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Monetary Policy, the Financial Cycle and Ultra-low Interest Rates

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March 2017

Discussion Paper

No. 55

Monetary policy, the financial cycle and ultra-low interest rates*

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Abstract

Do the prevailing unusually and persistently low real interest rates reflect a decline in the natural rate of interest as commonly thought? We argue that this is only part of the story. The critical role of financial factors in influencing medium-term economic fluctuations must also be taken into account. Doing so for the United States yields estimates of the natural rate that are higher and, at least since 2000, decline by less. As a result, policy rates have been persistently and systematically below this measure. Moreover, we find that monetary policy, through the financial cycle, has a long-lasting impact on output and, by implication, on real interest rates. Therefore, a narrative that attributes the decline in real rates primarily to an exogenous fall in the natural rate is incomplete. The influence of monetary and financial factors should not be ignored. Exploiting these results, an illustrative counterfactual experiment suggests that a monetary policy rule that takes financial developments *systematically* into account during *both* good and bad times could help dampen the financial cycle, leading to higher output even in the long run.

JEL classification: E32, E40, E44, E50, E52.

Keywords: natural interest rate, financial cycle, monetary policy, credit, business cycle.

* We would like to thank Raphael Auer, Stijn Claessens, Boris Hofmann, Jonathan Kearns, Giovanni Lombardo, Phurichai Rungcharoenkitkul, Anders Vredin and Hyun Shin for helpful comments and discussions, and Andreas Freitag for excellent statistical assistance. All remaining errors are ours. The views expressed are those of the authors and do not necessarily represent those of the Bank for International Settlements, the Bank of Finland, or the Bank of Thailand.

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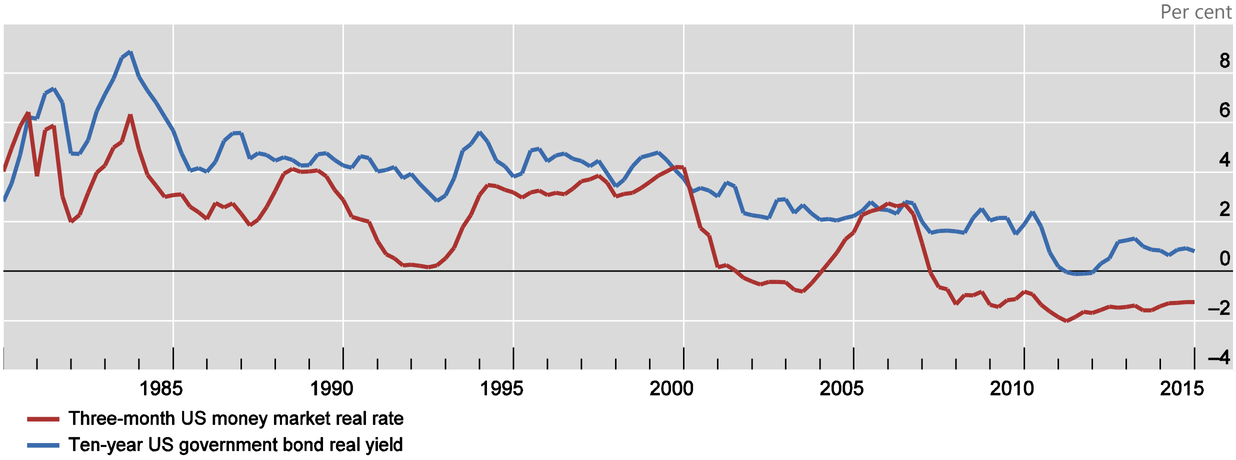
Introduction

Inflation-adjusted (real) interest rates, short and long, have been on a downward trend for a long time and have remained exceptionally low since the Great Financial Crisis (Graph 1). Why is this so?

The prevailing view is that this downward trend and the exceptionally low level largely reflect a fall in natural interest rates, driven by changes in saving and investment fundamentals (Bean et al (2015), IMF (2013), Rachel and Smith (2015)).[1] One prominent variant is the hypothesis that persistently weak demand for capital, a rising propensity to save and lower trend growth have brought about an era of "secular stagnation" (Summers (2014)). Another variant points to a higher propensity to save in emerging economies together with investors' growing preference for safe assets (Bernanke (2015), Broadbent (2014), Caballero et al (2008)).

The long-term decline in real interest rates[1] Graph 1



[1] Real rates are generated by subtracting realised PCE core inflation from nominal interest rates.

Source: National data.

Views about the natural rate are necessarily model-dependent. At the heart of the prevailing interpretation are two key features. First, the natural rate is defined as that which would prevail when actual output equals potential output. Second, *inflation* is the key signal that output is not at its potential, sustainable level. All else equal, if output is above potential, inflation will tend to rise; if it is below, inflation will tend to fall. The natural rate, so defined, is also known as the "Wicksellian" rate, following Wicksell (1898) and as refined more recently by Woodford (2003)). Crucially, this view presumes that over the medium term, monetary policy only passively tracks the natural rate. As a result, the observed decline in real interest rates is purely a function of forces beyond central banks' control.

We argue that this view is too narrow.[2] When we think of both potential output and the symptoms of unsustainability, we also need to consider *financial* factors. Output cannot be at a sustainable level if the financial side of the economy is out of kilter. And the key symptom of unsustainability may be outsize financial booms and

[1] See also Hamilton et al (2015), Kiley (2015) or Obstfeld and Tesar (2015).

[2] This position is more comprehensively argued in Borio (2016).

busts, which in turn can wreak havoc on output (eg Schularick and Taylor (2012), Borio and Lowe (2002)). Indeed, empirical evidence indicates that many recessions, especially those that coincide with banking crises, have permanent effects on output – growth may return to its pre-crisis long-term trend, but output does not, so that a permanent gap develops between the pre- and post-recession output trends (Cerra and Saxena (2008), BCBS (2010), Ball (2014)).[3] This evidence calls into question the validity of standard presumptions that cyclical fluctuations take place around a pre-determined trend (Martin et al (2015), Blanchard et al (2015)).

This alternative view of the natural rate, in which financial factors also play a role, has a couple of advantages. Analytically, it avoids the conclusion that interest rates may be at their long-run equilibrium or natural level and yet encourage the build-up of serious financial instability (eg Summers (2014), Bean et al (2015)). From this perspective, such a conclusion is more a reflection of the restrictiveness of the analytical frameworks used to define and to measure the natural rate than of an inherent tension between the natural rate and financial stability. Empirically, our view dovetails with the burgeoning literature documenting the limited usefulness of domestic measures of slack (deviations of output from potential) as determinants of inflation (eg Pain et al (2008), Ball and Mazunder (2011), IMF (2013), Blanchard et al (2015), Borio and Filardo (2007))[4] and – the mirror image – with the limited usefulness of inflation as an indicator of business cycle conditions (eg Borio et al (2014)). Indeed, a recent strand of empirical work indicates that, by contrast, financial cycle proxies are helpful indicators of those conditions (Borio et al (2013, 2014), Kiley (2015)).

This perspective has first-order implications for monetary policy. For one, it suggests that inflation may be an insufficient guide for monetary policy. If monetary policy has a material impact on financial booms and busts and if inflation is a poor indicator of deviations of output from potential, then ignoring financial cycles may lead policy astray. In addition, since financial cycles can lead to permanent output losses, monetary policy may not be neutral in the long run. As such financial cycles can be quite long (Drehmann et al (2012), Aikman et al (2014), this raises the possibility that lower-frequency – beyond typical business cycle durations – output fluctuations, too, are endogenous and influenced by monetary policy.

In this paper, we propose an empirical framework in which financial factors play a pivotal role in economic fluctuations so as to analyse these issues in more detail.[5] Our objective is twofold: (i) to revisit the measurement of the natural interest rate, and more ambitiously, (ii) to propose a monetary policy rule that *systematically* takes into account the state of the financial cycle. By establishing a link between monetary policy and long-run output trajectories, the framework also provides a richer

[3] The studies reviewed in BCBS (2010) that allow for the possibility of permanent effects point to a loss equivalent to some 6% of GDP on average. Reviewing the experience with the recent crisis, Ball (2014) estimates a permanent decline in potential output of over 8% among OECD countries.

[4] Consistent with this finding is the recent evidence that domestic output gaps in standard Phillips curve models provide little additional predictive content beyond lagged inflation when forecasting inflation (Stock and Watson (2007), Dotsey et al (2015)). Faust and Leeper (2015) also stress that inflation dynamics are not as simple as implied by models and rules based on economic slack.

[5] There is, of course, a much broader literature highlighting the role of financial factors in economic fluctuations and, more specifically, the GDP costs of financial or credit booms and busts. Some of those closest in spirit to the analysis performed here include, for instance, Reinhart and Rogoff (2009), Claessens et al (2009), Schularick and Taylor (2012), Mian and Sufi (2014), Mian et al (2016) and Jordà et al (2013)).

perspective on the secular decline in real interest rates. We apply the framework to US data over a 30-year period, 1985-2015.

We reach three main conclusions.

First, once financial factors are taken into account, the natural interest rate is higher and falls by less than prevailing empirical approaches would suggest, at least since 2000. Importantly, the actual real policy interest rate has been persistently below the natural rate, especially in the most recent period.

Second, monetary policy is indeed not neutral in the long run. The way policy is systematically conducted has a first-order impact on financial factors and hence on output fluctuations. And the resulting booms and busts leave permanent scars, at least on the *level* of output. This appears to be the case even when banking crises do not break out.

Together, the first two conclusions suggest that a narrative that attributes the decline in real interest rates and their persistently ultra-low post-crisis levels primarily to an exogenous fall in the natural rate is incomplete. Monetary policy, through its impact on the financial cycle, influences the evolution of real interest rates over the medium term. In this sense, beyond the structural evolution of the economy, the decline reflects, in part, also policy frameworks (Borio and Disyatat (2014), Borio (2016)).

Thus, monetary policy frameworks matter, which takes us to the third conclusion. An effective "lean-against-the-wind" approach requires policy to take financial developments into account *systematically*. In effect, it may be represented by a policy rule that takes the form of an augmented version of the standard Taylor rule (Taylor (1993)) and incorporates financial cycle indicators. Such a rule differs fundamentally from typical interpretations of "lean-against-the-wind" policy, whereby interest rates are raised only when signs of financial imbalances, such as credit and asset price run-ups beyond historical norms, emerge (eg Svensson (2014, 2016), Ajello et al (2015), IMF (2015)). Responding to financial stability risks only when they become evident would inevitably lead to doing too little too late, as it would ignore the *cumulative* impact of policy over the whole financial cycle. Rather, policy interest rates should be set so that the economy is *never too far away* from "financial equilibrium" – a notion that we will define more precisely below. Using an illustrative policy rule that embodies such features, our analysis suggests that it would have been possible to mitigate financial imbalances, leading to significant output gains.

In order to reach these results, we draw on previous work by Juselius and Drehmann (2015). The authors decompose traditional measures of the financial cycle – typically captured by the behaviour of (private sector) credit and asset prices, notably property prices – into two key variables that jointly pin down *sustainable* levels of the credit-to-GDP ratio. The first is a long-run equilibrium ("co-integrating") relationship between the credit-to-GDP ratio and asset prices, a rough measure of leverage; the second is a relationship between the credit-to-GDP ratio and the average lending rate on debt outstanding, in effect a measure of the debt service burden. By embedding the deviations of these relationships ("gaps") in a vector auto-regressive (VAR) system, the authors find that they are a major driver of output fluctuations. Strikingly, the system succeeds in capturing well *out of sample* the basic features of the Great Recession and of the subsequent weak recovery. Here, we simply extend the system to link the lending rate to the policy rate and to include inflation.

The dynamics of the system are critical for our results. They reveal that financial factors can have a very persistent impact on output. Specifically, the interaction of the leverage and debt service gaps gives rise to *endogenous* economic cycles that can have *permanent* output effects. And they reveal a prominent role for monetary policy. Policy does not just affect credit and asset prices but, more directly through interest payments, has a major influence on the debt service gap – a key variable driving long-run output dynamics.

Given this building block, we then proceed in two steps.

We expand the familiar Laubach and Williams (2003, 2015a) reduced-form model for estimating potential output and the natural rate by incorporating information from the leverage and debt service gaps. By doing so, we obtain estimates of the (unobservable) evolution of potential output and the natural real interest rate – what might be termed the *"finance-neutral"* potential output and *"finance-neutral"* natural rate. Intentionally, we make the smallest possible adjustments to the system put forward by Laubach and Williams, which relies heavily on the information content of inflation. By nesting this standard system in ours, we let the data speak. In line with Borio et al (2013, 2014), incorporating financial factors leads to potential output (or output gap) estimates that better capture sustainable economic trajectories and, in the process, also to different measures of the natural rate.

We then turn to the more ambitious part of the exercise. Here we use estimates of the output gap and the natural interest rate obtained from the filter to perform a counterfactual experiment using the previous VAR system based on a policy rule that takes financial factors systematically into account – the augmented Taylor rule noted above. This part of the exercise is necessarily more speculative, as it faces well-known and serious econometric challenges. A key one is the "Lucas critique": there is no presumption that the estimated coefficients are invariant to policy. Unfortunately, the question we wish to address makes such a critique inevitable, since we are interested in the *systematic* part of policy, not in small and, above all, temporary deviations from an established pattern. We draw some reassurance from the stability of key parameter estimates over different subsamples, including post-crisis, and from the possibility that our results would actually be reinforced if agents were to internalise the systematic policy reaction and respond even more strongly. Even so, there is no way we can avoid the critique. Thus, our results here should best be interpreted as suggestive and will need to wait for the accumulation of further evidence.

The rest of the paper is organised as follows. Section 1 explains in more detail the VAR system we use to capture the role of financial factors in driving business fluctuations, highlighting the role of the debt service and leverage gaps. Section 2 develops and estimates the smaller system (multivariate Kalman filter) designed to measure potential output and the natural rate of interest. Section 3 uses these as inputs in the counterfactual monetary policy experiment and elaborates on the policy implications. The conclusion summarises the key results and considers possible avenues for future work. Technical details and robustness checks are contained in annexes.

1. The financial cycle and output fluctuations

Our starting point is an empirical system that links financial factors to standard macroeconomic variables building on stable relationships in the data. The system has two distinctive features. First, a significant part of economic fluctuations, especially long-duration ones, are driven by *endogenous* variations in the economy's financial state. Second, it is fully consistent with evidence that the impact of financial crises, and recessions more generally, is long-lasting (and possibly permanent). By according a role for the financial cycle in driving economic fluctuations over the medium term, we share common ground with recent work that calls into question the standard presumption that cyclical fluctuations take place around a predetermined trend (Blanchard et al (2015), Martin et al (2015), Reifschneider et al (2015)).

1.1 The VAR system: key features

At the heart of our VAR system are two key co-integrating relationships that trace out the long-term (equilibrium) relationships between financial and real variables. Conceptually, these two relationships help to decompose previous characterisations of the financial cycle – typically in the form of combinations of (private sector) credit, asset prices and their relationship to output (eg Drehmann et al (2012)) – into more fundamental or structural components. Once embedded into a full VAR, these relationships can then help explain the dynamics of the financial cycle and its interaction with output.[6]

The first co-integrating relationship is between the credit-to-GDP ratio and inflation-adjusted (real) asset prices (equation (1)). The asset prices included are those for residential property, commercial property and equities, with the corresponding weights adding up to one (Annex 1). This relationship captures the well-known positive link between debt and asset prices, which may arise from the latter's use as collateral or, more generally, as a source of revenue or service streams (housing). It can be interpreted as a very rough proxy for aggregate *leverage* at market prices.[7] In what follows, therefore, we will refer to this first co-integrating relationship as the *leverage gap*.

The second co-integrating relationship is between the credit-to-GDP ratio and the (average) lending rate on debt outstanding (equation (2)). This relationship captures the link between debt and interest payments, consistent with the notion that a lower interest bill allows households and firms to service the same stock of debt with lower income in the long run. As it turns out, this is a very good proxy for the actual private sector's *debt service* burden – defined as the ratio of interest payments plus amortisations of households and non-financial companies to their income, itself a stationary variable (Annex 1). This suggests that the variable is closely linked to cash flow constraints. In what follows, we will refer to deviations of this variable from its long-term co-integrating relationship as the *debt service gap*.

Technically, these two relationships can be written as[8]

$$\widetilde{lev}_t = (cr_t^r - y_t^r) - \beta_{lev} p_{A,t}^r - \overline{lev} \tag{1}$$

6 See Annex 1 for a detailed derivation of these relationships and a comparison with their purely data-based statistical analogues.

7 Technically, Juselius and Drehmann (2015) derive the relationship under the assumption that the credit-to-assets ratio – or leverage – is constant in the long run. In fact, while the combined debt-to-assets ratio of households and non-financial corporates from the flow of funds exhibits a slight deterministic trend, its deviations from this trend are closely correlated with the deviations from the long-term co-integrating relationship (Annex 1).

8 In what follows, we use smaller letters to denote the natural logarithm of a variable, for example $y_t = \ln(Y_t)$ for the log of nominal GDP, except for the interest rate, which is in levels. The superscript r is used to denote real variables, for example, $y_t^r = y_t - p_t$, where p_t denotes the GDP deflator.

$$\widetilde{dsr}_t = (cr_t^r - y_t^r) + \beta_{dsr} i_{L,t} - \overline{dsr} \tag{2}$$

where cr_t^r is real credit, y_t^r is real output, $p^r_{A,t}$ is real asset prices, $i_{L,t}$ is the nominal average lending rate on the stock of credit, and $\overline{lev}$ and $\overline{dsr}$ are the constants in the co-integrating vectors. The aggregate asset price index is constructed as a credit-weighted average of estimated sector-specific asset price indices for households and non-financial corporations (Annex 1).[9]

Another way of thinking of these two relationships is that they pin down the *long-run equilibrium level of the credit-to-GDP ratio*, consistent with other variables in the system, namely real asset prices (via the leverage gap) and the nominal lending rate (via the debt service gap). This is important, since the credit-to-GDP ratio plays a key role in leading indicators of financial distress but has exhibited a clear upward trend (eg Borio and Lowe (2002), Drehmann et al (2011), BCBS (2010)). The two stationary co-integrating vectors could allow policymakers to avoid relying on this arbitrary deterministic trend, intended as a very rough proxy for natural financial deepening.

Put differently, once embedded as error correction mechanisms in a co-integrated VAR model, the system's steady state is characterised by the credit-to-GDP ratio, real asset prices and the lending rate taking values consistent with *both* leverage and debt service gaps being closed – a measure of *financial equilibrium*. These gaps constitute our measure of financial imbalances and form the financial core of the economy. The evolution of this financial core plays a key role in driving economic fluctuations. Indeed, as shown in Juselius and Drehmann (2015), the two gaps help to trace in real time and out of sample much of the output dynamics surrounding the Great Recession.

The full VAR system in error correction form is as follows:

$$\begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta e_O^r \\ \Delta p_A^r \\ \Delta \pi \\ \Delta i_L \\ \Delta i \end{pmatrix}_t = \gamma_0 + \alpha \begin{pmatrix} \widetilde{lev} \\ \widetilde{dsr} \\ \widetilde{spr} \end{pmatrix}_{t-1} + \sum_{j=1}^{3} \Psi_j \begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta e_O^r \\ \Delta p_A^r \\ \Delta \pi \\ \Delta i_L \\ \Delta i \end{pmatrix}_{t-i} + \Gamma s_t + \epsilon_t \tag{3}$$

where e_P^r is real domestic private expenditure (consumption plus investment), e_O^r other expenditures (the trade balance plus government spending), π inflation, i the policy rate, s_t a vector of seasonal and impulse dummies, and Δ the difference operator. We split output into the two expenditure components because the debt service ratio and leverage should be expected to affect them differently. We then derive the evolution of GDP simply by combining these two components weighted by their shares in GDP.

In (3) we include the policy rate as an endogenous variable. Thus we are implicitly estimating a monetary policy rule as a function of the variables in the system. Alternatively, we could impose a particular policy rule by dropping i from the set of endogenous variables and include it instead as an exogenous variable on the right-hand side. We discuss this below.

The relationship between the policy rate and the lending rate comes through $\widetilde{spr}_t$, defined as

[9] See Annex 1 for a discussion on this point as well as for the construction of $i_{L,t}$.

$$\widetilde{spr}_t = i_{L,t} - i_t - \overline{spr} \quad (4)$$

where $\overline{spr}$ is the average spread between the lending rate and the policy rate and can be thought of as a constant long-run mark-up, consistent with theory. Our tests indicate that this co-integrating relationship is not rejected by the data.

Importantly, the average lending rate on the stock of credit, $i_{L,t}$, prevailing at any moment has a long memory. It does not just reflect *current* interest rate conditions, but also past money market rates, past interest rate expectations and past risk premia, as embedded in the stock of outstanding contracts. This stock will contain a mix of loans with different maturities and different interest rate types (fixed or floating and, if floating, indexed to different rates).[10] Thus, at any given point in time, the relevant rate, and the debt service ratio, are influenced by current *and* past monetary policy decisions. Our rate differs from those typically found in the literature, such as the interest rate on new lending, which have no such memory.

