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Will Macroprudential Policy Counteract Monetary Policy's Effects on Financial Stability?*

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Abstract

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1 Introduction

The financial crisis has reignited the debate on whether monetary policy should target financial stability. Those who favor a policy of leaning against the buildup of financial imbalances (Borio and White, 2004; Rajan, 2006; Borio and Zhu, 2012; Disyatat, 2010; Schularick and Taylor, 2012; Stein, 2014) find their argument strengthened by a growing body of empirical research, which shows that the policy rate significantly affects bank risk taking.[1] But the opponents contend that this does not necessarily justify an altered mandate for the monetary authority: why cannot the bank regulator alone take care of bank risk (Svensson, 2014)?

Would a macroprudential authority indeed take care of the financial stability side effects of monetary policy? This paper confronts two issues towards answering this question. First it models the effects of monetary policy on banks' behavior and identifies two channels, termed the profit and leverage channels. Second, it asks whether the regulator can neutralize these effects. Modeling the trade-off faced by a macroprudential regulator explicitly, we show that an optimizing regulator will not neutralize the impact that monetary policy has on financial stability. This, in itself, does not justify an altered mandate for monetary policy. But it does nuance the argument that macroprudential policy is a precision tool to address any externalities from monetary policy to the financial sector.

In our model a bank chooses both the riskiness of its asset profile, as well as how much to lever up its liability side. Risky bank portfolios and leveraged balance sheets often go together, as they did in the run-up to the global financial crisis. When banks have higher leverage, they have less at stake, because their own equity is then a smaller fraction of the total balance sheet. And risky assets make the possibility of externalizing losses to society through higher leverage more attractive, if bank debts are covered by explicit or implicit

[1] This is found by Altunbas, Gambacorta and Marquez-Ibanez (2010, 2014), Delis and Brissimis (2010), Maddaloni and Peydró (2011, 2013), Delis and Kouretas (2011), Delis, Hasan and Mylonidis (2011), Paligorova and Santos (2012), Geršl et al. (2015), Dell'Ariccia, Laeven and Suarez (2017), Buch, Eickmeier and Prieto (2014a,b), Jiménez et al. (2014), Ioannidou, Ongena and Peydró (2015) and Morais, Peydró and Ruiz (2015). Monetary policy may also induce risk taking in the non-bank sector (Feroli et al., 2014; Hanson and Stein, 2015; Chen et al., 2015; Galí and Gambetti, 2015; Cecchetti, Mancini-Griffoli, and Narita, 2017). See also the discussions in Bayoumi et al. (2014), Smets (2014) and IMF (2015).

government guarantees. Hence, from the bank's perspective, asset side riskiness and liability side indebtedness are complementary.

In this setup we show that the monetary policy rate affects the bank's risk decisions through two channels, *profit* and *leverage*, with countervailing effects. On the one hand, a higher rate pushes up the bank's funding costs. This reduces its profitability and the bank then has less to lose from a risky strategy: when a deposit-insured bank has less own "skin-in-the-game" it is more inclined to consider the upside of risk only. This is the profit channel of monetary transmission to bank risk. On the other hand, a higher policy rate makes leverage more expensive to the bank, which as a result would then opt for less debt funding.[2] This means that the bank internalizes more of its risk taking and reduces the riskiness on its asset side. We call this the leverage channel of monetary transmission to bank risk.

The cumulative effect of monetary policy on bank risk taking will depend on which of the two channels dominates. If it is the *leverage* channel that dominates, then the transmission confirms the results of the empirical literature: lower policy rates translate into higher risk.

A macroprudential regulator is introduced in the model, whose tool is a cap on the leverage ratio, as has recently been implemented within the regulatory framework of Basel III. The regulator moves after monetary policy has been set (exogenously) and before the bank takes its decisions. His aim is financial stability and capping leverage retains more of the bank's capital buffer and also generates incentives for the bank to take less asset risk, thus reducing its probability of default. However, there are also costs associated with financial disintermediation as a result of limiting leverage, and the regulator takes these into account. His preferences are concave up, which means that sacrificing additional credit supply against improved financial stability becomes more costly the more the regulator tightens his standards. We show that his trade-off can be represented by a standard possibilities frontier and indifference curve.

We show that the interest rate affects the regulator's entire possibilities frontier. Both credit supply and bank soundness are affected by monetary policy, and therefore the entire

[2] The economic significance of this effect is confirmed in the empirical work on monetary policy and leverage of Adrian and Shin (2009, 2010), Adrian, Moench and Shin (2010), Bruno and Shin (2015), and Angeloni, Faia and Lo Duca (2015).

environment in which the regulator operates responds to monetary conditions. As we show using our model, it would take a knife-edge parameterization for the regulator to maintain the same level of financial stability in the face of any interest rate change. Normally the regulator would allow part of the transmission from monetary policy to bank risk to "pass through" and would not use his tool to counteracts its effects in full.

The direction in which monetary policy affects macroprudential policy is not trivial, however. Under one set of conditions, which arguably relate to the upward phase of a financial cycle, the leverage effect dominates. Then, an interest rate cut worsens financial stability. The regulator optimally tightens in response, but not to the point where financial stability returns to what it was before the rate cut.

