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INFLATION TARGETING, CREDIT FLOWS, AND FINANCIAL STABILITY IN A REGIME CHANGE MODEL

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Recent papers point to the problem that inflation-targeting models do not as of yet consider financial market stability that can considerably derail inflation-targeting monetary policy, implying significant nonzero crisis probabilities that could come along with large negative output and employment gaps. Credit flows and the instability of credit appear to be at the root of the financial instability problem. On the other hand, some authors recently questioned whether a too early and too strong leaning against the wind policy by central banks might have higher costs than benefits in terms of output and employment losses. In our paper, we include in an inflation targeting model a financial stabilization goal. In contrast to infinite horizon and two-period models, we propose a finite horizon model. The model is solved by using a new global solution algorithm, called Nonlinear Model Predictive Control (NMPC), exploring stabilizing/destabilizing effects of price and nonprice (credit volume) drivers of the output gap, inflation, and credit flows. We substantiate the theoretical part of the paper by approaching the subject empirically, relying to that end on a regime-switching structural vector autoregressive (VAR) for the euro area. The empirical model contains standard macroeconomic variables along with credit flows and loan interest rates, the central bank policy rate, and European Central Bank (ECB) balance sheet variables. The regime-switching feature of the model is meant to capture the state-dependent relationship between the variables, with specific nonlinearities having direct counterparts in the theoretical model. Based on a sign restriction methodology, we explore conventional and unconventional monetary policy shocks, loan supply, and demand shocks, under different regime assumptions to reveal the state-dependent effects of both interest rate and volume-based policies. The empirical results are used as guidance for the calibration of the theoretical model variants.

Keywords: Monetary Policy, Macroprudential Policy, Financial Stability, Regime Switching

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1. INTRODUCTION

Papers such as Woodford (2012), Svensson (2014), and Ajello et al. (2016) have pointed to the problem that the inflation targeting model of Svensson (1997) did not consider financial market instability that can considerably derail inflation-targeting monetary policy and create a probability of crisis and large negative output gaps and unemployment. Credit flows and the instability of credit[1] appear to be at the root of the financial instability problem.

Concerning monetary policy and financial instability, economists have taken three positions. The first position argues that monetary policy should only concentrate on the traditional targets of inflation and real output. The second view claims that financial stability is at least as important as the traditional objectives and financial stability should be a third mandate of the central banks (CBs). The third view, recently arising, is that financial instability is somewhat state dependent and accepts that financial stability is important in some circumstances when the benefit of leaning against the wind is greater than the cost from it in terms of output loss and unemployment, see Zdzienicka et al. (2015).

Yet, Svensson (2014, 2016) points to the issue that a too early and too strong leaning against the wind policy by the CBs, using an interest rate hike, may imply higher costs than benefits in terms of output and employment losses. As Svensson (2014, 2016) argues, the costs are likely to exceed the benefits from leaning against financial instability for empirically estimated parameters that he obtains from the Schularick and Taylor (2012) data set. The Svensson model evaluates the costs against benefits where there is only unemployment contained in the loss function.

With a view to macroeconomic modeling of these aspects, recent papers have emerged that aim at a more general loss function including output loss, inflation deviations, and financial stability, with CBs targeting also financial stability, for example, Woodford (2012). Types of monetary policy models have been developed not only with inflation targeting but also targeting financial stability by controlling credit flows that, as in Schularick and Taylor (2012), can undergo considerable boom-bust cycles,[2] generating macroeconomic instability. A further important aspect is that monetary policy is not constrained by affecting credit costs and credit flows through interest rate hikes or decreasing credit spreads, for example, through QE type of policies, but can also affect the supply and demand side of credit flows.

Seen against this evolving stream of the literature, the theoretical model that we develop in this paper departs from an inflation and output targeting framework, as well as credit flows and financial stabilization policies in the context of a monetary policy model that includes an intertemporal loss function, with penalty on output loss, loss from failed inflation targeting, and loss from credit overexpansion, as in Ajello et al. (2016). The model includes as state equations a Phillips curve, an output gap, and credit dynamics, the latter following Ajello et al. (2016). In this context then output, inflation, and credit flows dynamically respond to both price and nonprice drivers of credit flows impacted by monetary policy. Monetary policy can affect the interest rate and credit spreads, as well as the volume of credit flows—through affecting the demand and supply of credit. We will contrast interest rate and volume-based policies in the regime change model variants.

For solving the model variants, we use a new solution technique called Nonlinear Model Predictive Control (NMPC), which allows us solving continuous time control problems. The method allows us to evaluate the dynamics and the size of the losses generated by the use of different model variants, where the model variants are finite time horizon models. We thus can compute not only the solution paths for finite horizon problems, but also the cumulative cost involved in the dynamic decision path of the monetary control problem. Since the NMPC method allows for regime changes, we can also compute the paths and the cumulative costs permitting state- or regime-dependent responses to policy decisions.

Since there is quite some uncertainty as to what the credit drivers are, how the credit dynamic equation should look like, and what type of monetary policy is effective, we examine four scenarios, from the perspective of both the theoretical and the empirical model. The scenarios comprise the use of conventional interest rate policy, unconventional volume-based policy, as well as more direct loan supply and demand-type policies. One of the main results of our empirical assessment is that most policies help contain credit spreads. As to the best policy, QE relying on APP might theoretically be an efficient policy but may, according to the empirical estimates, not be sufficiently potent to reduce credit spreads during a recession regime.

Section 2 provides the generic monetary policy model with inflation, the output gap, and financial stability as the three targets. Section 3 explores globally the four scenarios [conventional monetary policy, unconventional policy, credit supply shocks (price-based), and credit demand shocks (volume-based) policies] in the regime change model variants. The same scenarios are then also explored in Section 4 in a regime-switching vector autoregressive (RS-VAR) model for the euro area. The focus throughout all sections will lie on the potential for the various policies to contain credit spreads. Section 5 concludes the paper.

2. A GENERIC MONETARY POLICY MODEL WITH CREDIT FLOWS

We start with the Svensson (1997) type model used in Gross and Semmler (2017) and include the credit–output–inflation link. It is a monetary policy macromodel with optimal Taylor rule, an IS equation, a nonlinear Phillips curve, and a dynamic equation for the credit flows. Though the Svensson (1997) model is formulated in discrete time, with linear response coefficients, we here formulate the model in continuous time, as in Werning (2012),[3] which allows for a third target in the objective function and a third state equation, a dynamic equation for credit flows. We also extend the model by introducing a state dependence of credit spreads, reflecting regime changes in the credit–inflation–output link. Moreover, we assess the effects of nonprice drivers of credit flows and their impact on the output gap and inflation.

We solve the discretized model by a new numerical procedure, with NMPC, that allows for a finite decision horizon. In contrast to previous models, such as New Keynesian models, that work with infinite time horizon we present model variants based on a finite decision horizon. We pursue a more realistic strategy and build a model based on a short-term behavior of agents that allows for regime changes. The infinite horizon framework implies a pronounced smoothness in the evolution of the choice variables by construction, as discussed by Gruene et al. (2015). Our finite horizon model permits a certain nearsightedness in the behavior of economic agents, and monetary policy reactions responding to them, which appears more realistic. We first start with a model involving a quadratic objective function and nonlinear state equations whereby the nonlinearities are in the state equations that give rise to regime changes.

We commence by outlining the model as proposed by Svensson (1997) and include the financial variables in the objective function as well as among the state equations. The model defines the feedbacks of the output gap and inflation rate to both the inflation rate in the Phillips curve and to the output gap in the IS equation, but a credit spread can significantly impact the IS equation. The dynamics will be presented by using the basic Svensson model where there is a delay allowed.[4] Since there are three state equations, there can be cyclical movements—in contrast to unidirectional movements back to the steady state.[5]

The state equations can be written in continuous time for shorter time horizon as[6]

$$V(\pi, y) = \min_{i_t,} \int_0^T e^{-\rho t} \frac{1}{2}((\pi_t - \pi^*)^2 + \lambda_y y_t^2 + \lambda_l (l_t - l^*)^2) dt \tag{1}$$

subject to

$$\dot{\pi} = \alpha_1 \pi_t + \alpha_2 y_t, \tag{2}$$

$$\dot{y} = \beta_1 y_t - \beta_2 (i_t + \delta_t - \pi_t - r), \tag{3}$$

$$\dot{l} = \gamma_1 l_t + \gamma_2 y_t + \gamma_3 i_t - \pi_t. \tag{4}$$

In equation (1), there is a quadratic penalty function that has to be minimized by choosing an interest rate i_t, as the CB's decision variable, which may be bounded by zero.[7] Losses are occurring if the inflation rate, output, and credit flows, deviate from their targets.[8] Those losses are computed by our NMPC procedure for different model variants, defined in the integral of equation (1) for t time steps. Note that for each time step t there is a decision horizon N, but the time period is T over which the cumulative cost of monetary control is computed, see Appendix A for details.

Moreover, whereas π_t is the actual inflation rate and the term π^* represents the target inflation rate for the CB. There are weights λ_y and λ_l attached to the output gap and the credit gap, respectively. The parameter ρ defines the discount rate. Equation (2) represents the Phillips curve as differential equation that defines the reaction of the change of the inflation rate to the inflation rate and output gap.[9] As in Svensson, in a first step, those reaction coefficients, $\alpha_1 \leq 0, \alpha_2 > 0$, are assumed to be constant, so far, but those can also be made state dependent. For elaborating on linear and nonlinear Phillips curves, see Gross and Semmler (2017).[10]

We want to stress that the Phillips curve, the output gap, and the credit flow equations used here are not necessarily backward looking. In our finite horizon model, the decision and state variables are on a path approximately consistent with forward looking behavior, since our solution method approaches the infinite time horizon solutions as the time horizon becomes larger, see Gruene et al. (2015).

