Banks and Endogenous Firm Entry

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Abstract

The Global Financial Crisis brought much needed attention to the hazards of highly leveraged bank balance sheets. In the wake of the crisis, the rate of consolidation of non-financial firms has increased, and more large firms are turning inward to finance new investments. This begs the question, what are the consequences of firm leverage as compared to bank leverage? This paper starts with a standard RBC model augmented with balance-sheet constrained financial intermediaries. To address the question, we then introduce financially constrained firms that own the country's capital stock as they enter and exit endogenously. We show principally from the estimated model that much of the variation in U.S. consumption and investment originates from constraints on firm balance sheets, rather than constraints on bank balance sheets. Modeling the two agents independently with separate but related sources of financing allows the model to parse the two sources of volatility, and to take a stand on which is empirically a greater source of variance. The paper's results are increasingly relevant in a world with large firms that depend more on internal sources of finance, instead of borrowing from banks or government entities.

1 Introduction

The fall in the number of productive firms is a likely contributor to the slow recovery in the U.S. following the 2008 Global Financial Crisis (GFC). A key result from the theoretical and empirical literature is that destruction in the stock of firms takes time to rebuild, particularly for industries faced by sunk entry costs and financial constraints. A fast-growing literature focuses on the interplay between firm entry and financial crises, and argues convincingly that firm entry is an important transmission mechanism for financial shocks. Much of this literature, however, abstracts from the many interrelationships between borrowing firms and lending banks, so that a 'financial shock' is usually only modeled as applicable to one side of the credit market or the other—but an observation since the crisis is that a shock's origin can matter. Christiano, Motto, and Rostagno (2010) find that a model with two financial shocks are valuable for understanding the GFC.[1] In this paper, we ask then, does the role of firm entry following a financial shock depend on where the financial shock originated?

To address the question, we develop an RBC model with the unique feature that it imposes leverage constraints on both firms *and* banks, each subject to independently distributed, exogenous shocks. While the modeling of the banking sector is in line with the literature on constrained financial intermediaries (e.g. Gertler and Karadi (2011)), the firm sector is modeled with endogenously entering firms, subject to sunk costs and an exogenous exit rate similar to Ghironi and Melitz (2005). Firm entry dynamics prove to be essential for our results. Even while total profits fall after bank and firm leverage shocks, the profits of surviving firms rise due to increased market power after firms exit. When faced with a bank shock, these additional profits are reinvested in unproductive debt-repurchases as the costs of maintaining high debt levels rises with the lending spread. Under a firm-shock, however, firms re-invest profits in productive capital, igniting a credit boom that grows the capital stock.[2] The model is then estimated using standard Bayesian techniques on U.S. data, and we provide a historical accounting of the shocks in the most recent U.S. recessions of 2001 and 2008. Using a standard variance-decomposition, we arrive at estimates for the contribution of each shock to the total market's volatility. Firm financial shocks account for roughly 1/3 to a half of volatility in the market, and financial shocks contribute roughly as much.

When we augment the model to include sticky prices, we show that the interest rate policy following a simple Taylor rule reacts differently depending on the shock. In particular, rates rise in response to a firm-shock, and fall in response to a bank shock. Under sticky-prices, this split interest rate response leads to a temporary growth in output under both shocks. The intuition behind the success of a simple Taylor-rule is this: under a firm-shock, higher interest rates encourage savings to feed the investment boom. Under a bank-shock, lower interest rates and higher inflation keeps the real price of consumption low, so that banks are less constrained in their lending and, as a result, keep down the price of borrowing.

The importance of multiple, distinct or conditional sources of financial frictions are well

[1]While the first of their shocks perturbs the dispersion of the returns to investment, the second is a 'financial wealth shock' that lowers the total value of equity in the economy.

[2]This mechanism is also described and documented in Bergin, Feng, and Lin (2017)

established in the financial literature. Iacoviello (2005) for instance, develops a 'conditional' financial accelerator, where the mechanism only amplifies shocks that lead to a positive correlation between output and inflation. Shocks that lead to a negative relationship between output and inflation are instead dampened. Similar papers that build on this framework and show the conditional nature of financial shocks include Iacoviello and Neri (2010) and Guerrieri and Iacoviello (2017). Christiano et al. (2010) has two financial shocks in their model, where the first perturbs the dispersion of the returns to investment, and the second is a 'financial wealth shock' that lowers the total value of equity in the economy. Brand, Isoré, and Tripier (2019) insert frictions on both the firm side through search and matching frictions, and on the bank side as lenders and borrows settle on a contract with costly state verification. Beck, Colciago, and Pfajfar (2014) provide a literature review of some recent contributions.

This paper is closely related to the growing literature on firm entry dynamics, leading examples of which include Bilbiie, Ghironi, and Melitz (2007), Bilbiie, Ghironi, and Melitz (2012), and Bergin et al. (2017). A subset of related papers in this literature focus on the dynamics and investment choices of entering firms, usually with heterogeneous firm models that build on the framework in Hopenhayn (1992). Palazzo, Clementi, et al. (2010) uses this framework to model the investment decisions of entering firms, and successfully matches their model to U.S. data on the dispersion of firm assets across time and firm-age. Clementi, Khan, Palazzo, and Thomas (2014) build on Palazzo et al. (2010) to put particular emphasis on the existing firm's decision to continue producing, exit, or invest to better match the distribution of firms in the U.S. Siemer (2016) shows that new firms are particularly sensitive to financial constraints, and the data shows that during tight credit market conditions, a missing generation of entrants can make the post-crisis recovery especially slow. Using a similar framework, and with special attention to crises, Khan and Thomas (2013) and Khan and Thomas (2008) show that if capital is firm-specific, that is, if capital markets are not perfectly competitive, then rapid periods of entry/exit will lead endogenously to falls in TFP.

The significance of firm leverage for the macro-economy, particularly of large firms, is not new. In one strand of literature, Gabaix (2011) contends that a portion, roughly 1/3, of U.S. volatility in output is due to shocks to individual, large firms through sudden increases or decreases in sales or large one-time dividend payouts. Acemoglu, Carvalho, Ozdaglar, and Tahbaz-Salehi (2012) argue that the same results can follow from an input output structure with asymmetric relationships between industries. Also, Acemoglu, Ozdaglar, and Tahbaz-Salehi (2017) and Acemoglu, Ozdaglar, and Tahbaz-Salehi (2013) extend this mechanism to explain tail risks, or the likelihood of extreme business cycle behavior during booms and busts. Alfaro, Asis, Chari, and Panizza (2019) applies the theory of granular firms to the role of firm leverage. They argue that this mechanism is even more important for financially sophisticated economies because the presence of multi-national firms drives up their Herfindahl index and makes the country more vulnerable to firm-level shocks.

In the next section we lay out the structure of the economy with particular attention given to banks and differentiated goods firms. The estimation of the model is then discussed and the results are presented. In Appendix C, we present an extended version of the model to include sticky prices to show that our results are robust in this setting also.

2 A Model of Constrained Banks and Firms

We introduce banking frictions into a standard closed economy RBC model with endogenous firm entry. The unique feature of this model is that both firms and banks are constrained in the degree that they can invest. While the firm is constrained in the amount of capital they can purchase for next period, the bank is constrained in the quantity of loans they can supply to the firm. Effectively, this parses financial constraints into the two sides of the credit market, supply and demand, with the goal that the model can identify the unique channels through which shocks spill out into the general equilibrium.

There are two main agents in the model. First, a continuum of monopolistically competitive firms produce a differentiated good using capital and labor. Along with normal operation profits, we allow these firms to purchase and own capital, sell claims on their profits, and have loans from a financial intermediary. The second principal agent, the intermediary or 'bank', follows roughly from Gertler and Karadi (2011) in that their profitable investments are funded by consumer deposits, but they are constrained in how much leverage they can extend. Banks supply loans and purchase the claims on profits using non-contingent one-period nominal bonds as their funding source. As is standard in the RBC literature, time is discrete and infinite. Two shocks are the focus of this paper: a bank financial shocks (Γ_t^B), and a firm financial shock (Γ_t^F) that each follow autocorrelated but independent process around their calibrated steady state values. In the spirit of estimating the model and parsing the separate roles for these two shocks, we also include a standard set of shocks to TFP and government spending, each arriving unexpectedly in the economy at the start of each period. A representative consumers exhibits rational expectations when making investment decisions for next period, and since we assume the bank and firms are owned by the consumer, they too exhibit rational expectations.

In the remainder of this section, we outline the details of the model. In addition to the bank and differentiated goods firms, a representative consumer supplies labor and holds deposits with the bank to purchase consumption of a final good. Final goods are a composite of the differentiated intermediate good and a non-differentiated good that requires only labor to produce.

2.1 Market Structure

Final goods, G_t, are produced by perfectly competitive firms using inputs from two sources: a non-differentiated intermediate good G_t^N, and a composite of the differentiated goods, G_t^D. Intermediate goods are combined using a standard Constant Elasticity of Substitution (CES) aggregator with elasticity ϕ, while the parameter ϱ determines the degree of preference in production for good N versus D:

$$G_t = \left(\varrho^{1/\phi}\left(G_t^H\right)^{\frac{\phi-1}{\phi}} + (1-\varrho)^{1/\phi}\left(G_t^D\right)^{\frac{\phi-1}{\phi}}\right)^{\frac{\phi}{\phi-1}}. \tag{1}$$

From the cost minimization problem of final-goods firms, the final price, P_t, is a weighted composite of prices of N and D: $P_t = \left(\varrho\left(P_t^N\right)^{1-\phi} + (1-\varrho)\left(P_t^D\right)^{1-\phi}\right)^{\frac{1}{1-\phi}}$. The corresponding demand for each input is standard,

$$G_t^N = \left(\frac{P_t^N}{P_t}\right)^{-\phi} G_t \varrho, \tag{2}$$

$$G_t^D = \left(\frac{P_t^D}{P_t}\right)^{-\phi} G_t (1-\varrho). \tag{3}$$

Demand for differentiated goods is itself a composite of the many varieties of intermediates, supplied by a total of n_t firms each indexed by i, and subject to an elasticity of substitution (σ) between varieties:

$$G_t^D = \left(\int_0^{n_t} (g_t(i))^{\frac{\sigma-1}{\sigma}} di\right)^{\frac{\sigma}{\sigma-1}}. \tag{4}$$

In the next section we will show, as in most models with differentiated producers (e.g. Ghironi and Melitz (2005)), that prices will be identical across varieties following from the assumption that markets for productive resources (capital and labor) are perfectly competitive. With n_t firms, we can express the demand for each variety as a function of the number of firms in the market producing at time t. The demand for each variety is

$$g_t(i) = (n_t)^{\frac{-\sigma}{\sigma-1}} G_t^D. \tag{5}$$

The price index for all varieties is, likewise, a function of the individual firm's prices and the number of firms, $P_t^H = p_t(i) (n_t)^{\frac{1}{1-\sigma}}$. The next section provides details on the consumers' problem, who will consume these final goods using their income from supplied labor and investments.

2.2 Consumers

A representative consumer purchases consumption (C_t) using earnings from labor supplied (L_t), and returns from holding domestic deposits with the bank in the form a one-period non-contingent nominal bond (B_t). Providing labor will earn the consumer a wage of W_t, and savings will earn the consumer a return of R_{t-1}. T_t are taxes that fund a government out of final goods. Lump-sum payment also arrive to the consumer from the profits and net assets of exiting banks and firms. We group these payments into a single term, Π_t that we define in Section (3),

$$C_t \leq W_t L_t + \Pi_t + B_{t-1} R_{t-1} - B_t - T_t. \tag{6}$$

Consumers choose C_t and L_t to maximize their lifetime utility, given each period by the function $U(C_t, L_t)$. Future utility is discounted at a constant rate (β):

$$\max_{C_t, L_t} E_t \left\{ \sum_{s=t}^{\infty} \beta^{s-t} U(C_s, L_s) \right\}. \tag{7}$$

The function for utility exhibits habits in consumption, so the consumer has dis-utility from changing consumption levels quickly, governed by the parameter h. The consumer's degree of risk aversion is controlled by the parameter γ. Labor supply is controlled by the parameters χ and the inverse of the Frisch Elasticity of labor supply ($1/\psi^L$).

$$U(C_t, L_t) = \frac{(C_t - hC_{t-1})^{1-\gamma}}{1-\gamma} - \chi \frac{L_t^{1+\psi^L}}{1+\psi^L}. \tag{8}$$

Letting λ_t represent the consumer's marginal utility, $\lambda_t = (C_t - hC_{t-1})^{-\gamma} - h\beta E_t (C_{t+1} - hC_t)^{-\gamma}$, the first order conditions from the consumer problem yield the condition for labor supply, $L_t = (W_t \lambda_t)^{1/\psi^L}$. The interest rate on bonds gives a price on the future expected marginal utility. Consumers hold a non-zero balance of bonds in equilibrium as they lend to the bank, and we let B_t represent the net balance of consumer-bank borrowing and lending, so that B_t may be positive, negative or zero. To match U.S. data, we calibrate the model so that B_t is positive and represents a savings rate of around 5% of total income:

$$\lambda_t = R_t \beta E_t (\lambda_{t+1}) . \tag{9}$$

In total, the consumer's problem is quite standard. Labor supply is increasing in the wage level but decreasing in the amount of consumption. The interest rate falls as current consumption rises due to the consumer driving up the supply of savings in order to smooth consumption. Likewise, future expected drops in consumption cause the interest rate to fall as the consumer tries to save for the future.

