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Rethinking Potential Output: Embedding Information about the Financial Cycle

by

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Rethinking potential output: Embedding information about the financial cycle*

Claudio Borio, Piti Disyatat and Mikael Juselius[†]

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Abstract

This paper argues that information about the financial cycle should be incorporated in measures of potential output. Identifying potential output with non-inflationary output is too restrictive given that growing financial imbalances can place output on an unsustainable path even if inflation is low and stable. We propose a simple and transparent framework to accommodate information about the financial cycle in constructing output gap estimates. Applied to US data, our approach yields measures of potential output that are not only estimated more precisely, but also much more robust in real time. Inflation, by comparison, carries very little information that can be exploited to infer potential output.

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Table of Contents

Introduction	1
I. Potential output and the financial cycle: a conceptual extension	4
II. Potential output and the financial cycle: an empirical extension	7
A parsimonious multivariate filter	8
Results	13
III. Assessment and further considerations	18
Real-time performance	19
Statistical precision	20
The limitations of using inflation to condition potential output estimates	21
Conclusion	25
References	25

Introduction

The global financial crisis has made it abundantly clear that the financial and real sectors of the economy are inextricably linked. If the ebb and flow of the financial cycle are associated with economic booms and busts, then surely assessments about the sustainability of a given economic trajectory should take financial developments into account. Yet prevailing methods for estimating potential output, which are inherently premised on some notion of sustainability, pay little attention to financial factors.

Starting with the work of Okun (1962), a vast literature defines deviations from potential output with reference to inflation developments. The basic idea is that, all else equal, inflation tends to rise when output is above potential and vice versa (eg Mishkin (2007)). 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. We argue that this paradigm is too narrow because it neglects the role of financial factors.

Conceptually, given that sustainability is a key defining feature of potential output, equating it with non-inflationary output is too restrictive. Experience 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 global financial crisis is just the latest reminder of this possibility. From a *measurement* perspective, if financial developments contain information about the cyclical component of output, then ignoring such information may lead to less reliable estimates of potential output.

In this paper we take a first step in remedying this deficiency. We develop a simple and transparent framework for measuring of potential output in which financial factors are allowed to 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. As such, our contribution can be seen as an extension of the burgeoning literature that links financial cycles to business cycles and banking crises (eg Aikman et al (2011), Claessens et al (2011a,b), Schularick and Taylor (2011)). Based on the findings by Drehmann et al (2012), Borio and Drehmann (2009) and Alessi and Detken (2009), we pay special attention to booms and busts in credit and property prices.

Our framework aims to condition output gap estimates on economic information in a way that is simple, transparent and robust to misspecifications. It can be seen as a restricted

version of the more general system-based approach used in the literature. But rather than imposing structural equations that embody priors on economic relationships, such as through a Phillips curve, it evaluates directly the ability of plausible observable economic variables to explain cyclical output fluctuations *at a specific frequency*.¹ This keeps the dimension of the system small and reduces the need for prior assumptions which can have large effects on the outcomes. It also turns out to be critical for good real-time performance. We refer to this approach as the “parsimonious multivariate filter”.

We find that information about the financial cycle – as captured 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 outside financial booms, regardless of what happens to inflation; (ii) are estimated more precisely; and, above all, (iii) are more robust in real time.

In contrast, inflation does very little to help condition output gap estimates. This is true both in our framework as well as in the conventional approach of embedding a Phillips curve in a system of equations. We show that the latter approach can lead to Phillips curve estimates with plausible and significant coefficients even if the relationship is effectively redundant. This is highly misleading and reflects the opaqueness of these methods.

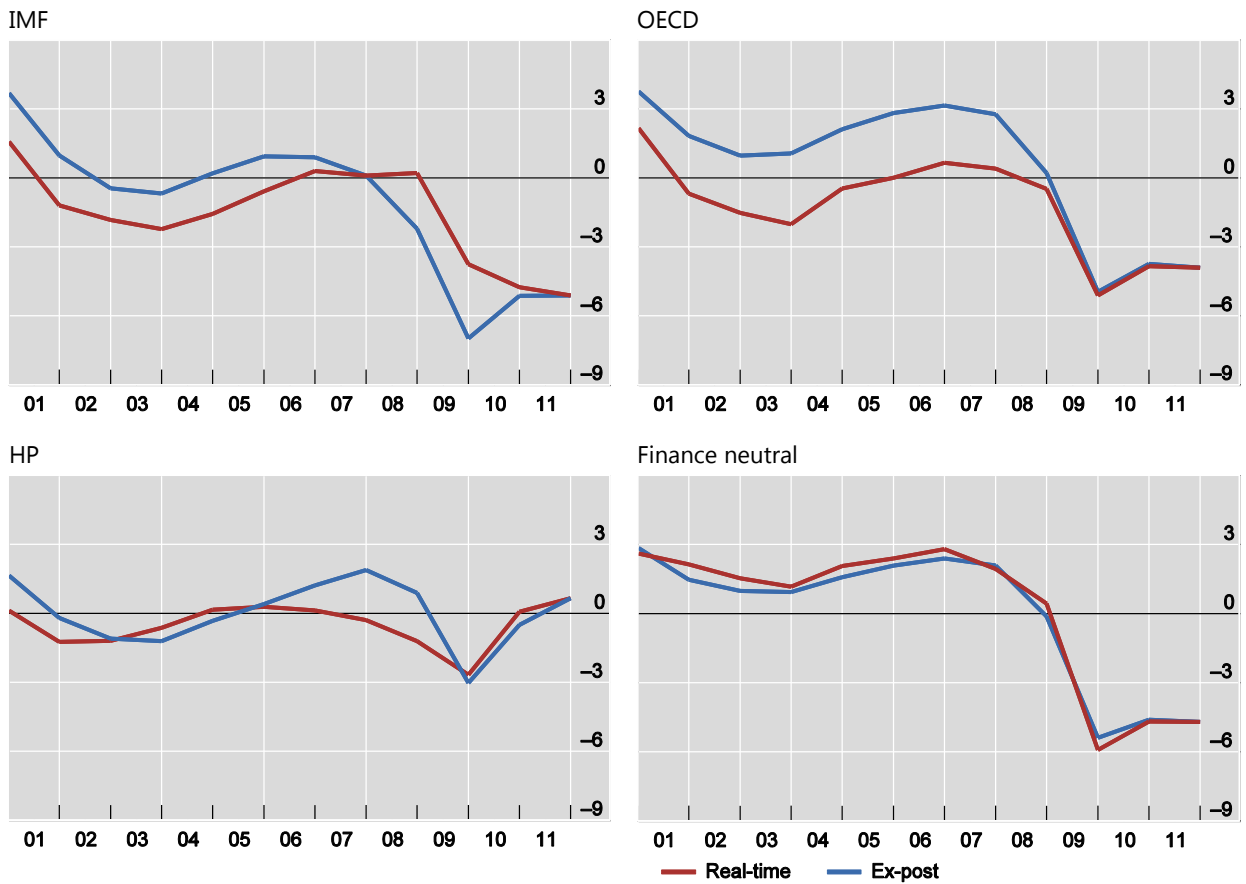
To illustrate the benefits of conditioning on financial information, Graph 1 compares our finance-neutral output gap with estimates provided by the OECD, IMF, and those based on simple HP filters for the case of the United States. Strikingly, *ahead* of the financial crisis, as the financial boom played 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. 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. 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. Such a measure would arguably help put policymakers in a better position to assess potential vulnerabilities as they build up.