Equation (3) is the continuous time form of the IS equation representing the output gap, y_t given by the log of actual output, y^a, minus potential output, y^*. The change of the output gap is driven by the output gap and the excess of the real interest rate over the natural interest rate r,[11] this excess being zero at the steady state. Equation (3) is also a differential equation with coefficients, with $\beta_{1,} \leq 0$ $\beta_2 > 0$. Yet, there is a credit spread that depends on the size of the output gap, y_t, and monetary policy, in the following way:

$$\delta_t(y_t) = \mu_1, \quad \text{for } y < 0, \tag{5}$$

$$\delta_t(y_t) = \mu_2, \quad \text{for } y > 0. \tag{6}$$

In the above formulation of the credit spread, we follow many recent papers on the impact of a financially caused recession that let the credit spread rise at the onset of a downturn, due to insolvencies, default risk, and instability triggering a recession.[12] We usually assume $\mu_1 > \mu_2$, but in Section 4 we also show that it is not easy to reduce credit spread in a recession, and in particular to reduce it more than in a boom.

Those two regimes are likely to be related to the third state variable, the dynamics of credit as defined in equation (4). There is a great uncertainty to what extent credit responds to macrovariables and to policy action. With respect to the credit equation (4), we thus pursue a number of alternative modeling strategies and undertake some global as well local evaluations.

We first follow Ajello et al. (2016) and their variant of credit flows, making the change of the flow of credit depending on the credit level, l_t, the output gap, y_t, the interest rate, i_t, and the inflation rate, π_t. The inflation rate is subtracted so as to compute the total credit volume in real terms. This specification of credit flows is estimated in Ajello et al. (2016), where it is empirically validated that the flow of loans respond to past loans, output, and the interest rates, using the data set of Schularick and Taylor (2012).

Though Ajello et al. (2016) do not find the interest rate term always significant, we include here an interest rate effect in the dynamics of credit flows. The coefficients estimated by Ajello et al. (2016) are $\gamma_1 < 0$ and $\gamma_2 > 0$. The latter could impact the credit supply. The coefficient signs are reasonable, in particular γ_1 is estimated to be small, which means the loan repayments are small and there are on average loans taken for longer duration. As to the response of the output gap impact on credit flows, we will also consider a regime-switching version here.

With respect to the response of credit flows to interest rates, γ_3 is ambiguous according to their estimates, it is small but insignificant. One may have the view that banks might react to low policy rates with increasing credit supply, since this is driving their short-run borrowing cost.[13] On the other hand, with the increased capital flows across borders, there is often a positive relation of interest rates and credit flows.[14] So, we will explore both variants, a negative and positive coefficient γ_3. On the other hand, the credit equation (4) can also be formulated in a traditional way as it is in theoretical macromodels, the result of such a variant will be explored in Appendix.

Note that the New Keynesian literature uses an infinite horizon version of the optimal interest rate decision model of the CB. We here employ a finite horizon decision model that presumes some limited information agents in the sense of Sims (2010). This is an important difference to the standard model since we can allow for some nonsmoothness—instabilities are smoothed out by an infinite horizon decision-making model—and, as mentioned, we can also permit regime changes in our model solution method. Yet, we can still compute the value function that, in our case, is the cumulative cost of policies.

We discuss different variants of the model where either the credit cost is directly affected by the monetary policy, by either a change of the policy rates, i_t, or through its effects on the credit spread δ_t. A policy to reduce credit spreads might not so easily be implemented and not so successful in removing instability. Another variant of how credit flows are affected is through the volume of credit, either impacting the supply side or demand side of credit. Thus, we consider prices and nonprice drivers of credit flows and their impact on the output gap, inflation rate, and financial stability. In the latter case of a volume-based policy, stability might enhanced.

3. DYNAMIC MODEL AND MONETARY POLICY SCENARIOS

Next, we explore four monetary policy scenarios and to what extent they may support expansions but also help to reduce financial instability. We present the global solution of those scenarios in order to observe the out of steady state dynamics of the output gap, inflation rate, and credit flows.

3.1. Scenario 1: Control of Short-Term Interest Rates

We first discuss that interest rate-based policies are monetary policies that affect credit cost. CBs might set a policy rate, and affect the short-term (for example, 3 months) money market rate. Yet, credit cost for longer term loans, for risky investments as well as risky bonds with longer maturity, could be high because of a credit spread arising from large negative output gaps, being reflective of high default risk of bank borrowers. Much can be measured by credit spreads,

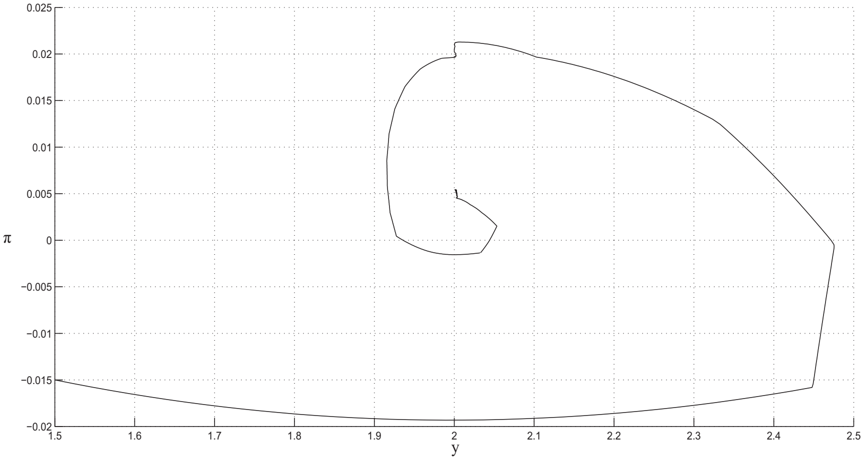

FIGURE 1. Credit cost dependent macrodynamics: credit cost high. Here, we set $\gamma_3 = 0.03$, and large credit spreads $\mu_1 = 0.08$ and $\mu_2 = 0$, as in equations (5) and (6), not significantly reduced by monetary policy; potential output is 2 and output gap is zero at 2; for initial conditions, the inflation rate (vertical axis) and output gap (horizontal axis) move in a cycle around the steady state; small changes of the inflation rate in the region of negative output gap (see the region from 1.5 to 2), and a faster rising inflation rate in the region of positive output gap; monetary policy not activated, high-state-dependent credit cost, persistently large output gap, and slow convergence; cumulative policy cost, $V = 0.653$.

and there is plenty of empirical evidence that credit spread in equations (5) and (6) is countercyclical and regime dependent.[15] We assume in our first scenario $\mu_1 > \mu_2$, with $\mu_1 = 0.08$ and $\mu_2 = 0$.

For our first scenario, we also assume another positive feedback that is related to loan growth and interest rates in equation (4). Much literature justifies $\gamma_3 > 0$. We take $\gamma_3 = 0.03$, which indicates that if we allow for an open economy, high interest rate will induce capital inflows and increase credit supply and excessive borrowing by agents, even if the interest rate is high, see Kumhof et al. (2012, 2013). This might justify a positive co-variation between interest rates and loan growth.[16]

In Figure 1, potential output is set to 2 and output gap is zero at 2. Our parameters are chosen such that at some steady state the inflation rate is zero. As can be observed for initial conditions $y(0) = 1.5$ and $\pi(0) = -0.015$, the inflation rate (vertical axis) and output gap (horizontal axis) move in a cycle around the steady state. With our initial conditions, the inflation rates stay negative in the region of negative output gap (see the region from 1.5 to 2), and a faster rising inflation rate in the region of positive output gap. The reaction coefficient to credit in the credit equation (4) is set to $\gamma_3 = 0.03$.

This model variant with $\gamma_3 = 0.03$ has still large credit spreads. We can observe a persistently large output gap, rising inflation rates, cyclical behavior of our three

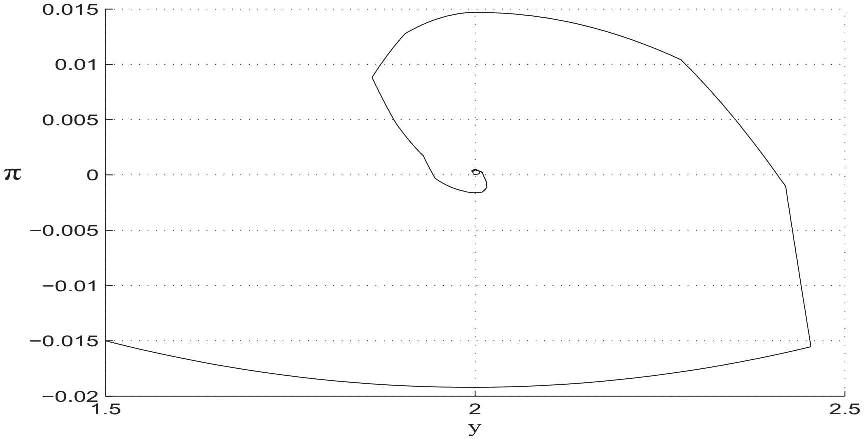

FIGURE 2. Credit cost dependent macrodynamics: low credit spread. Here, we still set $\gamma_3 = 0.03$, credit spread in equations (5) and (6) is reduced to μ_1 =0.02 by financial stress reduction; potential output is 2 and output gap is zero at 2; for initial conditions, the inflation rate (vertical axis) and output gap (horizontal axis) move in cycles around the steady state; small changes of the inflation rate in the region of negative output gap (see the region from 1.5 to 2) and a faster rising inflation rate in the region of positive output gap; QE in the form of APP is reducing credit cost, shrinking output gap, inflation rates adjusting, and generating convergence; cumulative policy cost, $V = 0.31$.

variables, and finally a nonconvergence. Thus, it is not a weak "leaning against the wind" policy of the CB, using interest rates as instruments, that is creating the large swings, but rather the strong credit spread due to large output gaps. It is the negative output gap that exerts pressure on the credit costs via higher probabilities of defaults on the side of bank debtors.

