Working Paper Series
Department of Economics
University of Verona

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WP Number: 20 December 2014

ISSN: 2036-2919 (paper), 2036-4679 (online)

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December 15, 2014

Abstract

This paper analyzes and extends the original study by Borio (2013), which includes proxies for the financial cycle in the process for estimating potential output. We extend the estimation to more countries (USA, UK, Spain, Italy, France, Austria, Netherlands and Switzerland) to check the robustness of the original method, and propose short-term debt as a new proxy for liquidity. We confirm that "finance neutral" measures of potential output are more reliable even though the original proxies are not particularly robust across countries, and that including liquidity information in the estimation process (whose analysis is conducted for United States, Australia and Canada) leads to better estimates, that are significant in all of the countries we analyze.

JEL Classification: C11, C32, E61

Keywords: Potential output, output gap, financial cycle, liquidity, monetary policy, fiscal policy.

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Contents

1 Introduction

The output gap is a fundamental concept in modern macroeconomics. Its relation with inflation is embedded in one of the three equations of the so-called "New Consensus Macroeconomics," while governments and Central Banks make many policy decisions based on the deviations of actual output from its potential. While in the long run a faster growth of potential output corresponds to a growing path of actual output, in the short run policy makers have to analyze whether the output gap is due to desired responses of the economy to shocks, or to undesirable deviations from the optimal path. The issue of how to measure and estimate the output gap is therefore of primary importance.

Despite having a relatively simple definition (the gap is the difference between actual and potential output), there are many difficulties that impede its estimation: first and foremost, potential output is not observable, not even ex post.

The debate on how to calculate it regards both the statistical and the conceptual level: from the one side researchers debate on which is the best way to estimate potential, from the other some argue that more information should be included in the estimation process.

In this work, we first describe the main issues in the estimation process, and then - taking Borio et al. (2013) as a reference - study how to further improve the output gap estimation methods.

2 The Crisis of the Phillips Curve and the Financial Cycle

The output gap appears to be a simple concept: it is the difference between actual and potential output. It assumes positive values when periods of strong demand drag the rate of utilization of capacity up, and falls below zero when demand decreases below the level which could be potentially achieved with the existing production capacity.

Calculating potential growth is a primary issue for policy makers: they make policy decisions based on these estimates. Estimates of the output gap are used for macroeconomic forecasts, provide a reference to analyze inflationary pressures (which are linked to a positive value of output gap), and form an indicator to locate the economy in the business cycle.

The New Keynesian Phillips Curve describes inflation as a function of output gap.[1] The strength of this key macroeconomic relation seems to have weakened over time: for instance, during the economic boom which preceded the 2008 crisis, output was running fast but inflation pressures were not as strong as economic theory would suggest. During and after the downturn recessions did not correspond to downward pressures on prices (or at least their magnitude was lower than expected), and inflation remained stable even though unemployment increased significantly during the crisis.

Tthe 2013 IMF World Economic Outlook (IMF, April 2013) analyzed the reasons why inflation did not fall more: the recent rise in unemployment was largely structural, inflation has been less volatile and responsive to economic fluctuations (while inflation expectations are having a much more important role) and the credibility of central banks inflation targets has risen. For all of these reasons, the downward pressure on prices and wages has been limited.

Is the Phillips Curve in crisis? The econometric analysis conducted in the World Economic Outlook confirms the view of Montoya and Dohring (2011), underlining how the impact of the output gap on inflation has lowered over time, causing the Phillips Curve to flatten. Consequently, the response of inflation to economic fluctuations is smaller. This relatively new phenomenon seem to imply that the relation between output gap and inflation is now much lower than it used to be.

[1] And expected future inflation.

Another concept that should be taken into account when estimating potential output is that of financial cycles. Recent works at the Bank for International Settlements (BIS) make some first steps in this direction, mainly by including in the estimation process some proxies for the cycle. The justification for such a procedure is quite straightforward: it is hard to doubt that financial variables such as credit and property prices carry useful information about the potential output a country could reach; one of the main lessons that the recent crises has taught us is that inflation can remain stable even for a prolonged period of time, while financial variables mask underlying imbalances that keep output on an unsustainable path.

However, in the setup we present it is the model itself to suggest which variables are significant and which are not.

But what is - in detail - the financial cycle? According to Borio,

[It] denotes a sequence of self-reinforcing interactions between perceptions of value and risk, attitudes toward risks and financing constraints, which translate into booms followed by busts. (Borio et al., 2009).

A first feature of the financial cycle is that it seems to follow the cyclical increases and decreases of key variables such as credit and property prices, and is characterized by a much lower frequency relative to the more usual "business cycle": 15-20 years compared to - generally - 2 to 8 years.

A second characteristic is that peaks in the financial cycle tend to coincide with crises in the banking sector, and with periods of considerable financial distress.

Moreover, since the proxies used to characterize the financial cycle tend to be highly correlated across different markets, cycles are often synchronized across countries, even though recent BIS data show otherwise (BIS (2014)).

Finally, it seems to be strongly shaped by the macroeconomic framework and policy decisions: both its length and amplitude increased since the beginning of the financial liberalization of the early 1980s (Borio and Drehmann (2009), Borio and Tsatsaronis (2012) and BIS (2014)).

In this context, we claim that wider methods for estimating the output gap are needed, since computing it as the non-inflationary level of actual output is too narrow a view.

As we assert in the previous section, the discussion regarding this concept regards both the theoretical and the methodological level. We analyze these two topics separately.

2.1 Conceptual Issues

As of today, researchers still debate about the concept of potential output. First and foremost, there is not a clear and widely accepted definition of it: in a too narrow perspective, some refer to it as the highest level of GDP not causing inflationary pressures (non-inflationary output gap). Following a similar definition, some international institutions define it as that level of output corresponding to the NAIRU (Non-accelerating inflation rate of unemployment); another concept is that of sustainability, referring to the level of output sustainable by the economic structure. However, being estimated using economic modeling theory, this view is clearly too model-dependent. In any case, there is no agreement nor a precise and shared definition of potential output.

Second, its estimation presents different problems, and researchers do not agree on how to measure it. Not even the IMF or the ECB have an "official" method to compute it. Its estimation is usually computed by smoothing out business cycle fluctuations by measuring the trend component in the actual GDP series. However, even if there exist reliable statistical tools to isolate the cycle, estimating potential output in real-time gives poor results, since the trend can be estimated only relying on past data.

Clearly, neither rough information about real-time potential output nor precise information about past estimates are useful, so researchers debate on how to increase the accuracy of real-time measurements.

A particularly serious issue is that of ex post revisions of the estimtes, which can lead to completely different results:

According to the European Central Bank,

The [ex post] downward revision in the real GDP outlook for the period 2009-2010 [...] is so sizeable that not only are current and future rates of growth of potential output dragged down by a significant amount, but historical growth as well (ECB, 2009).