2.3 Banks

Banks collect deposits from the consumer and invest in the differentiated goods firms through two instruments: profit shares and loans. Profit shares are simply claims on a portion of next periods profits, where shares sold by each firms $(\theta_t(i))$ are sold at a competitive rate of $p_t^\theta(i)$ and yield a return of $\theta_t(i)\left(p_{t+1}^\theta(i) + d_{t+1}(i)\right)$ next period. As an alternative to shares, banks can extend loans in one-period non-contingent obligations $(Q_t(i))$ to a firm with a definite return (R_t^L) next period. As we discuss below, the model is calibrated so that both loans and profit shares are positive in steady state, that is, both loans and equities appear as assets on the bank's balance sheet, in accordance with U.S. data. $Q_t(i)$ in the model can be more broadly interpreted in the data as any liability with a set return, including corporate bonds, long and short term loans, etc.

A death shocks arrives at the end of each period so that with probability ξ, a bank continues into the next period and with probability $1 - \xi$ they exit to become a consumer again, taking with them their stock of retained earnings. While the total net assets in the banking sector is certainly important for the model, the number of firms is indeterminate. This is a standard result in keeping with the banking literature (e.g. Gertler and Kiyotaki (2010), Gertler and Karadi (2011)), and follows from the fact that bank services are not differentiated and banks enter without fixed or sunk costs. Effectively, then, banks behave as if their services were perfectly competitive and have constant returns to scale. Modeling a competitive banking sector is useful as it makes for straightforward aggregation and puts the model's focus squarely on the role of the friction of study. A host of papers in the literature model banks similarly, as in Christiano et al. (2010) and Goodfriend and McCallum (2007). Some papers that model banks as monopolistically competitive, or as monopolists, are Aslam and Santoro (2008) and Cúrdia and Woodford (2009), where banks that have market power to set interest rates, giving rise to the loan-deposit spread.

As we discuss below, firms by contrast produce a differentiated good and have sunk costs. The problem is made simpler because, as we show in the next section, every firm sets identical prices and will earn identical profits. They sell the same quantity of profit shares and borrow equally. With n_{t+1} firms investing and operating at the start of each period, we can drop the i indexes and write $Q_t = n_{t+1}Q_t(i)$, $p_t^\theta = n_{t+1}p_t(i)^\theta$, $d_t = n_{t+1}d_t(i)$ and $\theta_t = n_{t+1}\theta_t(i)$. Together with loans from the consumer, these instruments compose the banks' net assets (N_t^B), so that in total:

$$N_t^B = Q_{t-1}R_{t-1}^L + \theta_{t-1}\left(p_t^\theta + d_t\right) - B_{t-1}R_{t-1}. \tag{10}$$

At the start of period t, the banks then distribute their retained earnings across new investment in loans and equities, while borrowing from consumers in the form of deposits.

$$N_t^B = Q_t - \theta p_t^\theta - B_t \tag{11}$$

At the end of each period, after the resolution of uncertainty, banks are confronted with maximizing the lifetime value of their investments. Letting V_t^{bank} be the value of being a bank at the end of period t, every bank solves for the optimal allocations for Q_t and θ_t. Since banks are owned by the consumer, future earnings are discounted stochastically by the consumer's expected future change in marginal utility, $\Omega_{t+1} = \lambda_{t+1}/\lambda_t$.

$$V_t^{bank} = \max_{Q_t,\theta_t} E_t\Omega_{t+1}\left\{(1-\xi)\,N_{t+1}^B + \xi V_{t+1}^{bank}\right\} \tag{12}$$

An incentive compatibility constraint (ICC) limits banks' investments each period. Shown below, the constraint says that the continuing value of the firm must exceed some share of the assets they intend to purchase. If this constraint is not satisfied, then bank managers have the incentive to abscond with the assets as long as they can escape with portion Γ_t^Q of the loans, or portion $\mu\Gamma_t^Q$ of the profit shares. The parameter μ captures the relative ability of institutions to abscond with profit-shares vs. loans, and is calibrated in the model to match the spread between loan and deposit interest rates.

$$V_t^{bank} \geq \Gamma_t^Q \left(Q_t + \theta_t p_t^\theta \mu \right) \tag{13}$$

The bank then solves (12) subject to (13), (10) and (11). We summarize the solution in Result 1, and leave the proof for Appendix A.

Result 1. Solving the bank problem yields the value function as a sum of time varying coefficients v_t^Q, v_t^n, and v_t^θ multiplied by state variables Q_t, N_t^B, and θ_t.

$$\begin{aligned} V_t^{bank} &= v_t^Q Q_t + v_t^n N_t^B + v_t^\theta \theta_t p_t^\theta \\ &\text{with} \end{aligned} \tag{14}$$

$$v_t^Q = E_t\left(\hat{\Omega}_{t+1}\right)\left[R_t^L - R_t\right] \tag{15}$$

$$v_t^N = E_t\left(\hat{\Omega}_{t+1}\right) R_t \tag{16}$$

$$v_t^\theta = E_t\left(\hat{\Omega}_{t+1}\left[\frac{p_{t+1}^\theta + d_{t+1}}{p_t^\theta} - R_t\right]\right) \tag{17}$$

$$v_t^Q \mu = v_t^\theta \tag{18}$$

where the stochastic discount factor for the firm in these expressions is defined as

$$\hat{\Omega}_{t+1} = \Omega_{t+1}\left(1 - \xi + \xi \frac{\Gamma_t^Q v_{t+1}^N}{\Gamma_t^Q - v_{t+1}^Q}\right). \tag{19}$$

Also, the value for a bank's Lagrange multiplier on the ICC constraint is

$$\lambda_t^{bank} = \frac{Q_t + p_t^\theta \mu}{N_t^B}\left(\frac{R_t^L - R_t}{R_t}\right). \tag{20}$$

For the proof, see Appendix A. There are a few things to note here. First, we calibrate the model to ensure that the constraint on banks is always binding, i.e. $\lambda_t^{bank} > 0$. Second, the last expression for the Lagrange multiplier on the banks' investment constraint has a simple counterpart in the data, where $(Q_t + p_t^\theta \theta_t)/N_t$ is the leverage ratio, and $R_t^L/R_t - 1$ is the spread between loans and deposits. Third, lower future expected returns reduce V_t^{bank} and cause the constraint to bind more tightly, thereby raising the loan-deposit spread, while also reducing the quantity of available loans or profit-shares supplied to firms. Finally, Γ_t^Q is time varying, so that unexpected changes in its value away from the steady state value

(Γ^Q) will constitute the model's 'financial shock.' Sudden increases will reduce a banks ability to extend credit, thereby igniting a financial accelerator mechanism that reduces investment and output throughout the economy. To see this, we re-arrange the banks' value function and ICC constraint above to yield,

$$\frac{Q_t + p_t^{\theta}\theta_t}{N_t} = \frac{v_t^N}{\Gamma_t - v_t^F}. \tag{21}$$

We discuss the exogenous process that determines Γ_t^Q in Section (4) below.

2.4 Non-Differentiated Goods: G_t^N

Non-differentiated goods are produced using a simple production function that is linear in labor, $f(l_t) = al_t$, with the constant technology parameter a . Since the market is competitive among produces, the price for the good is $P_t^N = w_t/a$. Total output of the product, Y_t^N must be equal to total demand, G_t^N. Therefore, the total labor used in production of good N is

$$aL_t^N = Y_t^N = G_t^N. \tag{22}$$

These producers hold no assets and make no investments. From a modeling standpoint, this sector is important to drive a wedge between the marginal products of labor in the two goods markets. Since labor is perfectly mobile between sectors, the wage rates for non-differentiated and differentiated goods production must be the same but equal only to the competitive wage for non-differentiated goods. Hence, monopolistically competitive producers in D can set a price above marginal costs.

2.5 Differentiated Goods: $g_t(i)$

Our treatment of the differentiated goods sector is a central component of the model, and is the distinguishing feature that separates this paper from the existing literature on financial frictions. This sector has two features that drive our results. First, we impose a unique constraint on firms' investment decisions that depends on their retained earnings, a state variable, rather than on future earnings, a forward looking variable. While the literature has models with financially constrained producers, this is the first paper to impose a constraint based on retained earnings that we know of. Second, firms are monopolistically competitive and they enter and exit from the goods market endogenously. In this setup, firm profits are a function of the number of firms in the market. As the number of firms grow, competition increases and profits fall. Firms enter when the value of doing so exceeds a sunk cost denominated in units of labor, and firms exit at an exogenous rate.

Each period begins with a mass of firms (n_t) carried over from prior period, and each firm holds retained earnings from last period, $N_t^F(i)$.[3] Firm i produces output $y_t(i)$ and will either continue into the next period with probability ψ, or will exit upon the arrival of an idiosyncratic shock with probability $1-\psi$. Only $\psi n_t = n_{t+1}^o$ firms survive into the next period, where 'o' stands in for 'old'. At the end of each period, after firms have exited and all uncertainty has been resolved, mass n_t^e firms enter according to a condition that we discuss in Section (2.7) below. All together, at the end of period t, there are n_{t+1} firms that will produce next period,

$$n_t = n_t^o + n_t^e. \tag{23}$$

Each variety i of the differentiated good is produced by one of the n_t unique firms, and $y_t(i)$ is produced each period with a constant-returns-to-scale Cobb-Douglass production technology that uses capital and labor. An economy-wide shock to this technology, z_t, hits all firms at the start of the period. Factor markets are competitive, so that every firm is subject to the same costs for hiring the quantities of capital and labor they use each period. Production for variety i is: $y_t(i) = z_t\,(k_t(i))^{\alpha}\,(l_t(i))^{\alpha}$, where α determines the capital intensity of production. All firms hire capital ($k_t(i)$) and labor ($l_t(i)$) from the stock of available capital K_{t-1} and labor L_t, sold at the competitive price of r_t and W_t, respectively.

With frictionless factor markets, firms choose prices to maximize profits, subject to the demand for each variety, $g_t(i) = \left(\frac{p_t(i)}{P_t^D}\right)^{-\sigma} G_t^D$. Much of a firms' decision for profit maximization is standard: the firm's cost minimization problem determines their marginal cost of production, $mc_t = (r_t)^{\alpha}\,(W_t)^{1-\alpha}\,\alpha^{-\alpha}(1-\alpha)^{\alpha-1}$, and the price paid to capital is determined by the first order optimality condition from the firm, so that we must have $r_t = \frac{\alpha}{1-\alpha} W_t L_t / K_{t-1}$. This pins down the price of capital, together with labor demand from the non-differentiated goods sector. Profits are defined as total revenue minus total cost,

$$d_t(p(i)) = \left\{ \left(\frac{p_t(i)}{P_t^D}\right)^{-\sigma} G_t^D\,[p_t(i) - mc_t] \right\}. \tag{24}$$

[3]We suppose that there was some n_0 mass of firms in the initial period.

With flexible prices, the optimal price set by the firm is relatively standard, where the markup over marginal costs is a function of the elasticity of substitution between goods,

$$p_t(i) = mc_t\left(\frac{\sigma}{\sigma-1}\right).$$

Profits are $d_t(i) = (p_t(i))^{1-\sigma}\left(P_t^D\right)^{\sigma} G_t^D/\sigma$. In the extension of this model to have sticky prices (Appendix C), we show that the choice for the optimal price is complicated by the fact that firms make this decision as a net-asset maximizer. In contrast to the standard New-Keynesian setup, in which firms are owned by the consumer so that future profits are discounted by the consumers' stochastic discount factor, here the solution is muddled because the firm's stochastic discount factor is slightly different from the consumer's, following from the leverage constraint on investment. Despite the more complicated expression for prices, the central results of the model are unaffected.

