EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Justine Guillochon, Julien Le Roux

Unobserved components model(s): output gaps and financial cycles

No 2832

Abstract

The Global Financial Crisis established that policymakers should consider the stage of the financial cycle to better evaluate the cyclical position of the economy when designing monetary policy decisions. If financial variables are omitted from the estimations of the output gap, a common and unobserved indicator of the business cycle, important financial or external imbalances that may lead to future recessions may not be captured. This paper presents a suite of estimates of output gaps incorporating financial variables. The estimates are based both on small unobserved components models and a large unobserved components model that follows a production function approach. The results show that exploiting the information content of financial variables, which co-move strongly with the output cycle, can sometimes improve output gap estimates. However, these improvements are of a limited magnitude and very sensitive to the choice of the chosen financial variables.

JEL Codes: C32, E32, E44, E47, E52

Keywords: Output gap, potential output, financial cycle, monetary policy, unobserved components model.

Non-technical summary

Following the Global Financial Crisis (GFC), the concept of Finance-Neutral Output Gaps (FNOG) has gained widespread attention among policymakers. Borio et al. (2013) presented this concept as a substitute to the conventional concept of inflation-neutral output gap given the possibility that the economy overheats even if price inflation is low, if financial or external imbalances are building up. Introducing financial variables into the output gap estimations may yield to complementary tools for policymakers to avoid diagnosis errors associated with financial booms.

The concept of potential growth and output gap is most often based on the absence of inflationary or disinflationary pressures. However, several factors can lead to a disconnect between price inflation and financial asset prices. Frequently, financial booms coincide with positive supply-side shocks, leading to a drop in prices (lowering inflation). Concurrently, upswings in financial markets lead to an increase in valuations of real assets that in turn reduce financing and supply constraints (collateral effect). Furthermore, buoyant financial markets may sometimes lead to an appreciation of the domestic currency, resulting in lower consumer prices through the import price channel. Finally, accommodative financing conditions may not only spur demand in the short run, but also have persistent effects on the supply side through labour, productivity, or capital accumulation (reverse hysteresis effect), weakening further supply constraints and prices.

The idea behind this paper is to construct output gaps and potential output measures for the euro area underpinned by both macroeconomic relationships and financial variables. For this, we follow two approaches. On the one hand, we include financial information in small Unobserved Components Models commonly used to assess FNOG. On the other hand, and this constitutes a novelty of this paper, we elaborate on a richer Unobserved Components Model embedding a production function, as in Tóth (2021) in which we include financial factors.

This exercise is challenging for at least four reasons. First, the resulting output gaps should track the current narrative on macroeconomic cycles and trends, especially the labour market trends as they are provided in the UCM. Second, we should improve (or at least not worsen) the real time performance of the model. Third, in a central banking context we would like to estimate output gaps with good forecasting ability. Finally, we have to select appropriate financial variables out of a large set of variables, stemming from different sources (national accounts, private providers, etc.).

1 Introduction and literature review

Financial conditions, potential output and output gap

Although the concept of potential output is pivotal in various economic policy areas (fiscal, monetary, financial stability or structural policies), no full consensus has emerged on its definition and on the most appropriate method for estimating it. While the concept of potential output does not admit a univocal definition, the one provided in the ECB Monthly Bulletin 2013[3] suggests that:

> *"...potential output may be taken as an indication of the level or rate of activity that could be achieved in the economy in the medium to long term. Indeed, it is often thought of as the level or rate of activity that can be sustained by means of the available factors of production without creating pressure on prices and the rate of inflation."*

However, this definition may be somewhat controversial, as only shocks, e.g., demand, supply, or financing and monetary conditions, that are considered persistent affect the medium-term growth rate of potential output. Additionally, this definition does not highlight sufficiently the important role of financial factors in the assessment of potential output, as well as the role of the financial system in shaping the business cycle. The aim of this paper is to overcome this shortcoming and build on the existing literature and tools to construct,for the euro area, alternative potential output and output gap measures accounting for financial variables.[4] Extracting the path of potential output and more broadly trends from observable variables is subject to various statistical and theoretical caveats and assumptions which deserve attention. These include, for instance, a targeted frequency band for cyclical fluctuations, the smoothness of the trend governing potential output and the co-movement between cyclical components of multiple observable variables. In addition, within our analysis, the choice of the financial variables is also critical.

Our work contributes to the literature that argues that incorporating information about the financial cycle may improve measures of potential output and output gaps, as these variables have the property to co-move strongly with the business cycle (see Borio et al. (2013)). Indeed, the available empirical evidence shows an increasing correlation of output, consumption, and

[3] See "Potential output, economic slack and the link to nominal", Monthly Economic Bulletin, ECB, November 2013 (ECB, 2013), or "The impact of COVID-19 on potential output in the euro area", Economic Bulletin, Issue 7, ECB, 2020, (Bodnár et al., 2020).

[4] As there is no unique approach to achieving this objective, our work is not meant to be exhaustive.

investment growth with credit over time (Òscar Jordà et al., 2017)). The period preceding the GFC showed that nominal variables could be less reliable indicators of overheating against the backdrop of buoyant housing and/or financial markets. The other way round, in the aftermath of financial crises, the sluggish recovery in demand related to the need to deleverage may be misinterpreted as a chronic demand deficiency (secular stagnation), leading to an underestimation of potential output (Rogoff, 2015)). In this context, another strand of the literature suggests augmenting the estimation of the output gap with other sources of imbalances - such as the current account deficit (Galstyan, 2019). However, this approach seems to be more relevant for emerging economies than for developed countries (Amador-Torres, 2016) and, consequently, we decided not to pursue this avenue in this paper.

Financial factors have long been considered as a driving force of business cycle fluctuations, at least since the seminal contribution of Fisher (1933). More recent general equilibrium approaches[5] also emphasize the role of financial frictions in output fluctuations. According to this strand of the literature, the financial system is not neutral with respect to the business cycle: it can either act as an amplifier of shocks or it can be the source of shocks that trigger business cycle fluctuations in the first place. Indeed, the balance sheet of households, firms and banks can give rise to various pro-cyclical mechanisms (such as the financial accelerator). For example, demand shocks can be amplified through corresponding changes in collateral values (such as residential or commercial property) and the real value of nominally fixed debt.

More specifically, a large strand of literature has also documented the predictive power of real M1 for real economic activity (see, for example, Musso (2019)). The leading and pro-cyclical properties of real M1 for real GDP remain a robust stylised fact in the euro area.[6] It is now well-established that not only short-term interest rates, but also monetary quantities capture the monetary policy stance. The theoretical arguments behind this procyclical pattern for real M1 are manifold and are related to different factors: the role of real balance effects (Pigou (1943), the preference for money holdings (Serletis (2007), the role of money as an indicator of relative prices of assets (Nelson (2003)).[7]

Our study also touches upon the discussion on the effects of monetary policy in stabilising the macroeconomic cycle, as well as its effects on potential output growth. By stabilising the business cycle, monetary policy is aimed at reducing support for demand and guarding against the risk of

[5]See Kiyotaki and Moore (1997), Gertler and Karadi (2011), Bernanke et al. (1999), Iacoviello (2005).
[6]The narrow monetary aggregate M1 covers the sum of currency in circulation and overnight deposits.
[7]Brand et al. (2003) provide a comprehensive literature review on the topic.

a persistent upward shift in inflation expectations, and in that respect is not assumed to affect potential output. This assessment mainly builds on the assumption that money is neutral in the long run, which means that changes in the money supply only affect nominal variables in the long run. A vast literature spanning decades has gradually built up this acceptance.[8] However, some recent endogenous growth models show that determinants of potential output may exhibit positive/negative hysteresis.[9]

In this perspective, the FNOG concept is appealing and has been tested on many countries, but not yet, to the best of our knowledge, on the euro area as a whole.[10] This paper fills this gap. Notwithstanding the usefulness of FNOG for policymakers, it is important to acknowledge the limits of these kind of measures - as it is the case of any unobservable variable such as potential output - from the start. Results from the literature usually show that FNOGs differ substantially from traditional gaps, especially around financial crises. This is also what our work will highlight. Katay et al. (2020) also show that FNOGs may be not robust to alternative assumptions for some countries in their sample.

