahead* of the financial crisis, as the financial boom played itself out, most of the commonly used measures of potential output indicated that output was *below, or at most close to,* potential. Estimates by the OECD, IMF, and those based on simple HP filters, all told the same story in real time (Graph 1).[1] Only *after* the crisis did these measures recognise that, to varying degrees, output had been above its potential, sustainable level. By contrast, our finance-neutral measure is able to spot the unsustainable expansion in real time, pointing to a substantial positive gap between output and potential during the boom.

[1] In what follows, we refer to output gaps estimates that are based solely on data that are available up to that point, and hence on one-sided filters, as "real-time". We refer to output gaps that are based on the full sample of data, and hence on two-sided filters, as "ex-post".

Moreover, there is hardly any difference between the real-time estimates and those produced after the crisis. History does not get rewritten with the passage of time. Had policymakers relied on this information ahead of the crisis, they surely would have been in a better position to assess potential vulnerabilities as they built up.

The rest of the paper is organised as follows. The first section discusses concepts of potential output in the existing literature as well as prevailing measurement approaches. The second introduces our proposed extension of the concept, in which financial factors play a key role, and outlines our new measurement approach. The third presents the basic results, comparing the estimates that incorporate financial cycle information with more traditional ones, in particular with the standard HP filter and the production function approach. The fourth evaluates the finance-neutral measures more systematically, based on the statistical precision of the estimates, their performance in real time, as well as their implications for cyclically adjusted fiscal balances and popular benchmarks for monetary policy (Taylor rules).

I. Potential output: concepts and measurement

Concepts

A common thread tying together the various concepts of potential output is that of *sustainability*: potential output is seen as representing a level of output that is sustainable given the underlying structure of the economy. For example, the most popular notion corresponds to a level of output that involves the full utilisation of factor inputs. That level is in turn deemed sustainable because, other things equal, it does not generate unwelcome economic outcomes that, sooner or later, lead to some form of correction. The most common such outcome relates to inflation developments. From at least Okun (1962) on, admittedly with some variations, this has been the prevailing concept in economic analysis and policymaking.[2]

That said, the specific notion of sustainability is model-dependent. Sustainability is closely tied to the notion of equilibrium; in turn, the features of an equilibrium necessarily vary across models. At the cost of some oversimplification, it is possible to trace a certain evolution of the concept, reflecting changing views concerning the relationship between economic slack and inflation – the Phillips curve. In the first set of Keynesian formulations, which assumed a long-run trade-off between inflation and economic slack, if actual output equalled potential output inflation would be zero (eg Samuelson and Solow (1960)). Later on, following Phelps (1967) and Friedman (1968), the models implied that equality would yield stable inflation: all else equal, inflation would rise if output exceeded potential and fall otherwise. In this view, given adaptive expectations, potential output was the production equivalent of the non-accelerating inflation rate of unemployment (NAIRU). This is still, by far, the most common notion in practical policy making. This quotation from a 2007 speech by Rick Mishkin, at the time serving on the Board of Governors of the Federal Reserve System, is very representative:

"It is natural to think of potential output as the level of output that is consistent with the maximum sustainable level of employment: That is, it is the level of output at which demand and supply in the aggregate economy are balanced so that, all else being equal, inflation tends to gravitate to its long-run expected value."

The notion of potential output in New Keynesian dynamic stochastic general equilibrium (DSGE) models is very similar in terms of its relationship to inflation. These models define

[2] Congdon (2008) provides an excellent discussion of the evolution of the concept in academia and policymaking.

potential output as the output that corresponds to fully flexible prices and wages. Accordingly, the output gap measures the deviation of actual from potential output that arises because of rigidities in those prices and wages, which prevent them from responding freely to changes in demand and supply – so-called nominal frictions. The rigidities again imply that, all else equal, inflation would tend to rise (fall) when actual output exceeds (falls short of) potential (eg Woodford (2003)).[3]

Behind the notion of potential output, and fluctuations around it, there is also a normative element. Potential output is often seen as the level of output policymakers should seek to attain; correspondingly, deviations from it are undesirable, all else equal. This is the essence of macroeconomic stabilisation policy.[4] The point is fully explicit in the DSGE framework, which seeks to derive welfare prescriptions from the very structure of the models, grounded on the optimising behaviour of economic agents. It is perhaps less explicit, but just as present, in the alternative frameworks.

This normative element helps to define what should and should not be allowed to determine potential output. One common answer hinges on the nature of the undesirable features of the economy – in DSGE parlance, the relevant "frictions" – that the researcher as policymaker takes as *given* (exogenous). Potential output itself is taken as given by macroeconomic stabilisation policy: output is stabilised *around* it. As such, potential output incorporates the constraints of the undesirable features that stabilisation tools *can do nothing about*. For example, tax arrangements or monopolistic elements may constrain output to be below what is desirable.[5] But since these are not the targets of stabilisation policy – and, moreover, may not be self-correcting over time – they are incorporated in the corresponding notions of potential output. Correspondingly, the impact of other undesirable features on output is left to determine the deviations of output from potential, which are regarded as legitimate targets of stabilisation policy. This is as true of NAIRU-type models as it is of DSGE ones.[6]

Different views about potential output have implications for its variability over time and relationship to actual output. At one end, in Real Business Cycle (RBC) models (eg Kydland and Prescott (1982)), economic agents respond efficiently to unexpected changes ("shocks") in technology and preferences. As a result, potential output is *always* equal to actual output and, therefore, just as variable by construction.[7] Benchmark New Keynesian DSGE models (eg Neiss and Nelson (2005), Basu and Fernald (2009), Justiniano and Primiceri (2008)) add nominal price rigidities to otherwise frictionless RBC economies and thereby generate a non-

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3 Strictly speaking, because rigidities last longer than one period and economic agents are forward-looking, the whole trajectory of output gaps, presently and in the future, is relevant.

4 It goes without saying that avoiding, as opposed to limiting, deviations is purely an ideal. How far stabilisation should be pursued in practice depends on a host of well known factors that go beyond the confines of any specific model and need not be repeated here.

5 In fact, nominal rigidities in DSGE models *require* the assumption of monopolistic elements. Otherwise, optimising behaviour and nominal rigidities would result in *rationing*. For example, take prices. Under perfect competition and profit-maximising behaviour, price equals marginal cost. Given prices, any shocks to demand or supply that disturbed the original equilibrium would imply a deviation, which is not consistent with optimising behaviour. A change, say, in technology that raised marginal cost, would induce the firm to produce less than demanded, ie to ration customers. Quantities, rather than prices, would enter as the relevant exogenous factors in the optimising problem. This is the basic notion underlying the general equilibrium economics of rationing, which had its heyday in the late 1970s but then fell out of fashion (eg Barro and Grossman (1971), Benassy (1975), Malinvaud (1977)). By contrast, in the presence of monopolistic power, the equilibrium price would be higher than marginal cost, providing a cushion to absorb shocks and allowing firms to meet demand at the given price without violating optimising behaviour.

6 An exception to this comprises frameworks in which the policymaker is seen to stabilise output at a level above its natural rate, which with rational expectations can give rise to the famous time inconsistency problem and the associated upward bias to inflation (Kydland and Prescott (1977)). This type of analysis, however, is best regarded as descriptive rather than normative.

7 This also means that to tie down inflation, it is necessary to assume that inflation is driven by a separate process unrelated to the output gap (eg the instantaneous rate of growth of the money supply).

zero output gap. Nevertheless, as a consequence of optimising agents' response to shocks, the underlying flexible-price equilibrium – and hence the corresponding measure of potential output – can vary substantially. By contrast, those working outside the DSGE framework tend to view potential output as less variable, reflecting the assumed slow motion of the underlying determinants of productive capacity.

In practical applications, a measure that is less variable fits more naturally with the typically medium-term orientation of policy deliberations.[8] Conditioning policy on estimates that display a high degree of short-run volatility can be harmful. For example, in macroeconomic stabilisation, policymakers tend to avoid fine-tuning.[9]

Measurement

Approaches to estimate the unobservable potential output vary substantially in terms of the economic information they incorporate (eg Gerlach and Smets (1999)). At one end are univariate statistical approaches, which derive estimates based purely on the behaviour of the output series itself by seeking to filter out the trend component from the cyclical one at a particular frequency.[10] At the other end are fully fledged structural approaches, which derive measures of potential output that are consistent with the restrictions implied by the models. In between, the approaches vary considerably. Most of them, however, incorporate the key notion that the inflation rate is a function of economic slack and hence of the output gap.

Probably the most popular univariate statistical approach is the HP filter (Hodrick-Prescott (1997)). Other established univariate approaches include the Beveridge-Nelson decomposition (Beveridge and Nelson (1981)), unobserved components (UC) models (eg Watson (1986)) and the band-pass filter (Baxter and King (1999), Christiano and Fitzgerald (2003)). The main advantage of these approaches is their simplicity. However, they all suffer to some extent from the well known end-point problem: estimates of the underlying trend can be very sensitive to the addition of new data and can change substantially as time unfolds. In effect, history gets rewritten. This limits their real-time usefulness for policy.

The structural approach, in contrast, seeks to derive a measure of potential output from an estimated theoretical structure. This structure, of course, can vary substantially across exercises. In policy circles, the production function approach, which combines detailed information about the utilisation of factor inputs with a Philips curve, is probably the most common; the one used by the OECD is a very good such example (eg Giorno et al (1995)). Reliance on DSGE models, embodying much tighter theoretical restrictions, has also been gaining ground (eg Smets and Wouters (2003)). The main appeal of the structural approach is that it allows for a direct economic interpretation of observed movements in cyclical output. Moreover, it fully exploits economic priors. Both of these advantages, however, depend on the models being a close approximation to reality. In a companion paper (Borio et al (2013)), we show that output gap estimates can be very sensitive to misspecification in the structural economic relationships. Moreover, the estimation technique may bring back through the

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8 Technically, as will be discussed further below, the variability of potential output is determined in a state-space framework through a combination of the signal-to-noise ratio and the transition equation for potential output. These jointly determine the volatility of potential output and the size and persistence of its deviation from actual output. All else equal, a less smooth transition function for potential output and/or a lower signal-to-noise ratio imply greater variability in estimates of potential output.