¹ Here we simply adopt the HP-filter frequency, the most widely used in the analysis of the business cycle. That said, the “right” frequency depends on the specific question. We leave this for future work.

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

In per cent

Graph 1



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

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

The rest of the paper is organised as follows. The first section proposes an extension of the prevailing potential output concept in which financial factors play a key role. The second introduces the “parsimonious multivariate filter” approach and presents the results from an application to US data. The third section assesses both the real-time performance and the statistical precision of the finance-neutral output gap compared to traditional output gap estimates. The final section concludes.

I. Potential output and the financial cycle: a conceptual extension

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. 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. In the existing literature, the symptom of unsustainability is closely tied 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

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 potential output as the output that corresponds to fully flexible prices and wages (eg Neiss and Nelson (2005), Basu and Fernald (2009), Justiniano and Primiceri (2008)). 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

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

freely to changes in demand and supply. These nominal frictions again imply that, all else equal, inflation would tend to rise when actual output exceeds potential and vice versa (eg Woodford (2003)).

While variation in inflation is certainly one plausible symptom of output being above or below potential, 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*. 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 monetary policy that is focused on stabilising near-term inflation (Borio and Lowe (2002a)). 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.

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

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 inflows surge. 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.

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)).³

There is a burgeoning literature seeking to explain the factors at work during unsustainable financial booms. 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. 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)).

The upshot is what Borio and Disyatat (2011) termed the "excess elasticity" of the financial system. 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.

In more practical terms, 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

³ 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)).

sustained. By doing so, we arrive at something akin to a “*finance-neutral*” measure of potential output.

II. Potential output and the financial cycle: an empirical extension

Approaches to estimating 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. 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 Hodrick-Prescott (HP) filter. 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 change substantially as new data becomes available. History, in effect, gets rewritten as time unfolds. This limits their real-time usefulness for policy. Based on these considerations, Orphanides (2001) and (2003) has stressed the importance of relying on real-time data to evaluate policies, as we do below.

The structural approach, in contrast, seeks to derive a measure of potential output that is anchored to presumed theoretical relationships. The structure of these relationships, of course, can vary substantially. 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. A good example is the one used by the OECD (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 (2014)), 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 backdoor some of the problems that plague univariate statistical approaches. In the production function approach, for example, 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.

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), Benes et al (2010)) 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.

A parsimonious multivariate filter

Our measurement approach is designed to be transparent and to avoid constraining the data too much while at the same time incorporating key information 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.

Given T observations on actual output (in logs), y_t , the HP filter chooses potential output, y_t^* , to minimise the loss function

$$\sum_{t=1}^T \left(\frac{1}{\sigma_1^2} (y_t - y_t^*)^2 + \frac{1}{\sigma_0^2} (\Delta y_{t+1}^* - \Delta y_t^*)^2 \right) \quad (1)$$

where σ_1^2 is the variance of the output gap, σ_0^2 is the variance of the change in potential output, and Δ is the difference operator. A closed-form solution to the minimisation problem exists for a fixed value of the scaling parameter $\lambda_1 = \sigma_1^2/\sigma_0^2$. As formula (1) indicates, the scaling parameter determines the relative weight attached to deviations of potential output from actual output and to the smoothness of the potential output series itself. The standard value for λ_1 in quarterly data is 1600, which limits the maximum length of the business cycle to approximately 8 years.

Alternatively, one can minimise the loss function in (1) using the Kalman filter. Specifically, note that one can interpret the second term in (1) as the squared residuals from the following *state equation*

$$\Delta y_{t+1}^* = \Delta y_t^* + \varepsilon_{0,t+1} \quad (2)$$

where $\varepsilon_{0,t}$ is assumed to be normally distributed with mean zero with variance σ_0^2 . Similarly, one can interpret the first term in (1) as the squared residuals from the *observation equation*

$$y_t = y_t^* + \varepsilon_{1,t} \quad (3)$$

where $\varepsilon_{1,t}$ has mean zero and variance σ_1^2 . The errors $\varepsilon_{0,t}$ and $\varepsilon_{1,t}$ are assumed to be uncorrelated at all lags and leads.

Since the Kalman filter is an algorithm for calculating the linear *least squares* forecasts for the variables of the system, it jointly minimises the squared residuals in (2) and (3). As a result, the solution for y_t^* will coincide with that of the HP-filter provided one restricts the ratio between the residual variances, σ_1^2/σ_0^2 , to be λ_1 . This ratio – often referred to as the noise-to-signal ratio – determines how strictly potential output is anchored to actual output and, therefore, also *which output frequencies belong to the business cycle*. The lower the value of λ_1 , the higher the relative penalty assigned to deviations of potential output from actual output in (1), and the more closely potential output is tied to actual.⁴

In Borio et al (2014), we show that a robust way of embedding economic information in output gap estimates is to augment (3) with additional variables as follows

$$y_t = y_t^* + \beta(y_{t-1} - y_{t-1}^*) + \gamma'x_t + \varepsilon_{2,t} \quad (4)$$

where x_t is a vector of economic variables and $\varepsilon_{2,t}$ represents a normally and independently distributed error term with mean zero and variance σ_2^2 . The inclusion of a lagged output gap acts to account for the pronounced serial correlation generally present in HP-filtered output gaps. Together with (2), equation (4) corresponds to the loss function

$$\sum_{t=1}^T \left(\frac{1}{\sigma_2^2} (\varepsilon_{2,t})^2 + \frac{1}{\sigma_0^2} (\Delta y_{t+1}^* - \Delta y_t^*)^2 \right) \quad (5)$$

This loss function is similar to (1) with the output gap term swapped for $\varepsilon_{2,t}$, which now depends on the autoregressive term and the economic variables. The corresponding signal-to-noise ratio is given by $\lambda_2 = \sigma_2^2/\sigma_0^2$. To generate measures that are of comparable cyclicity to the standard HP filter, we set λ_2 such that

$$\text{var}(y_t - y_{HP,t}^*)/\text{var}(\Delta y_{HP,t}^* - \Delta y_{HP,t-1}^*) = \text{var}(y_t - y_{ALT,t}^*)/\text{var}(\Delta y_{ALT,t}^* - \Delta y_{ALT,t-1}^*) \quad (6)$$

⁴ It is possible to estimate the scaling factor, λ_1 , in the Kalman filter rather than fixing it at the outset, but this will generally involve a substantial upward bias. In other words, it will tend to smooth potential output too much and reduce correspondingly the degree of mean reversion in the output gap: the business cycle will appear more persistent or longer than it really is. This is known as the “pile-up problem” and makes it difficult to infer the “right” value of the noise-to-signal ratio from the data (see Borio et al (2014)).

where $y_{HP,t}^*$ and $y_{ALT,t}^*$ are the potential output estimates from the standard HP-filter and any model that uses equation (2) together with (4), respectively.⁵

This set-up has a highly desirable property. Minimising (5) subject to (6) implies that only variables that are directly relevant in explaining output fluctuations *at the chosen frequencies*, and have stable means, will receive a non-zero weight in (4). That is, a variable will enter (4) with a statistically significant coefficient if and only if its presence reduces the unexplained part of the estimated output gap. Moreover, trending conditioning variables causes the variability of the output gap, or the variability of the change in potential output growth if (6) is enforced, to increase with time and would hence eventually receive zero weight in the minimization. This contrasts with prevailing semi-structural methods, such as the multivariate filter, where embedded economic relationships can display statistically significant coefficients even though the equation does very little to condition output gap estimates. We illustrate this below.

