Monetary Policy, the Financial Cycle, and Ultra-Low Interest Rates*

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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. 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 significant output gains and little change in inflation.

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

1. 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 (figure 1). Why is this so?

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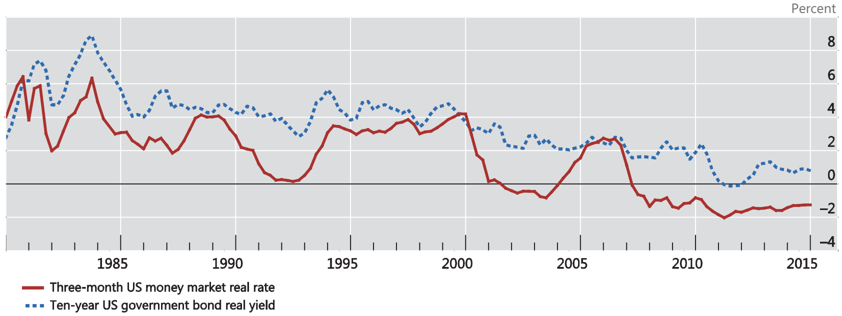
Figure 1. The Long-Term Decline in Real Interest Rates



Source: National data.

Note: Real rates are generated by subtracting realized PCE core inflation from nominal interest rates.

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 (International Monetary Fund 2014, Bean et al. 2015, Obstfeld and Tesar 2015, Rachel and Smith 2015). 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 (Caballero, Farhi, and Gourinchas 2008, Broadbent 2014, Bernanke 2015, Del Negro et al. 2017).

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 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. 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 outsized financial booms and busts, which in turn can wreak havoc on output (e.g., Borio and Lowe 2002, Schularick and Taylor 2012). 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, Basel Committee on Banking Supervision 2010, Ball 2014).

We present an alternative view of the natural rate, in which financial factors also play a role. This 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 buildup of serious financial instability (e.g., Summers 2014, Bean et al. 2015). 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 (e.g., Borio and Filardo 2007, Pain, Koske, and Sollie 2008, Ball and Mazumder 2011, IMF 2014, Blanchard, Cerutti, and Summers 2015)[1] and—the mirror image—with the limited usefulness of inflation as an indicator of business-cycle conditions (e.g., Borio, Disyatat, and Juselius 2014). Indeed, a recent strand of empirical work indicates that, by contrast, financial-cycle proxies are helpful indicators of those conditions (Borio, Disyatat, and Juselius 2014, 2017; Kiley 2015).

This perspective has first-order implications for monetary policy. It suggests that inflation may be an insufficient guide for monetary policy. If monetary policy has a material impact on financial booms and busts, thereby resulting in swings in medium-term

[1]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 (Dotsey, Fujita, and Stark 2015). Faust and Leeper (2015) also stress that inflation dynamics are not as simple as implied by models based on economic slack.

output trajectories, and if inflation is a poor indicator of deviations of output from potential, then ignoring financial cycles may lead policy astray. To analyze these issues in more detail, we propose an empirical framework in which financial factors play a pivotal role in economic fluctuations.[2] 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 the financial cycle, the framework also provides a richer perspective on the secular decline in real interest rates.

We apply the framework to U.S. data over a thirty-year period, 1985–2015, and reach two 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, the way monetary policy is systematically conducted has a first-order impact on financial factors and hence output fluctuations. And the resulting booms and busts have persistent effects even when crises do not break out. As a corollary, taking the financial cycle into account can improve economic performance.

Together, these two conclusions suggest that a narrative that attributes the decline in real interest rates and their persistently ultra-low post-crisis levels 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

[2] 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, Claessens, Kose, and Terrones (2009), Reinhart and Rogoff (2009), Schularick and Taylor (2012), Jordà, Schularick, and Taylor (2013), and Mian, Sufi, and Verner (2016). On the theoretical side, following Bernanke, Gertler, and Gilchrist (1999), a prominent strand of research has focused on the role of financial frictions in New Keynesian models with increasing emphasis on variations in credit spreads (e.g., Del Negro, Giannoni, and Schorfheide 2015, Adrian and Duarte 2016, Cúrdia and Woodford 2016, Del Negro et al. 2017).

economy, the decline also reflects, in part, policy frameworks (Borio and Disyatat 2014, Borio 2016).

Thus, monetary policy frameworks matter. An effective "lean against the wind" approach requires policy to take financial developments into account *systematically.* One possible representation of such a policy rule, as described here, takes the form of an augmented version of the standard Taylor rule (Taylor 1993) that incorporates financial-cycle indicators. Such a rule differs fundamentally from typical interpretations of a "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 (e.g., Svensson 2014, 2016; Ajello et al. 2015; IMF 2015). Responding to financial stability risks only when they become evident would 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.

To reach these conclusions, we expand the familiar Laubach and Williams (2003, 2015a) reduced-form model for estimating potential output and the natural rate by incorporating financial-cycle information. Our measure of the financial cycle focuses on the role of leverage and debt service burdens, assessed relative to their long-run levels. As Juselius and Drehmann (2015) find, such a measure can account for a substantial part of the evolution of output in the short to medium term.[3] By harnessing financial-cycle information, we obtain different estimates of potential output and the natural real interest rate—what we refer to as *"finance-neutral"* estimates. 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 framework in ours, we let the data speak. Hence, if the financial terms are

[3]In particular, the dynamics implied by these two gaps captures well and out of sample the basic features of the Great Recession and of the subsequent weak recovery (Juselius and Drehmann 2015).

unimportant, the estimates will simply revert to more conventional estimates.