Financial cycle, credit availability and total factor productivity

The main contributor to potential growth and to the output gap is Total Factor Productivity (TFP). It is therefore the obvious candidate to relate to financial variables in a multivariate filter, as proposed by Melolinna and Tóth (2019). This also has the advantage of improving the understanding of what is hidden behind TFP, which generally is merely a residual. One issue which remains unclear, however, is the causality between the credit/financing cycle and cyclical productivity. In particular: is cyclical productivity positive or not during a credit boom? Our results tend to answer positively. However, there is no clear consensus on these results.

Manaresi and Pierri (2018) provides a good review of the literature and interesting results on the link between the financial cycle and productivity. It also stresses the fact that there is not a consensus on the sign of the relationship between credit supply and productivity as several channels are at play (see also the discussion in ECB (2021)). The paper states that *"the sign of the causal relationship between the availability of external finance and productivity is theoretically and empirically ambiguous."*

[8] See for a literature review: King and Watson (1992)

[9] See: Jordà et al. (2021) and Elfsbacka Schmöller and Spitzer (2022)

[10] For Latin America, see: Amador-Torres (2016), for South Africa, see: Kemp (2015).

First, there is a strand of the literature that is aligned with our results and shows that an increase in credit availability (like in credit booms) leads to positive effects on total factor productivity including capital productivity. Credit availability may have positive effects on firm productivity, as it might support productivity-enhancing strategies, not only because it facilitates investment, but also because it fosters demand and the willingness of companies to invest. Firms experiencing tighter financing conditions may undertake less R&D investment due to the risk of liquidity (Aghion et al., 2010) and may also purchase fewer intangible assets as it is harder to use them as collateral (Garcia-Macia, 2017). Credit-constrained firms are likely to pursue fewer breakthrough innovations (Caggese, 2019), while Midrigan and Xu (2014) highlight the role of fixed costs.

Second, looking beyond the credit boom period, the results during the crisis suggest that capital productivity decreases. This is aligned with the work of Khwaja and Mian (2008), Chodorow-Reich (2013), and Amiti and Weinstein (2018) who exploit linkages between lenders and borrowers to provide evidence that negative shocks experienced by banks diminish credit supplied to borrowing firms and constrain those firms' investment and employment, regardless of whether the firms have access to the financial markets or only to bank financing. In addition, negative credit shocks are detrimental to small businesses by forcing managers/entrepreneurs to spend time building relationships with new lenders at the expense of enhancing productivity ("managerial inattention") (Manaresi and Pierri, 2018).

Third, one can argue that accommodative financing conditions may also permit lower-quality projects to be undertaken, with a risk of capital misallocation and negative effect on productivity. Even if misallocation of capital can negatively impact productivity, it might not cancel the positive effects described above when credit is becoming more available. Misallocation also takes place during periods of financial frictions and credit constraints (Midrigan and Xu, 2014), when we see a decrease in the capital productivity. During credit booms, misallocation of capital seems to be a phenomenon that is happening in countries with lower financial development (Gopinath et al., 2017). Our analysis focuses on the euro area, whose core countries have developed financial systems, so this could explain why other mechanisms pushing productivity up during credit booms have more weight.

The remainder of the paper is organised as follows. Section 2 presents the methodology and develops the different models that are used, namely a suite of small Unobserved Components Models (UCMs) following Borio et al. (2013) and a larger production-function UCM, as in Tóth

(2021). In Section 3, we construct a Financial Condition Index (FCI) for the euro area based on a dynamic factor model which aims to summarise information on financing conditions from a large set of financial indicators. Section 4 presents the results including a Phillips curve forecasting performance exercise and Section 5 concludes.

2 Methodology

2.1 A small Unobserved Components Model

In a first step, we use a small Unobserved Components Model (UCM), inspired from Melolinna and Tóth (2019) who also build on Borio et al. (2013) and Borio et al. (2014), where a set of key variables are decomposed into cyclical and trend components. The selected variables are real GDP (y_t), the unemployment rate (u_t) and a measure of core inflation (π_t).[11] In addition to these macroeconomic variables, a financial indicator (ϕ_t) is introduced, whose nature may change depending on the specification of the model (see Section 3). The measurement equations below specify how the four observable variables (identified on the left) are linked to their unobservable counterparts, where hats (∧) denote cyclical components, bars (−) denote trend components, and tildes (~) denote trend growth rates.

Measurement equations:

$$y_t = \widehat{y_t} + \overline{y_t}$$

$$u_t = \widehat{u_t} + \overline{u_t}$$

$$\pi_t = \widehat{\pi_t} + \overline{\pi_t}$$

$$\phi_t = \widehat{\phi_t} + \overline{\phi_t}$$

The processes that determine the evolution of the unobservable variables are specified by the transition equations that appear in the following blocks of state equations, and include an Okun's law and a price Phillips curve. Cyclical components are assumed to follow autoregressive structures. Trend output is assumed to be a random walk with drift, while the output gap depends directly on the financial cycle among other factors. In other words, fluctuations in the financial cycle affect the business cycle through changes in the output gap. In that respect,

[11] HICP excluding food and energy, which is seasonally adjusted.

we follow Borio et al. (2013) who use variables such as real credit growth in the estimation of potential output. However, we depart from their methodology, given that they exclude price Phillips curve equations from their framework.[12] The estimation is based on a Bayesian approach.[13]

Transition equations:

Output:

$$\widehat{y_t} = \alpha_1 \widehat{y_{t-1}} + \alpha_2 \widehat{y_{t-2}} + \alpha_3 \widehat{\phi_{t-1}} + \epsilon_t^{\widehat{y}}$$

$$\overline{y_t} = \overline{y_{t-1}} + \widetilde{y_{t-1}} + \epsilon_t^{\overline{y}}$$

$$\widetilde{y_t} = \widetilde{y_{t-1}} + \epsilon_t^{\widetilde{y}}$$

Unemployment rate:

$$\widehat{u_t} = \gamma_1 \widehat{y_{t-1}} + \gamma_2 \widehat{u_{t-1}} + \gamma_3 \widehat{u_{t-2}} + \epsilon_t^{\widehat{u}}$$

$$\overline{u_t} = \overline{u_{t-1}} + \epsilon_t^{\overline{u}}$$

Price Phillips curve:

$$\widehat{\pi_t} = \beta_1 \widehat{\pi_{t-1}} + \beta_2 \widehat{y_{t-1}} + \epsilon_t^{\widehat{\pi}}$$

$$\overline{\pi_t} = \overline{\pi_{t-1}} + \epsilon_t^{\overline{\pi}}$$

Financial variable:

$$\widehat{\phi_t} = \rho_1 \widehat{\phi_{t-1}} + \rho_2 \widehat{\phi_{t-2}} + \epsilon_t^{\widehat{\phi}}$$

2.2 A broader set-up of the Unobserved Components Model (UCM)

In this section, we build on Tóth (2021) who proposes to estimate the euro area output gap and potential output using an Unobserved Components Model (UCM). In a first step, we recall the main features of the UCM as developed by Tóth and in a second step we present the way chosen to incorporate financial variables into the UCM.

[12] Borio et al. (2013) use a simple HP-filter which is extended by embedding information representing the financial cycle. They reject the idea of introducing a Phillips curve in their set-up, given the constraints that it imposes to the output gap estimates.

[13] See Annex A for more details on the estimation.

2.2.1 Current set-up of the UCM -Tóth (2021)

The Unobserved Components Model relies on a common Cobb-Douglas production function and on a large set of equations (Okun's law, price and wage Phillips curves). In that respect, output can be expressed as follows:

$$Y_t = A_t L_t^{\theta} K_t^{1-\theta} \tag{1}$$

Where A_t, L_t, K_t and θ denote total factor productivity, labour, capital stock and labour share respectively. By taking the natural logarithm, the production function is linearized as follows:

$$y_t = a_t + \theta l_t + (1-\theta)k_t$$

which can be decomposed into:

$$\overline{y_t} + \widehat{y_t} = \overline{a_t} + \widehat{a_t} + \theta(\overline{l_t} + \widehat{l_t}) + (1-\theta)k_t$$