9 Svensson (2011) echoes such a sentiment in advocating that monetary policy target the "sustainable unemployment rate" rather than some short-term NAIRU defined by a Phillips curve. The former corresponds to a steady-state equilibrium unemployment rate that evolves only slowly over time, as structural economic features, such as demographics, preferences and taxes, change. The concept derives from models that generate unemployment as an equilibrium outcome, so that monetary policy involves a trade-off between inflation and employment stabilisation – that is, models in which the "divine coincidence" does not hold (eg Blanchard and Gali (2010)).

10 Clearly, in line with the vast majority of current models, these approaches assume that over time output does revert to potential.

backdoor some of the problems that plague univariate statistical approaches. Not least, in the production function approach it is common to estimate "normal" levels of factor utilisation with univariate filters such as the HP filter. In this case, the end-point problem reappears.[11]

In between, other approaches strike a compromise between simplicity and tight economic priors. Specific examples include the multivariable HP filter (eg Laxton and Tetlow (1992)) and various multivariate UC models (eg Clarke (1989) and Kuttner (1994)). A very common key economic prior is that inflation is determined by some variant of the Phillips curve. Our method belongs to this general class. The main difference lies in the type of economic information that we include and how we allow it to constrain the estimates.

II. Potential output: an extension

Concept

One intuitive way of pinning down potential output is through the conditions that arise when production differs from potential. As we have noted, in the extant literature, it is the behaviour of inflation that signals whether output is above or below potential. And yet experience suggests that this view is too narrow. As the recent financial crisis has powerfully reminded us, output may be on an unsustainable path because financial developments are out of kilter *even if inflation remains low and stable*.[12]

There are at least four reasons for this. One is that unusually strong financial booms are likely to coincide with positive supply side shocks (eg Drehmann et al (2012)). These put downward pressure on prices while at the same time providing fertile ground for asset price booms that weaken financing constraints. This combination can turbo-charge the financial cycle, especially if supported by a monetary policy focused on stabilising near-term inflation (Borio and Lowe (2002a)).[13] A second reason is that the economic expansions may themselves weaken supply constraints. Prolonged and robust expansions can induce increases in the labour supply, either through higher participation rates or, more significantly, immigration. For instance, there was a strong increase in immigration in Spain and Ireland during pre-crisis financial boom, not least to work in the construction sector that was driving the expansion. By adding new capacity, the capital accumulation associated with economic expansion itself may also weaken supply constraints.[14] A third reason is that financial booms are often associated with a tendency for the currency to appreciate, as domestic assets become more attractive and capital flows surge.[15] The appreciation puts downward pressure on inflation. A fourth, underappreciated, reason is that unsustainability may have to do more with the *sectoral* misallocation of resources than with *overall* capacity constraints. The sectors typically involved are especially sensitive to credit, such as real estate.

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[11] Based on considerations such as these, Orphanides (1999) and (2003) has stressed the importance of relying on real-time data to evaluate policies, as we do below.

[12] In fact, stable or falling inflation is not uncommon (eg Borio and Lowe (2002a)). This also means that estimates of potential output that rely on the Phillips curve relationship can be very misleading for policy (Borio et al (2003)), as the authorities may be tempted to reduce interest rates further, adding fuel to the financial boom.

[13] It is no coincidence that the financial booms that preceded the recent financial crisis went hand in hand with the globalisation of the real side of the world economy and the entry of China and other former communist countries into the global trading system. No doubt this represented a major string of positive supply side shocks.

[14] At the same time, buoyant asset prices flatter *measured* investment returns, masking the underlying decline in the return on capital associated with aggregate overinvestment.

[15] Consistently with this possibility, Borio and Lowe (2002b) find that the combination of unusually strong credit expansion and a real appreciation of the currency helps predict financial crises in emerging market economies.

Thus, unsustainable financial booms can be especially treacherous, as it is all too easy to be lulled into a false sense of security. Economic activity appears deceptively robust. Financial and real developments mask the underlying financial vulnerabilities that eventually bring the expansion to an end. And as the bust follows the boom, exceptionally tight financial conditions can hold back the economic recovery. During such times, the overhang of debt makes the task of reshuffling capital and labour harder, hindering the correction of the resource misallocations built-up during the boom (eg Hall (2012), Borio (2012)).[16] The impact on feasible output trajectories can be substantial. The bottom line is that the financial cycle amplifies the business cycle. This can be the case even if banking or financial crises do not break out (eg Taylor (2012)).

There is a burgeoning literature seeking to explain the factors at work during unsustainable financial booms (see eg Borio (2011) for an overview). Our own view is that a combination of limitations in incentives and in perceptions of value and risks can drive self-reinforcing but unstable spirals between financing constraints, the valuation of assets and economic activity. In all this, credit plays a key role. Credit is the oil that makes the economic machine run more smoothly. But unless it is sufficiently well anchored, credit creation can also support unsustainable paths.[17]

So, what exactly are we after? Basically, we try to capture the *information content that financial factors have for the cyclical, potentially highly persistent, variations in output and filter such movements out to obtain estimates of sustainable output.* In today's popular language, we assign a key role to variations in "financial frictions", and to the availability of finance more broadly, in determining the degree with which a given level of economic activity can be sustained.[18] These factors can give rise to what elsewhere we have termed the "excess elasticity" of the financial system (Borio and Disyatat (2011)). Just like a piece of rubber that stretches too far and eventually snaps, the self-reinforcing interaction between credit creation, asset prices and the real economy can lead to a build-up of financial imbalances that eventually derails economic activity. At the same time, financial burdens can prevent the economy from running at full capacity – so called "financial headwinds". Thus, it is important to take into account the extent to which financial conditions facilitate or constrain economic activity when formulating judgements about the sustainable level of economic activity. By doing so, we arrive at something akin to a *"finance-neutral"* measure of potential output. This contrasts with what might be termed the *"inflation-neutral"* potential output concept that underlies much of the literature and policy work.[19]

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16 For instance, there is cross-country evidence that a higher concentration of job losses in specific sectors – a sign of the degree of sectoral imbalances during expansions – explains the increase in unemployment even better than the magnitude of the output drop (Okun's law); see BIS (2012)). In addition, it is well known that financing constraints, by restraining the ability to purchase factor inputs, such as working capital, can constrain output further (eg Campello et al (2010), Jordà (2011)).

17 One way to think of credit is as an essential input in the production process. If it is complementary with other inputs, in the spirit of Jones (2011), then variations in its supply will affect the feasible production level of the economy. More broadly, financial developments reflect the ebb and flow of agents' expectations, sentiment and degree of uncertainty, which are important drivers of the level of aggregate economic activity (eg Bloom 2009). A key feature underlying all of this is the ability of the banking system to create purchasing power through the extension of credit (eg, Disyatat (2011)).

18 These "frictions" operate in addition to, and interact with, those that are part of canonical macro models, such as nominal rigidities. From a *normative* perspective, should the impact of financial frictions be included in potential output or in the deviations from it? Since we do not specify a full model, we do not need to take a strong stand on this. But we are especially interested in the extent to which they influence the deviation from potential, which we regard as a legitimate target for adjustments in monetary and prudential tools.

19 What is the relationship between our measure of the output gap and those associated with the main family of models used nowadays? More specifically, should it be also the relevant one for determining inflation? A fully satisfactory answer would require a fully articulated model. That said, as noted above, there are reasons to believe that aggregate measures of slack are unlikely to capture all the main (domestic) resource considerations that influence inflation. Sectoral misallocations, for instance, can play an important role over the typical policy horizons. Moreover, once estimation issues are taken into account, the inclusion of financial

Measurement

Our measurement approach is designed to be transparent and to avoid constraining the data too much while at the same time incorporating stylised facts about the financial cycle. We take as our point of departure a very simple and purely statistical measure, namely the HP filter expressed in state-space form. This serves as a useful starting point because the approach is very familiar and free of strong economic assumptions.

We then extend the filter to embed additional economic information without imposing strong priors on the data. Technically we achieve this by adding economic variables to the HP filter observation equation for output and use the Kalman filter to derive new estimates of potential output. In particular, we eschew what has become a very popular approach, namely to impose on the estimates of unobservable output a Phillips curve relationship, ie a relationship that *forces* the behaviour of inflation to be driven by the output gap. The equivalent in our case would be to force the estimates of the output gap to explain or mimic the financial variables. Rather, we allow the data to determine whether financial variables are informative about the cyclical component of output fluctuations. As we show elsewhere (Borio et al (2013)), inferring output gaps from the a priori assumption that they drive inflation can result in large biases whenever this maintained hypothesis is not easily supported by the data, as is often the case.[20]

We include credit and property prices as core proxies for the financial cycle. This is consistent with the growing empirical literature highlighting the information content of credit and, increasingly, property prices for business fluctuations and financial crises (eg, Borio and Lowe (2002a, 2004), Alessi and Detken (2009), Drehmann et al (2012), Claessens et al (2011a,b), Aikman et al (2011), Schularick and Taylor (2011)). But we also allow these variables to compete with others, including interest rates. As we aim primarily to illustrate the potential for exploiting the information content of financial factors in estimating output gaps, our approach is reduced-form.

Finally, and drawing on the same empirical literature, the way we incorporate information about the financial cycle allows for a non-linear relationship between the financial cycle proxies and output. In particular, the evidence indicates that the information these proxies contain for subsequent busts is strongest when variables such as the ratio of credit to GDP and asset prices exceed certain historical thresholds – proxies for financial imbalances. This non-linearity arises partly from the fact that the financial cycle is much longer than the traditional business cycle. Non-linearities also reflect the asymmetric nature of booms and busts. For example, credit grows rapidly during the boom, supporting the financial upswing, but can contract only slowly during the bust, when the debt overhang becomes the constraint.