Based on this framework, we then explore the interaction between policy and the financial cycle. We use the estimates of the filter and perform a counterfactual experiment with 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 possibility that our results would actually be reinforced if agents were to internalize the systematic policy reaction and hence respond even more strongly. In any case, our aim here is simply to illustrate how a systematic interaction between policy and the financial cycle can have persistent effects on economic performance.

The rest of the paper is organized as follows. Section 2 develops extensions to a baseline system in the spirit of Laubach and Williams (2003). Section 3 introduces the data and presents the estimates. Section 4 simulates the system under different specifications of the policy rule. Possible avenues for future work are considered in the conclusion.

2. The Financial Cycle, Potential Output, and the Natural Interest Rate

Before turning to the detailed extension of the small-scale version of the standard Laubach-Williams framework to take into account financial-real linkages, it is useful to introduce our empirical measure of the financial cycle.

2.1 Characterizing the Financial Cycle

To model the financial cycle, we build on previous work by Juselius and Drehmann (2015). The authors use two co-integrating (long-run) relationships to pin down the long-term evolution of three key variables, namely the credit-to-GDP ratio, real asset prices, and the nominal lending rate. They show that deviations from these long-run relationships provide a useful decomposition of the financial cycle.

The first long-run relationship is between the credit-to-GDP ratio and inflation-adjusted (real) asset prices. This relationship captures the well-known positive link between debt and the price of assets, which may arise from the latter's use as collateral or, more generally, as a source of revenue or service streams (housing). The relationship can be interpreted as a very rough proxy for aggregate *leverage* at market prices. As it turns out, this is well approximated by the ratio of debt to assets (Juselius and Drehmann 2015). We refer to the deviations of this relationship from its long-run value as the *leverage gap*, $\widetilde{lev}_t$, which can be expressed as[4]

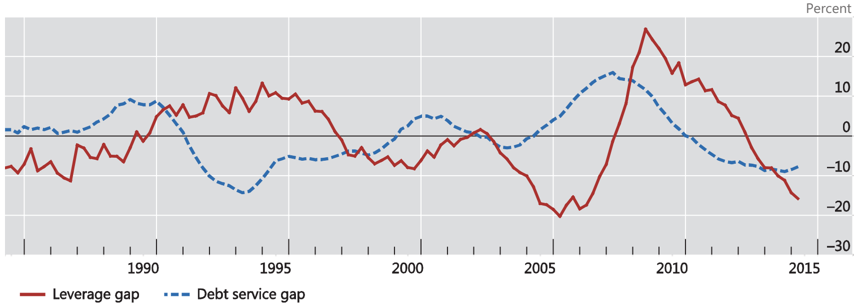
$$\widetilde{lev}_t = (cr_t - y_t) - (p_{A,t} - p_t) - \overline{lev}, \tag{1}$$

where cr_t is credit to the non-financial private sector, y_t is output, $p_{A,t}$ is a real asset price index, p_t is the consumer price level, and $\overline{lev}$ is a steady-state constant. The asset price index is constructed from residential property prices, commercial property prices, and equity prices, with the corresponding weights adding up to one (see appendix). When leverage is below its long-run value (e.g., when asset prices are high), credit tends to increase faster than normal, and vice versa.

The second long-run relationship is between the credit-to-GDP ratio and the (average) lending rate on the debt outstanding. 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 ratio*—defined as the ratio of interest payments plus amortizations of households and non-financial companies to their income (Juselius et al. 2016). This suggests that the variable is closely linked to cash flow constraints. We refer to deviations of

[4]In what follows, we use lowercase 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.

Figure 2. Evolution of the Leverage and Debt Service Gaps



Source: Authors' calculations.

this variable from its long-term relationship as the *debt service gap*, $\widetilde{dsr}_t$, which can be written as

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

where $i_{L,t}$ is the nominal average lending rate on the stock of credit, and $\overline{dsr}$ is a steady-state constant. Importantly, $i_{L,t}$ reflects not only *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. Thus, it is influenced by current *and* past monetary policy decisions.

Together, relationships (1) and (2) pin down the long-run level of the credit-to-GDP ratio, consistent with real asset prices (via the leverage gap) and the nominal lending rate (via the debt service gap). In effect, when *both* leverage and debt service gaps are closed, the credit-to-GDP ratio, real asset prices, and the lending rate take values that are consistent with their long-run levels. We adopt this as our measure of *financial equilibrium.*

Figure 2 depicts estimated leverage and debt service gaps for the United States from 1985:Q1 to 2015:Q1.[5] The debt service gap was

[5]Details of the estimation of the co-integration system are set out in the appendix. Commercial property prices are not available before 1985 and, hence, constrain the sample period.

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 buyout (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. 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.

2.2 A "Finance-Neutral" Filtering System

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. Building on previous work which has found that financial variables can help improve estimates of potential output (e.g., Arseneau and Kiley 2014, Borio, Disyatat, and Juselius 2014, 2017), we construct a filtering system that allows financial factors to play a role in business-cycle 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. Specifically, we modify *as little as possible* the standard baseline framework of Laubach and Williams (2003) to take the financial cycle into account.