These revisions clearly had some policy implications. Once revised downward after the 2008 economic crisis, potential output significantly dragged down the level of output gap, thus lowering the expected downward pressures on prices.

Potential GDP is strongly data-dependent, and very sensitive to the inclusion of new data. There is little doubt that in the years before the recent crisis many economies were running above potential (US surely was, after ex-post potential output revisions, Gavin, 2012), but the level of inflation remained low for a prolonged period of time (which is also one of the reasons why the non-inflationary view of potential output is addressed as too narrow). When dealing with such an imprecise and not robust estimate there seems to be an underlying problem, either in the statistical method used or in the validity of the relation estimated. The conceptual relationship between potential output and inflation implied by the Phillips curve is strong, despite the recent flattening.[2] So if the estimates of potential output are as we argued (ECB, 2009), then the problem must be in the method used to measure it.

2.2 Methodological Issues

Even though in the last few years the research on the estimation methodologies has partly moved from the academic community to international institutions, there is still not a widely accepted way of calculating potential GDP.

As Borio (2013) suggests, researchers in the literature adopt two different approaches to estimate potential GDP: on the one hand there are univariate statistical approaches, which usually consist of filtering out the trend component from the cyclical one; on the other there are the structural approaches, which derive the estimates directly from the theoretical structure of a model.[3] The most widely used univariate statistical approach is the H-P filter (Hodrick Prescott, 1997). This method estimates an unobserved variable and consists of solving a simple minimization of an objective function of the form

$$Min \sum_{t=1}^{T} (y_t - y_t^*)^2 + \lambda \sum_{t=2}^{T-1} [(y_{t+1}^* - y_t^*) - (y_t^* - y_{t-1}^2)]^2 \tag{2}$$

Implying a trade-off between goodness of fit to the actual series (first term) and degree of smoothness of the trend series (second term).

The Beveridge-Nelson decomposition - another univariate statistical method - extracts cycle and trend from a series by imposing restrictions: cycle and trend are assumed to be negatively correlated, and trend is assumed to follow a random walk path.

The Baxter-King filter, in order to isolate the business cycle removes from the data both low and high frequencies: it filters out irregular high-frequency components and slow moving trend components.

Despite being simpler than structural approaches, these methods all suffer from the so called end-point problem: they are extremely sensitive to the addition of new data and to real-time data revisions.

[2]The higher output gap, the stronger inflationary pressure on prices, and vice-versa.

[3]We could also identify simple trend models, which assume the trend component to follow a particular function of time, for instance linear in logs as

$$ln(Y_t) = \alpha + \beta t + \epsilon_t \tag{1}$$

Another issue is that of imprecise data collection and measurement errors: these problems have been pointed out by Athanasios Orphanides (2003), who – through counterfactual analyses with revised data of US output – argued that one of the reasons for the unsatisfactory policy responses to rising inflation was the wrong real-time calculation of the output gap.

The alternative to univariate statistical methods are structural approaches, which are based on the implications and restrictions of the models built; these measures do not suffer from the end -point problem, but vary greatly across models.

It is also common to find hybrid approaches, mixing the two perspectives together. For example the OECD uses a method which stands somewhere in between a univariate approach (mainly the H-P Filter) and a model-built measure (relying on some economic relations to calculate – for example – the NAIRU[4]) to calculate trend participation rates, trend hours worked and trend total factor productivity (Cotis et al., 2004).[5][6]

Around ten years ago the European Union changed its method of computing potential output to one very close to the OECD's (Denis et al., 2002) using a Cobb-Douglas production function with an exogenous trend.

The International Monetary Fund does not have an official method for computing potential output, and every country desk decides which measure fits best. The most common IMF approach uses a production function approach, with assumptions that vary greatly across countries, but discretion is left to the country desks which can decide otherwise[7].

The different approaches of supra-national institutions can be very different, but generally share a common basis: the concept of a "macroeconomic production function", which splits the contributions to potential output between changes in the use of the key inputs of capital and labor in the economy, and changes in their productivity – what is usually called Total Factor Productivity (TFP). This last measure is a good indicator of technological progress and innovation of the economy.

2.3 Potential Output Estimates during the Crisis

While the global economy tries to recover from the economic crisis, researchers want to measure the extent to which potential output has been affected by

[4]Non-Accelerating Inflation Rate of Unemployment, referring to some sort of modernization of the concept of Natural Level of Unemployment, the level of unemployment below which inflations pressures arise.

[5]This method, however, is highly correlated to an output gap estimated by using the H -P filter (correlation close to 0.9 for all the G7 countries, apart from Germany for which it is 0.4.

[6]This method is explained precisely in Giorno et al., 1995.

[7]For instance among the methods chosen for the United States we find the HP filter, the split time trend, the band pass filter.

the prolonged recession. The recent downturn has affected the potential of many different countries, dragged down by the deep and long recession. Not surprisingly, the estimates of potential growth for the next few years by the IMF, European Commission and OECD have been revised down significantly. The crisis has hit the potential of the economies, and the potential growth estimates have fallen from 1.9% in the period 2000-2007 to 0.9% in 2008-2010 for the Euro area, and from 2.5% to 1.8% for United States (EU, 2011). The difference between the estimates of the various institutions has widened, as a consequence of the big uncertainty surrounding the "recovery."

There are many reasons why both the rate of growth of potential output and its absolute level might have fallen after the contraction in output due to the 2008 global crisis. One potential reason is the sharp decline in investment: it is quite normal for investment to contract in periods of recession, lowering the level of capital stock. As a consequence, the contribution of capital to growth falls, thus reducing the growth in the capacity of the economy. An important consequence of the decline in investment is that technological change and innovation slow down. This is particularly true when a crisis is global, and firms in countries experiencing a recession cannot benefit from the technological progress of other innovating countries.

In addition to the lower contributions of technology and capital to growth, the role of labor also has been reshaped: unemployment has risen, and hours worked have declined. If the prolonged recession results in structural changes in the labor market, then there might be consequences for the structural rates of employment and labor force participation. This is exactly what the ECB is forecasting: they expect the NAIRU to grow because of the decline in both hours worked and market participation rates. However, since the current level of unemployment is still far above the "natural" level, there is still a notable gap between potential and actual labor input.

In a long-term perspective, potential output might be lowered persistently by a prolonged crisis. The excess capacity which accumulated during the crisis will inevitably adjust and reshape the size of those sectors which grew disproportionally during the boom (think of the financial or construction sectors during the 2008 downturn). However, the long term effects strongly depend on the policy responses of the affected countries, contributing to increase the level of uncertainty of the trend of potential output.