2.6 Assets for Differentiated Goods Firms

Firms that existed in the prior period and survived into the current period, start with their stock of retained earnings, $N_t^F(i)$. As with the bank, their current amount available is the sum of their investments from last period, minus the financing costs paid to the bank through interest on loans and dividend payments. Firms have a tax incentive to borrow in bonds, so that of the rate R_t^L charged for bonds, firms only pay $R_t^L(1-\tau)$. In the calibration of the model, τ is essential for calibrating the spread between loans and deposits (given by $R_t^L - R_t$), and for ensuring that the ICC constraints on firms and banks are always binding. The key asset for firms is the stock of physical capital, in which they invest each period to earn the competitive return of r_t, and lose share δ at the end of each period to depreciation.

$$N_t^F(i) = K_{t-1}(i)\left[r_t + 1 - \delta\right] + \theta_{t-1}(i)\left(d_t(i) + p_t^{\theta}\right) - B_{t-1}(i)R_{t-1}^L(1-\tau). \tag{25}$$

They are confronted with making an optimal decision for next period by allocating retained earnings. Again, similar to the bank, they face a constraint on investment,

$$N_t^F(i) = K_t(i) - Q_t(i) + \theta_t(i)p_t^{\theta} + AC_t^{\theta}. \tag{26}$$

and solve for the capital, equity shares and loans to maximize the lifetime value of net assets. The last term in (26) is an adjustment cost applied to the level of profit-shares bought by the firm, defined as: $(\psi^\theta/2)\left(\theta_t(i)p_t^\theta\right)^2/N_t^F(i)$. Imposing a costly adjustment of profit-shares will mean that, if faced with a rising cost of borrowing, the firm will be oriented towards investing in capital instead of profit-shares. Without this friction, the real effect of bank-shocks would be minimal in the model. The firm problem is

$$V_t^{firm}(i) = \max_{Q_t(i),\theta_t(i)} E_t\Omega_{t+1}\left\{(1-\psi)\,N_{t+1}^F(i) + \psi V_{t+1}^F(i)\right\}. \tag{27}$$

A firm's investment in capital, however, is constrained by an incentive compatibility constraint. The intuition here is similar to the banks' constraint in (13), so that firm owners are able to abscond with share Γ_t^K of physical assets, and therefore the value of continuing in production must exceed the value of ceasing production and selling off the firm's physical assets.

$$V_t(i)^{firm} \geq \Gamma_t^K\left(K_t(i)\right). \tag{28}$$

The firm then solves (27) subject to (28), (25) and (26). We summarize the solution below.
Result 2. Solving the firm's problem yields the value function as a sum of time varying coefficients ρ_t^K, ρ_t^n, and ρ_t^θ multiplied by state variables $K_t(i)$, $N_t^F(i)$, and $\theta_t(i)$.

$$\begin{aligned} V_t^{firm} &= \rho_t^K K_t(i) + \rho_t^n N_t^F(i) + \rho_t^\theta\theta_t(i)p_t^\theta \\ &\text{with} \end{aligned} \tag{29}$$

$$\rho_t^K = E_t\left(\breve{\Omega}_{t+1}\left[r_{t+1}+1-\delta-R_t^L(1-\tau)\right]\right) \tag{30}$$

$$\rho_t^n = E_t\left(\breve{\Omega}_{t+1}\right)R_t^L(1-\tau) \tag{31}$$

$$\rho_t^\theta = E_t\left(\breve{\Omega}_{t+1}\left[\frac{p_{t+1}^\theta + d_{t+1}}{p_t^\theta} - R_t^L(1-\tau)\right]\right) \tag{32}$$

$$p_t^\theta\theta_t(i) = \frac{\rho_t^\theta N_t^F(i)}{\psi^\theta\rho_t^n} \tag{33}$$

where the stochastic discount factor for the firm in these expressions is defined as

$$\breve{\Omega}_{t+1} = \Omega_{t+1}\left(1-\psi+\psi\frac{\Gamma_t^K\rho_{t+1}^n - \frac{\Gamma_t^K(\rho_{t+1}^\theta)^2}{\rho_{t+1}^n\psi^\theta 2}}{\Gamma_t^K - \rho_{t+1}^K}\right). \tag{34}$$

Also, the value for the firms' Lagrange multiplier is

$$\lambda_t^{firm} = \frac{\rho_t^K}{\Gamma_t^K - \rho_t^K}. \tag{35}$$

See Appendix A for the proof. Several results follow from this setup that deserve some attention. First, in what seems quite intuitive, returns on bank loans, capital, and profit shares will be equalized in steady state. Also in steady state, there will be a spread between these returns and return on deposits, so that $\bar{R}^L = \bar{r}+1-\delta = (\bar{p}^\theta + \bar{d})/\bar{p}^\theta > \bar{R}$. Divergences from this steady state will depend on how risky banks feel relative to firms. For example, from the firm problem, taking (32), and (33), we have the price of equities traded between banks and firms, $p_t^\theta = \frac{E_t\left(\hat{\Omega}_{t+1}[d_{t+1}+\rho_{t+1}]\right)}{E_t\left(\hat{\Omega}_{t+1}\right)R_t^L}$. Share prices are decreasing in the rate charged by banks, as this lowers firm profits and directs financing away from dividend payments towards debt servicing. Share prices are also decreasing as profits fall relative to the return on capital, as the firm sells profit-shares and purchases capital to enjoy excess return.

Second, in response to an increase in Γ_t^K, firms will be forced to decrease leverage. Looking at (35), the Lagrange multiplier on the ICC constraint will increase, putting pressure on either V_t^{firm} to increase, or the firm's investments to decrease, or some combination. By re-arranging these conditions, we have an expression for firm leverage in terms of Γ_t^F,

$$\frac{K_t(i)}{N_t(i)} = \frac{\rho_t^n - \frac{(\rho_t^\theta)^2}{\rho_t^n \psi^\theta 2}}{\Gamma_t^F - \rho_t^K}. \tag{36}$$

Financial shocks arrive to the firm as Γ_t^F changes unexpectedly at the start of each period following an autocorrelated exogenous process. We discuss this process and the other exogenous shocks in the model in greater detail in Section (4).

2.7 Firms Entry, Exit and Aggregating

A mass of n_t^e new firms enter at the end of each period and face identical constraints to existing firms, namely the ICC (in equation 28). They enter with a fixed amount of startup capital priced in labor units, $(\omega^s W_t)$, that they can use as collateral for leveraging new investments. While they have startup funds, entering firms are also subject to a sunk investment of $c^s W_t$ that is financed out of labor. Entry occurs until the value of entering, V_t^e is equal to the sunk costs of entry. The value function must then satisfy two constraints: one faced by all firms when investing in capital, and one that is satisfied ex-post.

$$\text{Free entry: } V_t^e(i) = c^s W_t \tag{37}$$

$$\text{Incentive Compatibility: } V_t^e(i) = \Gamma_t^K\left(K_t(i)\right) \tag{38}$$

To arrive at the total flow of firms' net assets across time, we integrate across all new and existing firms at the end of period. A key feature of the model makes this straightforward– all existing firms choose the same ratio of capital, equity shares and loans when scaled by their level of net assets. In the Appendix A, we show that all firms' net assets can be aggregated into a unified expression describing the evolution of net assets for 'old' firms. Here we use bars $(\bar{})$ over variables to indicate averages and drop subscripts for variety i. Below is the expression for 'old' firms net assets, $\bar{N}^o_t$. From this value, total net assets are easily found because $n^o_{t+1}\bar{N}^o_t = N_t$ and $n_t\psi = n^o_{t+1}$.

$$\begin{aligned}\bar{N}^o_t =& \psi\bar{N}^o_{t-1}R^L_{t-1}(1-\tau) + \frac{n^e_t}{n^o_t}\omega^s W_{t-1}R^L_{t-1}(1-\tau) \\ &+ p^\theta_{t-1}\left[\bar{\theta}^e_{t-1}\frac{n^e_t}{n^o_t} + \bar{\theta}^o_{t-1}\psi\right]\left[\frac{p^\theta_t + d_t}{p^\theta_{t-1}} - R^L_{t-1}(1-\tau)\right] \\ &+ \left[\bar{K}^e_{t-1}\frac{n^e_t}{n^o_t} + \bar{K}^o_{t-1}\psi\right]\left[r_t + 1 - \delta - R^L_{t-1}(1-\tau)\right]\end{aligned} \tag{39}$$

This equation captures the role of entering firms on the average level of net assets for existing firms. Because startup capital is calibrated to be small, $\bar{K}^e_t < \bar{K}^o_t$, and $\bar{N}^o_{t+1}$ must fall below $\bar{N}^o_t$ when n^e_t is sufficiently large. Holding everything else constant, a rise in firm entry will be associated with an increase in the total capital stock, but a decrease in the average level of capital per firm. Profits likewise will rise in total, but fall for the individual firm because of increased competition. This will push firms to borrow more heavily from banks using loans, driving up leverage, and also increasing the percent change in leverage per firm when unexpected changes in returns arise.

3 Market Clearing

In this section we close the economy by discussing the market clearing conditions. First, investment is defined as the difference between the new stock of capital and the depreciated old stock of capital. Also, total capital bought by new and old firms must sum to the total capital stock.

$$\begin{aligned}I_t &= K_t - K_{t-1}(1-\delta) \\ K_t &= n^o_{t+1}\bar{K}^o_t + n^E_{t+1}\bar{K}^e_t\end{aligned}$$

Total final goods output is used in consumption, investment, and government consumption.

$$G_t = C_t + I_t + g_t$$

and total borrowing among firms must equal total lending from banks

$$Q_t = n^o_{t+1}\bar{Q}^o_t + n^e_{t+1}\bar{Q}^e_t.$$

Total shares sold by firms, along with the total dividends issued by firms, must equal total shares bought by banks and the total dividends received by consumers. Since there are n_t firms each selling 100% of the shares on profits next period, there are n_t total profit shares available in the economy.

$$n_{t+1} = \theta_t + n_{t+1}\bar{\theta}_t$$

With constant returns to scale, total output in the differentiated goods sector is $Y_t = z_t\left(K_{t-1}\right)^{\alpha}\left(L^D_t\right)^{1-\alpha}$ and the total output must be $y_t(i)n_t = Y_t$. Labor supply must equal labor demand, so that

$$L_t = L^D_t + L^N_t + n^e_t\omega^s + n^e_t c^s \tag{40}$$

where L^D_t is the sum of labor used by all firms, $n_t l_t(i)$. Sunk costs and initial investment for new firms must also be funded out of labor. From Section (2.2), the term Π_t in the consumer's budget constraint is a catchall term for the net assets of firms and banks as they exit to become consumers again. This term must equal $\Pi_t = N^F_t\frac{1-\psi}{\psi} + N^B_t\frac{1-\xi}{\xi}$. Finally, the government must have a balanced budget so that total spending is equal to total revenue: $g_t = T_t + \tau R^L_{t-1}Q_{t-1}$.

4 Shocks and Calibration

The model is hit by four distinct shocks: TFP shocks to differentiated goods production (z_t), bank financial shocks (Γ^Q_t), firm financial shocks (Γ^K_t) and a government spending shock (g_t). The innovations for each of these processes ($\epsilon_{z,t}$, $\epsilon_{Q,t}$, $\epsilon_{K,t}$, $\epsilon_{g,t}$) are uncorrelated, with variances that we estimate from the data. Persistence in each of the shocks (ρ_z, ρ_Q, ρ_K, ρ_g) is likewise estimated from the data, as we discuss more below in Section 5.

$$log(z_t) = \rho_z log(z_{t-1}) + \epsilon_{z,t} \tag{41}$$

$$log(\Gamma_t^Q) = \rho_Q log(\Gamma_{t-1}^Q/\Gamma^Q) + \epsilon_{Q,t} \tag{42}$$

$$log(\Gamma_t^K) = \rho_K log(\Gamma_{t-1}^K/\Gamma^K) + \epsilon_{K,t} \tag{43}$$

$$log(g_t) = \rho_g log(g_{t-1}/\bar{g}) + \epsilon_{g,t} \tag{44}$$

Our focus in this inquiry is on the separate but related contribution of financial shocks from firms and banks. An important part of this goal to find appropriate values for the parameters on the ICC constraints for firms and banks, Γ^K and Γ^Q. For this we turn to data on leverage for banks and firms, and choose values for these parameters that match (1) the average bank-leverage ratio of 7.6 in the U.S. and (2) the average capital to net asset ratio of U.S. non-financial firms of 40.45 in the U.S. economy.

