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Interactions and Coordination between Monetary and Macroprudential Policies†

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I study monetary and macroprudential policy intervention in a general equilibrium economy with recurrent boom-bust cycles. Recurrence causes forward-looking variables to also react to policy intervention during phases in which the intervention is inactive. Macroprudential policies that contain systemic risk in financial markets during booms, therefore, relax market-based funding constraints during busts, which helps mitigate the severity and shorten the duration of economic meltdowns. Contractionary monetary interventions during booms also have (latent) beneficial effects during busts. Coordination between the two policy instruments improves social welfare over standard, noncoordinated policy interventions, but improvement is moderate. (*JEL* E32, E44, E52, E61)

The recent financial crisis has fostered the development of macroprudential policy interventions aimed at curbing excessive risk-taking in financial markets during upturns. A key ongoing policy debate is whether those prudential regulatory developments suffice or if other state-contingent policy instruments—notably monetary policy—are needed to safeguard the stability of the financial system.

This paper addresses this debate, taking into particular consideration the inherent recurrent nature of financial cycles. What are the effects of additional capital requirements set during a boom on the likelihood and magnitude of a bust? And once in a bust, what are their latent effects, if any, on the pace of recovery from and expected duration of the ensuing meltdown? What are the corresponding effects of interest rate policies that also respond to concerns about financial stability—apart from those about instability in inflation—during either booms, busts, or both? How do the interactions between these two policies ultimately shape the frequency, intensity, and duration of boom-bust cycles?

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To address these questions, I develop a continuous-time stochastic general equilibrium model with recurrent boom-bust cycles in the spirit of Brunnermeier and Sannikov (2014). Recurrence causes forward-looking variables, such as asset prices, intermediary franchise value, and Tobin's Q, to also react to policy intervention during phases in which the intervention is inactive. Even policies that intervene only in a narrow set of phases, therefore, may have significant effects on the frequency of and economic conditions during other phases and on the overall behavior of cycles. This is the distinctive force the model captures concerning the effects of monetary and macroprudential policy intervention on financial cycles. This force will play a central role in the answer to the above questions.

The model economy has financial intermediaries that channel funds from households to firms. In an ideal world without funding frictions, financial intermediaries provide financing to all of the firms, and production is efficient. However, the actual world is far from ideal: first, because financial intermediaries must invest net worth in their financing operations in order to not have incentives to divert funds (i.e., they face the same incentive-compatible leverage constraint as in Gertler and Kiyotaki 2010 and Gertler and Karadi 2011), and second, because financial intermediaries must concentrate risk in their balance sheets when they take on leverage to finance firms (since they can raise funds through noncontingent debt claims alone but financing to firms is risky).

These two funding frictions combined render the wealth share of financial intermediaries the key state that determines the phase of the cycle. Also, the frictions cause the cycle to oscillate from booms to busts continuously throughout. In this cycle, production is efficient, and changes in financial conditions do not affect economic activity, when the intermediary wealth share is sufficiently high. (Indeed, in these "boom" phases, the incentive-compatible leverage constraint is slack.) In contrast, production is inefficient and deteriorations in financial conditions depress economic activity—and the other way around—when the wealth share is instead sufficiently low. In these "bust" phases, moreover, financial intermediaries must sell assets (i.e., loans to firms) following unexpectedly poor returns on their financing operations. The asset sales dislocate asset prices, in effect, because in equilibrium, households must be willing to buy the assets—but they are willing to do so only at a discount, as a consequence of their relatively poor skills in monitoring firms. A two-way feedback loop between asset price drops and intermediaries' net worth losses, therefore, arises—which, in general, creates excessive instability in financial markets and economic activity over what is socially desirable.

Equipped with this model, I conduct the policy intervention analysis, and to ease exposition, I proceed progressively in three steps. First, I abstract away from monetary considerations to isolate the effect of macroprudential policy intervention. I restrict attention to a (common) limit on leverage that is the same for all of the financial intermediaries and can be set to be contingent on the aggregate state.

I obtain a policy-based leverage limit that is binding either when the intermediary wealth share is sufficiently high or when low is not socially convenient. Rather, it is socially optimal to make the limit binding only when the wealth share attains intermediate values. In those in-between phases, financial intermediaries as a whole are sufficiently well capitalized to have significant price effects—and also to provide financing to a sizable share of firms—but they are not well capitalized enough to tolerate adverse disturbances without liquidating assets. The social benefits from mitigating the feedback loop thus outweigh the social costs of curtailing financing to firms on impact. Relative to laissez-faire, the socially optimal policy reduces the frequency of busts, and conditional on the economy being in a bust, it mitigates the severity as well as shortens the duration of the economic meltdown. This (latent) effect during busts arises, because improvements in the stability of the financial system boost intermediary franchise value throughout the boom-bust cycle, which also relaxes incentive-compatible leverage limits during busts, when those limits instead are binding. All in all, the socially optimal policy helps keep boom-bust cycles more stable around better-capitalized phases closer to booms.

In the second step, I incorporate monetary considerations into the analysis but abstract away from macroprudential policy intervention. I restrict attention to interest rate policies that determine the nominal interest rate. These policies also affect real variables such as real interest rates, consumption, employment, and production, because firms adjust their nominal price sluggishly—as in the baseline New Keynesian framework with Calvo (1983) pricing—which generates sluggishness in the inflation rate.

I obtain that relative to a neutral monetary policy that keeps inflation stable at its structural rate, interest rate policies that stimulate the economy during busts and slow it down during booms improve the stability of the financial system and boom-bust cycles. Paradoxically, interest rate policies that stimulate the economy permanently do not affect financial intermediation, financial stability, or the cycles. This is because asset prices respond one-to-one to permanent changes in asset returns, which leaves the rate of return on assets and intermediary profitability unchanged. Because monetary policy can then stimulate intermediary profitability only temporarily, expansionary monetary interventions are most beneficial during busts, when financial intermediaries as a whole are severely undercapitalized and financing to firms is severely impaired. Contractionary monetary interventions during booms (alone) are also beneficial, but their role instead is to strengthen the temporary component of the stimulating forces exerted during busts. In the absence of macroprudential policy intervention, therefore, an active monetary policy that is also concerned with financial stability—apart from stability in inflation—mops up after the financial crash and, in addition, leans against credit imbalances in the buildup. The active monetary policy improves social welfare over the neutral one, provided that departures from inflation stabilization remain contained.

Lastly, I incorporate both instruments into the policy intervention analysis. Social optimality requires that the instruments behave in a manner similar to what is required in the previous cases in which only one of them is available. An important difference in behaviors, however, is that the instruments are required to respond less to concerns about the stability of the financial system (or boom-bust cycles) relative to what they are required to do in those cases. This implies that monetary and macroprudential policy interventions are substitutes as far as financial stability is concerned but that using both instruments to safeguard the stability of the financial system is sociable desirable. Relative to a noncoordinated policy intervention, in which monetary policy is concerned only with inflation stability and macroprudential policy is concerned only with financial stability, social optimality mitigates instability in boom-bust cycles—but by doing so, it exerts inflationary pressures during busts and deflationary pressures during booms. Ultimately, it improves social welfare only moderately.

Related Literature.—This paper primarily relates to the literature that studies prudential policy intervention in general equilibrium economies with recurrent episodes of systemic financial distress. He and Krishnamurthy (2013) and Brunnermeier and Sannikov (2014) have pioneered macroeconomic models of financial intermediation with those characteristics. Of that class of models, the banking autarky economy in Maggiori (2017) is the closest to the flexible price economy in this paper. A key difference between these two economies, however, is that in Maggiori (2017), the incentive-compatible leverage constraint is always slack, whereas in this paper that constraint occasionally binds. Because such a constraint, in general, is forward-looking, an occasionally binding version further intertwines boom and bust phases; thus, it strengthens latent effects during busts from policy intervention during booms. Also, an occasionally binding version generates an additional, binding-constraint pecuniary externality (as classified by Dávila and Korinek (2018)), which creates further excessive instability in boom-bust cycles over that already created by the feedback loop.

Phelan (2016) and Di Tella (2019) also study macroprudential regulation of financial intermediaries in a He-Krishnamurthy/Brunnermeier-Sannikov economy. As opposed to Phelan (2016), however, in this paper, financial intermediaries face multiple leverage constraints—in particular, a market- and a policy-based constraint. Another critical difference is that in this paper, policy-based limits can vary over the aggregate state. The financial frictions in Di Tella (2019) are instead limited participation in asset markets and hidden trade. Notwithstanding, in that paper as well, macroprudential regulations that reduce asset prices appropriately improve financial stability over laissez-faire.

Lastly, this paper is related to the literature that studies whether monetary policy should also respond to concerns about financial stability apart from those about inflation stability (e.g., Svensson 2017; Gourio, Kashyap, and Sim 2018) and/or whether monetary responses to the former concerns should be coordinated with those of macroprudential policy (e.g., Carrillo et al. 2016, Collard et al. 2017, and De Paoli and Paustian 2017). Most of the papers in this literature, however, focus instead on either comparing steady states or local deviations from an initial steady state that eventually drift back to the original state.

Layout.—Section I lays out the model, which Section II solves. Section III conducts the policy analysis, and Section IV concludes.

I. The Model

Consider a dynamic stochastic general equilibrium economy evolving in continuous time with nominal rigidities in price setting and frictions in financial intermediation. The economy is populated by a continuum of households, firms, and financial intermediaries, each of which lies, without loss of generality, in the unit interval. A monetary authority sets the short-term nominal interest rate, and a prudential regulatory authority sets a state-contingent limit on intermediary leverage. The environment has three building blocks.

A. *New Keynesian Block: Production and Price Setting*

The structures of production and price setting are the same as in the baseline New Keynesian economy with Calvo (1983) pricing.

Production.—Each firm produces a single intermediate good variety flow $y_{j,t}$ during time interval $(t, t+dt)$, with $j \in [0,1]$, using labor $l_{j,t}$ and capital services $k_{j,t}$ as inputs. The production technology is the same for all of the firms, and it is Cobb-Douglas:

$$y_{j,t} = A_t l_{j,t}^{\alpha} k_{j,t}^{1-\alpha}, \tag{1}$$

with $\alpha \in (0,1)$ being the labor share of output and A_t total factor productivity (TFP). Aggregate TFP A_t is exogenous, and it evolves over time stochastically according to

$$\frac{dA_t}{A_t} = \mu_A dt + \sigma_A dZ_t, \tag{2}$$

with Z_t being a standard Brownian motion that satisfies the usual conditions and $\mu_A > 0$ and $\sigma_A > 0$ two positive constants. Brownian shock dZ_t is the single source of aggregate risk (it represents serially i.i.d. shocks to the growth rate of aggregate productivity). The intermediate good varieties are useful for producing a final consumption good, y_t, which is also produced during $(t, t+dt)$, according to a CES aggregator,

$$y_t = \left[\int_0^1 y_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{3}$$

with $\varepsilon > 1$ being the (constant) elasticity of substitution across the intermediate goods.

Nominal Rigidities.—Firms hire labor and rent capital services in competitive markets and sell their intermediate good variety in monopolistic competitive markets. In the latter markets, firms receive opportunities to reset their nominal price $p_{j,t}$ at exogenous random times that occur stochastically according to a Poisson arrival rate θ. The infrequency of these random times is the source of nominal rigidities in the model. The random times are idiosyncratic and i.i.d. across firms, which renders the price-setting problem of all firms that have the opportunity to reset their nominal price at a same time t identical. I lay out that problem in Section II, in which I solve the model.

B. *Financial Block: Financial Intermediation and Financial Frictions*

The structure of financial intermediation and the nature of financial frictions build on the works of Brunnermeier and Sannikov (2014), Gertler and Kiyotaki (2010), Gertler and Karadi (2011), and Maggiori (2017). Financial intermediation facilitates production by increasing the aggregate quantity of capital services available to firms.

Real Asset.—The capital services that firms employ in production are derived from a real asset in positive fixed supply, which I refer to as physical capital.[1] Firms cannot own physical capital; rather, to get capital services, they have to rent these services short term from $(t, t+dt)$ in the corresponding market. Only households and financial intermediaries can own the stock of physical capital. Financial intermediaries have an edge in managing this asset relative to households, however, as they can provide more capital services to firms per unit of physical capital. For simplicity, I assume that financial intermediaries can do so at a one-to-one rate, while households can do it at a rate $a_h < 1$, with a_h being a parameter. This productivity edge can be rationalized as resulting from differences in monitoring technologies, with monitoring being useful for mitigating moral hazard problems in equity markets between firms and their shareholders, as in Tirole (2010). (See the online Appendix for details.) The productivity edge is the single reason that financial intermediaries provide value in the model.