3.2. Scenario 2: Unconventional Monetary Policy

We now assume in a first more specific scenario the better effectiveness of monetary policy to lowering of low credit costs that CBs might be able to achieve through financial stress reduction, using unconventional monetary policy, such as QE in the form of an Asset Purchasing Program (APP). This usually is enacted by expanding CBs balance sheets. The APP by the CB (QE policies) is usually aiming at reducing credit spreads in the credit or bond markets, between risky and less risky bonds and loans.

In the case of Figure 2, monetary policy can help contain credit costs through the policy rate and/or QE in the form of APP by compressing credit spreads. In particular, with QE, the CB, by purchasing risky assets, can reduce credit spreads. The negative output gap becomes smaller and inflation rate moves down due to the output gap in the Phillips curve. There are still some positive feedbacks in equations (4)–(6), yet there is quite fast convergence, see Figure 2, predicting globally some long-run swings in our macroeconomic variables.[17] Figure 2 represents a very ideal case that the CB is quite effective in compressing the credit spread. But as we will observe empirically, using a regime-depending VAR, it is in fact rather difficult to compress credit spreads in a recession.

Overall, we could observe that there is not a significant reduction of credit spreads through monetary policy, and credit growth is likely to still reveal a positive association with interest rates—arising from a need for liquidity and rising supply of loans through capital inflows. In the regime of a negative output gap, it is empirically difficult to reduce credit spread, and thus there will be cumulative losses and the stabilization cost is likely to be high, as we show in our empirical analysis. However, this result depends very much on feedbacks, whether firms and households are not deterred by high interest rates when they need liquidity and credit. Higher market interest rates due to credit spreads are likely to trigger capital inflows, increasing credit supply. Empirical work seems to suggest that such a positive nexus cannot be excluded.[18]

Thus, the dynamics of system (1)–(6) is likely to entail, as Schularick and Taylor (2012) and Jorda et al. (2010, 2013) state, long swings in total credit, with periodically high loan growth, but then moving strongly down again. So, financial instability induced by credit flows could still be a threat. The fact that the unconventional monetary policy is still not very effective is likely to come from the presumption made here that there is a positive feedback effect, $\gamma_3 = 0.03$, in the credit flow equation (4), and a considerable credit spread for a negative output gap. Of course, QE in the form of APP can have a greater effect if the negative response of the credit flow to interest rates is presumed, $\gamma_3 < 0$, see Figure 4, and/or credit flows have also an effect on the demand of credit, see Figure 5.

3.3. Scenario 3: Credit Supply-Based Policies

We next discuss credit supply policies. We first keep assuming a positive co-variation of interest rate and credit growth, and we presume that higher interest rates do not deter credit growth. Such a credit growth might be possibly fueled by capital inflows.[19]

In general, credit supply-side actions have been undertaken for a long time as the Zdzienicka et al. (2015) and Cerutti et al. (2016) studies show. Credit supply-side policies can be pursued by (1) changing lending ceilings, (2) limit short-term credit lines, (3) varying reserve and capital requirements, (4) changing portfolio restrictions, and (5) modifying supervisory guidance. We presume that all of those policies will allow banks to offer larger amounts of low interest rate loans to household and businesses.

In the empirical part of our paper, we represent the effect of those components of credit supply by a price-based approach, by assuming that credit supply, for example, by banks, will actually contribute to a greater (realized) loan supply if this way the actually bank lending rates are reduced. Here, in the theoretical model, we will spell out this effect as volume increase of credit offering.

We keep a low credit spread of $\mu_1 = 0.03$, resulting, for example, from some QE and APP programs, but we reformulate our model in terms of the volume effect[20] and take for simplicity

$$\gamma_{4,t}(y_t) = \nu_1, \qquad \text{for } y < 0, \tag{7}$$

$$\gamma_{4,t}(y_t) = \nu_2, \qquad \text{for } y > 0, \tag{8}$$

and then have instead of equation (4) the following credit equation[21]:

$$\dot{l} = \gamma_1 l_t + \gamma_{4,t} y_t + \gamma_3 i_t - \pi_t. \tag{9}$$

In this version, the credit boom could be stimulated more (increased liquidity) and in a recession credit could contract more (shrinking credit and liquidity by banks).[22]

Here, we want to explore the effect if the banks, encouraged through some CB credit policy, do loosen their credit supply conditions during a recession, maybe through increasing credit lines, and maybe do or not respond in a boom by tightening credit supply conditions.

We take $\gamma_{4,t}(y_t) = \nu_1 = -0.1$ and $\gamma_{4,t}(y_t) = \nu_2 = 0.1$. Thus, a credit supply policy could be enacted asymmetrically, as defined by equations (7) and (8). This has the effect of an increase in credit and liquidity (credit lines) in recessions, and also allows for an decrease in booms, see Zdzienicka et al. (2015).

As can be observed in Figure 3, for given initial conditions, the inflation rate (vertical axis) and output gap (horizontal axis) move in shrinking cycles around the steady state; small changes of the inflation rate in the region of negative output gap (see the region from 1.5 to 2) and a faster rising inflation rate in the region of positive output gap. Here again we have used $\gamma_3 = 0.03$, i.e., we still assume a positive feedback between interest rates and credit growth. As mentioned this could be justified by an open economy feature whereby a higher interest rate may attract capital inflows and increase credit supply.[23]

CBs could however interfere with that positive feedback. Here, we then would observe smaller output gaps, smaller inflation rates, and convergence, see Figure 4. This holds also for leaning against the wind policy—a state-dependent policy: contractionary credit volume policy during the boom, and expansionary in recessions. Of course here, too, a financial policy with the opposite behavior such as stimulating credit supply in booms and restricting it in recession would be destabilizing.

On the other hand, if the economy is in a stage of a still significantly negative output gap and monetary policy leans against the wind by increasing the policy rate and reduces too early QE, generating an interest rate and credit spread hike, this might have higher costs than benefits in terms of output and employment loss and one might get back to the situation of Figure 1 with larger output gaps, heightened vulnerability of a weak economy, and rising credit spreads whereby the cost of financial stabilization is likely to exceed the benefits from leaning against

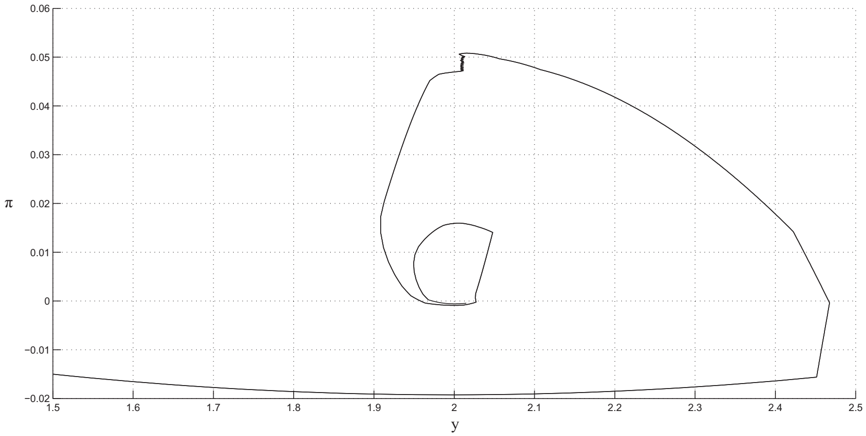

FIGURE 3. Counter cyclical credit supply policies, responding to output gap: convergence. We use here $\gamma_3 = 0.03$; with $\gamma_{4,t}(y_t) = \nu_1 = -0.1$, $\gamma_{4,t}(y_t) = \nu_2 = 0.1$; we observe convergence, but as compared to Figure 1 credit supply policy triggers more cyclical credit, inflation, and output movements; potential output is 2 and output gap is zero at 2; for initial conditions, the inflation rate (vertical axis) and output gap (horizontal axis) move in shrinking cycles around the steady state; small changes of the inflation rate in the region of negative output gap (see the region from 1.5 to 2) and a faster rising inflation rate in the region of positive output gap; we observe smaller output gaps, smaller inflation rates, and convergence. This holds contractionary credit volume policy during the boom and expansionary in recessions; cumulative policy cost, $V = 0.572$.

financial instability. This is similar to the Svensson case, but note that Svensson (2016) evaluates the cost against benefits where there is only unemployment in the loss function. We here evaluate the cost in terms of three arguments, inflation, output gap, and overexpansion of credit.