An interesting work on the effects of recessions on potential output is that of Haltmaier (2012). The author – after estimating potential output growth using the HP filter – compares the period of recession with the ones immediately before and after it. The estimates suggest that the Great Recession has caused a 3% decline on trend output growth in advanced economies, but had little effects on the economies of developing countries. According to the author, industrialized economies suffer for the depth of recessions but not for its length, while the opposite is true for emerging markets.

3 A New Way of Thinking Potential Output

If one analyzes how many factors and determinants contribute to build the potential output of an economy, it appears that the statistical measures developed up to now (and in particular the univariate ones) are too simplistic and unsatisfactory.

The evolution of output gap depends directly on supply conditions: in the short run potential fluctuates because of variations of the endowment of the economy, the key inputs of capital and labor, and of their productivity and degree of utilization. These factors are, in turn, directly linked to labor market trends, technology innovation, and variations in the degree of investment. In the long run, the capacity of an economy is shaped by its legal, institutional, and economic framework: not only its set of laws, its tax system, its market regulations, the stability of its monetary system and the efficiency of its responses, but also the quality of its educational system, demographic factors, financial market trends and many other features. Thus, in the long run potential output depends on the level of development of the country.

In the most simplistic way, potential and actual output differ when potential and actual production differ. In the literature, the benchmark for the sustainability of the path of output is inflation; however, this view is too narrow since inflation can remain low for a prolonged period of time, even though output is following an unsustainable growth path (as the recent economic crisis has shown).

Output gap is not measureable directly, and the contribution of all these factors cannot be quantified with certainty. Moreover, potential output depends on a large number of different factors, which contribute in different directions and with different magnitudes to modify its path. The reasoning that wider ideas of potential output and output gap are desirable, especially those embedding information about the financial cycle, is thus straightforward.

In a recent paper, Borio et al. (2013) developed an innovative way to embed more information in the estimation process for potential output. We quickly summarize their methodology:

They start with a state space model of the form:

$$\Delta y_t^* = \Delta y_{t-1}^* + \epsilon_{0,t} \tag{3}$$

$$y_t = y_t^* + \epsilon_{1,t} \quad (4)$$

In this simple representation, which specifies output gap for the standard HP filter, the difference between actual and potential output is just a normally distributed error term.

The basic model can be rewritten in companion form as:

$$\begin{pmatrix} y_t^* \\ y_{t-1}^* \end{pmatrix} = \begin{pmatrix} 2 & -1 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} y_{t-1}^* \\ y_{t-2}^* \end{pmatrix} + \begin{pmatrix} \epsilon_{0,t} \\ 0 \end{pmatrix} \quad (5)$$

$$y_t = \begin{pmatrix} 1 & 0 \end{pmatrix} \begin{pmatrix} y_t^* \\ y_{t-1}^* \end{pmatrix} + \epsilon_{1,t} \quad (6)$$

Where

$$Q = E\left[\begin{pmatrix} \epsilon_{0,t} \\ 0 \end{pmatrix} \begin{pmatrix} \epsilon_{0,t} & 0 \end{pmatrix} \right] = \begin{pmatrix} \sigma_0^2 & 0 \\ 0 & 0 \end{pmatrix} \quad (7)$$

$$R = E\left[\epsilon_{1,t}\epsilon_{1,t}\right] = \sigma_1^2 \quad (8)$$

where $y_t = ln(Y_t)$ is the natural logarithm of real GDP, and $\epsilon_{0,t}$ and $\epsilon_{1,t}$ are assumed to be two normally and independently distributed error terms with mean zero and unknown variances σ_0^2 and σ_1^2 , respectively. The ratio between the variances of the error terms in the state and measurement equation is nothing but the lambda term of the HP filter (the so called noise-to-signal-ratio) $\lambda = \sigma_1^2/\sigma_0^2$, which is set to 1600, as usual for quarterly data.

The idea of Borio, Disyatat and Juselius to enrich this estimate, is to apply the Hodrick-Prescott filter by means of a Kalman filter, including in the model some proxies for the financial cycle.

In order to include information about the financial cycle in the estimates of the output gap, the authors augment equation (4) with a vector including additional variables:

$$y_t = y_t^* + \gamma^{'} x_t + \epsilon_{2,t} \quad (9)$$

Where x_t is the vector containing these additional variables: lags of the output gap itself, indicators of house prices, interest rates, credit, while $\epsilon_{2,t}$ is a normally and independently distributed error term with mean zero and unknown variance σ_2^2.

Now, using an extended version of the measurement equation (9), in order to keep the same duration of the business cycle as the standard HP filter the authors use the state equation (3), and set the new noise-to-signal ratio $\lambda_2 =$

σ_2^2/σ_0^2 such that:

$$\frac{Var(y_t - y^*_{(2),t})}{Var(\Delta^2 y_{(2),t})} = \frac{Var(y_t - y^*_{(3),t})}{Var(\Delta^2 y_{(3),t})} \tag{10}$$

Where $y_{(2),t}$ and $y_{(3),t}$ are the output gap series obtained from the measurement equations (4) and (9), respectively.

The authors consider many different specifications of (9), including different variables in the vector x_t. In its final version, the measurement equation has the form:

$$y_t - y^*_t = \beta(y_{t-1} - y^*_{t-1}) + \gamma_1 r_{t-k_r} + \gamma_2 \Delta cr_{t-kcr} + \gamma_3 \Delta ph_{t-kph} + \epsilon_{3,t} \tag{11}$$

Where $r_t = i_t - \Delta p_t$ is the ex post real interest rate, Δp_t is the first difference of the natural logarithm of the consumer price index, Δcr_t is the percent growth of real credit to the non-financial private sector, Δph_t is the percent growth of the real residential property price index, and $(y_{t-1} - y^*_{t-1})$ is an autoregressive component for output gap.

Each of these variables enters only once in (11) with a lag k_j, with $j = 0, 1, 2, 3, 4$ chosen to maximize the statistical fit. To clarify this point, the authors try one by one the first four lags of each variable, and choose to include in the final expression of the equation only the one which fits best [8].

In order to estimate equation (11), Borio et al. adopt a Bayesian approach. The procedure employed is two-fold: first the unknown variances σ_0^2 and σ_3^2 are estimated via maximum likelihood; second, the Kalman filter is used in order to obtain the smoothed values of the unknown series y^*_t, using the maximum likelihood estimates of the variances $\hat{\sigma}_0^2$ and $\hat{\sigma}_3^2$. There is of course a loss of information here: by considering the sigmas as known values you do not consider, for instance, the variability of the estimates.

The authors, without any clear justification, assume the priors for all parameters to be gamma distributions with standard deviation equal to 0.2. They then also force β to lie between 0 and 0.95, with a prior mean of 0.80, while γ_i with $i = 1, 2, 3$ are restricted to lie between 0 and 1, with a prior mean equal to 0.2.