In the current exercise, we retain the common assumption that business cycle fluctuations occur within a specific frequency range (up to 8 years). Technically, this corresponds to a value of lambda in the HP filter of 1600 (quarterly data), the one universally used in this context. We do so despite the fact that the financial cycle is considerably longer (some 16 to 20 years) and that also in the case of output low-frequency fluctuations (medium-term cycles) dominate the variability of the series (Comin and Gertler (2006), Drehmann et al (2012)). This choice allows us to compare our estimates with those in the literature more easily. That said, we feel that the assumption has not received the scrutiny it deserves.

Our approach to measurement also has important implications for the interpretation of our estimates of potential output and output gaps. Because we simply seek to filter out the cyclical component of output at the traditional frequency, the resulting estimates are *directly*

factors in the measurement may yield proxies of aggregate slack that actually outperform those based on approaches that omit those factors in predicting inflation, at least out of sample.

[20] There is a large empirical literature on the waning information content of output gaps for inflation. See, eg, Borio and Filardo (2007) and Anderton et al (2010).

comparable to those of potential output that identify it with the trend component of output at that frequency, a very common procedure. This naturally extends to the corresponding measure of the output gap. It is therefore an entirely empirical question which of the estimates is a better measure of economic slack.

III. Potential output: estimation

Procedure and empirical specification

It is well known that the HP filter can be cast in state-space form by specifying the state and measurement equations as

$$\Delta y_t^* = \Delta y_{t-1}^* + \varepsilon_{0,t} \tag{1}$$

$$y_t = y_t^* + \varepsilon_{1,t} \tag{2}$$

where $y_t = ln(Y_t)$, Y_t is real GDP, and $\varepsilon_{i,t}$, for $i = 0,1$, is assumed to be a normally and independently distributed error with mean zero and variance σ_i^2. For a given state equation, such as (1) above, the parameter $\lambda_1 = \sigma_1^2/\sigma_0^2$ – the so-called noise-to-signal ratio – determines the relative variability of the estimated potential output series. When λ_1 becomes very large, potential output approximately follows a linear trend; when λ_1 approaches zero, potential output mimics actual output. We set this parameter so that the duration of the estimated output gap is at most eight years, corresponding to standard views about the business cycle. This implies a value for λ_1 of 1600 in a quarterly sample. More generally, the functional form of the state equation and the noise-to-signal ratio jointly determine the relative variability of the potential output estimates.

In a companion paper (Borio et al (2013)), we show that a robust way of embedding economic information in output gap estimates is to augment (2) with additional variables. That is, we rewrite (2) as

$$y_t - y_t^* = \gamma' x_t + \varepsilon_{2,t} \tag{3}$$

Where x_t is a vector of economic variables, possibly containing lags of the output gap itself, and $\varepsilon_{2,t}$ represents a normally and independently distributed error term with mean zero and variance σ_2^2. To preserve the same duration of the business cycle as implied by the standard HP filter when extending (2) to (3), we use a state equation of the form (1) and set the signal-to-noise ratio $\lambda_2 = \sigma_2^2/\sigma_0^2$ such that

$$\mathrm{var}(y_t - y_{(2),t}^*)/\mathrm{var}(\Delta^2 y_{(2),t}^*) = \mathrm{var}(y_t - y_{(3),t}^*)/\mathrm{var}(\Delta^2 y_{(3),t}^*) \tag{4}$$

where $y_{(2),t}^*$ and $y_{(3),t}^*$ are the potential output series from equations (2) and (3), respectively.[21]

When the real interest rate is included as part of x_t, equation (3) resembles something akin to an extended IS-curve. In spirit, this is consistent with Woodford (2012), who shows that financial frictions would generally show up in the IS curve of a New Keynesian model. Accordingly, our approach based on (1) and (3) represents a compromise between theory and statistics in estimating potential output, stopping short of relying on a fully specified general equilibrium model. The advantage is that standard estimators of the parameters in (3) will assign a zero weight to any information in x_t that does not help to explain business

[21] The empirical noise-to-signal ratio for the HP filter (left-hand side of (4)) will generally be substantially higher than 1600 in short samples and converge only slowly towards 1600 as the sample size increases. The reason is that cyclical output is typically highly auto-correlated, thus violating (2). In this case, $var(y_t - y_t^*)$ will be larger than what is theoretically implied by (2). Thus, in practice, setting λ_2 such that (4) holds implies a relative volatility of potential output that is comparable with the one obtained from the HP filter.

cycle fluctuations. This contrasts with other semi-structural methods, such as the multivariate filter, which embed other economic relationships, such as the new Keynesian Phillips curve, into the system of equations. Those approaches *force* the output gap to explain the associated variables (eg inflation). This makes the estimated output gap highly sensitive to potential misspecification in these relationships, as we demonstrate in our companion paper. The disadvantage of our approach, of course, is that relying on a complete theoretical model could in principle yield more precise estimates of the parameters in (3), provided the model is well specified.

Given (1), we do not allow the identified financial factors to have a *direct* impact on potential output: we assume that they contain information only about the cyclical, or transitory, component of output. Such a direct impact, in fact, is possible. For example, there is evidence suggesting that banking crises that follow the booms have a permanent negative effect on output and hence, presumably, on potential. We do not explicitly model the structural determinants of potential output. That said, the information content that financial factors have for the transitory, cyclical component of output will have a substantial influence on the estimate of potential output. And since (3) constrains potential output to be proportional to actual output, any permanent effect, if it exists, will ultimately be reflected in potential output too.

We consider several specifications of (3), focusing in particular on two types of financial variables: (private sector) credit and property prices, here only house prices.[22] These help to capture the interaction between financing constraints, collateral values and wealth effects (eg Kiyotaki and Moore (1997)). We also add an autoregressive component for the output gap, in order to better reflect the dynamics of the variable. With these modifications, (3) becomes

$$y_t - y_t^* = \beta(y_{t-1} - y_{t-1}^*) + \gamma_1 r_{t-k_r} + \gamma_2 \Delta cr_{t-k_{cr}} + \gamma_3 \Delta ph_{t-k_{ph}} + \varepsilon_{3,t} \quad (5)$$

where $r_t = i_t - \Delta p_t$ is the ex-post real interest rate, Δp_t is consumer price inflation, Δcr_t is real credit growth in per cent, and Δph_t is real residential property price growth in per cent. All variables are mean-adjusted.[23] In what follows we allow each of these variables to enter (5) only once with a lag $k_j = 0, \ldots, 4$, $j = r, cr, ph$, chosen to maximise statistical fit.[24]

Baseline results

Based on this estimation procedure, we obtain output gaps for the United States, the United Kingdom and Spain over the quarterly samples 1980q1-2011q4 (for the United Kingdom, the sample ends in 2011q3). Appendix A contains detailed data definitions and sources.

To estimate (5) we adopt a conventional Bayesian approach. We use the Kalman filter to form the likelihood of the system, we specify prior distributions for the parameters and maximise the posterior density function with respect to the parameters.[25] As prior distribution, we assume the gamma distribution with standard deviation of 0.2 for all of the parameters.

[22] To check robustness, we also used a commercial property price index, an equity price index, and a combined aggregate asset price index in place of the residential property price, ph_t. Although these variables typically have similar effects on cyclical output, none of them dominated residential property price growth in terms of statistical performance.

[23] Because most of the variables display a high degree of cyclicality, we estimate their means by Cesàro averages, ie we take the mean of the sequence of means obtained by successively increasing the sample by one observation starting from the initial date. This produces much faster convergence and, thus, reduces pro-cyclicality in the mean-adjustment.

[24] We also tried several additional variables in (5), for instance, HP-filtered real interest rates, ex-ante real interest rates, inflation (mean-adjusted or HP trend-adjusted), the unemployment rate (mean adjusted), and the log real exchange rate. The mean adjusted unemployment rate generated significant results in the United States and Spain, but not in the United Kingdom. None of the other variables were significant at the 5% level. For a detailed discussion, see Borio et al (2013).

[25] We use the IRIS toolbox add-on to Matlab to perform these calculations.

We restrict β to lie between 0 and 0.95, with a prior mean of 0.80. The upper bound for this parameter is set to avoid unit-root output gaps: as discussed further below, we view as unsatisfactory any specification of (5) for which the posterior mode of β reaches this boundary. The parameters γ_1, γ_2, and γ_3 are all restricted to lie between 0 and 1, with prior means equal to 0.2. To obtain a value for λ_2 that yields cycles of comparable duration to the HP-filter with $\lambda_1 = 1600$, we use a simple line search algorithm.

Table 1

Regression results: individual explanatory variables

	United States				**United Kingdom**				**Spain**			
Model	1	2	3	4	1	2	3	4	1	2	3	4
β	0.95 (–)	0.90 (14.33)	0.82 (14.74)	0.91 (17.0)	0.95 (–)	0.95 (–)	0.94 (15.96)	0.88 (12.89)	0.95 (–)	0.95 (–)	0.90 (14.57)	0.95 (14.35)
r	–	–0.08 (3.79)	–	–	–	–0.02 (–0.85)	–	–	–	–0.03 (–1.85)	–	–
Δcr	–	–	0.58 (6.30)	–	–	–	0.10 (3.73)	–	–	–	0.15 (2.99)	–
Δph	–	–	–	0.17 (5.48)	–	–	–	0.11 (4.15)	–	–	–	0.07 (2.87)
k_r	–	–2	–	–	–	–1	–	–	–	0	–	–
k_{cr}	–	–	0	–	–	–	0	–	–	–	–2	–
k_{ph}	–	–	–	– 4	–	–	–	–2	–	–	–	–3

Note: Estimated maximum posterior modes with t-values in parenthesis. The last three rows indicate the chosen lag for each of the three forcing variables.