Instead, under conditions that resemble a post-crisis environment the profit effect dominates, and a rate cut *improves* financial stability. Here too, the regulator does not neutralize, but rather moves along with monetary policy by partly easing his policy (which in practice could take the form of post-crisis regulatory forbearance, for example). It is only under one very specific - knife-edge - condition that regulatory policy maintains financial stability at the same level for any interest rate, i.e., full ‘neutralization’ of the risk-taking channel of monetary policy.

The remainder of the paper is organized as follows. Section 2 summarizes related literature and how our contribution fits in it. Section 3 presents the bank’s problem and the assumptions that we make in order to derive analytical solutions. Section 4 then describes how monetary policy affects the bank’s behavior and thus identifies two channels. Section 5 describes the regulator’s problem and how monetary policy affects his operating space and therefore utility. Finally section 6 summarizes the results and discusses policy implications.

2 Related literature

The existing literature on the relation between monetary policy and the financial sector uses two types of models: DSGE macro models and bank-based models. In different ways both of these literatures have had much to say about the transmission of interest rates to the financial sector and about the implications for monetary policy. In some cases prudential tools are introduced and their merit as an alternative to leaning against the wind is considered. In comparison, our paper contributes by explicitly modelling the *optimization problem of a regulator* and how this is affected by monetary policy via a banking sector that has both endogenous asset risk and leverage.

In the DSGE macro literature many papers build on the framework of Bernanke, Gertler and Gilchrist (1999) by incorporating financial frictions. Reviews of this literature can be found in Gertler and Kyotaki (2010) and Loisel (2014). However, for the most part, banks are a passive friction in these models.[3] There are exceptions to this, such as Goodhart, Osorio and Tsomocos (2009), Gertler and Karadi (2011), Angeloni and Faia (2013), He and Krishnamurty (2013) and Laseen, Pescatori and Turunen (2017) who construct macro models with banks that decide upon riskiness. However, all risk taking occurs on the liability side of banks. Instead, in Cociuba, Shukayev and Ueberfeldt (2016) banks choose between risky and safe investments, while leverage is given.[4]

In the macro models of Angelini, Neri and Panetta (2014), De Paoli and Paustian (2017), and Collard et al. (2017) there is a macroprudential regulator, in addition to the monetary authority.[5] These papers investigate welfare under (non-)cooperation between the authorities. Our focus is instead on providing an analytical argument for why leaning against financial imbalances could make sense.

In Angelini, Neri and Panetta (2014) the macroprudential authority has a single task, namely maintaining financial stability. In the absence of coordination, it tightens its regulatory standards too much in response to an adverse financial shock, imposing negative exter-

[3] Nonetheless, even absent bank risk choice there can be interaction between monetary policy and bank regulation: bank capitalization affects loan rates, and thus interacts with monetary transmission. See, for instance, De Walque, Pierrard and Rouabah (2010), Darracq Pariès, Kok Sørensen and Rodriguez-Palenzuela (2011), Kannan, Rabanal and Scott (2012), and Agénor, Alper and Pereira da Silva (2013). Financial wealth can provide an alternative route to generate macrofinancial linkages (Vitek, 2017).

[4] Alternative approaches include non-linear modelling (Brunnermeier and Sannikov, 2014; Ajello et al., 2016) and general equilibrium models that are not dynamic and stochastic (Goodhart et al., 2013; Cesa-Bianchi and Rebucci, 2017).

[5] See also Bodenstein, Geurrieri and LaBriola (2016), Van der Ghote (2017) and Carrillo et al. (2017).

nalities on the monetary authority through reduced output growth. De Paoli and Paustian's (2017) model mechanisms are similar, but they derive the authorities' objectives from microfoundations and use these to analyze the effects of cooperation, discretion and first-mover assignments on the policy outcomes.

Collard et al.'s (2017) model provides a benchmark case in which the separation of monetary and prudential policies is optimal. In their model, the prudential regulator targets the excessive risk incentives that arise from banks' limited liability. Capital requirements affect output, but because bank risk is pure waste (and discrete-choice) in their baseline model, the externality to monetary policy is positive. Extending to an ad hoc negative externality, they find that nonetheless separation achieves first-best for plausible parameterizations.

The bank-based models (to which our paper belongs) highlight various types of channels through which monetary policy affects the financial sector: through the incentives of banks to monitor (Dell'Ariccia, Laeven and Marquez, 2014); the screening of borrowers by banks (Dell'Ariccia and Marquez, 2006); the skewness of bank returns (Valencia, 2014); the impact on information asymmetries (Loisel, Pommeret and Portier, 2012; Drees, Eckwert and Várdy, 2013; Dubecq, Mojon and Ragot, 2015); the incentives of bank loan officers or asset managers whose incentives deviate from profit maximization (Acharya and Naqvi, 2012; Morris and Shin, 2016); the impact on nominal contracts between banks and creditors that cannot be made state-contingent (Allen, Carletti and Gale, 2014); and moral hazard when policy rates are used as a bailout mechanism (Diamond and Rajan, 2012; Farhi and Tirole, 2012).