They consider four different specifications of the "simple" model; the first four are represented in Table (1): a simple autoregressive one considering only potential output at the previous period, one considering the autoregressive component and interest rate, one including the autoregressive component and credit, and one including the autoregressive component and property price.

[8] For instance for the case of United States real interest rate is taken at the second lag, real credit with no lag and house price at the fourth lag: the ones that maximize the statistical fit.

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	0.82	0.91	0.95	0.95	0.94	0.88	0.95	0.95	0.90	0.95
	(-)	(14.33)	(14.74)	(17.0)	(-)	(-)	(15.96)	(12.89)	(-)	(-)	(14.57)	(14.35)
r	-	-0.08	-	-	-	-0.02	-	-	-	-0.03	-	-
		(3.79)				(-0.85)				(-1.85)		
Δ cr	-	-	0.58	-	-	-	0.10	-	-	-	0.15	-
			(6.30)				(3.73)				(2.99)	
Δph	-	-	-	0.17	-	-	-	0.11	-	-	-	0.07
				(5.48)				(4.15)				(2.87)
kr	-	-2	-	-	-	-1	-	-	-	0	-	-
kcr	-	-	0	-	-	-	0	-	-	-	-2	-
kph	-	-	-	-4	-	-	-	-2	-	-	-	-3

Looking at Table (1), the introductory results confirm that the proxies for the financial cycle are significant and contain important information about the business cycle. In particular, the coefficients on credit growth and property price are strongly significant in all the nations examined. Real interest rate is significant only in the case of United States, while the autoregressive component of the output gap is always highly significant. This result strongly contradicts that of equation (4), which represents the static HP filter, where output gap was simply represented by the error term.

The authors then turn to a more general analysis, where all the variables are included simultaneously in the model (but still only at the lag which maximizes the statistical fit), and non-linear relations are allowed.

Once again, the autoregressive output gap component is highly significant for all specifications and countries, while the interest rate is never significant: this finding confirms the results of the basic model. Both changes in property prices and credit growth are significant in the general model, sustaining the hypothesis of the authors that proxies for the financial cycle carry information about the cycle.

Interestingly, the new estimates show much larger deviations of output from sustainable levels during the early 2000s, the period before the economic crisis. Since that was a time of increasing private sector leverage, the authors draw the implicit conclusion that their new estimation method performed better during the last decade. Even though the causal relationship might be called into question, estimates considering a wider concept of output gap are more precise and perform better than simple univariate statistical methods.

Table 2: Regression results: full specifications

	United States			United Kingdom			Spain		
Model	1	2	3	1	2	3	1	2	3
β	0.81	0.80	0.81	0.88	0.87	0.88	0.90	0.89	0.84
	(14.13)	(14.30)	(15.62)	(14.03)	(14.70)	(15.28)	(10.88)	(15.00)	(15.47)
r	-0.04	-	-	-0.03	-	-	-0.03	-	-
	(5.06)			(-1.20)			(-1.85)		
Δcr	0.51	0.52	0.62	0.09	0.09	0.12	0.12	0.13	0.54
	(5.06)	(5.56)	(5.59)	(3.54)	(3.81)	(3.79)	(2.25)	(2.91)	(4.85)
Δph	0.09	0.10	0.12	0.10	0.11	0.11	0.06	0.06	0.03
	(2.69)	(2.78)	(2.34)	(3.79)	(4.29)	(3.61)	(2.43)	(2.51)	(2.59)
kr	-2	-	-	-1	-	-	0	-	-
kcr	0	0	0	0	0	0	-2	-2	-2
kph	-4	-4	-4	-2	-2	-2	-3	-3	-3
τcr	-	-	0.044	-	-	0.024	-	-	0.017
τph	-	-	0.024	-	-	0.019	-	-	0.015
ρcr	-	-	9.85	-	-	18.50	-	-	31.90
ρph	-	-	17.60	-	-	28.35	-	-	42.35

The coefficients for real interest rates are significantly negative in all the countries examined. This result suggests that the higher the ex-post real interest rate, the lower the output gap will be. The coefficients for the autoregressive component, credit and house price index are instead positive. But more than signs and magnitudes of the coefficients, the key here is to underline that financial factors carry information to explain potential output, and that embedding such information leads to better estimates.

The new estimates are in fact more precise than the standard H-P filter ones (equation (4)): by comparing 95% confidence intervals for the output gap estimates, the authors find that the sizes of these intervals are significantly smaller with the new estimation method.[9]

The finance neutral estimates[10] are also less subject to ex-post revision: Borio's measure of output gap follows the ex-post gap much more precisely than other estimates which do not take into account financial factors. Moreover, the new estimation method produces a series which is remarkably more sensitive in detecting unsustainable booms like the one which preceded the 2008 global economic crisis.

The last four rows of the table represent non-linearities. Financial variables are weighted in equation (11) according to the size of the underlying imbalances (estimated relying on Borio and Drehmann (2009)).

The results for non-linearities are significant, but not as much as the authors

[9] More than halved for United States, form ± 3.50 to ± 1.35, and notably smaller both for Spain (from ± 3.85 to ± 2.10) and United Kingdom (from ± 2.95 to ± 1.80).

[10] Those in which proxies for the financial cycle are included.

expected. They do not have a strong impact on any of the countries analyzed.

3.1 Replication

In order to widen the analysis of Borio et al., which considered only three countries (United States, United Kingdom and Spain), we conduct the study for more nations to check the validity and robustness of their method. We also use a different dataset, containing longer time series.

We first replicate the analysis for the three countries considered in the original paper, finding similar results, and then consider more nations to check if their finding that including proxies for the financial cycle leads to better estimates applies more generally.[11]

Following the original methodology, we consider logarithmic first differences of real variables, assign the same gammas as prior distributions to the parameters, and solve the model. First we consider the "property price neutral" model, in which we include real property price in the estimation of potential output, then the "credit neutral" version of the model in which we include the logarithm of real credit to the private sector, and finally the "finance neutral" one, fully specified with both of the proxies for the financial cycle.

Our results show significant differences among countries. We confirm the results of the original paper for United States and Spain (even though we find that the statistical significance is somewhere maximized for different lags), while for United Kingdom we do not find any significance for real credit.

Apart from replicating the work for these three countries, we performed the same calculations for Italy, France, Netherlands, Austria, Switzerland, Canada and Australia. The single explanatory variable estimations are presented in Tables (3) and (4).

For the states where both the proxies are significant, we also perform the full-specification regression, reported in Table (6).
We confirm the results for the three countries initially considered by Borio et al., except for the case of United Kingdom, for which we do not find any statistical significance for credit.

This result is quite consistent across countries: the property price index is highly significant in almost all the countries analyzed (apart from the Netherlands), while real credit seems to have a more limited role.

