Credit Channels of Monetary Policy: a Theoretical Assessment of the Identification Strategies

Roger Aliaga Díaz*

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Abstract

Does all the existing empirical evidence supporting the theory of the balance sheet channel of monetary policy really rejects the alternative bank lending view? This seems to be the consensus reached by the profession in the debate between the two alternative theories of the credit channel of monetary policy. In this paper I show that a dynamic general equilibrium model that is consistent with the bank lending channel is capable of reproducing most of the empirical regularities that are presented as evidence for the balance sheet channel and the "flight to quality" hypothesis. The model's simulations can track well firms' financing choices, a differential access to credit markets across firm sizes, the compositional effects in the change of the financing mix after a monetary policy tightening and the asymmetric response of small firms over the cycle to a contractionary policy. This paper calls for further identification efforts in order to disentangle the relative contribution of the two transmission mechanisms of the credit channel.

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*Department of Economics, LeBow College of Business, Drexel University. Matheson Hall 501, LeBow College of Business, Mail Stop 11-106, 3141 Chestnut St., Philadelphia, PA 19104, USA. Tel: 1-215-563-4468. E-mail: raaliaga@drexel.edu.

1 Introduction

Two different credit based explanations exist in the macroeconomics literature as transmission mechanisms of monetary policy: the bank lending channel and the balance sheet channel. The **bank lending view** (Bernanke and Blinder, 1988) holds that an independent effect of monetary policy operates through the assets side of banks' balance sheets. The fall in bank reserves that follows after a monetary contraction directly affects banks ability to extend credit and the supply of loan falls.[1] Two necessary conditions must be met for this channel to be operative. First, banks must find it costly to make it up for a change in reserves either by issuing non-reservable sources of funds or by re-balancing their portfolio of assets (securities and loans). Second, bank-dependent borrowers cannot freely substitute bank loans with alternative financing methods. The **balance sheet channel** (Bernanke and Gertler, 1989), also known as the broad credit channel, states that banks have no special role in the transmission mechanism of monetary policy. Rather, it is borrowers' balance sheets that limit their access to credit. Because of informational asymmetries between borrowers and lenders, loan contracts usually require the former pledging their net worth as collateral. This establishes a tight link between borrowers' balance sheets and the amount of credit they receive. A contractionary monetary policy, or for the matter, any other shock that negatively affects their balance sheet positions will also limit their access to either direct debt or intermediated lending. Monetary shocks may work their way through different "sub-channels" such as changes in interest rates that affect the borrower's cash flow, or changes in financial asset prices that affect borrowers's net worth.

All in all, it seems that the profession has inclined to think that the

[1]This is in contrast to the traditional IS-LM setting where a monetary contraction causes a fall in banks' liabilities, a surge of the interest rate and ultimately a fall in the demand for credit.

balance sheet channel gives a much more reasonable (and theoretically appealing) account of the events occurring in the economy after a monetary policy shock (see Walsh, 1997 and Mishkin, 2004). Perhaps contributing to this shift of interest toward a balance sheet channel and away from the bank lending channel is the idea that banks can easily overcome any shock to reserves from the monetary authority by issuing non-reservable deposits (such as CDs) or by re-arranging their portfolio of assets (securities vs loans).[2] Also, even though nobody denies it is difficult for bank-dependent firms to substitute bank loans by alternative financing methods, as the bank lending channel predicts, many think this is due to agency problems affecting more severely small bank-dependent firms, something that lies at the heart of the alternative theory, namely the balance sheet channel.

The goal of this paper is to study the extent to which the predictions of the bank lending channel share enough common features with those of the balance sheet channel, as for them to be considered observationally equivalent theories. Specifically, the dynamics of firm level data on sales, short-term debt and financing choices after a monetary policy shock have been used to make a strong case for the balance sheet mechanism (see Gertler and Gilchrist, 1994; Oliner and Rudebusch, 1996a, 1996b and Bernanke, Gertler and Gilchrist, 1996). So the question that I intend to answer is whether the patterns in the data, deemed to be consistent with the balance sheet view, can be reproduced by a theoretical model of the bank lending channel of monetary policy. If so, additional identification strategies would be needed.