Related to our paper is also Freixas, Martin and Skeie (2011), who model the interaction between the monetary policy rate and optimal prudential regulation, although their focus is on liquidity regulation, whereas ours is on bank capital regulation (through a leverage ratio). They show that the policy rate affects both the pre-crisis incentives of banks to hold cash reserves and the risk of bank runs during a crisis. Moreover, liquidity regulation cannot perfectly substitute for the policy rate's impact, implying that conducting monetary and prudential policies separately is sub-optimal. Freixas, Martin and Skeie (2011) and our paper are complements in this respect, highlighting a similar point from the perspectives of liquidity and capital regulation, respectively.[6]

3 The bank's problem

We begin by describing the bank's problem. The bank's entire balance sheet consists of debt d and internal capital c. Owners and managers of the bank are one and management thus strives purely to maximize the residual claims for the capital owners. Here c can arise from either retaining past earnings or inside equity of bank owners. Internal equity holders accrue the bank's residual returns. The issuance of additional external equity is assumed to be prohibitively costly. This type of structure, a reduced form departure from the Modigliani-Miller world with irrelevant capital structure, is used elsewhere in the banking literature (Thakor, 1996). In addition to d and c, we define the following variables:

x :	bank's chosen risk profile
r :	bank funding rate
$R(x)$:	gross rate of return on the bank's risky project
$p(x, d)$:	probability of bank survival (non-default), which depends on the bank's risk profile (x) and its leverage (d).

The bank's expected profit is then as follows:

$$E[\Pi] = p(x, d)[R(x)(d + c) - rd], \tag{1}$$

which is the probability of bank survival times the net return conditional on survival. Both x and d are defined in a closed interval, $x \in [0, X]$ and $d \in [0, D]$, (necessary to ensure consistency with a probability $p(x, d) \in [0, 1]$). We assume the following features hold:

1. $p(x, 0) = 1$, since without debt there is nothing to default on.

[6] If we accept that monetary policy should include a financial stability objective along its traditional objectives of inflation and output stabilization, then we can show that the timing of optimal monetary policy changes, as we do in the companion paper Agur and Demertzis (2013). In response to a negative demand shock, rate cuts become both deeper and shorter-lived, as the monetary authority aims to mitigate the buildup of bank risk caused by protracted low rates.

2. $p(0,d) = 1$, since absent risk taking the bank always survives. That is, the $x = 0$ profile is defined to be the risk-free profile.

3. $p(X,d) = 0$ and $p(x,D) = 0$. We thus normalize maximum risk to certain default.

4. $p'_x < 0$, $p''_x < 0$, $p'_d < 0$, $p''_d < 0$: the probability of default rises exponentially in the risk and leverage taken by the bank. Also a minimal amount of risk is very unlikely to lead to default but as risky behavior increases, the likelihood of default rises faster and therefore the probability of survival declines concavely.

5. $R'(x) > 0$ and $R''(x) < 0$. Contingent upon not defaulting, the bank earns $R(x)(d+c) - rd$. Increased risk taking lowers the probability of the bank's survival but, if the bank does survive then it earns a higher return. While the rate of return R rises in risk, the marginal gain from additional risk taking is declining. In other words, the bank has to push risk to increasingly large levels in order to generate ever higher returns. Note that the partial equilibrium nature of the model is implicit in the fact that the return on a risky project, $R(x)$, does not depend on the state of the economy (including r).

6. $p(\varepsilon_1, \varepsilon_2)[R(\varepsilon_1)(\varepsilon_2 + c) - r\varepsilon_2] > 0$ for $\varepsilon_1 \to 0^+, \varepsilon_2 \to 0^+$. A marginal amount of asset risk and leverage yields a higher expected return than no risk or debt (a sufficient but not necessary condition for this could be to impose that $p'_x \to 0$ for $x \to 0$, and $p'_d \to 0$ for $d \to 0$). In conjunction with $p(X,d) = 0$ and $p(x,D) = 0$ (see point 3) this implies interior solutions. We restrict attention to interior solutions only as it is there that risk taking and leverage respond to monetary and prudential policies.

7. By implication, $x^* \in (0,X)$ and $d^* \in (0,D)$, where x^* and d^* are **optimal** asset risk profile and leverage respectively.

8. $r = R(0)$, that is, r is the same as the risk-free ($x = 0$) rate of return. The bank's funding rate, r. The monetary policy rate - such as the Federal funds rate in the US or the repo rate in the euro area - affects the cost of short-term wholesale bank funding

directly. In the context of the model, we identify the policy rate with the risk-free rate r and will in the next section use it to perform comparative statics. The fact that banks pay no risk premium on their funding costs implies the that there is a deposit-insurance in place, assumed to be exogenous to the model (i.e. funded by the government not the bank itself).

