Optimal Monetary and Macroprudnetial Policies: Gains and Pitfalls in a Model of Financial Intermediation*

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March 26, 2014

Abstract

We build a quantitative general equilibrium model with nominal rigidities and financial intermediation to examine monetary and macroprudential stabilization policies. We find that an optimal monetary policy is sufficient to ensure efficiency, even in the presence of financial shocks. Therefore, under optimal monetary policy, there is limited need for a macroprudential approach. However, we find that a simple rules-based approach to monetary policy cannot approximate the optimal monetary policy when financial shocks are important: While a moderate response of the nominal interest rate to credit fluctuations delivers efficiency gains, it falls far short of optimal policy – opening the possibility of welfare gains from macroprudential policies. We then consider a simple rules-based approach for adjusting a macroprudential instrument – a tax on intermediary leverage. A simple rules-based approach is effective under the leverage tax in delivering substantial welfare gains.

JEL Classification Code: E58, E61, and G18

1 Introduction

A growing chorus of voices has suggested that counter-cyclical macroprudential policies may help insulate the economy from inefficient fluctuations caused by disturbances to

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financial intermediation, while other views have emphasized a need for monetary policy to counteract such developments in the absence of such tools or evidence regarding their efficacy.[1]

We analyze three related questions:

- In an environment with traditional "New-Keynesian" sources of fluctuations (e.g., technology, price/wage markup, and nominal aggregate demand shocks), an intermediation sector subject to financial frictions, and disturbances to the intermediation sector, is a macroprudential instrument necessary if monetary policy is chosen optimally?

- Under more realistic conditions, in which monetary policy is adjusted in response to macroeconomic factors such as inflation, economic activity, and potentially credit conditions, should monetary policy respond to credit conditions or is there value in adjusting a macroprudential policy instrument to smooth inefficient economic fluctuations?

- How does the choice of macroprudential instrument affect the trade-off between using monetary policy and macroprudential policies, especially when the policy instruments are set using simple rules-based approaches?

To study these issues, we build a quantitative model that incorporates key frictions from the New-Keynesian models used for monetary policy and some of the financial frictions important for understanding the role of intermediation in business-cycle fluctuations. In the model, a central role is played by financial intermediaries, which raise debt and equity funds in capital markets to finance productive investment. In particular, the financial frictions in the model lead to a *valuation wedge* that distorts the efficient allocation of investment funds in a manner that depends on the liquidity conditions of financial intermediaries. This opens up the possibility that public policy interventions, by acting on the liquidity conditions of the financial intermediaries, can improve social welfare.

Monetary policy can limit the adverse consequences of disturbances within the intermediation sector through two distinct channels: First, monetary policy can act directly

[1] Svensson (2012) describes in detail developments in Sweden between 2008 and 2012, a period over which this debate affected policy deliberations at the Riksbank.

upon aggregate demand, and thus improve the liquidity condition of the financial intermediaries *indirectly* by affecting overall business cycle condition; second, monetary policy can directly affect the borrowing costs and risk-taking of the financial intermediaries. However, these possible beneficial effects may also be accompanied by influences that may distort the efficient intertemporal consumption profile. [2]

We focus on a tax on intermediary leverage as our macroprudential instrument, in the spirit of recent contributions emphasizing such a tax in models with leverage constraints (e.g., Bianchi, Boz, and Mendoza (2012) and Jeanne and Korinek (2013)). Our analysis of the interaction of monetary and macroprudential policies proceeds in several steps. We first consider optimal policy strategies as chosen by a Ramsey social planner maximizing the welfare of the agents in the model. Our analysis of such optimal policies includes optimal monetary policy in the absence of a macroprudential instrument, optimal monetary and macroprudential policies, and the optimal setting of the macroprudential instrument when monetary policy is governed by a simple rule for the nominal interest rate.

These optimal Ramsey strategies are complex, model-dependent functions of the entire "state vector". Because of this complexity and model-dependence, we follow our consideration of optimal policies with a description of how simple policy rules perform relative to the optimal policies. With regard to monetary policy, we consider responses to inflation and economic activity, as in the traditional monetary policy literature, as well as an augmented approach in which policy responds to credit conditions directly. With regard to macroprudential policy, we examine simple rules for a leverage tax linked to credit conditions.

We find that an optimal monetary policy is sufficient to ensure efficiency, even in the presence of financial shocks. Therefore, under optimal monetary policy, there is limited need for a macroprudential approach. However, we find that a simple rules-based approach to monetary policy cannot approximate the optimal monetary policy when financial shocks are important: While a moderate response of the nominal interest rate to credit fluctuations delivers efficiency gains, it falls far short of optimal policy – opening the possibility of welfare gains from macroprudential policies. We then consider

[2] The monetary policy dilemma created by financial shocks was pointed out by Gilchrist and Leahy (2002) in the context of stabilizing the effects of net-worth shocks to entrepreneurs in an environment similar to Bernanke, Gertler, and Gilchrist (1999) although they did not search for alternative policy instruments.

a simple rules-based approach for adjusting a macroprudential instrument – a tax on intermediary leverage. A simple rules-based approach is effective under the leverage tax in delivering substantial welfare gains.

Related literature: Our analysis builds on several strands of recent research. Our starting point is the introduction of a central role for financial intermediation in the transformation of household savings into productive capital (e.g., work following Gertler and Kiyotaki (2010)). Our implementation most closely resembles that of Kiley and Sim (2014): In particular, we emphasize, as in that earlier work, the need for intermediaries to make lending decisions prior to having complete knowledge of their internal funds, which exposes intermediaries to liquidity risk and the possibility of needing to raise costly external funds; relative to Kiley and Sim (2014), we allow for intermediary default, an extension which creates a market-based leverage constraint on intermediaries (driven by the willingness of households to hold risky intermediary debt). The time-variation in potential external funding needs will drive the inefficiency wedge from intermediaries to vary over time inefficiently, thereby affecting investment in physical capital and overall economic activity. Overall, embedding this mechanism within a business-cycle framework creates a New-Keynesian dynamic general equilibrium model in which intermediaries affect asset pricing in mush the same way as emphasized in work on intermediary-based asset pricing models such as Holmstrm and Tirole (2001) and He and Krishnamurthy (2012). Moreover, the framework emphasizes the potential importance of shocks to the intermediary sector, a factor found to be empirically important in Christiano, Motto, and Rostagno (2014).

Our consideration of the interaction of the financial frictions in our model on optimal monetary policy echoes the focus in Bernanke and Gertler (1999), Gilchrist and Leahy (2002), and Iacoviello (2005) on how monetary policy should respond to asset prices. Other recent analyses in a similar vein, which also add consideration of macroprudential policies, include Prakash, Pau, and M. (2012), Lambertini, Mendicino, and Punzi (2013), Collard, Dellas, Diba, and Loisel (2012), Angeloni and Faia (2013) and Christensen, Meh, and Moran (2011). As in the latter two analyses, we emphasize intermediation. Moreover, these earlier analyses do not consider a core framework closely tied to the types of New-Keynesian models used at central banks. As we will see, careful consideration of the behavior of monetary policy, and in particular of the links between the optimal policy and the form of efficient strategies based on simple rules, affects the evaluation of macroprudential instruments in a way that is important to the conclusions in, for example, Angeloni and Faia (2013) and Christensen, Meh, and Moran (2011).

The remainder of this paper is organized as follows. Section 2 develops our dynamic general equilibrium model that works as a laboratory for our policy analysis. Section 3 analyzes the optimal policies that would be pursued b a Ramsey planner. Section 4 studies the potential gains and pitfalls of implementing macroprudential policies in via simple policy rules. Section 5 concludes.

2 The Model

The model economy consists of (i) a representative household, (ii) a representative firm producing intermediate goods, (iii) a continuum of monopolistically competitive retailers, (iv) a representative firm producing investment goods, and (v) a continuum of financial intermediaries.

The representative household lacks the skill necessary to directly manage financial investment projects. As a result, the household saves through financial intermediaries by holding debt and equity claims on intermediaries. In addition to the assumed role of intermediation, we will adopt a framework in which raising equity from external funds is costly – a key financial friction in our model. As we discuss further below, a distinction between internal and external funds lies at the heart of much research in corporate finance (e.g., Myers and Majluf (1984)).

Finally, we assume a timing convention in intermediaries' financing decisions that is designed to highlight risks associated with intermediation. A key aspect of intermediation is that financial intermediaries make long-term commitments despite short-run funding risks. For example, a substantial portion of commercial and industrial lending by commercial banks are in the form of loan commitments; more generally, banks have substantial mismatches between the maturities of their assets and liabilities. Rather than introducing long-term assets, we adopt a simple framework which splits a time period into two subperiods. Lending and borrowing (e.g., asset and liability) decisions have to be made in the first half of the period t; idiosyncratic shocks to the returns of the projects made at time $t-1$ are realized in the second half of the period t, at which point lending and borrowing decisions cannot be reversed (until period $t+1$).[3]

[3] Another related approach would be the following. One can assume that a random fraction of

This set of assumptions has two advantages: First, the intra-period irreversibility in lending and borrowing decisions, in conjunction with costs of external equity financing, creates liquidity risk and generates *precaution* in lending decisions; second, the timing convention helps us derive an analytical expression for the equity issuance and default triggers of intermediaries, allowing a sharp characterization of the equilibrium.

We now walk through the financing decisions (for debt, equity, and payouts) of intermediaries. The model discussion of non-financial activities (of households and non-financial firms) is relatively brief, as those aspects of our model follow standard practice.

2.1 The Financial Intermediary Sector

Financial intermediaries are necessary to finance investment projects. These projects are financed with debt and equity raised from investors – in our model, the representative household. Intermediaries wish to use debt – that is, to be leveraged – because such financing is cheap and because raising equity from outside investors is costly. While a number of factors could motivate cheap access to debt on the part of intermediaries (e.g., liquidity services from deposits and other short-term debt liabilities with money-like characteristics, as emphasized by Gorton and Pennacchi (1990)), we introduce a preference for debt through a corporate income tax that preferentially treats debt.

In presenting the model, we first walk through the costs facing intermediaries in raising funds (via debt and equity) to finance the investment projects. Given the funding constraints, we then turn to the intermediaries' optimal choices of lending to investment projects, financing of these projects via borrowing and equity, and dividend payout policies to maximize shareholder value.

2.1.1 The Intermediary Debt Contract

The cost and terms of borrowing are determined by the debt contract between a financial intermediary $i \in [0, 1]$ and an investor. Denote the fraction of a lending/investment

households require early redemption of their debts/deposits at intermediaries in the second half of the period. In this case, the idiosyncratic redemption rate replaces the idiosyncratic shocks to the return on lending. Owing to the illiquidity of the investment project, the intermediary has to raise additional funds on the interbank market or elsewhere to meet the "run". This will create a similar effect on the lending decision of the intermediary under the assumption that raising such funds involves a cost analogous to the cost of outside equity we emphasize.

project financed with equity capital by m_t. $1-m_t$ then denotes the fraction of borrowed funds. The debt is collateralized by the total investment project. If the intermediary does not default in the next period, it repays this debt (in amount $(1+r^B_{t+1})(1-m_t)$, where r^B_{t+1} is the interest rate on borrowing). In the event of default, the investor receives the collateral asset, whose per unit market value is Q_{t+1}. Because investors are assumed to lack the skill to manage investment projects, immediate liquidation of the investment project is required at a distressed sales cost, a fraction $\eta \in (0,1)$ of the asset value.

The intermediary's investment project delivers a random gross return, $1+r^F_{t+1}$ after tax. The return on lending/investment projects consists of an idiosyncratic component ϵ_{t+1} and an aggregate component $1+r^A_{t+1}$ such that $1+r^F_{t+1} = \epsilon_{t+1}(1+r^A_{t+1})$ where the idiosyncratic component has a time-varying distributions $F_{t+1}(\cdot)$.[4] In particular, we assume that the second moment of the distribution follows a Markov process (detailed further below), while the first moment is time-invariant (and normalized to equal one, $\mathbb{E}_t[\epsilon_{t+1}] = 1$). The time-variation in the second moment of the idiosyncratic return will have aggregate implications under the financial market frictions considered herein.

After the tax deduction on interest expenses, the debt burden of the intermediary is equal to $[1+(1-\tau_c)r^B_{t+1}](1-m_t)$, where τ_c denotes the corporate income tax rate. A default occurs when the realized asset return $\epsilon_{t+1}(1+r^A_{t+1})$ falls short of the value of the debt obligation $[1+(1-\tau_c)r^B_{t+1}](1-m_t)$. This implies a default trigger ϵ^D_{t+1} – realizations of the idiosyncratic return below this value imply default

$$\epsilon_{t+1} \leq \epsilon^D_{t+1} \equiv (1-m_t)\frac{1+(1-\tau_c)r^B_{t+1}}{1+r^A_{t+1}}. \tag{1}$$

Investors discount future cash flows with the stochastic discount factor of the representative household, denoted by $M_{t,t+1}$. Given the default trigger (A.1) and the assumption regarding the bankruptcy costs, the no-arbitrage for the investors should satisfy

$$1-m_t = \mathbb{E}_t\left\{M_{t,t+1}\left[(1-\eta)\int_0^{\epsilon^D_{t+1}} \epsilon_{t+1}(1+r^A_{t+1})dF_{t+1} + \int_{\epsilon^D_{t+1}}^{\infty}(1-m_t)[1+r^B_{t+1}]dF_{t+1}\right]\right\} \tag{2}$$

where $M_{t,t+1} \equiv \beta(\Lambda_{t+1}/\Lambda_t)/(1+\pi_{t+1})$ with β, Λ_t and π_{t+1} being the time discount

[4] We assume that the time-varying distribution can be described by a lognormal distribution with the volatility level σ_t following an AR(1) process.

factor, the marginal utility of consumption of the representative household, and inflation, respectively. The first term inside the parentheses on the right-hand side is the funds recovered upon default, where the recovery rate $1-\eta$ owes to the costs of bankruptcy/liquidation η. The second term is non-default income. The discounted value of this total return must equal the value of funds lent to intermediaries by the investors, $1-m_t$.

This equation works as the households' participation constraint in the intermediary's optimization problem for capital structure – that is, intermediaries must take into account the required return to households on debt in deciding leverage. For later use, it is useful to replace r^B_{t+1} in the participation constraint with an expression including ϵ^D_{t+1}. Using the definition of the default trigger, we can express the borrowing rate as $r^B_{t+1} = \frac{1}{1-\tau_c}\left[\frac{\epsilon^D_{t+1}(1+r^A_{t+1})}{1-m_t} - 1\right]$. Substituting this in the participation constraint yields

$$\begin{aligned} 1-m_t = \mathbb{E}_t \left\{ M_{t,t+1} \left[\int_0^{\epsilon^D_{t+1}} (1-\eta)\epsilon_{t+1} dF_{t+1} + \int_{\epsilon^D_{t+1}}^{\infty} \frac{\epsilon^D_{t+1}}{1-\tau_c} dF_{t+1} \right] (1+r^A_{t+1}) \right\} \\ - (1-m_t)\frac{\tau_c}{1-\tau_c}\mathbb{E}_t\left[M_{t,t+1}[1-F_{t+1}(\epsilon^D_{t+1})]\right] \end{aligned} \quad (3)$$

2.1.2 Intermediary Equity Finance

We now turn to the problem of intermediary equity financing. The equity stake in the intermediary entitles the representative household to the profits from the lending capacity of the intermediary and, as is standard in the corporate finance literature, we assume that the managers of the intermediaries maximize the value of incumbent shareholders. However, intermediaries may find themselves short of cash flow (in circumstances described below) in which case they must enter bankruptcy or raise additional equity.