To facilitate the exposition and build up intuition for our approach, we begin by successively estimating (5) with only one of the explanatory variables at a time. This allows us to assess the effect that each variable taken in isolation has on the estimated output gap. Table 1 reports the estimated coefficients, with corresponding t-values in parenthesis, and the optimal lag-length for each variable.

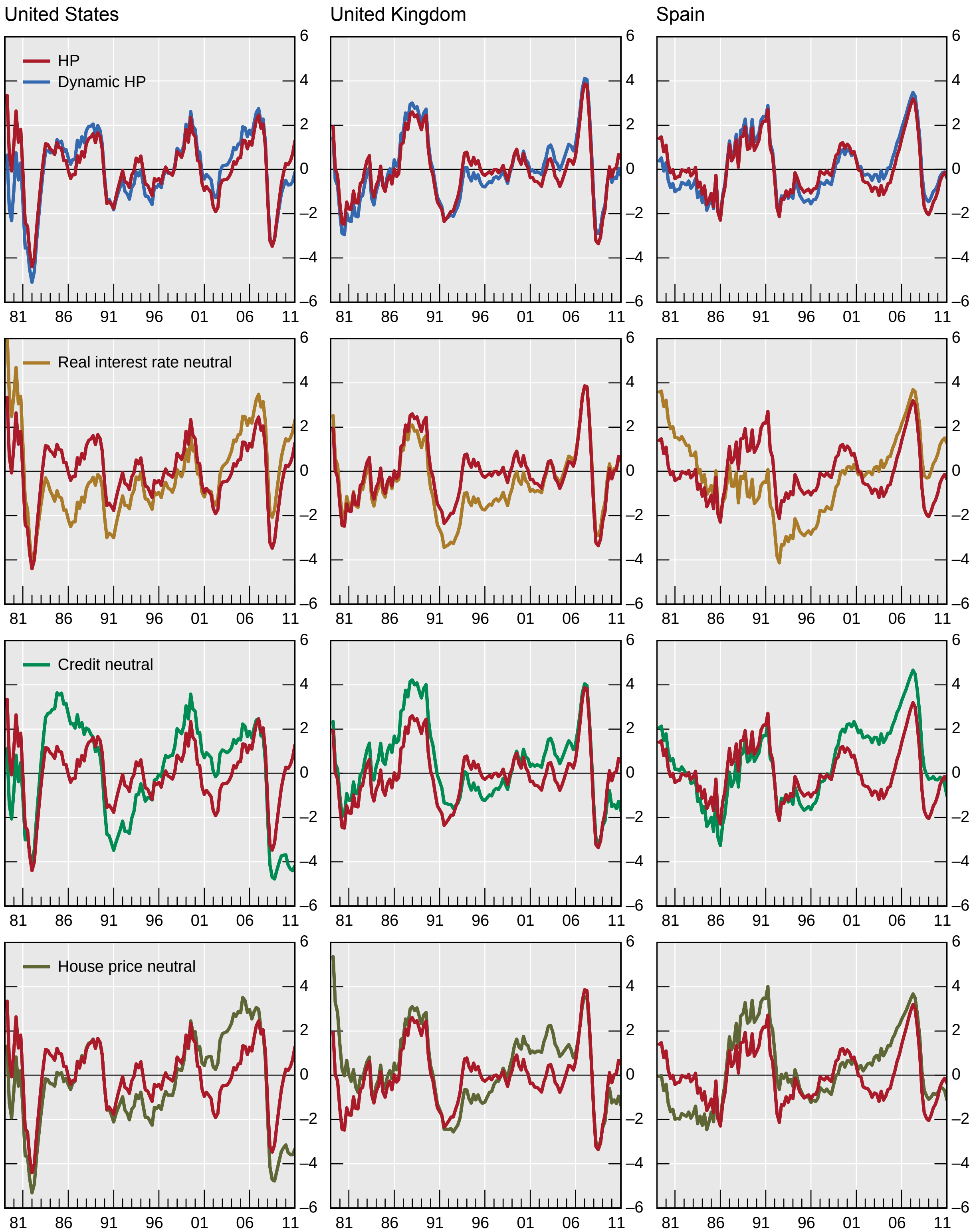
Modifying the traditional HP filter by adding a lagged output gap, which we will refer to as the dynamic HP filter, highlights the statistical properties of this variable but makes hardly any difference to the point estimates. The output gaps are highly persistent, very close to unit-root processes: the β estimates reach the 0.95 upper boundary in all three cases. As shown in the upper panels of Graph 2, this makes little difference to the point estimates themselves: the corresponding output gap is virtually identical to that constructed from a static HP filter. But the two models generate vastly different estimates of the precision of the estimated output gaps, as we discuss in more detail below. In particular, allowing for auto-correlated output gaps suggests that confidence bands should be much wider.

Turning to the explanatory variables, the results in Table 1 indicate that financial cycle proxies contain substantial information about business cycle fluctuations and that this information trumps that of the interest rate. The coefficients on real credit growth are relatively large and clearly significant in all cases. Property prices, too, are highly statistically significant. By contrast, the real interest rate is statistically significant only in the case of the United States. A corollary is that financial factors do a better job than interest rates in explaining observed changes over time in the amplitude and duration of the cyclical component of output.

Graph 2

Output gaps: information of individual variables[1]

In per cent of potential output



[1] Comparison between the estimated output gaps in Table 1 and HP-filtered output gaps.

Source: Authors' calculations.

To get a more concrete sense of the relative economic importance of these variables, the remaining panels in Graph 2 report the corresponding output gap estimates and compare them with those based on the simple HP filter. In the graph, we refer to each of the models that incorporate additional information as interest rate- credit- and house price-neutral, respectively.

Graph 2 confirms that both credit and property prices modify substantially the corresponding output gap estimates. Their information content is especially important during financial booms, such as in the second half of the 1980s and, even more clearly, in the second half of the 2000s. In these cases, they reduce the estimates of potential output considerably relative to actual output. They also result in larger negative gaps than the HP filter during the busts. The fact that the post-crisis negative output gap for the United States is much larger than those for Spain and the United Kingdom reflects the larger downturn in credit growth there. On the positive side, this more rapid deleveraging is likely to help set the foundation for a stronger recovery later on (Bech et al (2012)).

These results are intuitive. Incorporating information about the financial side of the economy leads to sustainable output estimates that also incorporate the degree to which the financial sector is acting to facilitate or constrain economic activity. All else equal, we would expect that in the boom phase this would result in *lower* estimates of sustainable output, since the surge in credit availability boosts output temporarily and, in some sense, “artificially”. Conversely, in the bust phase the corresponding estimates would be *higher*, since tighter credit constraints and balance sheet weaknesses restrain economic activity below normal levels. This is indeed what we find.

Full specification and non-linearities

We next analyse the effects of including simultaneously several variables in (5). We also allow for financial variables to affect the output gap non-linearly.

The results from the full version of (5) are presented in Table 2 (model 5) and confirm the previous picture. Both credit growth and changes in property prices are generally economically and statistically significant, whereas the real interest is not statistically significant. The only exception is Spain, where all of the three coefficients are borderline significant. This result appears to be primarily driven by changes in the coefficients over the sample: the Spanish real interest rate has a larger effect in the beginning of the sample, whereas credit becomes important only during the last decade (Graph 2). We discuss the implications of time-varying coefficients for real-time output gap estimates in Section IV. Since the effect of the real interest rate is insignificant for the United Kingdom and the United States, and empirically unstable for Spain, we report a parsimonious specification without it (model 6 in Table 2). This does not change the results much. The t-values on credit and property price growth increase slightly and the auto-regressive coefficient decreases moderately, even for Spain. Credit growth has a much stronger effect than real property price increases in the United States than in the other countries, where the effects of these two variables are more similar to each other.

Visual inspection highlights the economic relevance of the financial cycle variables. The output gaps that result from model 6 in Table 2 are reported in Graph 3. Clearly, the output gaps that use both credit growth and property price information are substantially different from those based on the standard HP filter. In particular, they point to much larger deviations from sustainable levels of output in the 2000s, a period of sustained run-up in private sector leverage.

Table 2

Regression results: full linear and non-linear specifications

	United States			United Kingdom			Spain		
Model	5	6	7	5	6	7	5	6	7
β	0.81 (14.13)	0.80 (14.30)	0.81 (15.62)	0.88 (14.03)	0.87 (14.70)	0.88 (15.28)	0.90 (10.88)	0.89 (15.00)	0.84 (15.47)
r	–0.04 (–1.30)	–	–	–0.03 (–1.20)	–	–	–0.04 (–2.25)	–	–
Δcr	0.51 (5.06)	0.52 (5.56)	0.62 (5.59)	0.09 (3.54)	0.09 (3.81)	0.12 (3.79)	0.12 (2.25)	0.13 (2.91)	0.54 (4.85)
Δph	0.09 (2.69)	0.10 (2.78)	0.12 (2.34)	0.10 (3.79)	0.11 (4.29)	0.11 (3.61)	0.06 (2.43)	0.06 (2.51)	0.03 (2.59)
k_r	–2	–	–	–1	–	–	0	–	–
k_{cr}	0	0	0	0	0	0	–2	–2	–2
k_{ph}	–4	–4	–4	–2	–2	–2	–3	–3	–3
τ^{cr}	–	–	0.044	–	–	0.024	–	–	0.017
τ^{ph}	–	–	0.024	–	–	0.019	–	–	0.015
ρ^{cr}	–	–	9.85	–	–	18.50	–	–	31.90
ρ^{ph}	–	–	17.60	–	–	28.35	–	–	42.35

Note: Estimated maximum posterior modes with t-values in parenthesis. The last seven rows indicate the chosen lag for each of the three forcing variables and the parameters of weighting functions.