Return on Real Asset.—Physical capital is traded continuously in spot markets at a real price $q_t > 0$ (which is expressed in terms of the final consumption good). The total real rate of return on physical capital $dR_{e,t}$, therefore, is

$$dR_{e,t} \equiv \left[a_h \mathbf{1}_{e=h} + 1 - \mathbf{1}_{e=h}\right] \frac{r_{k,t}}{q_t} dt + \frac{dq_t}{q_t}, \quad \text{with } e = \{f, h\}, \tag{4}$$

with the first term on the RHS being the real dividend yield rate ($r_{k,t}$ is the real rental rate of capital services), the second term being the real capital gain/loss rate, and the difference between $dR_{f,t}$ and $dR_{h,t} < dR_{f,t}$ resulting from the managing edge of financial intermediaries (f) over households (h). I postulate that in equilibrium, spot price q_t evolves over time stochastically according to

$$\frac{dq_t}{q_t} = \mu_{q,t} dt + \sigma_{q,t} dZ_t, \quad \text{with } \sigma_{q,t} \neq 0, \tag{5}$$

with $\mu_{q,t}$ and $\sigma_{q,t}$ being endogenous drift and diffusion processes, respectively, to be determined later and dZ_t being the same Brownian shock that governs the evolution of aggregate productivity A_t.[2] This postulate implies that physical capital is risky.

[1] Phelan (2016) refers to a similar real asset as land.

[2] This postulate will be consistent with the equilibrium results that q_t is a present discounted value of future rental rates $\{r_{k,s}\}_{s \geq t}$ and future $r_{k,s}$ is proportional to its contemporaneous aggregate productivity A_s.

Put formally, capital gain/loss rate dq_t/q_t responds on impact to Brownian shock dZ_t, which implies that rental rates $dR_{f,t}$ and $dR_{h,t}$ are locally risky during $(t, t+dt)$.

Debt (*Deposits*) *Funding*.—Besides physical capital, there is nominal debt. This debt is short term, meaning that it matures at time $t+dt$. It is also allegedly noncontingent, meaning that it promises to repay during $(t, t+dt)$ a nominal rate of return $i_t dt$ that is fixed and, in particular, independent of shock dZ_t. Nominal debt is in zero-net supply; therefore, for convenience, I refer to this debt as "deposits" in what follows. Deposits allow taking leveraged positions on physical capital. However, in equilibrium, they will preclude decoupling leverage from risk-taking. This is because of their difference in riskiness with respect to physical capital. This riskiness difference is one of the two frictions that, when combined in equilibrium, will generate instability in financial intermediation, pecuniary externalities in financial markets, and excessive risk-taking of financial intermediaries over what is socially desirable, and thus will justify the need for policy intervention in the model. (I will elaborate on this point in Section IIF and Section III.) The other friction is limited enforcement in deposits markets (similar to the enforcement problems in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011)), which in equilibrium will ensure that deposits are de facto locally risk-free. (I will elaborate on this other point right below.) Based on the difference in capital rates of return, $dR_{f,t} > dR_{h,t}$, in what follows, I postulate that in equilibrium, only financial intermediaries issue deposits to take leveraged positions on physical capital.

IC Portfolio Constraint.—The limited enforcement friction is such that financial intermediaries can divert a portion $1/\lambda \in (0,1)$ of their assets immediately after raising deposits—in which case they must renege on their deposit obligations on the spot, provided that the remanent assets after diversion are not enough to cover the principal in full. A default on deposits is costly for financial intermediaries, however, because it triggers closure of the intermediary company, which has a nonnegative franchise value $V_t \geq n_{f,t}$, with $n_{f,t} \geq 0$ being intermediary net worth in real terms. Following Maggiori (2017), for this friction to also be relevant in a continuous-time framework, I assume that financial intermediaries are each owned by a single household and that each financial intermediary can borrow only from households other than their owner. All in all, the limited enforcement friction shapes an incentive-compatible (IC) portfolio constraint that restricts the real deposit issuances of financial intermediaries (i.e., $b_{f,t} \geq 0$) and also their capital positions (i.e., $q_t \bar{k}_{f,t} \geq 0$) according to

$$q_t \bar{k}_{f,t} = n_{f,t} + b_{f,t} \leq \lambda V_t, \tag{6}$$

with the equality resulting from their balance sheets. The IC constraint must always hold in equilibrium (otherwise, households would not be willing to hold deposits in the first place), which is actually the reason that nominal deposit rate $i_t dt$ is de facto locally risk-free during $(t, t+dt)$. Naturally, the IC constraint affects portfolio decisions. However, these decisions will also be affected by the interventions by policy. Therefore, before describing portfolio optimization problems and the equilibrium concept (with which I conclude the description of the model), I describe the policy block.

C. *Policy Block: Monetary and Macroprudential Policy*

The policy toolkit consists of interest rate policies (monetary policy) and state-contingent limits on intermediary leverage (macroprudential policy). For simplicity, I restrict attention to policy instruments that are considered the most standard in the literature. For the same reason, I abstract away from an effective lower bound (ELB) on nominal interest rates.

Monetary Policy.—The monetary policy rate and the nominal deposit rate in equilibrium are the same. This is because the deposit rate is de facto locally risk-free, which implies that both rates are perfectly arbitraged. Based on this result, in what follows, I regard $i_t dt$ as the policy tool of the monetary authority.[3]

Macroprudential Policy.—A policy-based limit on intermediary leverage shapes an additional portfolio constraint:

$$q_t \bar{k}_{f,t} \leq \Phi_t n_{f,t}, \tag{7}$$

with $\Phi_t \geq 1$ being the policy tool of the prudential regulatory authority. This limit can restrict leveraged capital positions $q_t \bar{k}_{f,t} \geq n_{f,t}$ further below IC limit λV_t depending on the aggregate state, with varying degrees of intensity when it does so. It is common to all of the financial intermediaries, and all of them take it as given.

D. *Portfolio Problems*

Portfolio optimization problems are standard. In particular, the problem of financial intermediaries is the same as that in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) but cast in continuous time and with an additional portfolio constraint: (7). The problem of households is a standard portfolio problem without portfolio constraints but with consumption c_t and labor supply l_t decisions. I lay out these problems as well in Section II, in which I solve the model.

E. *Equilibrium Concept*

In equilibrium, firms, financial intermediaries, and households optimize and markets for labor, capital services, intermediate goods, consumption, and physical capital clear. The market for deposits automatically clears because of Walras' law. In the market for consumption, $c_t = y_t$, because there is no investment or fiscal policy.

[3] The implementation mechanism of monetary policy is the same as in the New Keynesian framework. See Clarida, Galí, and Gertler (1999) for a reference.

II. Solving the Model

To solve the model, I begin by solving the problems of firms, financial intermediaries, and households, in that order. In the process, I combine optimality conditions with market clearing to derive key aggregate variables in equilibrium such as inflation, price dispersion, endogenous TFP, a marginal investor on physical capital, a labor wedge, and social welfare. I continue by defining a Markov equilibrium, then use this more specific, yet tractable, equilibrium concept to finish solving the model.

A. *Optimal Prices, Inflation, and Price Dispersion*

Firms combine labor and capital services to minimize production costs while taking competitive real wage rate w_t and competitive real rental rate $r_{k,t}$ as given. Minimum product costs, $x_t(y_{j,t})$, are therefore

$$x_t(y_{j,t}) = \frac{1}{A_t}\left(\frac{w_t}{\alpha}\right)^{\alpha}\left(\frac{r_{k,t}}{1-\alpha}\right)^{1-\alpha} y_{j,t}. \tag{8}$$

Also, when they have the opportunity to do so, firms reset their nominal price, $p_{j,t}$, to maximize the present discounted value of their profit flows over the time horizon during which their nominal price is expected to remain fixed. During that time horizon, firms must accommodate their indirect demand—which, at every future time instant, $s \geq t$, is given by $y_{d,s}(p_{j,t}) \equiv (p_{j,t}/p_s)^{-\varepsilon} y_s$, with $p_s \equiv \left[\int_0^1 p_{j,s}^{1-\varepsilon}\, dj\right]^{1/(1-\varepsilon)}$ being the nominal price of the final consumption good, or equivalently in equilibrium, the aggregate price level.[4]

Price-Setting Problem.—The price-setting problem of firms, therefore, is

$$\max_{p_{j,t}>0} E_t \int_t^{\infty} \theta\, e^{-\theta(s-t)} \frac{\Lambda_s}{\Lambda_t}\left[(1-\tau)\frac{p_{j,t}\, y_{d,s}(p_{j,t})}{p_s} - x_s\big[y_{d,s}(p_{j,t})\big]\right] ds, \tag{9}$$

with $\theta\, e^{-\theta(s-t)}$ being the survival density function of fixed nominal price $p_{j,s} = p_{j,t}$, Λ_t the stochastic discount factor (SDF) of households, and $\tau < 0$ an ad valorem sales subsidy to be determined below. (Firms take Λ_t and τ as given.)

Optimal Price.—The nominal price that solves the price-setting problem is $p_{*,t}$, with

$$\frac{p_{*,t}}{p_t} = \underbrace{\frac{\varepsilon}{(\varepsilon-1)(1-\tau)}}_{=1} \frac{E_t \int_t^{\infty} \theta\, e^{-\theta(s-t)} \frac{\Lambda_s}{\Lambda_t} x_s\big[y_{d,s}(p_t)\big]\, ds}{E_t \int_t^{\infty} \theta\, e^{-\theta(s-t)} \frac{\Lambda_s}{\Lambda_t} \frac{p_t\, y_{d,s}(p_t)}{p_s}\, ds}. \tag{10}$$

[4] The demand function follows from minimizing the costs of producing the final consumption good taking intermediate good prices as given. The aggregate price level is defined over intermediate good prices that are charged—yet not necessarily set—at the current time instant.

Following Woodford (2011) and Galí (2015), I impose that $\tau = -1/(\varepsilon - 1)$ to eliminate distortions from monopoly pricing, which implies that firms set competitive prices. The numerator in the second factor on the RHS is the present discounted value of production costs of an average firm that charges a nominal price of p_t; the corresponding denominator is the present discounted value of gross sales revenues of that same firm.

Inflation Rate.—In equilibrium, a law of large numbers implies that backward density function $\theta e^{-\theta(t-s)}$ measures the aggregate share of firms that had the opportunity to reset their nominal price for the last time at $s \leq t$. Because at time t all of those firms charge the same nominal price $p_{*,s}$, the aggregate price level p_t satisfies

$$p_t = \left[\int_{-\infty}^{t} \theta e^{-\theta(t-s)} p_{*,s}^{1-\varepsilon} ds\right]^{\frac{1}{1-\varepsilon}}, \tag{11}$$

and therefore it evolves over time deterministically, according to[5]

$$\frac{dp_t}{p_t} = \pi_t dt + 0dZ_t, \quad \text{with} \quad \pi_t \equiv \frac{\theta}{\varepsilon - 1}\left[1 - \left(\frac{p_{*,t}}{p_t}\right)^{-(\varepsilon-1)}\right]. \tag{12}$$

This is the notion of sluggishness in inflation in the model. The inflation rate, i.e., dp_t/p_t, does not respond on impact to Brownian shock dZ_t—which implies that $dp_t/p_t = \pi_t dt$ moves at a lethargic pace relative to the aggregate shocks that hit the economy. A related implication is that dp_t/p_t is locally risk-free during $(t, t + dt)$. Inflation is positive, $\pi_t > 0$, when spot optimal prices exceed the aggregate price level, i.e., $p_{*,t}/p_t > 1$; it is negative, $\pi_t < 0$, when the opposite happens, i.e., $p_{*,t}/p_t < 1$.

Price Dispersion.—The consumer-based measure of price dispersion in intermediate goods (hereafter, "price dispersion" for short) is

$$\omega_t \equiv \int_0^1 \frac{y_{j,t}}{y_t} dj = \int_{-\infty}^{t} \theta e^{-\theta(t-s)} \left(\frac{p_{*,s}}{p_t}\right)^{-\varepsilon} ds, \tag{13}$$

with the equality holding only in equilibrium. Price dispersion is inefficient because the CES aggregator has decreasing marginal returns. Put differently, $\omega_t \geq 1$ because of Jensen's inequality. Price dispersion evolves over time deterministically, according to

$$\frac{d\omega_t}{\omega_t} = \mu_{\omega,t} dt + 0dZ_t, \quad \text{with} \quad \mu_{\omega,t} \equiv \theta\left[\left(\frac{p_{*,t}}{p_t}\right)^{-\varepsilon} \frac{1}{\omega_t} - 1\right] + \varepsilon \pi_t, \tag{14}$$

[5] This law of motion follows from differentiating both sides in (11) with respect to time t. Brownian shock dZ_t cannot affect the evolution of p_t on impact, because in equilibrium, p_t is given by a Riemann integral.

which, combined with (12), implies that $\omega_t \rightarrow 1$ if $\pi_t \rightarrow 0$; that is, inflation stabilization eventually eliminates price dispersion (as is standard in a New Keynesian model with Calvo (1983) pricing).[6] Price dispersion will be one of the two key state variables in the Markov equilibrium (see Section IIE).