Next, keeping equation (4), we can examine the case of a positive reaction of credit expansion to the positive output gap, but a negative reaction of credit flows to the interest rate in equation (4). So, we have $\gamma_2 > 0$ and $\gamma_3 < 0$, with $\gamma_3 = -0.03$. The credit flows may fall when interest rates rise,[24] but there is also a supply by the CB: Credit supply and liquidity are reduced,[25] even if the interest rate tends to rise. Those actions could break the positive link between interest rate and credit growth.

Figure 4 shows that in this case, for our initial conditions, the inflation rate (vertical axis) and output gap (horizontal axis) move in shrinking cycles around the steady state; small changes of the inflation rate in the region of negative output gap (see the region from 1.5 to 2) and a faster rising inflation rate in the region of positive output gap, yet when initial output is 2 and output gap is zero at 2; yet, now with $\gamma_3 = -0.03$, we observe smaller output gaps, smaller inflation rates, and convergence. This means that a negative feedback is introduced that is likely to

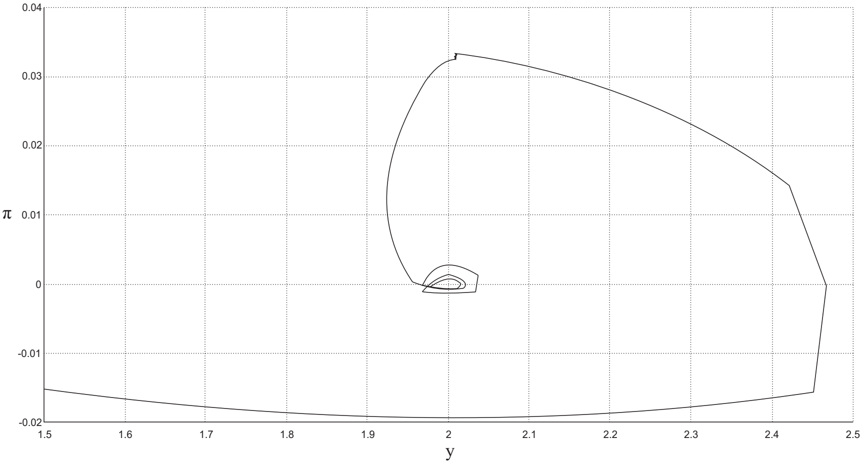

FIGURE 4. Negative feedback in interest rate dependent credit dynamics: convergence. We here leave out the expansionary credit volume effect in the recession, but introduced a negative feedback, $\gamma_3 = -0.03$, and reduction of credit spread, based on equation (4); potential output is 2 and output gap is zero at 2; for initial conditions, the inflation rate (vertical axis) and output gap (horizontal axis) move in shrinking cycles around the steady state; small changes of the inflation rate in the region of negative output gap (see the region from 1.5 to 2) and a faster rising inflation rate in the region of positive output gap; yet, we also observe smaller output gaps, smaller inflation rates, and convergence; cumulative policy cost, $V = 0.33$.

be stabilizing. We can observe persistently smaller output gap, shrinking inflation rates, smaller cyclical behavior of our three variables, and finally a convergence.

Note that this stability result holds for policy rates taken down and a decreasing credit spread resulting from QE. On the other hand, leaning against the wind too early, by raising the cost of borrowing, as in Figure 1, the stronger rise of credit spread, and $\gamma_3 > 0$, is likely to create globally unstable paths and to high a cost of leaning against the wind.

Credit volume[26] can be impacted in principle by increasing the credit supply through equation (4), with the expectation that credit will be passed on to households and firms. For an open economy, credit supply could also be increased by capital inflows.[27] On the other hand, policy can ease constraints on credit demand through equation (3), which is discussed next.

3.4. Scenario 4: Credit Demand-Based Policies

In the next step, we discuss credit demand policies. Such policies could be (1) setting limits on loans to value ratios (LTV), a stock–stock measure, (2) setting caps on loan to income (LTI) ratios, a stock-to-flow measure, (3) debt service to income (DSTI) ratios, a flow-to-flow measure, (4) changing margin requirements

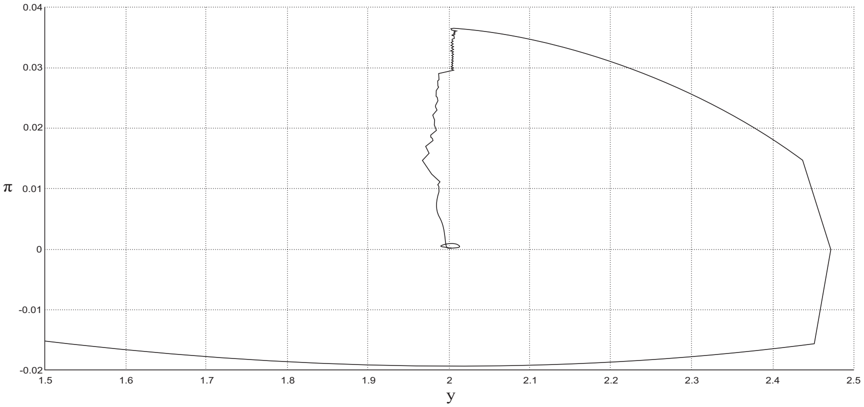

FIGURE 5. Credit dependent IS equation: convergence. Use of equation (10) instead of (3), $\gamma_2 > 0$, $\beta_3 > 0$, and $\gamma_3 = -0.03$, policy supporting credit demand and output gap, y_t, reacting to credit flows; potential output is 2 and output gap is zero at 2; for initial conditions, the inflation rate (vertical axis) and output gap (horizontal axis) move in a shrinking cycle around the steady state and finally converge; cumulative policy cost, $V = 0.4791$.

for borrowing, (5) varying credit standards and collateral requirements, (6) policies in relation to the maturity of loans, and (7) variation of tax policies, for example, providing subsidies for loan demand.

We now examine the effect of such credit volume policies that stimulate credit demand and thus may have an effect on the output gap. This means that there are nonprice drivers of credit flows, for example, initiated by policies that have an indirect effect on credit flows and thus an impact on output.[28] We can assume for our output gap equation

$$\dot{y} = \beta_1 y_t - \beta_2(i_t + \delta_t - \pi_t - r) + \beta_3 l_t. \qquad \textbf{(10)}$$

We take $\beta_3 = 0.05$, which could indicate the ease of credit constraints, as stated in our above-mentioned list, and thus be giving rise to higher realized credit demand.[29] The results using equations (1), (2), (4), and (10) are shown in Figure 5.

From Figure 5, we can observe that, with our initial conditions $y(0) = 1.5$ and $\pi(0) = -0.015$, the inflation rate and output gap move in a long but converging cycle around the steady state, here with equation (10) instead of (3), $\gamma_2 > 0$, $\beta_3 > 0$, and again with $\gamma_3 = -0.03$. We obtain a more unidirectional convergence if the output gap reacts to the ease of credit constraints and demand of credit increases through supporting policies. Note that the output gap does not become so negative as in scenarios 1–3, see Figures 1 and 2, as well as Figures 3 and 4. The result apparently holds because of the positive increase of credit flows, stimulating consumption and investment demand, which will make the output gap shrinking less, or recovering faster.

This result can be interpreted as resembling the effect arising from some monetary policies, such as easing limits on LTV ratios or any of the other above-mentioned credit demand type policies, which have been considered in the past for many sectors.[30]

On the other hand, a leaning against the wind policy, by lowering the LTV ratio, higher collateral and margin requirements, and adverse tax policies can reduce the credit demand—enacted, for example, by macroprudential policies—will likely to have an adverse effect on increasing the negative output gap, and increase the cost of the financial stabilization policy if enacted during a recessionary regime.

If there is a negative relation between interest rates and credit growth, in the case of credit volume policies, we observe faster convergence for both credit supply and credit demand policies, but as to the loss evaluation of the paths, demand policies seem to be less costly than credit supply policies, see the cumulative loss, V, for Figure 3 compared to Figure 5.

Scenario 4 entails a lower cumulative cost than price-based credit policy, such as scenario 1. The reduction in policy cost seems to be higher when policies directly support credit supply and demand, in particular in the presences of a negative feedback of credit growth and interest rate. Credit demand policies, see Figure 5, seem to be even less cost intensive in terms of reducing welfare through a nonprice easing of credit flows through lowering credit standards and reducing collateral requirements; this will make the negative output gap dissipating faster and reveals a less costly adjustment path than credit supply policies.[31]

Concerning our assessment of the global model dynamics, overall, leaving aside the Scenario 2, which seem to be theoretical superior, but empirically not easy to achieve, see below, we seem to obtain better results when credit supply and demand are explicitly targeted, or targeted in the context of a mix of policies. Our four scenarios will be assessed in a local manner now in the next section where we estimate a regime-switching structural VAR model for the euro area.

4. EMPIRICAL ANALYSIS USING A RS-VAR FOR THE EURO AREA

Our empirical analysis departs from a linear along with an RS-VAR model for the euro area. The RS-VAR structure can be written as follows:

$$y_t = c_r + \sum_{i=1}^{p} A_r y_{t-i} + B_r z_t + u_{rt}, \tag{11}$$

where $y_t = (y_{1t}, \ldots, y_{Kt})'$ is a vector of dimension $K \times 1$ comprising K endogenous variables, c_r are the intercept coefficients under the two regimes ($r = 1, 2$), A_r are $K \times K$ matrices of coefficients, and B_r are $K \times G$ coefficient matrices loading an exogenous variable vector $z_t = (z_{1t}, \ldots, z_{Gt})'$ of length G. u_{rt} is a K-dimensional error term whose covariance matrix $E(u_{rt}u'_{rt}) = \Sigma_r$ is allowed to be regime specific, too. For the linear variant of equation (11) without regime dependence, we let the r subscripts drop.