The baseline system consists of four key equations. First, there is a reduced-form IS equation linking the output gap, $y_t - y_t^*$, to the difference between the real rate and the natural rate, $r_t - r_t^*$ (the interest rate gap), where $r_t = i_t - E_t\pi_{t+1}$. For simplicity, we assume that expected and actual inflation coincide, i.e., $E_t\pi_{t+1} = \pi_t$, throughout.[6] Second, there is a standard Hodrick-Prescott (HP)

[6]This is similar in spirit to Laubach and Williams (2003), who use a weighted average of current and past inflation rates as a proxy for expected inflation. In general, our system has a less elaborate autoregressive structure than theirs, and we link potential output and the natural rate directly rather than adding an additional equation for potential output growth. This leaves small high-frequency components in our potential output and the natural rate estimates, but does not otherwise affect the results.

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

$$y_t - y_t^* = \beta_3(y_{t-1} - y_{t-1}^*) - \varphi_{31}(i_{t-1} - \pi_{t-1} - r_{t-1}^*) - \varphi_{32}\widetilde{lev}_{t-1} + \vartheta_{3t} \tag{3}$$

$$y_t^* = 2y_{t-1}^* - y_{t-2}^* + \vartheta_{4t} \tag{4}$$

$$(\pi_t - \pi^*) = \beta_5(\pi_{t-1} - \pi^*) + \varphi_5(y_{t-1} - y_{t-1}^*) + \vartheta_{5t} \tag{5}$$

$$r_t^* = \beta_6 r_{t-1}^* + (1 - \beta_6)\left(z_t + \frac{1}{\rho}4\Delta y_t^*\right) + \vartheta_{6t} \tag{6}$$

$$z_t = \beta_7 z_{t-1} + \vartheta_{7t} \tag{7}$$

$$\widetilde{lev}_t = \beta_8\widetilde{lev}_{t-1} + \varphi_{81}\widetilde{dsr}_{t-1} + \varphi_{82}\widetilde{dsr}_{t-4} + \varphi_{83}(r_{t-1} - r_{t-1}^*) + \vartheta_{8t} \tag{8}$$

$$\widetilde{dsr}_t = \beta_9\widetilde{dsr}_{t-1} + \varphi_{91}\widetilde{lev}_{t-1} - \varphi_{92}\widetilde{lev}_{t-4} + \varphi_{93}\Delta i_{L,t-1} + \vartheta_{9t} \tag{9}$$

$$i_{L,t} = i_{L,t-1} - \varphi_{101}(i_{L,t-1} - i_{t-1} - \overline{spr}) + \vartheta_{10t}, \tag{10}$$

where $\vartheta_{it} \sim iid(0, \sigma_i^2)$ and the quarterly potential growth rate in (6) is annualized by multiplying it by 4.

Our extension relative to the baseline system is shown in grey. We first adjust the baseline system to allow for the possibility that the leverage gap contains information about the output gap.[7] If one thought of the corresponding equation, (3), as a typical reduced-form expenditure function, then the leverage could be regarded as

[7] An additional benefit of using an observable variable (the leverage gap) to relate monetary policy and real outcomes in (3) is that it helps to anchor potential output and the natural rate in the filter.

a proxy for the strength of the credit constraint. It enters with a negative sign because a positive leverage gap is associated with low asset prices, and hence low credit growth and correspondingly lower output.[8] 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, Disyatat, and Juselius 2014, 2017). The leverage gap can be seen as a more structured way of capturing the same information.

If the leverage gap turns out to be informative for the output gap (i.e., $\varphi_{32} > 0$), we also need an equation that characterizes its evolution. 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, the debt service gap feeds negatively into asset price growth and, hence, boosts the leverage gap (Juselius and Drehmann 2015). Since the debt service effect is quite sluggish in the data, as a shortcut to modeling it with a more elaborate autoregressive structure we allow it to enter with both one- and four-quarter lags (equation (8)).

As Juselius and Drehmann (2015) show, there is a feedback loop between the leverage gap and the debt service gap running from new debt to the debt service and, in turn, from debt service to asset prices and thereby back to the leverage gap. And this loop underpins how the financial cycle interacts with the real economy. For instance, it can lead to persistent endogenous cycles that pose a significant challenge for monetary policy. To capture this two-way interaction, we allow the leverage gap to feed into the debt service gap in equation (9). Again, we include both the first- and fourth-quarter lags of this variable. The debt service gap is also directly related to changes in the average nominal interest rate on debt.

Clearly, the average nominal interest rate on debt can be closely influenced by monetary policy. We therefore postulate that the

[8]The effects from the leverage gap are unlikely to reflect more standard wealth effects. Juselius et al. (2016) show that the leverage gap has a stable positive effect on output growth via credit growth in a vector error-correction model (VECM). This effect does not change when the growth rates of various asset prices enter the model.

average lending rate is a weighted average of the past lending and policy rates with a constant, $\overline{spr}$, in the long run. This is expressed in equation (10).

3. Results

We now briefly describe the data used in estimating the system (3)–(10) and the key results.