In Italy only real property price is significant, and the same result arises for France, Australia, and Canada. The Netherlands represent an exception: real property price does not carry useful information, while credit is highly

[11] We replicate the original paper for Australia, Austria, Canada, France, Greece, Italy, Japan, Spain, Switzerland, United Kingdom and United States.

Table 3: Regression results: full specifications

	United States		United Kingdom		Spain	
Model	1	2	1	2	1	2
β	0.88	0.95	0.92	0.93	0.76	0.95
	(16.31)	(26.21)	(15.00)	(19.95)	(7.92)	(4.88)
Δ cr	0.32	-	0.04	-	0.14	-
	(3.69)		(0.90)		(4.40)	
Δph		0.22		0.14		0.11
		(4.50)		(4.60)		(2.42)
kcr	0	-	0	-	-4	-
kph	-	-3	-	-1	-	-1

Table 4: Regression results: individual explanatory variables

	UK		Spain		Italy		France	
Model	1	2	1	2	1	2	1	2
β	0.92	0.93	0.76	0.95	0.92	0.93	0.95	0.95
	(15.00)	(19.95)	(7.92)	(4.88)	(15.59)	(19.68)	(22.88)	(11.53)
Δ cr	0.04	-	0.14	-	0.01	-	0.01	-
	(0.90)		(4.40)		(0.35)		(0.32)	
Δph		0.14		0.11		0.30		0.06
		(4.60)		(2.42)		(4.96)		(2.21)
kcr	0	-	-4	-	-3	-	0	-
kph	-	-1	-	-1	-	-3	-	0

significant.

One notable fact is that property price is usually most significant in lagged value, probably reflecting the lag with which the housing market responds to economic shocks.

These results suggest that the financial cycle proxies do not carry the same information in all countries, so we cannot draw common or general conclusions. Credit and real property price surely ameliorate the estimation of potential output, but the source and magnitude of this improvement varies across countries and thus has to be analyzed case by case.

The fact that some of our estimates differ from those of Borio et al. might arise from the fact that we used longer time series (see Appendix B for a precise description of the data used),[12] but could also mean that the theory underlying the idea of the original paper is not very robust: in fact we do not find the

[12]Apart for United Kingdom for which we used shorter time series, and in fact the results we find differ with respect to the reference paper.

Table 5: Regression results: individual explanatory variables

	Austria		Netherlands		Switzerland	
Model	1	2	1	2	1	2
β	0.50	0.29	0.72	0.23	0.95	0.95
	(5.94)	(3.78)	(7.13)	(3.17)	(1.97)	(5.20)
Δ cr	0.26	-	0.42	-	0.05	-
	(8.73)		(10.09)		(2.47)	
Δph		0.50		0.08		0.07
		(5.03)		(0.66)		(2.07)
kcr	0	-	0	-	0	-
kph	-	-4	-	-2	-	-2

Table 6: Regression results: individual explanatory variables

	US	Spain	Switzerland	Austria
β	0.87	0.78	0.95	0.47
	(16.01)	(7.02)	(0.24)	(5.83)
Δ cr	0.21	0.14	0.05	0.23
	(2.54)	(4.49)	(2.64)	(8.02)
Δph	0.20	0.09	0.07	0.31
	(3.75)	(2.15)	(2.39)	(3.20)
kcr	0	-4	0	0
kph	-3	-1	-2	-4

same results regarding the lags,[13] and significance of the variables, and do not find any statistical significance in some of the countries analyzed (Australia, Canada, Greece and Japan).

4 Extension: Short-term Debt

Credit and property price are just two of the possible proxies that could be included in the estimation procedure. The preceding analysis raises the question of whether other variables might carry significant information in estimating potential output, and thus might be used in the model specified in the previous paragraphs.

One potentially interesting variable to introduce into the model is a measure

[13] Once again, every specification of the model considers for credit and property price only the lag – among the first four – which maximizes the statistical fit.

of liquidity. We strongly believe that liquidity plays a central role in informing about the health of the financial sector: it is important for analyzing both the level of systemic risk (aggregate measures of liquidity are helpful to detect systemic risks during a period of growth) and the financial situation of economic agents (from single agents to firms).

This concept becomes even more important when analyzing a period of financial crisis, since liquidity is a key response indicator: as Brunnermeier (2013) states, market participants have different reactions to shocks, depending on whether or not they face liquidity problems.

The aspect of liquidity we want to account for in the model is that of short-term debt (over GDP). The trend of the most liquid liabilities before a crisis – before a period of economic troubles when many assets will become illiquid – seems to be a good indicator of contingent underlying tensions of the economy. This does not necessarily imply a cause-effect relation, in the sense that growth in the amounts of short-term debt should increase the vulnerability of the economy, but instead implies that short-term debt is a good indicator of the imbalances in the economy which might then result in a financial crisis. In this sense, our view is not in contrast with Benmelech and Dvir (2010), which see short term debt as "reflecting, rather than causing distress in the banking sector," and is perfectly in line with Krishnamurthy and Vissing-Jorgensen (2012) when saying that short-term debt (in particular that issued by financial institutions) is a good predictor of financial crises.

Our final goal is to further filter out the financial cycle: according to the BIS, if policymakers make their decisions focusing only on the business cycle, some imbalances might arise, such as overindebtedness in the corporate or household sectors. Particularly in the private sector, high debt levels "can undermine sustainable economic growth" (BIS (2014)).

4.1 Liquidity estimates for United States

It was with surprise that we discovered an impressive lack of data on short-term debt. Our initial idea was to consider the amount of liabilities due within one year as a proxy for the financial cycle, and to analyze their contribution disaggregating data by sector of debt issuer. A sectorial analysis would in fact give a better understanding of the relationship between short-term debt and financial cycle. However, because of the lack of data on the proxy we have identified, our idea immediately revealed insurmountable limits: central banks hardly publish such data, and the available series for debt are not disaggregated, neither by maturity nor by sector.

The only country for which we have been able to retrieve a satisfactory se-

Table 7: Regression results: extension with short-term debt

	United States		
Model	1	2	3
β	0.78	0.81	0.82
	(12.73)	(15.33)	(15.30)
Δ nfstd	0.08	0.04	0.06
	(3.94)	(2.21)	(3.20)
Δ cr	-	0.23	-
		(3.14)	
Δ ph	-	-	0.22
			(4.29)
k nfstd	0	0	0
k cr	-	0	-
k ph	-	-	-3

ries of data (i.e. long enough to allow us to perform a complete analysis and diagnostic) is United States. We take short term debt of the nonfarm and non-financial corporate business as a proxy for the financial cycle, which we include in equation (9). The results of this specification of the model are reported in Table 7.

As in the previous paragraphs, we estimate the model successively including short-term debt at different lags. The coefficient of the proxy we include is positive and highly significant: it seems that United States debt due within one year is a valid proxy for the financial cycle, confirming our initial hypothesis. Moreover, the statistical fit is maximized in the model with the unlagged series for debt.