Parameters ω^s, c^s, and μ are chosen to match, first, mean values for the interest rate spread on loans, and second, the ratio of net assets for new firms (less than 1 year old) and existing firms. The steady state loan-deposit interest rate spread in the model is $R^L = R\frac{\Gamma_t^Q - \Gamma_t^\theta}{(1-\tau)\Gamma_t^Q - \Gamma_t^\theta}$. Given that $R_t^L/R_t - 1$ in U.S. data is approximately 0.021% quarterly, and with a given τ from Jermann and Quadrini (2012), this implies a value for μ such that $\mu = (1 - \tau - \tau\frac{R}{R^L - R})$. The exit rates for firms and banks, respectively ψ and ξ, are set to match 6% and 2% annual exit rates for firms and banks.

We choose standard values for the parameters commonly found in the RBC literature. The coefficient of relative risk aversion (γ) is set to 2, the elasticity of labor supply (ψ^L) is set to 1/1.9, and the discount factor β is set to 1/1.011 to fit the 90 day annualized interest rate on Treasuries. The elasticity of substitution in the differentiated goods sector is $\sigma = 6$ to give a 20% markup, and ϕ (the elasticity of substitution between homogeneous and differentiated goods) is also 6. The tax benefit of borrowing with loans versus profit-share issuance follows Jermann and Quadrini (2012) so that $\tau = 0.35(1 - 1/R^L)$ where R^L is the steady state return on bank loans. The rate of depreciation for capital is $\delta = 0.025$. The principal parameters in the model are reported in Table (1).

Table 1: **Baseline Model Parameters**

Parameter	Value	Description
ψ^L	0.5	Frisch elasticity of labor supply
β	0.991	Consumer discount factor
γ	2	Coefficient of relative risk aversion
ϕ	6	Elasticity of substitution, final goods
α	0.4	Capital share in production
ϕ	0.3	Preference for non-differentiated goods
σ	6	Elasticity of substitution, differentiated goods
ξ	.981	Persistence rate for banks
ψ	0.4	Persistence rate for firms
Γ^Q	2.50	Constraint parameter for bank loans
Γ^θ	1.33	Constraint parameter for bank-held shares
Γ^K	0.51	Constraint parameter for firms
τ	0.12	Corresponding to $R^L(1-\tau) = 1 + r^L(1-0.35)$
ω^s	0.012	New firm startup capital ($\star$)
c^s	0.025	Sunk entry costs

5 Estimation

The baseline model is estimated on four commonly used data series: growth rates of real GDP, growth rates of investment, percent changes in hourly compensation and the spread on AAA rated bonds for non-financial firms in the U.S. The last series for the spread is particular significant for our results, and deserves some discussion. For the model estimation, the bond spread in the data is used to discipline the model's loan-deposit spread: R_t^L/R_t. A strict interpretation of R_t^L/R_t from the model might be the *loan*-deposit spread, i.e. long term commitments that are not securitized. We choose here to take the broader interpretation of R_t^L/R_t, since in the data, lending rates and corporate bond rates are highly correlated. Also, bonds spreads are more easily measured, and owing to the fact that corporate bonds are openly traded, interest rates on AAA bonds are well documented. Data for bond spreads extend back farther and the data is readily available on a quarterly basis. Details on the other data series are provided in Appendix B, and the data used for estimation are plotted in Figure (9)

Parameters fitted to the data are described in Table 2 that also displays the assumptions about prior distributions and initial values for the estimation of the mean, mode and standard deviation for each of the fitted parameters. The results from the log-likelihood maximization procedure to identify the parameters are provided in Figure (8). In the extension of this model to include sticky prices a la Rotemberg (1982), we also use data on the Federal Funds Rate to estimate parameters on the Taylor rule for monetary policy, and the parameters that govern policy shocks. This extended model with sticky prices takes one step towards the model in Smets and Wouters (2003), but lacks several of the key frictions in that model, such as sticky wages. Our sticky-price extension is also distinct from Smets and Wouters (2003) in that there are only five shocks, abstracting from a host of innovations like risk premium shocks, investment-specific technology shocks, or wage and price mark-up shocks.

Table 2: Assumptions and Initial Values for Estimation

					Bounds*		90% HPDI	
	Distribution	Mean	Mode	Std.dev.	Lower	Upper	Lower	Upper
$stderr : \gamma$	Inv. Gamma	0.0010	0.0005	0.0500	0.0001	56.3448	0.0003	0.0025
$stderr : \kappa$	Inv. Gamma	0.0010	0.0005	0.0500	0.0001	56.3448	0.0003	0.0025
$stderr : z$	Inv. Gamma	0.0010	0.0005	0.0500	0.0001	56.3448	0.0003	0.0025
$stderr : v$	Inv. Gamma	0.0010	0.0005	0.0500	0.0001	56.3448	0.0003	0.0025
$pers : \gamma$	Beta	0.5000	0.5000	0.2000	0.0001	0.9999	0.1718	0.8282
$pers : z$	Beta	0.5000	0.5000	0.2000	0.0001	0.9999	0.1718	0.8282
$pers : \kappa$	Beta	0.5000	0.5000	0.2000	0.0001	0.9999	0.1718	0.8282
$pers : v$	Beta	0.5000	0.5000	0.2000	0.0001	0.9999	0.1718	0.8282
ϱ	Beta	0.3000	0.1222	0.2000	0.0000	0.9996	0.0354	0.6786

6 Results

Table (3) presents the results from the variance decomposition of the estimated model. Most importantly, we show that the combined effect of bank and firm financial shocks is roughly a third of the entire variance in the total output (GDP), with firm shocks contributing the lions' share of the variance in the total capital stock (51%), consumption (58%) and the bank lending rate (61%). Shocks to financial intermediaries are responsible for the majority of variance in labor supply (75%), investment (64%) and the interest rate on deposits (23%). Shocks to TFP are the next largest contributor to total variance, but in none of the variables do TFP shocks contribute more than half to volatility Government spending shocks come into the model only through the resource constraint, and they rarely contribute more than a percent to total volatility of any one variable.

An interesting model prediction is that while banks contribute most to investment volatility, firms contribute most to capital stock volatility. This follows from the fact that firm financial shocks are persistent relative to bank shocks, with the persistence parameter for firms estimated at 0.71 and for banks at 0.007. The large swings in the capital stock are then driven by shocks to firm's balance sheets. While more persistent, firm shocks have a much smaller standard error estimated at 0.01 compared to the standard error for bank shocks, 0.0851. Short-lived shocks in the banking sector drive the short run dynamics of investment, but these shocks average to zero quickly, so that the long run behavior of capital is instead driven by persistent shocks to firm leverage.

Table 3: **Variance Decomposition of Estimated Model**

Variable	Bank (κ)	Firm (γ)	Technology(z)	Government(v)
GDP	37.2	39	23.2	0.6
K	4.3	51.5	43.9	0.3
C	0.3	58.5	41.2	0.1
L	74.5	12.1	12.6	0.8
I	64.3	29	6.2	0.5
Share Payout	10.4	82.5	6.9	0.2
Debt Repurch.	55.7	36.8	6.5	0.9
N^{bank}	1.3	87.1	10.9	0.6
N^{firm}	16.3	59.7	23.7	0.3
R	98.2	1.2	0.5	0
R^L	23.5	60.9	13.8	1.8

Firm Shocks

Firm financial shocks have their principle effect on the economy due to firm entry. Referring to the impulse responses in Figures (1) and (6), upon the arrival of an unexpected change in Γ_t^F, the economy falls into a recession with a %1 drop in total output. At the same time, however, it experiences an investment boom that is driven by two principle sources. First, the average level of leverage across differentiated firms falls. This is a first order effect that follows immediately from (36), where the fall in leverage occurs because firms are exogenously constrained in the amount of capital they can purchase. The decrease in leverage means that individual firms are constrained in the returns they can earn each period, so that value of being a firm (V_t^{firm}) falls. Through the free entry condition (37), a fall in (V_t^{firm}) is met by a fall in firm entry, so that the net effect on firm number is negative. As firms entry dwindles, the labor demand falls too as the amount of labor used to create startup capital (ω^s) falls. This leads to a fall in wages and labor demand throughout the economy, but with cheaper labor, the differentiated goods sector experiences a one-period boom in productivity as they hire a portion of the newly-unemployed. With the drop in labor income, the consumers reduces consumption. But with the cheap labor, the differentiated goods sector has a heightened return on capital, igniting investment.

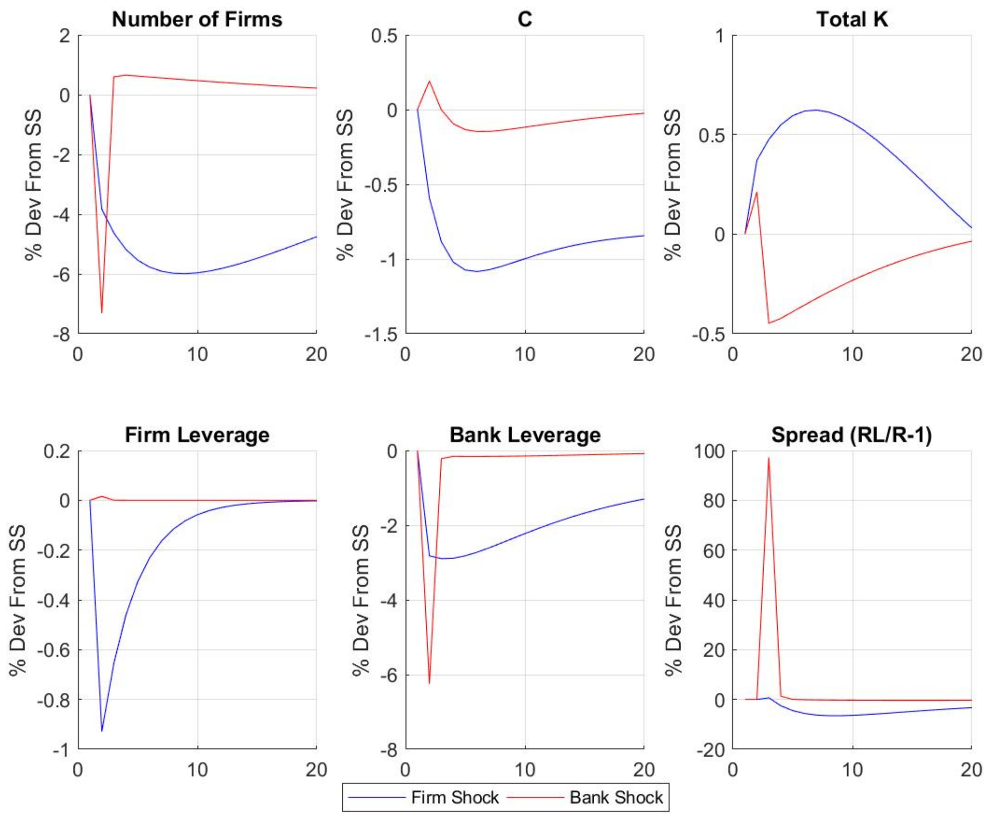
This investment boom continues into the subsequent periods because firm profits have risen. Constraints on firms and banks falls after the initial period: this happens because profits for existing firms rise suddenly as the market is now less competitive. This results in a small cohort of well financed firms, each earning profits quickly and accumulating net assets. A sustained rise in profits raises their value function, relaxes their constraint on borrowing, and allows them to invest in capital. They buy back profit shares and take out new loans. Their profits are rising fast enough that even with this new investment, their leverage is still below steady state levels. As the firm invests, and the economy is flush with credit, banks also can raise rates, earn profits, and reduced their own ICC constraint. With flush credit, spreads on loans R_L/R falls, which continues the credit boom.

An important point to note is that capital investment is partly driven by adjustment costs on profit-shares. As the firm looks to invest with their new-found profits, their investments are biased towards productive capital, rather than purchasing back equity shares. For this reason, in Figure (5), the change in equity shares hardly moves more than the percent of firms exiting. This boom mechanism would exist without these adjustment costs, but it would be much smaller.