3.1 Data

We use quarterly time series for the United States from 1985:Q1 to 2015:Q1. Output, y_t, is measured by real GDP. Our short-term interest rate, i_t, is the three-month federal funds rate, and we use the log change in the core personal consumption expenditure index as our inflation measure, π_t. To construct the leverage gap we also need a credit stock and a general asset price index. As a measure for the credit stock, cr_t, we use total credit from all sources to the private non-financial sector, obtained from the financial accounts. Our aggregate asset price index, $p_{A,t}$, is a weighted average of residential property prices, commercial property prices, and equity prices. The appendix provides details about its construction. The average lending rate on the stock of credit, $i_{L,t}$, is constructed by dividing private-sector interest payments, recorded in the national accounts, by the credit stock.[9]

3.2 Estimates

We estimate the parameters of the system (3)–(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_3 to lie in the interval between 0 and 0.95, while we allow the other autoregressive parameters to take any value in the

[9] We also account for financial intermediation services indirectly measured (FISIM)—an estimate of the value of financial intermediation services provided by financial institutions. When national accounts compilers construct the sectoral accounts, parts of interest payments are reclassified as payments for services and classified as output of the financial intermediation sector.

unit interval. For φ_{31}, φ_{32}, φ_5, φ_{85}, and φ_{101}, we assume the gamma distribution with mean 0.3 and standard deviation 0.2 and that they are positive. Since we split the cross-equational effects of the debt service and leverage gaps between lags 1 and 4, we set the prior means of φ_{81}, φ_{82}, φ_{91}, and φ_{92} to 0.15 with corresponding standard deviations of 0.1. There is no good guide for setting the prior of φ_{93}, but a straightforward regression suggests that its value is close to 10. Hence, we use this as prior mean with standard deviation 0.5. Rather than estimating the discount rate, ρ, we set it to 0.99, in line with the literature. We also fix the inflation target, π_t^*, at 2.

We use the inverse gamma distribution for the shock variances. We rely on historical variances of the first difference of HP-filtered output, inflation, the leverage gap, the debt service gap, and the average lending rate to calibrate the prior means of $\sigma^2_{4,t}$, $\sigma^2_{5,t}$, $\sigma^2_{8,t}$, $\sigma^2_{9,t}$, and $\sigma^2_{10,t}$ respectively, as well as on the variance of HP-filtered output growth (as a baseline for the natural rate) for the prior means of $\sigma^2_{6,t}$ and $\sigma^2_{7,t}$. 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.[10]

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 1).

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_{31} and φ_{32}) are broadly similar. But in the sample, the interest rate gap varies between –3.5 and +1.5 percentage points, whereas the leverage gap ranges from –20 to +27 percent, which translates into a –0.9 to +1.2 direct effect on the output gap. Moreover, the leverage gap is more persistent, leading to much higher long-run effects.

[10]In particular, we set the scaling parameter $\lambda = \sigma^2_{3,t}/\sigma^2_{4,t}$ 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 cutoff for the business cycle as in the HP case. The two filters coincide if $\beta_3 = \varphi_{31} = \varphi_{32} = 0$. See Borio, Disyatat, and Juselius (2014) for an in-depth discussion of these restrictions.

Table 1. Parameter Estimates for the Minimal Extension

Equation	Parameter	Loading On To	Prior	Prior Std.	Posterior	Posterior Std.
IS Curve, (3)	β_3	$y_{t-1} - y^*_{t-1}$	0.70	0.20	0.738	0.083
	φ_{31}	$r_t - r^*_t$	0.30	0.20	0.037	0.022
	φ_{32}	$\widetilde{lev}_t$	0.30	0.20	0.045	0.010
Phillips Curve, (5)	β_5	$\pi_{t-1} - \pi^*$	1.00	0.00	1.000	0.000
	φ_5	$y_t - y^*_t$	0.30	0.20	0.015	0.010
Natural Rate, (6)	β_6	r^*_{t-1}	0.70	0.20	0.616	0.069
z-factor, (7)	β_7	z_{t-1}	0.70	0.20	0.685	0.020
Leverage Gap, (8)	β_8	$\widetilde{lev}_{t-1}$	0.70	0.20	0.949	0.019
	φ_{81}	$\widetilde{dsr}_{t-1}$	0.15	0.10	0.004	0.001
	φ_{82}	$\widetilde{dsr}_{t-4}$	0.15	0.10	0.003	0.001
	φ_{83}	$r_t - r^*_t$	0.30	0.20	0.007	0.003
Debt Service, (9)	β_9	$\widetilde{dsr}_{t-1}$	0.70	0.20	0.960	0.011
	φ_{91}	$\widetilde{lev}_{t-1}$	0.15	0.10	0.020	0.006
	φ_{92}	$\widetilde{lev}_{t-4}$	0.15	0.10	0.051	0.008
	φ_{93}	$\Delta i_{L,t}$	10.00	0.50	7.442	0.310
Lending Rate, (10)	φ_{101}	$i_{L,t-1} - i_{t-1}$	0.30	0.20	0.093	0.012

Note: Results from estimating system (5)–(10) using a Kalman filter.

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 real interest rate as a tool for controlling the gap? The answer is "not very." The coefficient estimate of the real interest rate gap in (8), φ_{83}, is about 0.007. Given the leverage gap range, this is tiny *on impact*. But given the leverage gap's high degree of persistence, the effect is eventually twenty times as large and implies that a 1 percentage point increase in the real rate above the natural rate increases the leverage gap by 0.13 percentage points. That said, the real interest rate effect on the output gap is much smaller than that reported in Laubach and Williams (2003). One reason might be that we use a shorter sample owing to the limited availability of commercial property prices.

The estimates of equation (8) also reveal that the lagged debt service gap terms are important drivers of the leverage gap. Given the range of the debt service gap, its economic effect is about ten times as large as that of the interest rate gap. The debt service gap, in turn, is also affected by the leverage gap. This gives rise to the potential for endogenous cycles (Juselius and Drehmann 2015). Moreover, via the effects on the lending rate (equation (10)), the nominal policy rate is directly linked to the debt service gap, implying a transmission channel from debt service to leverage and finally to output and inflation.