The main reason for the stark differences between the finance-neutral and HP-filter gaps is that financial factors can explain a large share of cyclical variation in output. To get a sense of how much they do so, Graph 4 shows a decomposition of the output gap measures into components explained by the financial factors and those that are unexplained (the error term plus the autoregressive term in (5)). As can be seen, the size of the error component is generally small compared to the estimated gap, highlighting the explanatory power of financial variables. The only notable exceptions are the more dramatic movements in the error component a few quarters before and after the onset of the financial crises in the United Kingdom and, to a lesser extent, Spain.[26] This suggests that, by themselves, the credit and property price growth rates are not always sufficient to account for the more dramatic output swings around crisis dates. One possible explanation is that self-reinforcing feedback loops heighten the effects of the financial variables when the underlying financial imbalances become sufficiently large. That is, there may be potential non-linearities in the relationship between financial variables and cyclical output.

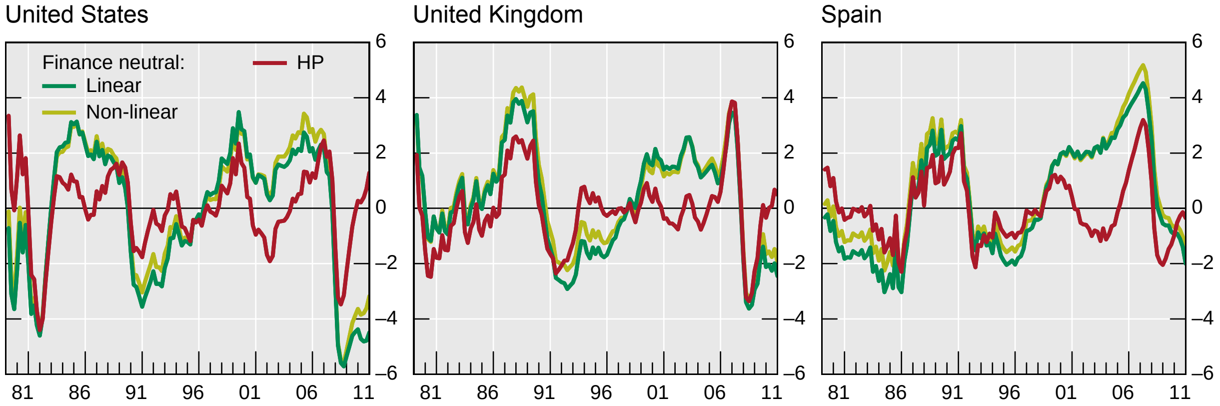
To explore this, we next permit the effects of the financial variables to vary with the strength of the underlying financial imbalances. In particular, these effects should be strongest when overall financial imbalances are large. As discussed above, this also reflects the asymmetric nature of booms and busts.

[26] The relatively small output gap for Spain in 2011 despite unemployment in the double digits reflects the limited contraction in credit and softening in property prices. This in turn points to a large financial overhang that may be impeding the recovery of the economy.

Graph 3

Output gaps: full specification[1]

In per cent of potential output



[1] Comparison between the estimated output gaps in Table 2, equations 6 and 7, and HP-filtered output gaps.

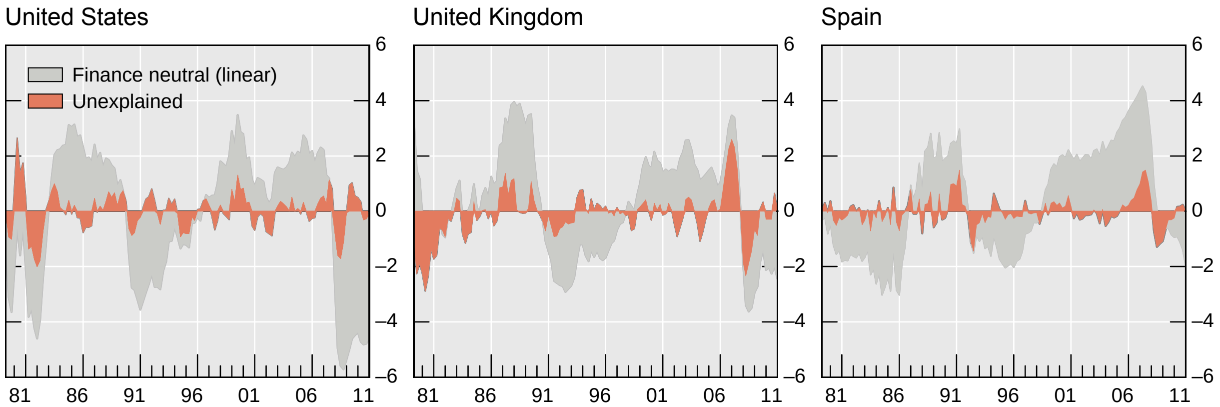
Source: Authors' calculations.

One possible way of incorporating such non-linearities is to weigh the financial variables in (5) based on the size of the underlying imbalances. To approximate the imbalances, we draw on previous work on leading indicators of banking crises (eg, Borio and Drehmann (2009)). That work finds that positive deviations of the credit-to-GDP ratio and real property prices from long-term trends ("gaps") in excess of certain thresholds convey information about subsequent crises in real time. The gaps are calculated based on real-time (one-sided) HP filters with a high value of lambda (400000), which roughly corresponds to the low frequency of the financial cycle (Drehmann et al (2011)).[27] We then attach weights to the growth rate of credit and property prices as a function of these gaps.

Graph 4

Output gaps: explained vs. unexplained[1]

In per cent of potential output



[1] The unexplained component is the total dynamic effect of $\varepsilon_{3,t}$ in (5) for each country using the estimated autoregressive coefficient reported in model 6, Table 2.

Source: Authors' calculations.

[27] Using these gaps directly in (5) does not produce significant results. This is consistent with the findings of Drehmann et al (2012), which indicate that the financial cycle is much longer than the traditional business cycle.

The specific weighting functions for credit growth and property prices are $\exp(\rho^{cr}(crgap_t - \tau^{cr}))$ and $\exp(\rho^{ph}(phgap_t - \tau^{ph}))$, respectively. Here, $crgap_t$ and $phgap_t$ denote, respectively, the deviation of credit-to-GDP ratio and real property prices from their long-term trends. We choose the threshold parameters τ^{cr} and τ^{ph} to match the 90th percent quantiles of the associated gap variables. These functions place less than unit weight on credit growth or house price increases when the gaps are below their respective thresholds and a greater than unit weight when they are above. We calibrate the parameters ρ^{cr} and ρ^{ph} such that the weights are 0.5 when the gaps reach their 10th percent quantiles. We multiply the financial variables in (5) by these functions, yielding smooth and gradual increases in their magnitude as imbalances build up.[28]

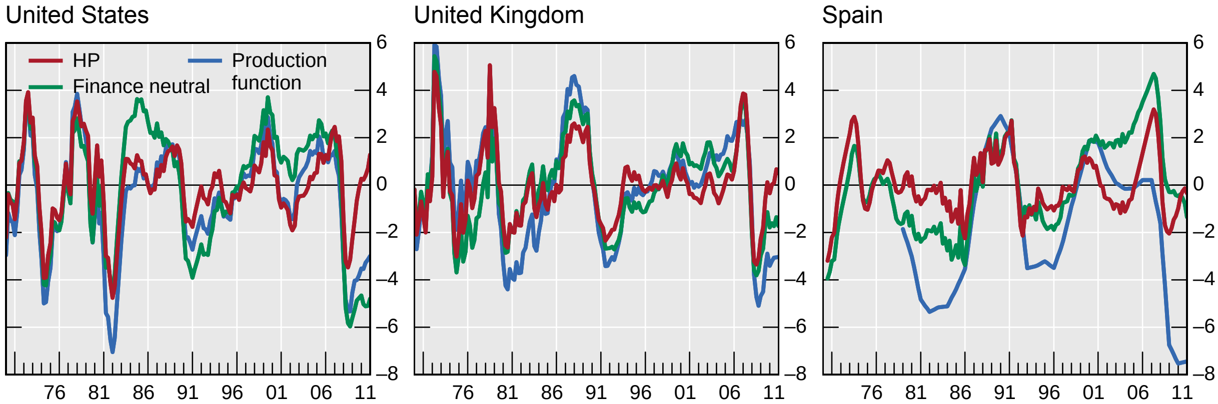
Allowing for non-linearities does influence the results, but not as much as we expected. This can be seen from Graph 3, which also shows the non-linear output gap estimates. The associated coefficients are reported as model 7 in Table 2. The non-linearities have the largest impact on Spain, where they increase the significance of the financial variables and decrease the auto-regressive coefficient. The results for the remaining countries remain more or less unchanged. The main effect is that output gaps based on the non-linear specifications are somewhat larger during peaks and a bit smaller during troughs.

The failure to detect strong non-linear effects may partly reflect our specific modelling choice, which is admittedly *ad hoc*. It may also reflect the inability to capture directly some of the channels we conjecture are at work, such as sectoral debt and capital stock overhangs and associated labour mismatches. We leave a more detailed treatment of this issue for future research.

Graph 5

Output gaps: extended sample

In per cent of potential output



Note: Comparison between finance neutral, the HP-filtered, and the OECD production function gaps over the sample 1971q1-2011q4. The OECD production function gap is only available at an annual frequency from 1978 onward for Spain. The graph shows linearly interpolated values for this series.

Sources: *OECD Economic Outlook*; authors' calculations.

Finally, we note that the influence of financial variables on the output gap estimates varies across countries and time with the amplitude of the financial cycle, as critically affected by the degree of financial liberalisation (eg Drehmann et al (2012)). Graph 5 shows the estimated finance-neutral output gaps for an extended sample from 1971q1-2011q4. We compare these gaps with those obtained from the HP filter and the OECD production function approach.

[28] Alternatively, the parameters of the weight functions could be specified and estimated as in Juselius and Kim (2011), who study non-linear dynamics in credit losses.