For this purpose I build a model in which the bank lending channel is the

[2]However, in a very careful study Kashyap and Stein (2000) find this not to be the case for small banks whose balance sheets are not liquid enough (i.e. banks with low ratios of securities to assets). Besides, it is difficult to think that a re balancing of either the bank portfolio of assets or the liabilities following a monetary tightening is completely costless for the bank. The slightest friction in this re-optimization process will translate in to a shock to the loan supply schedule of the bank.

only transmission mechanism of monetary policy in operation.[3] Although there exist informational asymmetries between borrowers and lenders, in order to "block" the balance sheet channel I have not included any role for borrowers' balance sheet positions in credit contracts. I then embed this bank lending mechanism into a dynamic general equilibrium model with heterogeneous firms, where firms make endogenous investment and financing decisions.

The main result of the paper is to successfully reproduce the qualitative dynamics corresponding to the disaggregated level data on firms' sales, capital stock, short-term debt and the financing mix (defined as total bank loans as a fraction of total short-term external finance). Evidence on these data is often deemed to be consistent only with the balance sheet channel of monetary policy. This result raises a word of warning for those that, based on the existing evidence supporting a balance sheet channel, conclude that the bank lending channel is less important (or not important at all). Moreover, this paper calls for further identification efforts in the empirical research in order to disentangle the relative (quantitative) importance of each transmission mechanism of monetary policy.

Both, the general equilibrium setting and firm heterogeneity prove to be key for the results obtained here. In particular, the endogenous response of the equilibrium interest rate after a policy shock shapes the behavior of larger firms, allowing to match the data for both small bank-dependent firms as well as for large firms. Without an endogenous response of the interest rate, large firms, that borrow mostly from the capital market, would not be affected by the monetary policy shock in this model of the lending channel.

The structure of the paper is as follows. Section 2 presents the debate

[3] In the model I do not address the issue on the ability of banks to overcome a policy shock to bank reserves. I rely on Kashyap and Stein (2000) evidence and I take as given the fact that a monetary contraction affects banks credit extension.

on the empirical identification strategies for the credit channel of monetary policy. Section 3 states the assumptions of the model and presents the firms' problem focusing on their financing decisions. Section 4 uses the partial equilibrium model of firms' financing choices and embeds it into an otherwise standard dynamic general equilibrium model of a closed economy with capital accumulation. Section 5 simulates the model numerically in order to study the response to a monetary policy tightening of both macroeconomic aggregates and individual firm variables. Section 6 concludes and summarizes the results.

2 The Debate on the Empirical Identification Strategies

Kashyap, Stein and Wilcox (1993) is the first empirical attempt to shed some light on the debate about the relative importance of these two transmission channels. Using aggregate data they show that the financing mix used by firms (measured as aggregate bank credit as a fraction of total short-term external finance) responds negatively to a monetary tightening, and that there is a direct and statistically significant relationship between changes in this financing mix and investment. They argue that this identification strategy provides evidence favorable to the bank lending view of monetary policy: this shift in the financing mix seems to be induced by a shock to the supply of bank loans rather than a change in the borrowers' balance sheet positions that would affect all forms of credit equally. In a comment to that paper, Oliner and Rudebusch (1996a) call into question Kashyap, et al (1993) results by arguing that the evidence they present is a mere artifact of aggregation. They show that if one discriminates between small and large firms, then the financing mix computed within each size class no longer responds to monetary policy innovations. In their view, the aggregate financing mix results presented by Kashyap, et al (1993) are explained by compositional effects that take place when monetary policy, operating trough channels other than the bank lending channel, affects small and large firms differently. In particular, small firms which rely disproportionately on bank lending are more severely affected after a monetary contraction than large firms, so bank credit falls by more than alternative sources of financing driving the result for the aggregate financing mix. Gertler and Gilchrist (1994) also find no differential response of the mix after a monetary tightening across the subsamples of small and large manufacturing firms.

Kashyap, Stein and Wilcox (1996) argue strongly that Oliner and Rudebusch (1996a) and Gertler and Giltchrist (1994) disaggregated data results, may seriously challenge Kashyap, et al (1993) identification strategy, but by no means the evidence presented by them contradicts the theory of the bank lending channel. The lack of response of the financing mix at the disaggregated level may indicate simply that small firms are almost entirely bank financed, while large firms use almost entirely commercial paper for their short-run financing (see Kashyap, et al 1993, 1996; Oliner and Rudebusch, 1996a). Bank-dependent firms are thus directly affected by changes in bank loans supply, even more than if they did change lenders.

One particularly compelling argument posed against the lending view is that its simple story hinging on bank-dependent borrowers cannot account for the rich dynamics of disaggregated data on sales, inventories, short-term debt and the financing mix (see Gertler and Gilchrist, 1994; Oliner and Rudebusch, 1996a, 1996b; Bernanke, Gertler and Gilchrist, 1996). In particular, the lending view (in its canonical form) is silent about the effect of a monetary policy shock on large firms behavior and thus cannot account for the "flight to quality" phenomenon identified in Bernanke, Gertler and Gilchrist (1996).