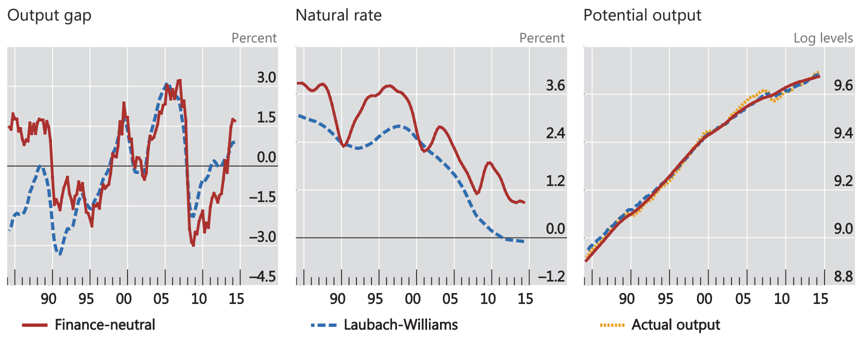
The estimates of the Phillips curve, (5), seem reasonable. The coefficient on lagged inflation is very close to unity. For simplicity, we impose this value strictly, in line with much of the literature. The coefficient on the output gap is rather small, but this is consistent with the literature pointing to a weak link between domestic slack and inflation. Finally, the estimates for the z_t factor suggest that this element is clearly stationary and relatively small.

Figure 3 compares our estimates of the output gap and the natural interest rate with those of Laubach-Williams (2015b).[11] Two points stand out with respect to the output gap (left-hand panel).

First, when estimated over the full sample, the two gaps move together from the mid-1990s. Recognizing the financial tailwinds, our output gap measure clearly indicates that the economy was running

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

Figure 3. The Financial Cycle: Implications for the Natural Rate and Trend Output



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

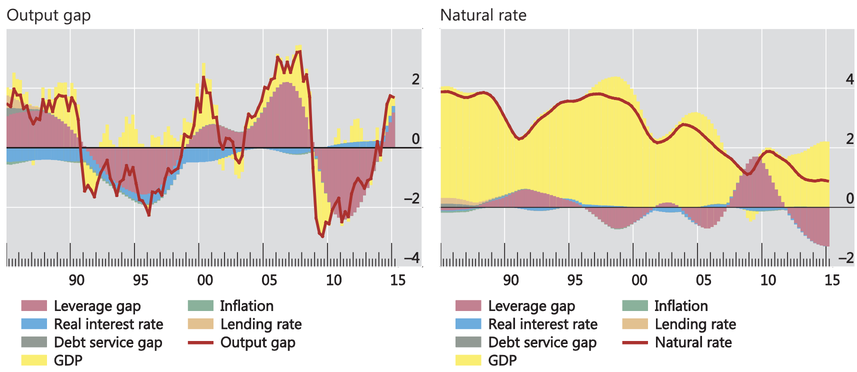
Notes: The finance-neutral variables are the result of estimating system (3)–(10). For the Laubach-Williams variables, we show the results of the two-sided filter using data until 2015:Q3 taken from Laubach and Williams (2015b).

above sustainable levels in the years leading up to the financial crisis. Conversely, output was below potential in the aftermath of the crisis owing to 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 U.S. 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. 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 next to nothing to the variance in the output gap in our specification (left-hand panel, figure 4). The leverage gap is the main contributor, followed by the real interest rate gap.

Figure 4. 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 percent)

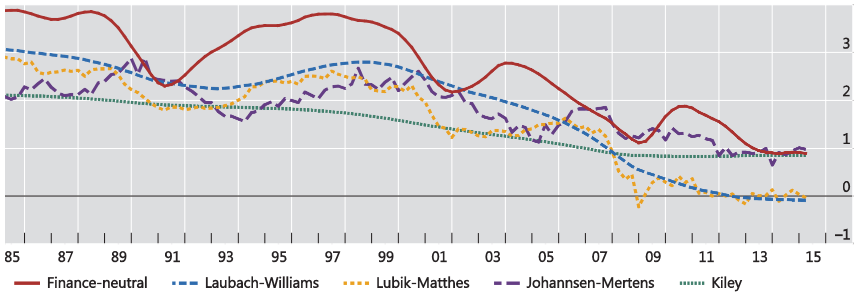


Sources: National data; authors' calculations.

For present purposes, the focus is on the natural interest rate (middle panel, figure 3). In particular, our estimate shows a decline from 4 percent to 0.9 percent over the last thirty years. This is in line with the downward trend in potential output growth (right-hand panel, figure 3). Starting in 2000, our natural rate estimate has clearly declined by less than its Laubach-Williams counterpart. Interestingly, actual interest rates (see figure 1) have remained below the estimated natural rate for almost the whole period under study. Sharp interest cuts in response to financial strains in the early 1990s, early 2000s, and 2008 were not taken back in the ensuing normalization phase, suggesting substantial policy asymmetry with respect to the financial cycle. Finally, given the tight specification, GDP growth accounts for most of the variance in the evolution of the natural rate (right-hand panel, figure 4).

By contrast, the natural rate estimated by Laubach-Williams is consistently below our estimates and is currently negative (middle panel, figure 3). This reflects the emphasis the framework places on inflation in pinning down both the natural rate and potential output, through the IS curve and the Phillips curve, respectively. In the early part of the sample, the downward trend in inflation leads to

Figure 5. A Comparison of Various Natural Rate Estimates (in percent)



Sources: Laubach and Williams (2015b); Lubik and Matthes (2015); Kiley (2015); Johannsen and Mertens (2016); authors' calculations.