Problem 1 *The bank chooses a risk profile and level of debt to maximize its expected profits, i.e.:*

$$\max_{x,d} \{E[\Pi]\} = \max_{x,d} \{p(x,d)[R(x)(d+c) - rd]\}. \tag{2}$$

4 Monetary transmission

In the context of our model the so-called risk-taking channel of monetary transmission (Borio and Zhu, 2012) is formalized as the impact of r on bank risk choice, x^*. Monetary policy rate changes are considered here exogenous events, like in the other bank-based models discussed in section II. While clearly a simplification, we can think of the divergence of real and financial cycles as a justification for their exogenous nature, from the perspective of the financial sector. That is, monetary policy might target inflation and the output gap, which diverge from the leverage and credit cycle generated by the financial sector (Borio and Shim, 2007). There are then policy rate "shocks" to the financial sector that originate in monetary policy's response to the business cycle.

Remark 2 *The policy rate affects bank risk taking incentives in two ways: directly through profits, and indirectly through debt:*

$$\frac{dx^*}{dr} = \frac{\partial x^*}{\partial r} + \frac{\partial x^*}{\partial d^*}\frac{\partial d^*}{\partial r}. \tag{3}$$

Then,

Proposition 1 *We identify these effects as the two transmission channels:*

Channel 1 -"Profit effect", $\frac{\partial x^*}{\partial r} > 0$*: for given leverage, a higher* r *increases* x^*

Channel 2 -"Leverage effect", $\frac{\partial x^*}{\partial d^*}\frac{\partial d^*}{\partial r} < 0$*: a higher* r *lowers* d^**, and consequently also* x^*

Proof. The proof comes in two parts. ■

Part 1: Profit Effect

We first take the FOC of expected profits in (2) w.r.t. x.

$$p'_x(x,d)\left[R(x)(d+c) - rd\right] + p(x,d)\,R'(x)(d+c) = 0,$$

or,

$$\frac{rd}{d+c} = R(x) + \frac{p(x,d)}{p'_x(x,d)}R'(x),$$

which, given that $p'_x < 0$ can be more intuitively written as:

$$\frac{rd}{d+c} = R(x) - R'(x)\frac{p(x,d)}{|p'_x(x,d)|}. \tag{4}$$

We can use (4) to infer the relation between r and x as it holds for all x, including x^*. The right-hand side (RHS) of (4) increases unambiguously in x, i.e. $\frac{\partial RHS}{\partial x} > 0$. This is because:

1. $R(x)$ increases in x (as $R'(x) > 0$);
2. $R'(x)$ declines in x (as $R''(x) < 0$);
3. $p(x,d)$ declines in x (since $p'_x < 0$);
4. $|p'_x(x,d)|$ increases in x (since $p''_x < 0$).

Re-write (4) as $\frac{rd}{d+c} = RHS$: it follows that whatever increases term $\frac{rd}{d+c}$ must also increase optimal risk taking x^*. This implies that:

- $\frac{\partial x^*}{\partial c} < 0$: an increase in bank capital reduces a bank's risk taking incentives.

- $\frac{\partial x^*}{\partial d} > 0$: and increase in debt increases risk taking.[7]

- $\frac{\partial x^*}{\partial r} > 0$: the policy rate affects bank risk taking directly: profit effect.

Part 2: Leverage Effect

We have already shown that $\frac{\partial x^*}{\partial d} > 0$ above. It remains to show that $\frac{\partial d^*}{\partial r} < 0$. We can obtain this derivative from the FOC w.r.t. d:

$$p'_d(x,d)\left[R(x)(d+c) - rd\right] + p(x,d)\left[R(x) - r\right] = 0.$$

Solving for d we get:

$$d^* = \frac{p(x,d)}{|p'_d(x,d)|} - \frac{cR(x)}{R(x) - r}. \tag{5}$$

It follows from (5) that $\frac{\partial d^*}{\partial r} < 0$, and it turn that $\frac{\partial x^*}{\partial d^*}\frac{\partial d^*}{\partial r} < 0$: the leverage effect.

4.1 A discussion of the risk-taking channel

Our result shows that a higher policy rate has two countervailing effects on bank risk. On the one hand, it lowers bank profitability because the rate the bank has to pay on its funding increases with the risk free rate. With lower profitability the bank has less at stake and is more inclined to take risk. On the other hand, the increase in the policy rate raises the cost of debt and induces the bank to lever less. Leverage on the liability side and risk on the asset side are complementary, from the bank's perspective. With less leverage the bank sees fewer benefits to high risk projects, and thus lowers its optimal risk taking. If the "leverage effect" dominates the "profit effect" then a rate hike lowers bank risk taking and vice versa, consistent with the results of the empirical literature discussed in the introduction.

As concerns the "profit effect", note that we have considered a setup where there is no direct impact of the monetary policy rate on the bank's asset side. That is, the policy rate can influence the bank's choice of project (i.e., its risk profile), but the policy rate does not

[7] Strictly speaking, we also need to invoke property 4 from the list in Section III. That is: $p'_d < 0$, $p''_d < 0$. This ensures that $\frac{p(x,d)}{|p'_x(x,d)|}$ in (4) rises in d and therefore the RHS of (4) falls in d, absent an increase in x.

affect the returns of the projects. In reality there is of course a transmission from monetary policy to a bank's assets as well as its liabilities. The transmission to bank assets is less direct, however, as asset returns are usually affected by long rates, while the bank finances itself against short rates. The monetary policy rate directly determines short financing rates while it has a much smaller impact on long rates (a statement that is valid mainly for conventional monetary policy, however, since quantitative easing does affect long rates directly).