If the intermediary raises equity capital, we assume that they must sell new shares *at a discount*, which generates a dilution effect: issuing new equity with a notional value of a dollar reduces the value of *existing* shares more than a dollar. The discount can be structurally motivated if there is information asymmetry between the insiders and outsiders of the intermediary such that the outside investors face the uncertainty regarding the values of assets-in-place and new investment opportunities. Dilution occurs when the insiders try to get new financing by giving up a fraction of the ownership of the assets-in-place that are potentially *lemons* to the outsiders. This makes possible undervaluation of *good* intermediaries, which makes them reluctant to issue new shares and prefer to use internal funds or debt, driving out the good intermediaries from the equity market. Knowing this, the outsiders request a lemon premium.

Our approach, based on Bolton and Freixas (2000), is to assume a parametric form for the dilution cost: issuing new equity involves a constant per-unit issuance cost, $\varphi \in (0, 1)$.[5] We denote equity related cash flow by D_t. D_t is dividends paid when positive, and equity issuance when negative. With our assumption of costly equity issuance, actual cash inflow from the issuance $(-D_t)$ is $-(1-\varphi)D_t$. Total equity related cash flow for the intermediary is $-D_t + \varphi \min\{0, D_t\}$.

Suppose that the intermediary invests in S_t units whose market price is given by Q_t. The intermediary borrows $1 - m_t$ for each dollar of its lending/investment project. The cash inflow associated with this debt financing from households is given by $(1-m_t)Q_tS_t < Q_tS_t$. To close the funding gap, the intermediary has two other sources: internal funds, N_t and equity issuance $-D_t + \varphi \min\{0, D_t\}$ such that

$$Q_tS_t = (1 - m_t)Q_tS_t + N_t - D_t + \varphi \min\{0, D_t\}, \tag{4}$$

which is simply the flow of funds constraint facing the intermediary.

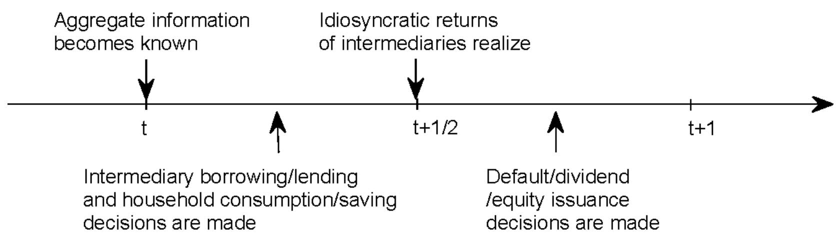
Without default, the internal funds of the intermediary are given by the difference between the total return from the asset minus the debt payment, i.e., $N_t = \epsilon_t(1 + r_t^A)Q_{t-1}S_{t-1} - (1+(1-\tau_c)r_t^B)(1-m_{t-1})Q_{t-1}S_{t-1}$. However, owing to the limited liability, internal funds are truncated by zero. Hence internal funds are given by

$$\begin{aligned} N_t &= [\max\{\epsilon_t, \epsilon_t^D\}(1 + r_t^A) - (1 - m_{t-1})(1 + (1 - \tau_c)r_t^B)]Q_{t-1}S_{t-1} \\ &= [\max\{\epsilon_t, \epsilon_t^D\} - \epsilon_t^D](1 + r_t^A)Q_{t-1}S_{t-1}. \end{aligned} \tag{5}$$

where the second equality uses the definition of the default trigger (A.1). Combining the flow-of-funds constraint (.28) with the definition of internal funds (.29) yields the cash-flow constraint that constrains intermediary decisions, inclusive of the impact of limited liability, that governs the link between past lending, equity and debt issuance,

[5] Our approach, based on Bolton and Freixas (2000), can be considered standard in corporate finance literature: See Gomes (2001) and Cooley and Quadrini (2001), for example. Pursuing a structural motivation for the existence of the dilution costs is beyond the scope of this analysis. See Myers and Majluf (1984) and Myers (2000) for a more formal presentation.

Figure 1: Sequence of Events



and dividend payouts,

$$0 = [\max\{\epsilon_t, \epsilon_t^D\} - \epsilon_t^D](1 + r_t^A)Q_{t-1}S_{t-1} - D_t + \varphi \min\{0, D_t\} - m_t Q_t S_t. \qquad (6)$$

2.1.3 Value Maximization

A Symmetric Equilibrium In order to present a sharp characterization of the equilibrium, the timing convention mentioned earlier is important. Formally, we assume: (i) all aggregate information is known at the beginning of each period; (ii) based on aggregate information, intermediaries make lending/borrowing decisions, which are irreversible within a given period; (iii) idiosyncratic shocks are realized after the lending/borrowing decision; (iv) some intermediaries undergo the default/renegotiation process; (v) finally, equity issuance/dividend payout decisions are made. Figure 1 shows the timing of information and decisions.

This timing convention and the risk neutrality of intermediaries imply a symmetric equilibrium in which all intermediaries choose the same lending/investment level and capital structure. The symmetric equilibrium also implies that all intermediaries face the same borrowing cost and default trigger at the borrowing/lending stage (e.g., the first half of period t). The shadow value of the participation constraint (the no-arbitrage condition for a bond investor, (A.2)), denoted by θ_t, also has a degenerate distribution since the borrowing decision is made before the realization of the idiosyncratic shock.

However, the distribution of dividends and equity financing do depend on the realization of idiosyncratic shocks, and thus has a non-degenerate distribution. Since the flow of funds constraint depends on the realization of the idiosyncratic shock, the shadow value of the constraint, denoted by λ_t, also has a non-degenerate distribution.

To simplify the dynamic problem, we decompose the intermediary problem into two stages in a way that is consistent with the timing convention: in the first stage, the intermediary solves for the value maximizing strategies for lending and borrowing without knowing its realization of net worth. In the second stage, the intermediary solves for the value maximizing dividend/issuance strategy based upon all information, including the realization of its net worth.

Formally, we define two value functions, J_t and $V_t(N_t)$. J_t is the ex-ante value of the intermediary before the realization of idiosyncratic shock while $V_t(N_t)$ is the ex-post value of the intermediary after the realization of idiosyncratic shock. In our symmetric equilibrium, the ex-ante value function does not depend on the intermediary specific state variables and J_t is a function of aggregate state variables only. The ex-post value function $V_t(\cdot)$, however, depends on the realized internal funds, N_t, which is a function of the realized idiosyncratic shock as shown by (.29). Since the first stage problem is based upon the conditional expectation of net-worth, not the realization, it is useful to define an expectation operator $\mathbb{E}_t^{\epsilon}(\cdot) \equiv \int \cdot dF_t(\epsilon)$, the conditioning set of which includes all information up to time t, except the realization of the idiosyncratic shock.

From the perspective of households, there is no new information in the second half of the period because of the law of large numbers: At the beginning of each period, the household exactly knows how much additional equity funding is required for the intermediary sector as a whole (as indicated by the timing of household decisions in figure 1). This ensures that the lending and borrowing decisions of intermediaries are consistent with the savings decisions of households.

All financial intermediaries are owned by the representative household, and hence discount future cash flows by the stochastic pricing kernel of the representative household, $M_{t,t+1}$. Before the realization of the idiosyncratic shock, the intermediary maximizes shareholder value by solving for the size of its lending, debt, and equity from retained earnings (through choices for the aggregate project size Q_tS_t, leverage m_t, and the default trigger ϵ_{t+1}^D,

$$J_t = \max_{Q_tS_t, m_t, \epsilon_{t+1}^D} \{\mathbb{E}_t^{\epsilon}[D_t] + \mathbb{E}_t[M_{t,t+1} \cdot \mathbb{E}_{t+1}^{\epsilon}[V_{t+1}(N_{t+1})]]\}. \tag{7}$$

$$\text{s.t (A.2) and (6)}$$

After the realization of the idiosyncratic shock, the intermediary solves

$$V_t(N_t) = \max_{D_t}\{D_t + \mathbb{E}_t[M_{t,t+1} \cdot J_{t+1}]\} \tag{8}$$
$$\text{s.t } (6)$$

Problem (B.1) solves for the optimal lending/borrowing /default choices based upon $\mathbb{E}_t^\epsilon[N_t]$ and $\mathbb{E}_t^\epsilon[D_t]$, which are aggregate information. At this stage, the intermediary does not know whether default or issuance or distribution of dividends will occur under its optimal strategy. In contrast, problem (B.2) solves for the optimal level of distribution/issuance based on the realization of net-worth. In the second stage problem, the truncated net worth N_t becomes a state variable through the intermediary's cash-flow constraint (6).

The first-order conditions associated with problems (B.1) and (B.2) are given by the following.[6]

$$Q_tS_t: \quad 0 = -m_t\mathbb{E}_t^\epsilon[\lambda_t] + \mathbb{E}_t\left\{M_{t,t+1} \cdot \mathbb{E}_{t+1}^\epsilon\left[V'_{t+1}(N_{t+1})\frac{\partial N_{t+1}}{\partial Q_tS_t}\right]\right\} \tag{9}$$

$$m_t: \quad 0 = -\mathbb{E}_t^\epsilon[\lambda_t] + \theta_t\left\{1 + \frac{\tau_c}{1-\tau_c}\mathbb{E}_t[M_{t,t+1}(1 - F_{t+1}(\epsilon_{t+1}^D))]\right\} \tag{10}$$

$$\begin{aligned} \epsilon_{t+1}^D: \quad 0 = {} & \mathbb{E}_t\left\{M_{t,t+1} \cdot \mathbb{E}_{t+1}^\epsilon\left[V'_{t+1}(N_{t+1})\frac{\partial N_{t+1}}{\partial \epsilon_{t+1}^D}\right]\right\} \\ & + \theta_t\mathbb{E}_t\left\{M_{t,t+1}\left[\left((1-\eta) - \frac{1}{1-\tau_c}\right)\epsilon_{t+1}^D f_{t+1}(\epsilon_{t+1}^D)\right](1 + r_{t+1}^A)\right\} \\ & + \frac{\theta_t}{1-\tau_c}\mathbb{E}_t\left\{M_{t,t+1}\left[[1 - F_{t+1}(\epsilon_{t+1}^D)](1 + r_{t+1}^A) + (1-m_t)\tau_c f_{t+1}(\epsilon_{t+1}^D)\right]\right\} \end{aligned} \tag{11}$$

$$D_t: \quad \lambda_t = \begin{cases} 1 & \text{if } D_t \geq 0 \\ 1/(1-\varphi) & \text{if } D_t < 0 \end{cases} \tag{12}$$

2.1.4 Discussion

Equation (B.6) states that the shadow value of the internal funds depends on the intermediary's realized equity regime: the marginal valuation of an additional dollar is equal to one as long as it does not face any difficulty in closing the funding gap, and as a result, distributes a strictly positive amount of dividends; the shadow value can be

[6] See Technical Appendix for derivation.

strictly greater than 1 if the intermediary faces a short-term funding problem and has to raise equity funds.

To see the economic effects of the time-variation in the value of intermediaries' internal funds, we solve for the value of the idiosyncratic portion of the lending return that requires raising external equity by determining the level of the idiosyncratic return that implies zero dividend in the flow of funds constraint (.28). Idiosyncratic returns below this "issuance trigger" require raising external funds

$$\epsilon_t^E \equiv (1-m_{t-1})\frac{1+(1-\tau_c)r_t^B}{1+r_t^A} + \frac{m_t Q_t S_t}{(1+r_t^A)Q_{t-1}S_{t-1}} = \epsilon_t^D + \frac{m_t Q_t S_t}{(1+r_t^A)Q_{t-1}S_{t-1}}. \quad (13)$$

(13) shows that the support of the idiosyncratic shock is divided into three parts: (i) $(0,\epsilon_t^D]$, (ii) $(\epsilon_t^D,\epsilon_t^E]$, and (iii) (ϵ_t^E,∞). In the first interval, the intermediary defaults. In the second interval, the intermediary avoids default, but needs to raise new funds externally. In the third interval, the intermediary pays dividends to the shareholders. Since the shadow value takes 1 with probability $1-F_t(\epsilon_t^E)$ and $1/(1-\varphi)$ with probability $F_t(\epsilon_t^E)$, the expected shadow value is given by

$$\mathbb{E}_t^{\epsilon}[\lambda_t] = 1 - F_t(\epsilon_t^E) + \frac{F_t(\epsilon_t^E)}{1-\varphi} = 1 + \mu F_t(\epsilon_t^E) \geq 1, \;\; \mu \equiv \frac{\varphi}{1-\varphi}. \quad (14)$$

The inequality is strict as long as $\varphi > 0$. The fact that the expected shadow value of internal funds is always greater than 1 shows that the intra-period irreversibility of the lending decision creates *caution* on the part of the risk-neutral intermediaries. Though intermediaries know that they may be swamped with excess cash flow *ex-post*, they follow a conservative lending strategy due to potential liquidity risks. Moreover, the degree of conservatism is endogenously time-varying as a function of macroeconomic developments (as captured in the aggregate state variables).

The Effects of Costly Equity Finance and the Default Option To see how the financial market frictions affect the prices of assets and the lending decisions of the intermediaries, we transform the FOC for investment (B.3) into an asset pricing formula. To that end, we first apply the Benveniste-Scheinkman formula to (B.2) to derive $V'(N_t) = \lambda_t$, update this one period, substitute it in (B.3), and combine it with the expression $\partial N_t / \partial Q_{t-1} S_{t-1} = [\max\{\epsilon_t, \epsilon_t^D\} - \epsilon_t^D](1 + r_t^A)$ from (.29) to derive

$$m_t \mathbb{E}_t^{\epsilon}[\lambda_t] = \mathbb{E}_t \left\{ M_{t,t+1} \left[\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1} \max\{\epsilon_{t+1}, \epsilon_{t+1}^D\}] - \mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}] \epsilon_{t+1}^D (1 + r_{t+1}^A) \right] \right\}.$$

Dividing the above through by $m_t \mathbb{E}_t^{\epsilon}[\lambda_t]$ and rearranging terms yields an asset pricing formula,

$$1 = \mathbb{E}_t \left\{ M_{t,t+1} \frac{\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}]}{\mathbb{E}_t^{\epsilon}[\lambda_t]} \cdot \frac{1}{m_t} \left[1 + \tilde{r}_{t+1}^A - (1 - m_t)[1 + (1 - \tau_c) r_{t+1}^B] \right] \right\} \tag{15}$$

where we define a modified asset return $1 + \tilde{r}_{t+1}^A$ as

$$1 + \tilde{r}_{t+1}^A \equiv \frac{\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1} \max\{\epsilon_{t+1}, \epsilon_{t+1}^D\}]}{\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}]} (1 + r_{t+1}^A) \tag{16}$$

and replace $\epsilon_{t+1}^D (1 + r_{t+1}^A)$ by $(1 - m_t)[1 + (1 - \tau_c) r_{t+1}^B]$ in (15) using the definition of default trigger (A.1) and the fact that $(1 - m_t)[1 + (1 - \tau_c) r_{t+1}^B]$ is aggregate information at time $t + 1$, and hence does not need the expectation operator $\mathbb{E}_{t+1}^{\epsilon}[\cdot]$.

As an asset pricing formula, (15) is different from the textbook version for three reasons. First, it is a levered asset pricing formula as can be seen in the fact that the net asset return is levered up by a factor $1/m_t$. Second, the pricing kernel of the financial intermediaries is a filtered version of the representative household's stochastic discount factor with the filter being the dynamic ratio of the shadow value of internal funds λ_{t+1}/λ_t. And third, the effective return of the intermediary is bounded below owing to the limited liability as shown by (16).