B. *Leverage Multiple and Tobin's Q*

Financial intermediaries maximize the present discounted value of their dividend payouts. Following Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), I assume that financial intermediaries pay out dividends only once at an exogenous random time that occurs stochastically according to a Poisson arrival rate γ. Dividend payout times are idiosyncratic and i.i.d. across financial intermediaries. When they pay out dividends, financial intermediaries transfer all of their accumulated net worth to their owner household; instantaneously afterward, they are replaced by a new financial intermediary, which is endowed—by the same owner household—with a portion $\kappa/\gamma > 0$ of the aggregate capital stock $\bar{k}$, with κ being a parameter. This dividend payout scheme precludes financial intermediaries from saving away the IC constraint. Also, it precludes financial intermediaries as a whole from eventually vanishing, as without net worth, individual financial intermediaries cannot borrow or operate. Lastly, the dividend payout scheme facilitates the aggregation; in particular, it allows a representative financial intermediary to exist in equilibrium.

Portfolio Problem.—The problem of financial intermediaries consists of maximizing

$$V_t \equiv \max_{\bar{k}_{f,t} \geq 0} E_t \int_t^{\infty} \gamma e^{-\gamma(s-t)} \frac{\Lambda_s}{\Lambda_t} n_{f,s}\, ds, \tag{15}$$

subject to the law of motion of their net worth

$$dn_{f,t} = dR_{f,t} q_t \bar{k}_{f,t} - (i_t - \pi_t)(q_t \bar{k}_{f,t} - n_{f,t})dt, \tag{16}$$

IC constraint (6), macroprudential leverage constraint (7), and solvency constraint $n_{f,t} \geq 0$. Financial intermediaries take Λ_t as given. All quantities, prices, and returns in this problem are expressed in real terms. The real deposit rate is evaluated at its equilibrium rate, $(i_t - \pi_t)dt$.

[6] Interesting mainly from a theoretical point of view, the fastest way to eliminate price dispersion is instead through generating some moderate amount of deflation during the transition toward $\omega_t = 1$. Specifically, $\pi_{E,t} \equiv \theta(1 - \omega_t^{\varepsilon-1})/(\varepsilon - 1) \leq 0$ minimizes $\mu_{\omega,t}$ for any given ω_t; therefore, if $\pi_t = \pi_{E,t}$ always, then price dispersion shrinks at the fastest possible pace for any initial ω_t. This is one of the reasons $\pi_{E,t}$ is socially optimal in an economy with nominal rigidities, without funding frictions, and without macroprudential policy interventions. The other reason is discussed in footnote 9. See the online Appendix for a formal proof.

Guess.—To solve this problem, I postulate that value function V_t is proportional to net worth $n_{f,t}$:

$$V_t = v_t n_{f,t}, \tag{17}$$

with $v_t \geq 1$ being never below 1, the same for all financial intermediaries, and independent of decision $\bar{k}_{f,t}$. Putting the latter property differently, when deciding their capital positions, financial intermediaries take the already optimal marginal value of net worth v_t as given. In the model, however, v_t is endogenous and will be determined later. This postulate implies that IC constraint (6) is linear in $n_{f,t}$; consequently, the portfolio problem is scale invariant with respect to individual net worth.[7] Optimality then implies that the leverage multiple, i.e., $q_t\bar{k}_{f,t}/n_{f,t}$, is the same for all financial intermediaries regardless of their net worth. In equilibrium, a representative financial intermediary therefore exists. I conjecture that value v_t evolves over time stochastically, according to a diffusion process with the same Brownian shock dZ_t as that in (2). In the online Appendix, I derive optimal leverage multiple ϕ_t and the equilibrium conditions below for v_t.

Leverage Multiple.—Optimal leverage multiple ϕ_t satisfies

$$\phi_t \begin{cases} = \min\{\lambda v_t, \Phi_t\} & \text{if } RR_{f,t} > 0 \\ \in \left[0, \min\{\lambda v_t, \Phi_t\}\right] & \text{if } RR_{f,t} = 0, \\ = 0 & \text{if } RR_{f,t} < 0 \end{cases} \tag{18}$$

with

$$RR_{f,t}dt \equiv E_t\left[dR_{f,t}\right] - (i_t - \pi_t)dt + \text{cov}_t\left[\frac{d\Lambda_t}{\Lambda_t} + \frac{dv_t}{v_t}, dR_{f,t}\right] \tag{19}$$

being the expected risk-adjusted excess return on physical capital over deposits that financial intermediaries earn during $(t, t+dt)$. When $RR_{f,t} > 0$, financial intermediaries strictly prefer physical capital to deposits; therefore, they consider it optimal to hit their upper limit on leverage, $\min\{\lambda v_t, \Phi_t\}$, with ϕ_t. When $RR_{f,t} = 0$, financial intermediaries are indifferent between the two asset classes; thus, they are willing to take any capital and deposit positions. Lastly, when $RR_{f,t} < 0$, financial intermediaries strictly prefer deposits; hence, they prefer not to hold physical capital. In equilibrium, however, only the first two cases are possible, and in the second one, $\phi_t \geq 1$. This is because households do not issue deposits. Based on these results, in what follows I discard case $RR_{f,t} < 0$ and restrict $\phi_t \in \left[1, \min\{\lambda v_t, \Phi_t\}\right]$ when $RR_{f,t} = 0$. Financial intermediaries are also concerned with financial risk $\text{cov}_t\left[dv_t/v_t, dR_{f,t}\right]$ apart from consumption risk $\text{cov}_t\left[d\Lambda_t/\Lambda_t, dR_{f,t}\right]$. This is because they are subject to portfolio constraints.

[7] Note that the objective function and the other constraint functions in (15) are either linear or affine in net worth. See the online Appendix for a formal derivation of the portfolio problem and a verification of the postulate.

Tobin's Q.—Value v_t satisfies

$$\widetilde{RR}_{f,t}dt + \frac{\gamma}{v_t}dt + E_t\left[\frac{dv_t}{v_t}\right] - \gamma dt + \mathrm{cov}_t\left[\frac{d\Lambda_t}{\Lambda_t}, \frac{dv_t}{v_t}\right] = 0, \tag{20}$$

with

$$\widetilde{RR}_{f,t}dt \equiv E_t\left[\frac{dn_{f,t}}{n_{f,t}}\right] - (i_t - \pi_t)dt + \mathrm{cov}_t\left[\frac{d\Lambda_t}{\Lambda_t} + \frac{dv_t}{v_t}, \frac{dn_{f,t}}{n_{f,t}}\right] \tag{21}$$

being the expected risk-adjusted excess return over deposits that financial intermediaries instead earn on net worth. This condition confirms that v_t measures the marginal value of net worth for financial intermediaries—i.e., Tobin's Q. From substituting (16) into (21), it follows that $\widetilde{RR}_{f,t} = RR_{f,t}\phi_t$, with ϕ_t being given as in (18). If $RR_{f,t}\phi_t = 0$ always, then value $v_t = 1$ equals 1 always as well.[8] However, because $RR_{f,t}\phi_t \geq 0$, in general, $v_t \geq 1$.

C. *Consumption, Labor Supply, and Savings*

Households maximize the present discounted value of their utility flows from consumption and labor supply. Households have separable preferences over the two quantities. Their preferences for consumption are logarithmic, and those for labor supply are isoelastic, with $\psi > 0$ being the inverse of the Frisch elasticity of labor supply. The SDF of households, therefore, is $\Lambda_t \equiv e^{-\rho t}/c_t$, with $\rho > 0$ being their subjective time discount rate. The relative weight to the disutility from labor hours is given by $\chi > 0$.

Portfolio Problem.—The problem of households consists of maximizing

$$U_t \equiv \max_{c_t, l_t, \bar{k}_{h,t} \geq 0} E_t \int_t^{\infty} e^{-\rho(s-t)}\left[\ln c_s - \chi\frac{l_s^{1+\psi}}{1+\psi}\right]ds \tag{22}$$

subject to the law of motion of their net worth $n_{h,t}$,

$$dn_{h,t} = dR_{h,t}q_t\bar{k}_{h,t} + (i_t - \pi_t)(n_{h,t} - q_t\bar{k}_{h,t})dt + w_t l_t dt + Tr_t dt - c_t dt, \tag{23}$$

and the solvency constraint, $n_{h,t} \geq 0$. In this problem as well, quantities, prices, and returns are expressed in real terms. The position of households on physical capital is $q_t\bar{k}_{h,t}$, and their savings in deposits is $n_{h,t} - q_t\bar{k}_{h,t}$. The combined net transfers that households receive from firms and financial intermediaries are Tr_t. (Firms transfer all of their profit flows on the spot.) A representative household exists because individual households are identical. I solve this problem in the online Appendix.

[8] I restrict attention to values v_t that are constant if $\widetilde{RR}_{f,t}$ is. This means that v_t cannot vary over time if $\widetilde{RR}_{f,t}$ does not. Note that if v_t is constant, then $dv_t/v_t = 0$ is null, and hence $E_t[dv_t/v_t] = \mathrm{cov}_t[d\Lambda_t/\Lambda_t, dv_t/v_t] = 0$ are null as well.

Solution.—Optimal capital position $q_t\bar{k}_{h,t}$ satisfies

$$q_t\bar{k}_{h,t} \begin{cases} = +\infty & \text{if } RR_{h,t} > 0 \\ \in [0,+\infty) & \text{if } RR_{h,t} = 0, \\ = 0 & \text{if } RR_{h,t} < 0 \end{cases} \tag{24}$$

with

$$RR_{h,t}dt \equiv E_t\left[dR_{h,t}\right] - \left(i_t - \pi_t\right)dt + \text{cov}_t\left[\frac{d\Lambda_t}{\Lambda_t}, dR_{h,t}\right] \tag{25}$$

being the expected risk-adjusted excess return on physical capital over deposits that households earn during $(t, t+dt)$. The interpretation of decision rule (24) is similar to that of (18). However, two important differences between the two are that for households, $RR_{h,t} > 0$ cannot arise in equilibrium and households are not concerned with financial risk. These differences arise because households are not subject to portfolio constraints. In addition to (24), at the optimal, households are indifferent on the margin between consumption and deposits, which implies that their expected marginal utility return from consumption $-E_t\left[d\Lambda_t/\Lambda_t\right]$ equals real deposit rate $\left(i_t - \pi_t\right)dt$. That is,

$$-E_t\left[\frac{d\Lambda_t}{\Lambda_t}\right] \equiv \rho dt + E_t\left[\frac{dc_t}{c_t}\right] - \text{var}_t\left[\frac{dc_t}{c_t}\right] = \left(i_t - \pi_t\right)dt. \tag{26}$$

Households are also indifferent on the margin between consumption and labor. Thus,

$$\frac{1}{c_t}w_t = \chi l_t^{\psi}. \tag{27}$$

D. *Endogenous TFP*, *Marginal Investor*, *Labor Wedge*, *and Social Welfare*

An aggregate production function (with an endogenous TFP component), a marginal investor on physical capital, and a labor wedge exist in equilibrium. These are the result of combining optimality conditions with market clearing. (I derive the aggregate production function and the labor wedge in the online Appendix.) Because a representative financial intermediary and representative household also exist in equilibrium, in what follows, to economize in notation, I make no distinction between individual and aggregate variables. The objects below will be critical for the definition and analytical characterization of the Markov equilibrium (Section IIE), the analysis of the economy with flexible prices and without policy intervention (Section IIF), and the policy intervention analysis (Section III).

Endogenous TFP.—The aggregate production function is Cobb-Douglas,

$$y_t = \zeta_t A_t l_t^{\alpha} \bar{k}^{1-\alpha}, \quad \text{with} \quad \zeta_t \equiv \frac{a_t^{1-\alpha}}{\omega_t} \leq 1, \tag{28}$$

with $a_t \equiv a_h \bar{k}_{h,t}/\bar{k} + \bar{k}_{f,t}/\bar{k} \in [a_h, 1]$ being the aggregate supply of capital services as a share of potential. This production function is identical to those of firms except that it is defined over physical capital—rather than over capital services—and has an endogenous TFP component, ζ_t. Endogenous TFP $\zeta_t \equiv a_t^{1-\alpha}/\omega_t$ measures the combined aggregate productivity losses from financial disintermediation and price dispersion. Indeed, productivity losses a_t, in equilibrium, are given by

$$a_t = a_h(1 - \phi_t \eta_t) + \phi_t \eta_t, \tag{29}$$

with $\eta_t \equiv n_{f,t}/(n_{f,t} + n_{h,t}) = n_{f,t}/q_t\bar{k} \in [0,1]$ being the aggregate net worth of financial intermediaries as a share of total wealth, and $n_{f,t} + n_{h,t} = q_t\bar{k}$ because physical capital is the single real asset. Wealth share η_t will be the other key state variable in the Markov equilibrium.