The basic idea here is to limit the number of specification assumptions and the complexity of their interactions with the data by keeping the dimensionality of the system small. Rather than adding additional structural relationships, we augment directly equation (3) with additional observable economic variables that could explain the evolution of the output gap. As such, our approach can be seen as a restricted version of the more general system-based approach used in the literature that typically includes as many equations as the number of conditioning variables and estimates many trends jointly. Reflecting this, we will refer to our approach as the “parsimonious multivariate filter”. By simply seeking to filter out the cyclical component of output at the traditional frequency, the resulting estimates are directly comparable to those that identify potential with the trend component of output at that frequency. It is therefore an entirely empirical question which of the estimates yields a better measure of economic slack.

Given (2), we do not allow the conditioning variables to have a *direct* impact on potential output: we assume that they contain information only about the cyclical, or transitory, component of output. With respect to financial factors, such a direct impact is, in fact, 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.

⁵ The empirical noise-to-signal ratio for the HP filter (left-hand side of (6)) 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 (3). In this case, $var(y_t - y_t^*)$ will be larger than what is theoretically implied by (3). Thus, in practice, setting λ_2 such that (6) holds ensures that the relative volatility of potential output is comparable with the one obtained from the HP filter.

While we do not explicitly model the structural determinants of potential output, 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 (4) 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 (4). We first explore the information content of inflation and the real interest rate. When the real interest rate is included along with financial factors 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. For the financial factors, we focus on two variables: (private sector) credit and property prices, here only house prices.⁶ These help to capture the interaction between financing constraints, collateral values and wealth effects (eg Kiyotaki and Moore (1997)). It is also consistent with the growing empirical literature highlighting their information content for business fluctuations and financial crises (eg, Borio and Lowe (2002), Alessi and Detken (2009), Drehmann et al (2012), Claessens et al (2011a,b), Aikman et al (2011), Schularick and Taylor (2011)).

In all we consider four variables: inflation (π_t), the real interest rate (r_t), the growth in real total non-financial private sector credit (Δcr_t), and real residential property price growth (Δrp_t). Each variable is allowed to enter (4) only once with a lag chosen to maximise statistical fit.⁷ All variables are mean-adjusted. A potential difficulty arises in *small samples* because variables that display a high degree of cyclicity – and are therefore often informative in the present context – will tend to have pro-cyclical means. This would tend to understate booms and busts in real time and hence reduce the information content of the output gap estimates. Similarly, even a trending (or non-stationary) variable can receive a positive weight in (11) if its stationary variation dominates its low-frequency trend within the sample. It is therefore important to investigate the mean stability of the condition variables.

Graph 2 plots each variable together with a sequence of its estimated mean. We obtain the sequence by extending the sample successively by one observation starting from the

⁶ 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. Although these variables typically have similar effects on cyclical output, none of them dominated residential property price growth in terms of statistical performance.

⁷ We also tried several additional variables in (4), including HP-filtered real interest rates, HP trend-adjusted inflation, mean-adjusted capacity utilization, mean-adjusted unemployment rate, and the log real exchange rate. The mean adjusted unemployment rate and capacity utilization rates generated significant results but present some problems of their own. None of the other variables were significant at the 5% level. For a detailed discussion, see Borio et al (2014).

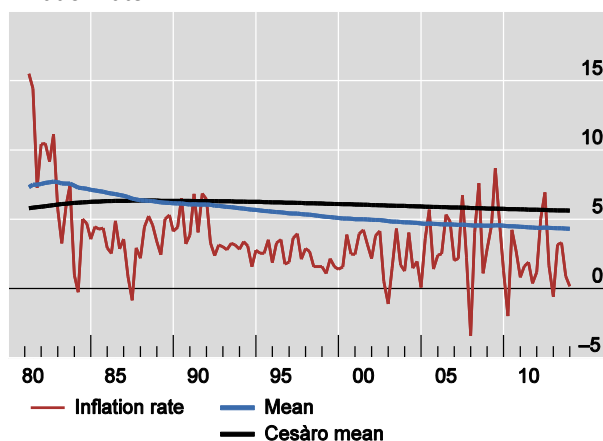
initial period 1970q1-1979q4. This initial period is long enough to get a meaningful starting estimate of the underlying mean provided that this is well-defined (constant).

Assessing the behaviour of the means

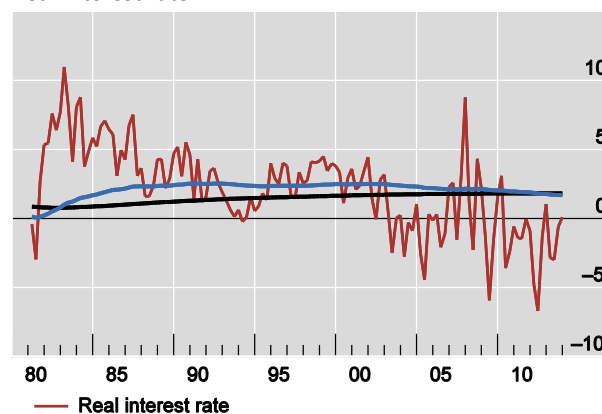
In per cent

Graph 2

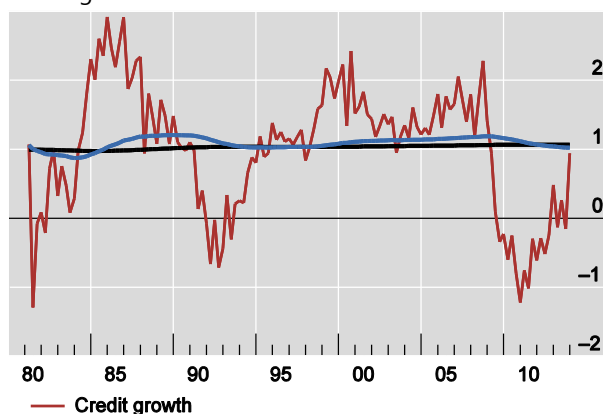
Inflation rate



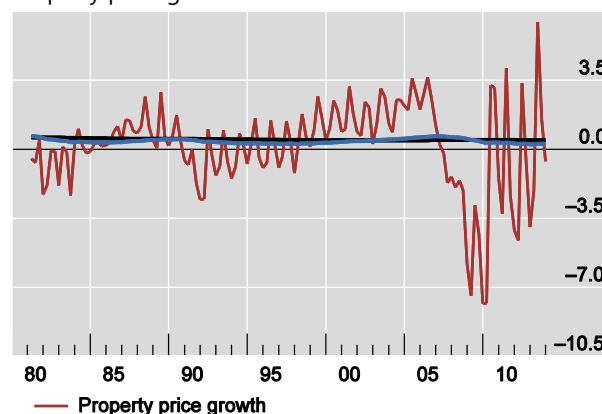
Real interest rate



Credit growth



Property price growth



Source: Authors' calculations.