1.2 The VAR system: data, estimation and results

We now turn to the details of the estimation results. Throughout the paper, we use quarterly time series for the United States from 1985 Q1 to 2015 Q1. The data sources are listed in Table A2.1 in Annex 2.

Formal co-integration tests confirm the existence of the three co-integrating relationships in the data, with intuitive factor loadings (Table 1). First, as regards leverage, higher asset prices support higher credit-to-GDP ratios. And a unit long-run elasticity of the credit-to-GDP ratio with respect to the aggregate asset price index cannot be rejected at the 5% significance level. Second, as regards the debt service burden, a 1 percentage point reduction in the average lending rate allows borrowers to service an additional 5.5 percentage points of debt for the same income in the long run, ie $\beta_{dsr} = 5.5$. This coefficient naturally depends on the mix of maturities and amortisation schedules. Finally, the results suggest that there is a constant mark-up in the long run, so that the average lending rate increases one-to-one with policy rates. Overall, the long-run relationships are very robust and do not depend on the boom-bust cycle that took place around the Great Financial Crisis.

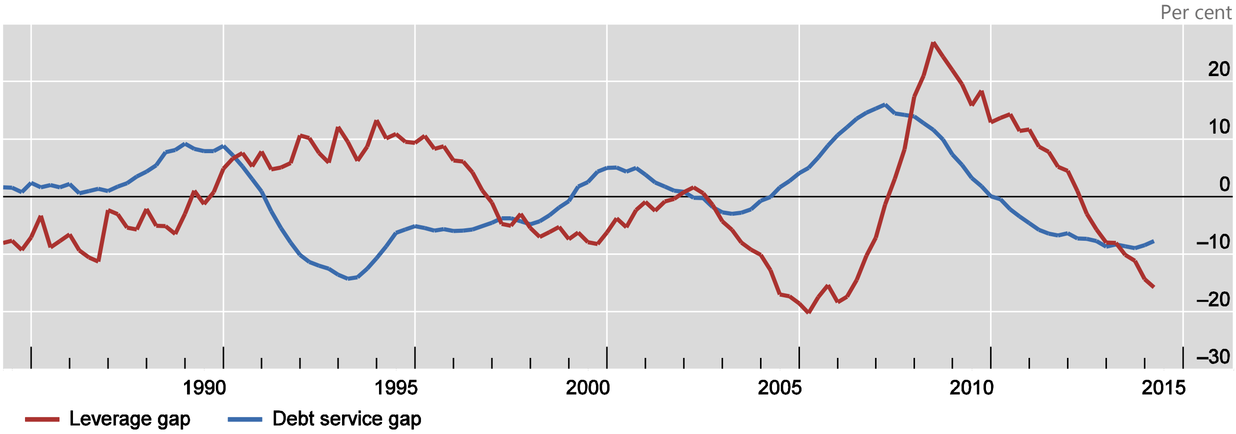
[10] For some cross-country information on these arrangements and a discussion of their importance in the transmission mechanism, see eg Borio (1996) and Angeloni and Ehrmann (2003).

Results for the long-run relationships[1]				Table 1
		Rank test statistics[2]		
Rank	0	1	2	3
p-value	0.00***	0.00***	0.02**	0.16
		Co-integrating vectors		
	$(cr-y)_t$	$p^r_{A,t}$	$i_{L,t}$	i_t
β_{lev}	1	-1[(3)]	-	-
β_{dsr}	1		5.54***	-
β_{spr}	-		1	-1[(3)]

[1] Stars indicate the level of significance, where ***/**/* correspond to the 1%/5%/10% significance level. [2] Rank test: p-values of the null hypothesis that the rank is less or equal to the specific integer. [3] Coefficient restricted to -1, which cannot be rejected. Test statistics are reported in Annex 2.

Graph 2 depicts the evolution of the corresponding leverage and debt service gaps (ie equations (1) and (2)). The debt service gap was large and positive before and during the three recessions in our sample, in particular for the most recent one. By contrast, the leverage gap was very low during the commercial real estate and leveraged buy-out (LBO) boom in the late 1980s and the housing boom in the mid-2000s. This simply reflects the fact that asset prices tend to run ahead of the credit-to-GDP ratio during booms, even as this ratio increases beyond historical trends.[11] In other words, while the credit-to-GDP ratio soars during a credit boom, the leverage gap, as measured here, actually declines, because asset prices increase even more. This also makes borrowers look deceptively solid in the boom phase.

Evolution of the leverage and debt service gaps — Graph 2



Source: Authors' calculations.

[11] Similar dynamics arise if raw measures of leverage and the debt service burden are constructed from the flow of funds (Annex 1).

The adjustment coefficients to the leverage and debt service gaps capture the key interactions between the financial cycle and the real economy. These are shown in Table 2, which also presents the estimated monetary policy impact through the lending spread, $\widetilde{spr}_t$. The full system is shown in Table A2.2 in Annex 2.

The results highlight that the financial cycle has sizeable real effects. A debt service burden that is above its long-run equilibrium – a positive debt service gap – depresses output growth (coefficient of -0.031 on $\widetilde{dsr}_{\,t-1}$ in the $\Delta e^r_{P,t}$ equation). This is consistent with micro-econometric evidence that high debt service ratios depress investment and consumption.[12] Such a gap also reduces real credit and asset price growth (columns Δcr^r_t and $\Delta e^r_{P,t}$ in the $\widetilde{dsr}_{\,t-1}$ row). A leverage ratio that is above its long run equilibrium – a positive leverage gap – reduces credit growth substantially (column Δcr^r_t in $\widetilde{lev}_{\,t-1}$ row) and, through this, affects output.

Monetary policy influences the economy through two main channels. First, it affects expenditures through the lending rate (column $\Delta i_{L,t}$ in $\widetilde{spr}_{\,t-1}$ row). This, in fact, turns out not to be too sizeable. Second, and most importantly, it affects them indirectly, through its impact on the financial cycle. Here, the most critical channel is its effect through the lending rate on the debt service gap (column $\Delta i_{L,t}$ in $\widetilde{dsr}_{\,t-1}$ row), which has a sizeable impact on growth.

Main coefficients of the VAR system[1]

Table 2

	$\boldsymbol{\Delta cr^r_t}$	$\boldsymbol{\Delta e^r_{P,t}}$	$\boldsymbol{\Delta e^r_{O,t}}$	$(\boldsymbol{\Delta y^r_t})^2$	$\boldsymbol{\Delta p^r_{A,t}}$	$\boldsymbol{\Delta \pi_t}$	$\boldsymbol{\Delta i_{L,t}}$	$\boldsymbol{\Delta i_t}$
Adjustment coefficients to long-run deviations								
$\widetilde{lev}_{\,t-1}$	-0.018***							-0.007***
$\widetilde{dsr}_{\,t-1}$	-0.029***	-0.031***	0.047**	*(-0.017)*	-0.086**		-0.002**	-0.009**
$\widetilde{spr}_{\,t-1}$					0.754***		-0.029***	0.093**
Short-run dynamics								
Δcr_{t-1}		0.103**		*(0.084)*	0.606***	0.078***	0.024***	
Δcr_{t-2}	0.351***					-0.059***		
Δcr_{t-3}	0.371***		0.631***	*(0.114)*			-0.022***	
Δi_{t-1}							0.102***	0.953***
Δi_{t-2}					2.361***		-0.048**	-0.229***

[1] Only significant coefficients are displayed. The complete results are shown in Table A2.2 in Annex 2. [2] The coefficients for the growth rate of real output (Δy^r_t) are calculated as ω times the coefficient on $\boldsymbol{\Delta} e^r_{P,t}$ plus $(1-\omega)$ times the coefficient on $\boldsymbol{\Delta} e^r_{O,t}$., where ω is the average share of private sector expenditure in GDP over the whole sample (82%).

To better understand the dynamics of the VAR system and the impact of policy, we conduct two experiments. Both start from a -10% negative leverage gap. In the first experiment, we let monetary policy react to the gaps in line with the estimated historical reaction function. In the second, we keep the policy rate fixed. Obviously, neither experiment is a standard impulse response analysis, since we do not identify the specific structural shocks that drive the system, ie the shock(s) leading to a negative gap. Instead, our main aim is to tease out the system's basic dynamics

[12] The negative effect of a high debt service burden on household consumption has been shown by eg Johnson and Li (2010) and Dynan (2012). Corporate investment, on the other hand, has been found to be sensitive to cash flows, which in turn are strongly influenced by debt service payments and hence by the debt service burden (eg Rauh (2006), Campello et al (2011), Chaney et al (2012)).

starting from similar values of the leverage gap that prevailed during the booms in the late 80s and mid-2000s (at their trough, -11% in 1987 and -20% in 2006).

The second experiment is more challenging and relies on two assumptions. First, we re-estimate the VAR conditioning on the policy rate, in essence assuming that it is exogenous (the exact specification and coefficient estimates are discussed in Annex 3, Table A3.1). But given that the policy rate is in fact endogenous, our estimates of its contemporaneous effect on the other variables must be biased to some extent. While we do not attempt to properly address this endogeneity issue, we note that the effect of the contemporaneous terms is very small compared to the overall effects of the policy rate in the system.[13] Hence, this aspect is unlikely to alter the conclusion much. Second, and more important, we assume that the parameters of the rest of the system remain constant even as we hold the policy rate fixed, in essence changing the implicit monetary reaction function. This is obviously at odds with the Lucas critique – an issue we discuss in greater depth in Section 3.2. Acknowledging these big caveats, we proceed with the experiments.

In the first experiment, which is based on the estimated monetary policy reaction function, a negative leverage gap initially induces a credit boom that then turns into a bust (Graph 3; the dynamic adjustments for all the other variables are shown in Graph A2.1 in Annex 2). Initially, the negative leverage gap is followed by rapid credit growth, which in turn feeds into a positive, albeit small, increase in private sector expenditure. But as credit outgrows output, the credit-to-GDP ratio and with it the debt service gap start to rise, putting an increasing drag on output and asset prices. A severe and drawn-out recession follows.

These dynamics, it turns out, enable the VAR to trace quite well the behaviour of output around the Great Recession. As shown in Juselius and Drehmann (2015), at the start of 2005, the real-time estimate of the leverage gap was significantly negative while the debt-service gap was positive. Given this starting point, the adjustment dynamics of the system would have predicted much of the subsequent output decline during the Great Recession. This suggests that the recession was not a "black swan" caused by an exogenous shock but, rather, the outcome of the endogenous dynamics of the system – a reflection of the interaction between the financial factors and the real economy.

Once monetary policy is blocked off in the second experiment, the economy adjusts to negative gaps through more drawn-out cycles lasting around 20 years. Even after 40 years, the system has not yet returned to its steady state. This contrasts with the case above, whereby policy rates are initially raised during the financial boom and then lowered aggressively during the bust. This helps to stabilise the economy, even though the initial cycle still lasts 10 years. Clearly, countercyclical monetary policy can help to dampen the boom-bust cycle.

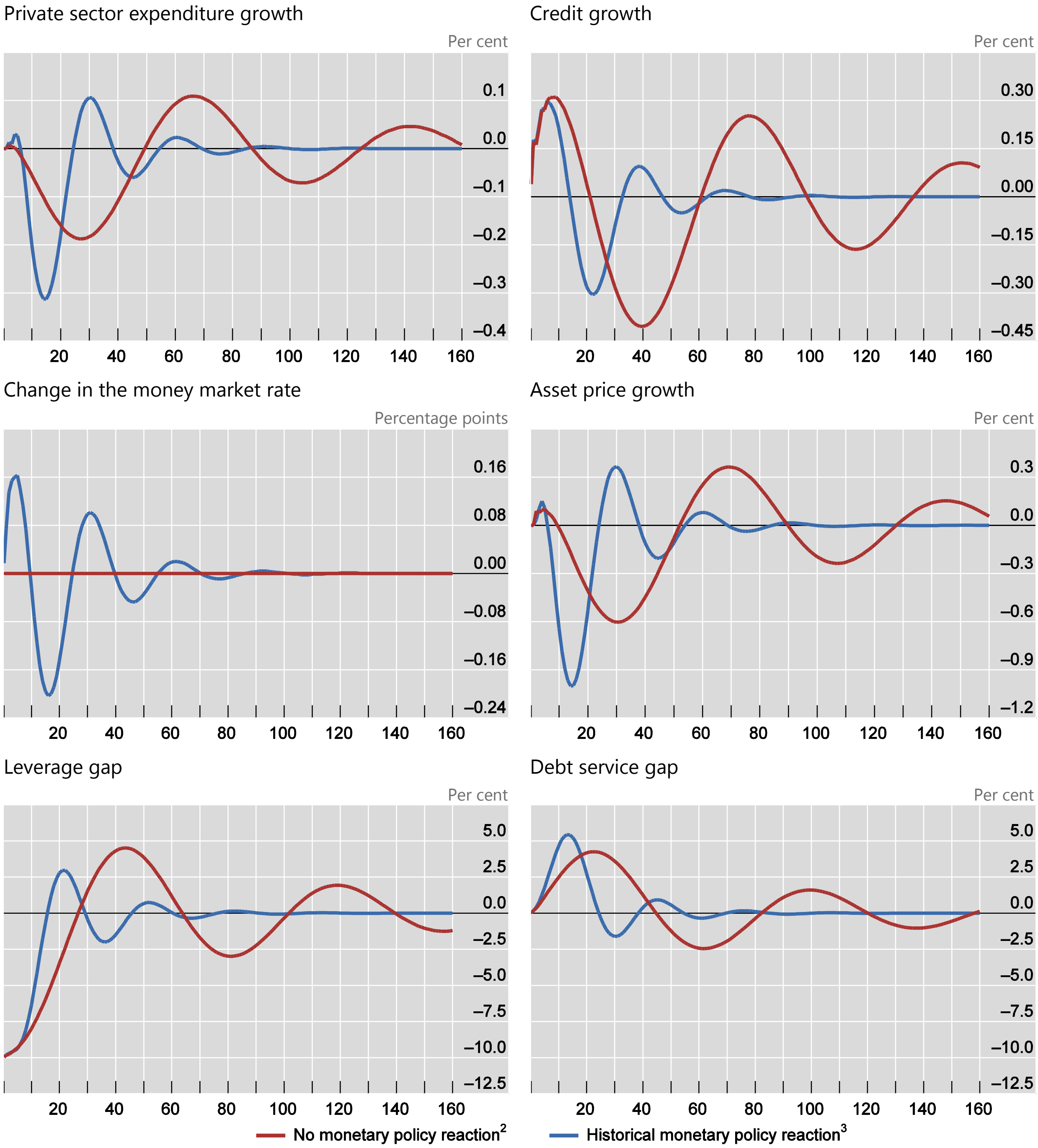
Digging deeper into the results reveals some further key features of the system.

First, even when monetary policy is allowed to react, the boom-bust financial cycle has *permanent* effects on output – monetary policy is not neutral (Graph 4). This, of course, means that potential output slows down temporarily. Intuitively, before the economy can start to grow again, it has to take a pause to "digest" the debt overhang

[13] We reach this conclusion by comparing the impulse responses from the system in Table A3.1 with those obtained by setting the coefficients on contemporaneous changes in the policy rate to zero.

The financial cycle drives economic fluctuations

Dynamic adjustment to a -10% leverage gap[1] Graph 3



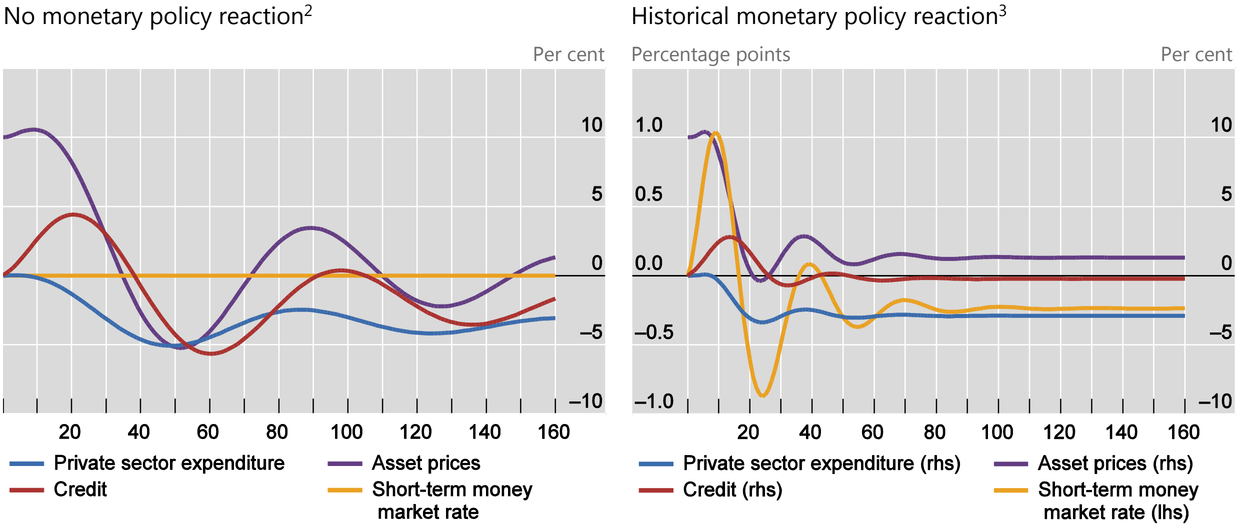
[1] VAR implied adjustment from a -10% leverage gap. All other variables are initially zero. [2] The results for the "no monetary policy reaction" are based on the VAR when policy rates are exogenous (Annex 3). [3] The results for the "historical monetary policy reaction" are based on the VAR when policy rates are endogenous (equation 3).

Source: Authors' calculations.

the previous boom left – hence the well-known "creditless" recoveries highlighted in the literature of credit crises (eg Calvo et al (2006), Tang and Upper (2010)). But there is nothing in the system requiring low output growth today to be offset by higher growth in the future: the system simply pins down long-run equilibrium relationships for the credit-to-GDP ratio, not for GDP itself. As a result, the economy does not converge back to a specific trend output level. Assuming that potential and actual output eventually converge – as most models require them to – this implies that potential output growth has to slow down temporarily.

The long-run impact of monetary policy

The change in levels following a -10% leverage gap[1] Graph 4



[1] VAR implied adjustment from a -10% leverage gap. All other variables are initially zero. [2] The results for the "no monetary policy reaction" are based on the VAR when policy rates are exogenous (Annex 3). [3] The results for the "historical monetary policy reaction" are based on the VAR when policy rates are endogenous (equation 3).

Source: Authors' calculations.

The permanent impact on output is sizeable. The impulse responses suggest that private sector expenditure drops by around 3 percentage points in the long run after a -10% leverage gap. Now, at the height of the credit boom in the mid-2000s the leverage gap was as low as -20%. This would explain around half of estimated post-crisis output losses.[14]

Second, given the monetary policy reaction function implicit in the data, the boom-bust also ushers in permanently lower policy rates (right-hand panel, Graph 4). Output drops permanently but debt increases, boosting the long-run credit-to-GDP ratio. Since in equilibrium all gaps must be zero, interest rates have to be lower in order to close the debt service gap. In this sense, low rates, which encourage the boom, beget lower rates.

All this suggests that the system's dynamics hinge critically on the systematic behaviour of monetary policy – as well as that of the other policies that impact on the financial cycle, not least prudential policy. There is nothing really pre-ordained about the amplitude and length of the financial cycle or about its interaction with the real economy. This endogeneity of the financial cycle with respect to policy regimes is critical (eg Drehmann et al (2012), Borio (2014)). In the last section, we return to this issue.

[14] Losses are offset by an increase in other expenditure, so that a -20% leverage gap is estimated to reduce output permanently by around 3%. Ball (2014) finds that potential output in the United States dropped by 5.3% after the most recent crisis. Studies surveyed in BCBS (2010) find that output drops permanently by around 7-10% in the aftermath of a banking crisis.

A couple of further points are worth highlighting.

These results are not an artefact of the Great Recession, and hence specific to it (Annex 6). The estimates determining the long-run relationships are quite robust. Estimating the gaps recursively starting in 2003 Q1 by successively expanding by one quarter, the difference between the full sample leverage gap and those estimated over the subsamples is at most 2.5 percentage points. The stability of the debt service gap is even greater. Throughout the sample, the corresponding difference is at most 1.6 percentage points. Equally, the VAR coefficients are very stable. Despite the Great Financial Crisis and the Great Recession, differences between quasi-real-time and full sample estimates of the loadings on the gaps and the spread are never statistically significant, except in one case (Graph A6.2a-c).