Let's consider the filtering of the stochastic discount factor in more detail. The wedge between the pricing kernels of the intermediaries, which we will denote by $M_{t,t+1}^B$, and that of the representative household ($M_{t,t+1}$) is determined by the liquidity condition measured by the ratio of expected shadow values of internal funds, today vs tomorrow,

$$M_{t,t+1}^B \equiv \frac{\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}]}{\mathbb{E}_t^{\epsilon}[\lambda_t]} M_{t,t+1} = \left[\frac{1 + \mu F_{t+1}(\epsilon_{t+1}^E)}{1 + \mu F_t(\epsilon_t^E)} \right] M_{t,t+1}, \tag{17}$$

a ratio summarizing the intermediary's expectation about their dynamic liquidity condition. Specifically, a large value for λ_t relative to λ_{t+1}, all else equal, is equivalent to a decrease in the household's stochastic discount factor, as might occur, for example, if the household were to become more impatient. As a result, anything that increases the shadow value of cash flow for intermediaries today versus tomorrow will boost required asset returns, crimp lending, and lead to weaker economic activity. A prime example of such a factor would be an increase in idiosyncratic uncertainty today versus tomorrow – a factor that is irrelevant in the absence of costly outside equity ($\varphi = 0$, hence $\lambda_t = 1$) and illiquidity/short-run commitments in lending. In this sense, (15) and (17) can be thought of as an application of liquidity-based asset pricing model (LAPM, Holmstrm and Tirole (2001)) in a dynamic general equilibrium economy. [7].

Now consider the possibility the intermediary is fully equity financed and hence the default options is irrelevant. In this case ($m_t = 1$ and $\epsilon_t^D = 0$ at all t), (15) becomes

$$1 = \mathbb{E}_t \left\{ M_{t,t+1} \frac{\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}]}{\mathbb{E}_t^{\epsilon}[\lambda_t]} \left[\frac{\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}\epsilon_t]}{\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}]} (1 + r_{t+1}^A) \right] \right\}.$$

Assuming costly equity financing ($\varphi > 0$), $\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}\epsilon_{t+1}]$ is always less than $\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}]$. This occurs because high realizations of the idiosyncratic return ϵ_{t+1} will be associated with higher internal funds and hence lower shadow values for cash (λ_{t+1}), and this negative covariance implies, via Jensen's inequality, that the former expression is less than the latter expression.[8] This means that the asset return $1 + r_{t+1}^A$ must be higher than it would be in a frictionless market, in which the covariance between cash-flow realizations and the value of cash is irrelevant, and that, under a diminishing marginal rate of return from capital, capital is under-accumulated because of capital market frictions.

Returning to the effect of default directly (with debt financing $m_t < 1$ and $\epsilon_t^D > 0$), it is clear that default occurs under low realizations of idiosyncratic returns (ϵ_{t+1} low) and high values for the shadow value of intermediary cash flow (λ_{t+1} high). More specifically, default creates an option value as the limited liability makes the return of the intermediary a convex function of idiosyncratic return. The option value is given by the difference between $\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1} \max\{\epsilon_{t+1}, \epsilon_{t+1}^D\}]$ and $\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}\epsilon_{t+1}]$; this difference is always greater than zero and the value of the option is strictly positive as long as

[7]See He and Krishnamurthy (2008), who derive an intermediary specific pricing kernel by assuming risk aversion for the intermediary. Also see Jermann and Quadrini (2009), who derives a similar pricing kernel by assuming a quadratic dividend smoothing function.

[8]In fact, we considered a related case in our earlier work (Kiley and Sim (forthcoming)).)in which we consider the financial intermediary sector under a regulatory capital requirement.

uncertainty is present. In contrast to the equity market friction ($\varphi > 0$), the default option associated with debt financing encourages risk-taking, pushing down the required return to capital $(1+r^A_{t+1})$ and inducing over-investment in capital assets, *ceteris paribus*.

This default option is more valuable when uncertainty regarding the asset return increases. This, however, does not imply that the financial intermediaries will increase their lending to risky assets at a time of heightened uncertainty: While greater uncertainty boosts the risk appetite of the intermediaries through the default option, the same increase in uncertainty boosts the expected shadow values of cash flow (the effect of the costly equity financing friction ($\varphi > 0$)), thereby elevating the required return to lending for the intermediaries, which then reduces lending to risky assets. Furthermore, the bond investors require greater protection for default. This increases the borrowing costs for the intermediaries, further dampening the effects of enhanced risk appetite associated with the default option.

2.2 The Rest of the Economy

To close the model, we now turn to the production, capital accumulation, and the consumption/labor supply decisions of non-financial firms and households. Regarding the structure of production and capital accumulation, we assume that the production of consumption and investment goods are devoid of financial frictions. This assumption, while strong, helps us focus on the friction facing the financial intermediaries in their funding markets rather than the friction in their lending (investment) market. [9]

2.2.1 Production and Investment

There is a competitive industry that produces intermediate goods using a constant returns to scale technology; without loss of generality, we assume the existence of a representative firm. The firm combines capital (K) and labor (H) to produce the intermediate goods using a Cobb-Douglas production function, $Y^M_t = a_t H^\alpha_t K^{1-\alpha}_t$, where the technology shock follows a Markov process, $\log a_t = \rho_a \log a_{t-1} + \sigma_a v_t$, $v_t \sim N(0, 1)$.

The intermediate-goods producer issues state-contingent claims S_t to a financial intermediary, and use the proceeds to finance capital purchases, $Q_t K_{t+1}$. A no-arbitrage

[9] Other recent studies of intermediaries, notably Gertler and Karadi (2011) and Gertler and Kiyotaki (2010), adopt a similar assumption.

condition implies that the price of the state-contingent claim must be equal to Q_t such that $Q_t S_t = Q_t K_{t+1}$. After the production and sale of products, the firm sells its undepreciated capital at the market value, returns the profits and the proceeds of the capital sale to the intermediary. The competitive industry structure implies that the firm's static profit per capital is determined by the capital share of revenue, i.e., $r_t^K = (1-\alpha)P_t^M Y_t^M / K_t$, where P_t^M is the price level of the intermediate goods. Hence the after-tax return for the intermediary is given by

$$1 + r_t^A = \frac{(1-\tau_c)(1-\alpha)P_t^M Y_t^M / K_t + [1-(1-\tau_c)\delta]Q_t}{Q_{t-1}}. \tag{18}$$

We assume costs of adjusting investment at the aggregate level to allow for time-variation in the price of installed capital (K_t) relative to investment. More specifically, we assume that there is a competitive industry producing new capital goods combining the existing capital stock and consumption goods using a quadratic adjustment cost of investment, $\chi/2(I_t/I_{t-1}-1)^2 I_{t-1}$.

2.2.2 Households

We assume that the consumption utility of the household sector has a property of "catching up with the Joneses"–that is, an external habit formation a la Abel (1990). In addition; we assume that there is a continuum of monopolistically competitive households, each of which supplies a differentiated labor input. We index these households by $j \in [0,1]$. The differentiated labor inputs are then aggregated by a representative labor input aggregator in a Dixit-Stiglitz form, and combined with capital to produce the intermediate goods Y_t^M.

Formally, household preferences can be summarized by

$$\sum_{s=0}^{\infty} \beta^s \left[\frac{1}{1-\gamma}[(C_{t+s}(j) - hC_{t+s-1}(j))^{1-\gamma} - 1] - \frac{\zeta}{1+\nu} H(j)_{t+s}^{1+\nu} \right], \tag{19}$$

where $C_t(j)$ is consumption, $H_t(j)$ is hours worked, β is the time discount factor, γ governs the curvature in the utility function, h is the habit parameter, ν is the inverse of the Frisch elasticity of labor supply, and ζ determines the relative weighting on hours worked in overall utility. In the symmetric equilibrium, all households make identical choices for labor supply and earn the same nominal wage. Hence, given identical preferences, they make identical consumption/saving decisions. We assume that each household invests in a perfectly diversified portfolio of intermediary debts such that $B_t(j) = \int[1 - m_{t-1}(i,j)]Q_{t-1}S_{t-1}(i,j)di$. Since all households make the same choice, $\int B_t(j)dj = B_t$ trivially.

For the interest of space, we do not derive the efficiency conditions for households' financial investment decisions here. The technical appendix shows that the participation constraint (A.2) for the intermediary problem is equivalent to the efficiency condition for households' intermediary bond investment. The technical appendix also shows that investment in the equity shares of the financial intermediary satisfies the equilibrium condition

$$1 = \mathbb{E}_t \left[M_{t,t+1} \frac{\mathbb{E}^{\epsilon}_{t+1}[\max\{D_{t+1}, 0\} + (1-\varphi)\min\{D_{t+1}, 0\}] + P^S_{t+1}}{P^S_t} \right] \tag{20}$$

where P^S_t is the ex-dividend price of an intermediary share. This is a standard dividend-price formula for the consumption CAPM, taking into account the effect of the equity issuance cost on dividend related cash flows to investors (as shown in the technical appendix). Note that in our symmetric equilibrium, $P^S_t(i) = P^S_t$ for all $i \in [0,1]$ where because $\mathbb{E}_t[M_{t,t+1} \cdot J_{t+1}]$ does not depend on intermediary specific variables. Finally, note that in general equilibrium, the existing shareholders and the investors in the new shares are the same entity, the representative household. Hence, costly equity financing does not create a wealth effect for the household, but affects the aggregate allocation through the marginal efficiency conditions of the intermediaries.

To see that there is no wealth transfer to the household, one can rewrite the flow of funds constraint for the intermediary (.28) at time $t+1$ as $D_{t+1} - \varphi \min\{0, D_{t+1}\} = N_{t+1} - m_{t+1}Q_{t+1}S_{t+1}$, and observe

$$D_{t+1} = \begin{cases} N_{t+1} - m_{t+1}Q_{t+1}S_{t+1} & \text{if } D_{t+1} \geq 0 \\ (N_{t+1} - m_{t+1}Q_{t+1}S_{t+1})/(1-\varphi) & \text{if } D_{t+1} < 0 \end{cases}.$$

Hence $\max\{D_{t+1}, 0\} + (1-\varphi)\min\{D_{t+1}, 0\} = N_{t+1} - m_{t+1}Q_{t+1}S_{t+1}$ always. This shows that the households do not face any consequences on their wealth from the equity market friction because they would get the same aggregate dividends $N_{t+1} - m_{t+1}Q_{t+1}S_{t+1}$ if there were no dilution effects, i.e., $\varphi = 0$.[10]

Finally, we assume that the representative household has access to a nominal bond whose one-period return equals the policy interest rate set by the central bank, R_t, adjusted for an exogenous aggregate "risk" premium Ξ_t (reflecting unmodeled distortions between the central bank and households). Under these assumptions, the condition linking households stochastic discount factor and the policy interest rate is given by

$$1 = \mathbb{E}_t \left[M_{t,t+1} R_t \Xi_t \right] \tag{21}$$

We assume that the "risk premium" follows a Markov process, $\log \Xi_t = \rho_\Xi \log \Xi_{t-1} + \sigma_\Xi w_t$, $w_t \sim N(0,1)$. Other models, most notably Smets and Wouters (2007) and Chung, Kiley, and Laforte (2010), have also used this aggregate risk premium shock to explain economic fluctuations. In particular, this shock is a pure shock to the natural rate of interest (e.g., Woodford (2003)) and represents a "nominal aggregate demand" disturbance – that is, this shock has no effect on economic activity under flexible prices, as it would simply pass through to nominal interest rates, but has important effects when prices are rigid and nominal rates influence demand. We turn to nominal rigidities in the next subsection.

2.2.3 Nominal Rigidity and Monetary Policy

We take a symmetric approach to nominal rigidity in both goods and labor market. We assume that a continuum of monopolistically competitive firms take the intermediate outputs as inputs and transform them into differentiated retail goods $Y_t(k)$, $k \in [0,1]$. To generate nominal rigidity, we assume that the retailers face a quadratic cost in adjusting their prices $P_t(k)$ given by $\chi^p/2 \left(P_t(k)/P_{t-1}(k) - \bar{\Pi} \right)^2 P_t Y_t$, where Y_t is the CES aggregate of the differentiated products with an elasticity of substitution ε, $\bar{\Pi}$ is the steady state inflation rate.

We also assume that the households supplying differentiated labor inputs face a quadratic cost in adjusting their nominal wages give by $\chi^w/2 \left(W_t(j)/W_{t-1}(j) - \bar{W} \right)^2 P_t Y_t$. This friction, together with the efficiency trade-off between the marginal consumption

[10] The expression $N_{t+1} - m_{t+1} Q_{t+1} S_{t+1}$ as aggregate dividend payouts is intuitive in that N_{t+1} is the beginning-of-the-period capital position (realized capital position), and $m_{t+1} Q_{t+1} S_{t+1}$ is the end-of-the-period capital position (target capital position). As a sector, the intermediaries pay out the difference to the shareholders.

utility of wage income and marginal disutility of labor hours determines the structure of the wage Phillips curve in the model as is standard in the New Keynesian literature.

In order to make the equilibrium of our model in the absence of nominal price rigidity and financial frictions "first best", we further assume that a system of distortionary subsidies to producers and households offsets the product and wage markups associated with monopolistic competitions.

Finally, monetary policy is governed by either the optimal rule implied by the maximization of household utility (e.g., the Ramsey optimal policy) or by a simple rule for the nominal interest rate. For a simple rule based monetary policy, we consider alternatives in which a rule for the change in the nominal interest rule reacts to inflation, the change in the output gap, and the ratio of credit (lending) to output ,

$$\frac{1+r_t}{1+r_{t-1}} = \left[\left(\frac{1+\pi_t}{1+\bar{\pi}} \right)^{\kappa \Delta p} \left(\frac{y_t y^*_{t+1}}{y^*_t y_{t+1}} \right)^{\kappa \Delta y} \right] \tag{22}$$

where $\bar{\pi}$ denotes the inflation target. The output gap is defined as the deviation of actual from a production based potential output, y^*_t. This form of the monetary policy reaction function has been shown to approximate the optimal monetary policy in New-Keynesian models (e.g., Levin, Wieland, and Williams (1999) and Chung, Herbst, and Kiley (2014)), and we will see that this strategy has similar properties in our model in response to technology, markup, and nominal aggregate demand/risk premium shocks.

2.2.4 Fiscal Policy

In our baseline model, the fiscal policy is simply dictated by the period-by-period balanced budget constraint. The revenues for government come from two sources: corporate income tax of the financial intermediaries and lump sum tax on households. The proceeds from the corporate income tax are assumed to be transferred back to the financial intermediaries in a lump sum fashion as this taxation is employed mainly for creating an incentive to take leverage in the steady state. We also assume that the distortionary subsidies on product prices and wages are funded by the lump sum tax on the households. Later, we will introduce leverage tax/subsidy on the financial intermediaries. Any proceeds (outlays) from the leverage taxation (subsidy) will be transferred back to the intermediaries (or funded by the lump sum tax in the case of subsidy).