The means of the inflation rate show persistent downward trends over the sample. The low-frequency trend also seems to dominate the cyclical variation. The means of the remaining variables show less obvious trends, although the mean of the real interest rate display sizeable and persistent changes over the sample. This suggests that the variable may contain low-frequency variation that reduces the reliability of their information content for output gaps. By contrast, the means of the financial variables appear comparatively more stable.

We attempt to mitigate the problem of cyclical means by using the Cesàro mean. Named after Ernesto Cesàro, a 19th century mathematician, a Cesàro mean is simply the mean of the sequence of means that we created earlier. Its key property is that it converges

faster to the population mean whenever this exists. The sequence of Cesàro means are plotted in Graph 2 (black lines). As can be seen, these means generally fluctuate less as the sample size grows. However, if the mean is not well-defined in the sample, as seems to be the case for inflation, applying a Cesàro mean will generally result in a greater divergence between the mean and the actual data compared to using a simple mean because the Cesàro mean adjusts more slowly. In what follows, we apply the Cesàro mean to de-mean all conditioning variables in (4).

Results

We adopt Bayesian techniques to estimate the state-space system consisting of equations (2) and (4) using quarterly data for the United States over the quarterly sample 1980Q1-2012Q4. This is convenient as it allows us to constrain certain parameters through the use of priors. We use the Kalman filter to form the likelihood of the system, specify prior distributions for the parameters and maximise the posterior density function with respect to the parameters.⁸ Priors for all parameters in (4) are assumed to follow a gamma distribution. The auto-regressive parameter, β , has a prior mean of 0.70 and standard deviation of 0.3 and is restricted to lie in the interval between 0 and 0.95. The upper bound for this parameter is set to avoid unit-root output gaps, which we view as unreasonable. We will view as unsatisfactory any specification of (4) for which the posterior mode of β reaches this boundary. The remaining coefficients have prior means and standard deviations equal to 0.3.

In each case, we multiply the elements of γ with the expected signs of the corresponding conditioning variables but otherwise allow them to be unrestricted in \mathbb{R}^+ . Moreover, we permit each variable to enter with a lag of up to four periods. The specific lag length is chosen to maximise the contribution of the conditioning variable to the estimated output gap. We also check for large outliers, as they can have a disproportionate impact on the estimates. Finally, we set the value for λ_2 iteratively so that (6) holds.

We proceed to successively estimate (4) 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. To evaluate the marginal information content of the conditioning relationship, we perform decomposition analyses based on Koopman and Harvey (2003). This provides break down of how much of the variation of a given variable can be explained

⁸ We use the IRIS toolbox add-on to Matlab to perform these calculations.

by variations in the other variables in the system, as well as the residual. Table 1 reports the results.

Estimated parameters of equation (4)						
t-statistics in parenthesis						Table 1
Model [†]	β	π_t	r_{t-2}	Δcr_t	Δrp_{t-4}	λ_2
Model 1	0.95 ^{††} (-)	—	—	—	—	72.25
Model 2	0.95 (24.65)	0.00 (0.27)	—	—	—	72.25
Model 3	0.95 (23.46)	—	-0.00 (0.20)	—	—	71.40
Model 4	0.86 (17.22)	—	—	0.43 (4.44)	—	25.50
Model 5	0.91 (19.92)	—	—	—	0.10 (2.97)	43.56
Model 6	0.83 (15.91)	—	—	0.43 (9.48)	0.07 (3.06)	20.70

[†] All models estimate a system containing equations (2) and (11) on quarterly US data over the sample 1980q1-2012q4. The scaling parameter, λ_2 , is set so that (6) holds. ^{††} t-value not available as the estimated value is at the upper boundary.

Modifying the traditional HP filter by adding a lagged output gap, which we will refer to as the dynamic HP filter, reveals a high degree of persistence in the output gap (Model 1 in Table 1). The β estimate reaches the 0.95 upper bound and the output gap is very close to a unit-root process. Nonetheless, as the left panel of Graph 3 shows, this modification 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. The right panel of Graph 3 illustrates this by comparing confidence bands from the static and dynamic HP-filtered gaps. Clearly, the precision of the HP gap is much lower once the high degree of serial correlation is taken into account. As pointed out by Harvey and Jaeger (1993), by fixing the noise-to-signal ratio, the HP filter estimate of $\varepsilon_{1,t}$ is no longer a white noise process. However, the standard errors obtained under the Kalman filter still assume that it is. This leads to estimates of the errors that are deceptively precise.

Turning to the explanatory variables, the estimates for inflation (Model 2 in Table 1) indicate that this variable contains virtually no information about the business cycle. For example, the auto-regressive parameter, β , reaches the upper boundary of 0.95 and the coefficient on inflation is practically zero. The upper left panel of Graph 4 plots the

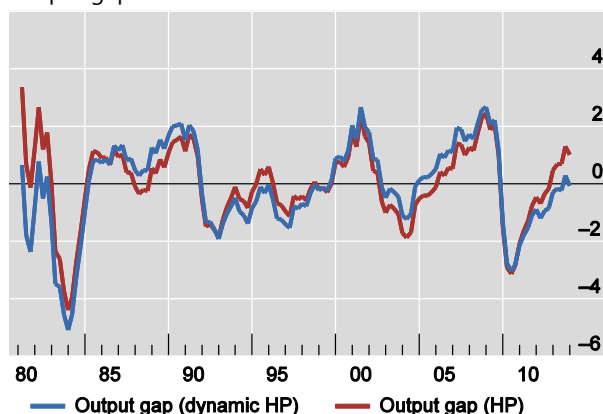
corresponding output gap, which is practically identical to the one obtained from the standard univariate HP filter. The panel also shows the low value added of inflation; almost all of the variation in the estimated output gap is due to the residual in (4). A similar result holds for the real interest rate (Model 3 in Table 1 and the top right-hand panel of Graph 4). This may be partly a reflection of the influence of inflation on central bank policies over the sample.