Marginal Investor.—The marginal investor on physical capital is either the representative financial intermediary or the representative household. Optimality conditions (18) and (24) imply that $RR_{h,t} \leq 0 \leq RR_{f,t}$, and in conjunction with market clearing, they imply that at least one of those weak inequalities always holds with equality—otherwise, no marginal investor would exist in equilibrium. I postulate that both weak inequalities cannot hold with equality simultaneously. Then

$$\begin{cases} RR_{h,t} = 0 < RR_{f,t}, & \text{when } \min\{\lambda v_t, \Phi_t\}\eta_t < 1 \\ RR_{f,t} = 0 > RR_{h,t}, & \text{when } \min\{\lambda v_t, \Phi_t\}\eta_t \geq 1, \end{cases} \tag{30}$$

and also $\phi_t = \min\{\lambda v_t, \Phi_t, 1/\eta_t\}$. These conditions imply that households are the marginal investors when financial intermediaries as a whole lack enough borrowing capacity to hold all of the aggregate capital stock. Also, they imply that financial intermediaries are instead those investors when the opposite happens. In the former region, financial intermediaries hold as much physical capital as possible given their portfolio constraints—that is, $\phi_t = \min\{\lambda v_t, \Phi_t\}$—and households hold the remanent aggregate share, $1 - \min\{\lambda v_t, \Phi_t\}\eta_t$. In the latter region, in contrast, financial intermediaries alone hold all of the aggregate capital stock—i.e., $\phi_t \eta_t = 1$. Condition (30) is the equilibrium pricing equation for physical capital.

Labor Wedge.—The labor wedge becomes apparent in the equilibrium expression for the real wage rate,

$$w_t = \left(\frac{l_t}{l_E}\right)^{1+\psi} \alpha \frac{y_t}{l_t}; \quad r_{k,t} = \left(\frac{l_t}{l_E}\right)^{1+\psi} (1-\alpha)\frac{y_t}{k_t}, \tag{31}$$

with $l_E \equiv (\alpha/\chi)^{\frac{1}{1+\psi}}$ being the equilibrium quantity of aggregate labor in the economy with flexible prices. Because all of the firms reset their nominal price at every instant if prices are flexible, in equilibrium $p_{*,t}/p_t = x_t(y_j)/y_j = 1$ and, hence, $\omega_t = 1$ and $l_t = l_E$. In the economy with sticky prices, instead, $x_t(y_j)/y_j = (l_t/l_E)^{1+\psi}/\omega_t \neq 1$ and $l_t \neq l_E$ in general; but if $\pi_t \to 0$, then $x_t(y_j)/y_j \to 1$ and $l_t \to l_E$. Putting the latter statement differently, inflation stabilization eventually eliminates the labor wedge as well, as is standard in the New Keynesian framework.[9]

Social Welfare.—The sources of inefficiency in the model are endogenous TFP and the labor wedge. These reduce the utility flows of households u_t according to

$$(32) \quad u_t = (1-\alpha)\ln a_t + \ln\frac{1}{\omega_t} + \alpha \ln l_t - \chi\frac{l_t^{1+\psi}}{1+\psi} + \ln A_t + (1-\alpha)\ln \bar{k},$$

with the first term on the RHS being the utility losses from financial disintermediation, the second term being the losses from price dispersion, the difference between the third and fourth terms being the losses from the labor wedge (note that $l_t = l_E$ maximizes that difference), and the last two terms being exogenous and therefore uninteresting. Because inflation stabilization eventually eliminates the last two utility losses, their sum could be referred to as the losses from instability in inflation. The first utility losses are the result of the funding frictions, and the last two are the result of the (nominal) rigidities in price-setting.

E. *Markov Equilibrium*

To finish solving the model, I conjecture that a Markov equilibrium exists. This equilibrium is a set of state variables Γ and a set of mappings $\vartheta : \Gamma \rightarrow \Gamma^c$ such that endogenous variables in Γ evolve in accord, and mappings $\vartheta : \Gamma \rightarrow \Gamma^c$ are consistent with the conditions of the equilibrium. I postulate that state variables are $\Gamma = \{A, \omega, \eta\}$ and that mappings ϑ are either linear in or independent of A. This implies that the size of the economy is proportional to exogenous aggregate TFP. All of these conjectures require the policy rules, i and Φ, to be Markov policy functions and to depend only on states $\{\omega, \eta\} \subset \Gamma$. That is, $i, \Phi : \{\omega, \eta\} \rightarrow \mathbb{R}$. One should bear in mind that as a consequence of these restrictions, socially optimal policies in Section III will not necessarily also be socially optimal in more general classes of policy rules or equilibrium concepts. Hereafter, because I restrict attention to Markov equilibria, I omit the time subscript t when denoting variables.

Equilibrium Conditions.—The conditions of the Markov equilibrium are the following: optimal real price p_*/p satisfies (10); inflation rate π is given by (12); marginal production costs are $x(y_j)/y_j = (l/l_E)^{1+\psi}/\omega$; leverage multiple is $\phi = \min\{\lambda v, \Phi, 1/\eta\}$; Tobin's Q v satisfies (20); aggregate consumption is $c = y = \zeta A\, l^\alpha \bar{k}^{1-\alpha}$; endogenous TFP is $\zeta = a^{1-\alpha}/\omega$, with $a = a_h(1-\phi\eta) + \phi\eta$; SDF of households is $\Lambda = e^{-\rho t}/y$; real deposit rate is $r = -E[d\Lambda/\Lambda | \omega, \eta]$; pricing condition of physical capital is given by (30); and exogenous TFP A, price

[9]The fastest way to eliminate the labor wedge is also through deflation rate $\pi_{E,t}$. In particular, if $\pi_t = \pi_{E,t}$ always, then $l_t = l_E$ on impact. Together with the result in footnote 6, this makes $\pi_{E,t}$ the socially optimal inflation rate in an economy with nominal rigidities, without funding frictions, and without macroprudential policy interventions. See the online Appendix for details.

dispersion ω, and wealth share η evolve over time according to (2), (14), and (33), respectively. The Markov equilibrium takes employment gap $\ln(l/l_E)$ and leverage limit Φ as given. Rather than policy rate i, $\ln(l/l_E)$ is taken as given to facilitate the solution method. This is valid because rate i can be recovered from (26) since the model abstracts away from an ELB on nominal interest rates.[10]

Solution Method.—Solving a Markov equilibrium requires solving $\{q/A, v, \pi\}$ for a given $\{\ln(l/l_E), \Phi\}$. These mappings suffice because any other can be derived from them. Mappings $\{q/A, v\}$ are characterized analytically as the solution to a second-order partial differential equation system (PDEs) in states ω and η. In all of the cases that I consider in the paper, however, the PDEs reduces to an ordinary differential equation system (ODEs) only in state η. Mapping π solves a forward-looking equation that in general depends on both states ω and η. I derive all of these equations in the online Appendix and solve them numerically using spectral methods and the parameter values specified in Table 1 (see the Supplemental Materials for details).

F. *Financially Unregulated Economies with Flexible Prices*

As a warm-up prior to the policy analysis, I consider two simple, financially unregulated economies to highlight the role of debt funding and the IC portfolio constraint in generating allocative inefficiency and cyclical deviations from normalized trend A. These economies will also be useful for illustrating the solution method.

Both economies have flexible prices; therefore, $p_*/p = 1$, $\omega = 1$, and $l = l_E$ in both, and without loss of generality, I set $\pi = 0$. The first is a frictionless economy with complete financial markets and full enforcement. Specifically, I allow $n_f < 0$, which could be interpreted as financial intermediaries being able to issue equity, and I set $\lambda = +\infty$, which rules out the possibility of diverting funds and, thus, also the IC portfolio constraint. The second economy is the original, frictional economy in Section I but with flexible prices and a policy of laissez-faire. Without loss of generality, I set $\Phi = +\infty$ in both.

Frictionless Economy.—The two most important results in this economy are that the allocation is efficient and no deviation from normalized trend A occurs. In particular, $\bar{k}_f/\bar{k} = \phi\eta = 1$ is a constant, and it equals 1, and thus so is $\zeta = a^{1-\alpha} = 1$. Value v and detrended price q/A are also a constant, with $v = 1$ and $q/A = q_E/A \equiv (1/\rho)\, r_{k,E}/A$ with $r_{k,E}/A \equiv (1-\alpha)\, l_E^{\alpha}\bar{k}^{-\alpha}$. Another key result is that financial intermediaries are the marginal investors. Thus, $RR_f = 0 > RR_h$.

Laissez-Faire Economy.—In the other economy, in contrast, the allocation is efficient only when wealth share η is sufficiently high, and cyclical deviations from trend are the norm. This other economy cannot be solved in closed form. To solve

[10] This method, however, does not allow studying the existence or number of the Markov equilibria given policy rate i.

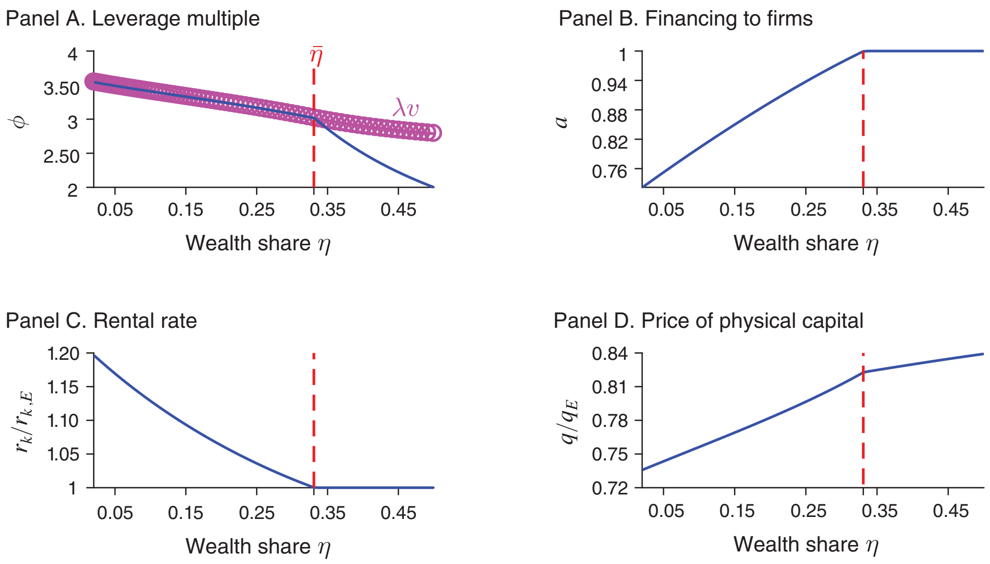

Figure 1. Markov Equilibrium as a Function of the Intermediary Wealth Share (Laissez-Faire Economy)

Notes: The magenta line with circle marker plots the incentive-compatible limit on leverage λv. The dashed vertical red line indicates the position of threshold state $\bar{\eta}$.

it, therefore, I proceed numerically, but to do so, I first postulate that in equilibrium, value v is bounded from above and strictly decreasing in η. This postulate ensures that IC leverage constraint $\phi \leq \lambda v$ binds only when state η is sufficiently low. Put formally, there exists a threshold state $\bar{\eta} \in (0,1)$ such that $\phi = \lambda v < 1/\eta \; \forall \eta < \bar{\eta}$ and $\phi = 1/\eta < \lambda v \; \forall \eta > \bar{\eta}$, with $\lambda v(\bar{\eta})\bar{\eta} = 1$. Together with the adjusted pricing condition of physical capital, $RR_h = 0$ when $\eta < \bar{\eta}$, while $RR_f = 0$ when $\eta \geq \bar{\eta}$; then, condition (20) determines an implicit ODEs for $\{q/A, v\}$ in state η.[11] Figure 1 and Figure 2 plot the Markov equilibrium.

Figure 1 shows that the equilibrium has two well-demarcated regions despite wealth share η being continuous. These regions differ inherently on whether financial intermediaries as a whole have or lack enough borrowing capacity to hold all of the aggregate capital stock. When $\eta \geq \bar{\eta}$ is high, financial intermediaries as a whole are well capitalized, they collectively hold all of the aggregate capital stock, and their leverage constraint $\phi = 1/\eta \leq \lambda v$ is slack (Figure 1, panel A). The allocation is efficient (Figure 1, panel B), as is detrended rental rate $r_k/A = a^{-\alpha} r_E/A$ (Figure 1, panel C), but detrended price $q/A < q_E/A$ is instead inefficient (Figure 1, panel D). When $\eta < \bar{\eta}$ is instead low, financial intermediaries as a whole are undercapitalized and collectively lack enough borrowing capacity to hold all of the aggregate capital stock; nonetheless, they hold as much physical capital as possible and take leveraged capital positions until their leverage constraint $\phi = \lambda v < 1/\eta$ binds. Households hold the remaining share of the aggregate capital stock, and the allocation therefore

[11] See the online Appendix for details.