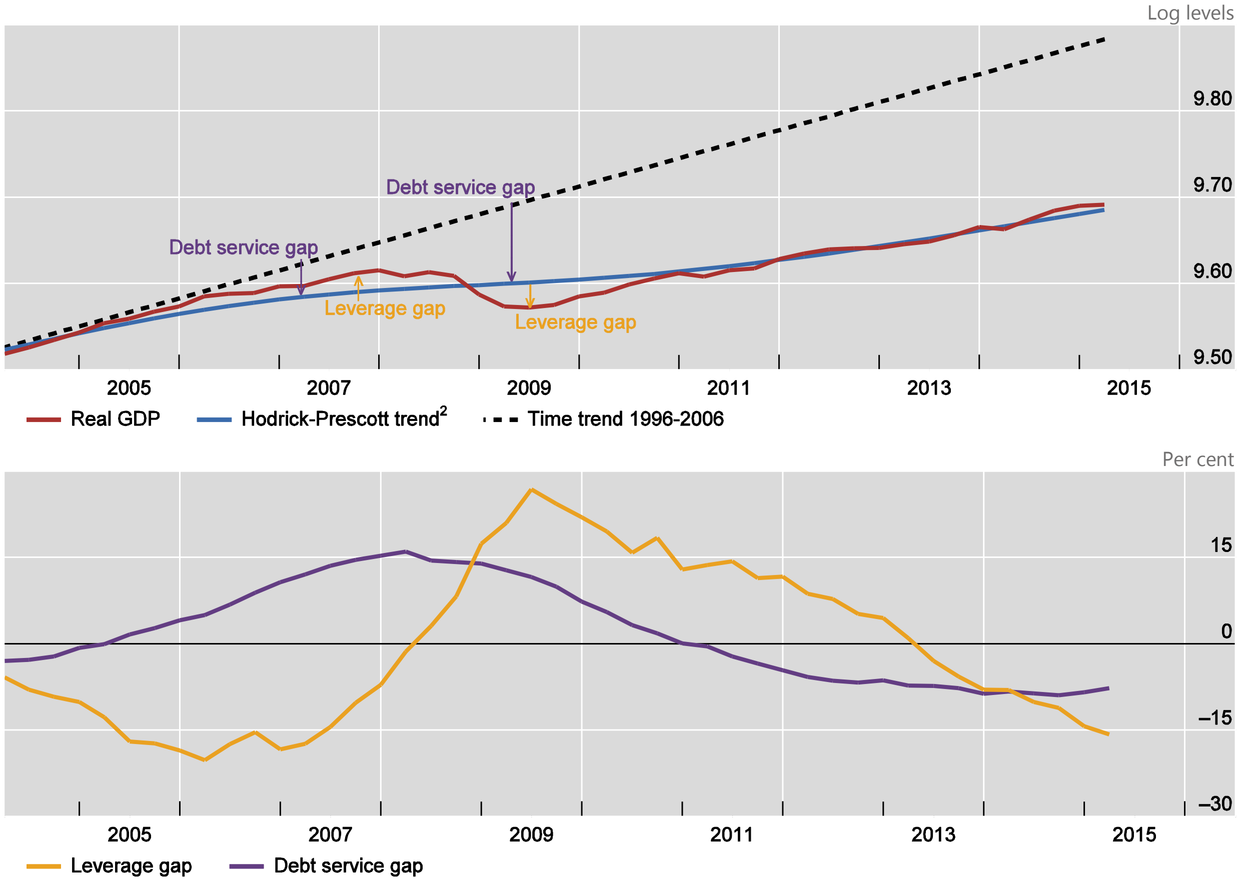
The system is not structural. Among other things, it may be tempting to think of the dynamics as being simply driven by aggregate demand, but this is clearly not the case. The system is silent about what is happening on the economy's supply side in the background. The evolution of the two gaps, not least that of the debt service gap, can hide a lot of action. For instance, recent research has found that credit booms tend to sap productivity growth, largely by inducing shifts of resources (labour) into lower productivity growth sectors, and that the impact of these (mis)allocations becomes much larger if a crisis subsequently follows (Borio et al (2015)). These factors could help explain, in particular, the long-lasting or permanent post-recession output losses.

2. The financial cycle, potential output and the natural interest rate

We next turn to the estimation of the unobserved variables such as potential output and the natural rate of interest, which are critical to understand the economy's sustainable path and alternative policies. If financial factors play an important role in driving economic fluctuations and contain information about the economy's cyclical variations, then ignoring them is bound to provide less accurate estimates of sustainable trajectories and trends. Thus, in this section we build on previous work, which has found that financial cycle proxies can help improve the estimation of potential output (eg Borio et al (2013, 2014), Arseneau and Kiley (2014), Kiley (2015)).[15]

[15] Arseneau and Kiley (2014) find that credit and house price developments are very important for estimating potential output and the natural unemployment rate. Kiley (2015) finds that the co-movement of output, inflation, unemployment and real interest rates, on its own, is too weak to yield precise estimates of the natural interest rate. Including credit spreads greatly improves inference. This is consistent with work by Gilchrist and Zakrajsek (2012), who document the role of credit spreads in output fluctuations. More generally, there is a large theoretical literature indicating that financial factors should contain information about output fluctuations, including the seminal work by Bernanke et al (1999) and Kiyotaki and Moore (1997), which emphasises the role of collateral constraints, captured by our leverage measure.

The effects of the leverage and debt service gaps on output[1] Graph 5



[1] Stylised representation of how the leverage and debt service gaps may impact trend output and the output gap. Real output ahead of the crisis was roughly on its previous 10-year trend, while a trend based on a two-sided HP filter indicates that output was running ahead of potential before 2009. Given the opposing effects of the debt service and leverage gaps in this phase, this suggests that the leverage gap is influencing the output gap while the debt service gap may affect trend output (see arrows). After 2009, both gaps push in the same direction. [2] Based on a two-sided HP filter with a standard smoothing factor of 1600.

Sources: National data; authors' calculations.

The build-up to the recent crisis gives a sense of how the financial cycle as measured by the leverage and debt service gaps may provide information about potential output and the output gap (Graph 5). During 2005 and 2006, output seemed to be on its previous 10-year trend. But, below the surface, the seemingly normal output growth reflected a precarious balance between two offsetting forces – the boost from the negative leverage gap and the drag from the positive the debt service gap. As the process continued, the drag from the debt service gap also reduced asset prices, pushing up the leverage gap, which turned positive. The positive debt service gap, which persistently dampens activity, captures well the eventual permanent drop in output, whereas the leverage gap hides this cost during the boom and exaggerates it during the bust. This suggests that the leverage gap is a good indicator of the *cyclical* fluctuations in output – the *output gap* – while the debt service gap may contain information about its underlying *trend*, or *potential output*. This is also consistent with previous work, which suggests that credit and property prices – the key components of the leverage gap – are very useful indicators of the output gap *in real time* (Borio et al (2013)).

This contrasts with mainstream approaches for estimating output gaps, including the Hodrick-Prescott (HP) filter and models that rely on inflation as the key signal of slack. With output seemingly moving along trend pre-crisis, a standard HP filter, for example, could not identify in real time that it was exceeding its sustainable level. The filter could do so only ex-post, after the recession occurred, as it rewrote history by re-estimating the trend. Moreover, since inflation was roughly stable pre-crisis, it could not provide much additional information to help estimate the output gap either. Hence the failure of such measures in real time as documented in Borio et al (2014).

2.1 The filtering system: key features

In this spirit, we construct a filtering system that allows financial factors to play a role in business fluctuations and then jointly estimate what might be termed the "finance-neutral" natural interest rate and potential output – in the sense that the estimates control for the influence of financial factors. As a baseline, we use a version of the standard framework by Laubach and Williams (2003). Our strategy is to modify this baseline as little as possible to take into account the financial-real linkages the VAR model has unveiled. Our more comprehensive system nests the standard framework.

The baseline system consists of four key equations. First, there is a reduced-form IS equation linking the output gap (ie the difference between actual output, y_t, and potential output, y_t^*) to the difference between the real rate, $r_t = i_t - E_t\pi_{t+1}$, and the natural rate, r_t^* (the interest rate gap). For simplicity, we assume that expected and actual inflation coincide, ie $E_t\pi_{t+1} = \pi_t$, throughout.[16] Second, there is a standard HP specification for potential output. The specification is very flexible and can even accommodate a trending growth rate, but we later impose technical restrictions that anchor it to actual output over the medium to long run. Third, there is a Phillips curve, which includes an inflation target, π^*. Finally, there is an equation linking the natural interest rate to the growth rate of potential output and a term, z_t, capturing other determinants of the natural rate, such as the rate of time preference. The system is closed with an equation describing the evolution of z_t.

With these choices, the baseline system, shown in black, becomes

$$y_t - y_t^* = \beta_5(y_{t-1} - y_{t-1}^*) - \varphi_{51}(r_t - r_t^*) - \varphi_{52}\widetilde{lev}_t + \vartheta_{5t} \quad (5)$$

$$y_t^* = 2y_{t-1}^* + y_{t-2}^* + \vartheta_{6t} \quad (6)$$

$$(\pi_t - \pi^*) = \beta_7(\pi_{t-1} - \pi^*) + \varphi_7(y_t - y_t^*) + \vartheta_{7t} \quad (7)$$

$$r_t^* = \beta_8 r_{t-1}^* + (1 - \beta_8)(z_t + \frac{1}{\rho}4\Delta y_t^*) + \vartheta_{8t} \quad (8)$$

$$z_t = \beta_9 z_{t-1} + \vartheta_{9t} \quad (9)$$

$$\widetilde{lev}_t = \beta_{10}\widetilde{lev}_{t-1} + \varphi_{101}(r_t - r_t^*) + \varphi_{102}\widetilde{dsr}_{t-1} + \vartheta_{10t} \quad (10)$$

where $\vartheta_{it} \sim iid(0, \sigma_i^2)$, the quarterly potential growth rate in (8) is multiplied by 4 to annualise it.

[16] This is similar to Laubach and Williams (2003), who use a weighted average of current and past inflation rates as a proxy for expected inflation.

Our extension relative to the baseline system is shown in red.[17] In line with our VAR results, we adjust the baseline system to allow for the possibility that the leverage gap contains information about the output gap. If one thought of the corresponding equation, (5), as a typical reduced-form expenditure function, then leverage – the ratio of assets to debt – could be regarded as a (crude) proxy for the incidence of collateral constraints. The specification dovetails with previous work, in which the growth rates of credit and (residential) property prices were found to greatly improve the estimates of potential output (Borio et al (2013, 2014)). The leverage gap can be seen as a more structured way of capturing the same information.

A first glance at the data are promising. The leverage gap and an output gap based on the two-sided HP filter are highly negatively correlated – a correlation of -0.6 in our sample. The correlation with inflation is considerably lower, at -0.18.

If the leverage gap is informative for the output gap (ie $\varphi_{52} > 0$), we also need an equation that characterises its evolution, (10). The corresponding formulation is intuitive. Since the leverage gap drives a wedge between actual and potential output, it is reasonable to relate it to deviations between the actual and natural real interest rates. Rates above the natural rate should decrease asset prices or output, which in turn increases the leverage gap. In addition, we know from the VAR dynamics that the debt service gap feeds negatively into asset price growth and, hence, affects the leverage gap positively. These aspects are captured in (10).[18]

Given the prominent role of the debt service gap in the VAR, why not include it also elsewhere? We could do so. A natural place would be in the state equation for potential output growth, (6). As the VAR suggests, a high debt service gap would at some point tip an economy into a recession. As the necessary adjustment took place, the economy would slow down before it started growing again, possibly leaving in its wake a permanent output loss. This would show up as a *temporary* slowdown in potential growth, as the estimate of potential subsequently catches up with actual output.

So as to keep the changes to the baseline filter to a minimum, we avoid this modification. However, such a specification would help provide a clearer channel for monetary policy to affect output in the long run. That is, it could proxy for the factors that lead to permanent output losses, regardless of the specific mechanisms at work. In Annex 4 we show that using it yields an output gap that is smaller in magnitude but otherwise similar.

Equations (5) to (10) completely describe the filter. By contrast, if we thought of the system as part of a more complete "model" of the economy, we would also need to "close it" by specifying equations for the debt service gap, the lending rate and the policy rate. However, since the first two of these do not contain any unobservables, they do not add value to the filter. Thus, we describe a possible way to close the model, consistent with the VAR results, in Annex 5, and leave the discussion of possible policy rules to the next section.

17 In addition, our system has a less elaborate autoregressive structure and we link potential output and the natural rate directly rather than adding an additional equation for potential output growth. This, however, does not affect the results.

18 An additional benefit of using an observable variable (the leverage gap) to relate monetary policy and real outcomes in (5) is that it helps to anchor potential output and the natural rate in the filter.

2.2 The filtering system: estimation

A clear advantage of nesting the standard Laubach-Williams framework in a more general specification is that we can simply allow the data to speak. Thus, we leave it to the data to decide whether the leverage and debt service gaps have any additional information content for potential output and the natural rate of interest. In particular, if the leverage gap is irrelevant in the output gap equation (ie $\varphi_{52} = 0$), then the leverage equation, (10) also becomes redundant. In that case, neither the leverage nor the debt service gap would help estimate potential output and the natural rate of interest.[19]

We estimate the parameters of the system (5)-(10) using a Bayesian approach with relatively weak priors. We assume that all β_j parameters follow the gamma distribution with mean 0.7 and standard deviation 0.2. To ensure that the output gap is strictly stationary, we restrict β_1 to lie in the interval between 0 and 0.95, whereas we allow the other autoregressive parameters to take any value in the unit interval. For the φ_j parameters we assume the gamma distribution with mean 0.3 and standard deviation 0.2 and that they are positive. The prior for the inflation target, π_t^*, is also gamma-distributed, with mean 2 and standard deviation 0.2. Rather than estimating the discount rate, ρ, we set it to 0.99, in line with the literature.

We use the inverse gamma distribution for the shock variances. We rely on historical variances of the first difference of HP-filtered output, inflation and the leverage gap to calibrate the prior means of σ_{6t}^2, σ_{7t}^2 and σ_{10t}^2, respectively, as well as on the variance of HP-filtered output growth (as a baseline for the natural rate) for the prior means of σ_{8t}^2 and σ_{9t}^2. We set the standard deviation to 0.5 for all of them. Furthermore, to ensure that the output gap captures conventional business cycle frequencies, we fix its variance in relation to the variance of potential output.[20]

Before turning to the estimates of potential output and the natural rate of interest, it is worth dwelling on some of the key coefficient estimates (Table 3).

The posterior estimates reveal that the leverage gap is an economically more important output gap driver than the standard real interest rate gap. The estimated coefficients (φ_{51} and φ_{52}) are broadly similar. But in the sample the interest rate gap varies between -3.5 and +1.5 percentage points. The leverage gap, by contrast, ranges from-20 to +27%, which translates into a -1.4 to +1.9 direct effect on the output gap. Moreover, the leverage gap is more persistent, leading to much higher long-run effects.

This suggests that the leverage gap is an important output gap driver and one of the main channels through which monetary policy can influence the real economy. But how effective is the interest rate as a tool for controlling the gap? The answer is not very effective on impact, but considerably over time. The coefficient estimate of the real interest rate gap in (10), φ_{101}, is about 0.11. Given the leverage gap range, this is not large. For example, to increase the leverage gap by 1 percentage point *on impact*, the real interest rate would need to be about 10 percentage points above the

19 Even if $\varphi_{52} = 0$, the leverage gap might still help pin down the natural rate if $\varphi_{101} > 0$.

20 In particular, we set the scaling parameter $\lambda = \sigma_{1t}^2/\sigma_{2t}^2$ in such a way that the ratio between the sample variance of the output gap and the acceleration of potential output is similar to that of the HP filter. This gives approximately the same frequency cut-off for the business cycle as in the HP case. The two filters coincide if $\beta_1 = \varphi_{11} = \varphi_{12} = 0$. See Borio et al (2014) for an in-depth discussion of these restrictions.

natural rate. Nevertheless, the leverage gap's high degree of persistence ensures that the effect is eventually sizeable.

Posterior estimates for the parameters in the reduced form system[1]

Table 3

Equation	Explained	Parameter (loading on)	Prior	Prior std	Posterior	Posterior std
(5)	$y_t - y_t^*$	β_5 $(y_{t-1} - y_{t-1}^*)$	0.70	0.20	0.699	0.061
		φ_{51} $(r_t - r_t^*)$	0.30	0.20	0.059	0.046
		φ_{52} $(\widetilde{lev}_t)$	0.30	0.20	0.069	0.010
(7)	$(\pi_t - \pi^*)$	β_7 $(\pi_{t-1} - \pi^*)$	0.70	0.20	0.936	0.016
		φ_7 $(y_t - y_t^*)$	0.30	0.20	0.028	0.0087
		π^*	2.00	0.20	1.951	1.776
(8)	r_t^*	β_8 (r_{t-1}^*)	0.70	0.20	0.617	4
(9)	z_t	β_9 (z_{t-1})	0.70	0.20	0.632	0.286
(10)	$\widetilde{lev}_t$	β_{10} $(\widetilde{lev}_{t-1})$	0.70	0.20	0.979	0.017
		φ_{101} $(r_t - r_t^*)$	0.30	0.20	0.109	0.098
		φ_{102} $(\widetilde{dsr}_{t-1})$	0.30	0.20	0.149	0.033

[1] Results from estimating system (5)-(10) using a Kalman filter.

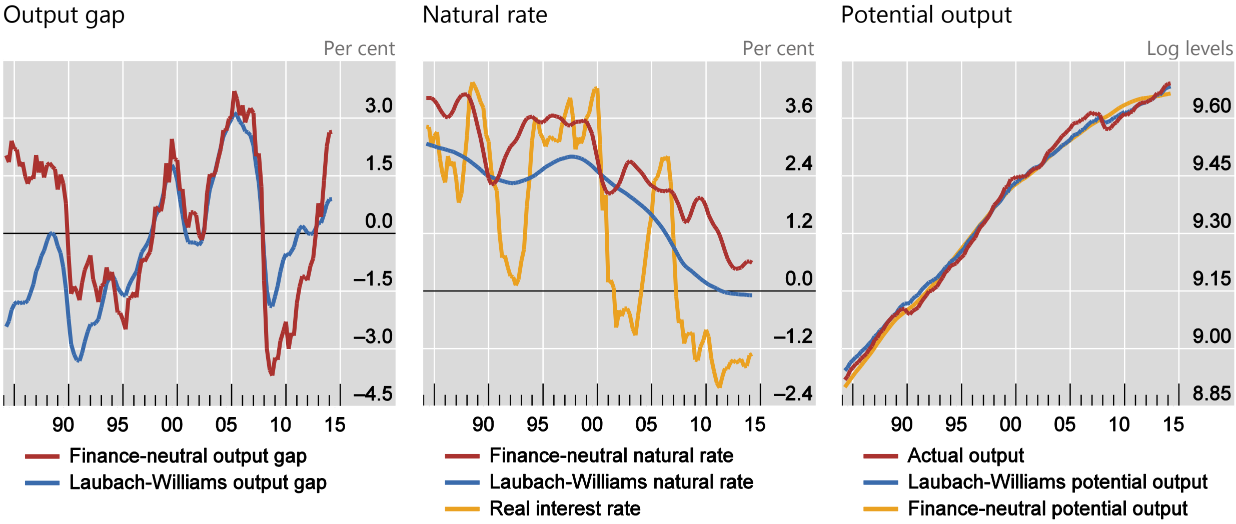
The estimates of equation (10) also reveal that the lagged debt service gap is an important driver of the leverage gap. Given its higher variance, its economic effect is about 10 times as large as that of the interest rate gap. Moreover, as the nominal policy rate is directly linked to the debt service gap, this may turn out to be one the most effective transmission channels.

The other equations do not deliver big surprises. The estimates of the Phillips curve, (7), seem reasonable. For instance, π^* is estimated to be 2%. The coefficient on the output gap is rather small, but this is consistent with the literature pointing to a weak link between domestic slack and inflation. Moreover, for much the same reason, as noted by Borio et al (2014), the relevance of the behaviour of inflation for potential output is marginal. Presumably, by extension, this also applies to the natural interest rate. Finally, the estimates for the z_t factor suggest that this component is clearly stationary and relatively small (see Graph A4.1).

2.3 The filtering system: results

It is instructive to compare our estimates of the output gap and the natural interest rate with those of Laubach-Williams (2015b) (Graph 6).[21]

The financial cycle: implications for the natural rate and trend output[1] Graph 6



[1] The finance-neutral variables are the result of estimating system (5)-(10). For the Laubach-Williams variables, we show the results of the two-sided filter using data until 2015 Q3 taken from Laubach and Williams (2015b).

Sources: Laubach and Williams (2015b); national data; authors' calculations.

Two points stand out with respect to the output gap (left-hand panel).

First, when estimated over the full sample, from the mid-1990s the two gaps move together. Recognising the financial tailwinds, our output gap measure clearly indicates that the economy was running above sustainable levels in the years leading up to the financial crisis. Conversely, output was below potential in the aftermath of the crisis on account of the substantial financial headwinds. The fact that output moved above potential towards the end of the sample reflects the significant support that financial factors provided to the US economy during that phase, with leverage and debt service below their long-run levels.