We also perform the regression of short term debt with credit and property price, the proxies we used in the previous analysis, and still find statistical significance. Estimating the model with the augmented specifications, we confirm all the results we obtained analyzing one variable at a time: all variables still have strong significance, and the statistical fit is maximized at the same lags of the case with the individual explanatory variables.

As we can see from figures (1) to (3), our measure of output gap estimates the economy to be over potential before the crisis, flattening then in proximity of the recession as if it was anticipating some sort of imbalance of the economy. The behavior is different with respect to the simple HP filtered series, whose estimate of potential output keeps on growing during the crisis. Another important feature of our estimation method is that it seems to be less subject

Figure 1: United States debt neutral output gap with confidence intervals

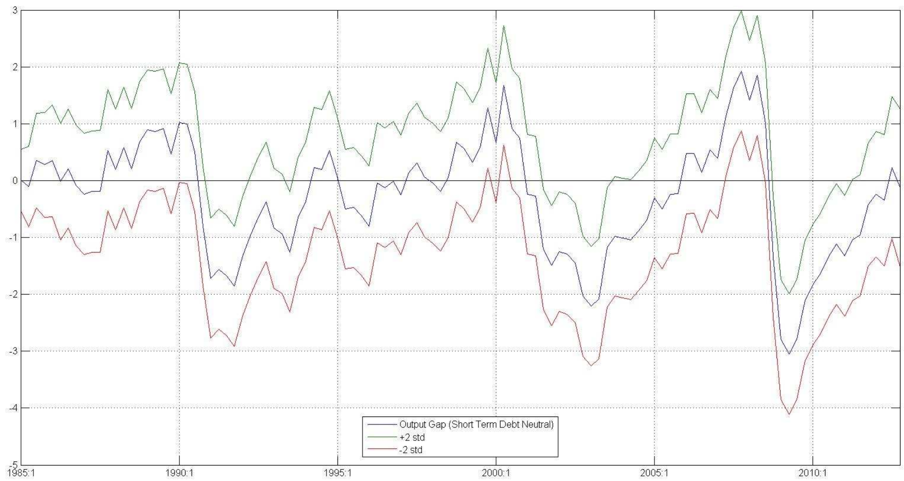
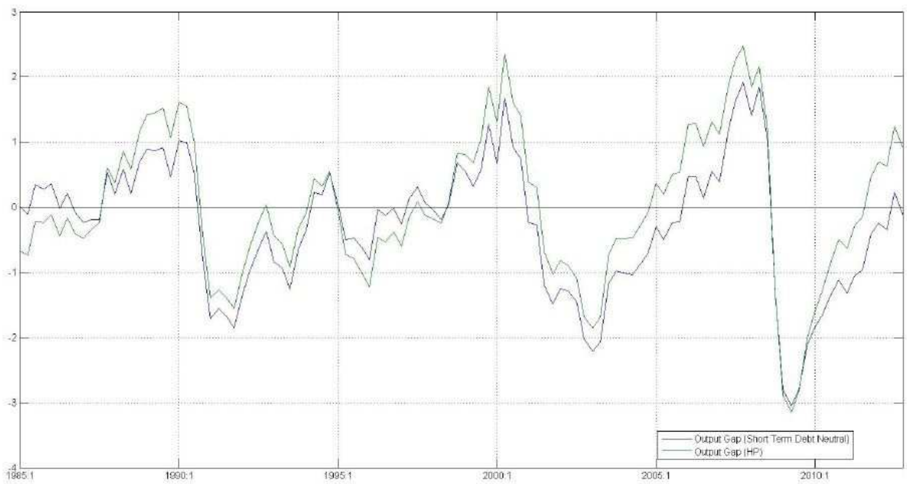
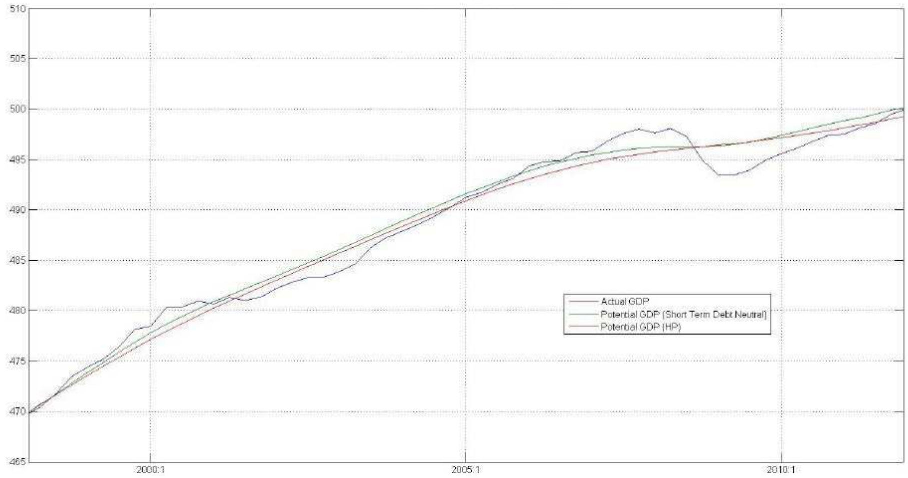


Figure 2: United States output gaps



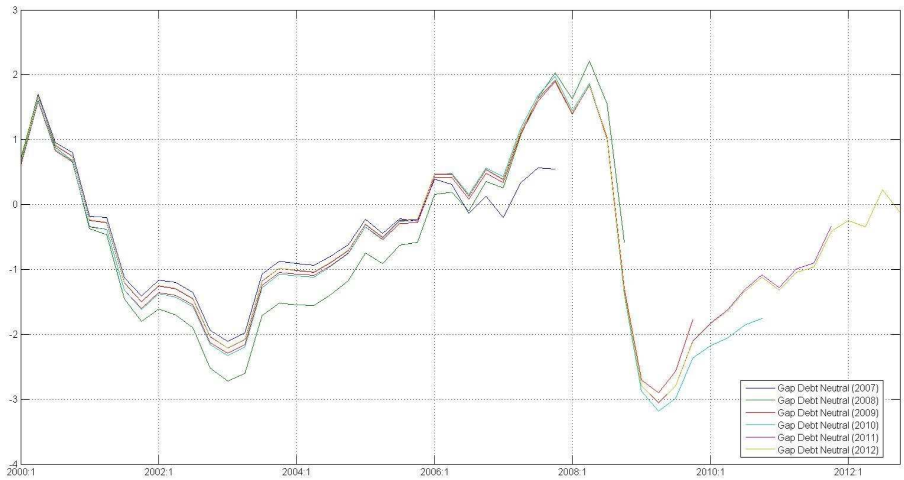
to ex-post revision, and to the addition of new data than simple filtering. Especially around the end of the sample, the "debt neutral" measure of output gap seems to perform better, when the sample is extended to include new data. Figures 6 and 7 show the differences in ex-post revisions between the simple