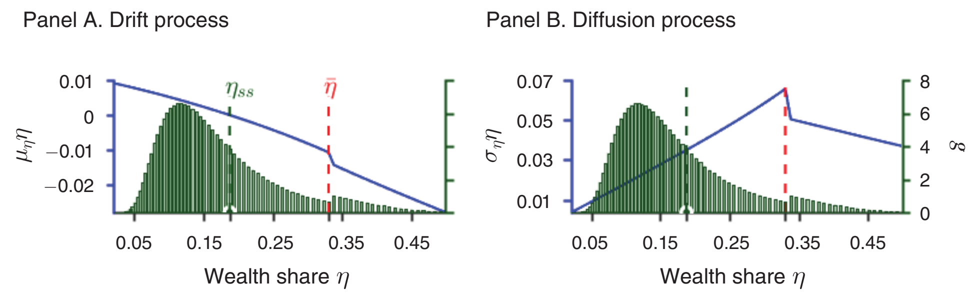

Figure 2. Equilibrium Dynamics (Laissez-Faire Economy)

Notes: The histogram plots the invariant distribution over wealth share η (i.e., g). The green dot indicates the position of the stochastic steady state, η_{ss}.

is inefficient (as is detrended rental rate r_k/A). Detrended price $q/A \ll q_E/A$ is still even more inefficient than in the other region.

When compared between the two regions, detrended rental rate r_k/A is high when η is low, whereas detrended price q/A is high in the other region. This seemingly counterintuitive difference arises because households are the marginal investors when $\eta < \bar{\eta}$, while financial intermediaries instead are those investors when $\eta \geq \bar{\eta}$. Even in the well-capitalized region (i.e., $\eta \geq \bar{\eta}$), detrended price $q/A < q_E/A$ is below efficiency. That is because investors are forward-looking and are also well aware that η oscillates between the two regions continuously over a sufficiently long time horizon (I will elaborate on this point below when I discuss Figure 2). For a similar reason, value $v > 1$ is above efficiency even when $\eta \geq \bar{\eta}$ is high, and $RR_f = 0$ is null.

The well-capitalized region could be interpreted as a boom, while the undercapitalized region could be interpreted as having two subregions: a bust and a transition between booms and busts. The former subregion occurs when $\eta \ll \bar{\eta}$ attains extremely low values and $a \ll 1$ is markedly below potential, while the latter does so when $\eta \simeq \bar{\eta}$ attains intermediate values and $a \simeq 1$ is relatively close to potential. In equilibrium, the economy fluctuates back and forth throughout from booms to busts, doing so in a nonlinear manner according to the law of motion of η:[12]

$$\frac{d\eta}{\eta} = \mu_\eta dt + \sigma_\eta dZ, \tag{33}$$

with

$$\mu_\eta \equiv \frac{r_k}{q}\phi + \left(\mu_q - r - \sigma_q^2\right)(\phi - 1) - \gamma + \frac{\kappa}{\eta} \quad \text{and} \quad \sigma_\eta \equiv (\phi - 1)\sigma_q. \tag{34}$$

Fluctuations are mean reverting (Figure 2, panel A, left y-axis). However, in general, they are not centered around stochastic steady state η_{ss}—i.e., the state to which the

[12] This law of motion follows from first applying Ito's quotient rule to ratio $\eta = n_f/qk$ and then subtracting, from the resulting expression, the net transfers from financial intermediaries to households, $\gamma - (\kappa/\eta)$.

economy would eventually converge if $dZ = 0$ forever (Figure 2, panel A, x-axis, green dot). Fluctuations are also stochastic, generically, because $\sigma_\eta > 0$ (Figure 2, panel B, left y-axis)—which follows from the difference in riskiness between dR_f and rdt.

Over a sufficiently long time horizon, law of motion (33) shapes an invariant distribution g over η that measures the share of time the economy spends on average at each point of state space (Figure 2, panels A and B, right y-axis). The area of g at the right of $\bar{\eta}$ measures the frequency of booms, while larger areas at the left of extremely low $\eta \ll \bar{\eta}$ mean that more severe busts happen more frequently. Positive values for both the areas at the left and right of $\bar{\eta}$ mean that the economy oscillates continuously between the two regions, or equivalently, that the IC leverage constraint occasionally binds in the invariant distribution. The area of g shows that the economy deviates from its output trend $y(\eta_{ss}) \propto A$ almost always in the invariant distribution. Together with processes μ_η and σ_η, that area shows that the deviations from trend exhibit, over a sufficiently long time horizon, a pattern of recurrent boom-bust cycles.[13]

III. Policy Intervention Analysis

I conduct the policy intervention analysis progressively in three steps to ease exposition. First, I examine the effects of macroprudential policy intervention in isolation. To this end, I consider the economy with flexible prices. Second, I examine the effects of monetary policy intervention in isolation as well. To this other end, I consider the economy with sticky prices but without macroprudential policy. Lastly, I examine the interactions and the potential need for coordination between the two policy instruments. To do so, I consider the original economy in Section I.

A. *Macroprudential Policy in the Flexible Price Economy*

The financially unregulated economies in Section IIF show that debt funding, together with an occasionally binding IC portfolio constraint, generate allocative inefficiency and recurrent boom-bust cycles. This section shows that those frictions also generate pecuniary externalities in financial markets and excessive risk-taking of financial intermediaries over what is socially desirable. This section also shows that appropriate (i.e., socially optimal) macroprudential policy interventions improve the stability of the financial system and social welfare over laissez-faire. Lastly, the section reports improvements on key financial metrics and annual consumption equivalent.

[13] Depending on parameter values, the economy instead may eventually remain stable at the efficient allocation. This is the case, for instance, if $\rho \geq \gamma - \kappa$. In this paper, I do not consider such cases, because an economy that eventually attains efficiency under laissez-faire is not interesting for policy intervention considerations. The economy under laissez-faire (i.e., the laissez-faire economy) may have multiple stochastic steady states, which can be efficient or inefficient. Under the parameter values in Table 1, however, the stochastic steady state is unique and inefficient (Figure 2, panel A).

Pecuniary Externalities.—The economy has three related—yet distinct—pecuniary externalities.

Shock-Triggered Pecuniary Externality.—A first externality operates through the sensitivity of the price of physical capital to changes in intermediary wealth share. This externality is triggered by shock dZ and is the one the literature has focused on the most (Gromb and Vayanos 2002, Lorenzoni 2008). It can be represented by the following amplification factor of shock dZ:

$$\frac{\sigma_q}{\sigma_A} = \frac{1}{1 - (\phi - 1)\,\varepsilon_q}, \tag{35}$$

with $\varepsilon_q \equiv (\partial q / \partial \eta)\eta / q$ being the elasticity of the price of physical capital q with respect to wealth share η.[14] Keeping state η fixed for the moment, because q is proportional to A, shock dZ triggers stochastic changes in dq/q by $\sigma_A\, dZ$, which in turn trigger stochastic changes in dn_f/n_f by $\phi\sigma_A\, dZ$, which, combined with those in dq/q, trigger stochastic changes in $d\eta/\eta$ by $(\phi - 1)\sigma_A\, dZ$. But note, then, that state η actually moves. As it does so, its rate of change $d\eta/\eta$ triggers additional stochastic changes in dq/q by $\varepsilon_q(\phi - 1)\,\sigma_A\, dZ$, with $\varepsilon_q > 0$, which sparks a positive feedback loop between $d\eta/\eta$, dq/q, and dn_f/n_f. The feedback loop has the pecuniary externality built in. This is because individual financial intermediaries do not internalize the effect of their own leverage multiple ϕ on capital gain/loss rate dq/q, the others' dn_f/n_f, rate of change $d\eta/\eta$, or the infinite loop between those rates that ensues (note that σ_q/σ_A is actually the infinite geometric sum over $(\phi - 1)\,\varepsilon_q$).

This pecuniary externality could be interpreted as a standard fire sale externality that stems from the need of high-valuation investors who are both highly leveraged and financially constrained to liquidate their assets following adverse shocks to their net worth. According to the classification in Dávila and Korinek (2018), this externality could be referred to as distributive, as it strengthens the reallocation of wealth between financial intermediaries and households following shock dZ. This externality is not present, however, in the frictionless economy, because $\partial q/\partial \eta = 0$ is null.

q-based Pecuniary Externality.—A second pecuniary externality operates instead through the level of the price of physical capital q. This externality arises because in equilibrium, financial intermediaries value physical capital more than households, and in the well-capitalized region, either agent can in principle be the marginal investor. Specifically, when $\eta \geq \bar{\eta}$ is high, financial intermediaries could collectively reduce their positions on physical capital—to induce households to hold physical capital and become marginal investors—but individually they neglect that possibility, remain marginal investors themselves, bid up the price of physical capital, and ultimately depress r_k/q, RR_f, and their collective profitability. This pecuniary externality cannot arise in the undercapitalized region, however, because in that region,

[14] The amplification factor follows from first using Ito's rule to obtain $\sigma_q q = (\partial q/\partial A)\,\sigma_A A + (\partial q/\partial \eta)\,\sigma_\eta \eta$ and then substituting $\sigma_\eta \equiv (\phi - 1)\,\sigma_q$ into the resulting expression. (Recall that q is linear in A.)

households are the only possible marginal investors. Nonetheless, because investors are forward-looking, its effects extend globally over the entire state space, reaching also that region. This pecuniary externality is independent of sensitivities $\partial q / \partial A$ and $\partial q / \partial \eta$, and in particular, it can arise even in an economy without shocks. It also could be classified as distributive. It is also not present in the frictionless economy, because in that economy, financial intermediaries alone can be marginal investors.

v-based Pecuniary Externality.—A third pecuniary externality operates through value v and arises because of the specificities of the IC leverage constraint. In particular, in a Gertler-Karadi-Kiyotaki economy, value v is a present discounted value of return $RR_f \phi$, which implies that all else constant, IC limit λv is inversely related to q. The global effects on q from the previous externality then affect intermediary leverage when $\phi = \lambda v$. Because individual financial intermediaries also neglect this additional effect, according to the classification in Dávila and Korinek (2018), a binding-constraint pecuniary externality arises. This pecuniary externality can also arise even in economies without shocks. However, were the IC leverage constraint different—for instance, if its leverage limit were exogenous rather than endogenous—then this pecuniary externality would not arise (although the other two, in general, would). This externality is also not present in the frictionless economy, because in that economy, leverage is unconstrained.

Real and Welfare Effects of Macroprudential Policy.—Macroprudential policy aims to curb the pecuniary externalities with the end purpose of maximizing social welfare in the long run:

$$\max_{\Phi \geq 1} \int \tilde{U}(\eta) g(\eta)\, d\eta, \tag{36}$$

subject to the conditions of the Markov equilibrium, with $p_*/p = x(y_j)/y_j = 1, l = l_E$ and $\omega = 1$, given $\pi = 0$ without loss of generality. The notion of "long run" is such that invariant distribution $g(\eta)$ determines the probability of reaching any given state η in the future regardless of the current state. This can be thought of as a situation in which macroprudential policy fixes a state-contingent rule for Φ at a premature stage that takes place before time unfolds and the economy unravels. Value $\tilde{U}$ is the present discounted value of utility losses from financial disintermediation, conditional on the economy's being in state η. It satisfies the Hamilton-Jacobi-Bellman (HJB) equation:

$$\rho \tilde{U} = (1 - \alpha) \ln a + \frac{\partial \tilde{U}}{\partial \eta} \mu_\eta \eta + \frac{1}{2} \frac{\partial^2 \tilde{U}}{(\partial \eta)^2} (\sigma_\eta \eta)^2. \tag{37}$$

Optimal Policy.—To solve for the socially optimal policy, I proceed numerically, and to simplify the numerical method, I restrict mapping Φ to be a polynomial function of state η. This restriction reduces the dimensionality of the problem from an infinite to a finite, usually small, number, thus rendering the numerical maximization problem tractable. Figure 3 and Figure 4 plot the Markov equilibrium

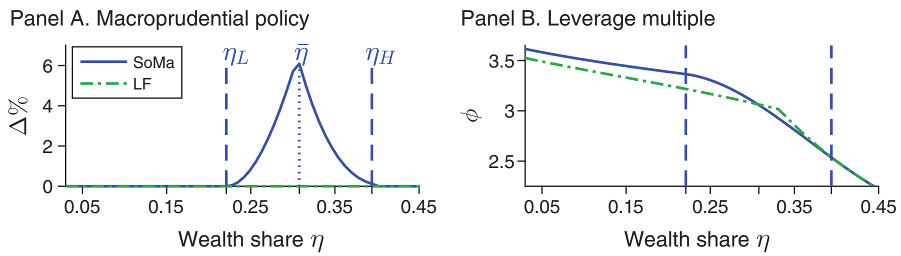

FIGURE 3. SOCIALLY OPTIMAL MACROPRUDENTIAL POLICY (SOMA) AND INTERMEDIARY LEVERAGE

Notes: The blue lines plot the Markov equilibrium in the economy with the socially optimal macroprudential policy (SoMa). The dashed vertical lines delimit the region in which the macroprudential limit on leverage is binding. The dotted vertical line indicates the position of threshold state $\bar{\eta}$. The dash-dot green lines plot the Markov equilibrium in the laissez-faire economy (LF).