This leads to:

$$\widehat{a_t} = \widehat{y_t} + \theta\widehat{l_t}$$

$$\overline{a_t} = \overline{y_t} - \theta\overline{l_t} - (1-\theta)k_t$$

The model also assumes that labour (total hours worked) can be decomposed into working age population (wp_t), labour force participation rate (l_t), the unemployment rate (u_t) and hours worked (ah_t). Building on these assumptions, the model can be expressed as below:
Output:

$$y_t = \overline{y_t} + \widehat{y_t}$$

$$\widehat{y_t} = \alpha_1\widehat{y_{t-1}} + \alpha_2\widehat{y_{t-2}} + \epsilon_t^{\widehat{y}}$$

$$\overline{y_t} = \overline{y_{t-1}} + \iota\Delta l_t + (1-\iota)\Delta k_t + \widetilde{a_t}$$

$$\widetilde{a_t} = \widetilde{a_{t-1}} + \epsilon_t^{\widetilde{a}}$$

Average hours worked:

$$ah_t = \overline{ah_t} + \widehat{ah_t}$$

$$\widehat{ah_t} = \gamma_6\widehat{y_t} + \epsilon_t^{\widehat{ah}}$$

$$\overline{ah_t} = \overline{ah_{t-1}} + \widetilde{ah_t}$$

$$\widetilde{ah_t} = \widetilde{ah_{t-1}} + \epsilon_t^{\widetilde{ah}}$$

Working age population:

$$wp_t = \overline{wp_t}$$

$$\overline{wp_t} = \overline{wp_{t-1}} + \widetilde{wp_{t-1}}$$

$$\widetilde{wp_t} = \widetilde{wp_{t-1}} + \epsilon_t^{\widetilde{wp}}$$

Capital stock:

$$k_t = \overline{k_t}$$

$$\overline{k_t} = \overline{k_{t-1}} + \widetilde{k_{t-1}}$$

$$\widetilde{k_t} = \widetilde{k_{t-1}} + \epsilon_t^{\widetilde{k}}$$

Labour force participation rate:

$$lp_t = \overline{lp_t} + \widehat{lp_t}$$

$$\widehat{lp_t} = -\gamma_4 \widehat{u_{t-1}} + \epsilon_t^{\widehat{lp}}$$

$$\overline{lp_t} = \overline{lp_{t-1}} + \widetilde{lp_{t-1}}$$

$$\widetilde{lp_t} = \widetilde{lp_{t-1}} + \epsilon_t^{\widetilde{lp}}$$

Unemployment rate:

$$u_t = \overline{u_t} + \widehat{u_t}$$

$$\widehat{u_t} = \gamma_1 \widehat{u_{t-1}} - \gamma_2 \widehat{u_{t-2}} + \epsilon_t^{\widehat{u}}$$

$$\overline{u_t} = \overline{u_{t-1}} + \epsilon_t^{\overline{u}}$$

Price Phillips curve:

$$\pi_t = \overline{\pi_t} + \widehat{\pi_t}$$

$$\widehat{\pi_t} = \beta_1 \widehat{\pi_{t-1}} + \beta_2 \widehat{y_{t-1}} + \epsilon_t^{\widehat{\pi}}$$

$$\overline{\pi_t} = (1 - \mu)\pi^\star + \mu \pi_{t-1} + \epsilon_t^{\overline{\pi}}$$

Wage Phillips curve:

$$w_t = \overline{w_t} + \widehat{w}_t$$

$$\widehat{w}_t = \beta_3 \widehat{w_{t-1}} + \beta_4 \widehat{u_{t-1}} + \epsilon_t^{\widehat{w}}$$

$$\overline{w_t} = \overline{\pi_t} + \Delta \overline{y_t} - \Delta \overline{l_t} + \epsilon_t^{\overline{w}}$$

2.2.2 Financial-Augmented version of the Unobserved Components Model

The structure of the UCM is kept broadly unchanged, but is augmented with financial variables along the following lines: Following the aforementioned production function (1), we assume that the labour and capital productivities are different and then the production function can be rewritten as:

$$Y_t = (A_t^L L_t)^{\theta} (A_t^K K_t)^{1-\theta}$$

Given that capital is assumed not to have a cyclical component, this leads to:

$$\widehat{a_t} = \widehat{y_t} - \theta \widehat{l_t}$$

$$\widehat{a_t} = \theta \widehat{a_t}^L + (1-\theta) \widehat{a_t}^K$$

We, then, further add capacity utilization (κ_t) so that:

$$\widehat{a_t} = \theta \widehat{a_t}^L + (1-\theta) \widehat{a_t}^K + (1-\theta) \widehat{\kappa_t}$$

The output gap becomes a function of the labour market (participation, unemployment and average hours) and total factor productivity which is a function of capital productivity, labour productivity and capacity utilization. The rationale behind this equation is that the traditional production function can also be rearranged in a form where the stock of capital and labour are corrected for: i) the production capacity utilised and ii) the productivity with which the factors are used. Capital efficiency is then directly linked to financing conditions ($\widehat{\phi_t}$) – see Section 1. In that regard, we follow the methodology suggested by Planas et al. (2013) who use the information content of capacity utilization for detrending total factor productivity, combined with the methodology of Denis et al. (2006) who elaborate on the concept of labour and capital efficiency.

3 Financial Condition Index (FCI)

Which financial variables should be included in our estimates is not clear-cut. We first follow Borio et al. (2013) who tested different specifications and concluded that the real residential property prices and credit to the non-financial private sector were the most relevant financial indicators in this context. However, in light of the mechanisms at work in the financial markets and their transmission to the business cycle (see Section 1), the choice of these two variables might be overly restrictive. We choose then to complement these variables with other asset price variables (stock market) and volume variables (monetary aggregates) by constructing a compound Financial Condition Index.

The selection of variables as well as the aggregation method are always arguable and should reach a compromise between good real time performance, parsimoniousness, and the inclusion of the relevant variables. Nevertheless, the large amount of financial data that is available calls for appropriate empirical tools to pre-select the relevant information for forecasting a specific macroeconomic indicator, or to combine the information in a simple and efficient way. This methodological discussion is beyond the scope of this paper, and we refer the reader to Darracq Paries et al. (2014) for further references.

We use a dynamic factor model to yield the Financial Conditions Index for the UCM. Doing so, we avoid the arbitrariness of choosing one single financial indicator to underpin the financial cycle, while remaining relatively agnostic about the exact sources of the financial shocks affecting the economy. Dynamic factor models were initially designed by Geweke (1976) and Sargent and Sims (1977), with the purpose to break down each variable into a common and an idiosyncratic component. The latter is variable-specific while the former is driven by a limited number of forces, the factors, which are common across all variables. This feature makes factor models particularly suited to aggregate economic variables, which theoretically are driven by a limited number of key shocks and tend to co-move and share not only trends but also cyclical fluctuations.

The financial indicators in the model are:

- Implied volatility - Euro Stoxx 50 (Bloomberg).
- Euro Stoxx Banks Index (Bloomberg).
- Euro Stoxx Index (Bloomberg).

- European Monetary Union Banks Equity Index (Price-to-book ratio)[14] (Thomson Reuters).
- European Monetary Union Non-Financial Index (Price-to-book ratio) (Thomson Reuters).
- European Monetary Union Insurance Index (Price-to-book ratio) (Thomson Reuters).
- Credit to private non-financial sectors (Bank for International Settlements).
- Real residential property prices (European Central Bank).
- Real M1 annual growth rate (European Central Bank).

All the above indicators are demeaned and standardized. They are depicted in Figure 1. The model is estimated over the period 2000-2020.

The resulting filtered factor is presented in Figure 2. It can be seen that it follows well the financial cycle, with a decline in the turn of the 2000s, following the collapse in the IT, media and technology stocks and the recovery in the following years, until the 2007–2008 financial crisis. The footprint of the European sovereign debt crisis also appears in the developments of our FCI. Conversely, the COVID crisis had little effect on financial conditions, due to both the brevity of the shock affecting the financial markets and the policy support at the time.

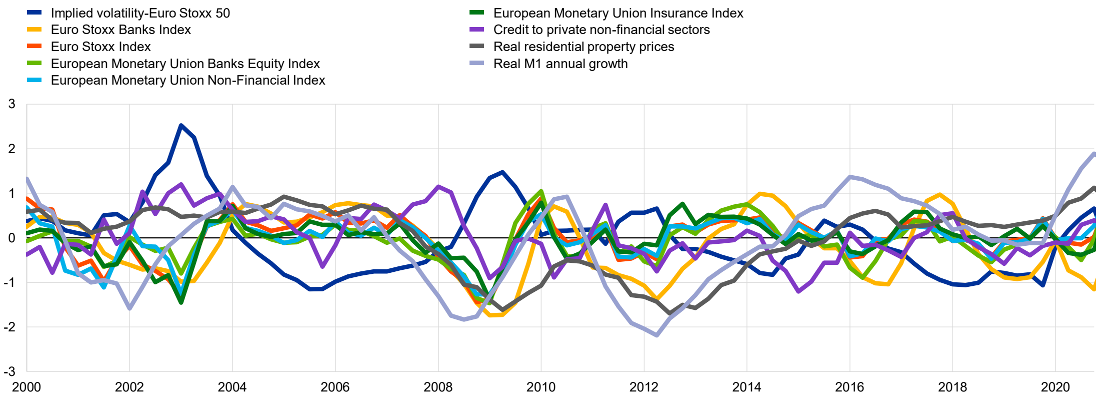


Figure 1: Euro area financial series, (index, standardized). Source: Bank for International Settlements, Bloomberg, Thomson Reuters, and own calculations.