2.3 Calibration

There are two sets of parameters: first, the parameters pertaining to preferences and technology, and second, the parameters crucial to the structure of the financial sector. The parameters related to preferences and technology are summarized in table 1. The discount factor β is set to 0.985. The households' risk aversion parameter γ is set to 4 to match evidences at the micro-level, while habit persistence (h) is set to 0.75, within the typical range in the literature. The labor-disutility parameter η is set to 1/3, implying a Frisch elasticity of labor elasticity of 3. We set the labor share in production α to 0.60 and the depreciation rate δ to 0.025. We adopt a moderate value for investment adjustment costs, with χ equal to 3, but choose a large value for the adjustment cost of prices by setting $\chi^p = 125$, broadly consistent with empirical work suggesting very flat "Phillips curves". Our framework allows wage rigidity to play a role in price dynamics. However, in our baseline calibration we set $\chi^w = 0$, making wage determination flexible. We do this for transparency. Our robustness check, however, indicates that this choice does not affect our main conclusions in any directions. We set the monetary policy reaction coefficients to output gap and inflation equal to 0.5

2.3.1 Financial Parameters and Stochastic Steady State

The parameters important for financial frictions have important effects on the (stochastic) steady state of the model. Figure 2, using the analytical moments of the second order approximation, shows the responses of key endogenous variables of the model to changes in the financial parameters: the corporate income tax rate (τ_c, column [1]); idiosyncratic risk (σ, column [2]); the cost of issuing outside equity (φ, column [3]); and the bankruptcy cost (η, column [4]). The key endogenous variables summarize the capital structure/risk taking behavior of the financial sector of the model: the equilibrium values of the capital ratio (m, row [1]); the return on equity (row [2]); and the borrowing rate of the intermediaries ($1 + r^B$, row [3]).[11]

The corporate income tax rate creates an incentive for the intermediaries to lever up their balance sheets to exploit the tax shield on interest expenses (panel [a]). As the tax rate goes up, the return on equity and borrowing cost also increase, as shown in panel

[11] Our approach based upon the analytical moments of the second order approximation is essentially consistent with the *risky steady state* approach by Coeurdacier, Rey, and Winant (2011).

Table 1: Baseline Calibration

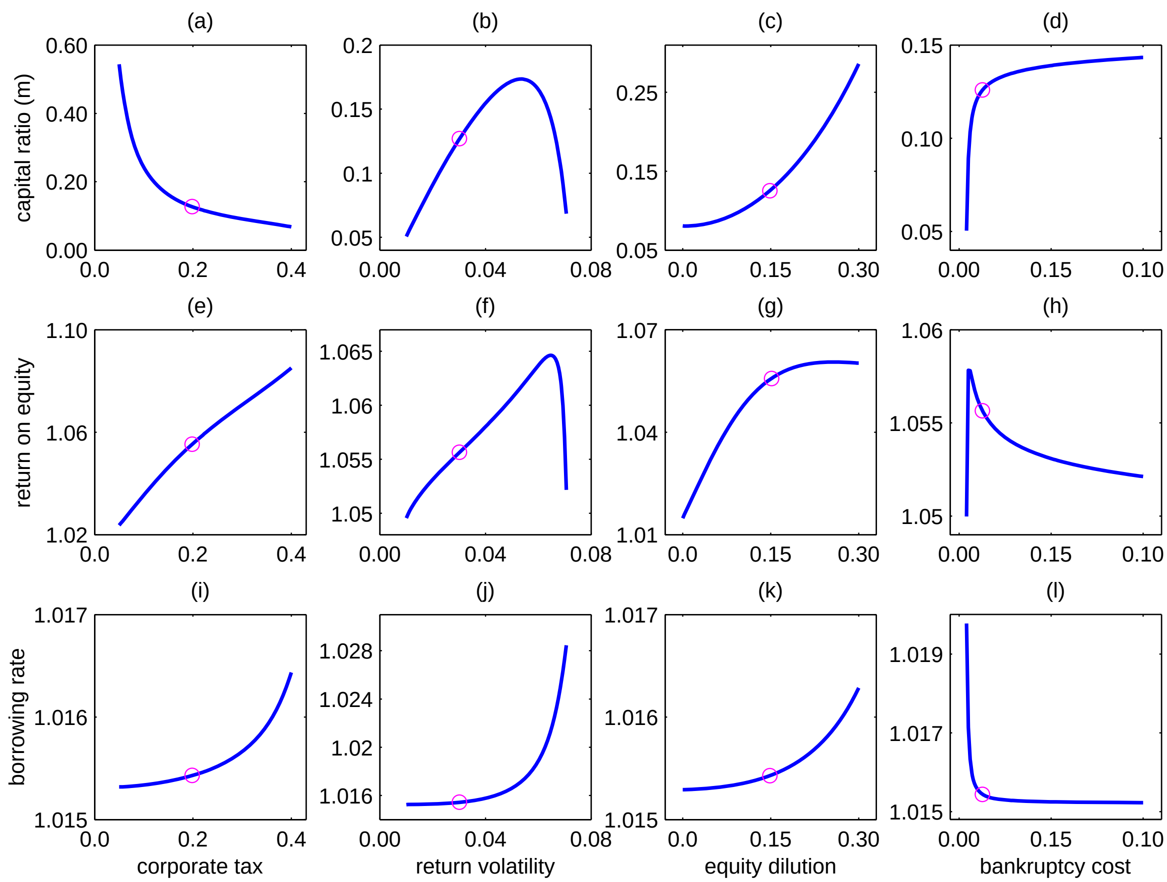
Description	Calibration
Preferences and production	
Time discounting factor	$\beta = 0.985$
Constant relative risk aversion	$\gamma = 4.0$
Elasticity of substitution (consumption)	$\varepsilon^p = 8.0$
Elasticity of substitution (labor)	$\varepsilon^w = 8.0$
Habit persistence	$h = 0.75$
Inverse of the elasticity of labor supply	$\nu = 3.0$
Value added share of labor	$\alpha = 0.6$
Depreciation rate	$\delta = 0.025$
Real/nominal rigidity and monetary policy	
Investment adjustment cost	$\chi = 2$
Adjustment cost of prices	$\chi^p = 125$
Adjustment cost of wages	$\chi^w = 0$
Monetary policy inertia	$\rho^r = 0.75$
Taylor rule coefficient for inflation gap	$\kappa^{\Delta p} = 1.5$
Taylor rule coefficient for output gap	$\kappa^{\Delta y} = 0.125$
Financial Frictions	
Liquidation cost	$\eta = 0.05$
Dilution cost	$\varphi = 0.15$
Corporate income tax	$\tau_c = 0.20$
Long run level of uncertainty	$\bar{\sigma} = 0.05$
Exogenous Stochastic Process	
Persistence of risk premium shocks	$\rho_\Xi = 0.90$
Persistence of financial shock	$\rho_f = 0.90$
Persistence of technology shock	$\rho_a = 0.90$

panel [e] and [i], as higher leverage increases risk. Given other parameters in the model, we set the tax rate equal to 20% to hit 12.5% capital ratio.[12]

Panel [b] exhibits the nonlinear effect of idiosyncratic return volatility on the leverage of intermediaries. Initially, as emphasized by Brunnermeier and Sannikov (2013, In Press), an increase in the volatility leads to lower leverage (or equivalently, an increase in the capital ratio), making the intermediaries more resilient against external shocks.

[12]This is a reasonable choice given that we abstract from other taxes such as interest income tax and capital gain tax for simplicity.

Figure 2: Financial Parameters and Stochastic Steady States



Note: The figure exhibits the analytical first moments of capital ratio (first row), return on bank equity (second row), and borrowing cost of banks (thrid row) using the second order approximation of the model as functions of the financial parameters such as corporate tax rate (first column), idiosyncratic return volatility (second column), dilution cost of equity issuance (third column), and bankruptcy cost (fourth column). The circled markers (magenta circles) indicate the location of baseline calibration of the model and corresponding stochastic steady states of the three endogenous variables.

However, as the volatility continues to go up, leverage starts to increase because the value of the default option overtakes the precautionary saving motive. The impact on equity return is highly nonlinear as well (panel [f]). We set the volatility as 3%, consistent with the s.d. of return on assets across the top 100 commercial banks in U.S. since 1986.

In the non-stochastic steady state of the model, an increase in the cost of outside equity decreases the equity margin, as intermediaries economize on equity. However, this relationship is reversed in the stochastic steady state, as shown in panel [c], where an increase in the cost of raising outside equity leads to an increase in the capital ratio. The seemingly counterintuitive result is due to the precautionary saving created by the financial frictions in the model: A higher cost of outside equity, in the stochastic environment, leads intermediaies to increase their equity capital base to limit the risk of having to raisee outside equity in response to shocks. For this to happen in equilibrium, the return on equity should rise in response as shown in panel [g]. As for the normal level cost of raising outside equity, we choose $\bar{\varphi} = 0.15$, in the middle of the range of calibrations/estimates in the existing literature.[13]

Finally, panel [d] shows the nonlinear effect of bankruptcy cost on the capital structure. In general, bankruptcy cost reduces the advantage of debt financing as a funding source because the cost is a welfare loss mutually detrimental to the both sides of the contract. The smaller the cost becomes, the more liquid the instrument becomes. However, as shown in panel [d], after a certain level, even a small decline in the cost can support a substantial increase in leverage.

2.3.2 Calibration of Shock Volatility

Our final calibration choices refer to the variances of the aggregate shocks generating-business cycle fluctuations. To highlight the role of traditional New-Keynesian forces emphasized in the monetary policy literature and the different implications of shocks to the intermediary sector, we consider two calibrations – a New-Keynesian and financial disturbance calibration.

- In the **New-Keynesian calibration**, the exogenous disturbances hitting the economy consist of the technology, markup, and aggregate risk premium shocks. Under the calibration, each shock accounts for 1/3 of the variance of output with the persistence levels of all shocks set equal to 0.9. In broad terms, this calibration results in a model with properties very similar to that of Smets and Wouters (2007): In particular, despite the presence of financial frictions, the basic structure of the model is similar to that used at many central banks – with important roles for technology, markup, and "aggregate demand" shocks.[14]

[13] For instance, Gomes (2001) provides a particularly low estimate of 0.06, while Cooley and Quadrini (2001) adopts 0.30. We choose a value, 0.15 in the middle of this range.

[14] The fact that the addition of financial frictions, in the absence of alternative disturbances, has little

- In the **Financial-Disturbance calibration**, the exogenous disturbances hitting the economy consist of the technology, markup, and cost of capital shocks. The last is implemented with a shock to the cost of issuing outside equity (φ). Under the calibration, each shock accounts for 1/3 of the variance of output with the persistence levels of all shocks set equal to 0.9. The emphasis on the cost of capital as a source financial shock is consistent with the recent studies in financial friction literature: Gilchrist, Schoenle, Sim, and Zakrajsek (2013), Warusawitharana and Whited (2013) and Eisfeldt and Muir (2012).[15]

The two calibrations share important similarities. For example, the calibraion implies that the variance of output is identical under each calibration (which also implies very similar variances for non-financial variables in general). Most importantly, in both cases it is optimal for policymakers, if they have sufficient policy instruments, to shut down the effects on economic activity of markup, aggregate risk premium, or cost of capital shocks as such shocks do not affect the production possibilities of the economy and only alter equilibrium outcomes through their effect on distortionary wedges in the economy. For example, markup shocks have real effects because of nominal rigidities and their effect on market power of intermediate goods-producing firms; risk premium shocks only affect activity because of nominal rigidities; and cost of capital shock only affects production because of financial frictions. Under an optimal policy, the effects of these shocks will be minimized and policymakers will attempt to support an efficient response to technology shocks.

However, these calibrations also are different in an important respect: In the New-Keynesian calibration, adjustments to the nominal interest can, in principle if not in practice, perfectly neutralize any real or inflationary effects of the risk premium shock, as the disturbance is a shock to the natural rate of interest. In contrast, a change in the nominal interest rate cannot perfectly insulate the economy from the impact of cost of capital shock for financially constrained agents. Such a policy may distort the efficient consumption/saving decisions of unconstrained agents by altering the prices of

effect on the properties of models of this type is consistent with the results in Boivin, Kiley, and Mishkin (2010) and Khan and Thomas (2008), for example.

[15] Christiano, Motto, and Rostagno (2014) consider risk shock, that is, shock to the idiosyncratic volatility of borrowers' return as a main driver of financial cycles. We are in line with this approach in that both shocks operate by chaning the weighted average cost of capital, although the emphasis in the former is on the debt market friction whereas ours is on the equity market friction.

consumptions today vs tomorrow.[16]

2.4 Model Dynamics

Some of the properties of the model important for policy design are illuminated through examination of the response of the model to the exogenous disturbances.

In particular, our model shares the basic properties of the typical New-Keynesian model (e.g., Smets and Wouters (2007)), with additional effects introduced through the modeling of financial intermediation. To illustrate these properties, we present impulses responses following the standard New-keynesian shock – technology, markup, and risk-premium shocks – and then present the consequences of an increse in the cost of outside equity capital.

For the experiments highlighting hte New-Keynesian shocks, We assume that the monetary policy is implemented with a standard nominal interest rate rule:

$$r_t = \rho_R r_{t-1} + [\bar{r} + \rho_y \log(y_t/\bar{y}_t) + \rho_{y1} \log(y_{t-1}/\bar{y}) + \rho_\pi \log(\pi_t/\bar{\pi})] \tag{23}$$

where $\bar{y}_t \equiv (z_t\bar{h})^{1-\alpha}k_t^\alpha$, the production capacity. We present results for two calibrations: The level specification assumes $\rho_R = 0.75$, $\rho_y = 0.03125$, $\rho_{y1} = 0$, and $\rho_\pi = 0.375$; the difference specification assumes $\rho_R = 1$, $\rho_y = \rho_{y1} = 0.5$, and $\rho_\pi = 0.5$.

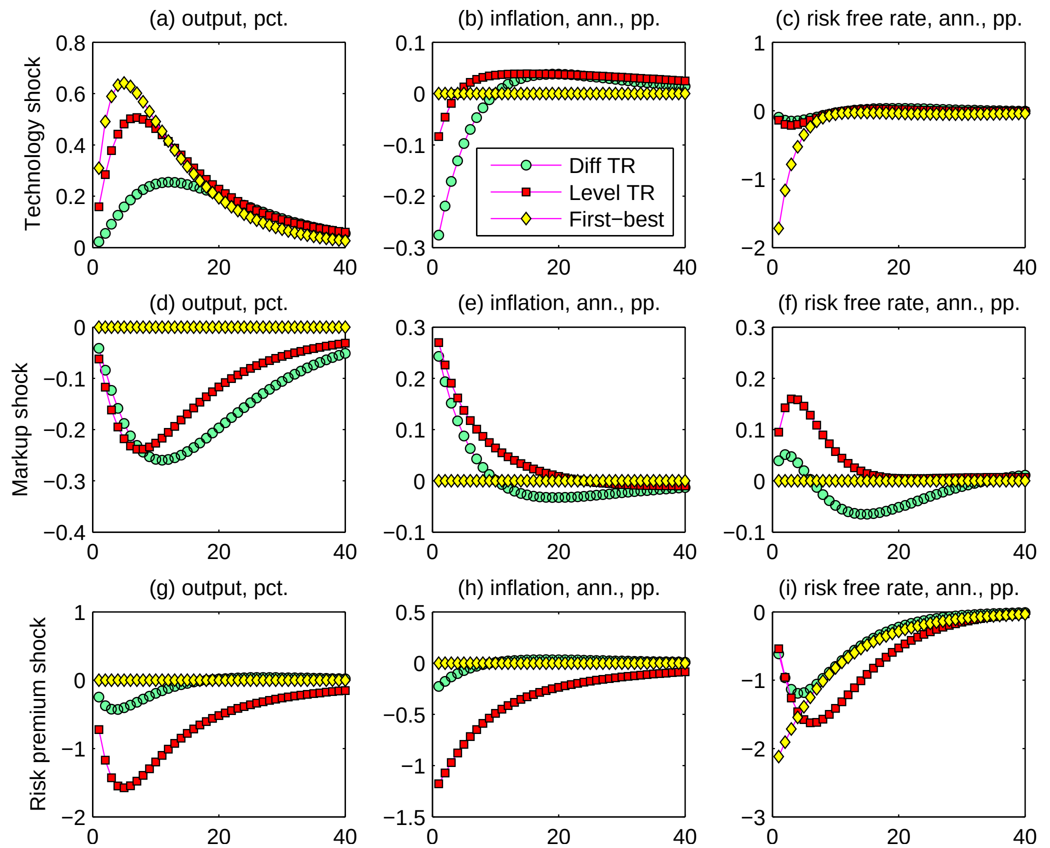
Figure 3 shows the response of the economy to one standard deviation shocks to aggregate technology (top row), markup (niddle row), and risk premium shock (bottom row). In these experiments, our focus is solely on the New-Keynesian properties of our model, and hence we only report responses for output, inflation, and the nominal interest rate. As is typical of in New-Keynesian models, output responds less than the efficient response (the yellow diamonds) following the technology shock under either policy reaction function, although the difference rule (the green circles) moves the output response a bit closer to the first-best response than does the level rule (the red squares).[17].