Bank Shocks

The shock to bank leverage causes a contraction of lending that leads to a quick recession. Fundamentally, the increased constraint on banks causes the supply of loans to decrease, lowering investment and sharply increasing the cost of borrowing. Looking to Figure (7) and again to (1), the shock Γ^Q is extremely short lived, but is long enough to cause temporary havoc. With a rising Γ^Q there is the first order effect that bank leverage decreases through equation (21). To satisfy the constraint, banks pull back on loans and sells off profit-shares. This raises the return on shares and also, as the supply of loans decreases, it pushes up the loan deposit spread. Firms are now confronted with a higher price for borrowing which drives them towards funding through equity issuance. As this channel is plagued by adjustment costs, rather than borrowing to finance new capital for next period, firms prefer

Figure 1: Impulse Responses



(a) Percent deviation from steady state following a one-standard deviation shock to firm and bank ICC constraints.

to neither borrow nor invest in capital. Constrained borrowing then reduces the capital stock after the first period, and output languishes as a result. With the higher costs for borrowing, the value function for entering falls immediately upon impact of the bank shock. Firms exit and profits rise, but there is no accompanying credit boom because banks are constrained and lending is not available to supply such a boom.

Comparing Figures (6) and (7), both shocks push down bank leverage, lower consumption in the long run, decrease the number of firms, and decrease output. Also similar to the firm-shock, there is a one period rise in output and investment as the bank-shock arrives. The two channels here are identical, namely, cheap labor freed up after firms exit turns to the differentiated goods sector, raising the rate of return on capital and increasing output and consumption for one period. The two shocks differ, most importantly, in what they imply for the lending spread, i.e. the spread decreases for a firm shock, but increases for a bank shock. It is this difference that causes an investment boom in the first case, but a credit crunch in the second. In the estimation for the model, using the lending spread together with data on GDP and investment, hopefully disciplines the model enough so that we can parse the distinct contributions of the two shocks.

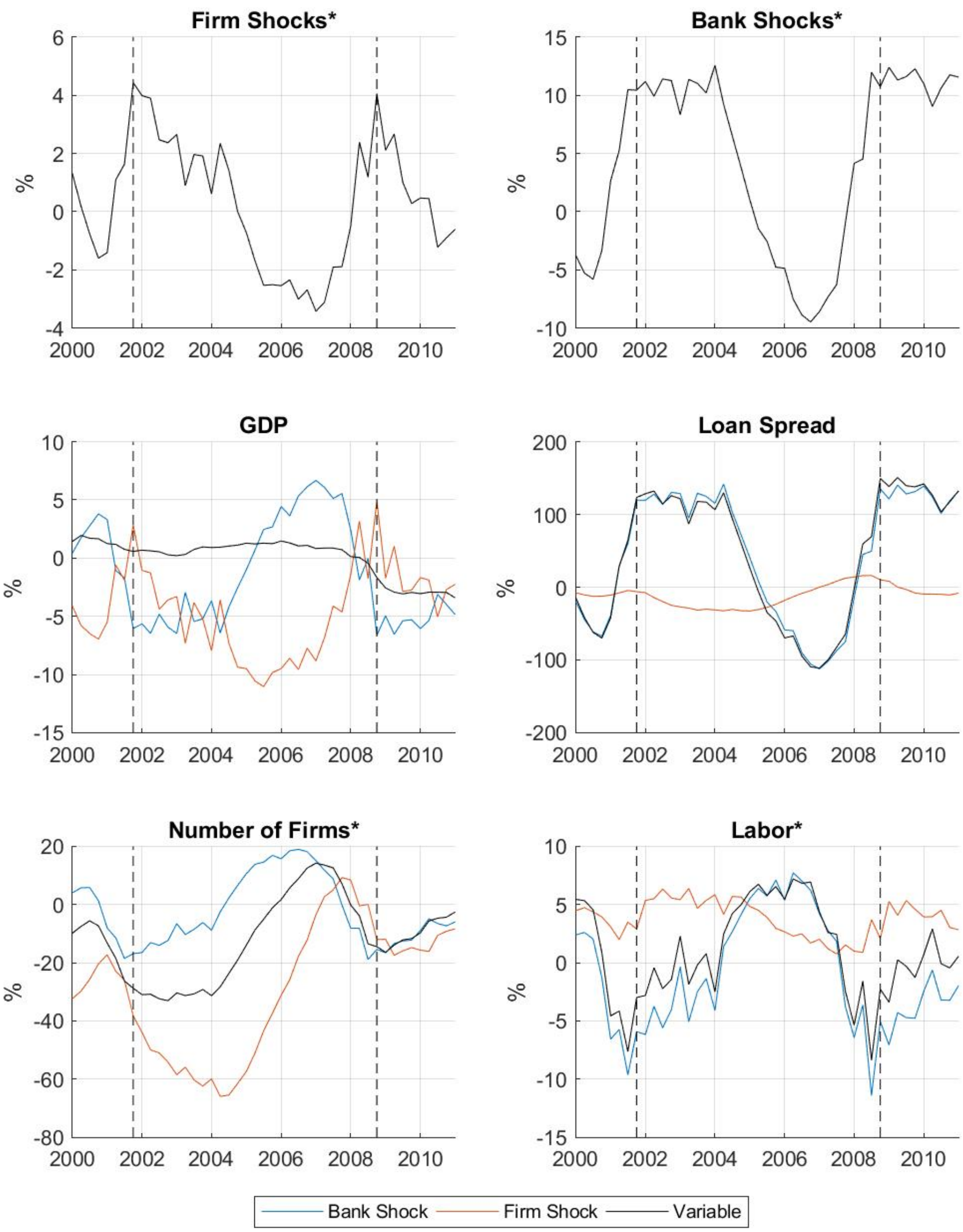
Two Recessions

Figure (2) shows a historical decomposition of U.S. data for GDP, the spread on AAA-rated bonds, the model-predicted number of firms and total labor supply from 1995Q1 until 2018Q1. The black lines in the plots are the percent deviations of the shocks and endogenous variables from their steady state values. In the case of GDP and the loan spread, these lines represent real data used in the estimation procedure, whereas for the other series, these are the model-predicted paths. The blue and red lies track the contribution of each shock to the percent deviation of the title variable from their steady-state value. For instance, of the roughly 2% fall in real GDP from trend in 2008, bank-shocks alone would have dropped GDP by around 5%. The presence of other shocks, particularly firm-shocks, countered bank-leverage shocks. The TFP and government spending innovations are not pictured here because to simplify the plots, as these two series are not the focus of the paper nor did they contribute much of the dynamics in the historical decomposition. Black vertical dotted lines mark the middle of recessions as demarcated by the National Bureau of Economic Research.

Both firms and banks experienced higher than average shocks to their leverage during the financial crises in both 2001 and 2008. As can be seen in the GDP plot, however, the fall in output was principally caused by shocks to banks. These shocks are roughly twice the size of firm-shocks, contributing to the dramatic rise in the loan-spread. Firm-leverage, in-fact, worked against the recessionary bank-leverage effect and boosted GDP above what it would have been. The mechanism behind this firm-leverage effect is discussed above, but to re-iterate, it reduces to the following: firm exit raises existing firm profits with the end result of increasing investment. Since investment is funded from total output, any increase in investment demand is also an increase in total demand, and therefore GDP.

A surprising result here is that the loan spread is almost entirely driven by bank shocks. In the model presented, we showed that the loan spread acts as a shock absorber for bank-leverage shocks. This is particularly clear from Equations (21) and (20) in Section (2). The world outside of the model is, of course, carefully monitored and tweaked by the Federal Reserve. Beyond their dual mandate, the loan spread is an important data point that goes into the decisions about the Federal Funds rate. So far in this model, however, we have abstracted from interest rate rules that target inflation, as this model does not have sticky prices. We present an extended version of the model with sticky prices in the next section. Many of the equations are relegated to the Appendix C.

Figure 2: Historical Decomposition: Baseline



(a) Y-axis is contribution to percent deviation of respective variable. Vertical blank lines mark the middle of recessions. The (*) indicates the series are model-predicted, rather than observed in the data.

Sticky Prices

The purpose of this section is to provide a robustness check on the main results of the paper. In particular, with an additional shock to monetary policy, we can estimate the model using the data series on the effective Federal Funds Rate that will discipline the model's results. Extending the real model to sticky prices is straightforward but there are two complications that deserve attention. First, future costs of price changes are discounted with the firm's stochastic discount factor, not the consumers. This requires a few extra steps in the algebra to find the optimal price, but does not have a material impact on the results. We provide details for the model in Appendix C. Second, share prices and changes in outstanding shares are now part of the pricing decision. This falls out naturally from the fact that firms make pricing decisions while they are also selling shares. To keep the value function linear and the model tractable, we need to make the assumption that the reverse cannot be true, i.e. that pricing decisions are part of the decision to sell equity shares. A monetary authority determines the interest rate following a rule, where parameters α_r, α_g, and α_p, are estimated with a standard Bayesian toolkit in Dynare, as we did for the baseline model.

$$\frac{R_t}{\bar{R}} = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\alpha_r} \left[\left(\frac{G_t}{G_{t-1}}\right)^{\alpha_g} \left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha_p}\right]^{1-\alpha_r} e_t^p \tag{45}$$

The interest rate is subject to occasional deviations (e_t^p) that follow an autocorrelated process with a unit mean, persistence (ρ_p) and innovations each period (ϵ_t^e). Data on the Federal Funds Rate disciplines this process as we use this data to estimate the persistence and standard deviation of the shock (e_t^p).

Results: Sticky Prices

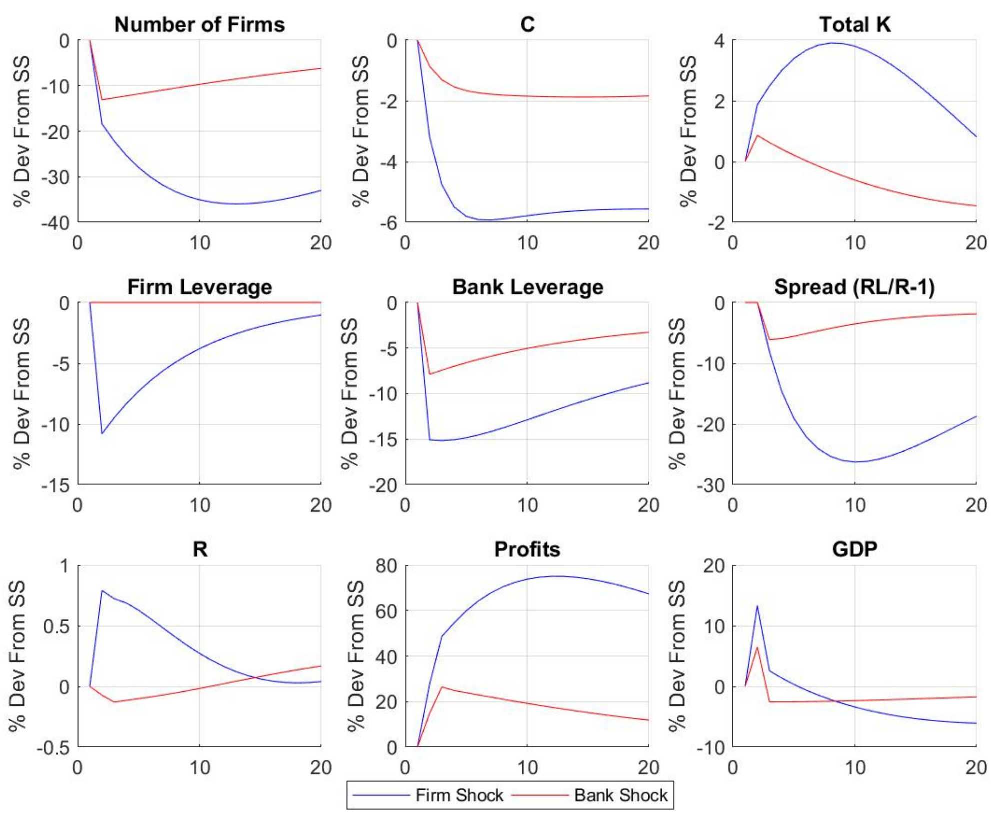
The impulse responses are presented in Figure (3) and are qualitatively similar to the baseline model. A key variable of interest here is the interest rate (R_t). Policy dictates a rise and gradual tapering of the interest rate for a shock to firm leverage, while the reverse is true for a shock to bank-leverage. In the first case, a firm-leverage shock acts as a credit-demand boom without a corresponding credit-supply boom. Since firms and consumer have different stochastic discount factors, consumers choose a sub-optimally low level of savings to finance credit demand. Because of this, capital growth lags and a recession begins. The policy rule gets around this problem by forcing up the interest rate to promote savings. With ample credit, the capital stock grows fast enough to lower the price of capital and increase output.