[14]Stock closing price relative to the latest quarter's book value per share.

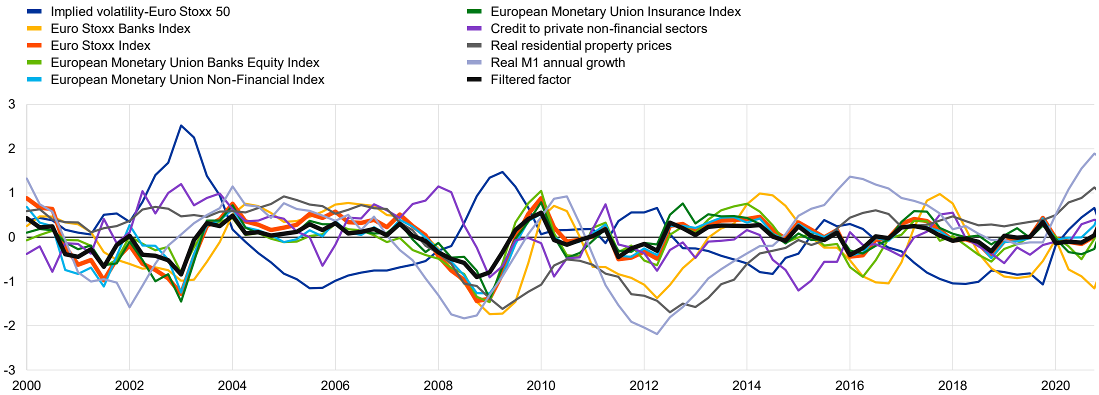
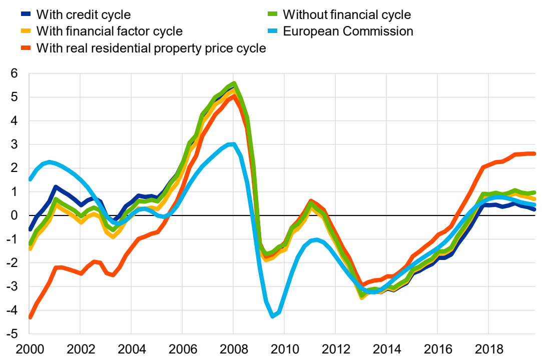


Figure 2: Euro area financial series and filtered unobserved factor, (index, standardized). Source: Bank for International Settlements, Bloomberg, Thomson Reuters, and own calculations.

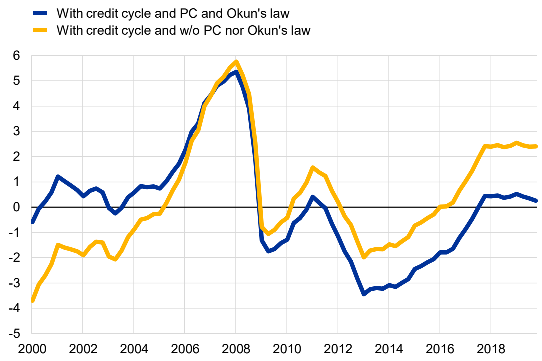
4 Results

4.1 A small Unobserved Components Model

Figure 3 summarises the different output gaps obtained with various versions of the small UCM which differ in two dimensions: whether financial variables are included or not and depending on the financial variables that are included. Our results are fourfold. First, the choice of financial series used for the analysis matter: the output gap which includes real house prices differ significantly from the alternative estimations, confirming the literature that shows how FNOGs may differ from traditional output gaps. Second, the output gap including the FCI is similar to that including credit to non-financial firms. Hence, the value added of deriving a synthetic indicator of the financial cycle vis-à-vis other simpler financial indicators is not significant. Third, the various estimates of output gaps which incorporate a financial cycle differ from that of the European Commission, but this might be rather the result of the simpler methodology used here than the fact that the output gap includes financial information. Finally, the addition of the Phillips curve, and to a lesser extent of the Okun's law, constrains the estimation of the output gap, and is determinant for the results. In the absence of these equations, the output gap is very different from the one obtained when constrained by the Philips curve (Figure 3b). This has implications for the predictive capacity of these output gaps for forecasting inflation in a reduced form Phillips curve (see subsection 4.3).



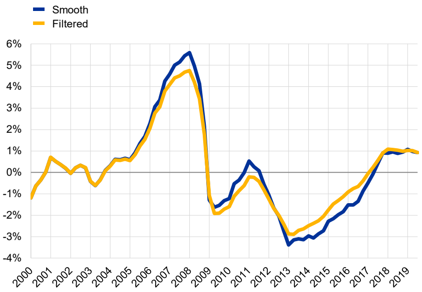
(a) Comparison across models



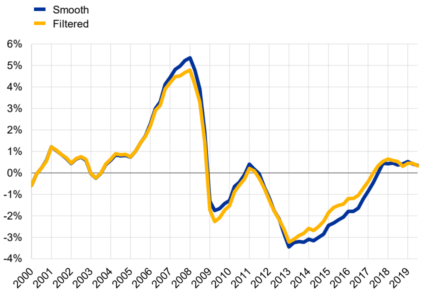
(b) Effects of the inclusion of a Phillips curve and an Okun's law into the model

Figure 3: Output gaps across models. The output gap is the difference between the natural logarithm of GDP and that of potential output. The credit cycle represents credits to non-financial corporations. The financial factor cycle accounts for the Financial Condition Index (see Section 3). Source: own calculations, European Commission Autumn 2022 Forecast.

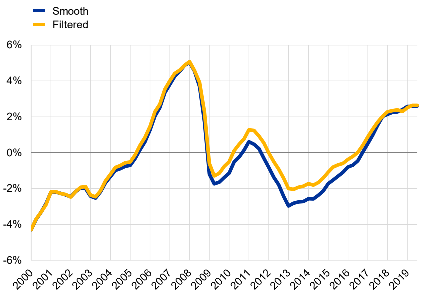
Figure 4 compares the output gaps of the small UCM for pseudo real-time filtered (one-sided) and smoothed (two-sided) estimates. One of the initial intuitions behind the inclusion of financial variables into output gap modelling was to add value to the model via improving real-time performance. Figure 4 confirms that including financial cycle information does improve the real-time reliability and thereby the usefulness for policy makers. However, these improvements are small in magnitude. In this regard, our results differ from those reported for other countries, where the improvement of the real time performance is much more noticeable. Figure 12 in Annex C illustrates this point for the UK (Melolinna and Tóth, 2019).



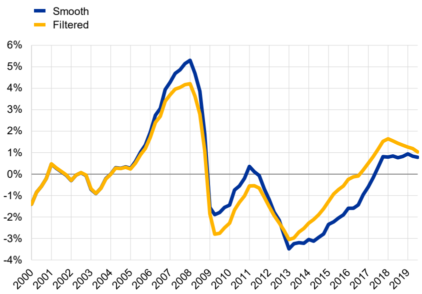
(a) Without financial cycle



(b) With credit to non-financial corporations cycle



(c) With real residential property prices



(d) With financial factor cycle

Figure 4: Output gap – smoothed and predicted. The charts show output gaps as measured in real time (one step ahead Kalman filter predictions) and taking into account the entire sample (Kalman smoother). Source: own calculations.

Although the real-time performance is overall only slightly improved when the credit cycle is introduced in the output gap estimation, the improvement is more noticeable during the GFC and sovereign debt crises (see Figure 5 for the yellow and red bars). However, this is only the case when considering the credit to non-financial companies, while the Financial Condition Index is not helpful in improving the real time performance of our model. These modest results can be explained by a multitude of factors that are difficult to disentangle. This may be due to the low share of the financial sector - in terms of value added, employment or balance sheet - in the euro area economy compared to other countries (see Figure 11 in Annex C). Other factors may be at play, such as an aggregation bias (Fortin, 1991), blurring the result at the euro area level.