The markup shock (middle row) leads to declines in output and a spike in inflation rate, and these movements present a challenge for stabilzation via monetary policy. In contrast, the risk-premium shock is a pure shock to the natural rate of interest, and hence

[16] This intuition is standard, e.g., Gilchrist and Leahy (2002).

[17] The under-response of output to a technology shock in typical paramterizations of New-keynesian models is a standard feature (e.g., Gali (1999) and Boivin, Kiley, and Mishkin (2010))

Figure 3: Effects of Shocks to Technology, Price Mark-up, and Risk Premium

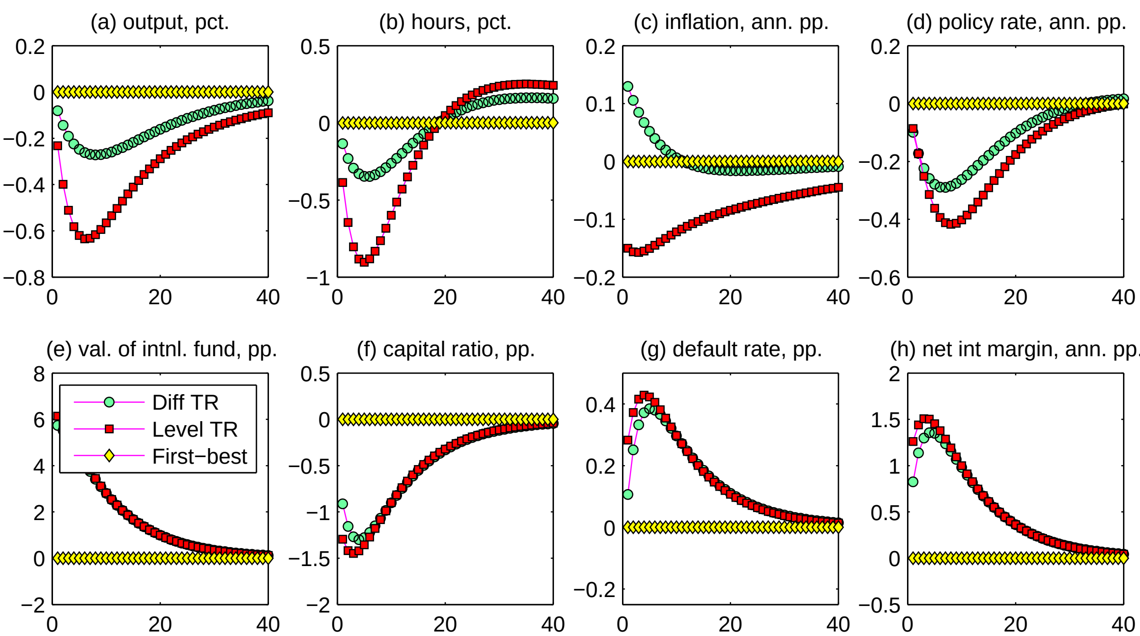


Note: The figure shows the impact of one standard deviation shocks to aggregate technology (top row), mark-up (middle row), and risk-premium (bottom row). See the main text for the calibration of the shock volatilities. The yellow diamonds present the first-best (efficient) response; the red squares present the responses under the level interest rate rule; and the green circles present the responses under the difference interest rate rule.

is suitable to stabilization via monetary policy; the first difference rule is somewhat more effective in this regard – stabilzing inflation almost completely and limiting the duration of the decline in output. As we will see below when examining optimal monetary policy, the difference rule provides a reasonable approximation to optimal monetary policy following these standard New-Keynesian shocks, a result well-known in the literature (e.g., Giannoni (2012) and Chung, Herbst, and Kiley (2014)). For this reason, the remainder of our analysis considers this rule as a baseline case.

Figure 4 depicts the responses of the economy to one standard deviation shock to the cost of capital. Output and hours (panel [a] and [b]) decline. Inflation increases modestly,

Figure 4: Effects of Shocks to the Cost of Capital



Note: The figure shows the impact of one standard deviation shock to cost of capital shocks. The yellow diamonds represent the first-best (efficient) response; the red squares represent the responses under the level interest rate rule; the green circles represent the responses under the difference interest rate rule. See the main text for the calibration of the shock volatilities.

despite the fall in output. The liquidity condition of intermediaries deteriorates sharply, as measured by the increase in the shadow value of internal funds (panel [e]), and the capital held by intermediaries declines (panel [f]). This is because the elevated cost of outside equity hinders the intermediaries from recapitalizing promptly. As a result, bank equity comes back to a normal level in a sluggish fashion, resulting in prolonged financial distress as reflected in the persistent increase in defaults and net interest rate margin (panel [f] and [h]). It is worthwhile to emphasize that the cost of capital shock does not destroy the capital base of the intermediaries directly through balance sheet loss. The shock simply increases the potential cost of recapitalization.[18] This leads to a restrictive lending stance, generating an endogenous fall in the market values of assets which amplifies the contraction by lowering intermediary equity (a pecuniary externality).

[18] Given the timing convention, some intermediaries are not subject to the cost of capital shock directly if their ex post returns are good enough to avoid recapitalization. However, even these intermediaries take the same defensive strategy ex ante.

3 Optimal Monetary Policy

We now consider optimal monetary policy in the absence of a macroprudential policy instrument.

The policy instrument is the nominal interest rate. The Ramsey planner maximizes the value function of the representative household given by

$$W_1(\mathbf{s}) = U(\mathbf{s}) + \beta \mathbb{E}[W_1(\mathbf{s}')|\mathbf{s}] \tag{24}$$

subject to the equilibrium conditions of the private sector, where $\mathbf{s}$ is the state vector of the economy and $U(\cdot)$ is the momentary utility function of the representative household. To consider the planning in a more realistic environment, however, we modify slightly the Ramsey planner's problem by assuming a preference for smooth adjustments of its policy instrument. A parsimonious way of achieving this is to modify the objective function of the planner into

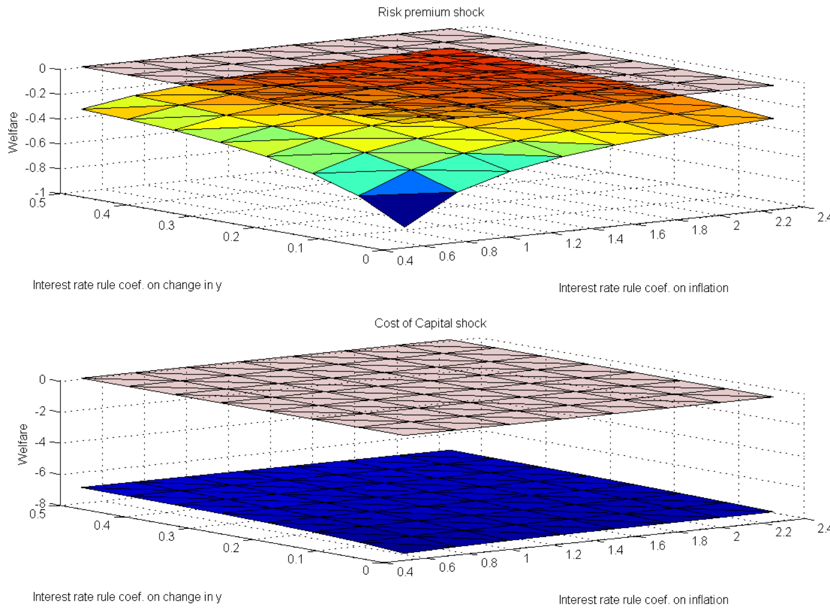
$$W_0(\mathbf{s}) = U(\mathbf{s}) - \gamma^P (\Delta r)^2 C_{-1} + \beta \mathbb{E}[W_0(\mathbf{s}')|\mathbf{s}], \tag{25}$$

which penalizes large changes in the policy interest rate, where the penalty is scaled to the level of (lagged) consumption. By suitably calibrating γ^P, one can replicate an AR(1)-like inertial dynamics, which is typical of popular, inertial interest rate rules. We note that this adjustment tends ti imply smoother movements in the nominal interest rate following shocks, but has essentially no effect on the level of household welfare achieved by the Ramsey planner and no substantive implications for the behavior of the economy.

We first compare the level of welfare under the optimal policy to that achieved by the simple monetary policy rule. Results are reported in figure 5: The top panel reports information for the New-Keynesian calibration, and the bottom panel reports information for the financial-intermediation calibration. In both cases, the level of welfare under the optimal policy is normalized to zero and is represented by the translucent plane at zero.[19] The surface below this plane represents the level of welfare (along the z-axis),

[19]Because the volatility of the economy is essentially identical under the two calibrations of exogenous disturbances, the absolute level of welfare is essentially identical across calibrations (as, in both cases, the optimal monetary policy can essentially neutralize the effect of distortionary shocks, as we will discuss further below). In this sense, our normalization of welfare has no substantive implications

Figure 5: Welfare Under A Simple Rule for the Nominal Interest Rate



Note: Upper panel: New-Keynesian calibration. Lower panel: Financial-intermediation calibration. The translucent surface at zero represents welfare under the optimal (Ramsey) rule for the nominal interest rate. The surface below this benchmark reports welfare (as a percent of steady-state consumption) under the nominal interest rate rule which responds to inflation and the change in output.

expressed in units of consumption, relative to the optimal policy for alternative combinations of the monetary policy rule coefficient on inflation (the x-axis) and on output growth (the y-axis); importantly, the response to credit in the monetary policy rule is set to zero in these parameterization of the simple rule. For example, a value of -0.5 would indicate that the associated parameterization of the policy rule delivers a level of welfare that is lower than that of the optimal policy by 1/2 percent of steady-state consumption.

Three results are apparent. First, the welfare surfaces for combinations of the coefficients on inflation and output growth are very flat. Second, under the New-Keynesian calibration, the simple rule achieves essentially the same level of welfare as the optimal policy (a result that is fairly standard for rules in the change in the nominal interest rate that respond to inflation and output growth, e.g. Chung, Herbst, and Kiley (2014)).

across calibrations.

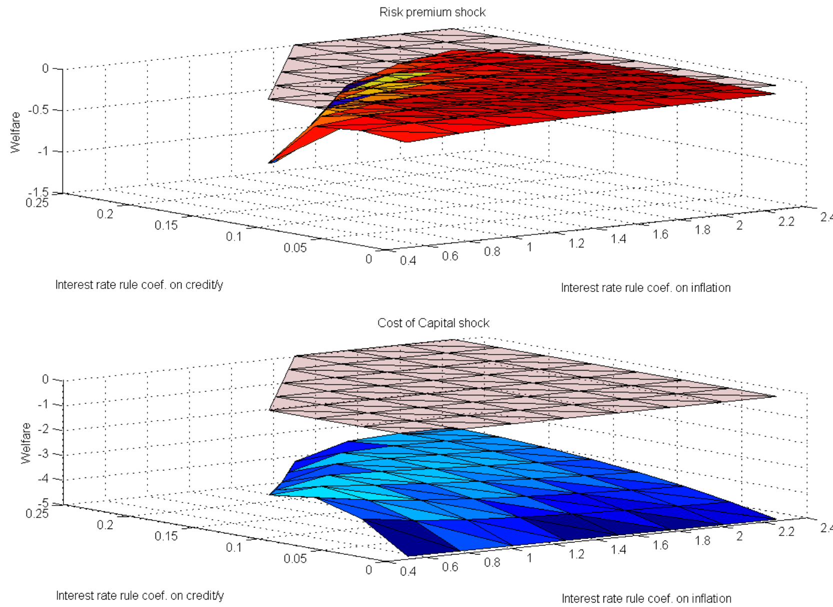
[20] And third, the simple rule for monetary policy does not approximate the optimal monetary policy under the financial-intermediation calibration.

To explore somewhat further the potential for a rules-based approach to approach the optimal policy in the financial-intermediation calibration, figure 6 presents analogous welfare surfaces for rules in which monetary policy actively responds to movements in credit relative to output (along the y-axis) (with the coefficient on output growth set to 0.5, and with the coefficient on inflation along the x-axis). Three results stand out. First, a very strong response to credit is counterproductive, as welfare falls sharply (the rapidly declining surface) or such a response implies equilibrium indeterminacy (which is indicated by the absence of surface in the indeterminacy region, which occurs for very large responses to credit). In addition, the welfare surface for the New-Keynesian calibration indicates that a moderate response to credit does little harm, but also does little good (which is not surprising, as there exists very little room to move toward a superior outcome given that responding to inflation and output growth essentially reproduces the level of welfare under the optimal policy, as shown in figure 5). Finally, a moderate response to credit moves welfare closer to the optimal policy under the financial-intermediation calibration – but only to a very small degree.

Figure 7 reports the impulse responses following a (positive) technology shock under the efficient response (blue, solid line), the simple-rule policy responding to inflation and output growth with coefficients of 0.5 (the black, dashed line), and the simple rule policy with the same inflation and output growth coefficients as well as a response to credit (relative to GDP) of 0.05 (the red, dash-dotted line). The upper three panels report output, inflation, and the nominal interest rate, and the lower three panels report the equity margin, aggregate credit, and the lending spread. It is apparent that a strong response to credit impedes the response to the technology shock – under the optimal policy, output and credit (along with investment) increase by more than under either simple rule in the early quarters, because periods of high productivity are good periods during which to produce and build wealth/productive capital to enjoy persistently higher consumption. Indeed, the credit cycle is substantially out of phase with that of output, and a response of monetary policy to credit imparts the long-lived credit

[20] A rule for the change in the nominal interest rate that responds to inflation and output growth is a rule lining the level of the nominal interest rate to the price level and output (e.g., flexible price-level targeting), which is typically close to the optimal policy when price rigidities are the key nominal rigidity Woodford (2003)).