The key results of the two shocks are the same as in the flexible price model. Firm number, consumption, and bank leverage fall as a result of both shocks. Profits also rise as firms exit, but the capital stock only rises for the bank-shock, just as before. There are several key differences, however, that highlight the beneficial role of monetary policy. Looking to the behavior of the interest rate and the loan spread, now, instead of a sharp rise as we had with flexible prices, the spread falls by 5% and 10% from its average for bank and firm shocks, respectively. What drives this difference? Following the interest rate rule in (45), the Federal Reserve first raises and then lowers R_t to smooth out the one-period boom and subsequent recession brought on by both shocks. In the case of the Firm-shock, raising interest rates actually bring about a sustained period of growth for almost 10 quarters. This arises because raising rates encourages savings that feed the investment boom.

The variance decomposition for the shocks provided in Table (4) of Appendix C gives significantly more credit to firm shocks and monetary policy shocks, leaving the banking sector as a fairly minor contributor. Banks never contribute more than 10% of the total volatility for any variable. The role of government shocks are now almost entirely zero. At the very least, these results verify the strong contribution of firm-shocks that we saw in the flexible price case. The model still lacks many of the frictions that are found in large scale Bayesian estimated New Keynesian models common in the literature, such as Smets and Wouters (2003), Christiano et al. (2010) or Gerali, Neri, Sessa, and Signoretti (2010). Smaller models that are similar in size to this one and ask similar questions, such as Jermann and Quadrini (2012), even include more frictions such as sticky wages. Including more shocks and frictions to test the robustness of these results is an important avenue for further research.

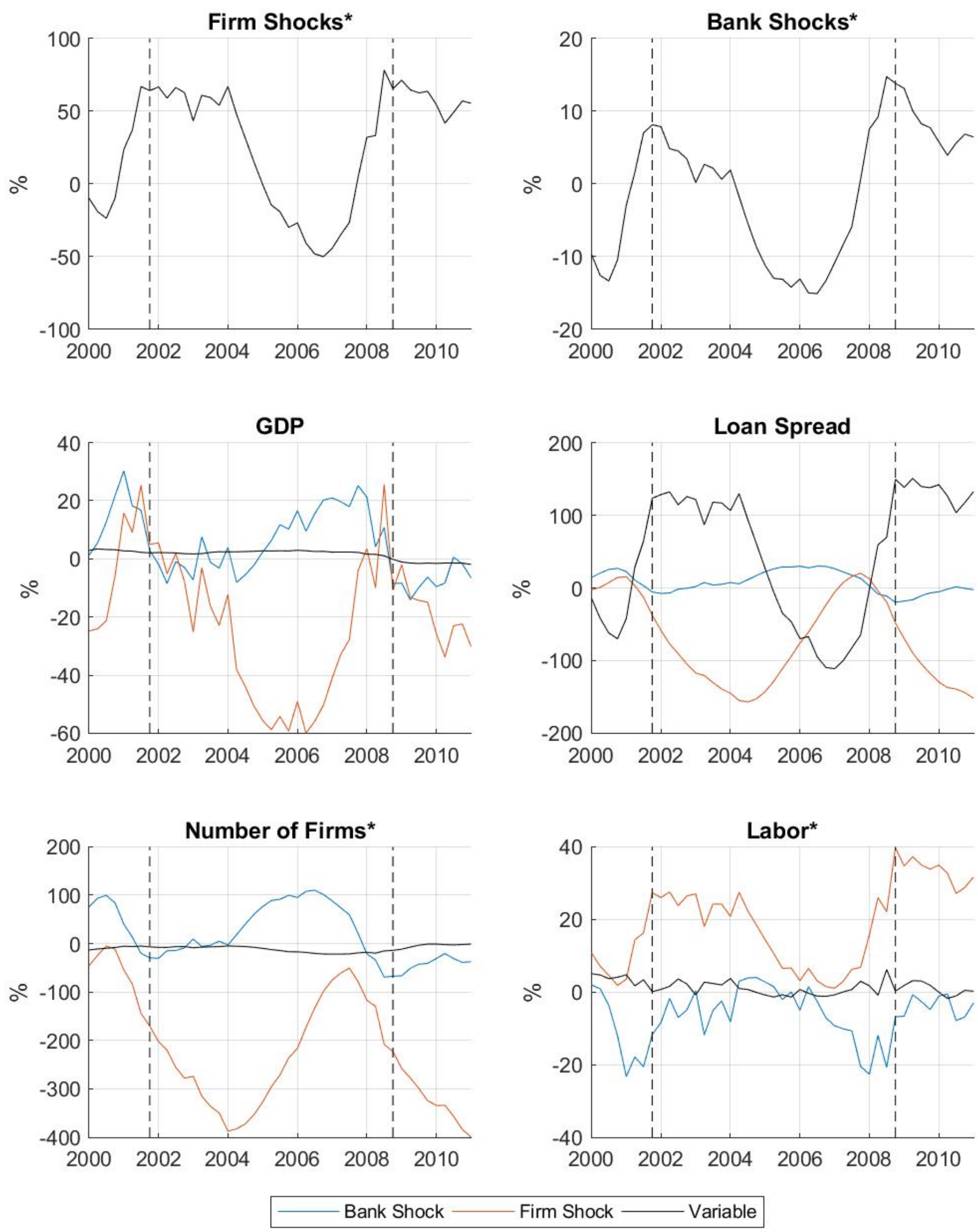
Finally, in Figure (4) we take a new look at the historical decomposition of several key endogenous variables. The figure resembles the decomposition in Figure (2) for flexible prices, namely in that bank and financial constraints were uncharacteristically high during the 2001 and 2008 recessions. These shocks lead to an exit of firms, with bank shocks being primarily recessionary, and firm shocks being largely expansionary. The important exception here is the behavior of the interest rate spread. Now, the spread is driven not by bank or firm shocks, but rather by the policy rate that is a function of the output gap and inflation following Equation (45). An alarming feature of these plots is the sheer magnitude of the swings in bank and firm shocks, and their estimated contributions to the economy. While these shocks cancel each-other out most periods, it is hard to rationalize this level of volatility in the shocks.

Figure 3: Impulse Responses: Sticky Prices



(a) Percent deviation from steady state following a one-standard deviation shock to firm and bank ICC constraints.

Figure 4: Historical Decomposition with Sticky Prices



(a) Tracks the contribution of each shock to the percent deviation of the title variable from steady state value. Plots are centered on 2010.

7 Conclusion

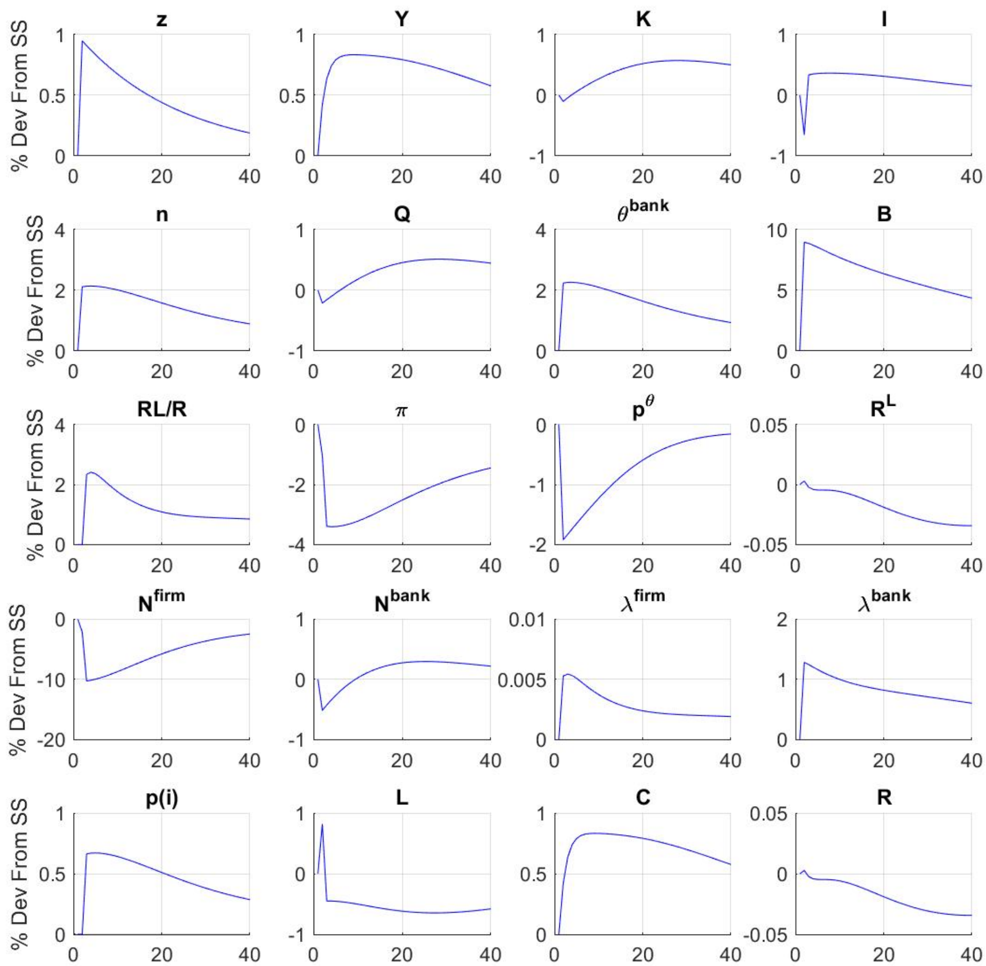
This paper seeks to quantify and provide intuition behind the role of shocks to firm leverage in the U.S. economy. To address this, the paper develops a theoretical model with the unique feature that it imposes leverage constraints on both firms *and* banks, each subject to independently distributed, exogenous shocks. While the modeling of the banking sector is in line with the literature on constrained financial intermediaries (e.g. Gertler and Karadi (2011)), the firm sector is modeled with endogenously entering firms, subject to sunk costs and an exogenous exit rate. Firm entry dynamics prove to be essential for our results. Even while total profits fall after bank and firm leverage shocks, the profits of surviving firms rise due to increased market power after firms exit. When faced with a bank shock, these additional profits are reinvested in unproductive debt-repurchases as the costs of maintaining high debt levels rises with the lending spread. Under a firm-shock, however, firms re-invest profits in productive capital, igniting a credit boom that grows the capital stock. The model is then estimated using standard Bayesian techniques on U.S. data, and we provide a historical accounting of the shocks in the most recent U.S. recession of 2001 and 2008.

When we augment the model to include sticky prices, we show that the interest rate policy following a simple Taylor rule correctly interprets the distinct origins of these two shocks. In particular, rates rise in response to a firm-shock, and fall in response to a bank shock. Under sticky-prices, this split interest rate policy leads to a temporary growth in output for both shocks. The intuition behind the success of a simple Taylor-rule is simple: under a firm-shock, higher interest rates encourage savings to feed the investment boom. Under a bank-shock, lower interest rates and higher inflation keeps the real price of consumption low, so that banks are less constrained in their lending and, as a result, keep down the price of borrowing. When the augmented model is brought to the U.S. data for estimation, the results from the flexible price model are largely upheld.

Several routes of further inquiry standout. First, the mechanism this paper highlights is demonstrated and tested in a standard DSGE framework, where the results are made more robust by including more frictions and shocks, and letting the model-estimation procedure decide what shocks are most relevant. In the sticky-price version of the model, we have five shocks, compared to the 18 shocks of Christiano et al. (2010) that tackles a similar question. Extending the model to include sticky wages, risk premium shocks, and markup shocks, are all very logical next steps. Secondly, a natural extension is to consider an open economy version of this model to test the impact of firm leverage[4]. Emerging markets often have large, highly leveraged multinational firms operating within their borders.