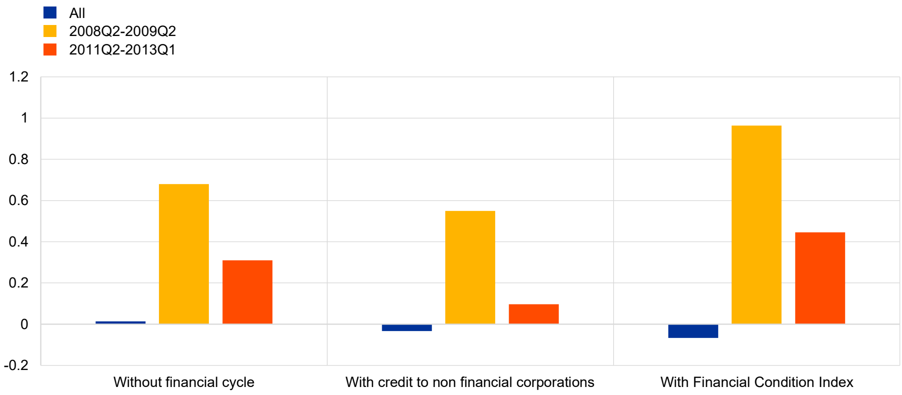


Figure 5: Real time performance across periods. The charts show the average difference between the smooth and the filtered output gaps over the specified period. Source: own calculations.

4.2 A broader set-up of the Unobserved Components Model (UCM)

Figure 6 summarises the output gap as estimated by the large set-up of the UCM which does not include financial variables (so-called Benchmark UCM). The production function approach allows for breaking down the output gap indifferent labour and TFP contributions.[15] Cyclical TFP accounts for the bulk of the output gap over the whole sample, while the unemployment gap plays a key role especially during the protracted period of activity slack following the Great Financial Crisis. At the same time, the cycle in hours worked per person and the participation rate gap played a more muted role.

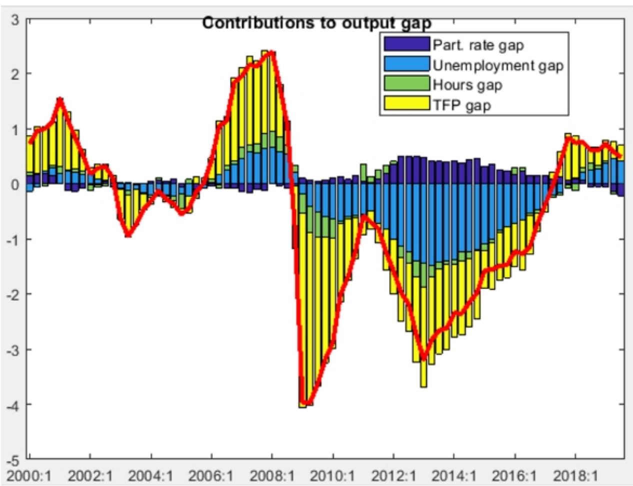
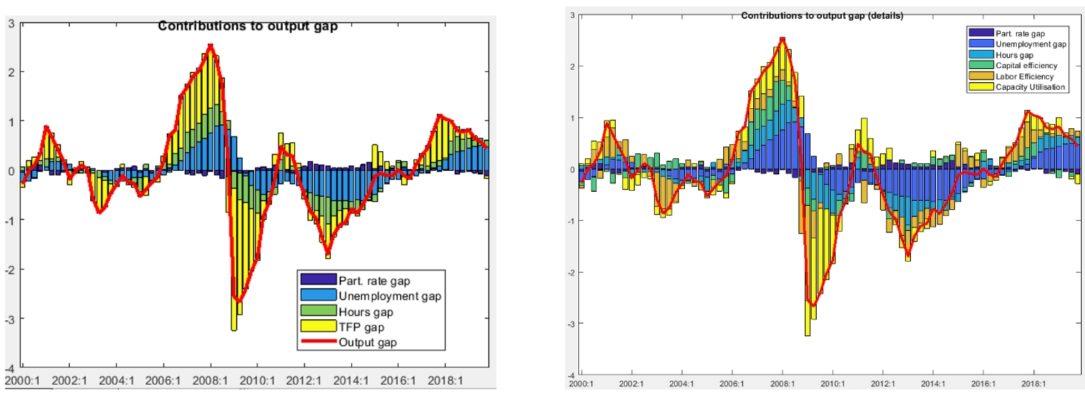


Figure 6: Euro area output gap decomposition – benchmark UCM, (percentage of potential output and percentage points). Source: own calculations.

[15]The stock of capital and the working age population are not filtered and thus do not enter the output gap decomposition.

Figure 7 shows the results after accounting for the financial cycle with the inclusion of the FCI as a determinant of capital productivity. The left-hand side of the chart shows the same decomposition as in Figure 6, to facilitate the comparison, while the right-hand side disentangles the contribution of capital productivity (and therefore of financial variables) to the TFP gap. In accordance with our prior, the productivity of capital is cyclical as financial conditions affect the access to the capital and thus the quality of the available capital, affecting in turn the efficiency and productivity of capital. We find the following results. First, in line with the previous findings using the smaller UCM (shown in section 4.1), the contribution to the output gap of financial factors (capital productivity) is somewhat limited. Second, the credit boom of the 2006-2007 period is associated with a somewhat large positive contribution of the capital efficiency. On the contrary, in the subsequent downturn, capital efficiency contributes negatively but mildly to the output gap. Hence, we support the findings that credit booms (busts) are associated with higher (lower) capital productivity. Finally, as a result of the accommodative monetary policy pursued in the euro area from the mid-2010s onwards with facilitated access to credit, the capital efficiency provided a positive, albeit reduced contribution to the closure of the output gap.



(a) (b)

Figure 7: Euro area output gap decomposition – UCM augmented with financial conditions (percentage of potential output and percentage points). Source: own calculations.

The different UCM output gaps show similar patterns although the output gap incorporating the financial cycle lies significantly above the Benchmark UCM output gap after the Great Financial crisis (Figure 8). Consequently, the financial-augmented UCM output gap points to a somewhat larger degree of tightness in the economy from 2009 onwards. The two measures are getting closer as of 2018, hovering in positive territory until the start of the pandemic. These differences have implications for the inflation-predicting performance of the different output gaps, which is shown in the next section.

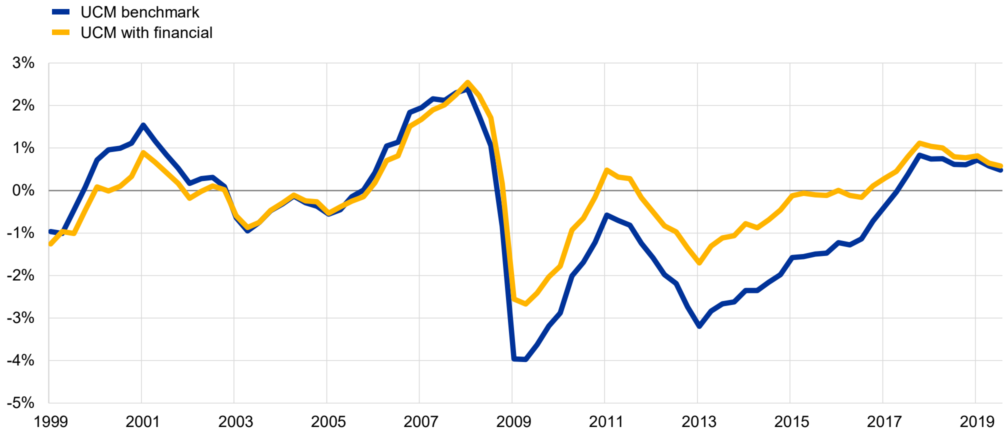


Figure 8: Euro area output gap comparisons. Source: own calculations.

4.3 Inflation - forecasting performance

We perform a pseudo-real time performance estimate of the different output gaps for assessing inflation in a reduced form Phillips curve (PC) for the seven following models.[16]

Model 1	Small UCM without any financial variable
Model 2	Small UCM augmented with credit to non-financial sector
Model 3	Small UCM augmented with FCI
Model 4	Small UCM augmented with credit to non-financial sector but in the absence of a Phillips curve and an Okun's law
Model 5	Small UCM augmented with real house prices
Model 6	Benchmark UCM
Model 7	UCM augmented with credit to non-financial sector

The forecast errors are measured one, two and four quarters ahead. Following standard practice, the quality of point forecasts is evaluated using the root Mean Square Error (MSE). Results are summarized in Figure 9 which reveals that the small UCM models provide the best

[16] A standard Phillips curve is estimated, of the following form: $\pi_t = \beta_0 + \beta_1 \pi_{t-1} + \beta_2 OG_t + \epsilon_t$, where π_t denotes the seasonally adjusted quarterly inflation rate of HICP, OG_t denotes the measure of the output gap and $\epsilon_t \sim iidN(0, \sigma^2)$.