Figure 6: Responding to Credit in a Simple Rule for the Nominal Interest Rate

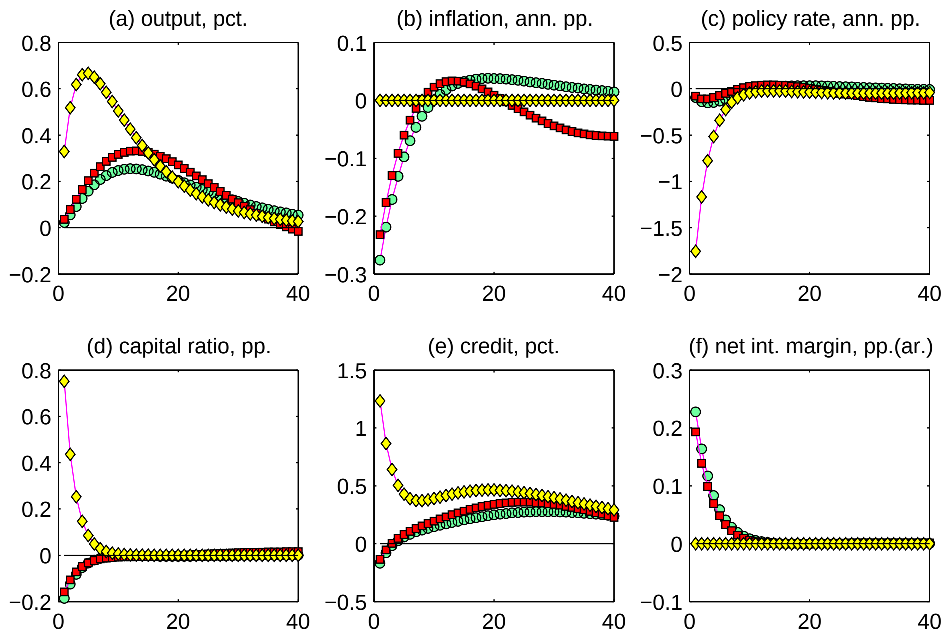


Note: Upper panel: New-Keynesian's calibration. Lower panel: Financial-intermediation calibration. The translucent surface at zero represents welfare under the optimal (Ramsey) rule for the nominal interest rate. The surface below this benchmark reports welfare (as a percent of steady-state consumption) under the nominal interest rate rule which responds to inflation, the change in output, and credit relative to output.

cycle to movements in output and inflation; these movements in output and inflation are undesirable, and a response of monetary policy to credit reduces welfare following a technology shock.

Figure 8 shows that a very small response to credit is also only at best of modest help under the financial intermediation calibration following an increase in the cost of equity capital. In the absence of a response to the nominal interest rate to credit under the simple rule (the black, dashed line), output falls by a touch more than if monetary policy responds to credit (the red-dashed-dottted line); however, the sliht cushioning of the fall in output that arises from responding to credit comes at the cost of larger fluctuations in inflation. In this sense, monetary policy (the nominal interest rate) is not an especially good instrument, under a simple rule approach, to dealing with the credit cycle associated with shocks to intermediation.

Figure 7: Impulse Rsponse Following a Positive Technology Innovation



Note: Yellow diamonds – efficient response; green circles – simple monetary policy with coefficients of 0.5 on inflation and change in output; red squares – simple monetary policy with the same coefficients on inflation and change in output and 0.05 on response to credit (relative to output).

4 Gains (and Pitfalls) from Macroprudential Policy

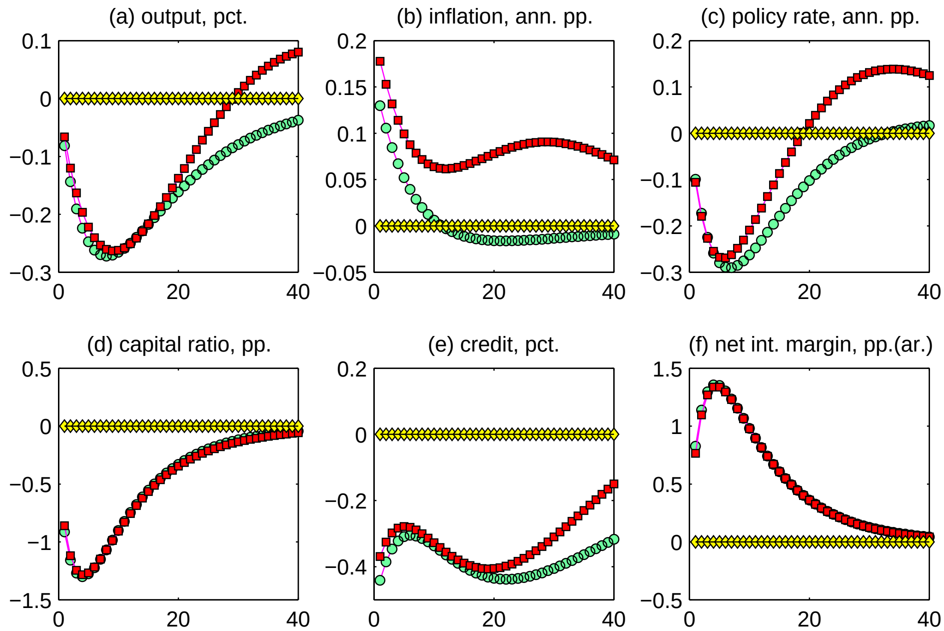
In this section, we introduce macroprudential policy. In particular, we study optimal policies that would be taken by the Ramsey planner if the planner had a macroprudential instrument – specifically, a leverage tax.

4.1 A Macroprudential Policy Framework

Assume the Ramsey planner can adjust a proportional tax on intermediary leverage, denoted by τ_t^m. The tax will affect outcomes by influencing the marginal incentives of intermediaries. We assume that the proceeds of taxation are transferred to the owners of the intermediaries, the representative household.

With the introduction of the leverage tax, the flow of funds constraint of the inter-

Figure 8: Impulse Response Following a Positive Innovation To the Cost of Capital



Note: Yellow diamonds – efficient response; green circles – simple monetary policy with coefficients of 0.5 on inflation and change in output; red squares – simple monetary policy with the same coefficients on inflation and change in output and 0.05 on response to credit (relative to output).

mediaries is modified into

$$0 = [m_t + \tau_t^m(1 - m_t)]Q_t S_t + N_t - D_t + \varphi \min\{0, D_t\}. \tag{26}$$

When an intermediary invests in the risky asset, the accounting marginal cost of investment is given by its capital ratio m_t. However, the economic marginal cost of such investment is $\mathbb{E}_t^\epsilon[\lambda_t]m_t$, which can deviate from the accounting cost m_t because the expected shadow value of one dollar is not always equal to one dollar, particularly when a financial intermediary faces a difficulty in raising external funds. $\mathbb{E}_t^\epsilon[\lambda_t]$ summarizes the liquidity condition of a given intermediary. Inefficient fluctuations in liquidity conditions can then distort the efficient balance of the marginal costs and benefits of investment projects. For instance, during good times, the shadow value of internal funds may be unusually low, prompting over-investment, which then lead to a further improvement in the liquidity condition due to rising asset prices. During bad times, the same mechanism applies, but in the opposite direction.

The idea of the macroprudential leverage tax is to to offset the distortions from such fluctuations in liquidity conditions, thereby breaking the link between the liquidity and investment. With the leverage tax (and subsidy, when negative), the economic cost is modified to

$$\mathbb{E}_t^{\epsilon}[\lambda_t][m_t + \tau_t^m(1 - m_t)] \gtreqless \mathbb{E}_t^{\epsilon}[\lambda_t]m_t \quad \text{if} \quad \tau_t^m \gtreqless 0.$$

The economic cost of investment increases when the tax rate is positive, and decreases when the tax rate is negative (a subsidy). Under this policy, the intermediary's asset pricing equation is modified to

$$1 = \mathbb{E}_t \left[M_{t,t+1}^B \cdot \left(\frac{1 + \tilde{r}_{t+1}^A - (1 - m_t)[1 + (1 - \tau_c) r_{t+1}^B]}{m_t + \tau_t^m (1 - m_t)} \right) \right] \tag{27}$$

One can see easily that the leverage tax policy reduces (increases) the leverage effect on the return on equity from $1/m_t$ to $1/[m_t + \tau_t^m(1 - m_t)]$ when the tax rate is positive (negative).

4.2 Gains from A Macroprudential Instrument Under Optimal Policy

Given the macroprudential instrument, we now consider their possible value when policymakers follow a Ramsey approach. We consider three possible combinations:

- An optimal approach to setting the nominal interest rate without any macroprudential instrument (as above).
- An optimal approach to setting the nominal interest rate and the leverage tax.
- A simple rule approach to monetary policy (with coefficients of 0.5 on inflation and output growth, and no response to credit) combined with the optimal setting of the leverage tax.

We consider these cases for both the New-Keynesian and the financial-intermediation calibration.

Table 2 reports the results for welfare (in consumption units). For both calibrations, the welfare results are relative to those under optimal monetary policy (e.g., the com-

Table 2: Changes (%) in Welfare Under Alternative Optimal (Ramsey) Policies

	New Keynesian Calibration		Financial Shock Calibration	
Instrument	ΔC (λ_0= 0)	ΔC ($\lambda_0 = \lambda_{ss}$)	ΔC ($\lambda_0 = 0$)	ΔC ($\lambda_0 = \lambda_{ss}$)
r_t	1.59	0.26	10.84	9.06
r_t and τ_t^m	3.52	0.29	12.53	8.31
τ_t^m	0.28	0.15	8.32	8.17

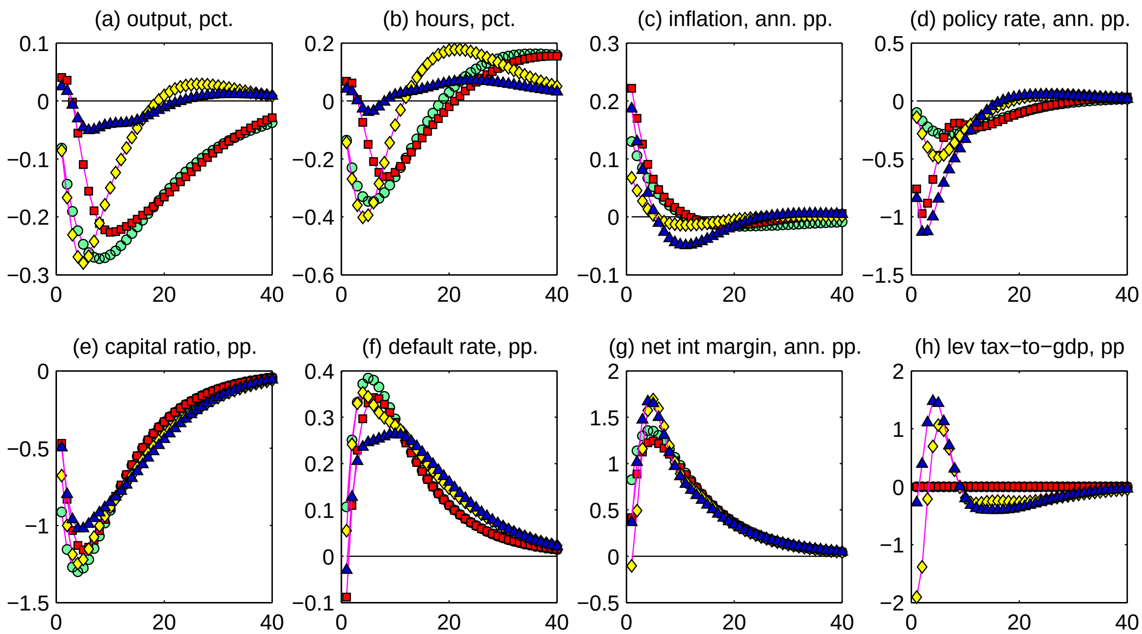
Note: The welfare is measured in terms of consumption equivalent (%) relative to the stochastic steady state of the baseline economies. $\lambda_0 = 0$ is the case with the initial multipliers of the planner problem set equal to zero and $\lambda_0 = \lambda_{ss}$ is the case with the multipliers set equal to their steady state values. When the monetary policy is not optimized by the Ramsey planner, it is assumed that the monetary policy follows the baseline difference Taylor rule. Welfare comparison is under the assumption of no costs associated with instrument volatility.

parison point in figures 5 and 6), and, as a result, the welfare levels for that case are normalized to zero.

One result stand out: The availability of a *macroprudential* instrument set optimally yields welfare levels in the calibration with financial intermediation shocks far above those achieved under a simple monetary policy in the absence of an optimally-determined macroprudential instrument – that is, welfare is close to the level under optimal monetary policy in the presence of an optimal leverage tax and simple monetary policy, whereas figures 5 or 6 reported welfare levels on the order of 9 percent of consumption below the level under an optimal monetary policy when there was no macroprudential instrument and monetary policy was determined by a simple rule.

Table 2 also has another lesson: The availability of a macroprudential policy instrument is not strictly necessary – if monetary policy can be set optimally, an additional macroprudential instrument has little effect on overall welfare. Indeed, the combination of the macroprudnetial instrument and the noominal interest rate in the second row leads to lower welfare evaluated at teh long-run steady state under the financial-shocks calibration, as an important part of the Ramsey stretegy is the exploitation of one-time gains to welfare associated with adoption of a (time-inconsistent) Ramsey policy (as can be seen in the columns referring to the welfare gains setting the Lagrange multipliers associated with the Ramsey problem equal to zero).

Figure 9: Effects of Cost of Capital Shock Under Optimal (Ramsey) Policies



Note: The figure shows the impact of one standard deviation shock to aggregate technology level under (i) baseline (green circles); (ii) Ramsey policy with the monetary instrument (red squares); (iii) Ramsey policy with the leverage tax instrument (yellow diamonds); (iv) Ramsey policy with both monetary and leverage tax instruments (navy triangles). We assume that the Ramsey planner problems are subject to the costs associated with instrument volatility with the quadratic cost coefficent set equal to 2.5. The monetary authority in the baseline economy is assumed to implement monetary policy with the difference Taylor rule with no macroprudential tool.

The welfare results are illuminated by considering the response of the econoomy to an increase in the cost of outside equity capital under alternative policy strategies, as presented in figure 9. Consider the optimal monetary policy (red square) outcomes. Absent macroprudential policy tool, the planner tries to stabilize the economy by cutting the interest rate substantially more than in the baseline. However, as mentioned in the introduction, such a policy distorts the dynamic consumption profile of unconstrained agents, which then shows up as much stronger inflation pressure as shown in panel [c]. As a result, the planner cannot take a more aggressive policy stance in addressing the effects of the financial disturbance. It is notable that the cost of capital shock induces output and inflation to move in the opposite direction, creating a challenge for complete stabilization via monetary policy .[21]

[21]See Gilchrist, Schoenle, Sim, and Zakrajsek (2013) for more in-depth discussion on this issue.

Next consider the optimal macroprudential policy. The planner subsidizes the investment of financial intermediaries, on the order of 2 percent of output, and such enhanced liquidity props up aggregate demand. The liquidity injection works as a circuit-breaker of the vicious cycle between illiquidity and deleveraging, substantially reducing the duration of the recession as shown in panel [a] and [b]. In panel [c], we observe that such a policy brings a substantially lower inflation rate as a by-product. This is because the macroprudential policy induces the Taylor rule to respond to the shock less aggressively by stabilizing the output growth. This also implies that *on the condition that the macroprudential policy is implemented optimally*, there is a much larger loom for monetary accommodation. Panel [d] shows that the optimal macroprudential policy allows the planner to take much more aggressive policy stance, resulting in a substantial marginal gain for the stabilization of output and hours.