While the output gaps for the United States and United Kingdom are virtually identical pre-mid-1980s, the difference increases thereafter. Pre-mid-1980s, financial market regulation was relatively tight in both countries, resulting in substantially shorter, albeit quite volatile, credit cycles.[29] Remarkably, the association between the financial variables and cyclical output remains more or less intact during this period, suggesting that the business cycle was also shorter and more volatile. In fact, the cycle is so short that even the HP filter produces similar gap estimates as the trend component does not have time to catch up with actual output before the cycle turns. The contrast between the gaps is more apparent for Spain, where a divergence emerges as early as the mid-1970s. After the mid-1980s, financial developments become more persistent and have a prolonged impact on output. For this reason, the finance-neutral gaps are generally larger during known financial booms than the other gaps. While the OECD production function gap also captures the effects of such booms, albeit to a somewhat lesser extent, it tends to predict substantially deeper recessions in their aftermath than both the finance-neutral and the HP-filter gaps.

IV. Potential output: evaluation

The results so far indicate that financial cycle variables help to explain the cyclical component of output at traditional business cycle frequencies. This, by itself, speaks in favour of incorporating them in estimating potential output and output gaps. We next evaluate their performance further, with an emphasis on their possible use in policymaking. We consider four aspects: (i) the statistical precision of the estimates; (ii) their robustness to the passage of time (ie, comparing real-time and full-sample results); (iii) their use in calculating cyclically adjusted budget balances; and (iv) their role in guiding monetary policy, as judged on the basis of otherwise very standard Taylor rules. In what follows, to keep matters simple, we rely on model 6, ie the *linear* specification that includes both credit and property prices.

Statistical precision of the estimates

To evaluate the statistical precision of the estimates, we construct confidence intervals and compare them with those for the dynamic version of the HP filter. One major advantage of using the Kalman filter is that it yields standard errors for the unobserved state variable(s) – here potential output. Of course, making valid inferences still requires that the assumed state-space structure fits the data well. For example, accounting properly for (near) unit-root persistence in the variables is especially important (eg Johansen (2006)). Specifically, two output gaps may look virtually identical, but failing to account for the underlying persistence in the variable would yield misleadingly narrow confidence intervals.

To illustrate this point, consider equation (2), which specifies the output gap process for the standard HP filter. This static version of the filter states that the output gap is simply a normally distributed, serially uncorrelated error. It is, however, sharply at odds with the very high estimates of the auto-regressive parameters for the dynamic version of the filter (model 1 in Table 1). Ostensibly, the model based on (1) and (2) is grossly misspecified and this would not be reflected in the confidence bands for the associated output gaps, which therefore would look deceptively narrow. One should therefore be very careful when drawing inferences based on misspecified models. At a minimum, (near) unit-root persistence must be taken into account. For our analysis, this means that the relevant benchmark with which to compare the precision of our "finance-neutral" output gap estimates is the dynamic, not the static, version of the HP filter.

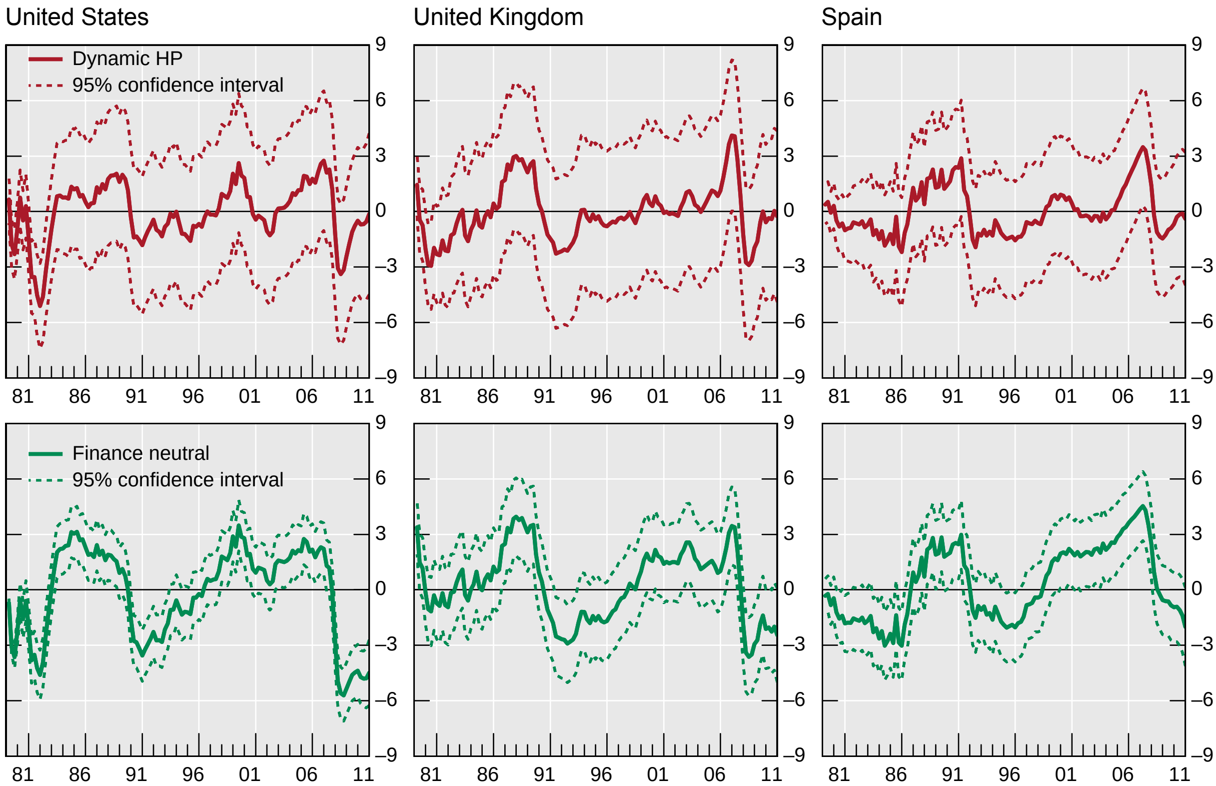
[29] In the United Kingdom, a short-lived financial liberalisation phase launched in 1970 gave strength to a short but quite intense financial cycle that led to the secondary banking crisis (Drehmann et al (2012)).

Embedding information about the financial cycle does help to improve the precision of the estimates. Graph 6 plots 95% confidence bands for the output gaps based on those obtained from model 6 in Table 2. While the bands are still rather wide, they are considerably smaller than those for the dynamic HP filter. In particular, for the United States, the size of the confidence band is more than halved, from ±3.50 to ±1.35 per cent on average; for Spain and the United Kingdom the reductions are somewhat smaller but still sizeable, from ±3.85 to ±2.10 and from ±2.95 to ±1.80, respectively. As a result, in contrast to the HP-filter specification, the confidence bands are narrow enough to produce output gaps that are statistically different from zero. This is an important step forward, given the simplicity of the underlying output gap equation in (5). Adding more lags and explanatory variables would very likely improve the fit, reduce further the "residual persistence" in the estimated output gaps and, possibly, substantially increase precision.[30] At the same time, one should always be mindful of the risk of over-fitting.

Graph 6

Finance neutral output gaps: statistical precision

In per cent of potential output



Source: Authors' calculations.

Real-time robustness

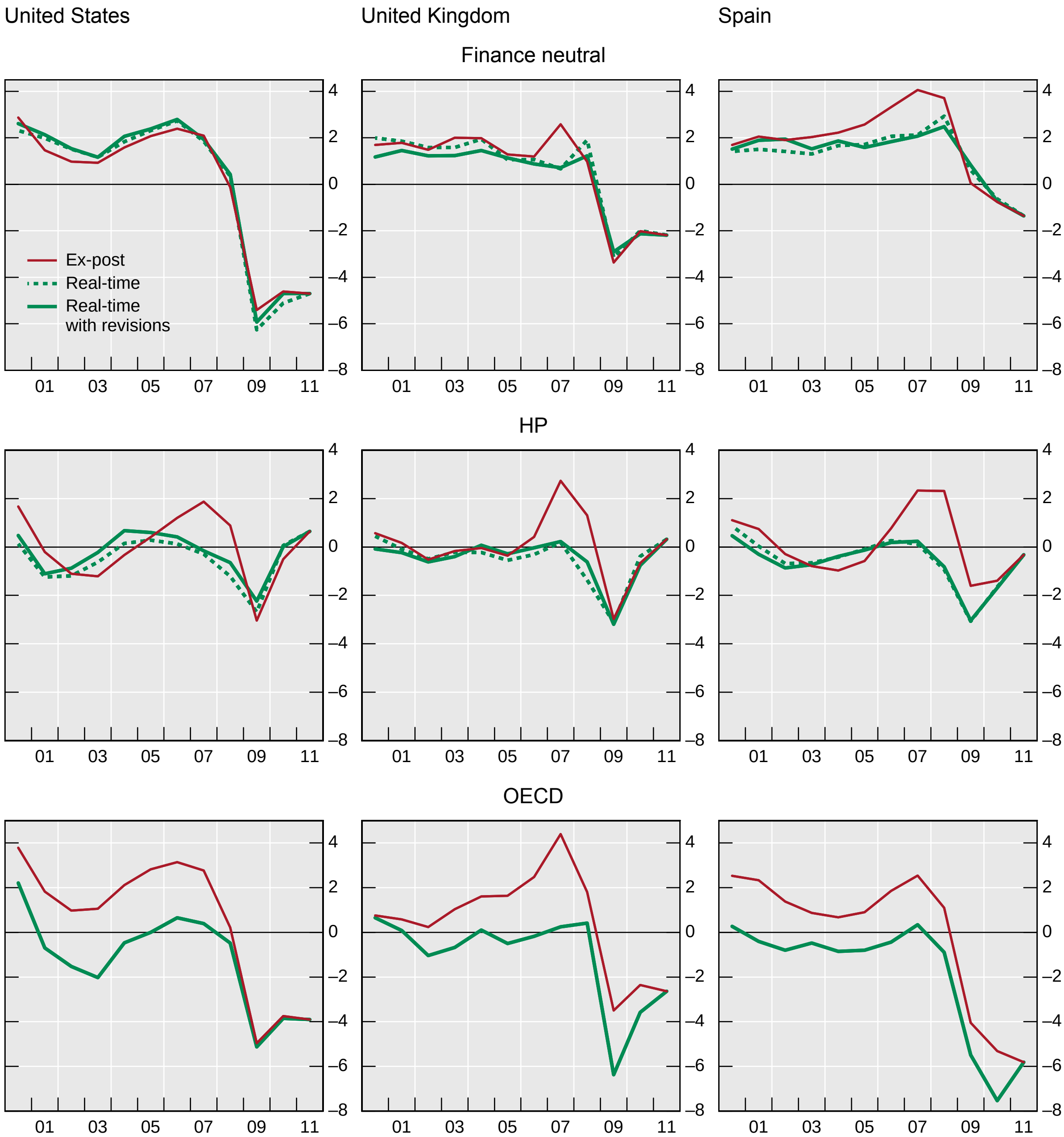
A core use of output gap estimates is to inform policy in real time. However, the estimates presented so far are ex-post, ie based on the full sample. How robust are our finance- neutral output gaps estimates to the passage of time?