PC-based forecast in the lot, but only when a Phillips curve and an Okun's law are included in the framework of the model. That is shown by the worse PC-based forecasting performance for inflation of model 4, which excludes the PC and Okun's law. When the latter equations are incorporated into the model, adding a financial variable to the specification improves slightly the PC-inflation forecasting performance two and four quarters ahead, whether we choose to use series of credit to the non-financial sector or the FCI (models 2 and 3 in comparison to model 1). By contrast, the small UCM which embeds the real house prices variable (model 6) shows very unreliable PC-inflation forecasts. Both models 5 and 6 support the evidence from the literature that suggests that FNOGs may differ from standard output gap estimates (Katay et al., 2020) and therefore might not be adequate gauges of inflationary pressures. The output gaps estimated with the larger UCM (models 6 and 7) prove to have good predictive inflation performance in comparison with the EC output gap, although the forecast errors are larger than for the output gaps of the small UCMs. This is due to the fact that the output gap is not exclusively identified by inflation in models 6 and 7. Finally, it is worth noting that the predictive inflation performance 4-quarters ahead of the UCM including financial variables (model 7) is slightly better than the Benchmark UCM (model 6).

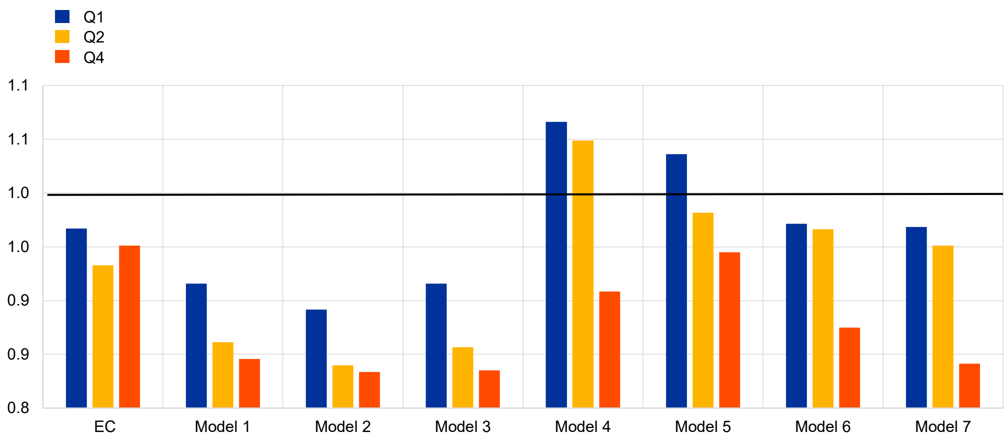


Figure 9: Forecasting performance of the different output gaps, (MSE wrt AR(2)). EC refers to the output gap established by the European Commission. Model 1 refers to the small UCM which does not include any financial variable. Model 2 refers to the small UCM augmented with a financial variable (credit to non-financial sector), Model 3 refers to the small UCM augmented with a financial variable (financial factor cycle), Model 4 refers to the small UCM augmented with a financial variable (credit to non-financial sector) but in the absence of a Phillips curve and an Okun's law. Model 5 refers to the small UCM augmented with a financial variable (real house prices). Model 6 refers to the large benchmark UCM and Model 7 refers to the large UCM augmented with a financial variable. Source: calculations, European Commission Autumn 2022 Forecast.

5 Conclusion

This paper details a number of methods for incorporating financial cycles and variables into the estimation of potential growth and of the output gap in the context of multivariate unobserved components models. Results confirm that finance neutral output gap estimates are more robust real-time relative to alternative output gaps. That is, including financial cycle information does improve the real-time reliability and thereby the usefulness for policy makers. However, these improvements are small in magnitude and are very sensitive to the choice of financial variables. The methods used in this paper present limitations that should be acknowledged. As linear models, unobserved components models may not be able to fully capture non-linearities stemming from financial fluctuations. Furthermore, financial cycles appear to be characterized by lower frequencies than business cycles and identifying both downturns and upturns in the business cycles from financial cycles turns out to be challenging. A suggestion for future research is to design alternative links between financial cycles and TFP, and also to investigate how the COVID-19 may have affected the estimation.

References

Philippe Aghion, George-Marios Angeletos, Abhijit Banerjee, and Kalina Manova. Volatility and growth: Credit constraints and the composition of investment. *Journal of Monetary Economics*, 57(3):246–265, 2010.

J. Sebastián Amador-Torres. Finance neutral potential output: an evaluation on an emerging market monetary policy context. Borradores de economia, Banco de la Republica de Colombia, September 2016.

Mary Amiti and David E. Weinstein. How much do idiosyncratic bank shocks affect investment? evidence from matched bank-firm loan data. *Journal of Political Economy*, 126(2):525–587, 2018.

Ben S. Bernanke, Mark Gertler, and Simon Gilchrist. The financial accelerator in a quantitative business cycle framework. In J. B. Taylor and M. Woodford, editors, *Handbook of Macroeconomics*, volume 1 of *Handbook of Macroeconomics*, chapter 21, pages 1341–1393. Elsevier, 1999.

Katalin Bodnár, Julien Le Roux, Paloma Lopez-Garcia, and Béla Szörfi. The impact of COVID-19 on potential output in the euro area. *Economic Bulletin Articles*, 7, November 2020.

Claudio Borio, Frank Piti Disyatat, and Mikael Juselius. Rethinking potential output: Embedding information about the financial cycle. BIS Working Papers 404, Bank for International Settlements, February 2013.

Claudio Borio, Piti Disyatat, and Mikael Juselius. A parsimonious approach to incorporating economic information in measures of potential output. BIS Working Papers 442, Bank for International Settlements, February 2014.

Claus Brand, Hans-Eggert Reimers, and Franz Seitz. Forecasting real GDP: what role for narrow money? Working Paper Series 254, European Central Bank, September 2003.

Andrea Caggese. Financing constraints, radical versus incremental innovation, and aggregate productivity. *American Economic Journal: Macroeconomics*, 11(2):275–309, April 2019.

Gabriel Chodorow-Reich. The Employment Effects of Credit Market Disruptions: Firm-level

Evidence from the 2008–9 Financial Crisis. *Quarterly Journal of Economics*, 129(1):1–59, October 2013.

Matthieu Darracq Paries, Laurent Maurin, and Diego Moccero. Financial conditions index and credit supply shocks for the euro area. Working Paper Series 1644, European Central Bank, 2014.

Cécile Denis, Daniel Grenouilleau, Kieran Mc Morrow, and Werner Röger. Calculating potential growth rates and output gaps - A revised production function approach. European economy - economic papers 2008 - 2015, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission, March 2006.

James Durbin and Siem Jan Koopman. *Time Series Analysis by State Space Methods*. Oxford University Press, May 2012.

ECB. Potential output, economic slack and the link to nominal . *Economic Bulletin Boxes*, 11, November 2013.

ECB. Key factors behind productivity trends in EU countries. Occasional Paper Series 268, European Central Bank, September 2021.

Michaela Elfsbacka Schmöller and Martin Spitzer. Lower for longer under endogenous technology growth. Bank of Finland Research Discussion Papers 6/2022, Bank of Finland, June 2022.

Irving Fisher. The debt-deflation theory of great depressions. *Econometrica*, 1(4):337–357, 1933.

Nicole M. Fortin. Fonctions de production et biais d'agrégation. *Annals of Economics and Statistics*, (20-21):41–68, 1991.

Vahagn Galstyan. Inflation and the Current Account in the Euro Area. Economic Letters 4/EL/19, Central Bank of Ireland, May 2019.

Daniel Garcia-Macia. The Financing of Ideas and the Great Deviation. IMF Working Papers 2017/176, International Monetary Fund, July 2017.

Mark Gertler and Peter Karadi. A model of unconventional monetary policy. *Journal of Monetary Economics*, 58(1):17–34, January 2011.

John Geweke. *The Dynamic Factor Analysis of Economic Time Series Models*. Workshop series / Social Systems Research Institute, University of Wisconsin. University of Wisconsin, 1976.