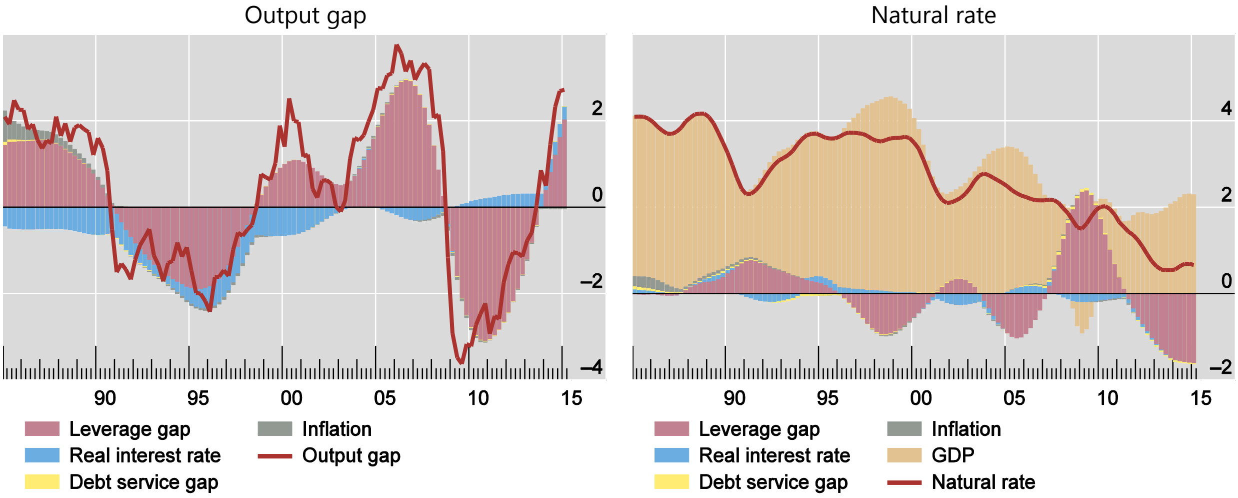
Second, in contrast to the Laubach-Williams output gap, which is persistently negative during most of the 1980s and 1990s, ours is positive ahead of the recession in the early 1990s and only negative afterwards. This is because a financial boom was under way at the time, qualitatively similar to the one that preceded the more recent crisis but smaller in size. Indeed, some banks faced serious strains in the early 1990s, and the expression "financial headwinds" was quite common (Greenspan (2004)).

A variance decomposition also provides a different perspective on the drivers of the output gap than what the standard literature would suggest. In particular, inflation contributes very little to the variance in the output gap in our specification (left-hand panel, Graph 7). The leverage gap is the main contributor, followed by the real interest rate gap.

[21] Note that these are two-sided, not real-time, estimates.

The financial cycle helps explain the variation in the output gap and the natural rate

Variance decomposition of the output gap and the natural rate, in per cent | Graph 7



Sources: National data; authors' calculations.

For present purposes, the focus is on the natural interest rate (middle panel, Graph 6). In particular, our estimate shows a decline from 4% to 0.6% over the last 30 years. This is in line with the downward trend in potential output growth (right-hand panel, Graph 6). Thus, given the tight specification, GDP accounts for most of the variance in the evolution of the natural rate (right-hand panel, Graph 7). Strikingly, actual interest rates have remained below the estimated natural rate for almost the whole period under study. Sharp interest cuts in response to financial crises in the early 1990s, early 2000s and 2008 were not taken back in the ensuing normalisation phase, suggestive of substantial policy asymmetry with respect to the financial cycle.[22]

By contrast, the natural rate estimated by Laubach-Williams is consistently below our estimates and is currently negative (middle panel, Graph 6). This reflects the close association of inflation with the output gap and the interest rate gap in the IS curve in the Laubach-Williams framework. In the early part of the sample, the downward trend in inflation leads to a persistently negative output gap and thus to an estimate of the natural rate that is generally below the real interest rate. Since the mid-90s, the Laubach-Williams estimates of the output gap fluctuate around zero. And given the IS curve, which depends only on the interest rate gap, the estimated natural rate must be below (above) the observed real rate, if the output gap is negative (positive). In contrast, our estimates are less sensitive to these factors, as the Phillips curve and the interest rate gap in the IS curve do not play such prominent roles.

Importantly for policy-making, our filtering system is quite robust in real time, confirming previous work on output gaps using financial information (Borio et al (2013, 2014)). At least the results suggest that this is so when we estimate the filter

22 In related work, Kiley (2015) finds that credit spreads contain important information for estimating equilibrium real interest rates, with such rates being more stable and higher when this information is taken into account (equal to approximately 1¼ % at the end of 2014). Hamilton et al (2015) focus on long historical averages of interest rates and find that real interest rates may be affected persistently over time by a host of factors, including financial regulation, inflation trends and bubbles. By their estimates, the natural real rate has fallen only slightly since the Great Financial Crisis and lies in the range of 1 to 2%.

using data only up to 2006 (Annex 6). Coefficients hardly change, so that we obtain very similar output gap and natural rate estimates even at the sharp end of the sample after 2004. This contrasts with Laubach and Williams (2015b).

As a prelude to the policy discussion below, it bears emphasising that the natural interest rate estimated here is the one associated with *full long-run equilibrium*: output, inflation and financial gaps are all closed. This is essentially a long-run perspective. But when the economy is not in long-run equilibrium, the interest rate must deviate from the natural rate in order to bring the system back into balance. Thus the natural rate that we estimate is a benchmark with which to judge policy but not a target for policy to track. That is, unless we start out in long-run equilibrium, the market interest rate must differ from the natural rate to compensate for the key gaps – output, inflation and financial ones. We next derive a systematic policy rule that promotes quicker convergence towards long-run equilibrium than traditional ones do.

3. The financial cycle and monetary policy

The VAR and the filtering system presented above illustrate two key properties of the economy. First, much of the cyclical movements in output, including those of durations longer than typical business cycles, can be attributed to financial factors. Second, financial developments may have a long-run impact on the level of economic activity. Recognising this would lead to a different design of stabilisation policies, not least that of monetary policy. In this section we take a preliminary step in exploring this. To do so, we propose a new monetary policy rule and evaluate it in an illustrative counterfactual experiment. Just like the exercise that fixes the policy rate in Section 1.2, this experiment comes with several caveats – the Lucas critique foremost among them. As such, it should at best be seen as indicative.

3.1 A counterfactual experiment: a new policy rule

We start from the popular Taylor rule and change it in two respects. First, consistent with our analysis, we allow the natural rate to change over time, ie the intercept in the rule is no longer a constant. This is quite standard.[23] Second, we augment it with a financial cycle indicator. The simplest way of doing this is to add the debt service gap. As the filter shows, the debt service gap closely influences the leverage gap and hence the output gap. In turn, the debt service gap is strongly influenced by policy (see equations (2) and (4) above). Thus, including it in the policy rule would be one way to increase traction over the financial cycle.

Hence, we analyse the following policy rule:

$$i_t = \left(r_t^* + \pi^* + 1.5(\pi_t - \pi^*) + 0.5(y_t - y_t^*) - \lambda\, \widetilde{dsr}_t\right) \quad (13)$$

[23] Carlstrom and Fuerst (2016) analyse this formally, in particular within a standard New Keynesian model, $r_t^* = r^* + \Delta prod_t$, where $\Delta prod$ is expected productivity growth. They then assess Taylor rules of the form $i_t = \left(r^* + \alpha(r_t^* - r^*) + \pi^* + 1.5(\pi_t - \pi^*) + 1(y_t - y_t^*)\right)$ and let α vary. In the absence of measurement error, $\alpha = 1$, but even if there are measurement errors in both the natural rate and the output gap, the optimal α is equal to 1.06.

We experiment with $\lambda \in [0, 0.25, 0.75, 1]$. If $\lambda = 0$ our rule collapses into the standard Taylor rule with a time-varying intercept that equals the natural rate.

This rule, however, is very myopic, as it abstracts from any effects policy has on the economy in the following periods, including on the leverage and debt service gaps. As a result, it could lead to unnecessarily large swings in real interest rates. To address this problem, we introduce some gradualism in (13). We smooth the interest rate by assuming a partial adjustment with coefficient $\rho = 0.9$, and we add a one-quarter lag in the policy response.[24]

This leads to the following specification:

$$i_t = \rho i_{t-1} + (1-\rho)\left(r_{t-1}^* + \pi^* + 1.5(\pi_{t-1} - \pi^*) + 0.5(y_{t-1} - y_{t-1}^*) - \lambda\, \widetilde{dsr}_{t-1}\right) \qquad (14)$$

3.2 A counterfactual experiment: estimation and results

To assess the potential benefits from monetary policy taking into account the financial cycle, we conduct a counterfactual exercise in which we combine the new policy rule with the filter and the variant of the estimated VAR in which we condition on the policy rate (Annex 3, Table A3.1).[25] We essentially ask what the evolution of the economy would have looked like from a given point in time if: (i) we followed the policy rule in (14), (ii) agents' behaviour remained invariant, so that the correlations embodied in the VAR did not change, and (iii) the economy was hit by the same historical shocks, including monetary policy shocks and the financial crisis. Put differently, differences between the counterfactual and historical outcomes are solely due to differences in the systematic policy interest rate path.

The assumption that agents' behaviour does not change as we change the systematic policy response is obviously at odds with the Lucas critique. This concern should not be understated. That said, we draw some comfort from past studies that have found the Lucas critique may be of limited relevance in practice.[26] For instance, a common finding is that the parameters of empirical VARs are remarkably stable despite changes in estimated policy equations in the sample (eg Favero and Hendry (1992), Leeper and Zha (2003), Rudebusch (2005)).[27] In the present context, we take some reassurance from the finding that the main parameters of our VAR model – notably the parameters of the long-run relationships, the loadings on their gaps and the equations for credit and private expenditure growth – are stable over both pre-

[24] As robustness check, we implemented a counterfactual from 2003 onwards in which the policy rate reacts more quickly to recent conditions, with $\rho = 0.8$. Swings in the nominal interest rate are therefore more pronounced, leading to somewhat lower output gains.

[25] The within-sample decline in the nominal policy rate generates a significant constant in its growth rate, as well as corresponding constants in credit-to-GDP and real asset price growth through the co-integration relationships between these variables. To avoid additional trending when we change the policy rate path, we also impose the co-integration restrictions on these constants in the VAR. As an additional check on the validity of these restrictions, we confirm that we can regenerate history for all of the system variables simply by setting the historical path for the policy rate in the counterfactual.

[26] Relaxing some of the strong assumptions that underpin mainstream monetary policy models could weaken the force of Lucas's argument even theoretically. For example, incorporating features such as rule-of-thumb agents, model uncertainty, ambiguity, incomplete information, multiple equilibria or constrained agents can have this effect.

[27] Linde (2001) and Lubik and Surico (2010) argue that these findings are due to the weak power of the stability tests. They find that changes in policy led to corresponding changes in the VAR parameters. But even if such changes can be detected statistically, they do not seem to be very large economically.

and post-crisis samples (Annex 6, Graph A.6.1a-c). This suggests, for instance, that the adoption of unconventional monetary policy tools post-crisis has not generated sizeable changes to the system's dynamics. To the extent that the adoption of these tools constitutes shifts in the monetary policy function, this provides indirect evidence against a strong Lucas critique effect in our sample.

Nevertheless, given that our counterfactual alters the monetary policy rule rather than just its coefficients, the Lucas critique may have more force in this context. Even then, at least two aspects are worth highlighting.

First, the Federal Reserve has seemingly reacted to debt service burdens in the past. For instance, it explicitly took debt service burdens into account when setting policy under Greenspan (Greenspan (1993)). In addition, we find some evidence that it has, directly or indirectly, reacted to a high debt service burden also more recently.[28] If so, our policy experiment would involve more a change in the intensity of the policy response than a fundamental change in the reaction function's shape.

Second, in some respects, an explicit acknowledgement of the Lucas critique might even strengthen our results. As explained below, monetary policy potentially has a large impact on output dynamics through its influence on the financial cycle. Were market participants to internalise the systematic response to financial developments, the policy's effectiveness in dampening the financial cycle could arguably be greater. To be sure, there is a possibility that this could come at the cost of lesser influence of inflation.

Despite these arguments, we fully acknowledge the shortcomings of our counterfactual exercise. On balance, given the potential changes in behaviour, our results can at best be seen as giving a rough indication of the benefits of a policy shift – a preliminary step that will need to be corroborated by further research and different approaches.

To implement the counterfactual experiment, we follow an iterative procedure, starting from a given point in the sample, t_0:

1. Derive the natural rate $r^*_{t_0-1}$ and the output gap $(y_{t_0-1} - y^*_{t_0-1})$ using the estimated filter.
2. Set policy rate for t_0 as $i_{t_0} = \rho i_{t_0-1} + (1-\rho)\big(r^*_{t_0-1} + \pi^* + 0.5(\pi_{t_0-1} - \pi^*) + 1(y_{t_0-1} - y^*_{t_0-1}) - \lambda\, \widetilde{dsr}_{t_0-1}\big)$ if this leads to $i_{t_0} > 0$ or set $i_{t_0} = 0$ otherwise.
3. Use the estimated VAR with exogenous policy rates (Annex 3) and generate predictions of all variables in the system for time t_0 conditional on the new policy rate, the retained errors ϵ_{t_0} and outliers Γs_{t_0}.[29]
4. Redo steps 1 to 3 for $t_0 + 1$, $t_0 + 2$... until the end of the sample.

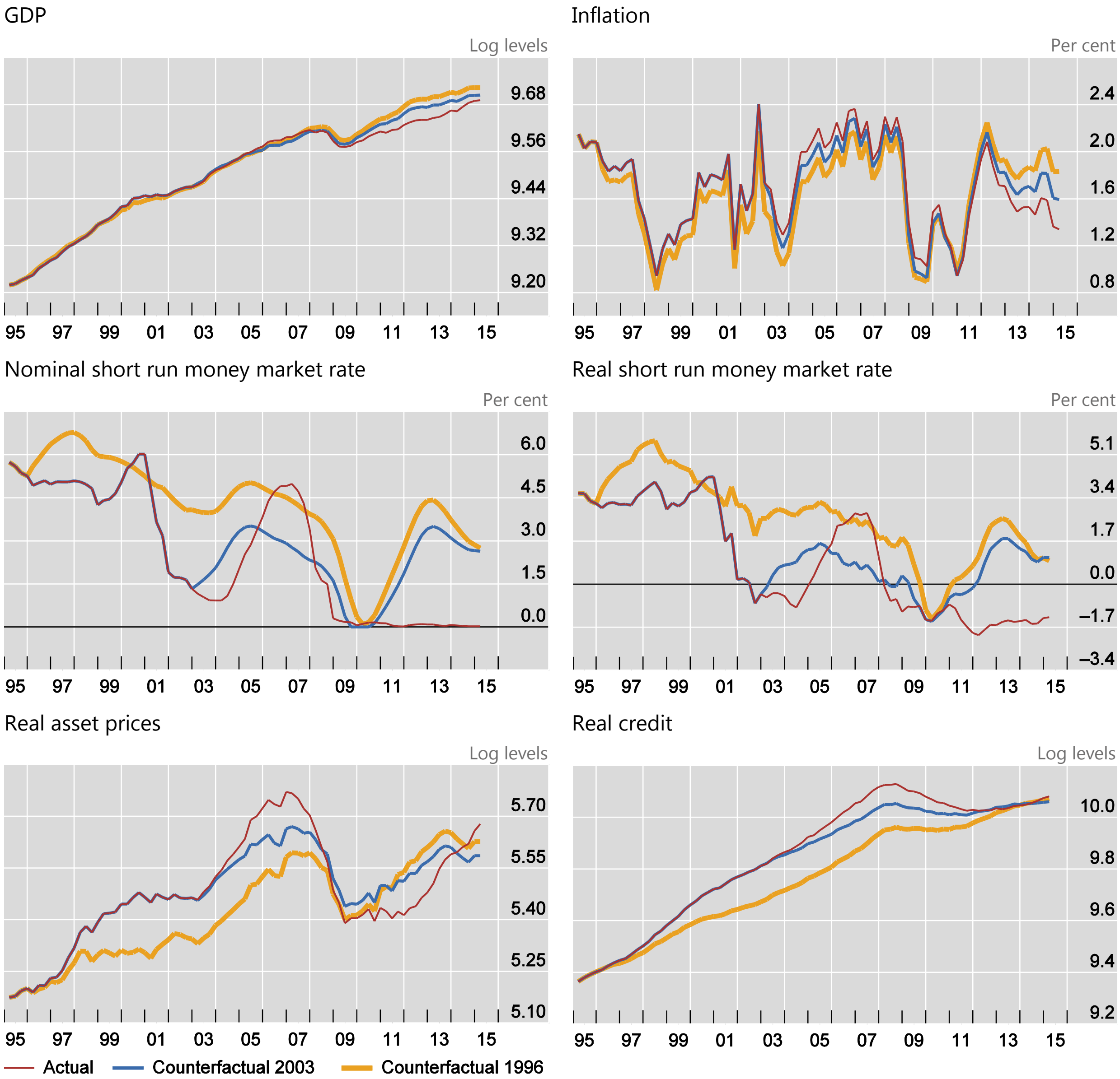
The various caveats notwithstanding, the counterfactual exercises generally find that the alternative policy rule potentially yields considerable output gains compared with actual history without significant costs in terms of inflation. Not surprisingly, the earlier in the sample the policy is implemented, the greater the benefits. To illustrate

[28] Cursory estimates of the central bank's reaction function over the sample period suggest a significant role for the debt service gap. Moreover, our counterfactual policy rule with λ=.25 is not far away from the historical behaviour of the policy rate (see below).

[29] The change in real output (Δy^r_t) in the counterfactual is calculated as ω_t times $\boldsymbol{\Delta} e^r_{P,t}$ plus $(1-\omega_t)$ times $\boldsymbol{\Delta} e^r_{O,t}$., where ω_t is the share of private sector expenditure in GDP in *t-1*.

this, we report the results from two counterfactuals, the first starting in 2003 Q1 and the second in 1996 Q1 (Graphs 8A-8B). In the base case, λ equals 0.75.

Leaning against the financial cycle improves outcomes[1] Graph 8A

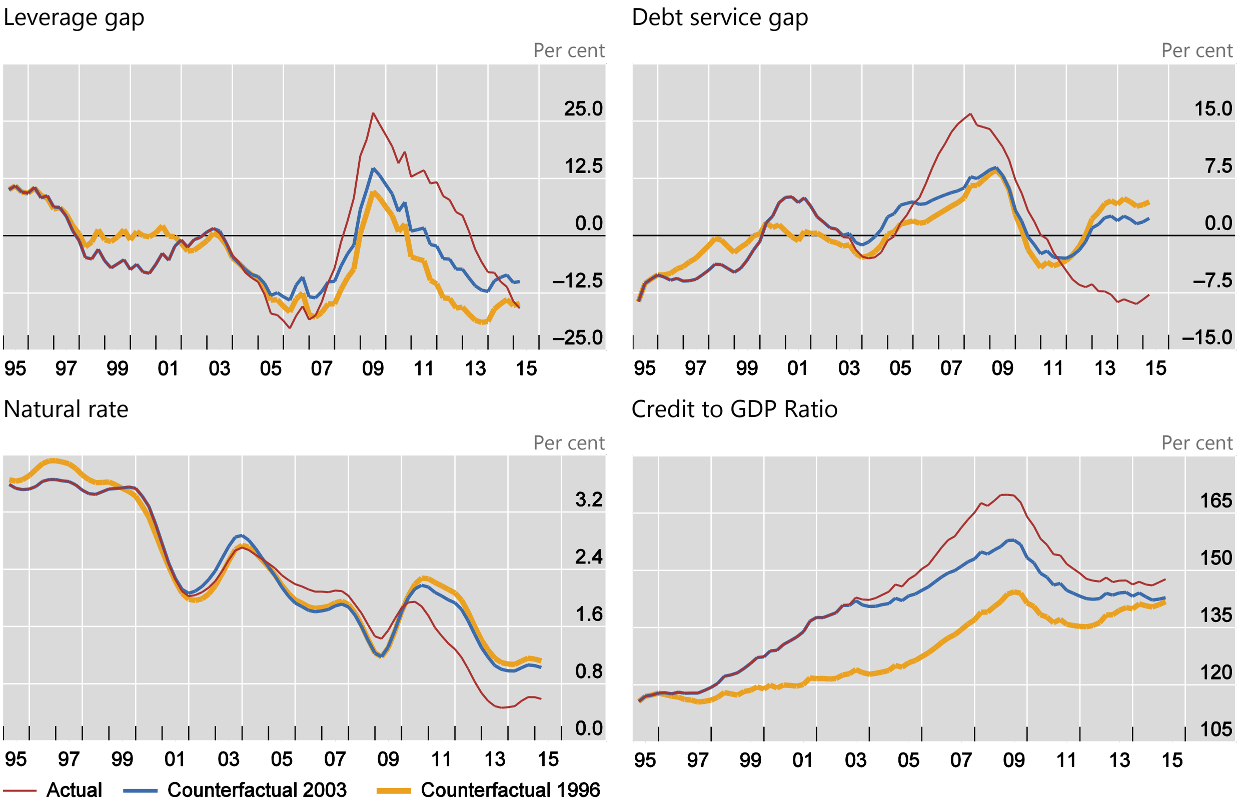


[1] In the counterfactual experiment, we set policy in line with an augmented Taylor rule that takes account of the finance neutral natural rate, the finance neutral output gap and the debt service gap in line with equation (14) with ρ=0.9 and λ=0.75. Results are based on the VAR system (3a, Annex 3) where policy rates are exogenous. We retain the historical errors and outliers of the VAR estimates to derive the evolution of the variables in the counterfactual. The counterfactual policy starts either in 2003 Q1 or 1996 Q1.

Sources: National data; authors' calculations.