5 Regulation

A macroprudential regulator faces a trade-off. On the one hand, he cares about financial stability, but on the other he does not wish to constrain unnecessarily financial intermediation and credit provision to the economy. Irrespective of his formal mandate, no regulator would want to implement excessively stringent requirements in reality, for a number of reasons. First, limiting leverage imposes a direct constraint on credit provision to the economy. In the context of our model, the bank provides $(d + c)$ worth of credit and thus the link between leverage and credit provision is linear. Admittedly, in reality there are several margins through which the impact on credit supply may be softened: banks may be able to issue some additional equity, or their borrowers may find alternative sources of funding, like bond or equity issuance. Nevertheless, both of these tend to provide only limited potential relief, since particularly small and medium sized enterprises often have few alternatives to bank-based funding, while banks usually have to pay significant discounts for additional equity issuance (Miller, 1995).

Second, bank debt is special in many ways. This is clearest for the case of demandable deposits, which provide payment services as well as maturity transformation benefits to retail depositors. Wholesale depositors are similarly interested in the maturity transformation services of banks. Thus, regulators undoubtedly do see costs to restraining bank leverage, and this is why they never actually opt for demanding primarily equity financed banks.

5.1 The regulator's problem

In the context of our model the financial stability objective is captured by $p(x,d)$, the probability of bank survival. The regulator maximizes the following utility function:

$$\Omega\left(p\left(x,d\right),d\right),$$

where $\Omega'_{p(\cdot)} > 0$ and $\Omega'_{d} > 0$. That is, the regulator cares about sustaining financial stability through $p(x,d)$, but at the same time puts a weight on retaining enough credit supply, and therefore allow the bank to raise funds, d. Here one can immediately sense the regulator's trade-off since:

$$\frac{d\Omega}{d\left(d\right)} = \frac{\partial\Omega}{\partial p\left(x,d\right)}\frac{\partial p\left(x,d\right)}{\partial d} + \frac{\partial\Omega}{\partial d},$$

where the first term is negative (since $\frac{\partial p(x,d)}{\partial d} < 0$) and the second is positive. Bank leverage has countervailing effects on the regulator's aims because leverage raises bank risk but also increases bank credit provision.

We provide the regulator with a simple tool, a leverage cap $\overline{d}$, with which it can control the bank's debt profile. This tool is akin to the leverage ratio in Basel III, and had been part of Basel I in the past. It was temporarily discarded during the Basel II era, but the degree of leverage buildup by financial intermediaries before the recent financial crisis convinced regulators to re-introduce the tool. This is the simplest tool to apply within our framework, and allows for clear-cut analytical results.

It is in the nature of a leverage ratio that its effects are broad-based, since credit supply is directly linked to the size of bank balance sheets, which in turn depend upon the price and availability of ample bank funding. We note that if instead the regulator would have access to some tool, which could directly target bank risk taking, x, without any other side effects, then the problem we investigate would not arise. There would be no trade-off to the regulator and he would simply maintain minimum risk according to his tool. We would argue, however, that most realistic macroprudential tools do have macroeconomic implications.

Similar to a leverage ratio, for instance, systemic capital surcharges affect bank funding costs, and may therefore impact credit supply. LTV ratios are another common macroprudential tool, which can improve the resilience of the property sector to adverse shocks, but also have macroeconomic consequences: households may need to consume less and save more in order to afford the larger down payments on a house. Thus, while we consider one specific type of macroprudential tool, we believe that the type of trade-off we allude to is more generally applicable.

Problem 3 *Given bank maximization of expected profits in (2), the regulator' chooses a leverage cap, $\overline{d}$, to maximize utility, i.e.:*

$$\max_{\overline{d}} \Omega \left(p \left(x, d \right), d \right). \tag{6}$$

That is, the regulator acts first, determining the leverage cap, after which the bank solves its optimization problem. Through backward induction the regulator knows how his tool will affect the bank's choice variables: namely, the extent to which $\overline{d}$ will constrain the bank's preferred d^*, and how this will affect x^* and in turn the effect on $p(x, d)$.

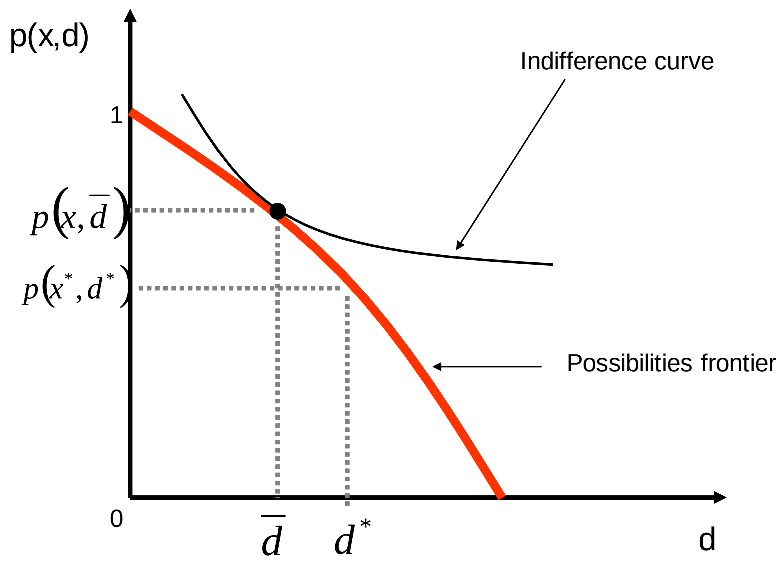
The regulator faces concave up indifference curves and concave down possibilities frontiers in the $[d, p(x, d)]$ space.