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 the observed real rate whenever the output gap is negative. 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.

For broader comparison, figure 5 plots our estimates of the finance-neutral natural rate alongside those constructed in a number of recent papers. For instance, Lubik and Matthes (2015) derive an estimate from a time-varying parameter vector autoregressive model for real GDP, inflation, and the real interest rate. Despite the sharp difference in method, they obtain estimates that are remarkably similar to those of Laubach and Williams. By contrast, using a framework that is similar in spirit to ours, Kiley (2015) finds that estimates of the natural rate become much higher once one augments the IS curve with additional financial variables, such as a corporate bond spread and credit growth. While the resulting estimates fluctuate less than ours and are generally lower, the estimated levels are very close in the recent period. A similar finding also appears in Johannsen and Mertens (2016), who estimate the expected long-run value for the real federal funds rate from an empirical model of the shadow rate that conditions on a long-term interest rate and the Congressional Budget Office unemployment gap.

Finally, it should be noted that our filtering system is quite robust in real time, confirming previous work on output gaps using financial information (Borio, Disyatat, and Juselius 2014, 2017). Coefficients hardly change, so that we obtain very similar output gap and natural rate estimates even after observing more data (Juselius et al. 2016). This is a very desirable property from a policymaking perspective.

4. The Financial Cycle and Monetary Policy

The above filtering system suggests that much of the cyclical movements in output can be attributed to financial factors. Moreover, the strong feedback dynamics between the leverage gap and the debt service gap suggest that the current state of the business cycle alone may be too crude a guide for policy. Recognizing this should lead to a different design of stabilization policies, not least that of monetary policy. In this section we take a preliminary step in exploring this. To do so, we propose a modification to a standard monetary policy rule, by including a systematic response to financial developments. We then evaluate our policy rule in an illustrative counterfactual experiment.

4.1 An Alternative Monetary Policy Rule

As an alternative 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, i.e., the intercept in the rule is no longer a constant. This is quite standard.[12] 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

[12] Carlstrom and Fuerst (2016) analyze this formally, in particular within a standard New Keynesian model with $r^*_t = r^* + \Delta prod_t$, where $\Delta prod$ is expected productivity growth. They then assess Taylor rules of the form $i_t = (r^* + \alpha(r^*_t - r^*) + \pi^* + 1.5(\pi_t - \pi^*) + 0.1(y_t - y^*_t))$.

debt service gap closely influences the leverage gap and hence the output gap (see equations (8) and (3)). And in comparison with the leverage gap, the debt service gap is strongly influenced by policy through lending rates (equations (9) and (10)). Thus, including the debt service gap in the policy rule is one way to increase traction over the financial cycle. Hence, we analyze the following rule:

$$\begin{aligned} i_t = \rho i_{t-1} + (1-\rho)(r^*_{t-1} + \pi^* + 1.5(\pi_{t-1} - \pi^*) \\ + 0.5(y_{t-1} - y^*_{t-1}) - \lambda \, \widetilde{dsr}_{t-1}). \end{aligned} \tag{11}$$

Here, we set $\rho = 0.85$ and $\lambda = 0.75$. In Juselius et al. (2016), we also explored other values for λ, including $\lambda = 0$, so that our rule collapses into the standard Taylor rule with a time-varying intercept that equals the natural rate.

4.2 A Counterfactual Experiment

To assess the potential benefits from monetary policy taking into account the financial cycle, we conduct a counterfactual exercise in which we embed the new policy rule in the economy as estimated by the filter. We essentially ask what the evolution of the economy would have been from a given point in time if (i) policymakers followed the policy rule in (11), (ii) agents' behavior remained invariant, so that the reduced-form structure of the economy estimated by the filter did not change, and (iii) the economy was hit by the same historical shocks, including for instance the financial crisis, but excluding shocks to monetary policy. Put differently, differences between the counterfactual and historical outcomes are solely due to the systematic policy interest rate path.

The assumption that agents' behavior 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 that the Lucas critique may be of limited relevance in practice.[13] For instance,

[13]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.

a common finding is that the parameters of empirical VARs are remarkably stable despite changes in estimated policy equations in the sample (e.g., Favero and Hendry 1992, Leeper and Zha 2003, Rudebusch 2005).[14] In addition, in Juselius et al. (2016) we implement an analogous counterfactual analysis with a slightly different approach and obtain very similar, in fact stronger, results.

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, in Juselius et al. (2016) we find some evidence that it has, directly or indirectly, reacted to a high debt service burden also more recently. 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 internalize the systematic response to financial developments, the policy's effectiveness in dampening the financial cycle could arguably be greater.

Despite these arguments, we fully acknowledge the shortcomings of our counterfactual exercise. On balance, given the potential changes in behavior, 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.

[14]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.