The variables that the vector y contains include real gross domestic product (GDP) in natural log (ln) differences month-on-month (MoM), consumer prices (lnMoM), new business bank loan volume flows to the nonfinancial private sector in lnMoM, banks' new business loan rates, European Central Bank (ECB) total assets in lnMoM, and a nominal short-term interest rate (3-month Euribor). Our choice of employing flow-based measures of volumes and interest rates instead of stock-based measures rests on economic grounds. The extent to which spending is financed by credit, consumption, and investment in a given period will reflect the new lending that is extended in that period. Since GDP is a flow concept, the rate of growth of GDP should be related to the rate of growth in the new flow of credit rather than to changes in the credit stock; also, in the theoretical model, the loan volume variable is supposed to reflect new business loan flows instead of stocks or changes of stocks,[32] which develops a theoretical model that highlights this point and shows that consumption and investment flows are related primarily to new lending rather than to the stock or changes in the stock of loans. Changes in the stocks of loans as a flow proxy are distorted by write-offs, changes in the valuation of securities and repos, and possible changes in the classification of loans to different loan segments. A pure loan flow measure shall be a superior measure to be related to real activity for these combined reasons. The frequency of the data is monthly, covering the period from January 2003 to April 2016. The model has two lags.

Concerning the regime process, one conventional way of estimating regime switching models is via a Markov Switching (MS) structure [see Hamilton (1994)]. We do not, however, infer the regime process from the VAR system and instead take a separate measure of economic slack as a basis to infer the regime process to then make all VAR system parameters including the residual covariance matrix depending on those regimes. Specifically, the measure is one developed by Jarocinski and Lenza (2016) who operate with a Bayesian dynamic factor model for the euro area to imply the estimates of the unobservable output gaps that are consistent with observed inflation dynamics. The authors developed seven variants of the output gap, resulting from different, combined assumptions for the real activity variables they included in the model; the inclusion of a long-term inflation expectation measure and the functional form of the trends was assumed for the real activity variables.

We take one measure as an input to our assessment, that is, their Model 4. This model is consistent with the view that trend and potential growth have not changed significantly, for the current output gap to be sizable rather temporarily (albeit being persistent) and the potential for it to be closed via demand side stimulus. The Model 4 measure is shown by the authors to be the best performing gap measure in terms of predicting inflation in real time, which is confirmed visually by the fact that it is the only measure that implies a nonincreasing gap, in line with flat inflation rate dynamics, over the 2012–2016 period. Moreover, as Jarocinski and Lenza (2016) argue, the Model 4 measure is subject to a rather limited risk of being revised substantially in real time due to new data arrival, which is a relevant concern in particular for filter-based output gap measures [see Orphanides and van Norden (2002)].

Based on the Model 4 measure from Jarocinski and Lenza (2016), we derive a 0–1 indicator, which is 1 if the output gap is positive and zero otherwise. The reasons for not employing a MS (or similar switching) mechanism based on the full system are twofold and related: First, the regimes that result from a VAR system do not necessarily reflect growth regimes, as the model contains many variables beyond the output measures, and moreover with a MoM transformation, masking the lower frequency business cycle dynamics; second, we want to build in the specific rationale of the theory we developed in the first part of the paper where the dependency of the model dynamics is specifically with respect to economic slack only. The results that we present in the following are robust to the various different output gap and regime inference schemes as presented in Gross and Semmler (2017).

To reveal the linear and nonlinear model's dynamics, we simulate and present sign-restricted impulse responses (SR-IRs).[33] To derive the impulse responses from the regime-switching models, we take the coefficient sets and covariance matrix estimates that are specific to the two regimes of the regime-switching version of the VAR and simulate the impulse responses assuming that the regimes keep prevailing.[34]

We simulate four scenarios, whose settings are summarized in Table 1. All four scenarios are positive shock scenarios and they correspond to a conventional interest rate-based monetary policy shock (CMP), an unconventional volume-based monetary policy shock (UMP), a loan supply shock (LS), and a loan demand shock (LD). There are no constraints imposed on real GDP and inflation in any of the scenarios. A positive constraint is under all scenarios imposed on nominal GDP, which is an off-model variable whose paths are proxied by the sum of real GDP growth and inflation during the simulation. The CMP and UMP constraints profiles in Table 1 are quite similar in terms of sign settings and differ only with respect to where an impulse is explicitly applied.

Under the LS and LD scenarios, the shocks are meant to originate more directly in relation to the banking system instead of the CB, in which case the CB total assets and the short-term interest rates are in fact not constrained. The motivation for having the direct LS shock is to be in a position to assess the effects of an *equally sized* (across regimes) shock in terms of nominal loan interest rates in this case, to reveal whether nominal and real activity as well as inflation react differently under the two regimes, and thereby not make the finding of how the economy reacts a function of the initial pass-through of monetary policy to bank lending conditions.

Overall, the first three scenarios reflect supply side-type shock scenarios, which can be seen by the fact that bank interest rates are assumed to fall or are shocked negatively. In addition to the responses of the core model variables, two off-model variables' reactions are shown, that is, the aforementioned nominal GDP proxy as well as a credit spread that is defined as the difference between the loan interest

Table 1. Sign restriction settings for linear and regime switching model-based impulse response analysis

		Real GDP growth	Price inflation	Nominal GDP growth	Bank loan volume growth (new business)	Bank interest rates (new business)	ECB total assets	Short-term interest rate
#	Description	RGDP	INF	NGDP	NBV	NBI	ECBTA	STN
1	Conventional expansionary monetary policy shock (price-based)	0	0	+	+	−	+	−25bps
2	Unconventional expansionary monetary policy shock (volume-based)	0	0	+	+	−	+5%	−
3	Positive loan supply shock (price-based)	0	0	+	+	−25bps	0	0
4	Positive loan demand shock (volume-based)	0	0	+	+5%	+	0	0

Note: The table summarizes the sign restriction settings that we use for conducting four different scenario simulations based on the RS-VAR for the euro area. +/−/0 denote a positive, negative, and no sign constraint, respectively. A percent or basis point entry denotes the shock.

rate and the short-term money market rate. That variable is the correspondent to the credit spread δ in the theoretical model.

Figures 6–9 show the results. Table 2, moreover, summarizes the differences of the variables' responses under the assumed expansion and recession regimes, right in the first month, and after 12 and 18 months.

A first finding is that across all four shock scenarios, the response of inflation is positive and it is more positive under the initial expansion regime, both on impact in the first month and in cumulative terms after 12 and 18 months. This outcome was not pre-informed by any sign constraints, and is as robust a finding as in Gross and Semmler (2017), also when considering various different measures of economic slack to inform the regime process.

The nominal GDP response was constrained to be positive; yet, we see the same feature that was not preinformed insofar as the nominal GDP response is more positive under the assumed expansion regime, under all four shock scenarios. Real GDP responses are generally positive, and by the end of the 18-month period are again more positive under the assumed expansion regime. Concerning nominal loan flow growth, we see a similar pattern as for nominal GDP, that is, positive responses, which are more positive under the expansion regime.

With a specific view to credit spread responses, we observe that it is negative and quite persistent under all scenarios, meaning that lending conditions ease not only because level interest rates fall but also the spreads on top, reflecting in turn that the borrowers' default risk would fall under the scenarios.

Under all scenarios, the difference between the expansion and recession regime-conditional response of credit spreads is positive, meaning that the fall in spreads is more negative under the initial expansion regime. Under the direct loan-side shock scenario, the difference between the spread responses under the two regimes is most pronounced, whereas under the direct loan supply shock scenario it is least pronounced. The regime differential falls in between for the two MP shock modes.

There is one additional assessment that we conduct with the model concerns equations (5) and (6). The regime probability-weighted interest rate spread, defined as the difference between the new business loan interest rate and the 3-month money market interest rate, equals 1.35pp and 2.2pp conditional on the expansion and recession regimes, respectively, over the January 2003–April 2016 period. The difference between the spreads in the two regimes therefore amounts to about 85 bps.

Overall, one important result that we shall highlight in our "local" empirical assessment is that in most cases the credit spread is easier to reduce in expansions than in recessions. This also holds for the second scenario, the unconventional monetary policy, where the QE and APP programs are pursued. The theoretical model variant, our scenario 2, indicates also a quite favorable result for this monetary stabilization policy. Since empirically, it is however more effective in an expansion than in a recession, this might mean that a too early leaning against the wind using a tapering of QE might have strong contractionary effects.