Concave up indifference curves: This is the result of standard concavity assumptions: i.e. $\Omega''_{p(.)} < 0$ and $\Omega''_{d} < 0$. Intuitively, this means that the marginal benefit of additional bank soundness is positive but declining (improving financial stability is more important when default risk is high than when it is low) and similarly the benefit of additional credit provision is positive but declining (more credit is particularly valuable when firms and households are credit constrained, but less so when there is already ample credit going around).

Concave down possibilities frontiers: Here the convexity of the possibilities frontier comes from previous assumptions: we recall that $p'_d < 0$ and $p''_d < 0$.

The regulator's optimization problem can be visually represented in figure 1. The point where the regulator's indifference curve is tangential to the possibilities frontier identifies the regulator's optimum. Figure 1 draws the interesting case where the regulatory constraint binds, i.e. $\overline{d} < d^*$, and therefore the regulator forces the bank to hold less leverage than the bank would have chosen absent of regulation. This, in turn, raises the probability of bank survival from $p(x^*, d^*)$ to $p(x, \overline{d})$, consistent with the regulatory motive of helping banks to survive.

Figure 1: regulator's optimization



Next we turn to the impact of an interest rate change, which as far as the regulator is conserned is exogenous. We can think of an exogenous monetary authority moving first, setting its interest rate according to its own objectives. Subsequently, the macroprudential regulator comes in and decides how to best respond given the interest rate environment. And finally the bank determines its asset risk profile and leverage given the interest rate and macroprudential policy. Note that here we are giving the regulator the maximum extent of "flexibility" to cope with bank risk taking. In reality, the macroprudential policy is infrequently adjusted in most countries, contrary to monetary policy which can move at a higher frequency. This would mean that the macroprudential regulator has less ability to counteract the impact of monetary policy on financial stability.

5.2 Interest rate impact on bank risk taking

Our focus is on how the regulator's operating space is affected by interest rate changes and how he responds as a result. Any interest rate change is going to affect the possibilities frontier and therefore the regulator's ability to achieve first best. To demonstrate that we derive first the slope of the possibilities frontier: $p'_d = \frac{dp(x,d)}{d(d)}$. In derived form this is:

$$\frac{dp\left(x,d\right)}{d\left(d\right)} = \frac{\partial p\left(x,d\right)}{\partial x}\frac{\partial x}{\partial d} + \frac{\partial p\left(x,d\right)}{\partial d}.$$

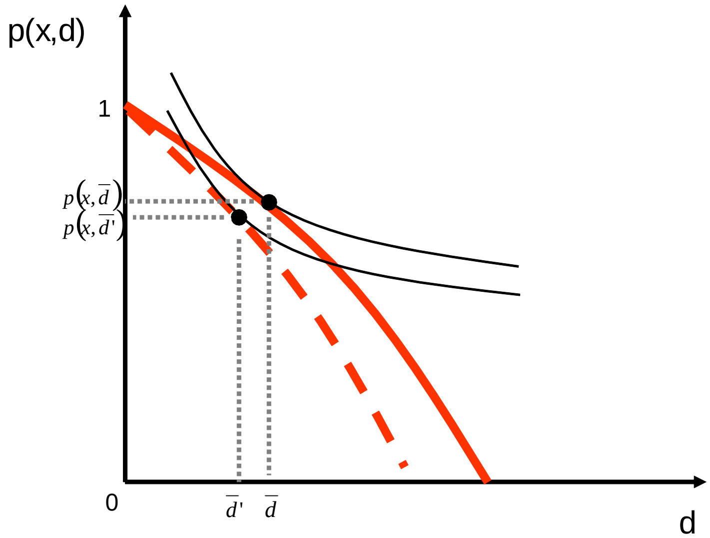
We can then examine how this slope changes with r and therefore also monetary policy:

$$\frac{\partial}{\partial r}\left[\frac{dp\left(x,d\right)}{d\left(d\right)}\right] = \underset{(-)}{\frac{\partial p\left(x,d\right)}{\partial x}}\underset{(+)}{\frac{\partial x}{\partial d}}\left[\underset{(-)}{\frac{\partial d}{\partial r}} + \underset{(+)}{\frac{\partial x}{\partial r}}\right] + \underset{(-)}{\frac{\partial p\left(x,d\right)}{\partial d}}\underset{(-)}{\frac{\partial d}{\partial r}}, \tag{7}$$

where term $\left[\frac{\partial d}{\partial r} + \frac{\partial x}{\partial r}\right]$ is the result from applying the power rule to differentiate $\left(\frac{\partial p(x,d)}{\partial x}\right)\left(\frac{\partial x}{\partial d}\right)$ with respect to r. Overall, the derivative $\frac{\partial}{\partial r}\left[p'_d\right]$ is of ambiguous sign, but only because $\left[\frac{\partial d}{\partial r} + \frac{\partial x}{\partial r}\right]$ is also of ambiguous sign. The term $\frac{\partial d}{\partial r}$ represents the impact of the interest rate on bank leverage, which is part of the leverage effect (equation 3), and $\frac{\partial x}{\partial r}$ is the direct impact of the interest rate on bank risk, the profit effect. We consider three separate cases.