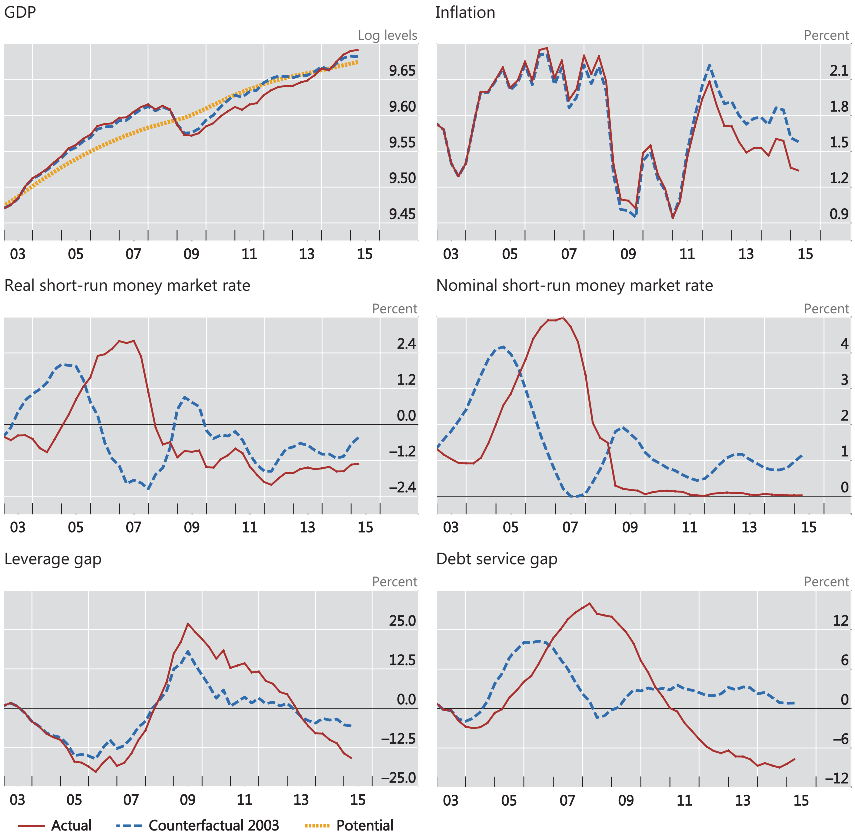
To implement the counterfactual experiment, we follow an iterative procedure, starting from 2003:Q1 as t_0:[15]

(i) Derive the natural rate $r^*_{t_0-1}$ and the output gap $(y_{t_0-1} - y^*_{t_0-1})$ using the estimated filter.
(ii) Set policy rate for t_0 as $i_{t_0} = 0.85\rho + 0.15(r^*_{t_0-1} + \pi^* + 1.5(\pi_{t_0-1} - \pi^*) + 0.5(y_{t_0-1} - y^*_{t_0-1}) - 0.75\widetilde{dsr}_{t_0-1})$ if this leads to $i_{t_0} > 0$ or set $i_{t_0} = 0$ otherwise.
(iii) Use the estimated filter and generate predictions of all variables in the system for time t_0 conditional on the new policy rate and the retained errors ε_{t_0}.
(iv) Redo steps (i)–(iii) for $t_0 + 1, t_0 + 2 \ldots$ until the end of the sample.

The various caveats notwithstanding, the counterfactual exercise shows that the alternative policy rule potentially yields considerable output gains compared with actual history with little change in inflation. By the end of the simulation period the cumulative output gain is over 15 percent, or around 1.25 percent per year (top left-hand panel, figure 6). 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, figure 6). Initially, the negative leverage gap and higher rates drive up debt service, which in turn helps to stabilize the leverage gap. But higher policy rates also weigh on economic activity. In fact, output in the counterfactual policy prior to 2008:Q4 is on average 1 percent lower than actually experienced. These output losses, however, are more than offset by the gains during the Great Recession, which still occurs also because the Lehman shock is included in the counterfactual. Moreover, lower financial imbalances in the form of lower debt service and leverage gaps mean that output after 2008 is on average 3 percent higher in the counterfactual than historically (third row, figure 6). And the leeway created by following the policy rule pre-crisis also means that interest rates are on average higher. As such, the central bank retains greater room for policy maneuver.

[15]In Juselius et al. (2016), we also explore a counterfactual which starts in 1996. We find that an earlier implementation succeeds in containing financial imbalances much better, thereby leading to higher gains.

Figure 6. Leaning Against the Financial Cycle Improves Economic Performance



Sources: National data; authors' calculations.

Notes: 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 (11). Results are based on the filter (3)–(10). We retain the historical errors to derive the evolution of the variables in the counterfactual. The counterfactual policy starts in 2003:Q1.

These output gains come with little change in overall inflation performance. This is not too surprising given the low traction that the output gap has on inflation in the filter. In fact, the output gap is, on average, smaller in the counterfactual. In particular, after

2010, output is close to potential and inflation ends up being a bit *higher* and closer to target, not lower.

It should be noted 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 might not even have materialized. This should be considered when evaluating the findings.

Finally, by making minimal changes to the standard filtering framework, we have deliberately restricted the extent to which the financial cycle, and hence monetary policy, can affect longer-run output trajectories. In particular, potential output and the natural rate are fully exogenous in the filter and do not change with changes in monetary policy. Moreover, since we assume that the estimated shocks from the filter also occur in the counterfactual experiment, both of these variables will take exactly the same paths as in the full sample. In the more elaborate, flexible, and in our view more realistic, setup detailed in Juselius et al. (2016), where economic trajectories are modeled through a VECM, not only are output gains under the alternative policy rule more persistent, but the natural rate estimates in the counterfactual are also higher. Thus, the results presented in this section in some sense can be viewed as a conservative illustration of the extent to which the monetary policy–finance nexus can influence macroeconomic outcomes.

4.3 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. 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 (e.g., Svensson 2014, 2016; IMF 2015).