Gita Gopinath, Sebnem Kalemli-Ozcan, Loukas Karabarbounis, and Carolina Villegas-Sanchez. Capital allocation and productivity in south europe. *Quarterly Journal of Economics*, 132(4): 1915–1967, November 2017.

Matteo Iacoviello. House prices, borrowing constraints, and monetary policy in the business cycle. *American Economic Review*, 95(3):739–764, June 2005.

Òscar Jordà, Sanjay Singh, and Alan Taylor. Longer-run economic consequences of pandemics. *The Review of Economics and Statistics*, 104:1–29, 03 2021.

Gabor Katay, Lisa Kerdelhué, and Matthieu Lequien. Semi-Structural VAR and Unobserved Components Models to Estimate Finance-Neutral Output Gap. Working Papers 2020-11, Joint Research Centre, European Commission, November 2020.

Johannes Kemp. Measuring potential output for the south african economy: Embedding information about the financial cycle. *South African Journal of Economics*, 83, 04 2015. doi: 10.1111/saje.12081.

Asim Ijaz Khwaja and Atif Mian. Tracing the impact of bank liquidity shocks: Evidence from an emerging market. *American Economic Review*, 98(4):1413–42, September 2008.

Robert King and Mark W Watson. Testing long run neutrality. Working Paper 4156, National Bureau of Economic Research, September 1992.

Nobuhiro Kiyotaki and John Moore. Credit cycles. *Journal of Political Economy*, 105(2):211–48, 1997.

Francesco Manaresi and Nicola Pierri. Credit supply and productivity growth. BIS Working Papers 711, Bank for International Settlements, 2018.

Marko Melolinna and Máté Tóth. Output gaps, inflation and financial cycles in the UK. *Empirical Economics*, 56(3):1039–1070, March 2019.

Virgiliu Midrigan and Yi Xu. Finance and misallocation: Evidence from plant-level data. *American Economic Review*, 104(2):422–58, 2014.

Alberto Musso. The predictive power of real M1 for real economic activity in the euro area. *Economic Bulletin Boxes*, 3, 2019.

Edward Nelson. The Future of Monetary Aggregates in Monetary Policy Analysis. CEPR Discussion Papers 3897, C.E.P.R. Discussion Papers, May 2003.

Arthur C. Pigou. The classical stationary state. *The Economic Journal*, 53(212):343–351, 1943.

Christophe Planas, W. Roeger, and Alessandro Rossi. The information content of capacity utilization for detrending total factor productivity. *Journal of Economic Dynamics and Control*, 37(3):577–590, 2013.

Kenneth Rogoff. Debt supercycle, not secular stagnation. *VoxEU*, 2015.

Thomas Sargent and Christopher Sims. Business cycle modeling without pretending to have too much a priori economic theory. Working Papers 55, Federal Reserve Bank of Minneapolis, 1977.

Apostolos Serletis. *Quantitative and Empirical Analysis of Energy Markets*. Number 6352 in World Scientific Books. World Scientific Publishing Co. Pte. Ltd., June 2007.

Máté Tóth. A multivariate unobserved components model to estimate potential output in the euro area: a production function based approach. Working Paper Series 2523, European Central Bank, February 2021.

Òscar Jordà, Moritz Schularick, and Alan M. Taylor. Macrofinancial History and the New Business Cycle Facts. *NBER Macroeconomics Annual*, 31(1):213–263, 2017.

Annex

A Estimation strategy

In this annex, we report prior and posterior distributions of the model's parameters. The equations in section 2.1 and 2.2 can be written as state-space models and estimated using the Kalman Filter.[17] The estimation methods are described in detail in Tóth (2021). Each disturbance term is assumed to have a variance σ_j where j takes the associated series notation. For these variance parameters, we use inverse gamma prior distributions. For the other parameters in the model, we use a set of beta, gamma and normal distributions. The prior and posterior distributions are summarised in Tables 1 and 2. The posterior distributions are broadly in line with our expectations. For example, the posterior median values for the coefficients in the Phillips curve have signs that, in advance may be considered reasonable. In the meantime, the posterior distributions for the disturbance terms variance parameters are considerably more condensed than their prior distributions, which suggests that data provide valuable information to the model.

[17] See, for example, Durbin and Koopman (2012) for a detailed review of state-space models and underlying methods of estimation such as the Kalman filter.

Parameter	Prior density type	Hyper-parameters	Posterior median (without financial cycle)	Posterior median (with credit cycle)	Posterior median (with real residential prices)	Posterior median (with factor index)
α_1	Beta	[μ =0.5, σ = 0.15]	0.440	0.417	0.422	0.416
α_2	Beta	[μ =0.7, σ = 0.15]	0.652	0.652	0.603	0.626
α_3	Beta	[μ =0.3, σ = 0.15]	-	0.228	0.242	0.226
γ_1	Gamma	[μ =0.2, σ = 0.3]	0.148	0.106	0.144	0.194
γ_2	Gamma	[μ =0.1, σ = 0.3]	0.083	0.097	0.090	0.028
γ_3	Beta	[μ =0.6, σ = 0.3]	0.534	0.551	0.592	0.546
β_1	Beta	[μ =0.6, σ = 0.3]	0.412	0.526	0.532	0.519
β_2	Gamma	[μ =0.6, σ = 0.3]	0.315	0.592	0.562	0.517
ρ_1	Beta	[μ =0.5, σ = 0.15]	-	0.035	0.036	0.068
ρ_2	Beta	[μ =0.5, σ = 0.15]	-	0.081	0.055	0.060
$\sigma_{\widehat{y}}$	Inv. gamma	[μ=1, σ=∞]	0.079	0.021	0.079	0.078
$\sigma_{\overline{y}}$	Inv. gamma	[μ=0.01, σ=∞]	0.031	0.031	0.035	0.100
$\sigma_{\widetilde{y}}$	Inv. gamma	[μ=0.001, σ=∞]	0.050	0.012	0.062	0.046
$\sigma_{\widehat{u}}$	Inv. gamma	[μ=1, σ=∞]	0.087	0.082	0.037	0.075
$\sigma_{\overline{u}}$	Inv. gamma	[μ=0.01, σ=∞]	0.077	0.090	0.059	0.075
$\sigma_{\widehat{\pi}}$	Inv. gamma	[μ=1, σ=∞]	0.096	0.066	0.016	0.073
$\sigma_{\overline{\pi}}$	Inv. gamma	[μ=0.01, σ=∞]	0.082	0.058	0.096	0.012
$\sigma_{\widehat{\phi}}$	Inv. gamma	[μ=1, σ=∞]	-	0.027	0.071	0.018
$\sigma_{\overline{\phi}}$	Inv. gamma	[μ=0.1, σ=∞]	-	0.096	0.100	0.086

Table 1: Prior and posterior statistics (small UCM)

Parameter	Prior density type	Hyper-parameters	Posterior median (without financial cycle)	Posterior median (with credit cycle)
α_1	Beta	[μ=0.5, σ=0.15]	0.340	0.437
α_2	Beta	[μ=0.7, σ=0.15]	0.593	0.612
γ_1	Gamma	[μ=0.2, σ=0.3]	0.098	0.106
γ_2	Gamma	[μ=0.1, σ=0.3]	0.073	0.097
γ_4	Beta	[μ=0.6, σ=0.3]	0.434	0.457
γ_6	Beta	[μ=0.6, σ=0.3]	0.434	0.451
β_1	Beta	[μ=0.7, σ=0.15]	0.412	0.547
β_2	Gamma	[μ=0.5, σ=0.3]	0.108	0.111
β_3	Beta	[μ=0.7, σ=0.15]	0.364	0.321
β_4	Gamma	[μ=0.5, σ=0.3]	0.288	0.267
ρ_1	Beta	[μ=0.7, σ=0.15]	-	0.035
ρ_2	Normal	[μ=0.3, σ=0.15]	-	0.081
ρ_3	Beta	[μ=0.7, σ=0.15]	-	0.023
$\sigma_{\widehat{y}}$	Inv. gamma	[μ=1, σ=∞]	0.066	0.017
$\sigma_{\overline{y}}$	Inv. gamma	[μ=0.01, σ=∞]	0.023	0.025
$\sigma_{\widetilde{y}}$	Inv. gamma	[μ=0.001, σ=∞]	0.044	0.008
$\sigma_{\widehat{u}}$	Inv. gamma	[μ=1, σ=∞]	0.055	0.035
$\sigma_{\overline{u}}$	Inv. gamma	[μ=0.01, σ=∞]	0.076	0.077
$\sigma_{\widehat{\pi}}$	Inv. gamma	[μ=1, σ=∞]	0.024	0.073
$\sigma_{\overline{\pi}}$	Inv. gamma	[μ=0.01, σ=∞]	0.068	0.068
$\sigma_{\widehat{w}}$	Inv. gamma	[μ=1, σ=∞]	0.085	0.056
$\sigma_{\overline{w}}$	Inv. gamma	[μ=0.01, σ=∞]	0.072	0.088
$\sigma_{\widehat{\phi}}$	Inv. gamma	[μ=1, σ=∞]	-	0.027
$\sigma_{\overline{\phi}}$	Inv. gamma	[μ=0.1, σ=∞]	-	0.096