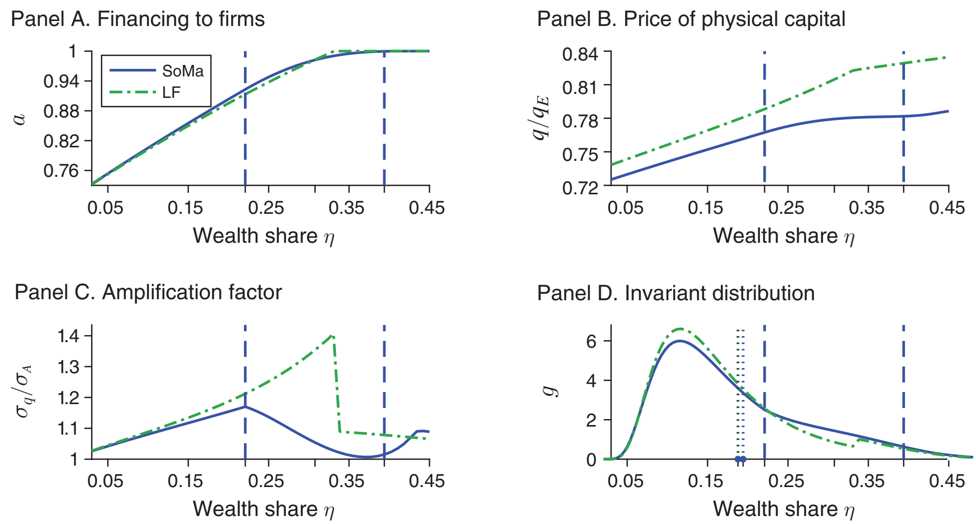

FIGURE 4. COSTS AND BENEFITS OF MACROPRUDENTIAL POLICY

Notes: The blue lines plot the Markov equilibrium in the economy with the socially optimal macroprudential policy (SoMa). The dashed vertical lines delimit the region in which the macroprudential limit on leverage is binding. The dash-dot green lines plot the Markov equilibrium in the laissez-faire economy (LF). The dotted lines indicate the position of the stochastic steady state, η_{ss}.

in the socially optimal regulated economy (solid blue lines), contrasting it with that in the laissez-faire economy (dash-dot green lines).

Social optimality requires that macroprudential policy restrict intermediary leverage ϕ further below natural upper bound $\min\{\lambda v, 1/\eta\}$ occasionally, depending on wealth share η. In particular, socially optimal limit $\Phi_F = \phi < \min\{\lambda v, 1/\eta\}$ is binding only around threshold state $\bar{\eta}$—or, more formally, between thresholds $\eta_L < \eta_H$ and η_H, with $\lambda v(\eta_L) = \Phi_F(\eta_L)$ and $\Phi_F(\eta_H)\eta_H = 1$ (Figure 3, panel A). Based on the percentage difference formula, $\Delta\% = 100|\Phi - \min\{\lambda v, 1/\eta\}|/\left[0.5\left(\Phi + \min\{\lambda v, 1/\eta\}\right)\right]$, limit Φ_F is binding more intensively the closer η is to $\bar{\eta}$.

The socially optimal policy generates both costs and benefits in terms of social welfare relative to a policy of laissez-faire. Costs result from reducing the aggregate supply of capital services to firms and hence also aggregate output, below potential when limit Φ is binding (Figure 4, panel A). Because utility from consumption has decreasing marginal returns, costs are lower when aggregate capital services share $a = (1 - a_h)\phi\eta + \phi\eta \simeq 1$ is close to or at potential than they are when it is $a \ll 1$ far below. This explains why socially optimal limit Φ_F is slack in financially distressed regions in which $\eta < \eta_L$ is low.

Benefits result from keeping the pecuniary externalities in check. One benefit follows from mitigating the feedback loop in financially unstable regions in which amplification factors are high (Figure 4, panel C). This is done by containing both σ_q/σ_A and σ_η/σ_A locally around state $\bar{\eta}$ through both a direct and an indirect channel. First, $\phi = \Phi < \min\{\lambda v, 1/\eta\}$ reduces the amount of aggregate risk that financial intermediaries concentrate in their balance sheets, thus decreasing multiplicative factor $(\phi - 1)\,\varepsilon_q$ directly. Second, $\phi = \Phi < 1/\eta$ also reduces the sensitivity of the price of physical capital q to changes in wealth share η (Figure 4, panel B, slope $\partial q/\partial\eta$), further decreasing $(\phi - 1)\,\varepsilon_q$ indirectly via ε_q. Formally, the indirect channel is the consequence of fixing households as the marginal investor during the policy intervention region, which precludes that investor from switching between financial intermediaries (high valuation) and households (low valuation) in region $[\eta_L, \eta_H]$, even if a prolonged sequence of same-sign dZ shocks hits. Less powerful amplification of shocks dZ around state $\bar{\eta}$ helps stabilize boom-bust cycles around better-capitalized regions with larger wealth shares (Figure 4, panel D, line). Also, it helps increase stochastic steady state η_{ss} (Figure 4, panel D, dot). This benefit then implies that macroprudential policy not only mitigates economic fluctuations but also centers those fluctuations around a higher mean.

Another benefit results from depressing the price of physical capital q globally throughout the state space (Figure 4, panel B). This is also done by extending the region in which households are the marginal investors, from $\eta < \bar{\eta} < \eta_H$ to $\eta < \eta_H$. The global fall in q boosts dividend yields r_k/q—and also the collective profitability of financial intermediaries—in a global manner as well. This primarily facilitates the recapitalization of financial intermediaries; it does so especially when $\eta < \eta_L$ is low and limit Φ_F is slack. This benefit then primarily helps reduce both the frequency and the expected duration of systemic financially distressed events. It also helps shift invariant distribution g and stochastic steady state η_{ss} rightward in the state space.

The last benefit results from relaxing the IC leverage limit in financially distressed regions in which the limit is binding, i.e., $\lambda v = \phi < \Phi_F$ (Figure 3, panel B). This benefit helps increase the aggregate supply of capital services to firms—and thus also aggregate output—precisely when those quantities are far below potential. In other words, it helps reduce tail risk in the economy. This benefit is latent in region $\eta < \eta_L$ in the sense that it materializes when limit Φ_F is slack as a consequence of that same limit being binding in other regions of the state space.

These costs and benefits combined deliver a prudential interpretation for the socially optimal policy intervention. On the one hand, by tightening intermediary leverage when aggregate output is close to potential, socially optimal limit Φ_F

Table 1—Parameter Values

Parameter	Expression	Value
Panel A. Financial intermediation		
Productivity edge over households at financing firms	$1 - a_h$	30%
Fraction of divertible assets	$1/\lambda$	40%
Aggregate endowment of starting intermediaries	$\kappa\bar{k}$	1%
Life-span of intermediary company	$1/\gamma$	10
Panel B. Technology		
Expected growth rate of exogenous TFP	μ_A	4%
Volatility of growth rate of exogenous TFP	σ_A	7%
Labor share of output	α	55%
Aggregate capital stock	$\bar{k}$	1
Panel C. Preferences		
Time discount rate	ρ	2%
Frisch elasticity of labor supply	$1/\psi$	3
Relative utility weight of labor	χ	2.8
Panel D. Parameters relevant only in economies with sticky prices		
Elasticity of substitution of intermediate goods	ε	2
Arrival rate of opportunity to reset nominal price	θ	0.5 ln 2

Note: The time frequency is annual.

generates output losses when the economy is close to a boom. On the other hand, by inducing financial intermediaries to internalize a number of pecuniary externalities, socially optimal limit Φ_F reduces the likelihood of busts, and, conditional on the economy's being in a bust, it mitigates the severity and shortens the duration of economic meltdowns. All of this is reminiscent of an insurance policy that commands a payment during good times with the benefit of reducing the odds of bad times and eventually providing some relief when the bad times occur. Despite being countercyclical, socially optimal limit Φ_F is not strictly inversely related with wealth share η or aggregate output.

Risk-Return Analysis.—I conclude this first step in the policy intervention analysis by reporting the effects of the socially optimal policy on conditional means and standard deviations over the boom-bust cycle and on social welfare gains over the laissez-faire economy in Section IIF. Table 1 displays the parameter values in the model.

The time frequency is annual. The first three parameter values target unconditional means in the laissez-faire economy. Productivity difference $1 - a_h = 0.30$ targets $\int SR(\eta) g(\eta)\, d\eta = 0.20$, with $SR \equiv \left(r_{k/q} + \mu_q - r\right)/\sigma_q$ being the Sharpe ratio for financial intermediaries. Fraction of divertible assets $1/\lambda = 0.40$ targets $\int \phi(\eta) g(\eta)\, d\eta = 3.25$, and the initial endowment share $\kappa = 0.01$ targets $\int \eta g(\eta)\, d\eta = 0.18$. The remaining parameter values are standard. The arrival rate of dividend payouts $\gamma = 0.1$ is consistent with Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), which interpret the frequency of dividend payouts as the expected life span of individual financial intermediary companies. The drift and diffusion processes of exogenous TFP A are $\mu_A = 0.04$ and $\sigma_A = 0.07$, respectively. The labor share of output is $\alpha = 0.55$. Aggregate capital stock $\bar{k} = 1$ is a

Table 2—Comparison of Key Financial and Macroeconomic Variables over the Boom-Bust Cycle between the Laissez-Faire and the Socially Optimal Regulated Economy

	Financial and macroeconomic variables							
	Dividend yields (in logs)		Tobin's Q		Endogenous TFP		Policy-based limit on leverage	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Panel A. Busts								
Laissez-faire	−3.49	1.15	1.38	0.72	0.893	0.57		
Socially optimal	−3.47	1.17	1.42	0.67	0.894	0.60		
Panel B. Transitions								
Laissez-faire	−3.57	5.49	1.32	4.00	0.936	2.58		
Socially optimal	−3.57	5.77	1.36	3.78	0.946	3.07	0.020	1.91
Panel C. Booms								
Laissez-faire	−3.72	0.47	1.17	2.26	1.000	0.00		
Socially optimal	−3.67	0.40	1.22	1.89	1.000	0.00		

Notes: The table reports the conditional means and standard deviations of the logarithmic of dividend yields, i.e., $\ln(r_k/q)$. The rest of the conditional means and standard deviations are computed using the actual units of the underlying variables. Standard deviations are expressed in percentage terms. As in the text, the intensity of the policy-based limit on leverage is measured by the percentage difference formula: $\Delta\% = 100|\Phi - \min\{\lambda v, 1/\eta\}|/\left[0.5\left(\Phi + \min\{\lambda v, 1/\eta\}\right)\right]$. Busts occur when $\zeta < 0.90$, transitions do so when $0.90 \leq \zeta < 1$, and booms occur when $\zeta = 1$. The time frequency is annual.

normalization. The subjective time discount rate is $\rho = 0.02$. The Frisch elasticity of labor supply is $1/\psi = 3$, and the relative utility weight of labor is $\chi = 2.8$ to ensure that aggregate labor hours $l_E = 1/3$ are one-third of the time unit.[15]

Table 2 compares conditional means and standard deviations over the boom-bust cycle between the laissez-faire and the socially optimal regulated economy. It focuses on those of dividend yields r_k/q, Tobin's Q v, and endogenous TFP $\zeta = a^{1-\alpha}$. Also, it reports the conditional mean and standard deviation of percentage difference formula $\Delta\% = 100|\Phi - \min\{\lambda v, 1/\eta\}|/\left[0.5\left(\Phi + \min\{\lambda v, 1/\eta\}\right)\right]$ over the region in which $\Phi = \phi < \min\{\lambda v, 1/\eta\}$ is binding. I impose busts whenever aggregate output falls by 10 percent below potential—which implies that $\Phi_F = \phi < \min\{\lambda v, 1/\eta\}$ is binding only within transitions.