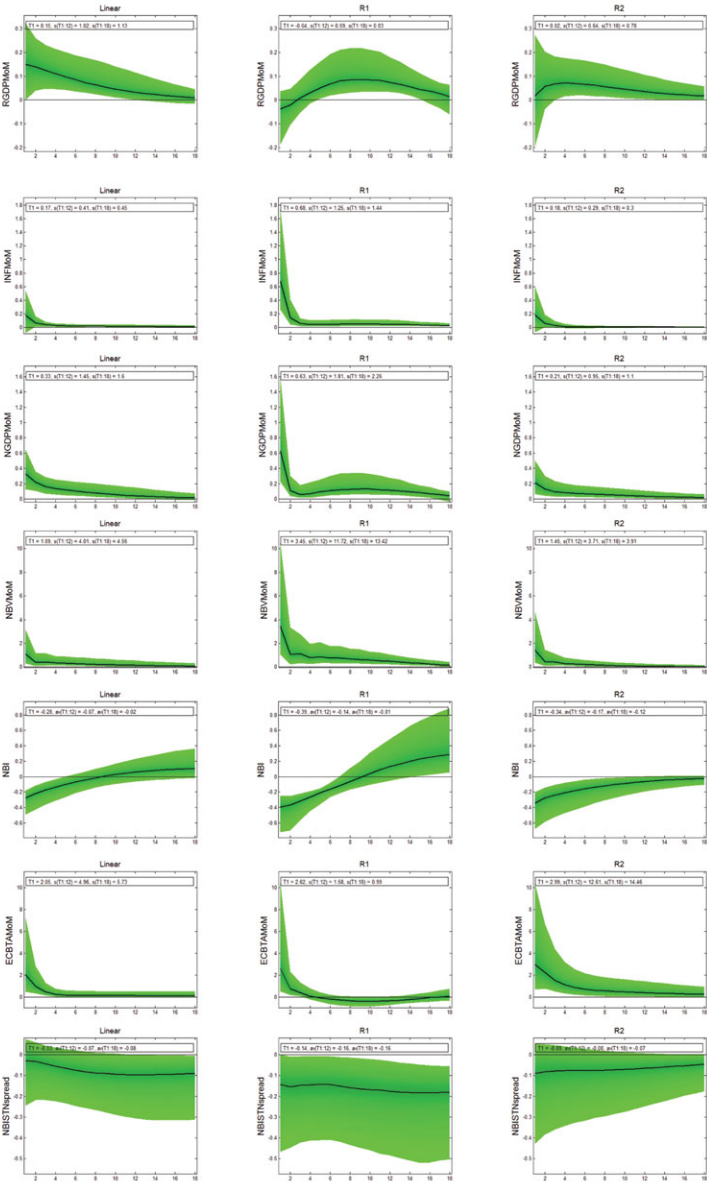

FIGURE 6. Sign-restricted IRs to *conventional expansionary monetary policy shock* (−25 bps on STN). The chart collection shows the sign-restricted impulse responses up to an 18-month horizon. RGDPMoM: real GDP growth MoM. INFMoM: euro area consumer price inflation MoM. NGDPMoM: nominal GDP growth, not included in the model but derived as the sum of the responses of real GDP growth and inflation (see text for some caveats). NBVMoM: new business loan volumes MoM. NBI: new business loan interest rates. STN: short-term interest rate. ECBTAMoM: ECB total assets MoM. The upper/lower end of the green shaded area mark the 10th/90th percentiles of the response distributions. Cumulative responses are reported in the text boxes embedded in the charts.

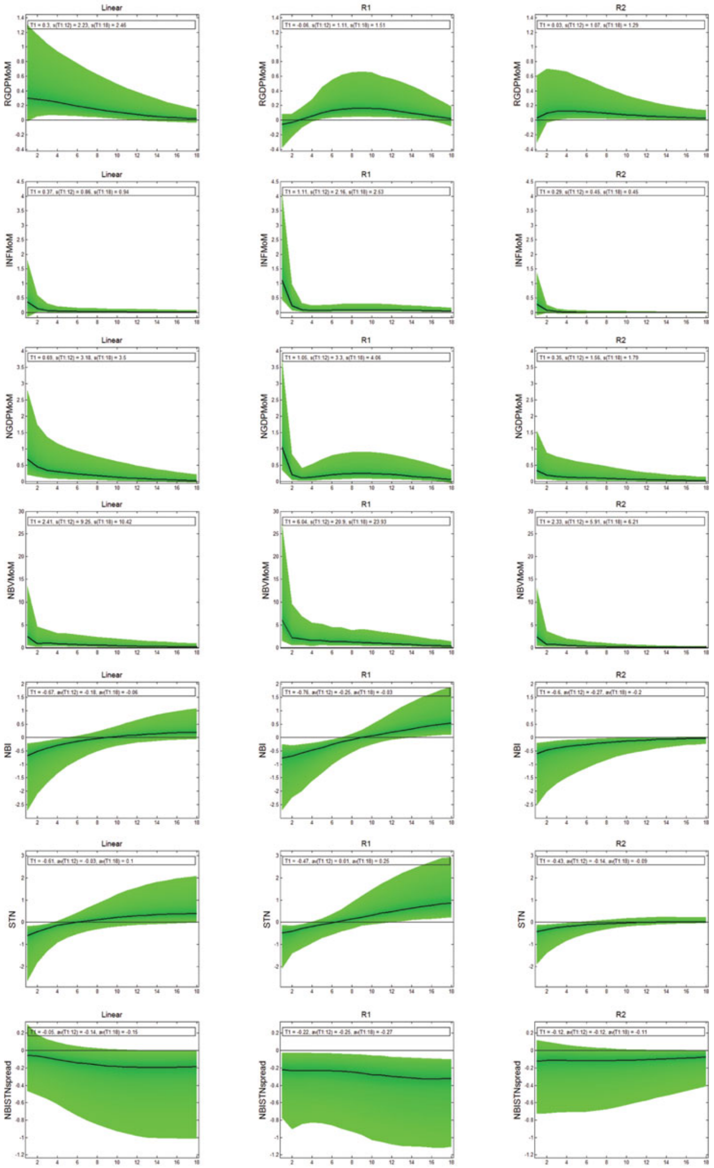

FIGURE 7. Sign-restricted IRs to *unconventional expansionary monetary policy shock* (+5% on ECBTA). The chart collection shows the sign-restricted impulse responses up to an 18-month horizon. RGDPMoM: real GDP growth MoM. INFMoM: euro area consumer price inflation MoM. NGDPMoM: nominal GDP growth, not included in the model but derived as the sum of the responses of real GDP growth and inflation (see text for some caveats). NBVMoM: new business loan volumes MoM. NBI: new business loan interest rates. STN: short-term interest rate. ECBTAMoM: ECB total assets MoM. The upper/lower end of the green shaded area mark the 10th/90th percentiles of the response distributions. Cumulative responses are reported in the text boxes embedded in the charts.

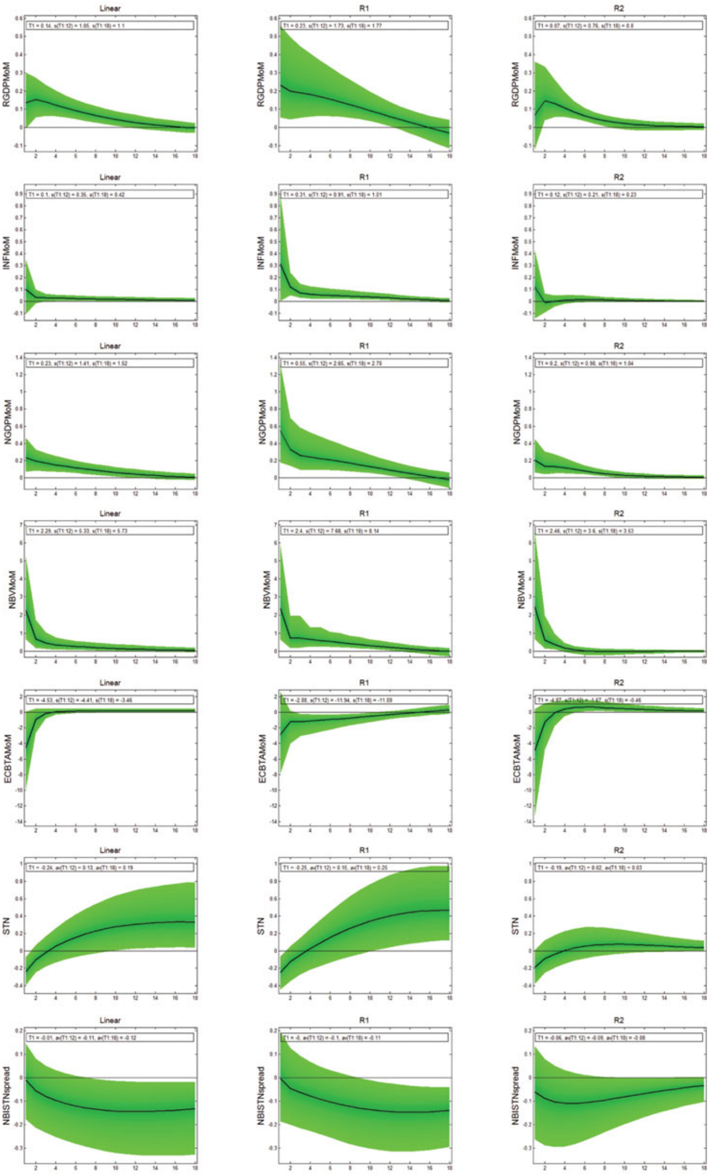

FIGURE 8. Sign-restricted IRs to *positive loan supply shock* (−25 bps on NBI). The chart collection shows the sign-restricted impulse responses up to an 18-month horizon. RGDPMoM: real GDP growth MoM. INFMoM: euro area consumer price inflation MoM. NGDPMoM: nominal GDP growth, not included in the model but derived as the sum of the responses of real GDP growth and inflation (see text for some caveats). NBVMoM: new business loan volumes MoM. NBI: new business loan interest rates. STN: short-term interest rate. ECBTAMoM: ECB total assets MoM. The upper/lower end of the green shaded area mark the 10th/90th percentiles of the response distributions. Cumulative responses are reported in the text boxes embedded in the charts.