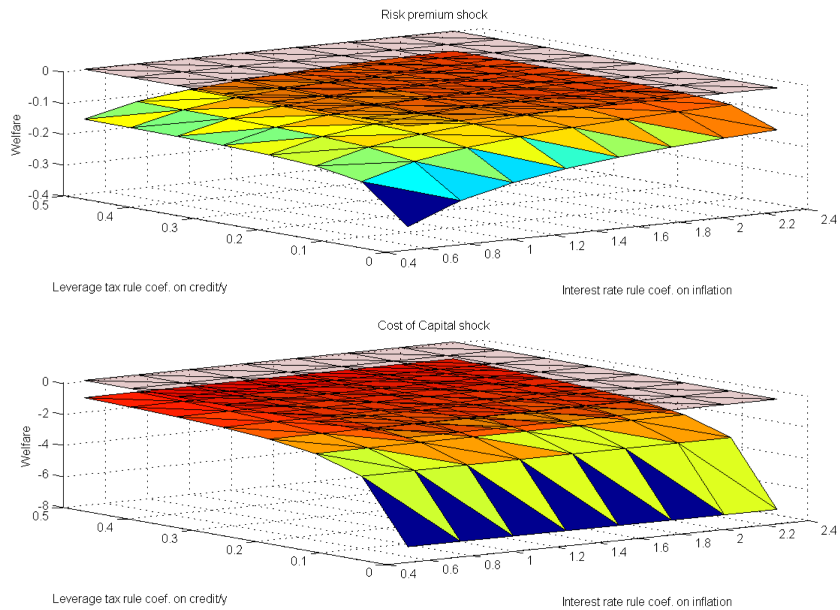
In the case in which monetary policy is the only available instrument (the blue line), the nominal interest rate is cut when the financial sector is hit by an increase in risk – a response which cushions the decline in output at the cost of higher inflation. The leverage tax lowers the need to rely on the nominal interest rate – thereby more effectively cushioning the decline in output and limiting any increase in inflation. Note that an important reason why monetary policy is insufficient in this case is that the shock to intermediation depresses lending disproportionately – that is, acts like an investment-specific shock – and a vigorous monetary policy response acts on both consumption and investment, rather than focusing specifically on credit sector developments as with the leverage tax.

4.3 Gains from Macroprudential Policy Under Simple Rules

The focus on optimal policies in the previous subsection highlights what is possible – but such policies involve complex adjustments in the policy instruments, implying that a consideration of simple rule-based approaches is valuable.

We highlighted previously how a simple-rule-based approach to monetary policy can result in welfare gains if monetary policy responds moderately to movements in credit relative to output, as moderate responses of this type limit the adverse consequences of financial volatility shocks without impeding the economy's adjustment to technology shocks. We now consider a simple rule for the leverage tax. We propose a rule in which

Figure 10: Welfare Under A Simple Rule for the Leverage Tax

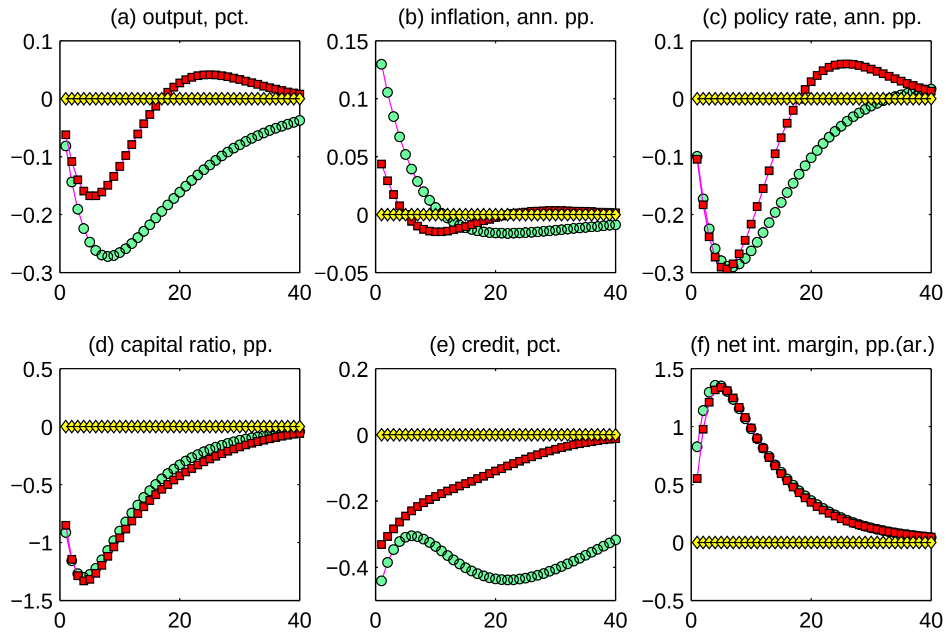


Note: Upper panel: New-Keynesian calibration. Lower panel: Financial-intermediation calibration. The translucent surface at zero represents welfare under the optimal (Ramsey) rule for the nominal interest rate. The surface below this benchmark reports welfare (as a percent of steady-state consumption) under the nominal interest rate rule which responds to inflation and the change in output and the leverage tax rule which responds to credit (relative to output).

the instrument is a function of the ratio of credit to output, the indicator we considered in our analysis of monetary policy and proposed for adjusting the counter-cyclical capital buffer in Basel Committee on Banking Supervision (2010).

Figure 10 presents welfare results for the leverage tax, relative to the level achieved under the optimal monetary policy (the translucent surface, normalized to zero). Welfare is reported in consumption units along the z-axis; the x-axis reports the inflation coefficient in the monetary policy rule (while the coefficient on output growth is held fixed at 0.5), and the y-axis reports the sensitivity of the leverage tax to the ratio of credit to output. As shown in the upper panel, the leverage tax, if adjusted only moderately in response to credit movements, does not have large adverse effects under the New-Keynesian calibration (but large responses lead to a notable deterioration in welfare); in contrast, welfare increases sharply with the sensitivity of the leverage tax, at least over some range, under the financial-intermediation calibration.

Figure 11: Impulse Response To Cost of Capital Shock Under Simple Rule Policies



Note: Yellow diamonds – efficient response; green circles – no leverage tax; red squares – simple rule for leverage tax.

As highlighted in figure 10, a macroprudential instrument is not especially valuable under the New-Keynesian calibration – this view of shocks is one in which monetary policy is the only necessary instrument. However, the situation changes when financial intermediation shocks are important: In this case, the level of welfare under a simple rule approach to monetary policy is much lower in the absence of a macroprudential instrument than in the presence of a macroprudential instrument.

To see the importance of the macroprudential instrument more clearly, figure 11 present impulse responses following an increase in the cost of outside equity for two cases: A simple rule for monetary policy (with no response to credit) and the same monetary policy with the simple rule for the leverage tax (with the sensitivity to credit (relative to output) set to 0.25). (The efficient (Modiliani-Miller) response is also shown – these responses are zero). In the absence of the leverage tax (the green circles), output falls notably and inflation rises (reflecting the pressures on marginal cost associated with depressed investment relative to consumption); the simple rule for the leverage tax (the red squares) mitigate these adverse consequences.

5 Conclusion

We have investigated the gains are from adopting optimal macroprudential regulation in a model with frictions associated with financial intermediation. We have specifically focused on a case reminiscent of the New-Keynesian literature – emphasizing technology, markup, and nominal demand shocks – with a case in which shocks to the intermediation sector are also important.

We have shown that an additional macroprudential instrument has limited value when monetary policy is set optimally (in the sense of Ramsey), but that a macroprudential instrument is of value when monetary policy must be set according to a simpler, rules-based approach. A simple rule for a leverage tax can deliver much of the gain associated with optimal monetary policy (or an optimal, Ramsey approach to the leverage tax). Moreover, deployment of a leverage tax has at most only modest adverse consequences following New-Keynesian shocks, suggesting that such a policy instrument may be welfare enhancing on average.

Finally, we explored how monetary policy should behave in the absence of a macroprudential instrument. A Ramsey planner would act to offset much of the adverse effects associated with shocks to intermediation via adjustments in the nominal interest rate – achieving much of the welfare gains that could be associated with a macroprudential instrument. In this sense, a macroprudential instrument is not strictly necessary for good economic performance. That said, such gains cannot be achieved via a simple rule for monetary policy: While a simple rule for the nominal interest rate shows a small welfare gain from responding to credit (in addition to output and inflation), this gain falls far short of that associated with a leverage tax when shocks to intermediation are important. As a result, it may be optimal for monetary policy to consider conditions in the financial sector when setting monetary policy, as suggested by Woodford (2012), but deployment of a well-designed macroprudential instrument may be much better, as suggested by Svensson (2012).

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Appendices

Without the Pigovian tax, the flow of funds constraint for an intermediary is given by

$$Q_tS_t = (1 - m_t)Q_tS_t + N_t - D_t + \varphi \min\{0, D_t\}, \tag{.28}$$

where the net-worth of the intermediary is now defined as

$$N_t = \epsilon_t(1 + r_t^A)Q_{t-1}S_{t-1} - [1 + (1 - \tau_c)r_t^B](1 - m_{t-1})Q_{t-1}S_{t-1}. \tag{.29}$$

Using the limited liability condition, one can write the net-worth as

$$N_t = \max\{0, \epsilon_t(1 + r_t^A)Q_{t-1}S_{t-1} - [1 + (1 - \tau_c)r_t^B](1 - m_{t-1})Q_{t-1}S_{t-1}\}. \tag{.30}$$

A Intermediary Debt Contract

A default is assumed to occur when the value of net-worth falls below zero. This means tha a default occurs when

$$\epsilon_{t+1} \leq \epsilon_{t+1}^D \equiv (1 - m_t)\left[\frac{1 + (1 - \tau_c)r_{t+1}^B}{1 + r_{t+1}^A}\right] \tag{A.1}$$

Using the definition of the modified default threshold, the expression for the net-worth can be simplified into

$$\begin{aligned} N_t &= \max\{0, \epsilon_t(1 + r_t^A) - \epsilon_t^D(1 + r_t^A)\}Q_{t-1}S_{t-1} \\ &= \max\{0, \epsilon_t - \epsilon_t^D\}(1 + r_t^A)Q_{t-1}S_{t-1} \\ &= [\max\{\epsilon_t, \epsilon_t^D\} - \epsilon_t^D](1 + r_t^A)Q_{t-1}S_{t-1}, \end{aligned}$$

which is the same as the one for the case without the reserve requirement policy.

The intermediary debt pricing equation is then modified into

$$1 - m_t = \mathbb{E}_t\left\{M_{t,t+1}\left[\int_{\epsilon_{t+1}^D}^{\infty}(1 - m_t)\frac{1 + r_{t+1}^B}{1 + \pi_{t+1}}dF_{t+1} + (1 - \eta)\int_0^{\epsilon_{t+1}^D}\frac{\epsilon_{t+1}(1 + r_{t+1}^A)}{1 + \pi_{t+1}}dF_{t+1}\right]\right\} \tag{A.2}$$

Solving (A.1) for r_{t+1}^B yields $r_{t+1}^B = (1-\tau_c)^{-1}[\epsilon_{t+1}^D(1+r_{t+1}^A)/(1-m_t)-1]$. Finally, substituting the expression for r_{t+1}^B in (A.2) yields

$$\begin{aligned} 0 = \mathbb{E}_t &\left\{M_{t,t+1}\left[\int_0^{\epsilon_{t+1}^D}(1 - \eta)\epsilon_{t+1}dF_{t+1} + \int_{\epsilon_{t+1}^D}^{\infty}\frac{\epsilon_{t+1}^D}{1 - \tau_c}dF_{t+1}\right](1 + r_{t+1}^A)\right\} \\ &- (1 - m_t)\left\{1 + \mathbb{E}_t\left[M_{t,t+1}\left(\frac{\tau_c}{1 - \tau_c}[1 - F_{t+1}(\epsilon_{t+1}^D)]\right)\right]\right\}. \end{aligned} \tag{A.3}$$

B Intermediary Value Maximization Problem

It is useful to formulate the problem as a set of saddle point problems as follows. The intermediary solves

$$
\begin{aligned}
J_t = \min_{\theta_t} \max_{Q_tS_t, m_t, \epsilon^D_{t+1}} \Bigg\{ & \mathbb{E}^{\epsilon}_t[D_t] + \mathbb{E}_t[M_{t,t+1} \cdot \mathbb{E}^{\epsilon}_{t+1}[V_{t+1}(N_{t+1})]] \\
& + \mathbb{E}^{\epsilon}_t \left[\lambda_t \left(N_t - D_t + \varphi \min\{0, D_t\} - m_t Q_t S_t \right) \right] \\
& + \theta_t Q_t S \mathbb{E}_t \left[M_{t,t+1} \left((1-\eta)\Phi(s^D_{t+1} - \sigma_{t+1}) + \frac{\epsilon^D_{t+1}}{1-\tau_c}[1 - \Phi(s^D_{t+1})] \right) (1 + r^A_{t+1}) \right. \\
& \left. - \ (1 - m_t) \left(1 + \frac{\tau_c}{1-\tau_c} \mathbb{E}_t \left[M_{t,t+1}[1 - F_{t+1}(\epsilon^D_{t+1})] \right] \right) \right] \Bigg\}
\end{aligned} \tag{B.1}
$$

before the realization of the idiosyncratic shock, and

$$
V_t(N_t) = \min_{\lambda_t} \max_{D_t} \left\{ D_t + \mathbb{E}_t[M_{t,t+1} \cdot J_{t+1}] + \lambda_t \left[N_t - D_t + \varphi \min\{0, D_t\} - m_t Q_t S_t \right] \right\} \tag{B.2}
$$

after the realization of the idiosyncratic shock, where $s^D_{t+1} \equiv \sigma^{-1}_{t+1}[\log \epsilon^D_{t+1} + 0.5\sigma^2_{t+1}]$, a standardization of the default threshold.

B.1 Efficiency Conditions of the Intermediary Problem

The efficiency conditions of the problem are given by

$$
Q_tS_t: \quad 0 = -m_t \mathbb{E}^{\epsilon}_t[\lambda_t] + \mathbb{E}_t \left\{ M_{t,t+1} \cdot \mathbb{E}^{\epsilon}_{t+1} \left[V'_{t+1}(N_{t+1}) \frac{\partial N_{t+1}}{\partial Q_t S_t} \right] \right\} \tag{B.3}
$$

$$
m_t: \quad 0 = -\mathbb{E}^{\epsilon}_t[\lambda_t] + \theta_t \left\{ 1 - \mathbb{E}_t \left[M_{t,t+1} \left((1-\eta) r^m_t \Phi(s^D_{t+1}) - \frac{\tau_c - r^m_t}{1-\tau_c}[1 - \Phi(s^D_{t+1})] \right) \right] \right\} \tag{B.4}
$$

$$
\begin{aligned}
\epsilon^D_{t+1}: \quad 0 = \ & \mathbb{E}_t \left\{ M_{t,t+1} \cdot \mathbb{E}^{\epsilon}_{t+1} \left[V'_{t+1}(N_{t+1}) \frac{\partial N_{t+1}}{\partial \epsilon^D_{t+1}} \right] \right\} \frac{1}{Q_t S_t} \\
& + \theta_t \mathbb{E}_t \left\{ M_{t,t+1} \left[(1-\eta) \frac{\phi(s^D_{t+1} - \sigma_{t+1})}{\sigma_{t+1}\epsilon^D_{t+1}} + \frac{1}{1-\tau_c} \left(1 - \Phi(s^D_{t+1}) - \frac{\phi(s^D_{t+1})}{\sigma_{t+1}} \right) \right] (1 + r^A_{t+1}) \right\} \\
& + \theta_t (1 - m_t) \mathbb{E}_t \left\{ M_{t,t+1} \frac{\phi(s^D_{t+1})}{\sigma_{t+1}\epsilon^D_{t+1}} \frac{\tau_c}{1-\tau_c} \right\}
\end{aligned} \tag{B.5}
$$

$$
D_t: \quad \lambda_t = \begin{cases} 1 & \text{if } D_t \geq 0 \\ 1/(1-\varphi) & \text{if } D_t < 0 \end{cases} \tag{B.6}
$$

B.1.1 FOC for Investment (Q_tS_t)

Using (B.6), we obtain $\mathbb{E}_t^\epsilon[\lambda_t] = \Pr(D_t \geq 0)\mathbb{E}_t^\epsilon[\lambda_t|D_t \geq 0] + \Pr(D_t < 0)\mathbb{E}_t^\epsilon[\lambda_t|D_t < 0]$. Hence,

$$\mathbb{E}_t^\epsilon[\lambda_t] = [1 - \Phi(s_{t+1}^E)] + \frac{\Phi(s_{t+1}^E)}{1-\varphi} = 1 + \mu\Phi(s_{t+1}^E) \tag{B.7}$$

where $\mu \equiv \varphi/(1-\varphi)$, $s_{t+1}^E \equiv \sigma_{t+1}^{-1}[\log \epsilon_{t+1}^E + 0.5\sigma_{t+1}^2]$ and ϵ_{t+1}^E is the equity issuance threshold (see the main text for the definition).