Figure 3: United States actual and potential outputs



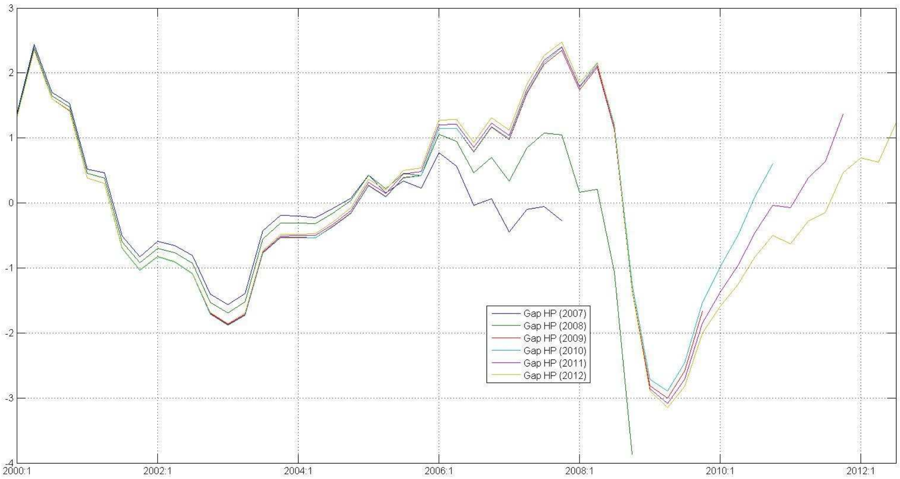
HP-filtered series and the debt neutral one.

Figure 4: United States debt neutral ex-post output gap



Note from the figures how in the case of the HP filtered output gap the ro-

Figure 5: United States HP filtered ex-post output gap



bustness of the estimates is much lower. Especially at the end of the sample, the extended model including short-term debt performs better and is subject to smaller revisions.

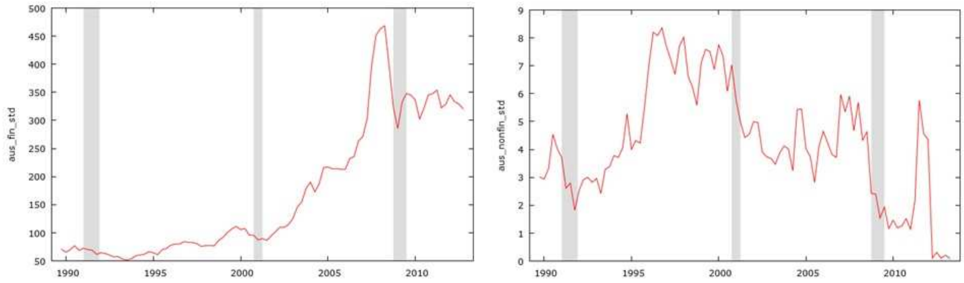
4.2 Analysis for other countries

Due to a lack of data we have been unable to construct satisfactory data series for short-term debt for many countries.

Apart from United States, for which government data are freely available, we use the BIS dataset on short-term amounts outstanding by sector. These series depict the path of those liabilities whose original maturity was within 12 months, and are disaggregated by sector according to three macro-categories: general government, financial and nonfinancial corporations. The main two problems with these series are the length (the longest ones start in the fourth quarter of 1989) and incompleteness (data for many developed countries are not collected, and for others the series is made of only a handful of observations). For these reasons we limit our analysis to the two countries for which data are satisfactory and permit at least a good preliminary analysis: Australia and Canada.

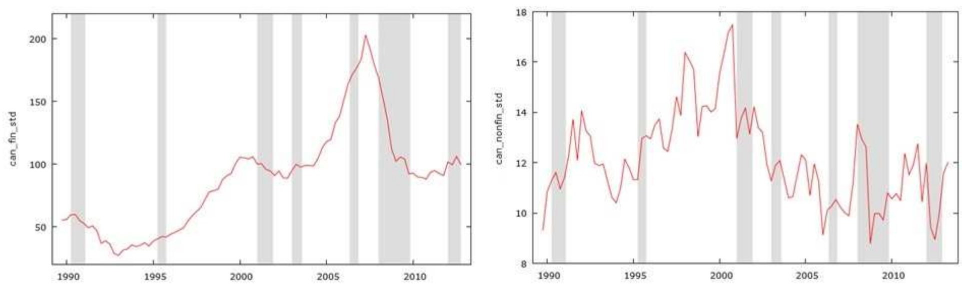
We start by drawing some quick stylized facts from the graphical representations of the BIS series, in order to justify our work (the graphs on the left represent short-term debt for the financial sector, while the ones on the right debt for the non-financial sector; grey bars represent recessions or periods of almost zero GDP growth).

Figure 6: Australia short-term debt for financial and non-financial sectors. Source: BIS



The graphs for Australia show three periods in which the economy has slowed down, and (especially for the non-financial sector) there has been a clear peak of debt before every GDP slowdown.

Figure 7: Canada short-term debt for financial and non-financial sectors. Source: BIS



Even in the case of Canada many quarters of GDP decrease have been preceded by a peak of short-term debt. In particular regarding the recent 2008 global crisis, the peak-drop pattern of debt in both financial and non-financial sector is evident. But despite being relatively smaller in absolute numbers, a similar pattern can be identified even in previous periods, especially for the financial sector (both in the early 1990s and in the early 2000s).

The case of Japan is interesting as well, but we analyze it only graphically

Figure 8: Japan short-term debt for financial and non-financial sectors. Source: BIS

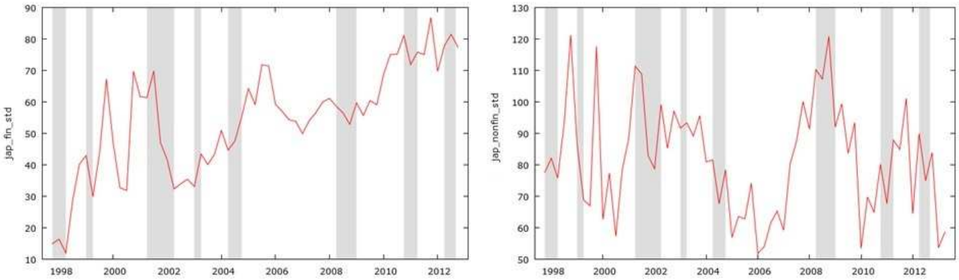


Table 8: Regression results: extension with short-term debt

	Australia		Canada	
Model	1	2	1	2
β	0.57	0.64	0.88	0.85
	(4.59)	(5.00)	(13.40)	(12.58)
Δ fstd	0.02	-	0.02	0.02
	(2.09)		(2.01)	(2.02)
Δ nfstd	-	0.004	-	
		(1.53)		
k fstd	2	-	2	3
k nfstd	-	0	-	-

since the series for short-term debt is too short: it consists only of a bunch of observations, and does not permit a satisfactory statistical analysis. The time series is missing almost the entire 1990s decade, a period which would be particularly interesting to analyze. In any case the data we have seem encouraging, even though these short series make it difficult to perform satisfactory estimates.