Static and dynamic Hodrick-Prescott filter

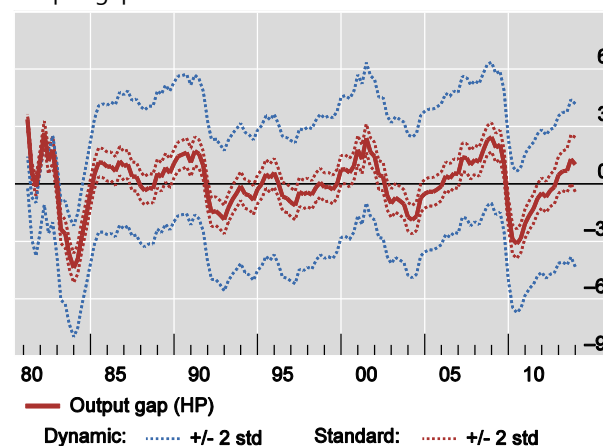
In per cent

Graph 3

Output gaps



Output gaps: confidence bands



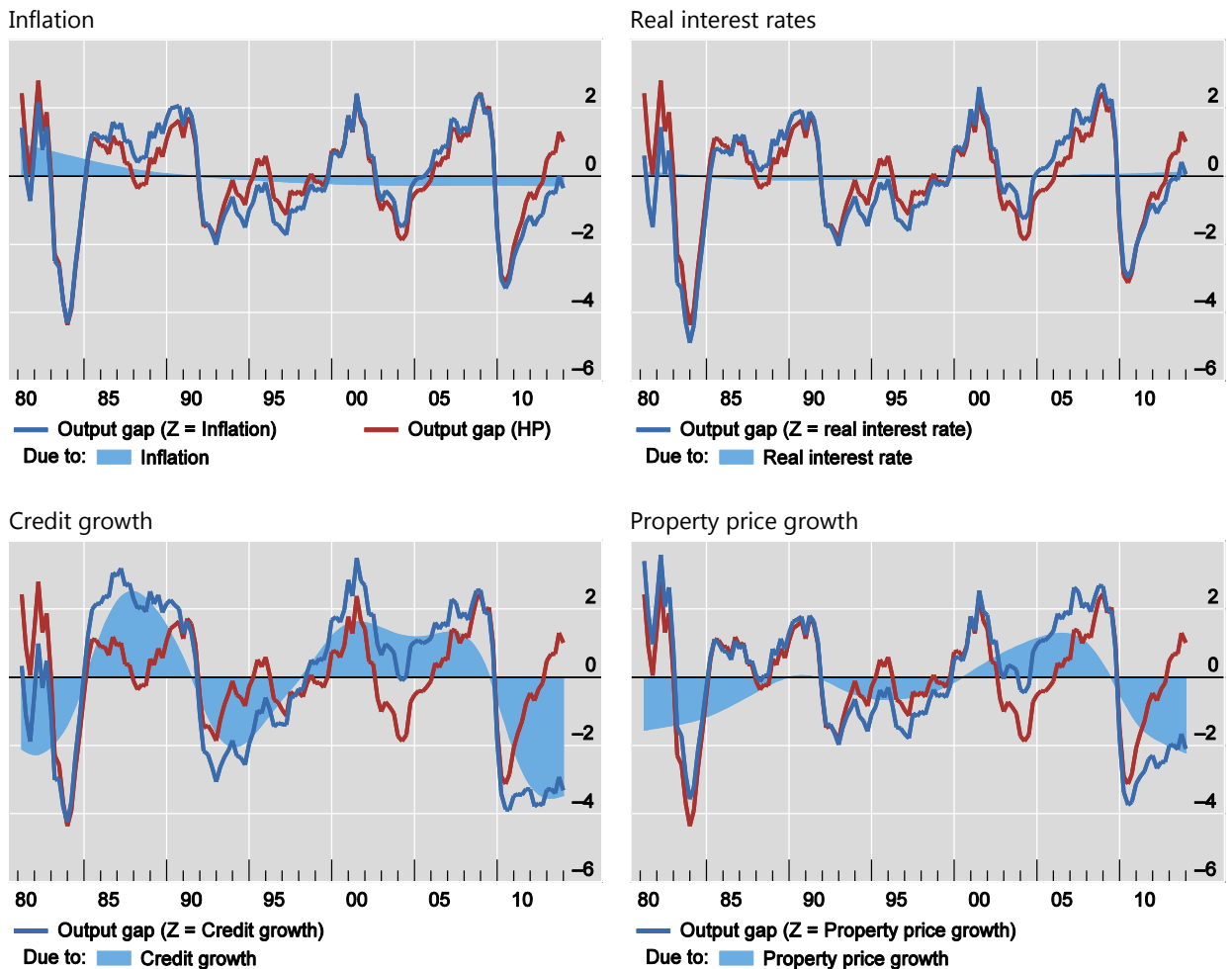
Source: Authors' calculations.

In terms of the results for the financial variables, we find that both credit and property price growth yield statistically significant results and deliver sensible output gap estimates. The auto-regressive parameter in the model for credit growth (Model 4) is statistically squarely in the stationary region and the coefficient on credit growth is highly significant. The associated output gap (bottom left panel in Graph 4) differs substantially from the HP filter benchmark, capturing the outside boom prior to the early 1990s crisis, the bust of the dot.com bubble, and the recent financial crisis. As can be seen in the graph, most of this variation is explained by credit growth. Compared with the HP filter, the approach also delivers deeper and longer recessions in the early 1990s and recently. The growth rate in the residential property price index is also statistically significant (Model 5), but explains a smaller portion of cyclical output variability overall. The associated output gap (bottom right panel of Graph 4) shows large deviations from the HP filter benchmark during the recent housing boom and the subsequent recession.

US output gaps based on individual conditioning variables

In per cent

Graph 4



Source: Authors' calculations.

Since the two variables that jointly proxy the financial cycle – credit and property prices – clearly contain important information about cyclical variations in output, a natural extension would be to combine their information content together. The estimation results for this “finance-neutral” output gap is reported as Model 6 in Table 1. Both credit and property price growth are statistically significant, with coefficients of a similar size to those found when included individually. As shown in the upper left hand panel of Graph 5, the finance-neutral output gap differs markedly from the HP filter benchmark. Their information content is especially apparent during financial booms, such as in the second half of the 1980s and, even more clearly, in the second half of the 2000s – a period of a period of sustained run-up in private sector leverage.

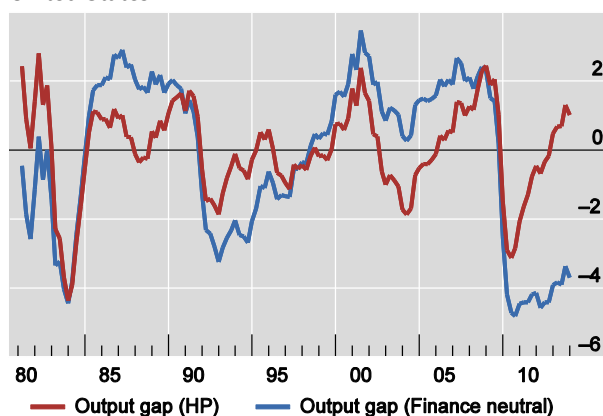
Finance-neutral output gap

In per cent

Graph 5

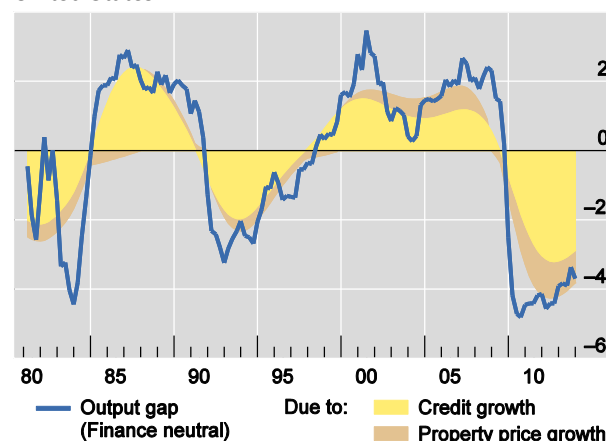
Finance-neutral and HP filtered output gaps:

United States

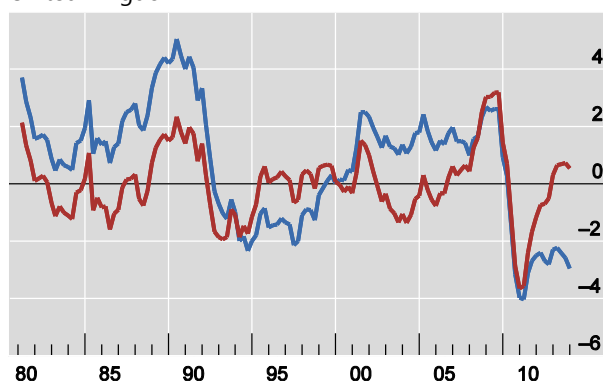


Contribution of credit and property prices:

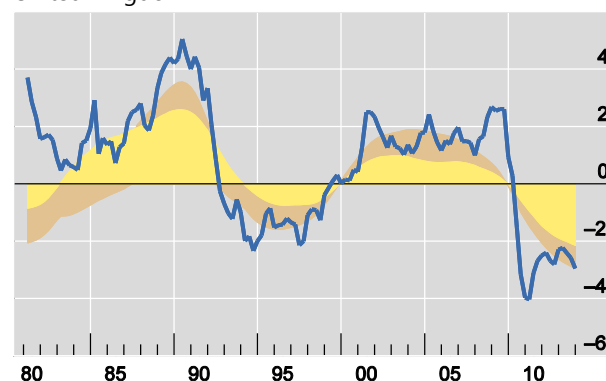
United States



United Kingdom



United Kingdom



Source: Authors' calculations.

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.

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. The upper right-hand panel of Graph 5 gives a sense of how much they do so, using the decomposition we outlined earlier. As can be seen, much of the variation of the output gap

is accounted for by developments in real credit and property price growth. In relative terms, credit growth explains a substantially larger portion of the estimated output gap than property price growth.

That said, the size of the error component (variations unexplained by the financial factors) is visibly larger during times of financial upheavals, such as those in the early 1980s and in 2008. 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. In Borio et al (2013), we take a preliminary step to explore this by extending the present framework to accommodate non-linearities but are unable to detect strong evidence of such effects. This may partly reflect the specific modelling choice adopted. Further research in this respect is warranted.

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. The lower panels of Graph 5 show the estimated finance-neutral output gap the United Kingdom compared with those obtained from the HP filter. While financial factors are important for cyclical output in both the United States and United Kingdom, the output gaps differ both with respect to their patterns and the relative contributions of the credit and property price growth. Pre-mid-1980s, financial market regulation was relatively tight in both countries, resulting in substantially shorter, albeit quite volatile, credit cycles. 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 than the HP-filter benchmark during periods where the financial cycle is particularly pronounced.

III. Assessment and further considerations

The results so far indicate that financial 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 output gaps. To further assess their potential for practical policy use, we examine their properties along two dimensions: (i) their real-time performance; and (ii) the statistical precision of the estimates.

Real-time performance

A critical factor that determines the usefulness of output gap measures, especially in policy use, is their real-time performance. It is well known that output gaps based on purely statistical filters are often subject to large ex-post revisions, undermining their value in policymaking.⁹ This is illustrated in the upper left-hand panel of Graph 6, which compares real-time and ex-post output gap estimates for the standard HP filter. The real-time estimates completely miss, for instance, the large boom ahead of the recent financial crisis, which becomes visible only in the ex-post estimates. The average absolute deviation between the real-time and ex-post gaps is 0.65 percentage points per standard deviation in the (ex-post) gap.

Following the popular approach of embedding a structural relationship in the form of a Phillips curve to the system (see below) does not help much. The real-time performance is very similar to that of the standard HP filter (right-hand panel of Graph 6). Indeed, the corresponding average absolute deviation is 0.63 percentage points per standard deviation in the gap. The bottom left-hand panel of Graph 6 also shows the real-time performance of output gaps constructed by the OECD using a production approach. They are similarly subject to very large ex-post revisions.

By contrast, our finance-neutral output gap estimates are remarkably robust to the passage of time. The real-time gap follows the ex-post gap much more closely than the other measures, with an average absolute deviation of 0.19 percentage points. Whereas 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 recent crisis, the finance-neutral output gap is able to detect the unsustainable boom ahead of the recent financial crisis in real time.

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. In Borio et al (2013a), we illustrate how finance-neutral output gap estimates can lead to marked differences in assessments of fiscal sustainability and the appropriate stance of monetary policy. Since the severity of the end-point problem depends on how well

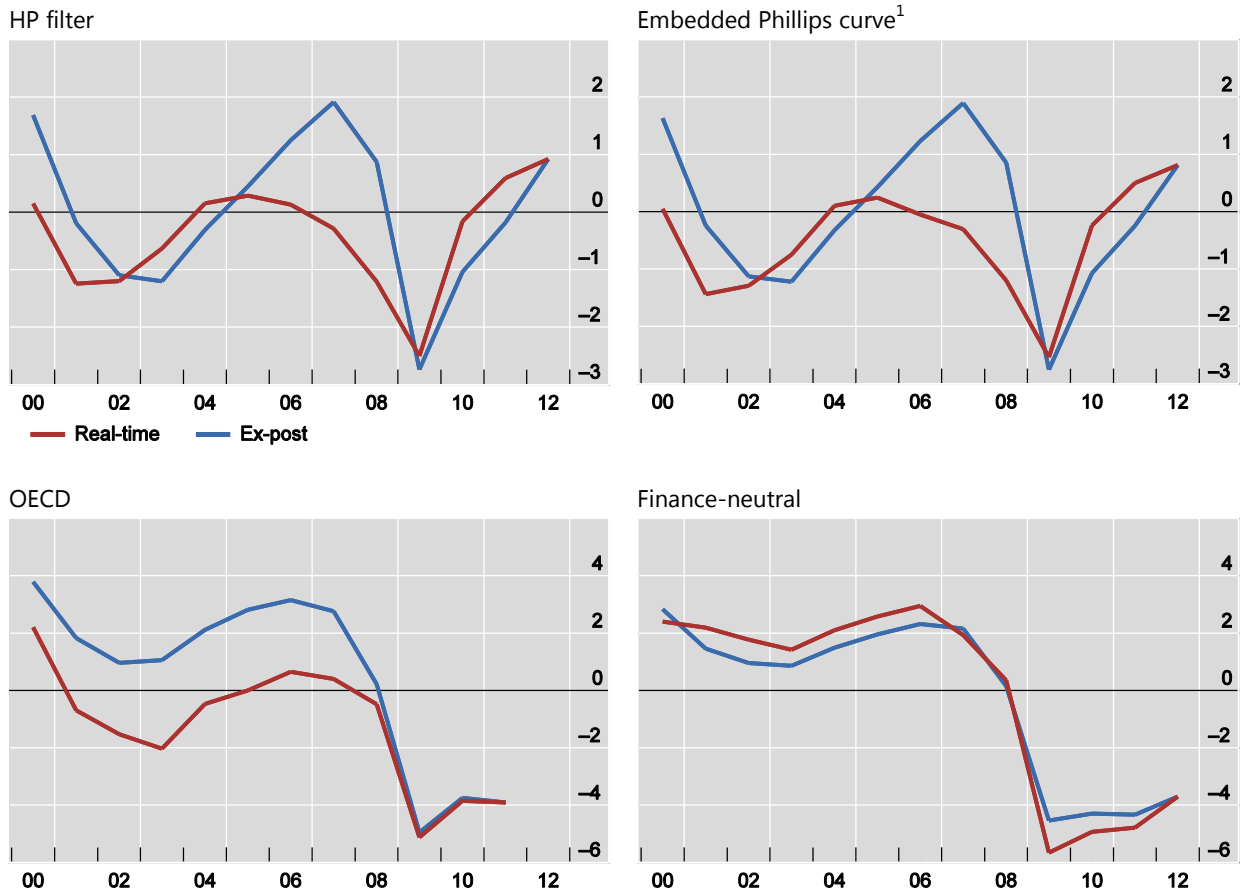
⁹ Various solutions to the end-point problem have been suggested in the literature. These range from using GDP forecasts in the estimations to statistical modifications to the filter, but none has been entirely successful (eg Mise et al (2005) and Garratt et al (2008)).