One particular piece of evidence supporting the "flight to quality", that apparently cannot be explained by the bank lending view, is the asymmetric response of small firms over the cycle to a monetary policy tightening (Gertler and Gilchrist, 1994). Small credit-constrained firms are likely to be more affected by a monetary policy shock during a downturn of the economy than during a boom, as the recession by itself weakens their balance sheet positions.[4] Under the bank lending view, however, there is no reason why bank-dependent firms should exhibit such an asymmetric response.

In what follows I build a theoretical model rich enough to address all the main points of this debate. The model also allows to isolate the bank lending channel of monetary policy and it provides an environment to assess the limitations in the identification strategies of the alternative credit channels of monetary policy.

3 Firms' Investment and Financing Decisions

The production sector of the economy is composed of a large number of firms of different types. A firm's type is represented by an index $p_k \in \{p_1, \ldots, p_N\}, p_1 < \ldots < p_N < 1$. The index p_k could be interpreted as the probability of a firm of that type exiting the market (i.e. bankruptcy) at a given moment of time. By the Law of Large Numbers (LLN), this is the proportion of each type of firms that die at each moment of time. In case of bankruptcy, the firm is liquidated and its assets are simply transferred to the new firms entering the market. That is, new firms start out with the same capital stock as the dying firms. [5]

The mass of firms of each type is exogenously given in the model and

[4] This is not the case for large firms, which are less likely to be credit-constrained at all times.

[5] This assumption is added for the sake of simplicity to avoid introducing some kind of secondary market in which the existing capital is traded among firms.

does not depend on the states of nature of the economy. The goal of this study is not to trace down how financial frictions affect the economy wide distribution of firms, but rather to analyze how, given firms' characteristics, different type of firms take different decisions in financial markets and how these financial decisions in turn feedback over their investment decisions. Thus, I assume that there is the same number P of firms of each type p_k, and this is constant over time.[6] With $\sum_{i=1}^{N} p_i P$ firms going out of business at each moment of time, the assumption is that there are $\sum_{i=1}^{N} p_i P$ new firms entering the economy. Without loss of generality I normalize P to 1.

All firms produce the same good and their production technology features decreasing returns to scale (DRS). This assumption is necessary to prevent the firms with the lowest risk and thus with the lowest cost of financing from driving other firms out of business by undercutting prices. [7]

Firms in this economy need to borrow in order to finance new investment projects and to replace depreciated capital. They can borrow directly by issuing commercial paper or they can sign a loan contract with a bank. This study introduces three different frictions in financial markets.

First, the firms' types are fully observed by all agents in the model. Thus there is no adverse selection problem in financial contracts signed between

[6]Instead of assuming a constant mass of firms for each risk type, I could have assumed some skewed distribution, where the mass of firms is clustered around high risk firms. This would not affect the main results obtained here, though.

[7]With CRS, the lowest p firm, that is charged the lowest risk premium, would incur marginal costs lower than the rest. Thus, this firm could undercut prices driving the other firms out of business. DRS technology is justified by the presence of a factor of production in fixed supply, such as managerial talent. I assume that the total endowment of managerial talent is equally distributed among the N firm types. Thus, managerial talent is a specific factor for a given firm's type. Now, within each firm class the fixed factor is allocated among the P firms competitively. Thus, the rent earned by this factor is equal to the difference between the firm's output and the payment to the other inputs, i.e. capital.

firms and their lenders. However, there is an informational friction in the model. As in Townsend (1979) and Gale and Hellwig (1985), even though firms' types are observed, verifying firm's cash flows in each state of nature is costly for lenders. Specifically, bondholders cannot observe freely which firm in particular has truly gone bankrupt among the firms of each type that claim to be in that state of nature. That is, a firm could fallaciously claim that it has fallen into bankruptcy, and due to a limited liability clause pay no other penalty for defaulting on its debt. Since reputation is not accounted for in this model, this firm could continue operating normally after that. As it will be clear later, this financial friction affects only the corporate bond market.

It is assumed that all bond issuers must pay this verification cost as an origination cost of the issue. If φ is the constant verification cost per unit of loan, each borrower pays $p\varphi$ per unit of borrowing. That is, this origination costs that is payed ex-ante is proportional to the firm's probability of default and, by the LLN, it exactly covers the total verification cost corresponding to the defaulting firms of each type in the economy.