First, the typical empirical framework understates the costs of financial imbalances to the extent that it ignores persistent, and possibly permanent, effects on the *level* of output. Our analysis above shows that the output effects even in the simple system can be quite persistent. In the more flexible framework of Juselius et al. (2016), the impact of the financial cycle on output lasts much longer, which is more consistent with the evidence that crises may have permanent effects on the level of output (Cerra and Saxena 2008, BCBS 2010, Ball 2014). Moreover, these costs may arise even if a full-blown crisis does not occur. Hence, the costs of neglecting the financial cycle are likely to be an order of magnitude higher.

Second, the typical empirical framework 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.[16] 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 typical empirical framework 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, i.e., avoiding straying persistently too far away from financial equilibrium, with large buildups 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, the central bank could simply be seen as precipitating the very recession it wishes to prevent. Selective attention is not the answer. A "through-the-cycle" policy is called for.[17]

[16] 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 behavior 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 of this introduces "noise" in the indicator's predictive content. This, in turn, will inevitably reduce the benefits of a leaning policy.

[17] See also Filardo and Rungcharoenkitkul (2016), who reach broadly similar conclusions based on a model that highlights the importance of the systematic policy rule when the financial cycle is endogenous.

At the same time, we should not take the suggested rule too literally. For instance, looking more closely at the behavior 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. 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 as macroprudential measures, in the later stages of financial booms.

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 U.S. 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 an asymmetrical policy can impart a downward bias to interest rates as the buildup 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 overindebted and overleveraged, 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. Unless financial factors are taken more systematically into account, and a sufficiently long horizon is adopted, policy steps that appear reasonable when taken in isolation may take policy astray when considered as a sequence. Central banks need to carefully weigh the medium- to long-term side effects of policy working through the financial cycle against the benefits of short-term stimulus.

5. Conclusion

The critical role that financial developments play in economic fluctuations has long been recognized. Yet the prevailing analysis of the business cycle, and of its relationship to interest rates, does not exploit these interlinkages much. The extraction of trends and long-run equilibrium variables, such as potential output and the natural interest rate, 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 an exogenous 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 U.S. data, we find that if one considers the influence of the financial cycle, the estimated natural interest rate is generally higher and, on balance, has declined by less since the 2000s. 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 very persistent 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 with little change in inflation. Such a policy can also result in a smaller decline in the estimated 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 buildup 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 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 behavioral 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 (Bank for International Settlements 2014, 2015), recognizing this could help integrate monetary policy into a more holistic and balanced macrofinancial 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.

Appendix. The Leverage and Debt Service Gaps

In this appendix, we discuss the construction and estimation of the leverage and debt service gaps.

To accurately measure the debt service gap, we need the average interest rate on the stock of debt. This variable can be obtained from the national accounts as gross interest payments plus financial intermediation services indirectly measured divided by the stock of credit (Drehmann et al. 2015).

For the leverage gap 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. Given stark differences between the types of collateral used by households (HH) and firms (NFC), as well as changes in the sectoral composition over the sample, we first estimate separate asset price indexes for each sector separately from long-run empirical relationships of the form

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

where $p_{res,t}$ denotes residential property prices, $p_{com,t}$ represents commercial property prices, and $p_{eq,t}$ stands for equity prices. These asset prices are obtained from the BIS databases. Superscript $s = H, NFC$ is used to denote the type of agent and superscript r is used to denote real values (e.g., $p_{res,t}^r = p_{res,t} - p_t$). We then construct the aggregate asset price as a weighted average

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

where ω_t is the share of private non-financial credit in the household sector.

We estimate the long-run parameters α_j^s for each sector from separate VAR models in error-correction form. Using Johansen's likelihood ratio test, we find that the co-integration rank is one in both cases. Moreover, formal exclusion tests suggest that commercial property prices and equity prices can be excluded for the households, whereas residential property prices can be excluded for the NFCs. Doing so gives us the estimates, $p_{A,t}^{r,HH} = p_{res,t}^r$ and $p_{A,t}^{r,NFC} = 0.72 p_{com,t}^r + 0.28 p_{eq,t}^r$. By a similar approach, we obtain the estimate $\beta_{dsr} = 5.54$ in (2). The details of these estimations can be found in Juselius et al. (2016).

Juselius et al. (2016) investigate the robustness of the estimates with respect to different samples. Despite their relatively high persistence, the two gaps can be accurately estimated from any sample that uses data up to at least 2003. The difference between the full-sample leverage gap and the gaps estimated over different subsamples is at most 2.5 percentage points, except in the mid-1980s where the difference is slightly higher. The stability of the debt service gap is even greater: the corresponding difference is at most 1.6 percentage points. Crucially, this implies that the gaps do not depend on the Great Recession and the financial boom that preceded it.

In Juselius et al. (2016), we also compare our estimated gaps with purely data-based measures as given by the credit-to-assets ratio for the financial accounts and debt service ratios calculated using a Federal Reserve Board methodology (Dynan, Johnson, and Pence 2003). The correspondence between these measures is close, suggesting that they broadly capture the same information.[18]

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[18]See also annex 1 in Juselius and Drehmann (2015). To be precise, while the debt service ratio is stationary, the debt-to-assets ratio of households and non-financial corporates from the flow of funds exhibits a slight deterministic trend, likely due to the fact that asset prices in the financial accounts are not fully marked to market. Deviations from this linear trend are closely correlated with the deviations from the long-term co-integrating relationship.

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