the underlying filter represents the data generating process, the improvement in real-time performance 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.

US output gaps: real-time performance

In per cent

Graph 6



For each time t , the "real time" estimates are based only on the sample up to that point in time. The "ex-post" estimates are based on the full sample. ¹ Real time estimates from Model 1, Table 2.

Sources: OECD Economic Outlook; authors' calculations.

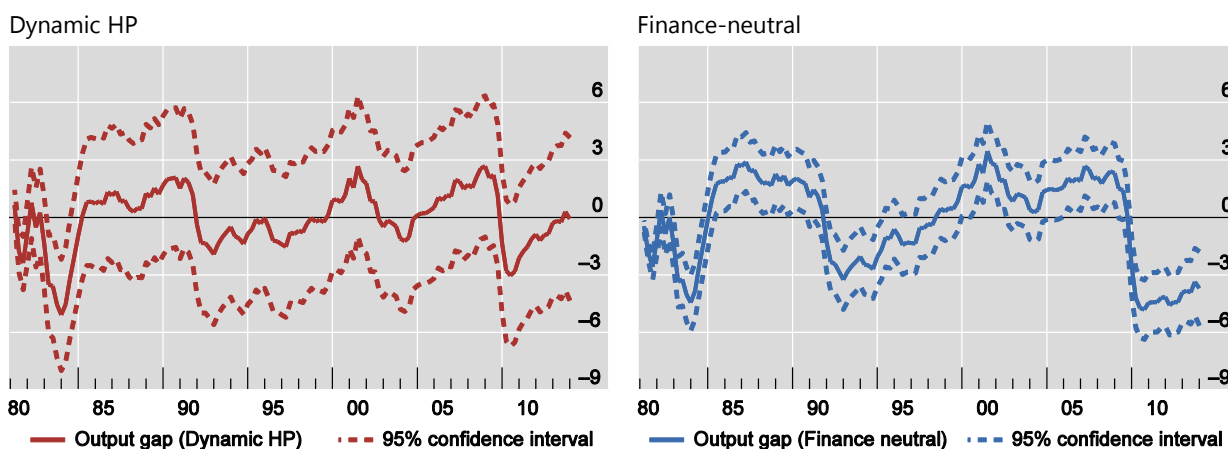
Statistical precision

To evaluate the statistical precision of our finance-neutral output gap estimates, we construct confidence intervals and compare them with those obtained from the dynamic version of the HP filter. That is, we compare the standard errors on output gap estimates from using equation (4) with and without the vector x of economic variables. This serves to highlight the marginal effect on precision of adding financial factors.

HP and finance-neutral output gaps: statistical precision

In per cent

Graph 7



Source: Authors' calculations.

Graph 7 plots 95% confidence bands for the output gaps based on those obtained from Model 6 in Table 1. While the bands are still rather wide, they are considerably smaller than those for the dynamic HP filter. The size of the confidence band is more than halved, from ± 3.50 to ± 1.35 per cent on average. As a result, 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 estimation method. 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. At the same time, one should always be mindful of the risk of over-fitting.

The limitations of using inflation to condition potential output estimates

In light of the prevalent reliance on using inflation as an information variable for estimating output gaps, it is worth highlighting some key limitations and pitfalls of doing so. As the results in Section II indicate, inflation appears to contain very little useful information for conditioning output gap estimates (Model 2 in Table 1). This may seem surprising in light of the popularity of prevailing approaches that use a Phillips curve as a key relationship to anchor such estimates. To shed light on this, we follow the conventional approach of adding a structural economic relationship, here a Phillips curve, to our system of equations.

Starting with the state-space system of the HP filter comprising of equations (2) and (3), we now add another observation equation of the form

$$\pi_t = \gamma_0 + \gamma_1 \pi_{t-1} + \gamma_2 (y_t - y_t^*) + \varepsilon_{3,t} \quad (7)$$

where π_t is the CPI inflation rate and $\varepsilon_{3,t}$ is normally distributed with mean zero and variance σ_3^2 . In Borio et al (2014) we consider more elaborate specifications of the Philips curves that, for example, include inflation expectation, allow an unobserved trend in inflation, or replaces inflation with inflation growth in (7). This does not change the outcome.

The loss function for this expanded system is

$$\sum_{t=1}^T \left(\frac{1}{\sigma_1^2} (y_t - y_t^*)^2 + \frac{1}{\sigma_0^2} (\Delta y_{t+1}^* - \Delta y_t^*)^2 + \frac{1}{\sigma_3^2} (\varepsilon_{3,t})^2 \right) \quad (8)$$

which is identical to the loss function associated with the multivariate HP filter introduced by Laxton and Tetlow (1992).

Compared to (1) and (5), not just one but two scaling factors, $\lambda_1 = \sigma_1^2/\sigma_0^2$ and $\lambda_3 = \sigma_1^2/\sigma_3^2$, determine the relative weights of the three terms in (8). The value of λ_1 plays a similar role as before, while λ_3 determines the relative weight accorded to relationship (7) in the estimation. That said, both scaling factors *jointly* influence key aspects of the outcome, such as the cyclicity of the estimated gap and the degree to which the conditioning economic relationships contribute to it. As Borio et al (2014) discuss in detail, the presence of an additional scaling factor complicates the analysis considerably because there is no clear guideline how to set it. For present purposes, we set the scaling factor λ_1 to 1600 in line with the standard HP filter and try both freely estimated and imposed values for λ_3 .

We follow the estimation procedure as before specifying a gamma distribution with standard deviation of 0.3 for all the parameters. The inflation persistence parameter, γ_1 , is restricted to lie between 0 and 1 with a prior mean of 0.70. The constant, γ_0 , and the parameter on the output gap, γ_2 , are unrestricted in \mathbb{R}^+ with prior means equal to $3.5 \cdot 0.3$ (approximately the average US inflation rate times one minus the prior on γ_1) and 0.30, respectively.