If the policy starts in 2003, by the end of the simulation period the cumulative output gain is more than 12%, or nearly 1% per year (blue lines, top left-hand panel, Graph 8A). As both the debt service gap and the leverage gap are initially negative – the latter strongly so – the policy rule calls for leaning against the financial boom by raising rates (second row, left-hand panel, Graph 8A). This helps moderate the run-up in asset prices as well as credit growth (third row, Graph 8A) and hence the decline in the leverage gap (top left-hand panel, Graph 8B) and the increase in the credit-to-GDP ratio (bottom right-hand panel, Graph 8B).

Leaning against the financial cycle improves outcomes (cont)[1] Graph 8B



[1] In the counterfactual experiment, we set policy in line with an augmented Taylor rule that takes account of the finance neutral natural rate, the finance neutral output gap and the debt service gap in line with equation (14) with ρ=0.9 and λ=0.75. Results are based on the VAR system (3a, Annex 3) where policy rates are exogenous. We retain the historical errors and outliers of the VAR estimates to derive the evolution of the variables in the counterfactual. The counterfactual policy starts either in 2003 Q1 or 1996 Q1.

Sources: National data; authors' calculations.

With the rising credit-to-GDP ratios and higher rates, the debt service burden starts to rise in early 2004 (top right-hand panel, Graph 8B). Given our policy rule, interest rates are reduced from early 2005. These steps cannot prevent the recession, however, as debt service burdens continue to rise until the end of 2008, putting pressure on output. Further, recall that the crisis is still included in the experiment as a large negative shock in 2008 Q3. But the leeway created by following the policy rule pre-crisis means that the debt burden is reduced much more rapidly, so that interest rates can rise again as early as in the second quarter of 2010. Thus, while higher interest rates initially lead to some output losses relative to historical outcomes, the gains become apparent over the medium term.[30]

These output gains come with little change in overall inflation performance, even though interest rates are generally higher than in the baseline. This is not too

[30] The counterfactual results do not depend on the specific parametrisation of the response to inflation and the output gap. For convenience, we use the original Taylor (1993) parametrisation with 1.5 on inflation and 0.5 on the output gap, but any combination of values between 0 and 2 for these parameters generates similar results.

surprising, of course, given the low traction that economic activity has on inflation in the VAR system and, importantly, that output ends up being *higher*, not lower. In fact, the output gap is, on average, smaller in the counterfactual. And inflation ends up being a bit *higher*, not lower, towards the end of the sample. Mitigating really bad outcomes naturally helps.[31]

The gains are considerably larger in all respects if one starts the counterfactual experiment further back in history, in 1996. An earlier implementation succeeds in containing financial imbalances much better (yellow lines in Graphs 8A and 8B). Output is cumulatively some 24% higher, or 1.2% per year. Essentially all the output gains occur after 2008. As the augmented Taylor rule prevents the large build-up of imbalances, output is on average nearly 4% higher per year from 2008 onwards. The price is slightly lower output beforehand, as interest rate conditions are tighter. Caveats notwithstanding, the analysis suggests that the potential gains are definitely material.

Importantly, in both counterfactuals, the central bank retains greater room for policy manoeuvre than historically. This is especially the case when policy is implemented early. In the 1996 counterfactual, the policy rate is lowered aggressively to contain the fallout of the 2008 crisis – which, it should be recalled, is still included as a shock in the counterfactual. Yet it never hits the zero lower bound. And as financial imbalances in both counterfactuals are much smaller, there is much less need to keep rates low for long.

Likewise, the counterfactuals also result in *considerably higher natural rates*. In both of them, these rates are around 50 basis points higher, on average, after the recession in 2009, reflecting more resilient potential output growth. This, in turn, supports policy normalisation.

The result for the interest rate is critical. It reflects the non-neutrality of monetary policy inherent in the system. Once both leverage and debt service burdens are high, the adjustment required to keep the credit-to-GDP ratio at sustainable levels leads to a protracted period of sub-par growth. Potential output growth is temporarily low during this phase. When the adjustment is complete, the economy returns to normal growth rates but never makes up the interim losses. A policy framework that mitigates the build-up of imbalances thus leads to higher output in the long run, as transition losses are avoided, even if activity may be somewhat lower during the upswing.

Evidently, the output gains depend on the degree to which policy reacts to information from the debt service gap (Graph A2.2). Output gains are actually negative if the debt service gap gets no weight, ie if $\lambda = 0$. In this case, rates are higher in the mid-2000s, reflecting the positive output gap and the natural rate. This dampens output. But the hypothetical policy rate is not lowered enough to buffer the crisis fallout. Interestingly, we find that a value of $\lambda = 0.25$ does reasonably well in replicating the historical evolution of the economy. As discussed, this suggests that actual policy was, indirectly at least, responding to some of the forces reflected in the debt service gap. Our simulations indicate that had the response been more forceful, subsequent outcomes may have improved.

31 This echoes the argument that resisting in the short run welcome disinflationary forces, such as those resulting from positive supply-side developments, can end up generating unwelcome disinflation in the longer run, by failing to lean against the boom than then generates the busts (eg Borio and Lowe (2002), Borio and Disyatat (2011), Borio (2014)).

Finally, note that retaining the Lehman crisis residuals stacks the deck against us. Presumably, had the authorities succeeded in restraining the boom in the first place, the shock might have been smaller, and possibly not even materialised. This should be considered when evaluating the findings.

3.3 Policy considerations

Our analysis points to a number of possible shortcomings of the typical *empirical* framework employed to consider the benefits and costs of a "leaning-against-the-wind" policy intended to reduce financial instability risks.[32] In that framework, policy is calibrated to reduce the probability of a crisis by deviating temporarily from its usual systematic response to influence a variable, typically credit growth, found empirically to have good leading indicator properties for banking crises. In addition, crisis costs are sometimes contained by assuming that, eventually, output returns to its pre-crisis trend (eg Svensson (2014, 2016), IMF (2015)).

First, such an approach understates the costs of financial imbalances to the extent that it ignores possible permanent effects on the *level* of output. Moreover, our analysis indicates that these costs may arise even if a full-blown crisis does not occur. If so, the costs of neglecting the financial cycle would be an order of magnitude higher.

Second, the approach underestimates the contribution of monetary policy to the imbalances. This is because it focuses on its *marginal* effect on the variables of interest, typically credit growth, but ignores its *cumulative* impact, notably on the credit-to-GDP ratio, and hence, through them, on the economy's path.[33] In addition, whenever the debt service ratio is ignored, the relevance of monetary policy is understated further, given its first-order effect on interest payments.

Third, for much the same reasons, the approach can be misleading. Thinking of a "leaning-against-the-wind" policy as one that involves temporary deviations from an otherwise standard rule is not that helpful. What matters is the *systematic* policy followed along the whole financial cycle, ie avoiding straying persistently too far away from financial equilibrium, with large build-ups in the two financial gaps. Following a "business as usual" policy most of the time, combined with occasional leaning only once the signs of financial imbalances become obvious, would result in doing too little too late. At worst, it could mean that the central bank is seen as simply precipitating the very recession it wishes to prevent. Selective attention is not the answer. A "through-the-cycle" policy is called for.

32 Such a framework is different from more theoretical model-based approaches, which limit themselves to considering whether, in general equilibrium models and based on typical objective functions, responding to variables other than output and inflation, such as credit or asset prices, can be superior to a hands-off policy (eg Woodford (2012), Fahr et al (2013), Gambacorta and Signoretti (2014)). These approaches illustrate the more general proposition that as long as these additional variables contain information about the behaviour of state variables or shocks, a response is called for – a well-known theoretical result.

33 One could raise a similar objection to the leading indicator of the crisis itself – credit growth. It is not credit growth per se that provides a good signal but the *cumulative* growth over and above certain thresholds alongside other developments, such as abnormal increases in asset prices (Borio and Drehmann (2009)) or the behaviour of the debt service burden (Drehmann and Juselius (2013)). For example, periods of rapid credit growth early on in the cycle are unlikely to signal impending crises. All this introduces "noise" in the indicator's predictive content. This, in turn, will inevitably reduce the benefits of a leaning policy.

At the same time, we should not take the suggested rule too literally. For instance, looking more closely at the behaviour of the underlying variables, the policy would have called for starting to ease around the peak in property prices and when credit expansion was still rather strong (Graph A2.3). This is because at that point the debt service gap switches sign, moving above its long-term average. It may well take a brave central bank, with great confidence in the underlying relationships, to stop tightening under those conditions. This puts a premium on the use of complementary tools, such a macroprudential measures, in the later stages of financial booms.

The previous discussion and the inevitable econometric limitations of the counterfactual experiment suggest caution. It is best to think of the current analysis as providing a new perspective from which to approach the policy problem together with some general guidelines rather than definite conclusions or, indeed, a specific rule. Complementary to our results, Filardo and Rungcharoenkitkul (2016) reach broadly similar conclusions based on a model that highlights the importance of the systematic policy rule when the financial cycle is endogenous. [34]

The analysis highlights the risks of policies that are asymmetrical in relation to the financial cycle. This is, in effect, what a policy focused primarily on inflation and short-term output fluctuations can produce, as the US example here illustrates – simply one among many. Such a policy does little, if anything, to restrain the upswing but reacts strongly and persistently to the downswing. In the case in question, it translates most conspicuously into an asymmetry in the evolution of the debt service gap, which was positive on average over the sample from 2000, ultimately resulting in a lower output path. The risks involved are apparent.

Over time, such asymmetrical policy can impart a downward bias to interest rates as the build-up of debt over successive boom-bust cycles leads to depressed economic activity, making it increasingly hard to raise interest rates – a kind of "debt trap" (Borio and Disyatat (2014), Borio (2016)). That is, both the leverage and debt service gaps end up being significantly above their long-run equilibrium levels and the growth impetus from already low interest rates is limited. At this point, the economy is over-indebted and over-leveraged, making it difficult to raise rates without damaging it.

These considerations highlight the possibility that, in more ways than one, over long horizons low interest rates may become, to some extent, self-validating. Low rates may beget lower rates as monetary policy contributes to financial booms and busts. And to the extent that these forces exert a temporary, if potentially persistent, impact on potential output growth, the natural rate may also be affected. Either way, policy rates would not be just passively reflecting some deep exogenous forces; they would also be helping to shape the economic environment policymakers take as given ("exogenous") when tomorrow becomes today. Path dependence is key.

The danger in all this is that policy frameworks become vulnerable to a new source of "time inconsistency", arguably more insidious than the one so familiar in the context of inflation (Borio (2014)). Unless financial factors are taken more systematically into account, and a sufficiently long horizon adopted, policy steps that appear reasonable when taken in isolation may take policy astray when considered as a sequence. In contrast to the argument in the case of inflation, here policy becomes suboptimal not because of the behaviour of private sector expectations, but

[34] Filardo and Rungcharoenkitkul posit a stylised economy characterised by recurrent financial cycles, of the type in Drehmann et al (2012), then estimate the key relationships on US data and derive optimal policy.

because of a failure to take into account its cumulative impact over time. The actions central banks take today can affect real macroeconomic developments in the long term, primarily through their impact on the financial cycle. These medium- to long-term side effects need to be weighed carefully against the benefits of short-term stimulus. The trade-off is, fundamentally, an intertemporal one.

Conclusion

The critical role financial developments play in economic fluctuations has long been recognised. Yet the prevailing analysis of the business cycle, and of its relationship to interest rates, does not exploit these inter-linkages much. The extraction of trends and long-run equilibrium variables, such as potential output and the natural rate of interest, need to go beyond the standard full employment-inflation paradigm. Surely, equilibrium outcomes should also be sustainable. If the ebb and flow of the financial cycle coincides with damaging economic booms and busts, then assessments of the sustainability of a given path for output or interest rates need to take financial developments into account. Financial and macroeconomic stability are essentially two sides of the same coin.

In contrast to the prevailing view, we argue that a decline in the natural real interest rate provides an incomplete explanation of the observed trend reduction in real interest rates and of their persistence at ultra-low levels today. Based on US data, we find that if one accounts for the influence of the financial cycle, the estimated natural interest rate is generally higher and, on balance, declines by less. Moreover, policy rates have been persistently below this estimate. We also find that monetary policy has a first-order effect on the financial cycle and that financial busts can have permanent effects on output. Together, these findings indicate that part of the observed decline in market interest rates reflects the interaction between monetary policy and the financial cycle. They suggest that policy has leaned aggressively and persistently against financial busts, but has failed to lean sufficiently promptly and deliberately against financial booms. The resulting asymmetry appears to have contributed to a downward bias in interest rates.

Accordingly, an illustrative counterfactual experiment suggests that a policy rule that systematically takes into account financial developments helps to dampen the financial cycle, leading to higher output even in the long run. Such a policy also results in a smaller decline in the natural rate. Because of well-known econometric limitations, this part of the analysis should be interpreted with great caution. At a minimum, though, it indicates that it is inappropriate to think of a financial-stability oriented monetary policy as one that simply leans against signs of the build-up of financial imbalances only when they become evident. Such a "selective attention" strategy could easily result in doing too little too late and would likely backfire. Rather, the right policy would need to take financial considerations *systematically* into account, never straying too far away for too long from some notion of "financial equilibrium". We conjecture that this conclusion, and the merits of such a policy more generally, will withstand further scrutiny.

Clearly, our analysis is just a one small further step in the development of a monetary policy framework that takes financial stability considerations, broadly defined, into account. For one, rather than being based on a fully-fledged "structural" model, it hinges on some key statistical relationships found in the data. While these could in principle be derived from more fundamental behavioural relationships and embedded in a system better suited for counterfactual policy analysis, we leave this for future work. Similarly, the econometric findings would be more convincing if they were shown to hold both across countries and monetary policy regimes. This would go a considerable way in addressing also the Lucas critique. We leave this, too, for future work.

Despite the limitations of our analysis, we hope to have shown that it is possible to make further progress in making a financial stability-oriented monetary policy framework more operational. And as argued elsewhere (BIS (2014, 2015)), recognising this would better help integrate monetary policy into a more holistic and balanced macro-financial stability framework that would include also other policies, notably prudential and fiscal policies. This would be a more effective way of promoting *lasting* monetary, financial and macroeconomic stability.

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Annex 1: The leverage and debt service gaps

In this Annex, we discuss the construction and estimation of the leverage and debt service gaps, starting from the basic data. We then consider the stability of the gaps across different subsamples. Finally, we compare them with their purely data-based counterparts, which require no estimation of co-integrating relationships.

Credit

We measure the debt of households (HHs) and non-financial corporations (NFCs) by credit (loans and debt securities) granted from all sources, as compiled by the BIS (Dembiermont et al (2013)). Thus, we capture both bank and non-bank credit. Given that we measure debt by credit, we will use the terms interchangeably. Even though these concepts are not exactly the same, this simplifies communication.

The average lending rate

To accurately measure aggregate debt service burdens, the interest rate has to reflect the average interest rate on the stock of debt. That stock contains a mix of new and old loans granted at different terms, including both fixed and floating interest rates of various kinds.

The average interest rate on the stock of debt is computed by dividing gross interest payments (GI) plus financial intermediation services indirectly measured ($FISIM$) by the stock of credit (Drehmann et al (2015)). *FISIM* is an estimate of the value of financial intermediation services provided by financial institutions. When national account compilers derive the sectoral accounts, parts of interest payments are reclassified as payments for services and allocated as output of the financial intermediation sector. In turn, this output is recorded as consumption by HHs and NFCs. As we are interested in the total burden of interest payments on borrowers regardless of their economic function, we add *FISIM* back to the interest payments reported in the national accounts.

The average interest rate on the stock of credit is given by the credit-weighted average of the lending rates in the two sectors, ie

$$i_{L,t} = \frac{GI_t^{HH} + FISM_t^{HH} + GI_t^{NFC} + FISM_t^{NFC}}{C_t^{HH} + C_t^{NFC}} = \omega_t i_{L,t}^{HH} + (1 - \omega_t) i_{L,t}^{NFC}$$

where $\omega_t = \frac{CR_t^{HH}}{CR_t^{HH} + CR_t^{NFC}}$ is the share of credit to the household sector. Within our sample, ω varies from 82% in 1985 to more than 90% in 2007, after which it falls slightly again.

The aggregate asset price index

In order to estimate the leverage relationship, we need an aggregate asset price index. This is generally not available and has to be constructed from the price indexes of various sub-asset classes.

Juselius and Drehmann (2015) assume a Cobb-Douglas specification for the general real asset price index in real residential property prices, real commercial property prices and real equity prices, ie $P_{A,t}^r = \left(P_{res,t}^r\right)^{\alpha_1} \left(P_{com,t}^r\right)^{\alpha_2} \left(P_{eq,t}^r\right)^{1-\alpha_1-\alpha_2}$. They then substitute the natural logarithm of this expression into (1) and estimate α_1 and α_2 using co-integration techniques. While this approach is convenient and generally produces reasonable estimates, it implicitly assumes that the shares of the two sectors remain constant over time. As discussed above, this is not the case, which affects the stability of the α_1 and α_2 estimates in different subsamples.

Here, to better reflect the evolving sectoral composition in the aggregate asset price index, we proceed in two steps. First, we estimate separate asset price indexes for HHs and NFCs. Second, we aggregate these using the sectoral credit stock to get a weighted average across the two sectors just as in the derivation of the average lending rate.

The parameters for the asset prices of each sector are estimated from

$$\widetilde{lev}_t^s = c_t^s - y_t^s - \alpha_1^s p_{res,t}^r - \alpha_2^s p_{com,t}^r - (1 - \alpha_1^s - \alpha_2^s) p_{eq,t}^r - \mu_{lev}^s$$

where $s = HH, NFC$. This produces a separate asset price index for each sector, s.

The estimates for the two sectors are shown in Table A1.1. It turns out that residential property is the only significant asset class for the household sector, whereas only commercial property and equity prices are significant in the non-financial corporate sector, with shares 0.72 and 0.28, respectively. These results are quite intuitive. Hence, we can use $P_{A,t}^{r,HH} = P_{res,t}^r$ and $P_{A,t}^{r,NFC} = \left(P_{com,t}^r\right)^{0.72}\left(P_{eq,t}^r\right)^{0.28}$. Moreover, and in contrast to estimating the aggregate asset price index for households and firms combined, the coefficients in the sub-sector estimates are very stable over time.

Estimates for the sectoral leverage relationships[1]

Table A1.1

	$(cr - y)_t$	$p_{res,t}^r$	$p_{com,t}^r$	$p_{eq,t}^r$
		Private non-financial corporate sector[2]		
β_{lev}^{NFC}	1	-	-0.72***	-0.28***
		Household sector[3]		
β_{lev}^{HH}	1	-1***	-	-

[1] Based on VAR models for $x_t^s = \left(c_t^s - y_t^s, p_{res,t}^r, p_{com,t}^r, p_{eq,t}^r\right)'$. We use Johansen's LR test to test for the co-integration rank, which for both sectors is found to be one. [2] A formal test of the hypothesis that residential property prices can be excluded from the co-integration vector yields a p-value of 0.82. [3] Formal tests that commercial property prices and equity prices can be excluded for the co-integration vector yield p-values of 0.05 and 0.59, respectively.

To derive the aggregate asset price index, we then take the credit-weighted average of the HH and NFC price indexes. We use a Cobb-Douglas specification with $P_{A,t}^r = \left(P_{A,t}^{r,HH}\right)^{\omega_t}\left(P_{A,t}^{r,NFC}\right)^{1-\omega_t}$ so that in logs we have

$$p_{A,t}^r = \omega_t p_{A,t}^{r,HH} + (1 - \omega_t) p_{A,t}^{r,NFC}$$

Purely data-based gap measures

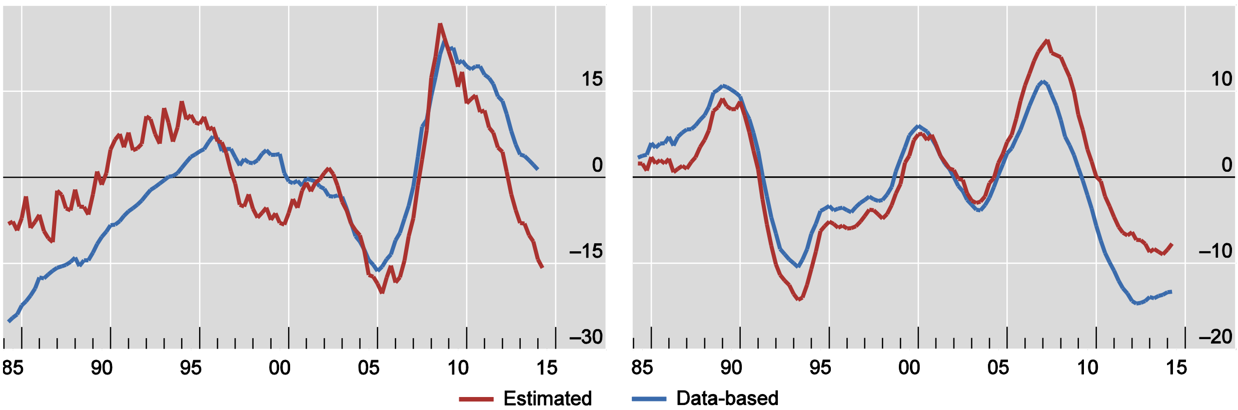
One can think of aggregate leverage as the ratio of (non-financial private sector) credit to assets, where the non-financial sector comprises households and corporations. As Juselius and Drehmann (2015) show, and we find empirically (Table 1), if this ratio is constant in the long run and if a constant fraction of GDP is invested in real assets, then the credit-to-GDP ratio should be co-integrated with real asset prices.