Case 1 $\left|\frac{\partial d}{\partial r}\right| \geq \frac{\partial x}{\partial r}$: the effect of monetary policy on debt dominates the effect on the bank's ability to generate profits. In this case, we unambiguously have that $\frac{\partial}{\partial r}\left[p'_d\right] > 0$ in equation (7). This means that the slope of p'_d rises (becomes less negative) with r. By symmetry, a rate cut will translate into an inward pivot of the possibilities frontier, as depicted in figure 2.

Figure 2: impact of a rate cut when the profit effect is relatively weak



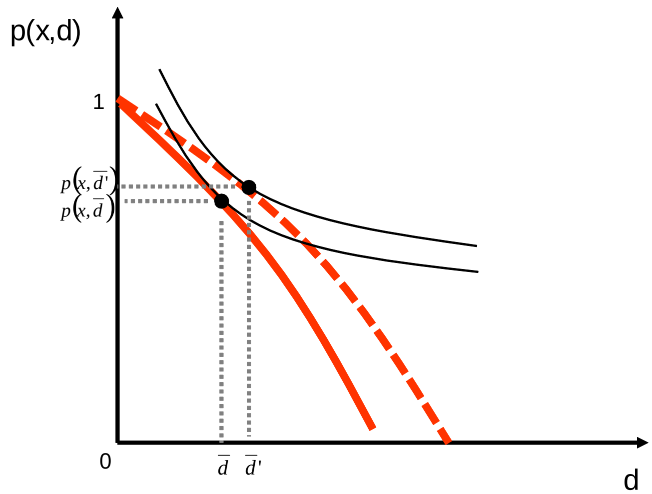
For any inward pivot of the possibilities frontier, and with concave up indifference curves, it must be true that the new optimum moves "inward" too. That is to say, the rate cut causes a decrease of both the regulator's leverage cap $\overline{d}$ and a decline in the bank's survival probability, $p(x, d)$. In other words, a rate cut puts upward pressure on bank risk, and the regulator counteracts this by tightening macroprudential policy. However, given the trade-offs he faces, he does not go so far as to keep financial stability the same. That is, he allows part of the effect of monetary policy on bank risk to "pass through" to financial stability, and bank soundness is unambiguously lower after the rate cut than before it, in spite of the regulator's tightening. The entire trade-off of a macroprudential regulator is affected by the policy rate, and since he is unwilling to truly "neutralize" its impact, monetary policy imposes a negative externality. The situation depicted in figure 2 depends on the relative strength of the leverage effect. As suggested by most of the cited empirical studies (see footnotes 1 and 2), this effect may have dominated in the run-up to the global financial crisis. If so, a low interest rate environment worsens the trade-off the regulator faces.

Case 2 $\left|\frac{\partial d}{\partial r}\right| < \frac{\partial x}{\partial r}$: following a monetary policy change, the effect on the bank's ability to generate profits dominates that on debt. Note that the overall impact of an interest rate change remains ambiguous in (from equation 7):

$$\underset{(-)}{\frac{\partial p\,(x,d)}{\partial x}}\underset{(+)}{\frac{\partial x}{\partial d}}\underset{(+)}{\left[\frac{\partial d}{\partial r}+\frac{\partial x}{\partial r}\right]}+\underset{(-)}{\frac{\partial p\,(x,d)}{\partial d}}\underset{(-)}{\frac{\partial d}{\partial r}}.$$

If $\frac{\partial x}{\partial r}$ is only slightly larger than $\left|\frac{\partial d}{\partial r}\right|$ then the situation depicted in figure 2 continues to hold. If instead $\frac{\partial x}{\partial r}$ is large enough relative to $\left|\frac{\partial d}{\partial r}\right|$, then $\frac{\partial}{\partial r}\left[p'_d\right] < 0$. That is, a rate cut would pivot the possibilities frontier outwards and the regulator would face a better trade-off than before. This is represented in figure 3.

Figure 3: impact of a rate cut when the profit effect is relatively strong



Intuitively, we could relate this to a post-crisis situation, where banks have to deleverage because, among other reasons, they face funding constraints. Given the need to deleverage, a rate cut does not spur levering incentives but does maintain banks' profitability. Absent that profitability, banks' incentives to gamble might rise, as arguably occurred in the wake of the US Savings & Loan crisis or the Japanese crisis of the early 1990s (Peek and Rosengren, 2005). In this type of situation a rate cut improves financial stability (at least temporarily) and the regulator allows this to "pass through" by partly loosening his standards. A realistic example would be regulatory forbearance on the rebuilding of capital buffers after a crisis, allowing banks a long period of time to acquire the needed equity.