Phillips curve estimates

t-statistics in parenthesis

Table 2

Model [†]	γ_0	γ_1	γ_2	λ_1	λ_3
Model 1	1.27 (8.22)	0.61 (13.38)	0.31 (2.42)	1600	0.43
Model 2	1.36 (3.86)	0.06 (0.94)	0.70 (6.26)	1600	100

[†] All models are estimated on quarterly US data over the sample 1980q1-2012q4. Models 1 and 2: system contains equations (2), (3), and (7).

Table 2 shows the results. For the specification in which λ_3 is estimated freely (Model 1), all parameter values look reasonable: the process for inflation is clearly stationary, although somewhat persistent, and the term on the output gap is significant. On this basis, the Phillips curve appears to help condition the potential output estimate.

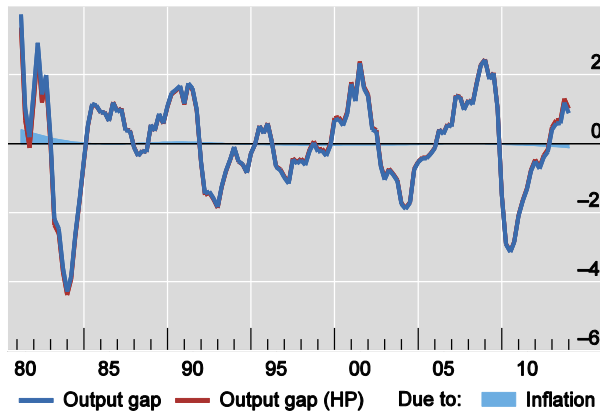
But appearances are highly misleading: it turns out that the Phillips curve in Model 1 is virtually irrelevant for the estimate of potential output. As shown in the top left panel of Graph 8, the output gap estimate is hardly distinguishable from the HP-filtered one and inflation only accounts for a tiny fraction of its variation. In other words, the value of $\lambda_3 = 0.43$ as determined freely by the data, in effect implies that the Phillips curve has little weight. Conversely, the bulk of the variation in inflation is due to the residual term in the regression, with the output gap accounting for at most 2 percentage points of this variation at any given time (upper right panel of Graph 8).

Output gaps conditioned on a Phillips curve

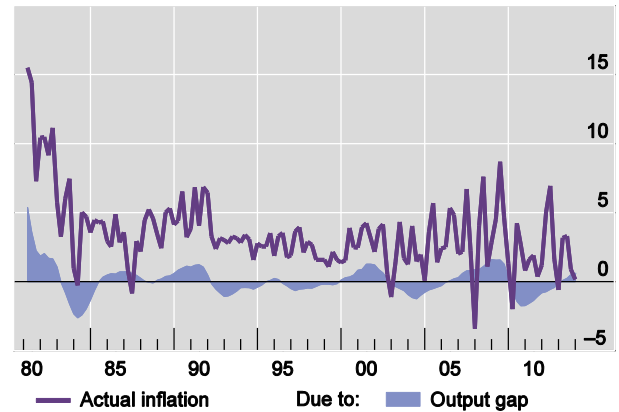
In per cent

Graph 8

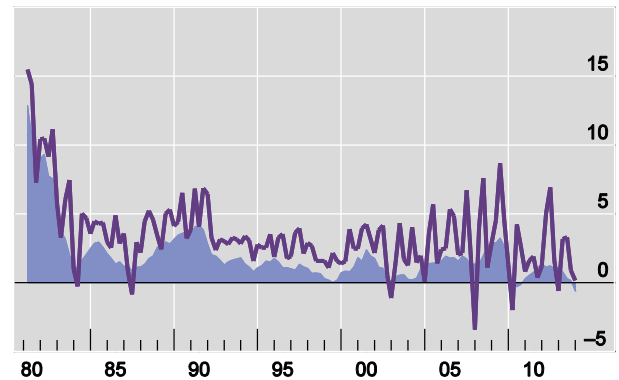
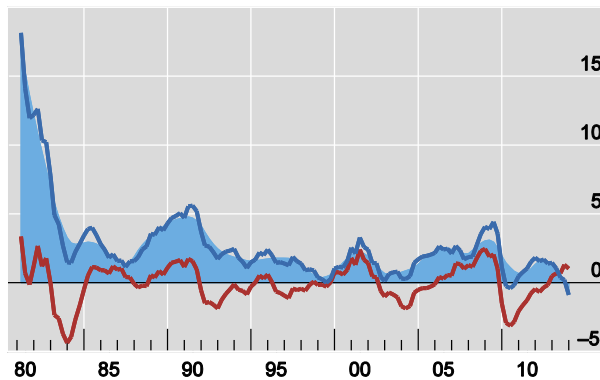
Contribution of inflation to the output gap



Contribution of the output gap to inflation



Model 2



Source: Authors' calculations.

Forcing the weight of the Phillips curve to be higher, rather than estimating it freely, produces the opposite problem. Now the relationship matters, but the output gap does not look economically plausible. Specifically, in Model 2 we set λ_3 equal to 100, compared with its freely estimated value of 0.43. This naturally forces the estimated output gap to mimic inflation increasingly closely. The coefficient estimates in Table 2 confirm the close correspondence between the output gap and inflation. In particular, the auto-regressive coefficient for inflation, γ_1 , is now statistically insignificant, while the coefficient for the output gap, γ_2 , is strongly significant. Inflation also accounts for a substantial fraction of the estimated output gap and vice versa (second row panels in Graph 8). But this occurs at the expense of the output gap inheriting the downward trend in inflation. Such trending output gaps are hard to reconcile with prevailing conceptual notions of potential output.

There is thus something akin to a “catch-22” dilemma. If one adopts specifications that ultimately assigns a sufficiently high weight to the Phillips curve, the trend in inflation will infect the output gap estimate resulting in a measure that does not look economically plausible. Alternatively, if the specifications adopted deliver intuitively sensible output gaps, the Phillips curve will be largely irrelevant as a conditioning relationship. The exact outcome depends quite sensitively on the specification assumptions adopted and the data cannot help the researcher to discriminate easily between these.

The bottom line here is that inflation is not a very informative variable with which to anchor estimate of potential output to. Not only does it perform poorly in our setup, but also in more conventional ones. In the latter case, the limited value added of inflation may be masked by the complexity of the underlying approach that makes it hard to link final outcomes to the myriad of specification assumptions adopted. As discussed in Borio et al (2013), this constitutes a key limitation of conventional methods that incorporate many structural relationships in output gap estimates. This, in turn, requires many auxiliary assumptions that interact in complex and unpredictable ways. By contrast, the approach we adopt in this paper to construct our finance-neutral output gap keeps the dimensionality of the system small, limiting the number of specification assumptions needed. It is therefore simpler, relatively robust to misspecification, and more transparent in the sense that the contribution of each conditioning variable is easier to evaluate.

Conclusion

The critical role that financial developments have on economic fluctuations has long been recognized. Yet prevailing measures of the economic cycle do not exploit these inter-linkages. We have shown that financial factors 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. Our contribution here is to construct a “finance-neutral” output gap measure that draws on the information content of credit and property prices. Indeed, not only do these variables turn out to have useful information about cyclical output variations, they are also much more informative compared to inflation in this respect.

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 dynamic 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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