Using Benveniste-Scheinkman formula, we have $V'(N_t) = \lambda_t$. Hence

$$\mathbb{E}_{t+1}^\epsilon\left[V_{t+1}'(N_{t+1})\frac{\partial N_{t+1}}{\partial Q_tS_t}\right] = \mathbb{E}_{t+1}^\epsilon[\lambda_{t+1}(\max\{\epsilon_{t+1}, \epsilon_{t+1}^D\} - \epsilon_{t+1}^D)(1 + r_{t+1}^A)]$$

Using this and dividing the FOC for investment through by $m_t\mathbb{E}_t^\epsilon[\lambda_t]$, one can rewrite the FOC as

$$1 = \mathbb{E}_t\left[M_{t,t+1}\frac{\mathbb{E}_{t+1}^\epsilon[\lambda_{t+1}]}{\mathbb{E}_t^\epsilon[\lambda_t]}\frac{1}{m_t}\left[1 + \tilde{r}_{t+1}^A - (1-m_t)(1 + (1-\tau_c)r_{t+1}^B)\right]\right] \tag{B.8}$$

where we use $\epsilon_{t+1}^D(1 + r_{t+1}^A) = (1 - m_t)[1 + (1 - \tau_c)r_{t+1}^B]$ and the modified asset return $1 + \tilde{r}_{t+1}^A$ is defined as

$$\begin{aligned} 1 + \tilde{r}_{t+1}^A &\equiv \frac{\mathbb{E}_{t+1}^\epsilon[\lambda_{t+1}\max\{\epsilon_{t+1}, \epsilon_{t+1}^D\}]}{\mathbb{E}_{t+1}^\epsilon[\lambda_{t+1}]}(1 + r_{t+1}^A) \\ &= \left\{\frac{\mathbb{E}_{t+1}^\epsilon[\lambda_{t+1}\epsilon_{t+1}]}{\mathbb{E}_{t+1}^\epsilon[\lambda_{t+1}]} + \frac{\mathbb{E}_{t+1}^\epsilon[\lambda_{t+1}\max\{0, \epsilon_{t+1}^D - \epsilon_{t+1}\}]}{\mathbb{E}_{t+1}^\epsilon[\lambda_{t+1}]}\right\}(1 + r_{t+1}^A) \end{aligned}$$

The first term inside the curly bracket can be evaluated as

$$\begin{aligned} E_{t+1}^\epsilon[\lambda_{t+1}\epsilon_{t+1}] &= \int_0^{\epsilon_{t+1}^E} \frac{\epsilon_{t+1}}{1-\varphi}dF_{t+1} + \int_{\epsilon_{t+1}^E}^\infty \epsilon_{t+1}dF_{t+1} \\ &= \frac{1}{1-\varphi}\Phi(s_{t+1}^E - \sigma_{t+1}) + 1 - \Phi(s_{t+1}^E - \sigma_{t+1}) = 1 + \mu\Phi(s_{t+1}^E - \sigma_{t+1}). \end{aligned}$$

Similarly, we can derive the analytical expression for the second term as

$$\begin{aligned} \mathbb{E}_{t+1}^\epsilon[\lambda_{t+1}\max\{0, \epsilon_{t+1}^D - \epsilon_{t+1}\}] &= \int_0^{\epsilon_{t+1}^D} \frac{\epsilon_{t+1}^D - \epsilon_{t+1}}{1-\varphi}dF_{t+1} \\ &= \frac{1}{1-\varphi}[\epsilon_{t+1}^D\Phi(s_{t+1}^D) - \Phi(s_{t+1}^D - \sigma_t)] \end{aligned}$$

where we use the fact that $\lambda_{t+1} = 1/(1-\varphi)$ when $\epsilon_{t+1} \leq \epsilon_{t+1}^D < \epsilon_{t+1}^E$. Combining the two expressions yields

$$1 + \tilde{r}_{t+1}^A \equiv \left[\frac{1 + \mu\Phi(s_{t+1}^E - \sigma_{t+1})}{1 + \mu\Phi(s_{t+1}^E)} + \frac{\epsilon_{t+1}^D\Phi(s_{t+1}^D) - \Phi(s_{t+1}^D - \sigma_t)}{(1-\varphi)[1 + \mu\Phi(s_{t+1}^E)]}\right](1 + r_{t+1}^A) \tag{B.9}$$

B.1.2 FOC for default threshold (ϵ_{t+1}^D)

To transform the FOC for ϵ_{t+1}^Dinto a form that is more convenient for computation, we need to evaluate the following differentiation

$$\begin{aligned}
&\mathbb{E}_t\left[M_{t,t+1}\cdot\frac{\partial N_{t+1}}{\partial\epsilon_{t+1}^D}V'_{t+1}(N_{t+1})\right]\frac{1}{Q_tS_t}\\
&=\mathbb{E}_t\left[M_{t,t+1}\frac{\partial\max\{\epsilon_{t+1},\epsilon_{t+1}^D\}-\epsilon_{t+1}^D}{\partial\epsilon_{t+1}^D}(1+r_{t+1}^A)V'_{t+1}(N_{t+1})\right]\\
&=\mathbb{E}_t\left\{M_{t,t+1}\mathbb{E}_{t+1}^{\epsilon}\left[\lambda_{t+1}\left(\frac{\partial\max\{\epsilon_{t+1},\epsilon_{t+1}^D\}}{\partial\epsilon_{t+1}^D}-1\right)\right](1+r_{t+1}^A)\right\}
\end{aligned}$$

where we used the envelope condition $V'_{t+1}(N_{t+1})=\lambda_{t+1}$and the law of iterated expectation in the third line. To that end, first, we think of $\max\{\epsilon_{t+1},\epsilon_{t+1}^D\}$as a function of a 'variable' $\epsilon_{t+1}^D$for a given 'parameter' $\epsilon_{t+1}$and take a differentiation of $\max\{\epsilon_{t+1},\epsilon_{t+1}^D\}$with respect to ϵ_{t+1}^Das follows

$$\frac{\partial\max\{\epsilon_{t+1},\epsilon_{t+1}^D\}}{\partial\epsilon_{t+1}^D}=\begin{cases}0 & \text{if } \epsilon_{t+1}^D\le\epsilon_{t+1}\\ 1 & \text{if } \epsilon_{t+1}^D>\epsilon_{t+1}\end{cases}.$$

Second, we now think of the above as a function a 'variable' $\epsilon_{t+1}$for a given 'parameter' ϵ_{t+1}^Dsince we now need to integrate this expression over the support of ϵ_{t+1}. Reminding that the shadow value is equal to $1/(1-\varphi)$when $\epsilon_{t+1}\le\epsilon_{t+1}^D<\epsilon_{t+1}^E$, one can see immediately that

$$\mathbb{E}_{t+1}^{\epsilon}\left[\lambda_{t+1}\frac{\partial\max\{\epsilon_{t+1},\epsilon_{t+1}^D\}}{\partial\epsilon_{t+1}^D}\right]=\int_0^{\epsilon_{t+1}^D}1\cdot\frac{dF_{t+1}}{1-\varphi}=\frac{\Phi(s_{t+1}^D)}{1-\varphi}.$$

Combining this expression with the FOC (B.5) yields

$$\begin{aligned}
0=&\,\mathbb{E}_t\left\{M_{t,t+1}\left[\frac{\Phi(s_{t+1}^D)}{1-\varphi}-[1+\mu\Phi(s_{t+1}^E)]\right](1+r_{t+1}^A)\right\}\\
&+\theta_t\mathbb{E}_t\left\{M_{t,t+1}\left[(1-\eta)\frac{\phi(s_{t+1}^D-\sigma_{t+1})}{\sigma_{t+1}\epsilon_{t+1}^D}+\frac{1}{1-\tau_c}\left(1-\Phi(s_{t+1}^D)-\frac{\phi(s_{t+1}^D)}{\sigma_{t+1}}\right)\right](1+r_{t+1}^A)\right\}\\
&+\theta\,(1-m_t)\,\mathbb{E}_t\left\{M_{t,t+1}\frac{\phi(s_{t+1}^D)}{\sigma_{t+1}\epsilon_{t+1}^D}\frac{\tau_c}{1-\tau_c}\right\}
\end{aligned}\tag{B.10}$$

C The Case with the Pigovian Tax

When the Pigovian tax is introduced, the flow of funds constraint facing the intermediaries becomes

$$0=-[m_t+\tau_t^m(1-m_t)]Q_tS_t+T_t+N_t-D_t+\varphi\min\{0,D_t\}\tag{C.1}$$

where T_t is the lump sum transfer of the proceeds from the leverage taxation. In equilibrium $\tau_t^m(1-m_t)Q_tS_t = T_t$, though T_t is taken as given by the intermediaries. The default threshold is now given by

$$\epsilon_{t+1} \leq \epsilon_{t+1}^D \equiv (1-m_t)\left[\frac{1+(1-\tau_c)r_{t+1}^B}{1+r_{t+1}^A}\right] \tag{C.2}$$

and the participation constraint of the intermediary is modified into

$$\begin{aligned}0 = \mathbb{E}_t &\left\{M_{t,t+1}\left[\int_0^{\epsilon_{t+1}^D}(1-\eta)\epsilon_{t+1}dF_{t+1} + \int_{\epsilon_{t+1}^D}^{\infty}\frac{\epsilon_{t+1}^D}{1-\tau_c}dF_{t+1}\right](1+r_{t+1}^A)\right\} \\ &- (1-m_t)\left\{1+\frac{\tau_c}{1-\tau_c}\mathbb{E}_t\left[M_{t,t+1}[1-F_{t+1}(\epsilon_{t+1}^D)]\right]\right\}.\end{aligned} \tag{C.3}$$

Following the same steps, one can derive the following efficiency conditions:

$$Q_tS_t: \quad 1 = \mathbb{E}_t\left[M_{t,t+1}\frac{\mathbb{E}_{t+1}^{\epsilon}[\lambda_{t+1}]}{\mathbb{E}_t^{\epsilon}[\lambda_t]}\frac{1}{m_t+\tau_t^m(1-m_t)}\left[1+\tilde{r}_{t+1}^A-(1-m_t)[1+(1-\tau_c)r_{t+1}^B]\right]\right] \tag{C.4}$$

$$m_t: \quad 0 = -(1-\tau_t^m)\mathbb{E}_t^{\epsilon}[\lambda_t] + \theta_t\left\{1+\frac{\tau_c}{1-\tau_c}\mathbb{E}_t\left[M_{t,t+1}[1-\Phi(s_{t+1}^D)]\right]\right\} \tag{C.5}$$

$$\begin{aligned}\epsilon_{t+1}^D: \quad 0 = \mathbb{E}_t &\left\{M_{t,t+1}\left[\frac{\Phi(s_{t+1}^D)}{1-\varphi} - [1+\mu\Phi(s_{t+1}^E)]\right](1+r_{t+1}^A)\right\} \\ &+ \theta_t\mathbb{E}_t\left\{M_{t,t+1}\left[(1-\eta)\frac{\phi(s_{t+1}^D-\sigma_{t+1})}{\sigma_{t+1}\epsilon_{t+1}^D} + \frac{1}{1-\tau_c}\left(1-\Phi(s_{t+1}^D)-\frac{\phi(s_{t+1}^D)}{\sigma_{t+1}}\right)\right](1+r_{t+1}^A)\right\} \\ &+ \theta_t\,(1-m_t)\,\mathbb{E}_t\left\{M_{t,t+1}\frac{\tau_c}{1-\tau_c}\frac{\phi(s_{t+1}^D)}{\sigma_{t+1}\epsilon_{t+1}^D}\right\}\end{aligned} \tag{C.6}$$

D Household's Optimization Conditions

We denote the total outstanding of intermediary debts by B_t. In equilibrium, $B_t = \int[1-m_{t-1}(i)]\ Q_{t-1}S_t(i)di = (1-m_{t-1})Q_{t-1}K_t$, where $i \in [0,1]$is an index for intermediary. The last equality is due to the symmetric equilibrium and the no-arbitrage condition mentioned in the main text. The realized aggregate return on intermediary debts, denoted by $1+\tilde{r}_t^B$, is given by

$$1+\tilde{r}_t^B \equiv \left[\int_0^{\epsilon_t^D}(1-\eta)\epsilon_t dF_t + \int_{\epsilon_t^D}^{\infty}(1-m_t)(1+r_t^B)dF_t\right]\frac{1+r_t^A}{1-m_{t-1}}.$$

Using $1+\tilde{r}_t^B$, we can express the household's budget constraint as

$$0 = W_tH_t + (1+\tilde{r}_t^B)B_t - B_{t+1} - P_tC_t - \int_0^1 P_t^S(i)S_{t+1}^F(i)di + \int_0^1[\max\{D_t(i),0\}+P_{t-1,t}^S(i)]S_t^F(i)di$$

where $W_t$is a nominal wage rate, $H_t$is labor hours, and $S_t^F(i)$is the number of shares outstanding at time t. $P_{t-1,t}^S(i)$is the time $t$value of shares outstanding at time $t-1$. $P_t^S(i)$is the ex-dividend value of equity at time t. The two values are related by the following accounting identity, $P_t^S(i) = P_{t-1,t}^S(i) + X_t(i)$where $X_t(i)$is the value of new shares issued at time t. The costly equity finance assumption adopted for the financial intermediary implies that $X_t(i) = -(1-\varphi)\min\{D_t(i), 0\}$. Using the last two expressions, one can see that the budget constraint is equivalent to

$$0 = W_t H_t + (1 + \tilde{r}_t^B) B_t - B_{t+1} - P_t C_t - \int_0^1 P_t^S(i) S_{t+1}^F(i) di$$
$$+ \int_0^1 [\max\{D_t(i), 0\} + (1-\varphi)\min\{D_t(i), 0\} + P_t^S(i)] S_t^F(i) di.$$

The household's FOCs for asset holdings are summarized by two conditions,

- FOC for $B_{t+1} : 1 = \mathbb{E}_t \left[M_{t,t+1}(1 + \tilde{r}_{t+1}^B) \right]$
- FOC for $S_{t+1}^F(i) : 1 = \mathbb{E}_t \left[M_{t,t+1} \frac{\mathbb{E}_{t+1}^{\epsilon}[\max\{D_{t+1}, 0\}] + (1-\varphi)\mathbb{E}_{t+1}^{\epsilon}[\min\{D_{t+1}, 0\}] + P_{t+1}^S}{P_t^S} \right]$.

where $E_{t+1}^{\epsilon}[\max\{D_{t+1}, 0\}] = \int_0^1 \max\{D_t(i), 0\} di$ and $E_{t+1}^{\epsilon}[\min\{D_{t+1}, 0\}] = \int_0^1 \min\{D_t(i), 0\} di$.