The credit-to-asset ratio can also be derived from national accounts data. To do so, we sum the credit to households and non-financial corporations and divide the result by the sum of real estate assets of households and non-financial corporations as recorded in the financial accounts. The corresponding leverage gap in Graph A1.2 (left-hand panel) is simply the deviation of this ratio from its sample mean.[35]

Econometric estimates of the gaps match data-based measures[1]

In per cent

Graph A1.2



[1] Comparison between the debt service and leverage gaps estimated from the VAR and the corresponding purely data-based measures. For the direct measures, the debt service gap is approximated by the debt service ratio calculated by Drehmann et al (2015) and the leverage gap by the ratio of credit to real estate assets of households and non-financial corporations. Gaps for the data-based measures are the deviations relative to the respective averages over the whole sample.

Sources: National accounts; authors' calculations.

As can be seen, the evolution of the leverage gap based on national accounts data is broadly similar to the gap based on the co-integrating relationship. The main difference is an upward tilt in the data-based measure, which arises because this measure is considerably lower in the 1980s and slightly higher in the most recent period. Most likely, this reflects the fact that asset prices in the financial accounts are not fully marked to market.

The debt service ratio is defined as the ratio of interest payments plus amortisations to income. As amortisations are not recorded in national accounts data, the debt service ratio for the aggregate private non-financial sector has to be derived. For that purpose, and based on previous work by the Federal Reserve Board (Dynan et al (2003)), Drehmann et al (2015) show that it is possible to use a standard instalment loan formula. This relies on the basic assumption that, for a given lending rate, debt service costs – interest payments and amortisations – on the aggregate debt stock are repaid in equal portions over the maturity of the loan (instalment loans). Hence, the aggregate debt service ratio (DSR) at time t can be estimated as:

$$DSR_t = \frac{i_{L,t}}{\left(1-\left(1+i_{L,t}\right)^{-s_t}\right)} * \frac{CR_{j,t}}{Y_{j,t}}$$

[35] The leverage gap looks very similar if we use total non-financial assets instead of real estate assets.

where s measures the average remaining maturity of the stock of credit. Based on this formula, data-based measures for the debt service ratio are published on the BIS website.

Once linearised, if this ratio has a constant long-run mean, then the DSR formula implies that the credit-to-GDP ratio is co-integrated with the average lending rate, $i_{L,t}$. Again, we find this is indeed the case in the data (Table 1).

In fact, the data-based debt service gap and the one derived from the estimated model are very close (Graph A1.2, right-hand panel).[36] Again, we assume that the long-run value for the DSR is given by its sample average so that the data-based debt service gap is expressed vis-à-vis this mean.

Importantly, the main properties of the VAR are robust to using these data-based measures instead of the gaps derived from the co-integrating relationships (Juselius and Drehmann (2015)).

[36] The slight downward trend in the direct measure seems to be driven by the large deleveraging episode in recent years.

Annex 2: Additional tables and graphs

Data sources[1]	Table A2.1
cr	Total credit from all sources to the private non-financial sector; financial accounts
y	GDP; Bureau of Economic Analysis
e_P	Private expenditure (personal consumption + private investments)
e_O	Other expenditure (GDP-private expenditure)
i_L	Average lending rate on the stock of debt, National Accounts (see Annex 2)
i	3-month money market rate,
p_i	Asset price index of asset class *i*; which can be residential property prices *res*, commercial property prices *com,* equity prices *eq*, or an average asset price index *A* which is a weighted average of the three asset classes (see Annex 2)
π	Inflation, core personal consumption expenditure index; Bureau of Economic Analysis

[1] As a convention, we use smaller letters to denote the natural logarithm of a variable, eg y = log(Y) for the log of nominal GDP, except for the interest rate, which is in levels. The superscript *r* denotes real variables.

VAR coefficients[1]

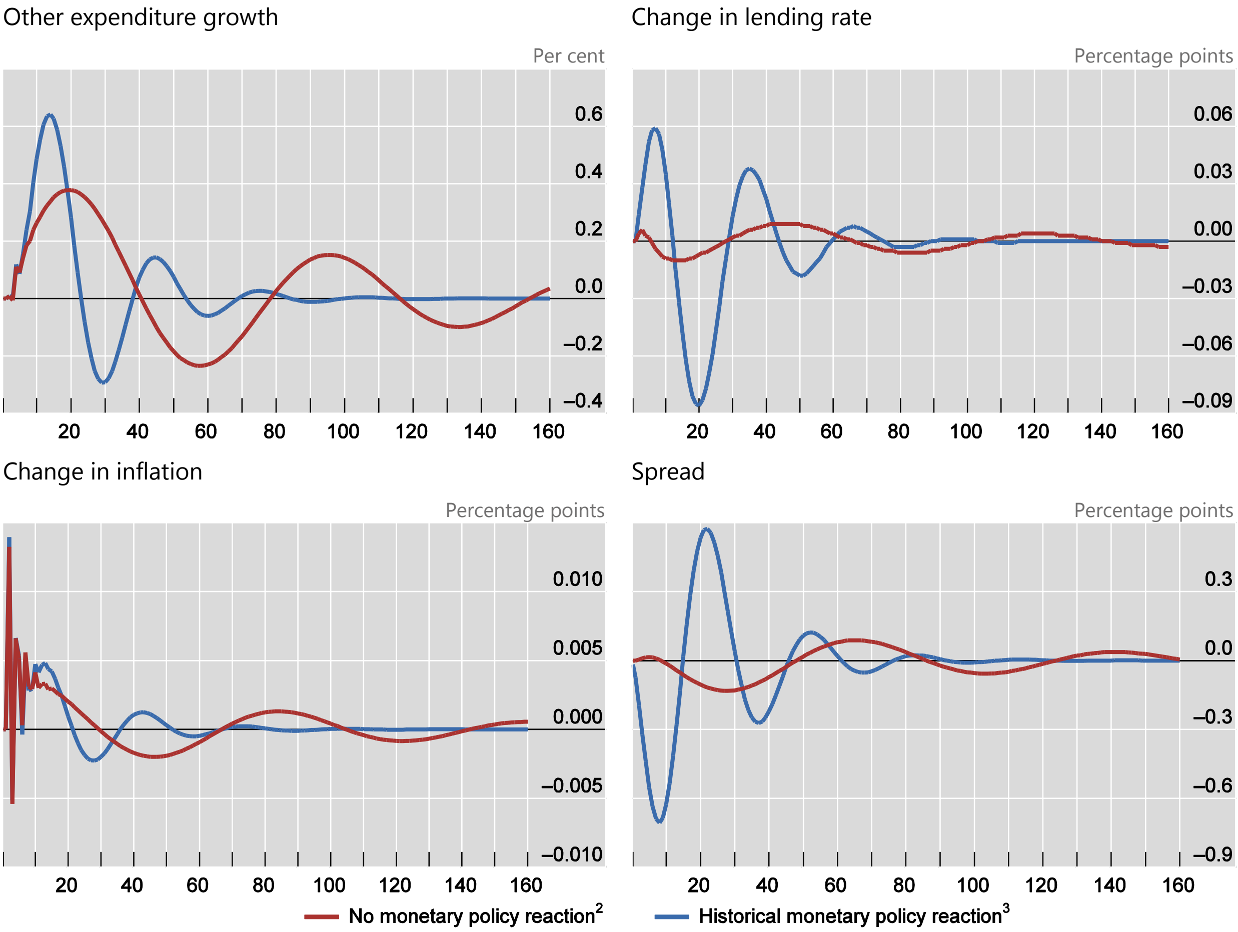
Table A2.2

	$\boldsymbol{\Delta cr_t^r}$	$\boldsymbol{\Delta e_{P,t}^r}$	$\boldsymbol{\Delta e_{O,t}^r}$	$\boldsymbol{(\Delta y_t^r)^1}$	$\boldsymbol{\Delta p_{A,t}^r}$	$\boldsymbol{\Delta \pi_t}$	$\boldsymbol{\Delta i_{L,t}}$	$\boldsymbol{\Delta i_t}$
Adjustment coefficients to long-run deviations								
$\widetilde{lev}_{\ t-1}$	-0.018***							-0.007***
$\widetilde{dsr}_{\ t-1}$	-0.029***	-0.031***	0.047**	*(-0.017)*	-0.086**		-0.002**	-0.009**
$\widetilde{spr}_{\ t-1}$					0.754***		-0.029***	0.093**
Short-run dynamics								
Δcr_{t-1}		0.103**		*(0.084)*	0.606***	0.078***	0.024***	
Δcr_{t-2}	0.351***					-0.059***		
Δcr_{t-3}	0.371***		0.631***	*(0.114)*			-0.022***	
$\Delta e_{P,t-1}^r$		0.448***	-0.510***	*(0.276)*	0.799***		0.024***	0.126***
$\Delta e_{P,t-2}^r$						-0.038**	-0.025***	-0.097***
$\Delta e_{P,t-3}^r$		-0.242***		*(-0.198)*	-0.639**			
$\Delta e_{O,t-1}^r$			-0.210**	*(-0.038)*				0.034***
$\Delta e_{O,t-2}^r$								
$\Delta e_{O,t-3}^r$								
$\Delta p_{A,t-1}^r$			-0.175***	*(-0.032)*				0.012*
$\Delta p_{A,t-2}^r$		0.040**	-0.103**	*(0.014)*				
$\Delta p_{A,t-3}^r$								
$\Delta \pi_{t-1}$						-0.573***	0.056***	0.298**
$\Delta \pi_{t-2}$						-0.241***		
$\Delta \pi_{t-3}$								
$\Delta i_{L,t-1}$		1.871***		*(1.534)*			0.602***	-1.001***
$\Delta i_{L,t-2}$		-2.238***		*(-1.835)*			0.355***	2.868*****
$\Delta i_{L,t-3}$							-0.354***	-1.707***
Δi_{t-1}							0.102***	0.953***
Δi_{t-2}					2.361***		-0.048**	-0.229***
Δi_{t-3}								

[1] Only significant coefficients are displayed. The system also includes impulse dummies and seasonal dummies that, for brevity, are not reported here. [2] The coefficients for the growth rate of real output (Δy_t^r) are calculated as ω times the coefficient on $\boldsymbol{\Delta e_{P,t}^r}$ plus $(1-\omega)$ times the coefficient on $\boldsymbol{\Delta} e_{O,t}^r$. ω equals the average share of private sector expenditure in GDP over the whole sample (82%).

The financial cycle drives economic fluctuations (additional series)

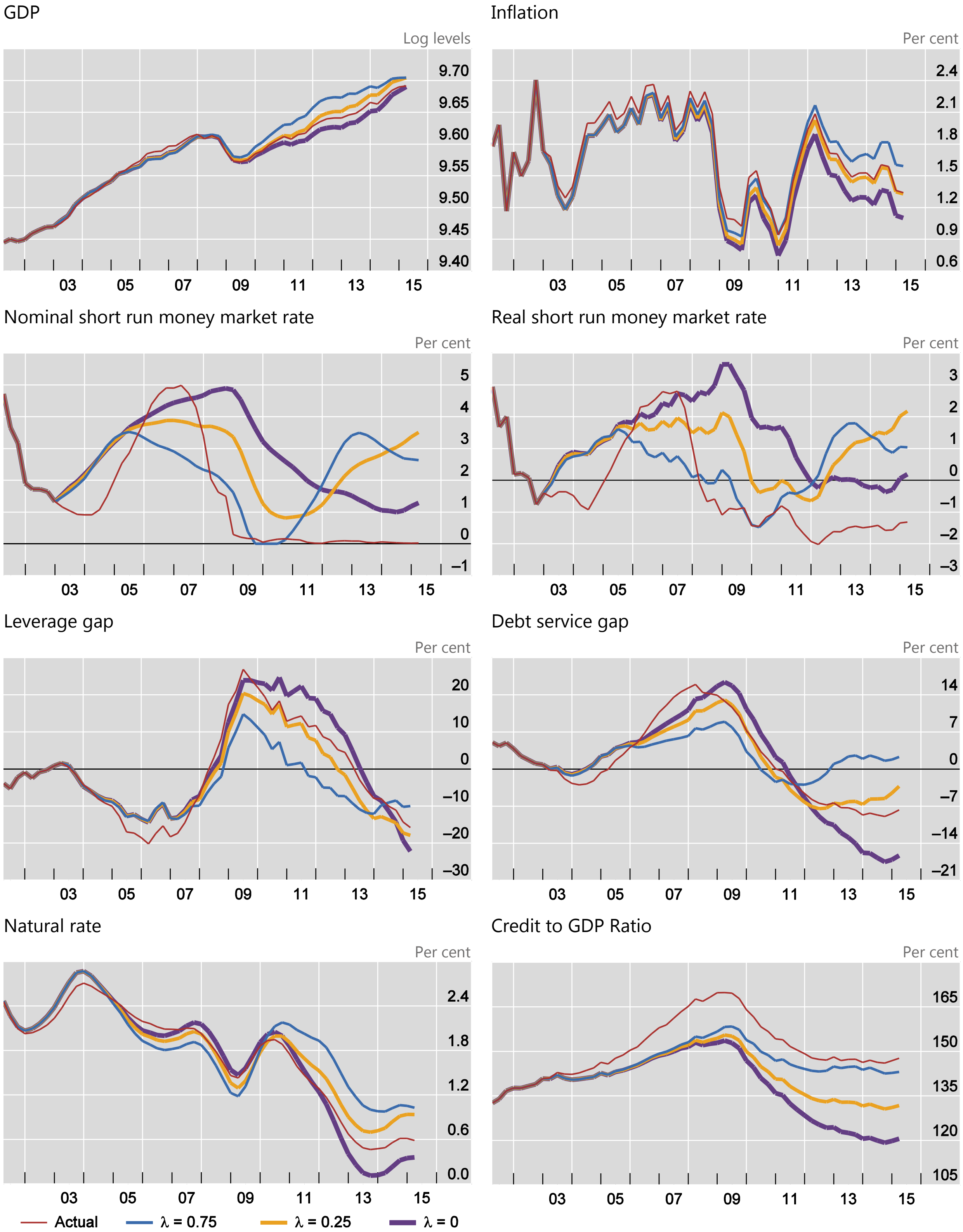
Dynamic adjustment given a -10% leverage gap[1] Graph A2.1



[1] VAR implied adjustment from a -10% leverage gap. All other variables are initially zero. [2] The results for the "no monetary policy reaction" are based on the VAR when policy rates are exogenous (Annex 3). [3] The results for the "historical monetary policy reaction" are based on the VAR when policy rates are endogenous (equation 3).

Source: Authors' calculations.

Leaning more strongly against the financial cycle yields higher output[1] Graph A2.2



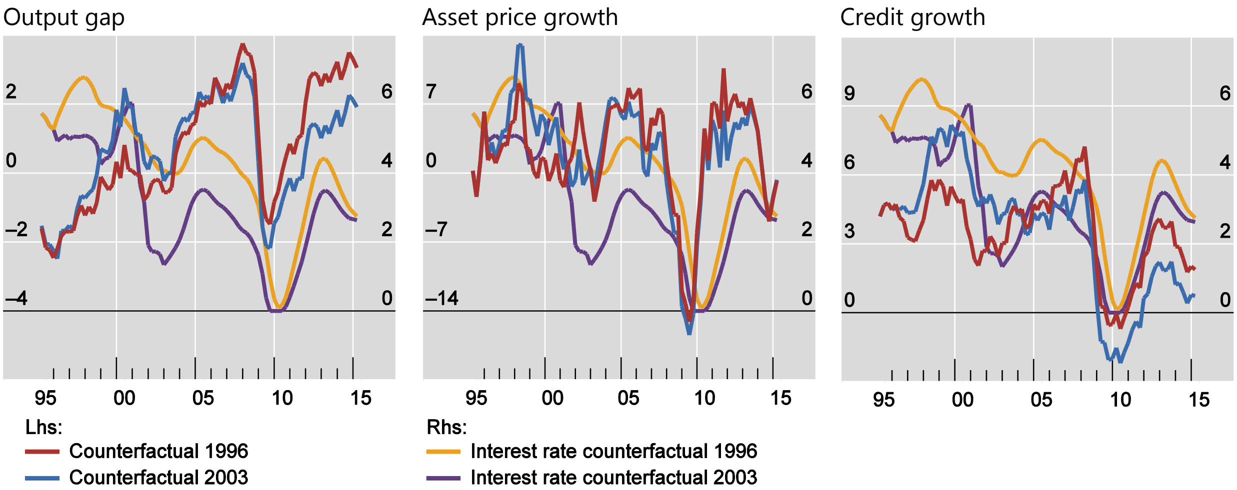
[1] In the counterfactual experiment, we set policy based on the augmented Taylor rule that takes account of the finance-neutral natural rate, the finance-neutral output gap and the debt service gap in line with equation (14) with $\rho=0.9$ and $\lambda \in [0;0.25;0.75]$. Results are based on the VAR system (3a, Annex 3) where policy rates are exogenous. We retain the historical errors and outliers of the VAR estimates to derive the evolution of the variables in the counterfactual. The counterfactual experiments start in 2003 Q1.

Sources: National data; authors' calculations.

Growth rates and nominal interest rates in the counterfactuals[1]

In per cent

Graph A2.3



[1] In the counterfactual experiment, we set policy in line with an augmented Taylor rule that takes account of the finance neutral natural rate, the finance neutral output gap and the debt service gap in line with equation (14) with ρ=0.9 and λ=0.75. Results are based on the VAR system (3a, Annex 3) where policy rates are exogenous. We retain the historical errors and outliers of the VAR estimates to derive the evolution of the variables in the counterfactual. The counterfactual policy starts either in 2003 Q1 or 1996 Q1.

Sources: National data; authors' calculations.

Annex 3: The VAR when policy rates are exogenous

For the impulse responses shown in Graph 3 and the counterfactuals, we use a variant of the VAR system in which we treat the policy rate as exogenous. In this case, the estimated system is given by:

$$\begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta e_O^r \\ \Delta p_A^r \\ \Delta \pi \\ \Delta i_L \end{pmatrix}_t = \gamma_0 + \alpha \begin{pmatrix} \widetilde{lev} \\ \widetilde{dsr} \\ \widetilde{spr} \end{pmatrix}_{t-1} + \sum_{j=1}^{3} \Psi_j \begin{pmatrix} \Delta cr^r \\ \Delta e_P^r \\ \Delta e_O^r \\ \Delta p_A^r \\ \Delta \pi \\ \Delta i_L \\ \Delta i \end{pmatrix}_{t-i} + \varphi \Delta i_t + \Gamma s_t + \epsilon_t \tag{3a}$$

where one of the system's dimensions is dropped and the contemporaneous change in the policy rate appears on the right-hand side.

Table A3.1 displays the coefficient estimates. As expected, the short-run adjustment dynamics with respect to the interest rate change. All other coefficients, including the adjustment to long-run deviations, are hardly affected.

VAR coefficients if the short-term interest rate is treated as exogenous[1]

Coefficients in brackets for the system with an endogenous short-term rate

Table A3.1

	Δcr_t^r	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta \pi_t$	$\Delta i_{L,t}$
Adjustment coefficients to long-run deviations						
$\widetilde{lev}_{t-1}$	–0.017*** (–0.018***)					
$\widetilde{dsr}_{t-1}$	–0.029*** –(0.029***)	–0.030*** (–0.031***)	0.048** (0.047**)	–0.084** (–0.086**)		–0.002** (–0.002**)
$\widetilde{spr}_{t-1}$				0.783*** (0.754***)		–0.035*** (–0.029**)
Short-run dynamics						
Δcr_{t-1}		0.070 (0.103**)		0.621*** (0.606***)	0.078*** (0.078***)	0.024*** (0.024***)
Δcr_{t-2}	0.345*** (0.351***)				–0.061*** (–0.059***)	
Δcr_{t-3}	0.382*** (0.371***		0.634*** (0.631***)			–0.025*** (–0.022***)
$\Delta e_{P,t-1}^r$		0.392*** (0.448***)	–0.513** (–0.510***)	0.793*** (0.799***)		– (0.024***)
$\Delta e_{P,t-2}^r$					–0.033** (–0.038**)	– (–0.025***)
$\Delta e_{P,t-3}^r$		–0.231*** (–0.242***)		–0.640** (–0.639**)		
$\Delta e_{O,t-1}^r$			–0.230** (–0.210**)			
$\Delta p_{A,t-1}^r$			–0.190*** (–0.175**)*			
$\Delta p_{A,t-2}^r$		0.039** (0.040**)	–0.096** (–0.103*)		–	0.003*** (–)
$\Delta p_{A,t-3}^r$					–	0.004*** (–)
$\Delta \pi_{t-1}$					–0.586*** (–0.573***)	– (0.056***)

$\Delta\pi_{t-2}$			−0.244*** (−0.241***)	
$\Delta i_{L,t-1}$	– (1.871***)			0.672*** (0.602**)*
$\Delta i_{L,t-2}$	– (−2.238***)			– (0.355***)
$\Delta i_{L,t-3}$				−0.123*** (−0.354**)
Δi_{t}	0.567*** (−)			0.123*** (−)
Δi_{t-1}	−0.679*** (−)			– (0.102***)
Δi_{t-2}	0.359** (−)	2.421** (2.361***)		– (−0.048**)

[1] Only significant coefficients are displayed. The system also includes impulse dummies and seasonal dummies that, for brevity, are not reported here. The VAR has a leg length of three for all variables. For brevity, lags are not reported in the table if they are not significant either in the system where the short rate is endogenous or in that where it is exogenous.