In any case, the peak-drop pattern is once again clearly evident.

Analyzing the case of Australia and Canada in Table (8), we can get a more general picture of the role that short-term debt plays in our output gap estimates.

For both of the countries we find slight significance of short-term debt of the financial sector. We instead find statistical significance for the nonfinancial sector only in the case of United States.

Recall that for both Canada and Australia we have not found any statistical significance for the financial cycle proxies (credit and property price), but the results for short term debt (of the financial sector) are encouraging, despite the slight significance.

These two countries represent a particularly interesting case, being advanced economies that were not particularly hit by the recent global economic downturn despite having had large financial booms in the late 2000s. This process of financial expansion has just slowed down because of the global crisis, and the fact that households continued to borrow (even though at a slower pace) together with the strong increases in commodity prices prevented a lasting turn of the cycle, causing real property prices to be back to the high (and possibly overrated) levels of the years of the boom.

As already pointed out, according to BIS data, countries are at very different stages of the financial cycle. This pattern is consistent with our findings that output gap measures must be personalized by country, and there is not a common and shared dogmatic measure that works for every nation. This is also indirectly in line with the approach of the IMF, where discretion is left at every country desk to choose the estimation method that fits best.

Even though liquidity conditions are often highly correlated across countries, the financial cycle seems to take a different shape in every country. And it is by filtering out the proxies identified (sometimes credit to GDP and property price, sometimes debt to GDP) that we make a first step in retreiving a reliable measure of "finance neutral" potential output.

The key statistical problem of these last estimates is the length of the BIS series used to compute them. Both Borio's work and our previous replications rely on quarterly data of at least 35 years, while the series available for short-term debt (apart for United States) date back to 1989q4 for Australia and Canada, and 1997q4 for Japan. Working with time series data, the span is far more important than the density of data, and we cannot say that our dataset is satisfactory from this point of view.

However, these preliminary results are encouraging, and we indeed find that short-term debt carries information regarding the financial cycle. Unfortunately, it is not easy to construct short-term debt time series for every nation: not all states collect quarterly data for short-term privately held liabilities. Moreover, even where available, these measures might be extremely heterogeneous among states, this complicating inter-state comparisons.

5 Conclusion

As we have seen, the concept of output gap has evolved much over time. The raw definitions of the 1960s have now developed into precise statistical measures, on which central banks and governments rely to take policy measures. However, we have argued that, despite being theoretically and statistically rigorous, today's measures to estimate potential output and output gap are not satisfactory, and wider estimation methods are needed.

On this behalf, we have started from the work of Borio et al. (2013), which includes proxies for the financial cycle to estimate potential output, analyzing and replicating their results in order to check the robustness of this innovative method. By replicating their analysis for more countries, we have found that financial information is important in explaining the potential of the economy, even though there is not a unique and precise rule to describe its role across countries.

All of our results (together with the most recent literature on the topic) suggest that the Phillips curve represents a less strong relation than it used to. As a consequence, if inflation has become less responsive to variations in output, and the Phillips Curve is in "crisis," then new methods to estimate the output gap are needed.

The new estimates presented in this paper suggest that "finance neutral" and "debt neutral" estimates perform better than traditional methods (H-P filter or production function approaches): including proxies for the financial cycle is a good way to improve the precision of the estimates of output gap.

We have also shown that credit and property price are not the only proxies for the financial cycle that perform well in this framework: even short-term debt carries statistical significance in estimating output gap via Borio's innovative method.

The bottom line is that even though the genereal estimation method is applicable to different countries, the result shaped by the data is diverse across nations. There is not a common and univocal measure that works for every country.

There are, however, many issues that are still open: despite showing strong statistical significance, the choice of the lags in the estimation procedure is quite arbitrary, and there is no justification apart from that of simply choosing the lag that maximizes the statistical fit. According to our computations, variables show statistical significance even at higher lags, in particular for housing prices (e.g. residential property price is highly significant for the US at lag 12, once again reflecting the lag with which the housing market responds to economic shocks).

Moreover, the estimates come from a simple state-space model, and not from a fully specified macroeconomic model, this preventing us from fully interpreting the result and conducting deeper analyses.

Further developments might also include testing for breaks and regime switches in the series and their eventual consequences on the estimates, the study of time-varying coefficients, and the development of a structural microfundeed model with financial frictions.

6 Appendix A: Variables specification

For sake of clarity, we specify *in extensor* all the variables and parameters included in the tables.

β is the coefficient for the AR component for output gap $(y_{t-1} - y^*_{t-1})$,

r represents the coefficient for the ex post real interest rate $r_t = i_t - \Delta p_t$,

Δp_t is the first difference of the natural logarithm of consumer price index,

Δcr_t is the % growth of the real credit to the non-financial private sector,

Δph_t is the percent growth of the residential property price index,

$\Delta nfstd_t$ is short-term debt of the non-financial sector,

$\Delta fstd_t$ is short-term debt of the financial sector,

k_r represents the lag considered for the ex post real interest rate,

$k_c r$ is the lag for credit to the non-financial private sector,

$k_p h$ represents the lag for the residential property price index,

$k_n fstd$ represents the lag for short-term debt of the non-financial sector,

$k_f std$ represents the lag for short-term debt of the financial sector,

ρ and τ represent the coefficients for non-linearity.

Moreover, since many variables show some cyclicality, the authors calculate their averages by Cesàro means: this is done by building a mean sequence in which the sample is successively increased by one observation. By doing so, the convergence is much faster and the pro-cyclicality in the mean-adjustment is reduced.

7 Appendix B: Data specification

The time series we have used were based on the following data:

GDP_t: seasonally adjusted nominal gross domestic product in own currency. Source: OECD Economic Outlook.

$PGDP_t$: GDP-deflator. Source: OECD, Main Economic Indicators.

RPP_t: Residential property price. Sources: Australian Bureau of Statistics for Australia, OECD data (Main Economic Indicators and Economic Outlook) for Austria, Netherlands, UK and Italy, Oxford Economics for the remaining countries.

CR_t: Credit to private non-financial sector. Source: BIS Data.

CPI_t: Consumer price index. Source: OECD, Main Economic Indicators.

STD_t: Short term debt. Sources: for United States Federal Reserve Short-term debt of Nonfarm Nonfinancial Corporate Business. For other nations BIS data.

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