8 Figures

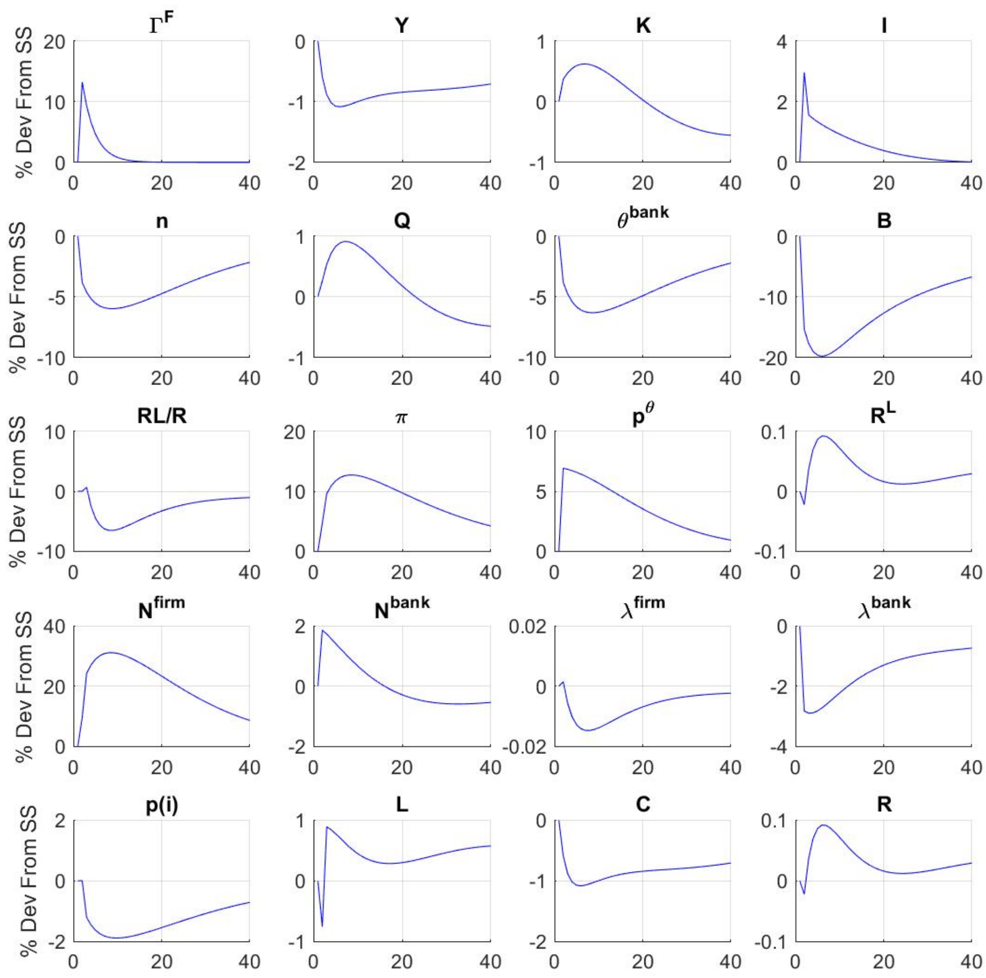
Figure 5: Technology Shock (z)



(a) Responses to a 1-standard deviation persistent shock to technology, z, in percent deviations from steady state.

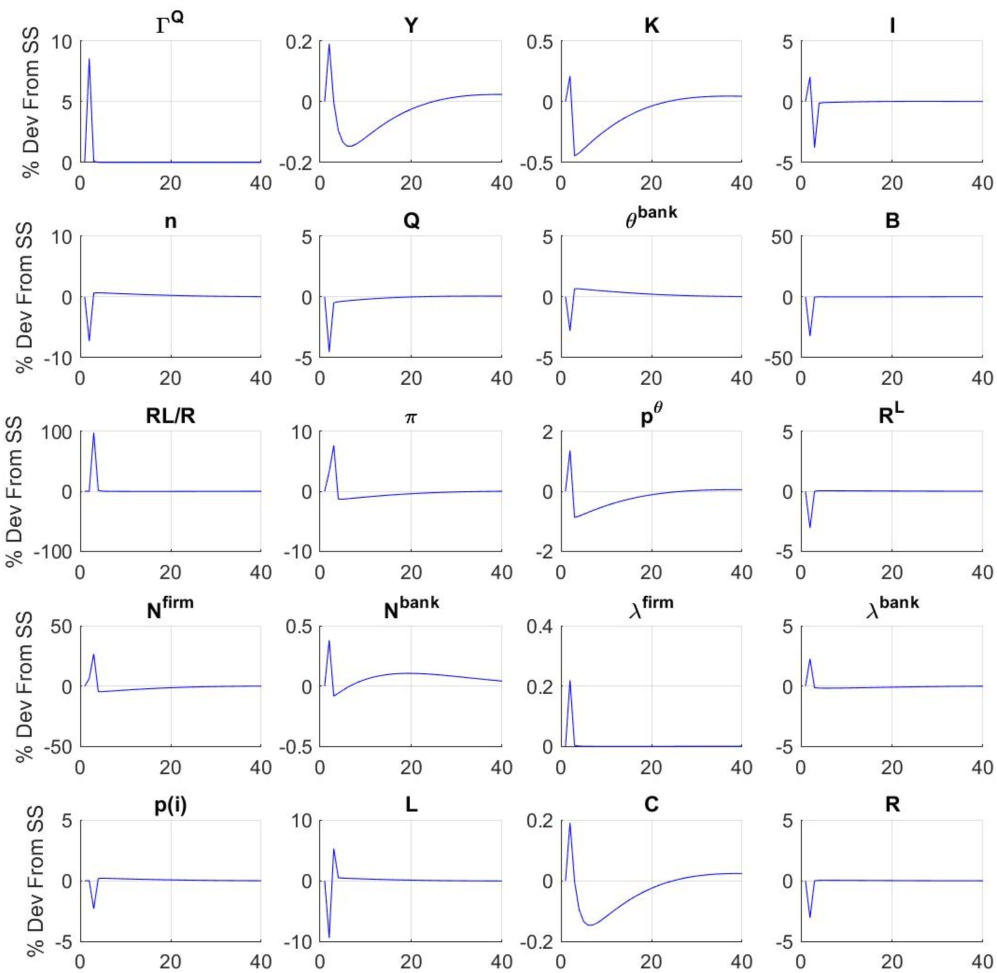
[4]See Coşar, Guner, and Tybout (2016), Alessandria, Pratap, and Yue (2013), Uusküla (2016)

Figure 6: Firm Financial Shock (γ)



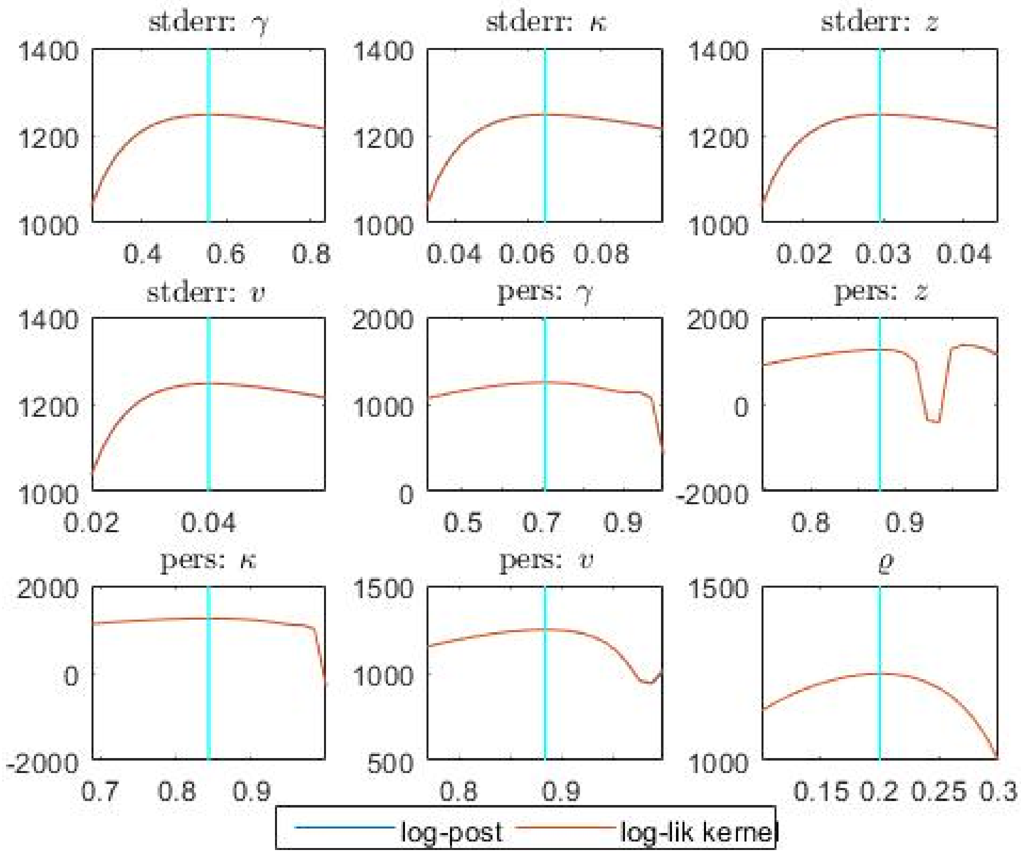
(a) Responses to a 1-standard deviation 1-period shock to bank net assets, γ, in percent deviations from steady state.

Figure 7: Bank Financial Shock (κ)



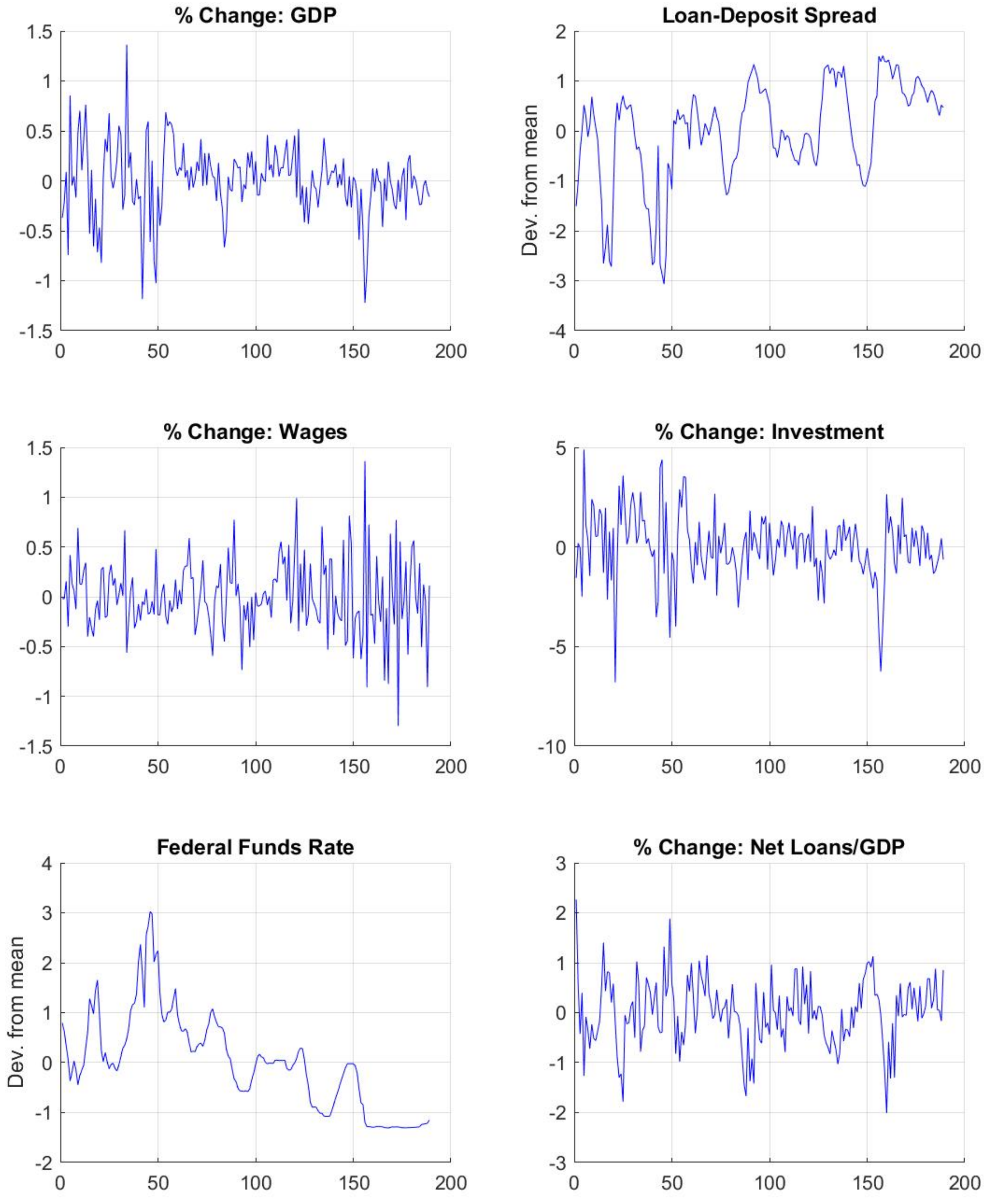
(a) Responses to a 1-standard deviation 1-period shock to bank net assets, κ, in percent deviations from steady state.