Annex 4: Does the debt service gap affect potential output?

The VAR suggests that the debt service gap may affect potential output in the short and medium run (Graph 4). The filtering system in the main text does not allow for this possibility in order to deviate as little as possible from the Laubach and Williams (2003) standard framework.

In this annex, we therefore re-estimate the filter with a different specification for potential output. Rather than using an HP filter, we assume that y_t^* follows a unit root process (6.1.a) and that its growth, η_t, is constant in the long run. At the same time, we allow for the possibility that the debt service gap may affect potential output growth in the short run (6.2a). Thus, the system now is:

$$y_t - y_t^* = \beta_5(y_{t-1} - y_{t-1}^*) - \varphi_{51}(r_t - r_t^*) - \varphi_{52}\widetilde{lev}_t + \vartheta_{5t} \tag{5a}$$

$$y_t^* = y_{t-1}^* + \eta_{t-1} + \vartheta_{61t} \tag{6.1a}$$

$$\eta_t = \beta_{62}\eta_{t-1} + (1 - \beta_{62})\mu - \varphi_{62}\widetilde{dsr}_{t-1} + \vartheta_{62t} \tag{6.2a}$$

$$(\pi_t - \pi^*) = \beta_7(\pi_{t-1} - \pi^*) + \varphi_7(y_t - y_t^*) + \vartheta_{7t} \tag{7a}$$

$$r_t^* = \beta_8 r_{t-1}^* + (1 - \beta_8)(z_t + \frac{1}{\rho}4\Delta y_t^*) + \vartheta_{8t} \tag{8a}$$

$$z_t = \beta_9 z_{t-1} + \vartheta_{9t} \tag{9a}$$

$$\widetilde{lev}_t = \beta_{10}\widetilde{lev}_{t-1} + \varphi_{101}(r_t - r_t^*) + \varphi_{102}\widetilde{dsr}_{t-1} + \vartheta_{10t} \tag{10a}$$

We use identical priors for the previously defined parameters and similar ones for the new parameters. For instance, we assume that β_{62}, μ, and φ_{62} follow gamma distributions with means 0.70, 0.63 and 0.02, respectively. The latter two values approximately reflect the full sample estimates of the mean of GDP growth and its adjustment to the debt service gap from the VAR (Table 2). As usual, β_{62} is restricted to the unit interval. To avoid unrealistic posterior estimates, we impose slightly tighter priors for their standard deviations, 0.10, 0.10 and 0.01, respectively.[37]

Given that β_{62} remains statistically below 1, the specification in (6.2a) is stationary and, hence, estimates of the variance of ϑ_{62t} do not give rise to a pile-up problem. The variance of ϑ_{61t} could still be subject to such a problem, but this is less of a concern, given that the role of this term (6.1a) is modest compared to η_{t-1}. As a result, we can abandon our previous scheme of fixing the variances to generate a frequency cut-off similar to the HP filter. Instead, we estimate the variances, and hence the frequency cut-off for the output gap, directly from the data. The variance of ϑ_{61t} follows an inverse gamma distribution with prior mean equal to the first difference of HP-filtered output and standard deviation 0.5, whereas ϑ_{62t} follows the same distribution with standard deviation scaled by 1 – 0.7 = 0.3 in line with the prior on β_{62}.

The results are shown in Table A4.1. We find that the long-run quarterly growth rate of potential output, μ, ,is 0.634, or in annual terms 2.49%, in line with standard estimates. The loading on the debt service gap looks rather small. Nonetheless, this

[37] In particular, there is a solution to the system that features a posterior node for β_7 that is statistically strictly less than one. However, since the inflation rate is trending over the sample, this case results in a trending output gap as well as a highly volatile natural rate. The root cause of these problems is that the priors on φ_{51} and φ_{101}, are too high, in the sense that their posterior nodes become smaller for smaller priors. This does not happen for the remaining parameters, all of which converge to the specific values in Table A3.1.

will not prevent it from having a substantial effect at some points in the sample, as the gap ranges widely, from -14 to 15%.

The other coefficients are remarkably stable across the two systems. However, it seems that the interest rate gap in the new system has somewhat greater traction on output and on the leverage gap. This reflects the fact that the new specification leads to a different estimate of the natural rate.

Given that the differences across the two systems are rather small, the estimated potential output and output gaps are broadly aligned (Graph A4.1). With the debt service gap affecting potential output growth, the volatility in potential output is somewhat higher than in the specification of the main text. This also dampens the output gap, even though it does not affect its sign or the dynamics.

The most striking differences concern the natural rate estimates. True, the gap between the estimate here and that in the main text averages zero over the whole sample. But there are periods in which the gap is sizeable. This is especially the case when the debt service gap is very high, as in the late 1980s and again ahead of the Great Financial Crisis. The gap is also material at present. As the debt service gap is currently very low, the filter that allows for that service gap to enter potential output yields a natural rate of 1.8%, twice the 0.6% obtained in the main text. Likewise, the overall decline over the sample is considerably lower.

Even though the natural rate estimates are quite different, this has little impact on the outcome of the counterfactual (Graph A4.2). The reason is threefold. First, the debt service gap, in particular in the mid-2000s, is rather large, and this is the main variable in the augmented Taylor rule. Second, the gradual adjustment assumed in the rule smooths out the difference. Finally, the evolution of the natural rate in both counterfactuals is broadly similar, except during the crisis, when the natural rate that includes the debt service gap in the potential output equation falls steeply. It is at this point that the largest differences between the counterfactuals emerge, even though they still remain quantitatively small in comparison to the actual evolution of the variables.

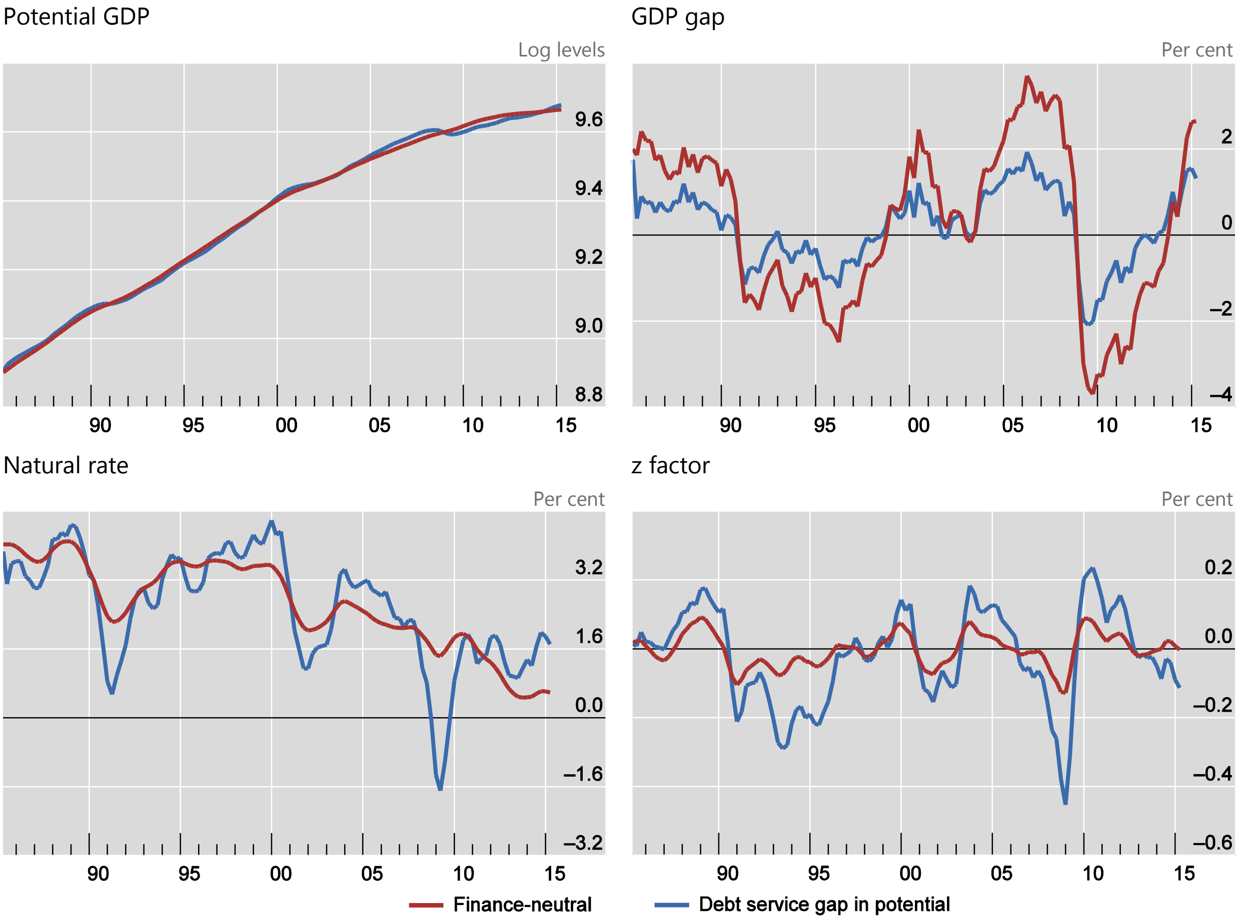
Posterior estimates for the parameters in the reduced form system that allows for effects of the debt service gap on potential output

Table A4.1

Eq.	Explained	Parameter (loading on)	Prior	Prior std	Posterior	Posterior std	Posterior system (5)-(10)
(5a)	$y_t - y_t^*$	β_5 $(y_{t-1} - y_{t-1}^*)$	0.70	0.20	0.551	0.082	0.699
		φ_{51} $(r_t - r_t^*)$	0.30	0.20	0.070	0.036	0.059
		φ_{52} $(\widetilde{lev}_t)$	0.30	0.20	0.038	0.009	0.069
(6a.2)	η_t	β_{6a} (η_{t-1})	0.70	0.10	0.702	0.047	-
		μ	0.63	0.10	0.634	0.057	-
		φ_{62} $(\widetilde{dsr}_{t-1})$	0.02	0.01	0.009	0.003	-
(7a)	$(\pi_t - \pi^*)$	β_7 $(\pi_{t-1} - \pi^*)$	0.70	0.20	0.943	0.015	0.936
		φ_7 $(y_t - y_t^*)$	0.30	0.20	0.059	0.018	0.028
		π^*	2.00	0.20	1.934	0.154	1.951
(8a)	r_t^*	β_8 (r_{t-1}^*)	0.70	0.20	0.559	0.100	0.617
(9a)	z_t	β_9 (z_{t-1})	0.70	0.20	0.652	0.220	0.632
(10a)	$\widetilde{lev}_t$	β_{10} $(\widetilde{lev}_{t-1})$	0.70	0.20	0.978	0.018	0.979
		φ_{101} $(r_t - r_t^*)$	0.30	0.20	0.180	0.082	0.109
		φ_{102} $(\widetilde{dsr}_{t-1})$	0.30	0.20	0.137	0.034	0.149

[1] Results from estimating system (5a)-(10a).

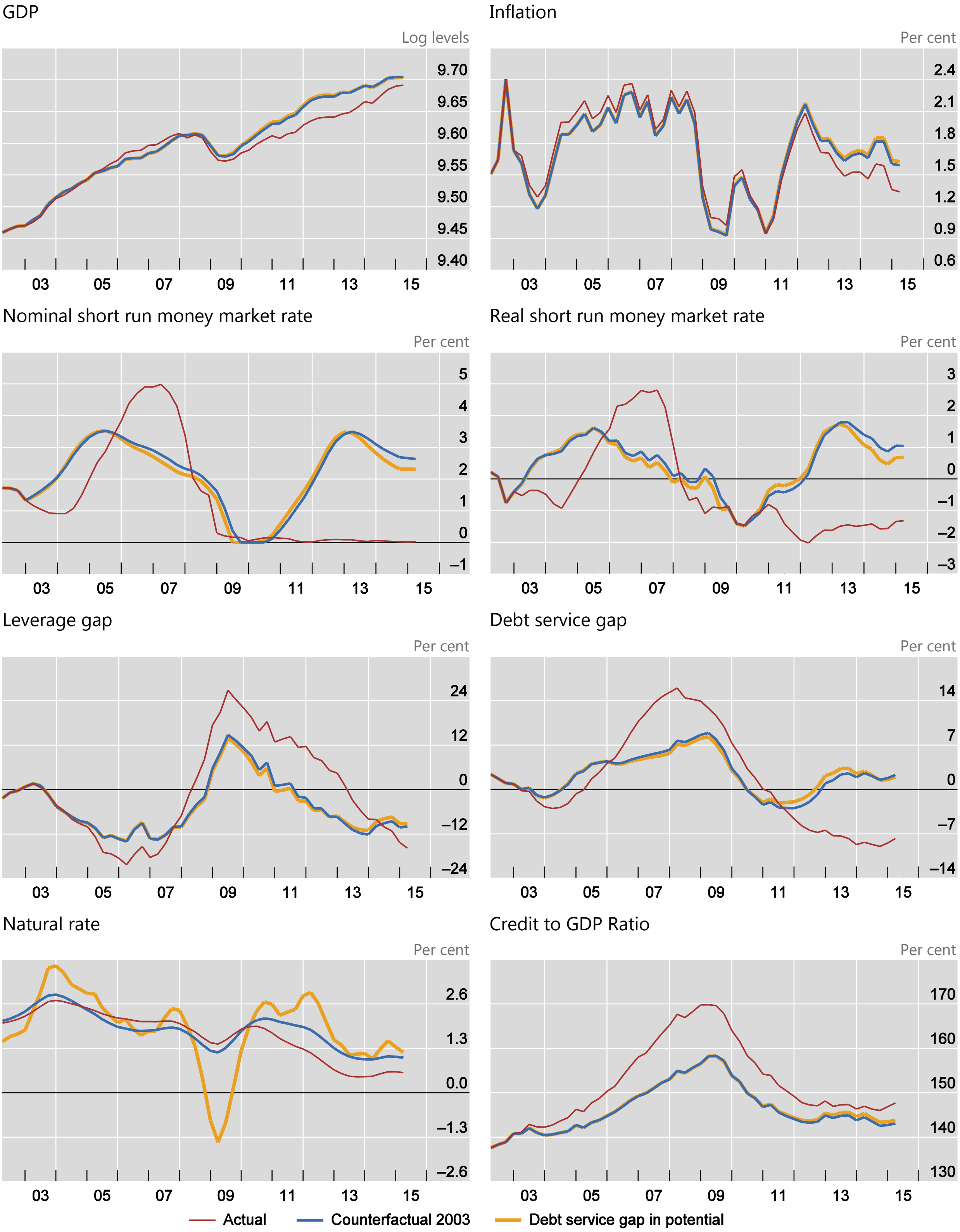
The debt service gap affects trend output and the natural rate[1] Graph A4.1



[1] The finance-neutral variables are based on system (5)-(10). The "debt service gap in potential" variables are based on the same system except that we allow the debt service gap to possibly affect potential output (system (5a)-(10a)).

Sources: National data; authors' calculations.

The gains from leaning arise also in the alternative filter specification[1] Graph A4.2



[1] In the counterfactual experiment, we set policy based on the augmented Taylor rule in line with equation (14) with ρ=0.9 and λ=0.75. The natural rate and the output gap are either derived from (5)-(10) or (5a)-(10a), which allows for the debt service gap to possibly affect trend output. Results are based on the VAR system (3a, Annex 3) where policy rates are exogenous. We retain the historical errors and outliers of the VAR estimates to derive the evolution of the variables in the counterfactual. The counterfactual experiment start in 2003 Q1.

Sources: National data; authors' calculations.

Annex 5: Treating the filtering system as a model

If we treat the filtering system as a model of the economy, how might it be closed?

Start with the equation for the debt service gap. We know from the VAR that this gap is directly related to the credit-to-GDP ratio and the average nominal interest rate on debt. As the leverage gap, in turn, is the primary driver of the credit-to-GDP ratio, this equation can be reduced to

$$\widetilde{dsr}_t = \beta_{11}\widetilde{dsr}_{t-1} - \varphi_{111}\widetilde{lev}_{t-1} + \varphi_{112}\Delta i_{L,t} + \vartheta_{11t}, \tag{11}$$

We also know from the VAR that the average lending rate follows the policy rate in the long run. In addition, there will be some direct pass-through from policy rates to lending rates, even though it will not be one-to-one since a portion of the loans has fixed interest rates. Over time, however, the lending rate adjusts to close $\widetilde{spr}$. Hence, lending rates could evolve as

$$\Delta i_{L,t} = \beta_{12}\Delta i_{L,t-1} + \varphi_{121}\Delta i_t + \varphi_{122}\widetilde{spr} + \vartheta_{12t} \tag{12}$$

Annex 6: Are the results an artefact of the Great Recession?

In this annex, we assess whether the results are driven by developments during the Great Financial Crisis and the Great Recession. We first look at the stability of the gaps and the VAR, to then re-estimate the filter using data only up to 2006. Finally, we combine the VAR and the filter estimated with data up to 2006 and re-run the counterfactual experiment. Throughout the annex, results are (quasi) real-time: we re-estimate the models using only data up to a specific point in time but do not use vintage data.

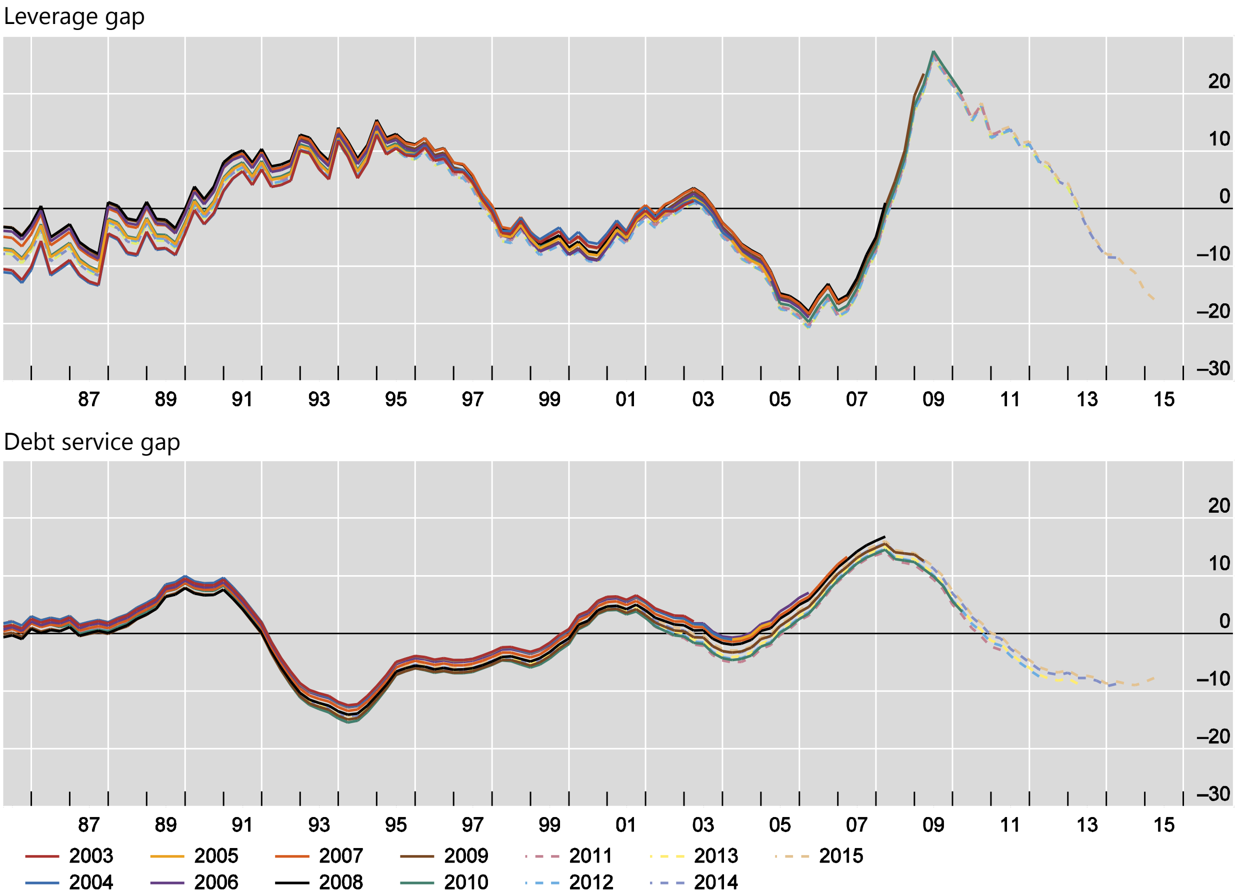
The stability of the gaps

Given their key role, we re-estimate the leverage and debt service gaps recursively by successively expanding a sample that ends in 2003 Q1 by one quarter. This includes an updated derivation of the aggregate asset price index.