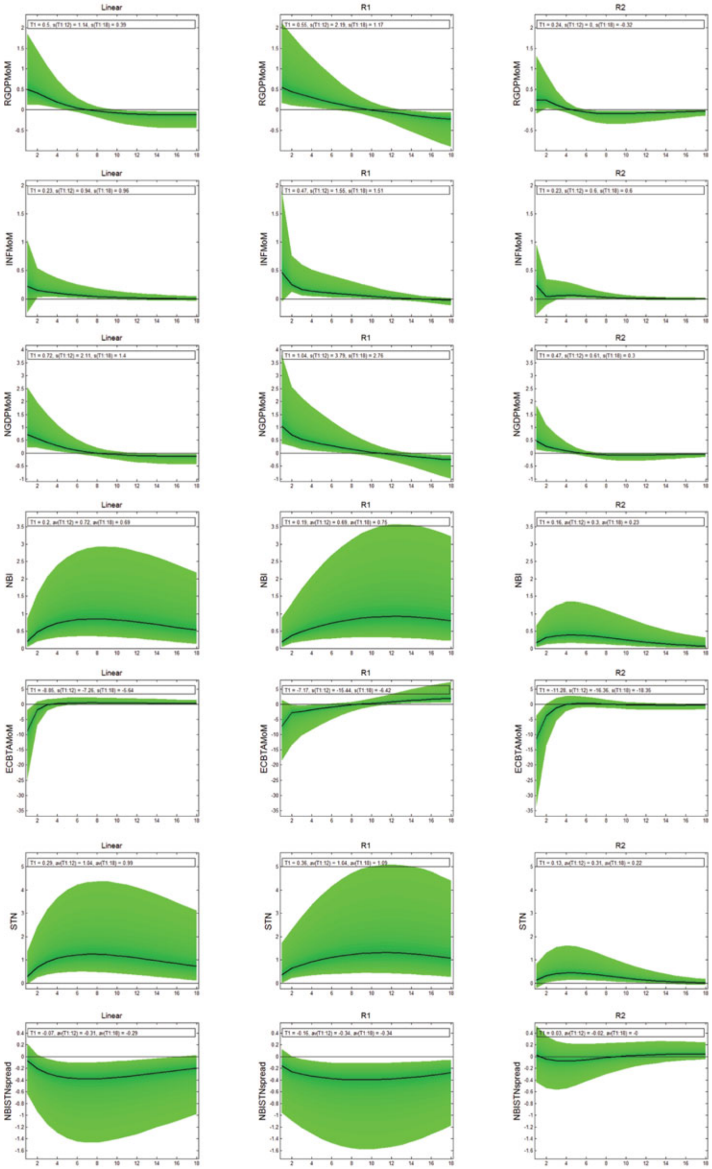

FIGURE 9. Sign-restricted IRs to positive loan demand shock (+5% on NBV). The chart collection shows the sign-restricted impulse responses up to an 18-month horizon. RGDPMoM: real GDP growth MoM. INFMoM: euro area consumer price inflation MoM. NGDPMoM: nominal GDP growth, not included in the model but derived as the sum of the responses of real GDP growth and inflation (see text for some caveats). NBVMoM: new business loan volumes MoM. NBI: new business loan interest rates. STN: short-term interest rate. ECBTAMoM: ECB total assets MoM. The upper/lower end of the green shaded area mark the 10th/90th percentiles of the response distributions. Cumulative responses are reported in the text boxes embedded in the charts.

TABLE 2. Differences of cumulative scenario responses under recession and expansion regimes

	Cumulative difference of the responses $(R2 - R1)$ after $H = 1$ month			
Scenario	1 Conventional expansionary monetary policy shock (price-based)	2 Unconventional expansionary monetary policy shock (volume-based)	3 Positive loan supply shock (price-based)	4 Positive loan demand shock (volume-based)
RGDP	0.06	0.09	−0.16	−0.30
INF	−0.50	−0.83	−0.19	−0.23
NGDP	−0.41	−0.71	−0.34	−0.57
NBV	−2.00	−3.70	0.06	0.00
NBI	0.05	0.16	0.00	−0.02
ECBTA	0.38	0.00	−1.99	−4.10
STN	0.00	0.04	0.06	−0.23
NBISTNspread	0.05	0.10	−0.06	0.19

TABLE 2. Continued

	Cumulative difference of the responses ($R2 - R1$) after $H = 12$ months			
Scenario	1 Conventional expansionary monetary policy shock (price-based)	2 Unconventional expansionary monetary policy shock (volume-based)	3 Positive loan supply shock (price-based)	4 Positive loan demand shock (volume-based)
RGDP	0.05	−0.04	−0.97	−2.19
INF	−0.96	−1.71	−0.70	−0.95
NGDP	−0.86	−1.74	−1.67	−3.19
NBV	−8.02	−15.00	−4.08	−6.28
NBI	−0.33	−0.28	−1.41	−4.69
ECBTA	11.04	16.81	10.26	−0.92
STN	−1.30	−1.81	−1.53	−8.79
NBISTNspread	0.96	1.60	0.08	3.85

TABLE 2. Continued

	Cumulative difference of the responses ($R2 - R1$) after $H = 18$ months			
Scenario	1 Conventional expansionary monetary policy shock (price-based)	2 Unconventional expansionary monetary policy shock (volume-based)	3 Positive loan supply shock (price-based)	4 Positive loan demand shock (volume-based)
RGDP	−0.06	−0.22	−0.97	−1.48
INF	−1.14	−2.08	−0.78	−0.91
NGDP	−1.16	−2.27	−1.75	−2.47
NBV	−9.51	−17.73	−4.61	−4.31
NBI	−1.95	−3.04	−3.22	−9.28
ECBTA	13.47	20.76	11.13	−11.93
STN	−3.74	−6.14	−3.96	−15.62
NBISTNspread	1.73	2.99	0.67	6.03

Note: The table reports the differences of the cumulative responses under the recession and expansion regimes at three points along the simulation horizon, after $H = 1, 12, 18$ months. A negative difference, for instance, means that the response of a variable was more positive (or less negative) under the expansion regime.

5. CONCLUSIONS

In a model with three targets in the objective function of the CB, and three state variables, we have assessed under what credit market mechanisms monetary policies can stabilize the financial side—credit flows in our context—and can also stabilize inflation rates, output, and employment. We explore several (regime switching) specifications and model variants and policy effects in particular with respect to specific modeling of credit market mechanisms. There is a considerable uncertainty as to what the drivers of credit flows are—shown also by recent empirical studies in relation to credit dynamics. This is why an exploration of different model variants and scenarios is warranted in our view.[35] We also combine a global, theoretical, analysis with a local, empirical analysis, using a RS-VAR for the euro area.

The theoretical model analysis suggests that although the short-term interest rate reduced by monetary policy would generate lower losses and thus imply a lower stabilization cost, it is essentially only effective if it leads to a reduction of the credit spread. Reducing credit spreads as policy is even more effective if credit flows do not respond much to a rise of interest rates. With credit flows responding negatively to interest rates, there is a stronger convergence effect and the loss as well as stabilization costs is low. Yet, this result depends very much on private credit demand behavior and whether firms and households do not respond to higher interest rates, or neglect the interest rate movements when output and credit booms develop. Price-oriented credit policy is more successful, if the reduction of credit spread through monetary policy is accompanied by a negative response of credit flows to the interest rate. Yet, the latter, since it is a private sector response, is less controllable by the CB (as well as commercial banks).

This appears to also hold for the results in relation to volume-based credit policies, where we observe on average some faster convergence for both credit supply and credit demand policies, but the latter appear to be less costly than credit supply policies. Both seem to have low cumulative cost, and the loss of welfare appears to be low with support of credit supply and demand policies. Policies that affect the flow of credits through credit supply, and this way reducing the output gap through some regime-dependent nonprice credit standards, seem to be quite effective.