Case 3: Knife-edge: there exists one specific case where regulation does not respond at all to monetary policy. This occurs for a very specific parameterization and figure 1 then represents the regulator's problem for any r. From equation (7) this occurs when the difference between $\frac{\partial x}{\partial r}$ and $\left|\frac{\partial d}{\partial r}\right|$ is exactly large enough so that:

$$\underset{(-)}{\frac{\partial p\left(x,d\right)}{\partial x}}\underset{(+)}{\frac{\partial x}{\partial d}}\underset{(+)}{\left[\frac{\partial d}{\partial r}+\frac{\partial x}{\partial r}\right]}=\underset{(-)}{\frac{\partial p\left(x,d\right)}{\partial d}}\underset{(-)}{\frac{\partial d}{\partial r}},$$

and therefore $\frac{\partial}{\partial r}\left[p_d^{'}\right]=0$. This serves as a benchmark to illustrate that it is unlikely that the regulator's possibilities frontier is invariant to monetary policy or, equivalently, that a regulator would hardly ever maintain the same level of financial stability regardless of the interest rate. In anything other than this knife-edge case financial stability ends up responding to monetary policy, in spite of the presence of a fully optimizing macroprudential regulator.

We summarize the results as follows:

Summary 4 *The impact of the interest rate, r, on the regulator's policy, $\overline{d}$, depends on the monetary transmission channels:*

1. When the profit effect, $\frac{\partial x}{\partial r}$, is relatively weak as compared to the impact of the interest rate on leverage, $\left|\frac{\partial d}{\partial r}\right|$, then $\frac{\partial}{\partial r}\left[\frac{dp(x,d)}{d(d)}\right]>0$. A rate cut $dr<0$ will then lead to a regulatory tightening $d\left(\overline{d}\right)<0$, but not to the point that the same level of financial stability is maintained: $dp<0$.

2. When instead $\frac{\partial x}{\partial r}$ is large enough compared to $\left|\frac{\partial d}{\partial r}\right|$, then $\frac{\partial}{\partial r}\left[\frac{dp(x,d)}{d(d)}\right]<0$. Here, a rate cut will lead to a regulatory loosening i.e.: $d\left(\overline{d}\right)>0$, which nonetheless maintains more financial stability than initially, i.e.: $dp>0$.

3. In between, there exists a knife-edge case where $\frac{\partial}{\partial r}\left[\frac{dp(x,d)}{d(d)}\right]=0$ and regulation maintains the same level of stringency for any interest rate.

Overall, then, the regulator does not counterbalance the risk-taking channel of monetary policy. This occurs in spite of the fact that the regulator decides on policy before the bank, has full knowledge of the bank's problem and has complete freedom to adjust his policy. The reason is that monetary policy affects the whole optimization problem of the regulator, not just bank risk. The regulator's optimal policy thus does not keep the probability of bank default constant. The analysis shows that monetary policy continues to affect bank risk taking. In an environment where both monetary and regulatory authorities are setting policy optimally but independently of each other, an interest rate change constitures an externality that the regulator will not neutralize.

6 Policy implications

The recent empirical literature has found confirming evidence that monetary policy affects financial stability. In this paper we set up a model in which we demonstrate that there are two channels through which a change in the interest rate affects a bank's behavior: through profit and leverage. The question that then follows is whether the regulator is in the position to neutralize these effects and still achieve his objective of safeguarding financial stability. We show that monetary policy affects the environment in which the regulator operates, (possibilities frontier) and that by itself implies that even in an optimizing framework, the regulator will not neutralize these two effects.

The direction in which monetary policy pushes macroprudential regulation depends on the state of the financial cycle. In buoyant times when financial intermediaries are inclined to take on more leverage and their profitability is secured, a rate cut is likely to spur on more risk taking. Following our model, this will only be partly counteracted by a regulatory tightening and the macroprudential authority would be allowing part of the negative impact of monetary policy to financial stability to "pass through". Instead, at times when banks are less inclined to lever and their profitability is impaired, such as in the aftermath of a financial crisis, a rate cut may actually translate into reduced risk taking incentives. The regulator will optimally move in the same direction as the monetary authority, and loosen regulation when monetary policy becomes more accommodative.

The question that follows this analysis, but which the paper does not address explicitly, is what the knowledge of these two transmission effects imply for monetary policy itself. Should monetary policy internalize the regulator's problem and therefore, 'lean against financial imbalances' on the upside but 'lean with the wind' on the downturn of the financial cycle? Or does the issue merit full coordination of monetary and macroprudential policies?[8] The paper stops short of providing an answer to this, but the recent trend of central banks acquiring macroprudential portfolios is a reflection of its potential merits.

[8]For more on the joint conduct of monetary policy and bank regulation, see Goodhart and Schoenmaker (1995), Peek, Rosengren and Tootell (1999), Ioannidou (2005) and Agur and Sharma (2014).

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