Real-time estimates of the gaps[1]

In per cent

Graph A6.1



[1] Real-time estimates include an updated estimation of the aggregate asset price index. Gaps are estimated with a sample that starts 1985 Q1 and ends in Q1 of the year indicated in the legend.

Source: Authors' calculations.

As can be seen from Graph A6.1, the gaps are very stable. Except in the mid-1980s, the difference between the full-sample leverage gap and the gaps estimated over different subsamples is at most 2.5 percentage points. The stability of the debt service gap is even greater: the corresponding difference is at most 1.6 percentage points.

The stability of the VAR

In line with the recursive gap estimates, we assess the stability of the VAR coefficients (system 3) by recursively estimating it with an expanding sample that first starts in 2003 Q1. To automate the process, we use the same zero restrictions as in the full sample. And given the small differences in the gap estimates, we use the full-sample gaps.

Graph A6.2 highlights that the loadings of the co-integrating relationships are very stable. While they fluctuate somewhat, in particular during the Great Recession, they are never statistically significantly different from the full-sample results. The exception is the effect of the spread on lending rates, which was much stronger in the early parts of the sample. This is not surprising, as lending spreads naturally widen at times of stress and post-crises.

Given that we use the VAR in which policy is exogenous in the counterfactual, we also re-estimate it using a sample from 1985 Q1 to 2006 Q1. In this case, we use real-time gaps and re-select the zero restrictions for the VAR.

Table A6.1 shows that the coefficients, including those for short-run dynamics, are stable. The main differences arise for credit growth and other expenditure, for which we find a bigger impact of the gaps (and the spread in case of credit growth) in the 2006 sample. In addition, asset prices seem to adjust more strongly to long-run deviations in the full sample.

Restricting the sample to 1985 Q1-2006 Q1

VAR coefficients if the short-term rate is treated as exogenous[1]

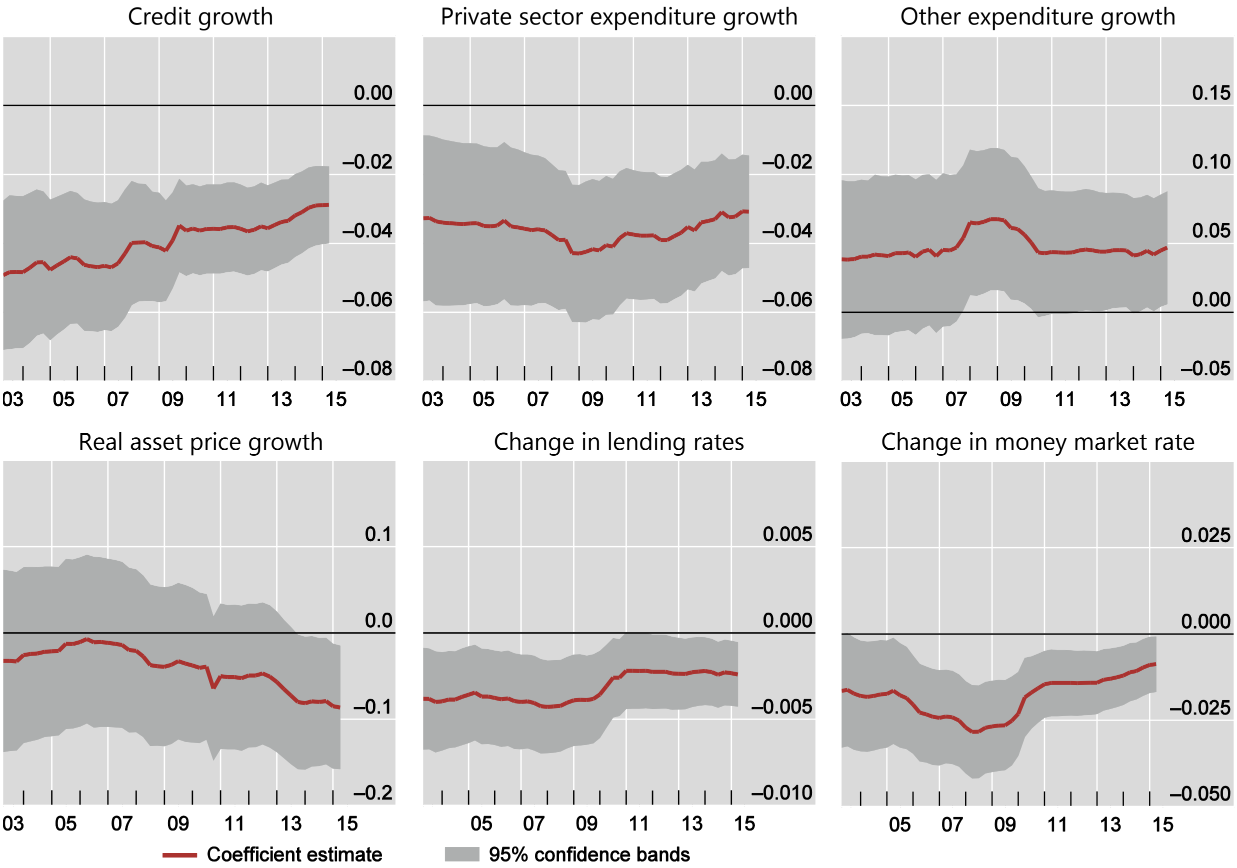
Coefficients in brackets for full-sample results (Table A3.1) Table A6.1

	Δcr_t^r	$\Delta e_{P,t}^r$	$\Delta e_{O,t}^r$	$\Delta p_{A,t}^r$	$\Delta \pi_t$	$\Delta i_{L,t}$
Adjustment coefficients to long-run deviations						
$\widetilde{lev}_{\ t-1}$	–0.044*** (–0.017***)		0.092** (–)		–0.005** (–)	
$\widetilde{dsr}_{\ t-1}$	–0.065*** (–0.029***)	–0.027*** (–0.030***)	0.124*** (0.048**)	–0.065* (–0.084**)		–0.002** (–0.002**)
$\widetilde{spr}_{\ t-1}$	0.250** (–)			0.563* (0.783***)		–0.051*** (–0.035***)
cr_{t-1}		– (0.070)	0.549** (–)	0.769** (0.621***)	– (0.078***)	0.023** (0.024***)
Δcr_{t-2}	0.243*** (0.345***)				– (–0.061***)	
Δcr_{t-3}	0.392*** (0.382***)		– (0.634***)			–0.027** (–0.025***)
$\Delta e_{P,t-1}^r$		0.241*** (0.392***)	– (–0.513**)	– (0.793***)		
$\Delta e_{P,t-2}^r$					– (–0.033**)	
$\Delta e_{P,t-3}^r$		– (–0.231***)		– (–0.640**)		
$\Delta e_{O,t-1}^r$			– (–0.230**)			
$\Delta e_{O,t-3}^r$	0.075** (–)		0.267 (–0.230**)	0.381** (–)		
$\Delta p_{A,t-1}^r$			– (–0.190***)		–0.013* (–)	
$\Delta p_{A,t-2}^r$		0.064*** (0.039**)	– (–0.096**)			– (0.003***)
$\Delta p_{A,t-3}^r$				0.143* (–)		– (0.004***)
$\Delta \pi_{t-1}$				2.097*** (–)	–0.675*** (–0.586***)	
$\Delta \pi_{t-2}$					–0.251*** (–0.244***)	
$\Delta i_{L,t-1}$						0.649*** (0.672***)
$\Delta i_{L,t-2}$			–2.152** (–)			
$\Delta i_{L,t-3}$	1.506*** (–)					–0.183*** (–0.123***)
Δi_t		0.730*** (0.567***)				0.121*** (0.123***)
Δi_{t-1}		–0.662*** (–0.679***)				
Δi_{t-2}		– (0.359**)	1.291*** (–)	– (2.421**)		
Δi_{t-3}				1.568** (–)		

[1] The system also includes impulse dummies and seasonal dummies that, for brevity, are not reported here. The VAR has a leg length of three for all variables. For brevity, lags are not reported in the table if they are significant neither in the full sample nor the 2006 system.

Stability of the VAR coefficients[1]

Loadings on the debt service gap Graph A6.2a



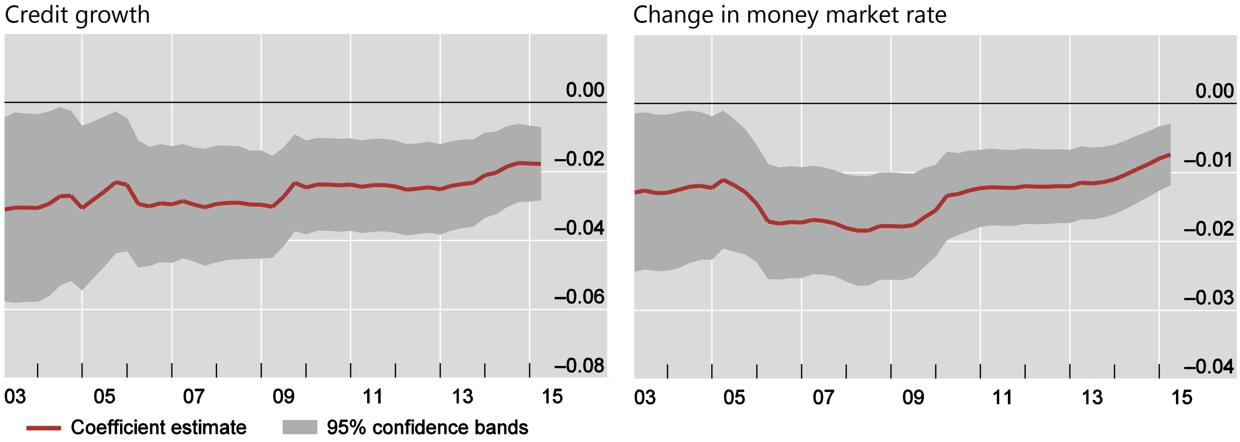
[1] Adjustment coefficients to the debt service gap in the various VAR equations when we recursively estimate the VAR (3) with an expanding sample that starts in 2003 Q1. The same zero restrictions as in the full-sample model and full-sample gaps are imposed.

Sources: National data; authors' calculations.

Stability of the VAR coefficients (cont)[1]

Loadings on the leverage gap

Graph A6.2b



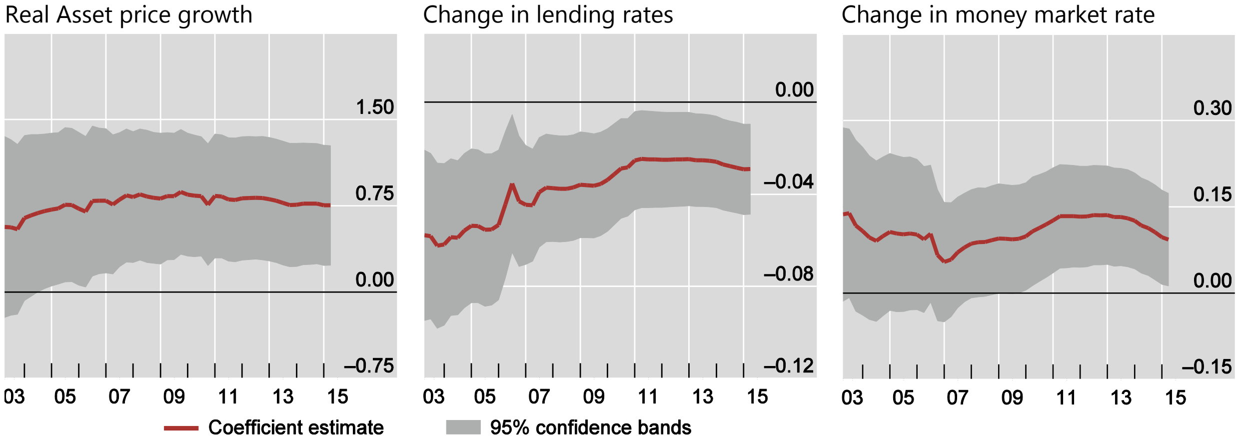
[1] Adjustment coefficients to the leverage gap in the various VAR equations when we recursively estimate the VAR (3) with an expanding sample that first starts in 2003 Q1. The same zero restrictions as in the full-sample model and full-sample gaps are imposed.

Sources: National data; authors' calculations.

Stability of the VAR coefficients (cont)[1]

Loadings on the spread

Graph A6.2c



[1] Adjustment coefficients to the spread in the various VAR equations when we recursively estimate the VAR (3) with an expanding sample that first starts in 2003 Q1. The same zero restrictions as in the full-sample model and full-sample gaps are imposed.

Sources: National data; authors' calculations.

The stability of the filtering system

To assess the real-time performance of the filtering system, we re-estimate it using only data up to 2006 Q1. This includes (quasi) real-time estimates of the leverage and DSR gaps.

Table A6.2 highlights that the filter results are very stable across different subsamples. The main difference arises for the leverage gap equation, where the real rate gap and DSR gaps are, respectively, slightly more and slightly less powerful than in the full sample. This is in line with the real-time VAR results showing that the gaps are less powerful drivers of real asset prices in the 2006 subsample.

Restricting the sample to 1985 Q1-2006 Q1

Posterior estimates for the parameters in the reduced form system[1] Table A6.2

Equation	Explained	Parameter (loading on)	Prior	Prior std	Posterior	Post. std	Posterior (full sample)
(5)	$y_t - y_t^*$	β_5 $(y_{t-1} - y_{t-1}^*)$	0.70	0.20	**0.787**	0.051	**0.699**
		φ_{51} $(r_t - r_t^*)$	0.30	0.20	**0.062**	0.042	**0.059**
		φ_{52} $(\widetilde{lev}_t)$	0.30	0.20	**0.047**	0.012	**0.069**
(7)	$(\pi_t - \pi^*)$	β_7 $(\pi_{t-1} - \pi^*)$	0.70	0.20	**0.940**	0.019	**0.936**
		φ_7 $(y_t - y_t^*)$	0.30	0.20	**0.042**	0.015	**0.028**
		π^*	2.00	0.20	**1.996**	0.174	**1.951**
(8)	r_t^*	β_8 (r_{t-1}^*)	0.70	0.20	**0.632**	4	**0.617**
(9)	z_t	β_9 (z_{t-1})	0.70	0.20	**0.633**	0.275	**0.632**
(10)	$\widetilde{lev}_t$	β_{10} $(\widetilde{lev}_{t-1})$	0.70	0.20	**0.980**	0.021	**0.979**
		φ_{101} $(r_t - r_t^*)$	0.30	0.20	**0.165**	0.101	**0.109**
		φ_{102} $(\widetilde{dsr}_{t-1})$	0.30	0.20	**0.058**	0.034	**0.149**

[1] Results from estimating system (5)-(10) using a Kalman filter.

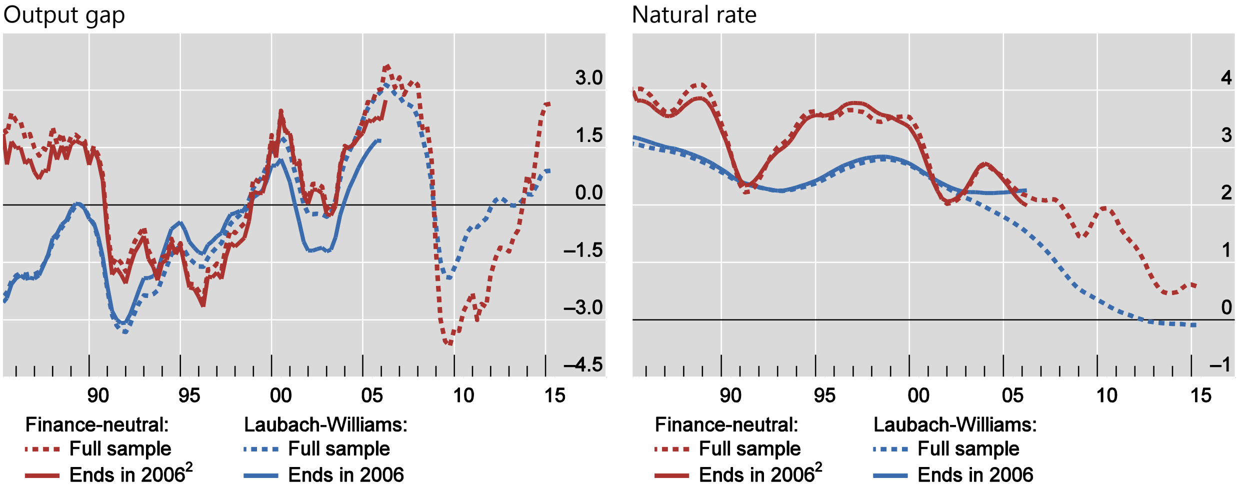
Given the stability of the filter, it is not surprising that the real-time estimates of the output gap and the natural rate closely match the full sample results (Graph A6.3). This contrasts with Laubach and Williams (2003). For instance, the difference between our full sample and real-time output gap estimates is on average 0.4 percentage points after 2004, where the same difference is on average 1.1 percentage points for Laubach and Williams.[38] The results for the natural rate are even more stable. In our

[38] Given that a two-sided filter is used, differences for early parts in the sample are very small. For Laubach and Williams, we use the two-sided estimates using data up to 2006 Q1 provided in Laubach and Williams (2015b).

case, the average difference from 2004 onwards is just 7 basis points, while it rises to close to 50 basis points for Laubach and Williams.

Finance-neutral output gaps and natural rates are reliably estimated in real time[1]

In per cent — Graph A6.3



[1] The finance-neutral variables are the result of estimating system (5)-(10). For the Laubach-Williams variables, we show the results of the two-sided filter using data until 2015 Q3 (full sample) or 2006 Q4 taken from Laubach and Williams (2015b). [2] System (5)-(10) is re-estimated using only data up to 2006 Q1. This includes (quasi) real-time estimates of the leverage and debt service gaps.

Sources: Laubach and Williams (2015b); national data; authors' calculations.

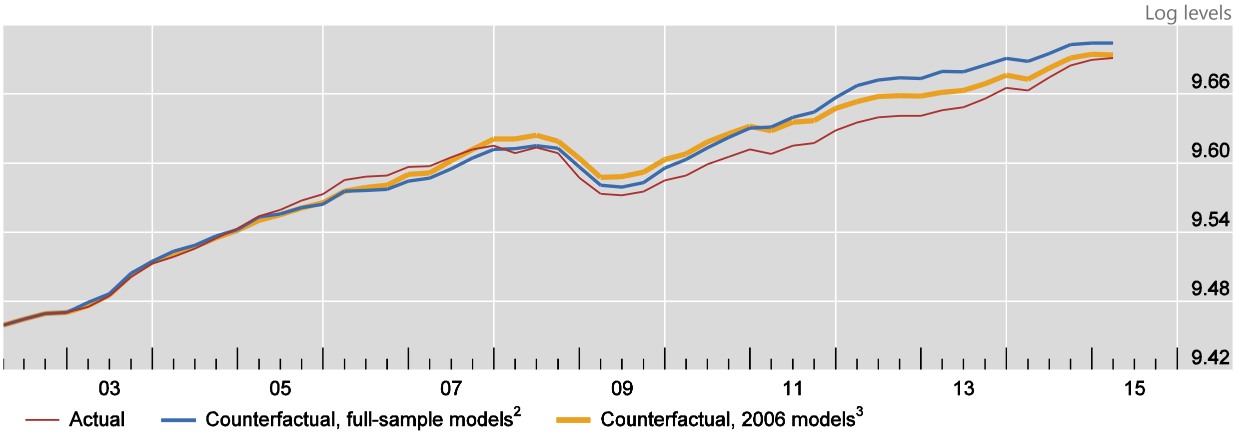
The counterfactual based on the estimation up to 2006

To better understand how sensitive the results of the counterfactual policy experiment are to the models estimated over the full sample, we re-run it using the filter (Table A6.2) and the VAR in which policy is exogenous (Table A6.1) as estimated only up to 2006 Q1. We continue to add the estimated errors to the counterfactual. For periods after 2006 Q1, these are derived as the difference between the actual and the one-period-ahead forecasted outcomes using the VAR estimated up to 2006, given the path of actual policy. We start the counterfactual in 2003 Q1. As for the main results, the policy rule weights the DSR gap by a factor of 0.75, ie $\lambda = 0.75$ in equation (13).

As shown in Graph A6.4, the results of the counterfactual do not depend on the full-sample estimates. Output gains are somewhat lower than if full-sample models are used. Nonetheless, they remain large, cumulatively 9.5% or 0.77% per year.

Output gains in the counterfactual are robust to model uncertainty[1]

The evolution of GDP | Graph A6.4



[1] In the counterfactual experiment, we set policy based on the augmented Taylor rule in line with equation (14) with ρ=0.9 and λ=0.75. The counterfactual experiments start in 2003 Q1. Results are based on the VAR system (3a, Annex 3) where policy rates are exogenous. The errors and outliers of the VAR estimates are retained to derive the evolution of the variables in the counterfactual. [2] Counterfactual based on the VAR and filter using the full sample as in the main text. [3] Counterfactual based on the VAR and filter estimated with data up to 2006 Q1. After 2006, errors are derived as the difference between the actual and the one-period-ahead forecasted outcomes using the VAR estimated up to 2006, given the path of the actual policy rate.

Sources: National data; authors' calculations.