Table 2 shows that socially optimal limit Φ_F is binding 26 percent of the time. When it is, it restricts intermediary leverage below $\min\{\lambda v, 1/\eta\}$, on average, by 2.0 percent, in terms of $\Delta\%$, with a standard deviation of 1.9 percent. Relative to laissez-faire, the socially optimal policy increases the conditional means—and also reduces the conditional standard deviations—of almost all of the variables in Table 2 over the three phases of the boom-bust cycle. In addition, it reduces the frequency of both busts and booms—from 12 percent to 9 percent and from 6 percent to 2 percent, respectively—and increases that of transitions. All in all, the socially optimal policy reduces the unconditional mean of aggregate productivity losses from

[15] Target values are also standard. Everything else constant, larger values for $1 - a_h$, γ, σ_A, or α increase the range and dispersion of a, r_k/A, q/A, and g, while larger values for λ or κ do the opposite. The value for μ_A does not actually affect the equilibrium. This is because A is the economic trend and preferences for consumption are logarithmic. The last two parameters in Table 1 are either not defined or irrevelant in the economy with flexible prices.

financial disintermediation without actually increasing their unconditional standard deviation. In particular, while the former falls from 6.42 percent to 5.75 percent, the latter barely falls from 3.30 percent to 3.25 percent. This means that the socially optimal policy improves both the risk and return profiles of financial intermediation. Ultimately, it improves social welfare by 0.67 percent in terms of annual consumption equivalent.

B. *Monetary Policy in the Financially Unregulated Economy*

So far, the policy analysis has abstracted away from monetary considerations. To incorporate those consideration into the analysis, in what follows I restrict attention to employment gaps $\ln(l/l_E)$ and policy-based leverage limits Φ that do not depend on state ω. This restriction highly simplifies the model, because it renders the economy proportional to A/ω rather than to only A.[16] Based on this result, hereafter, I interpret $\ln(l/l_E)$ and Φ as state-contingent policy rules that respond only to cyclical deviations from trend or to boom-bust cycles—and not, in particular, to endogenous fluctuations in normalized trend A/ω. In this section (i.e., Section IIIB), I abstract away from macroprudential policy interventions, but I incorporate those interventions in the next, and last, section.

Real and Welfare Effects of Monetary Policy.—To examine the effects of monetary policy intervention in isolation, I proceed progressively in two steps. First, I restrict attention to employment gaps that remain constant over state η. I refer to this class of employment gaps as acyclical. Then, I consider employment gaps that can instead vary over that state; I refer to this other class as cyclical. The acyclical class will allow me to derive closed-form expressions that are useful for understanding the effects of the cyclical class (which is more interesting). Regardless of its cyclicality (or lack thereof), monetary policy maximizes social welfare in the long run:

$$\max_{\ln(l/l_E)} \left[\tilde{U}(\eta) + \hat{U}(\omega,\eta)\right] g(\omega,\eta) d(\omega,\eta), \tag{38}$$

subject to the conditions of the Markov equilibrium, given $\Phi = +\infty$. Value $\hat{U}$ is the present discounted value of utility losses from instability in inflation, conditional on the economy's being in state (ω,η). It satisfies the HJB equation

$$\rho\hat{U} = \ln\frac{1}{\omega} + \alpha \ln l - \chi\frac{l^{1+\psi}}{1+\psi} + \frac{\partial \hat{U}}{\partial \omega}\mu_\omega \omega + \frac{\partial \hat{U}}{\partial \eta}\mu_\eta \eta + \frac{1}{2}\frac{\partial^2 \hat{U}}{(\partial \eta)^2}(\sigma_\eta \eta)^2. \tag{39}$$

Value $\tilde{U}$ satisfies the same HJB equation (37) as in the flexible price economy.

[16] Specifically, mappings $\{\omega q/A, v\}$ become the solution to an ODEs only in state η rather than being the solution to a PDEs in both states ω and η. The ODEs is exactly the same as that in the economy with flexible prices, except that aggregate labor l is a general function of state η rather than the constant $l = l_E$. See the online Appendix for details.

Acyclical Policies.—Under this class of policy rules, financial markets and boom-bust cycles behave the same as in the laissez-faire economy. Put differently, monetary policy has no impact on the profitability or leverage decisions of financial intermediaries, nor on the stability of the financial system. This monetary neutrality result holds because asset prices respond one-to-one to permanent changes in asset returns. Specifically, relative to the laissez-faire economy, rental rate r_k is scaled up by a constant factor of $(l/l_E)^{1+\psi+\alpha}$ (as expression (31) shows); consequently, the price of physical capital $q \propto (l/l_E)^{1+\psi+\alpha}$ is also scaled up by the same factor. Dividend yields r_k/q and intermediary profitability, therefore, are the same as in the laissez-faire economy, and so also is Tobin's Q, because value v is ultimately a present discounted value of leveraged dividend yields $\phi r_k/q$. Monetary policy, however, affects both inflation and price dispersion. In particular, in the invariant distribution, price dispersion ω is a constant and is given by

$$\omega = \left(1 - \frac{\varepsilon - 1}{\theta}\pi\right)^{\frac{\varepsilon}{\varepsilon-1}} \frac{1}{1 - \frac{\varepsilon}{\theta}\pi}, \tag{40}$$

with inflation π also being a constant and the positive root of quadratic equation

$$0 = \left\{(\varepsilon-1)\varepsilon\pi^2 - \left[(\rho+\theta)\varepsilon + \theta(\varepsilon-1)\right]\pi + (\rho+\theta)\theta\right\}\left[1 - \left(\frac{l}{l_E}\right)^{1+\psi}\right] + \rho\pi. \tag{41}$$

These two expressions combined imply that $\omega = 1$ if and only if $\ln(l/l_E) = \pi = 0$.[17] Put differently, in this class of policy rules, inflation stabilization is socially optimal, and it attains the same social welfare as the laissez-faire economy in Section IIF. The two expressions combined also imply that price dispersion ω is asymmetric at $\pi = 0$. This makes deflation $\pi < 0$ socially preferable to inflation $\pi > 0$ for a same absolute inflation rate, $|\pi| > 0$.

Cyclical Policies.—Under the other class of policy rules, in contrast, the monetary neutrality result above does not hold. In particular, also relative to the laissez-faire economy, rental rate r_k is scaled up by factor $(l/l_E)^{1+\psi+\alpha}$, but the price of physical capital q is less than proportional to that factor. This happens because the factor (now) varies over state η, and because asset prices respond less than one-to-one to temporary changes in asset returns. The weaker response of the price of physical capital to the factor renders dividend yields r_k/q—and hence also value v—positively related to it. The sensitivity of the price of physical capital, however, is still the strongest of the three, with that of dividend yields being stronger than that of Tobin's Q. This is because q is apresent discounted value of r_k, whereas v is ultimately a present discounted value of $\phi r_k/q$.

[17] Expression (40) follows from $\mu_\omega = 0$ and expression (41) from substituting (12) and (14) into (10). If $\ln(l/l_E) \geq 0$, (41) delivers a single possible equilibrium value for π. If $\ln(l/l_E) < 0$, it instead delivers two. In the former case, the equilibrium is stable, while in the latter, only one is stable. Because I analyze equilibria in the invariant distribution, in the latter case, I consider only the stable equilibrium, which turns out to be the one with lowest deflation rate $\pi < 0$ in absolute terms. See the online Appendix for details.

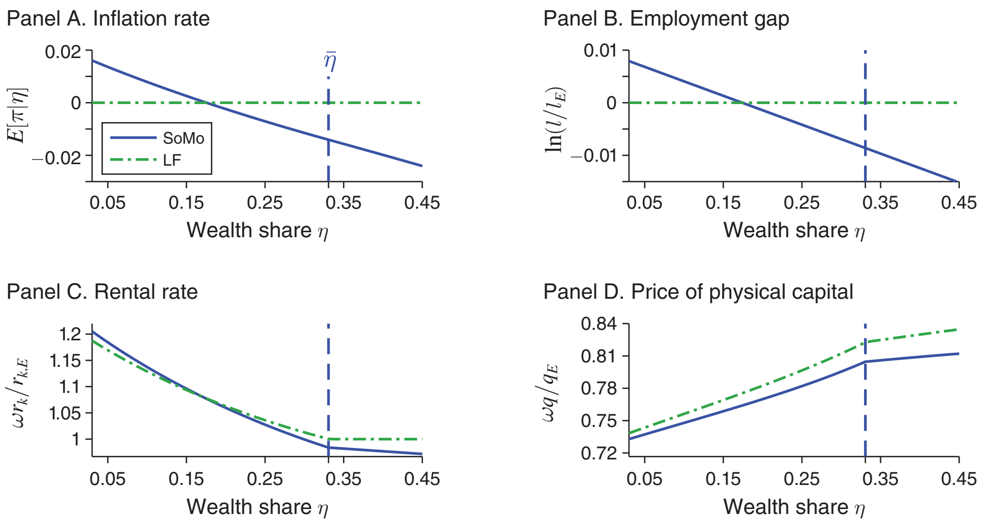

Figure 5. Equilibrium in the Economy with the Socially Optimal Monetary Policy (SoMo)

Notes: The blue lines plot the Markov equilibrium in the economy with the socially optimal monetary policy (SoMo). The dashed vertical line indicates the position of threshold state $\bar{\eta}$. The dash-dot green lines plot the Markov equilibrium in the laissez-faire economy (LF). The time frequency is annual.

All in all, the big difference between the two classes of policy rules is that only in this one does monetary policy affect intermediary profitability, intermediary leverage, boom-bust cycles, and the stability of the financial system relative to those in the laissez-faire economy. For instance, an employment gap that is countercyclical (i.e., inversely related to wealth share η) exerts upward pressure on r_k, q, r_k/q, and v when η is low, in that order in terms of degree of intensity, and downward pressure on the same variables when η instead is high, with the same intensity order (Figure 5, panels B, C, and D). These pressures make dividend yields r_k/q more countercyclical; therefore, they affect leveraged dividend yields $\phi r_k/q$ and intermediary profitability proportionally more during busts, when intermediary leverage ϕ is relatively high. The pressures also render the price of physical capital q smoother over the boom-bust cycle. (Put differently, they render q less sensitive to changes in wealth share η.) As a consequence, the pressures also help contain amplification factors σ_q/σ_A and σ_η/σ_A (Figure 6, panel A). All in all, the effects from the pressures combined help keep boom-bust cycles more stable around better-capitalized phases closer to booms. A procyclical employment gap, basically, does the opposite; notably, it renders boom-bust cycles more bimodal.

Optimal Policy.—Under a more general class of policy rules that also encompass the cyclical policies, inflation stabilization is no longer socially optimal. Rather, social optimality requires that the employment gap be countercyclical and oscillate close to zero asymmetrically, with a bias toward negative terrain (Figure 5, panel B). Equivalently, because optimal real price p_*/p is proportional to the present discounted value of marginal production costs $x(y_j)/y_j = \left(l/l_E\right)^{1+\psi}/\omega$, social optimality requires that inflation behave in a manner similar to the employment gap

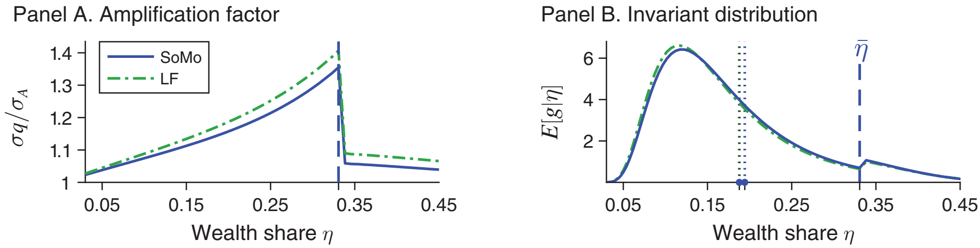

Figure 6. Amplification Factors and Invariant Distribution under the Socially Optimal Monetary Policy (SoMo)

Notes: The blue lines plot the Markov equilibrium in the economy with the socially optimal monetary policy (SoMo). The dashed vertical line indicates the position of threshold state $\bar{\eta}$. The (dash-dot) green lines plot the Markov equilibrium in the laissez-faire economy (LF). The dotted lines indicate the position of the stochastic steady state, η_{ss}. The time frequency is annual.

(Figure 5, panel A). Figure 5 and Figure 6, indeed, plot the Markov equilibrium under the socially optimal monetary policy, contrasting the equilibrium with that under inflation stabilization.[18]

Relative to inflation stabilization, the price of physical capital is low during busts (Figure 5, panel D) despite the employment gap being high during those same phases (Figure 5, panel A). This is because the employment gap is largely low during booms. This latent effect during busts further boosts dividend yields r_k/q and intermediary profitability when η is low; consequently, it further helps keep boom-bust cycles stable around well-capitalized regions in which η is high (although the total effect is small, for the reasons I will explain below). The employment gap remains close to zero throughout the boom-bust cycle to contain price dispersion. The tilt toward the negative domain further helps with this latter concern because of the asymmetry of price dispersion around $\pi = 0$. All in all, social welfare increases, because, starting from a situation with instability in financial intermediation but stability in inflation (as in the laissez-faire economy), on the margin, improvements in the former source of utility losses are of first-order importance relative to worsenings in the latter source.