[30] We have maintained a relatively simple specification for the output gap, partly for ease of exposition and partly to avoid the computational difficulties that adding more terms would entail for the adopted Bayesian framework.

Graph 7

Output gaps: ex-post and real-time estimates

In per cent of potential output



Note: For each time t, the "real-time" estimates are based only the sample of data up to that point. The "ex-post" estimates are based on the full sample of data.

Sources: OECD Economic Outlook; Authors' calculations.

The answer is that they are remarkably robust compared with the HP filter and the OECD production function approach. Graph 7 presents yearly real-time and ex-post estimates of the three different output gaps from 2000 to 2011. For each year the data are based on the following year's March vintage of the OECD's *Economic Outlook*. For example, the estimates for 2000 are based on the March 2001 data vintage.[31] As can be seen from the Graph, the real-time finance-neutral output gap (continuous green line) follows the ex-post gap much more closely than the other gaps.[32] And even more remarkable is its ability to detect in real time the unsustainable booms ahead of the recent financial crises in all three countries. By contrast, the real-time HP-filtered and production function output gaps indicate that the economy is actually at or close to its potential in the run-up to the crisis; only the ex-post filter eventually reveals the boom (continuous red line). This is due to the well-known end-point problem and the fact that booms take a longer time to build up than busts do to unfold.

Beyond this general result, the performance differs somewhat across countries. It is remarkably good for the United States. For this country, there is hardly any difference between the real-time and full-sample estimates (compare the continuous green and red lines). For the United Kingdom and Spain, there is a tendency for the real-time estimates to understate the boom. The main reason for this result is that the coefficients on the financial variables are very stable in the United States, but less so in the other two countries. For example, credit becomes increasingly important in Spain towards the end of the sample. In the United Kingdom, property price changes affect cyclical output with a shorter lag at the beginning of the sample than in the more recent period. This finding highlights the importance of continuously testing sensitivity with respect to different variables and sample periods for producing robust and reliable real-time estimates.[33] An additional benefit of our approach is that such testing can be done in a transparent and straightforward way.

Finally, we note that the effect of data revisions on the real-time gap estimates is not large. This can be seen from Graph 7 which also depicts real-time estimates based on the March 2012 data vintage for the finance-neutral and HP-filter gaps. This suggests that the differences between the real-time and ex-post gaps are predominantly due to methodological factors.

Together, these findings suggest that output gap estimates that embed information about the financial cycle are less vulnerable to the well known end-point problems that afflict the HP filter and production function approaches. As such, they could prove more reliable for policymakers. Since the severity of the end-point problem depends on how well the underlying filter represents the data generating process, this improvement simply reflects the fact that our model does a better job in explaining cyclical output variations than do the HP filter or the production function approach.

Informing fiscal policy: cyclically adjusted budget balances

One area where neglecting the financial cycle can significantly mask underlying problems is fiscal policy. The reason is simple: financial booms can flatter the fiscal accounts. The recent experiences of Spain and Ireland are quite telling (eg Benetrix and Lane (2011)). The fiscal accounts looked strong during the financial boom: the debt-to-GDP ratios were low and falling and fiscal surpluses prevailed. And yet, following the bust and the banking crises, sovereign crises broke out.

[31] In the case of the OECD production function approach, the estimates refer to the June release, which is the first release for the output gap estimates. Hence, it is likely that the data vintage on which these are based is actually more up to date than that used in our HP filter and finance-neutral estimates.

[32] To get a sense of how closely the real-time and ex-post gaps track each other, we calculate their mean deviation in absolute terms divided by the standard deviation of the ex-post gap. This roughly provides the average error per percentage movement in the output gap. This number equals 0.12, 0.24 and 0.38 for the finance neutral gaps in the United States, United Kingdom and Spain, respectively. The corresponding figures for the HP-filter gaps are 0.61, 0.42 and 0.68, and for the OECD production function gaps, 0.58, 0.71 and 0.59.

[33] For example, one could regularly carry out rolling regressions with relatively short rolling windows.

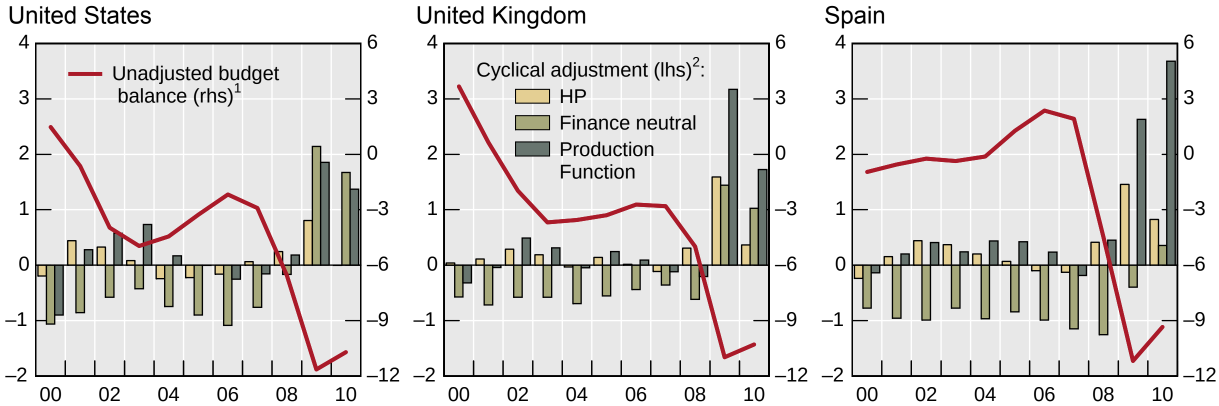
To illustrate the nature of the problem, we use our output gap estimates to cyclically adjust government budget balances. Constructing such structural budget balances requires estimates of the elasticity of tax and government expenditure categories with respect to output. Here we use OECD estimates (Girouard and André (2005)). It should be stressed that we do not correct for the additional effects that asset price booms or other aspects of financial booms may have on budget balances, by affecting the structure of revenues and expenditures. There is evidence, for instance, that asset price booms are revenue-rich (Price and Dang (2011) and Suarez (2010)). Nor do our estimates take into account the additional outlays needed to deal with the subsequent bust, such as those involved in buttressing the banking system. Thus, differences between the cyclically adjusted budget balances reflect solely those arising from output gap estimates. They therefore underestimate the true size of the needed adjustment. We focus only on the real-time estimates, which are the more relevant ones for policy.

As expected, the results indicate that the finance-neutral measure helps correct for the flattering effect of financial booms on the fiscal accounts. Graph 8 shows the actual fiscal balances (red line, right-hand scale) together with the cyclical adjustments based on the HP-filter and the finance-neutral measure (bars, left-hand scale). In this context, a difference of more than half a percentage point is generally regarded as economically significant. During the financial boom that preceded the financial crisis, the HP-filter and production function-based adjustments were small and sometimes even positive. By contrast, those based on finance-neutral measures were persistently negative, generally above 0.5 percentage points and often in the order of 1 percentage point, if not larger. They clearly indicate that underlying fiscal positions were substantially weaker than the headline figures suggested. That said, for the reasons noted above, they could not by themselves help anticipate the size of the subsequent deterioration.[34]

Graph 8

Budget balances and cyclical adjustments

In per cent of output



[1] As a percentage of GDP. [2] Cyclical correction of the unadjusted budget balance implied by the different output gap estimates. In percentage points.

Sources: *OECD Economic Outlook*; national data; authors' calculations.

[34] To do this would require using them alongside leading indicators of banking distress or stress tests. One question for future work is whether the finance-neutral output gaps themselves can contain such information.

Informing monetary policy: Taylor rules

The global financial crisis has given new impetus to the long-standing debate on how best to incorporate financial stability concerns into the formulation of monetary policy. A prominent line of argument is that a focus on minimising output and inflation gaps is sufficient, since monetary policy should only be concerned with financial imbalances to the extent that they impinge on output and inflation developments. The presumption is that forecasts of output and inflation already incorporate all relevant information, including that related to potential financial stability risks (eg Svensson (2011)). In practice, however, modelling limitations mean that financial stability concerns are largely absent from macroeconomic forecasts.

The question, then, is how best to incorporate them. One way could be to respond directly to proxies for financial imbalances. This basically amounts to introducing a term in central banks' loss functions that aims to avoid the build-up of financial imbalances in addition to traditional output and inflation terms (Disyatat (2010) and Woodford (2012)). An alternative way could be to rely on output gap measures that incorporate information about the financial cycle. This is a short-cut that compensates for the absence of an explicit model that adequately captures the endogeneity of financial cycles and the risk of financial instability. The finance-neutral output gap measure we propose represents one step in this second direction.

Here we investigate what difference such a measure could make as a guide to policy. To do so, we employ a standard Taylor rule, which sets the interest rate as a function of inflation and output gaps, and compare the trajectory of policy interest rates under the HP-filter, production function and finance-neutral estimates of the output gap. Again, we rely exclusively on real-time estimates.