Credit demand policies seem to be even less cost intensive in terms of reducing welfare through a nonprice easing of credit flows, for example, through lowering credit standards, reducing collateral requirements, and so forth. This will make the negative output gap dissipating faster, revealing a less costly adjustment path than credit supply policies.[36]

Our empirical assessment based on a linear and a regime-switching VAR for the euro area suggests that the responses of some main macroeconomic and financial aggregates to differently designed credit demand and supply shocks behave differently conditional on where the economy stands in the business cycle. We replicate some convex Phillips curve type relationships whereby expansionary credit shocks, be they initiated by the CB or by commercial banks directly, have a stronger potential to accelerate price inflation during boom times and less of that potential during recessions. Moreover, the simulation results suggest that it is easier to compress credit spreads by the same policy during boom than during recession times. This latter aspect is important and shall warrant further empirical investigation, about what the most favorable policy scenario is that would be able to reduce the credit spread in particular in a recession regime and thus be least destabilizing. Theoretically, a very favorable case is observed when a QE policy based on APP could be the appropriate policy. This is shown in scenario 2 in the theoretical part of the paper. However, as it turns out in our local analysis, compressing credit spreads through QE and APP is difficult to achieve in a recessionary period. For this scenario—as well as for most of the other scenarios—we could show that credit spreads are more easily compressed in expansions than in recessions.[37]

NOTES

1. Borio et al. (2015), Schularick and Taylor (2012), and Jorda et al. (2010, 2013), see also Chen and Semmler (2013).
2. For explicit credit cycles in the US data, see Ajello et al. (2016).
3. See also the work by Wymer (1997).
4. In the empirical part of our paper, we will also explore the role of delays. Note also that our state equations are not necessarily representing adaptive behavior, as opposed to forward-looking behavior. Our solution method for the decision and state variables guarantees well-defined approximations of the solution of a corresponding Belman equation and thus follows forward-looking and model consistent paths, see Gruene et al. (2015) and Gruene and Pannek (2011).
5. Note that already a 2 dim linear differential equation may have cyclical solutions if it has complex parts of the eigenvalue.
6. For details of how such type of short decision horizon model can approximate models with longer time horizons well on the basis of much less information for the agents, see Gruene et al. (2015). In order to avoid a numerical problem with respect the control variable “i”, arising from a bang–bang problem, we have added a scaled down square term of “i” in the objective function (1).
7. However, in the solution method, we can also allow for negative interest rates, see below.
8. As Jorda et al. (2010, 2013) show for international data, the financial instability is less caused by public debt, but rather by private, corporate, and household debt, and predominantly by mortgage debt.
9. We abstract here from productivity shocks that might impact the expected inflation rate.
10. Note that our model (1)–(4) is written in a way that resembles the New Keynesian model version in continuous time as in Werning (2012). The latter derives the continuous time form from an approximation of the Euler equation of a nonlinear model with preferences, as used in New Keynesian literature on monetary policy models. Our modeling of price expectations in the Phillips curve resembles the price expectations as derived from the survey data as discussed in Gross and Semmler (2017). Since the purely forward-looking Phillips curve does not perform well in empirical estimations, see Ball and Mazumder (2014), we use here the Svensson (1997) and Svensson and Rudebush (2002) versions for the Phillips curve, see also Ball and Mazumder (2014).
11. Though the natural rate might be affected by productivity shocks, we abstract from this effect, see Gavin et al. (2013).
12. See Woodford (2012), Mittnik and Semmler (2013), Schleer and Semmler (2015), and Gross et al. (2016).

13. Given that banks are involved in the transformation of maturity of loans, they borrow short and create loans with long maturities; a lower borrowing cost might, if passed through to loan interest rates, serve as a positive loan supply impulse.

14. See Kumhof et al. (2012). Momentum trading in carry trade studies show usually a positive co-variation of high interest rates and capital inflows.

15. See Blanchard (2013) and Schleer and Semmler (2015), see also Chen and Semmler (2013) and Mittnik and Semmler (2016).

16. This was, according to Kumhof et al. (2012), observable in some Southern European countries, for example, in Spain, after 2000.

17. Long-run credit cycles have been extensively explored in Schularick and Taylor (2012) and Jorda et al. (2010, 2013)

18. See Kumhof et al. (2012). This in particular seems to hold if momentum trading causes a positive co-variation of capital inflows and high interest rates.

19. Kumhoff et al. (2012).

20. For further details, see Zdzienicka et al. (2015); see also Cerutti et al. (2016) where it is argued that capital buffers, interbank exposure limits, concentration limits, and changes in reserve requirements can change the credit supply.

21. Such a regime switching in loan supply appears to be also observable in the data of Jorda et al. (2010, 2013). Further empirical evidence on regime dependent reaction of output change responding to the level of the output gap can be found in the empirical part of our paper. Such a regime dependence was also well known in the earlier theory of the nonlinear accelerator-multiplier models.

22. There are also a variety of agent-based and behavioral models that seem to support such a view that waves of optimism and pessimism can explain persistent borrowing behavior regardless of changes in the cost of credit.

23. The extensive data set by Jorda et al. (2010, 2013) and Schularick and Taylor (2012) also appear to support such a view that there are time periods of high credit growth, positively associated with higher interest rates. Our empirical estimates using a RS-VAR also seem to support such an assumption, in particular in certain regimes.

24. This case is also estimated by Ajello et al. (2016), and they find partially such a negative coefficient for the interest rate, though insignificant, but a positive coefficient for the output gap. Support of a regime dependent γ_3 is provided in the empirical part of the paper.

25. For an open economy, it could hold that the CB may counteract capital flows: Rising interest rates may lead to an increase of capital inflows and the CB fears inflation, which may induce the CB to reduce liquidity. Of course, credit demand could also fall with rising interest rates.

26. Note that in the following we do not specifically look at the asset price effects of lending and borrowing booms, such as equity or house prices, for those effects see Jorda et al. (2010, 2013).

27. We want to note that the supply of credit might not become effective if it is clogged by the banking system and not passed on to credit taking by the private sector.

28. See Zdzienicka et al. (2015) and Tressel and Zhang (2016).

29. Overall, relaxing credit constraints can change the credit demand, in particular for household borrowing and mortgage loans, see also Jorda et al. (2010, 2013). Corresponding empirical results are also provided in Section 4 of the paper.

30. See Zdzienicka et al. (2015).

31. For a further detailed study on such an effect of nonprice measures for macroprudential policies, see Tressel and Zhang (2016).

32. See, e.g., Biggs et al. (2009).

33. As an entry point to the literature related to sign-restricted SVARs, see Faust (1998), Canova and Nicolo (2002), and Uhlig (2005).

34. See, e.g., Ehrmann et al. (2001) who use the same regime-dependent impulse response simulation scheme. Other model settings are conceivable, whereby the regime process would be endogenous, for shocks to possibly imply, depending on their size, a transition between regimes.

35. In this context, it would be helpful to obtain some better grounding and thus to allow for further specifications, obtained from the field of behavioral economics.

36. For a further detailed study on such an effect of nonprice measures for macroprudential policies, see Tressel and Zhang (2016).

37. As to the fine tuning of the impact of credit policies on price and volume effects of credit on macroeconomic variables, there are of course for both the control of credit expansions and financial instability further macroprudential policy instruments developed.

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APPENDIX: ALTERNATIVE CREDIT DYNAMICS

We use here a debt equation as proposed by Blanchard (1983) and used in Mittnik and Semmler (2013) and Schleer and Semmler (2015) where there is a repayment of credit and a risk premium on interest rates when there is a recession and rising default risk as in equation (3). We now include thus in equation (4) also a risk premium arising in a recession that in our context means for a negative output gap. Leaving out the Ajello et al. (2016) terms, $\gamma_2 y_t + \gamma_3 i_t$, but using a common debt dynamics, we can write

$$\dot{l} = (i_t + \delta_t - \pi_t)l + \gamma_4 l_t \tag{A.1}$$

with an estimate of $\gamma_4 = -0.02$. Now, equation (A.1) represents an alternative real debt dynamics. Solving (1)–(3) and equation (A.1) numerically, we obtain Figure A.1.

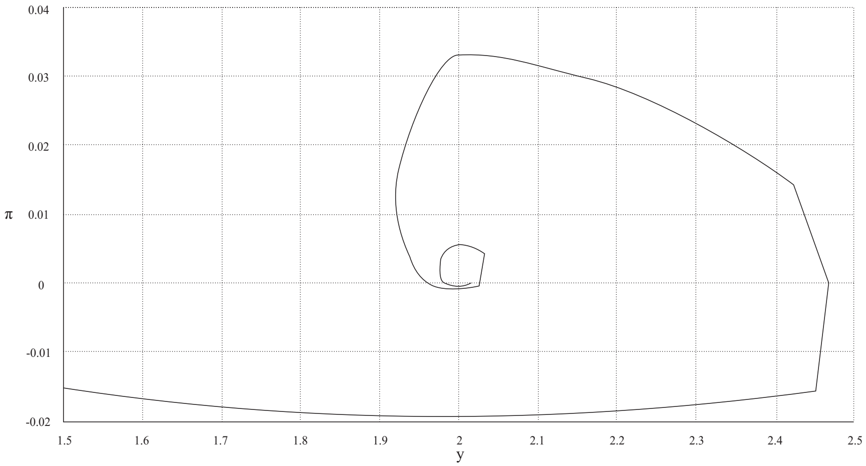

FIGURE A.1. Alternative credit dynamics: convergence. Use of equations (1)–(3) and credit equation (A4); potential output is 2 and output gap is zero at 2; for initial conditions, the inflation rate (vertical axis) and output gap (horizontal axis) move in shrinking cycles around the steady state; small changes of the inflation rate in the region of negative output gap (see the region from 1.5 to 2) and a faster rising inflation rate in the region of positive output gap; we observe converging output gaps, inflation rates, and credit gap, yet a long period of negative output gap.

From Figure A.1, we can observe that, with our initial conditions $y(0) = 1.5$ and $\pi(0) = -0.015$, the inflation rate also stays negative in the region of negative output gap (see the region from 1.5 to 2) and a faster rising inflation rate in the region of positive output gap. We observe converging output gaps, inflation rates, and credit gap, yet with a long period of negative output gap. This model holds as long as the credit cost i_t is not jumping up by credit and default risk, see Mittnik and Semmler (2013) and Schleer and Semmler (2015).

Empirically, the natural question arises whether the credit booms and busts may be characterized by regime-dependent macro feedbacks concerning loops between the macroeconomy and credit spread—the latter moving countercyclically. Other feedback loops, for example, the impact of nonprice drivers of credit flows, the output gap, and inflation rate, may also be different in different regimes.