The socially optimal monetary policy improves social welfare over the laissez-faire economy by 0.13 percent, reducing social welfare losses from financial disintermediation by 0.18 percent while increasing those from instability in inflation by 0.05 percent. However, relative to the socially optimal macroprudential policy in the flexible price economy (Table 2 versus Table 3), the effects on the boom-bust cycle and social welfare are smaller. This is primarily because monetary policy cannot preclude financial intermediaries from being the marginal investor, which severely limits its capacity to positively affect dividend yields r_k/q, intermediary profitability, and Tobin's Q throughout the boom-bust cycle.

[18] To compute the socially optimal policy, I proceed numerically, and to simplify the numerical method, I restrict mapping $\ln(l/l_E)$ to be a polynomial function of η. I use the parameter values in Table 1. The elasticity of substitution between intermediate goods is $\varepsilon = 2$, and arrival rate is $\theta = 0.5 \ln 2$. These two parameters do not affect the ODEs for $\{\omega q/A, v\}$; rather, they affect only p_*/p, π, and μ_ω. Larger values for ε generate a larger π as well as a larger $\int \omega g(\omega,\eta) d(\omega,\eta)$. Larger values for θ do the opposite.

Table 3—Behaviors of Key Financial and Macroeconomic Variables over the Boom-Bust Cycle in the Economy with the Socially Optimal Monetary Policy (SoMo)

	Financial and macroeconomic variables					
	Dividend yields (in logs)		Endogenous TFP (only component $\omega\zeta$)		Inflation rate	
Cyclical phase	Mean	SD	Mean	SD	Mean	SD
Busts	−3.48	1.08	0.893	0.56	0.0107	0.12
Transitions	−3.56	5.23	0.937	2.60	0.0007	0.60
Booms	−3.70	0.29	1.000	0.00	−0.0185	0.33

Notes: The table reports the conditional means and standard deviations of the logarithmic of dividend yields, i.e., $\ln(r_k/q)$. The rest of the conditional means and standard deviations are computed using the actual units of the underlying variables. Standard deviations are expressed in percentage terms. Busts occur when $\omega\zeta < 0.90$, transitions do so when $0.90 \leq \omega\zeta < 1$, and booms occur when $\omega\zeta = 1$. The time frequency is annual.

C. *Monetary and Macroprudential Policy in the Original Economy*

This last section incorporates the two policy instruments into the policy intervention analysis. To study the nonstrategic interactions between the two, I assume that instruments jointly maximize social welfare in the long run. I refer to the (then-) socially optimal policy intervention as the coordinated policy. To study coordination considerations, I contrast the coordinated policy with an ad hoc, noncoordinated policy intervention, which results from assigning separated objectives to the instruments and making them interact with each other strategically. Specifically, the assignment of individual objectives is such that monetary policy is concerned only with inflation stability (i.e., it minimizes the utility losses from instability in inflation in the long run) and macroprudential policy is concerned only with financial stability (i.e., it minimizes the losses from financial disintermediation in the long run, as well). The strategic interaction is such that policy instruments set their rules simultaneously (at the initial stage that takes place before time unfolds and the economy unravels) while taking the other's rule as given. This implies that the outcome of their strategic interaction is consistent with the concept of the Nash equilibrium. I refer to the optimal policies under the noncoordinated policy arrangement as the noncoordinated policy. The individual objectives and strategic interactions in this arrangement are the typical ones in developed economies.[19]

Coordinated Policy.—Social optimality requires that the instruments behave in a manner similar to the one that it requires in the cases in which only one of them is available. A key difference in behaviors, however, is that monetary policy must deviate from inflation stabilization less intensively and macroprudential policy must restrict intermediary leverage less often and also less intensively. This difference arises because sharing the costs of safeguarding financial stability between the two instruments is socially desirable. In particular, safeguarding financial stability only with macroprudential policy generates unnecessarily large forgone capital services

[19] As in the previous sections, I derive optimal policies numerically, and to facilitate the solution method, I restrict mappings $\ln(l/l_E)$ and Φ to be polynomial functions of state η. I use the parameter values in Table 1.

Table 4—Behaviors of Key Financial and Macroeconomic Variables over the Boom-Bust Cycle in the Economy with the Coordinated Policy

	Financial and macroeconomic variables							
	Dividend yields (in logs)		Endogenous TFP (only component $\omega\zeta$)		Inflation rate		Policy-based limit on leverage	
Cyclical phase	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Busts	-3.46	1.14	0.894	0.60	0.0056	0.06		
Transitions	-3.56	5.56	0.948	3.12	-0.0005	0.41	0.016	1.80
Booms	-3.65	0.38	1.000	0.00	-0.0131	0.09		

Note: Same clarifications as in Table 3.

to firms when limit $\Phi = \phi < \min\{\lambda v, 1/\eta\}$ is binding. Doing this only with monetary policy, on the other hand, generates unnecessarily large price dispersion and instability in employment throughout the boom-bust cycle. A social willingness for cost sharing thus renders monetary policy and macroprudential policy substitutes as far as financial stability considerations are concerned.

The coordinated policy improves social welfare over the laissez-faire economy by 0.78 percent, with social welfare losses from financial disintermediation falling by 0.80 percent and those from instability in inflation increasing by 0.02 percent. Most of these social welfare gains come from macroprudential policy. Specifically, relative to the economy without that policy instrument, social welfare increases by $0.80 - 0.14 = 0.66$ percent; relative to that without monetary policy, it does so by only $0.80 - 0.67 = 0.13$ percent. The corresponding differences in terms of policy rules are also smaller for macroprudential policy.

Noncoordinated Policy.—Under the noncoordinated policy arrangement, a dominant strategy for monetary policy is inflation stabilization, and the best response of macroprudential policy to inflation stabilization is the socially optimal limit of the flexible price economy. In what follows, I assume that monetary policy plays inflation stabilization. In the Nash equilibrium, therefore, the economy behaves as the socially optimal regulated economy with flexible prices in Section IIIA.

Policy Comparison.—Relative to the noncoordinated policy, the coordinated policy intervention thus improves social welfare only moderately. In particular, social welfare gains are $0.80 - 0.67 = 0.13$ percent; that is, the same as those over the socially optimal regulated economy with flexible prices. Social welfare improvements are larger the higher the productivity edge $1 - a_h$ or the more sluggish the optimal prices p_*/p—i.e., the smaller θ.

IV. Conclusion

In this paper, I show that macroprudential policy interventions during booms have beneficial, latent effects during busts. In particular, by improving intermediary franchise value throughout the boom-bust cycle, those interventions relax forward-looking funding constraints during busts, which helps mitigate economic meltdowns. Also, I show that contractionary monetary policy interventions during booms also have latent beneficial effects during busts. Lastly, I show that coordination between the two policy instruments improves social welfare over more typical, noncoordinated policy interventions in developed economies, but improvement is moderate.

The welfare gains from policy coordination depend on at least three critical features of the model. The first feature is the lack of a trade-off in the long run between inflation stability and macroeconomic stability in the version without funding frictions. This trade-off could be incorporated by introducing cost-push shocks, for instance, at the expense of adding one more aggregate state. A second feature is the lack of an investment technology in physical capital. This could also be incorporated into the model and at that same expense. However, rather than increasing the costs of using monetary policy to mitigate boom-bust cycles, as the first feature would do, it would instead weaken the relative beneficial effects of macroprudential policy to monetary policy during those cycles, since lower asset prices would lead to a decline in investment rates.

The last feature concerns the set of available policy instruments and restrictions on those instruments. I restrict attention to nominal interest rates and state-contingent limits on leverage, because they are the most standard in the literature (and also the least subject to political objections). However, other policy instruments worth considering would be equity injections or additional lending facilities, both directed to financial intermediaries.[20] Because these additional policy instruments would also help stimulate the profitability of financial intermediaries during busts, the need for interest rate policies for financial stability considerations would naturally be lower. Incorporating the possibility of an occasionally binding ELB on nominal rates in the original model would increase the relative benefits from the coordinated policy—but this last feature would preclude characterizing the financial block of the model as the solution to an ODEs and would thus pose additional challenges for the analysis.

REFERENCES

Brunnermeier, Markus K., and Yuliy Sannikov. 2014. "A Macroeconomic Model with a Financial Sector." *American Economic Review* 104 (2): 379–421.

Calvo, Guillermo A. 1983. "Staggered Prices in a Utility-Maximizing Framework." *Journal of Monetary Economics* 12 (3): 383–98.

Carrillo, Julio A., Enrique G. Mendoza, Victoria Nuguer, and Roldán-Peña Jessica. 2016. "Tight Money-Tight Credit: Tinbergen's Rule and Strategic Interaction in the Conduct of Monetary and Financial Policies." https://www.norges-bank.no/contentassets/3e9e16ea85e443598bb801484a01b42e/carrillo.pdf.

Clarida, Richard, Jordi Galí, and Mark Gertler. 1999. "The Science of Monetary Policy: A New Keynesian Perspective." *Journal of Economic Literature* 37 (4): 1661–1707.

Collard, Fabrice, Harris Dellas, Behzad Diba, and Olivier Loisel. 2017. "Optimal Monetary and Prudential Policies." *American Economic Journal: Macroeconomics* 9 (1): 40–87.

Dávila, Eduardo, and Anton Korinek. 2018. "Pecuniary Externalities in Economies with Financial Frictions." *Review of Economic Studies* 85 (1): 352–95.

[20] The Federal Reserve system deployed a variant of the former under the Troubled Asset Relief Program (TARP) right after the bankruptcy of Lehman Brothers, and the European Central Bank (ECB) deployed a variant of the latter under the Long Term Refinancing Operation (LTRO) program during the European sovereign debt crisis.

De Paoli, Bianca, and Matthias Paustian. 2017. "Coordinating Monetary and Macroprudential Policies." *Journal of Money, Credit and Banking* 49 (2–3): 319–49.

Di Tella, Sebastian. 2019. "Optimal Regulation of Financial Intermediaries." *American Economic Review* 109 (1): 271–313.

Galí, Jordi. 2015. *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework and Its Applications*. 2nd ed. Princeton, NJ: Princeton University Press.

Gertler, Mark, and Peter Karadi. 2011. "A Model of Unconventional Monetary Policy." *Journal of Monetary Economics* 58 (1): 17–34.

Gertler, Mark, and Nobuhiro Kiyotaki. 2010. "Chapter 11—Financial Intermediation and Credit Policy in Business Cycle Analysis." In *Handbook of Monetary Economics*, Vol. 3, edited by Benjamin M. Friedman and Michael Woodford, 547–99. Amsterdam: North-Holland.

Gourio, François, Anil K. Kashyap, and Jae W. Sim. 2018. "The Trade Offs in Leaning against the Wind." *IMF Economic Review* 66: 70–115.

Gromb, Denis, and Dimitri Vayanos. 2002. "Equilibrium and Welfare in Markets with Financially Constrained Arbitrageurs." *Journal of Financial Economics* 66 (2–3): 361–407.

He, Zhiguo, and Arvind Krishnamurthy. 2013. "Intermediary Asset Pricing." *American Economic Review* 103 (2): 732–70.

Lorenzoni, Guido. 2008. "Inefficient Credit Booms." *Review of Economic Studies* 75 (3): 809–33.

Maggiori, Matteo. 2017. "Financial Intermediation, International Risk Sharing, and Reserve Currencies." *American Economic Review* 107 (10): 3038–71.

Mendicino, Caterina, Kalin Nikolov, Javier Suarez, and Dominik Supera. 2019. "Bank Capital in the Short and in the Long Run." ECB Working Paper 2286.

Phelan, Gregory. 2016. "Financial Intermediation, Leverage, and Macroeconomic Instability." *American Economic Journal: Macroeconomics* 8 (4): 199–224.

Svensson, Lars E.O. 2017. "Cost-Benefit Analysis of Leaning against the Wind." *Journal of Monetary Economics* 90: 193–213.

Tirole, Jean. 2010. *The Theory of Corporate Finance*. Princeton, NJ: Princeton University Press.

Van der Ghote, Alejandro. 2021. "Replication data for: Interactions and Coordination between Monetary and Macroprudential Policies." American Economic Association [publisher], Inter-university Consortium for Political and Social Research [distributor]. https://doi.org/10.3886/E118645V1.

Woodford, Michael. 2011. *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton, NJ: Princeton University Press.