In interpreting the results, three points are worth bearing in mind. First, absent a model, it is not clear that the standard Taylor rule parameter values describing the central bank response to the inflation and output gaps are also the optimal ones to incorporate financial stability concerns. Moreover, other policy instruments – such as macroprudential ones – have an important role to play in addressing the build-up of financial imbalances. Likewise, promoting balance sheet repair is critical during the bust (eg Borio (2012)). The corresponding results, therefore, are purely illustrative. Second, that being said, our measure of potential output is quite general if interpreted simply as a way of better capturing the cyclical component of output fluctuations. From this second perspective, there is no presumption that the corresponding parameters should be different from those in the standard Taylor rule as long as the considerations underlying the rule are regarded as valid. Finally, the actual *levels* of the implied policy rates should not be taken at face value, as our assumptions regarding the equilibrium, steady-state real interest rate are purely illustrative. Rather, our focus is on the *difference* between policy rates that results exclusively from the alternative output gap measures.

Graph 9 compares the behaviour of the policy rate based on the real-time HP-filter, production function and finance-neutral output gaps; it also shows the behaviour of the actual rate. We consider only the United States and the United Kingdom, since Spain does not have an independent monetary policy. For illustrative purposes, we adopt the simple standard version of the Taylor (1993) rule

$$i_t = r^* + \pi^* + 1.5(\pi_t - \pi^*) + 0.5(y_t - y_t^*) \quad (6)$$

where i_t is the policy rate, r^* the equilibrium real interest rate, π^* is the central bank's inflation target, π_t is the inflation rate, and $y_t - y_t^*$ the output gap.[35]

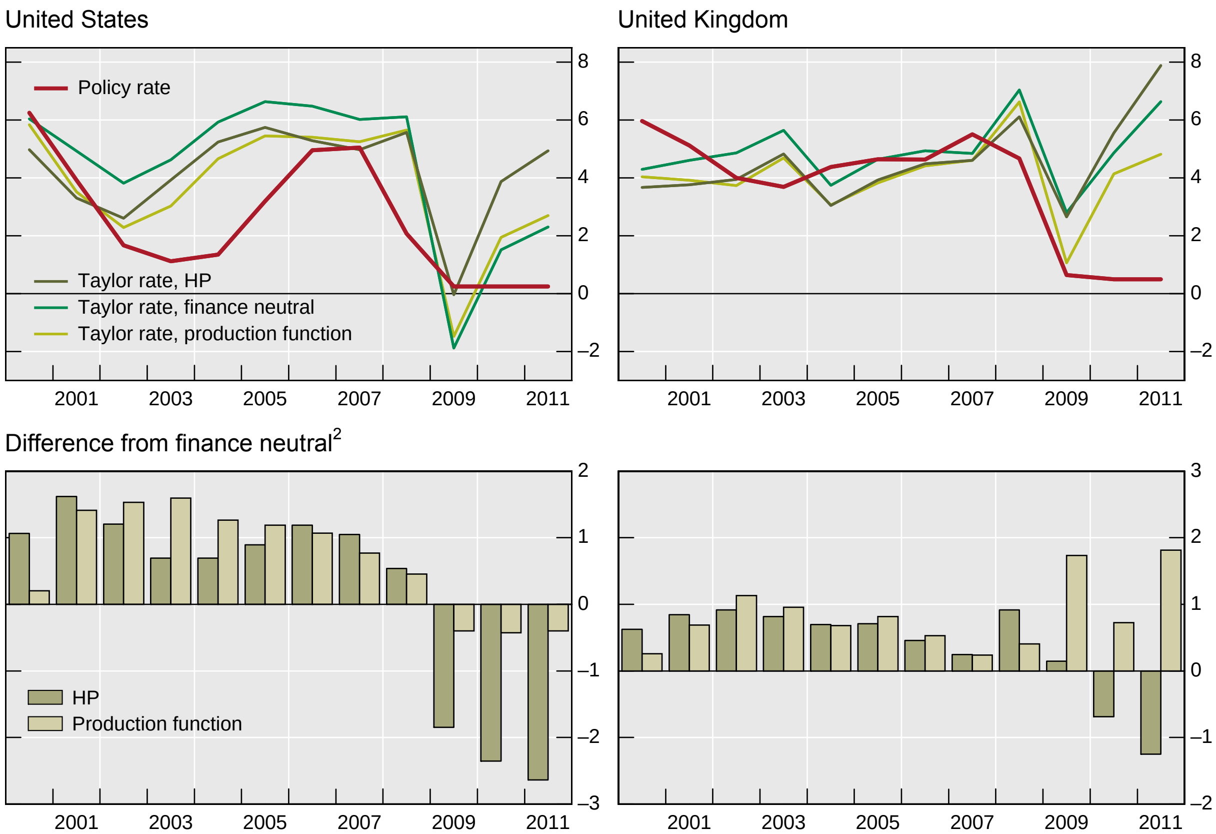
[35] For illustrative purposes, and following Taylor (1993) and Dale (2012), we assume that the steady-state equilibrium real interest rate is equal to 2. The precise value, however, is not important for our exercise, as we focus on the wedge between the policy rates implied by the different output gaps, not on the level of the policy rate as such. The differences are not affected by the value of the equilibrium real interest rate, which influences only the value of the constant term in equation (6).

The main takeaway from the Graph is that the finance-neutral measure of the output gap would have called for a considerably tighter monetary policy during the financial boom compared with the other estimates. According to the finance-neutral measure, the Taylor rate in the United States would have been typically around 1 percentage point higher during the boom. In the United Kingdom,[36] the rate would have been around 0.7 percentage points higher on average. In the bust phase, the picture is more mixed. The implied Taylor rule rates based on the finance-neutral measure would have been considerably lower than those based on the HP filter. By contrast, in relation to the production function approach, they would have been higher for the United Kingdom and slightly lower for the United States. In this second case, however, the result appears to depend on the use of a linear specification of the finance-neutral output gap, which makes the slump larger.

Graph 9

Policy rates and Taylor (1993) rules[1]

In per cent



[1] Calculated from the real-time output gap estimates in Graph 4. For the United States we calculated inflation based on the personal consumption expenditure price index and set $i^* = 2$ and $\pi^* = 2$. For the UK we set $i^* = 2$ and calculated inflation based the retail price index until 2003 and the consumer price index thereafter. The corresponding inflation targets were $\pi^* = 2.5$ and $\pi^* = 2$. [2] Difference between the rate implied by finance neutral output gap and Taylor rates implied by the HP-filtered and production function output gaps.

Sources: National data; authors' calculations.

As noted, these results should not be taken literally. In particular, we are *not* advocating that interest rates take on the full burden of leaning against financial tailwinds and headwinds.[37]

[36] The sharp increase in the policy rate for the United Kingdom at the end of the period is mechanically driven by a rise in headline inflation above target.

[37] In particular, see Borio (2012) for a discussion of the potential side effects of a prolonged and unusually aggressive monetary policy easing when dealing with a balance sheet recession, and Bech et al (2012) for some empirical evidence about the reduced effectiveness of monetary policy in that context.

From a policy perspective, the key message is simply that the finance-neutral measure does appear to capture the role of financial factors in influencing economic activity and to help incorporate them systematically and transparently into the information set available to policymakers.[38]

Conclusion

In this paper we have argued that financial factors are important in understanding and measuring potential output and output gaps. They play a key role in explaining cyclical output fluctuations at traditional business cycle frequencies and in determining which output trajectories are sustainable and which are not. Ignoring them or playing them down, as canonical macroeconomic models still do, means ignoring essential information. This can lead policy astray. It is therefore important to broaden the current analysis to incorporate them.

We have illustrated this point by estimating simple potential output and output gap measures that draw on financial cycle information, as captured by the behaviour of credit and property prices. The resulting "finance-neutral" measures improve on traditional estimates, notably on popular HP filters and production function approaches in several respects: they are estimated more precisely; are much more robust in real time; and hold out the promise of being more useful in policymaking, as they can yield more reliable estimates of cyclically adjusted budget balances and act as better guideposts for monetary policy.

That said, we have simply taken a first, preliminary step in incorporating financial information more systematically. We did not seek to optimise this information in terms of the variables used, their lag structures or the non-linearities involved; rather, we put a premium on simplicity to illustrate the potential of the approach. We did not incorporate directly information on the distortions generated by the build-up of financial imbalances on the real economy, in the form of aggregate and sectoral imbalances in the capital stock and allocation of labour; rather, we simply assumed that these are fully captured by the behaviour of credit and property prices – an heroic assumption. We did not evaluate the predictive content of the estimates for future economic activity or inflation; to do so reliably would require a more systematic cross-country analysis. We took traditional business cycle frequencies as given so as to make our results more comparable with the existing literature; but we argued that this standard assumption bears further scrutiny. And, of course, we did not develop a fully fledged macroeconomic model that could help interpret the measures more precisely and use them in counterfactual analysis. These are just a few of the key questions left for future research.

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[38] This is consistent with Taylor's (2012) suggestion that the neglect of credit would make "unconditioned" policy forecasts prone to errors and inferior to policy that is properly "conditioned" on the fact that credit booms have a systematic bearing on subsequent economic outcomes. Orphanides (2003) highlights the broader challenges involved in real-time policymaking.

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Appendix A: Data definitions and sources

y_t = log real seasonally adjusted GDP. Source: *OECD Economic Outlook*.

i_t = nominal three-month money market rate. Source: National data.

p_t = log consumer price index. Source: *OECD Economic Outlook*.

cr_t = log real credit to the non-financial private sector. Source: national data.

ph_t = log real residential property price index deflated by the CPI. Source: national data.

$crgap_t$ = cr_t deviations from real-time (one-sided) long term trend (HP-filter with $\lambda = 400000$). Source: authors' calculations.

$chgap_t$ = ph_t deviations from real-time (one-sided) long term trend (HP-filter with $\lambda = 400000$). Source: authors' calculations.