Figure 8: Posterior Results from Estimation



(a) Results from the log-likelihood estimation, where *pers* is the persistence parameter, *corr* is the correlation, and *stderr* is the standard error.

Figure 9: Data Series for Estimation



(a) .

9 Appendix

9.1 A: Proofs

(1) Proof of Result 1

The bank will solve their problem in (12) subject to their definition for net assets in (10), (11) and the constraint (13). Starting with a conjecture that the value function is linear, we set up the Lagrangian function,

$$\max_{Q_t,\theta_t} \mathcal{L} = v_t^Q Q_t + v_t^n N_t^B + v_t^\theta \theta_t p_t^\theta + \lambda_t^{bank} \left[v_t^Q Q_t + v_t^n N_t^B + v_t^\theta \theta_t p_t^\theta - \Gamma_t^Q Q_t - \Gamma_t^Q \mu \theta_t p_t^\theta \right] \tag{46}$$

From the first order conditions we have the value for the multiplier.

$$\lambda_t^{bank} = \frac{v_t^Q}{\Gamma_t^Q - v_t^Q} = \frac{v_t^\theta}{\Gamma_t^\theta - v_t^\theta} \tag{47}$$

From the constraint and the definition of net assets, we can arrive at

$$\frac{N_t^B \Gamma^Q v_t^n}{\Gamma^Q - v_t^Q} = V_t^{bank} \tag{48}$$

First we substitute this for the value function in the banks end-of-period optimization problem. Then using (10) and (11), we substitute N_{t+1}^B into the banks end-of-period optimization problem.

$$\begin{aligned}
V_t^{bank} &= \max_{Q_t,\theta_t} E_t N_{t+1}^B \Omega_{t+1} \left\{ (1-\xi) + \xi \frac{\Gamma^Q v_{t+1}^n}{\Gamma^Q - v_{t+1}^Q} \right\} && (49)\\
&= \max_{Q_t,\theta_t} E_t N_{t+1}^B \hat{\Omega}_{t+1} && (50)\\
&= E_t \left(\hat{\Omega}_{t+1} \left[Q_t \left[R_t^L - R_t \right] + N_t^B R_t + \theta_t p_t^\theta \left[\frac{d_{t+1} + p_{t+1}^\theta}{p_t^\theta} - R_t \right] \right] \right) && (51)\\
&= Q_t E_t \left(\hat{\Omega}_{t+1} \right) \left[R_t^L - R_t \right] + N_t^B E_t \left(\hat{\Omega}_{t+1} \right) R_t + \theta_t p_t^\theta E_t \left(\hat{\Omega}_{t+1} \left[\frac{d_{t+1} + p_{t+1}^\theta}{p_t^\theta} - R_t \right] \right) && (52)\\
&= v_t^Q Q_t + v_t^n N_t^B + v_t^\theta p_t^\theta \theta_t && (53)
\end{aligned}$$

Moving from (49) to (50) defines $\hat{\Omega}_{t+1}$, and moving from (51) to (52) defines v_t^Q, v_t^n and v_t^θ. From (47), we arrive at the expression that pins down p_t^θ in (18). Then by dividing the expression for v_t^Q into v_t^n and using (48), it is straightforward to arrive at (20). ■

(2) Proof of Result 2

The firm's solution follows the same procedure as the banks' solution, so this proof will resemble Result 1 above. Here we solve (27) subject to definition for net assets in (25), (26) and the constraint (28). Starting with a conjecture that the value function is linear, we set up the Lagrangian function,

$$\begin{aligned}\max_{K_t(i),\theta_t(i)} \mathcal{L} =& \rho_t^K K_t(i) + \rho_t^n N_t^F(i) + \rho_t^\theta \theta_t(i) p_t^\theta \\ &+ \lambda_t^{firm}\left[\rho_t^K K_t(i) + \rho_t^n N_t^F(i) + \rho_t^\theta \theta_t(i) p_t^\theta - \Gamma_t^K K_t(i) - \Gamma_t^K \theta_t(i) p_t^\theta\right]\end{aligned} \tag{54}$$

From the first order conditions we have the value for the multiplier.

$$\lambda_t^{firm} = \frac{\rho_t^K}{\Gamma^K - \rho_t^K} \tag{55}$$

From the constraint and the definition of net assets, we can arrive at

$$\frac{N_t^F(i)\Gamma_t^K \rho_t^n}{\Gamma^K - \rho_t^K} = V_t^{firm}(i) \tag{56}$$

First we substitute this for the value function in the banks end-of-period optimization problem. Then using (25) and (26), we substitute $N_{t+1}^F(i)$ into the banks end-of-period optimization problem.

$$V_t^{firm}(i) = \max_{K_t,\theta_t(i)} E_t N_{t+1}^F(i)\Omega_{t+1}\left\{(1-\psi) + \psi \frac{\Gamma_t^K \rho_{t+1}^n}{\Gamma_t^K - \rho_{t+1}^K}\right\} \tag{57}$$

$$= \max_{K_t,\theta_t(i)} E_t N_{t+1}^F(i)\breve{\Omega}_{t+1} \tag{58}$$

$$\begin{aligned}= E_t\big(\breve{\Omega}_{t+1}\big[K_t(i)\left[r_{t+1} + 1 - \delta - R_t^L(1-\tau)\right] + N_t^F(i)R_t^L(1-\tau) + \\ \theta_t(i)p_t^\theta\left[\frac{d_{t+1} + p_{t+1}^\theta}{p_t^\theta} - R_t^L(1-\tau)\right]\big]\big)\end{aligned} \tag{59}$$

$$= K_t(i)E_t\left(\breve{\Omega}_{t+1}\left[r_{t+1}+1-\delta-R_t^L(1-\tau)\right]\right)+N_t^F(i)E_t\left(\breve{\Omega}_{t+1}\right)R_t^L(1-\tau)+$$
$$\theta_t(i)p_t^\theta E_t\left(\breve{\Omega}_{t+1}\left[\frac{d_{t+1}(i)+p_{t+1}^\theta}{p_t^\theta}-R_t^L(1-\tau)\right]\right) \tag{60}$$

$$= \rho_t^K K_t(i)+\rho_t^n N_t^F(i)+\rho_t^\theta p_t^\theta \theta_t(i) \tag{61}$$

Moving from (57) to (58) defines $\breve{\Omega}_{t+1}$, and moving from (59) to (60) defines ρ_t^K, ρ_t^n and ρ_t^θ. Additionally, the first order condition with respect to $\theta_t(i)$ yields that $\rho_t^\theta = \rho_t^K$, which pins down the quantity $\theta_t(i)$. ■

(3) Aggregation of Net Assets

Given first that

$$N_t^o(i) = K_{t-1}^o(i)\left(r_t+1-\delta\right)+\theta_{t-1}(i)\left(\frac{d_t+p_t^\theta}{p_t^\theta}-R_t^L(1-\tau)\right)+N_{t-1}^o(i)R_{t-1}^L(1-\tau)$$

and correspondingly for entering firms,

$$N_t^e(i) = K_{t-1}^e(i)\left(r_t+1-\delta\right)+\theta_{t-1}(i)\left(\frac{d_t+p_t^\theta}{p_t^\theta}-R_t^L(1-\tau)\right)+\omega_{t-1}R_{t-1}^L(1-\tau)$$

then using these expressions for the definition of total net assets,

$$N_t = \psi\left(\bar{N}_t^o n_t^o+\bar{N}_t^e n_t^e\right)$$

together with the definition for total net assets, $N_t = n_{t+1}^o \bar{N}_t^o$, and $n_t\psi = n_{t+1}^o$ gives the result.

9.2 B: Data

(1) Data

Data is logged and linearly de-trended to be stationary and represent percent deviations. The data is as follows:

- GDP is Real Gross Domestic Product in Billions of Chained 2009 Dollars on a quarterly basis from 1947-01-01 to 2018-01-01.

- Investment data is from the series on Billions of Dollars of Quarterly Gross Private Domestic Investment from 1947-01-01 to 2018-01-01.
- The Effective Federal funds rate is sourced frmo the Federal Reserve Board. Data is averaged over each quarter from 1947-01-01 to 2018-01-01.
- Inflation: 'Consumer Price Index for All Urban Consumers: All Item' data is sourced from FRED on a quarterly basis from 1947-01-01 to 2018-01-01.
- Wages: Sourced from the U.S. Bureau of Labor Statistics, Non-farm Business Sector: Real Compensation Per Hour from 1947-01-01 until 2018-01-01.

9.3 C: Model with Sticky Prices

This section extends the flexible-price model of Section (2) to include sticky prices and monetary policy following a interest rate rule. The firms profit maximization problem is now amended to have standard Rotemberg-style adjustment costs for setting prices, $AC_t^p(i)$.

$$d_t(p(i)) = \left\{ \left(\frac{p_t(i)}{P_t^D} \right)^{-\sigma} [p_t(i) - mc_t] \, G_t^D - P_t AC_t^p(h) \right\} \tag{62}$$

where adjustment costs for changing prices are defined as

$$AC_t^p(i) = \frac{p_t(i) y_t(i)}{P_t} \frac{\psi_P}{2} \left(\frac{p_t^\star(i)}{p_{t-1}(i)} - 1 \right)^2 \tag{63}$$

Using the definition from firm net assets in (25) and (26), this first order condition of (27) with respect to prices in time t is

$$(1-\psi)\, \theta_{t-1}(i) \frac{\partial \Pi_t(p_t(i))}{\partial p_t(i)} + \psi \frac{\partial V_t^{firm}(i)}{\partial p_t(i)} = 0 \tag{64}$$

and using this with the definition of profits in (24), this simplifies to

$$p_t(i) = \frac{\sigma}{\sigma - v(i)} mc_t \tag{65}$$

where we define

$$v(i) = 1 - \psi_P(\pi_t(i) - 1)\pi_t(i) + \frac{\psi_P}{2}(\sigma - 1)(\pi_t(i) - 1)^2 + \psi_P\left(\frac{\psi}{(1-\psi)\theta_{t-1}(i)}\right)\left(\frac{1}{y_t(i)}\right)\frac{\partial V_t^{firm}(i)}{\partial p_t(i)} \tag{66}$$

Now we have to solve for $\frac{\partial V_t(h)}{\partial p_t(h)}$. Taking the first order condition of (27) with respect to $p_t(h)$ yields,

$$\frac{\partial V_t^{firm}(i)}{\partial p_t(i)} = \psi_P \rho_t \theta_t E_t\left(\breve{\Omega}_{t+1} y_{t+1}(i)(\pi_{t+1}(i) - 1)(\pi_{t+1}(i))^2\right) \tag{67}$$

Using this expression in (66), the firm chooses prices so that

$$v(i) = 1 - \psi_P(\pi_t(i) - 1)\pi_t(i) + \frac{\psi_P}{2}(\sigma - 1)(\pi_t(i) - 1)^2 + \left(\frac{\psi_P \rho_t \psi}{1-\psi}\right)\frac{\theta_t(i)}{\theta_{t-1}(i)} E_t\left(\breve{\Omega}_{t+1}\frac{y_{t+1}(i)}{y_t(i)}(\pi_{t+1}(i) - 1)(\pi_{t+1}(i))^2\right) \tag{68}$$

The stochastic discount factors for the firms, banks and consumers are now appended with an inflation term. Below is the variance decomposition for the model's key variables.

Table 4: **Variance Decomposition of Sticky Price Model**

Variable	Bank (κ)	Firm (γ)	Technology(z)	Government(v)	Policy (p)
GDP	6.5	51.6	0.2	0	41.7
K	7.3	61.1	0.2	0	31.4
C	4.6	58.5	0.3	0	36.6
L	9.4	47.7	0.3	0.2	42.3
I	7	42.4	0.1	0	50.5
Share Payout	3.3	58.6	0.1	0	38
Debt Repurch.	3.4	51.5	0.1	0	44.9
N^{bank}	2.1	65.7	0.1	0	32.1
N^{firm}	2.5	84.4	0.1	0	13
R	6.4	56.7	0.5	0	36.4
R^L	6.8	52.2	0.3	0.1	40.7

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