Table 2: Prior and posterior statistics (large UCM)

B Stylised representation of the UCM

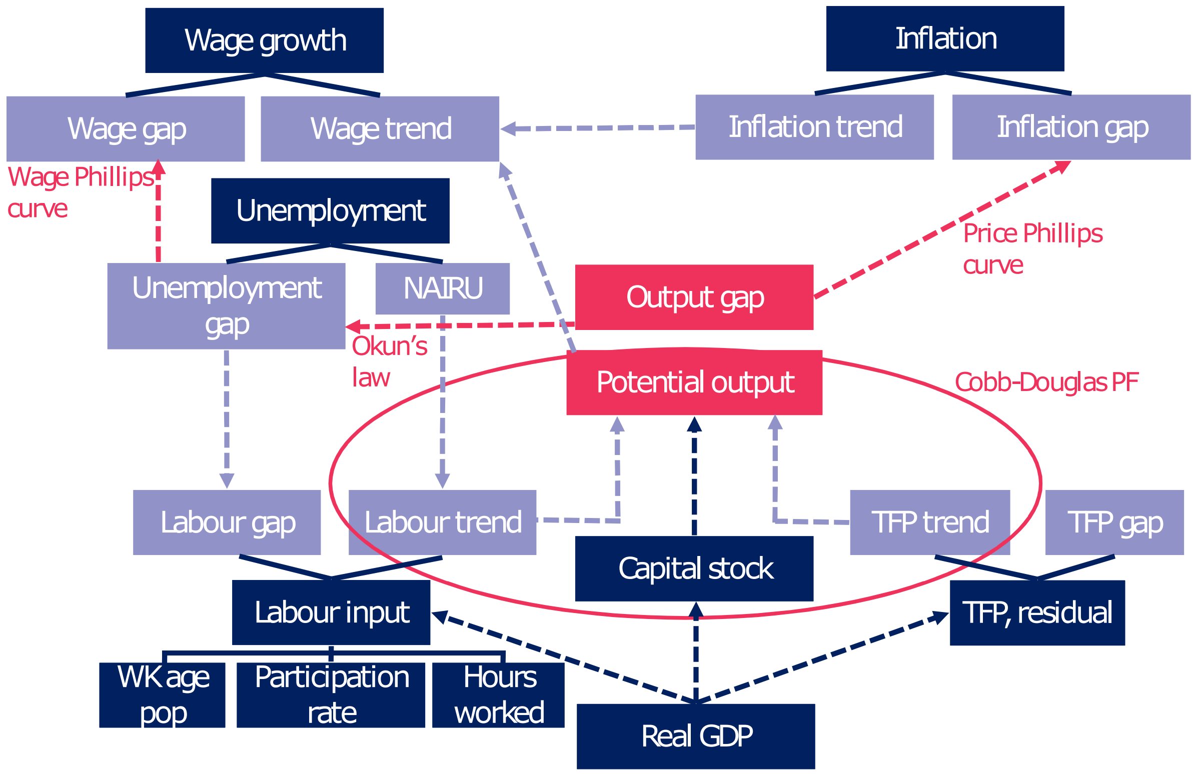
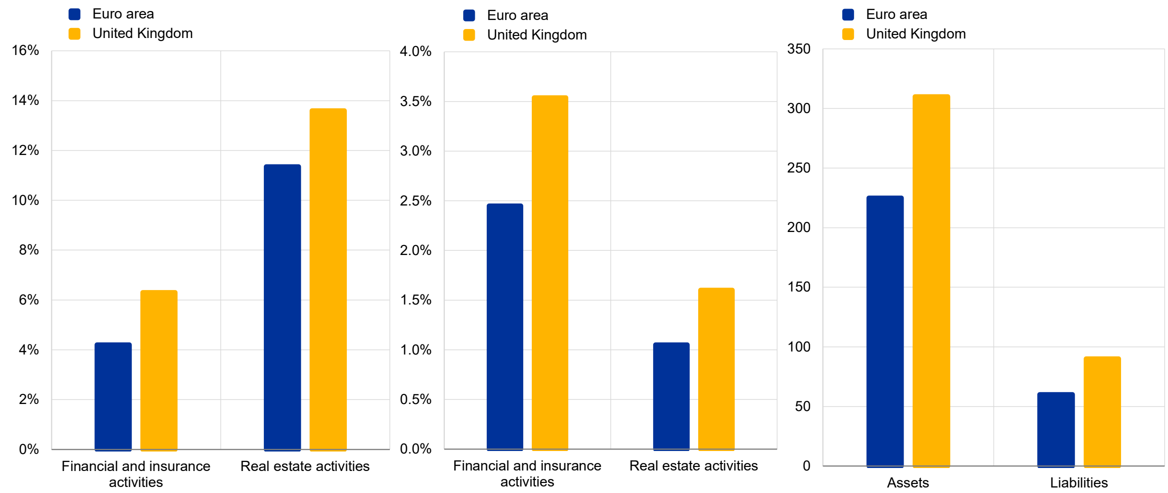


Figure 10: Stylised representation of the UCM. Source: Tóth (2021).

C Additional charts

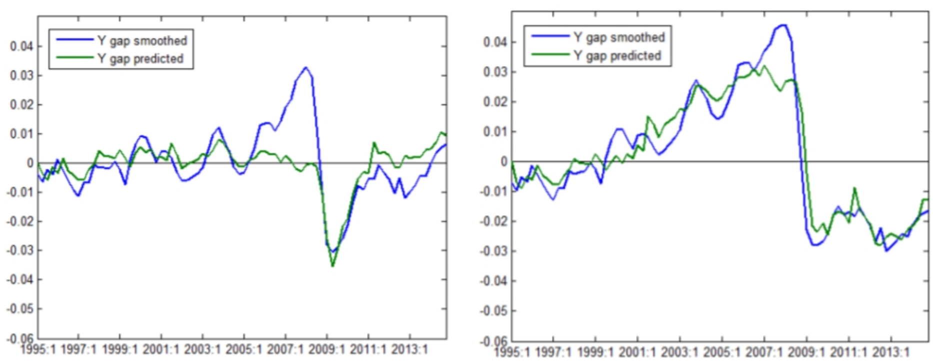


(a) Gross value added in selected sectors, (% of total value added)

(b) Hours worked in selected sectors, (% of total hours worked)

(c) Financial balance sheet of households, (% of GDP)

Figure 11: Comparison of the financial sectors in the euro area and the United Kingdom. The charts show the year 2019. Source: Eurostat (*nasa_10_f_bs*).



(a) Without financial cycle

(b) With financial cycle

Figure 12: UK output gap – smoothed and predicted. This chart shows UK output gaps estimated with a UCM, both in real time (predicted) and over the entire sample (smoother). These charts serve as an illustration of the role of financial variables for improving the performance of the real-time estimation of the output gaps. Source: Melolinna and Tóth (2019) (p.8).

Acknowledgements

We would like to thank João Sousa, Wolfgang Modery, David Sondermann, Paloma Lopez-Garcia, Máté Tóth, Guzmán González-Torres and participants of the Working Group on Forecasting for useful comments and suggestions. We would also like to thank an anonymous referee and the Editorial Board of the ECB Working Paper Series for their very useful comments and suggestions which we incorporated into this paper.

Justine Guillochon
City University of New York (CUNY) - CUNY Graduate Center, New York, United States; email: jguillochon@gradcenter.cuny.edu

Julien Le Roux
Banque de France, Paris, France; email: julien.leroux@banque−france.fr

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

This paper can be downloaded without charge from www.ecb.europa.eu, from the Social Science Research Network electronic library or from RePEc: Research Papers in Economics. Information on all of the papers published in the ECB Working Paper Series can be found on the ECB's website.

PDF ISBN 978-92-899-6117-2 ISSN 1725-2806 doi:10.2866/862332 QB-AR-23-069-EN-N