Second, there is a transaction cost in public debt financing. As in Gomes (2001) and Smith (2002), these costs represent underwriting fees and other flotation costs associated with new issues of public debt. Based on empirical evidence presented by Altinciliç and Hansen (2000) and Lee, Lockhead, Ritter and Zhao (1996), I model transaction costs per unit of loan that are increasing in the size of the issue but that are decreasing in the size of the firm. Thus, there is a second term in the origination cost of bond issues of the form $\phi(\frac{iv}{k})$, where $\frac{iv}{k}$ is the firm's investment rate (and, therefore, its financing needs relative to its size as measured by the capital stock held by the firm) and $\phi'(.) > 0$. Therefore, the total origination cost associated to bond financing is given by $\vartheta(p, \frac{iv}{k}) = p\varphi + \phi(\frac{iv}{k})$ per unit of borrowing.

Third, I assume that banks are endowed with an information technology that puts them at an advantage over other lenders. Because of this technology bank loan contracts are not subject to costly state verification. By lending to a firm the bank can extract all the information needed in order to observe at no cost the firm's cash flow in any state of nature.[8]

Still, banks incur in intermediation costs. These costs may be related to reserve requirements or capital adequacy ratios set by a regulator as well as to administrative costs (i.e. payments to factors used in the production process of loan services). In this model I assume that these intermediation costs are recovered by the bank by charging to the borrower an origination fee rather than setting up a mark-up over the marginal cost of funds. This assumption is consistent with standard practices followed by commercial banks.[9] In this model, therefore, borrowers pay a constant cost c^L per unit of loan at the moment of signing the credit contract with the bank.[10]

It is not necessary to introduce uncertainty in this model. If lenders' total

[8]Alternatively, the assumption of an informational advantage of banks can be rationalized with the existence of a costly verification technology that features economies of scale in the volume of funds audited. If banks' assets are large in relation to the size of the projects financed then banks can exploit these scale economies driving their average verification costs close to zero. Bondholders may also have access to this verification technology, however they cannot exploit the economies of scale since they can finance just a fraction of a single project. Bondholders cannot cluster in larger groups because of free-riding problems. This framework is close to Diamond (1984).

[9]This is the result of consumer protection regulations mandating information disclosure on the terms of the loan contract. One problem of these regulations is that they tend to put too much emphasis on the Annual Percentage Rate (APR) of the loan, and as a result banks prefer to keep quoted APRs low while charging origination fees and other expenses at the moment of granting the loan.

[10]This assumption is also mathematically convenient. In this way, the cost is comparable to the financial frictions arising in bond financing. Therefore, financial frictions from all sources in the model are observationally equivalent to adjustment costs to investment. I do not think that the main conclusions would be affected if intermediation costs were modelled as an interest rate margin.

assets are large relative to the size of the individual investment projects for which they provide financing then lenders can achieve perfect diversification of their portfolio of assets. By the LLN, the borrower's type will indicate exactly the proportion of non performing loans in each lender's assets portfolio. For the case of bondholders I assume that there is a mutual fund that undertakes the risk-pooling function.[11] Thus, and in addition to the origination fees described above, banks charge a default risk-adjusted interest rate on their loans $i^L = f(r^d, p)$, where r^d is the interest rate paid on deposits and p is a "credit risk premium".[12] On the other hand, the mutual fund (in representation of households) will also charge $i^b = f(r^b, p)$ for the loan to a type p firm, where r^b is the opportunity cost of capital and p is again a risk premium given by the probability of default.

The dynamic optimization problem for a perfectly competitive firm facing both investment and financing decisions can then be outlined as follows:

$$\begin{aligned}
\max_{\{iv_p\}} v_p(0) &= \int_0^\infty z_p(t)\{AF[k_p(t)] - w_p(t) - i^L(t)l_p(t) - i^b(t)b_p(t) - \\
&- iv_p(t)[1 + \iota_p(t)c^L + (1-\iota_p(t))\vartheta(p, \frac{iv_p(t)}{k_p(t)})] + \dot{b}_p(t) + \dot{l}_p(t)\}dt \\
s.t. & \\
\dot{k}_p(t) &= iv_p(t) - \delta k_p(t) \qquad (1)
\end{aligned}$$

[11]The assumption of risk-pooling applies very naturally to the case of banks. However, it is more difficult to invoke risk-pooling for the case of small bondholders. In this model, the debt-holder of the firms' issues is the representative household, an atomistic unit. Thus we should rather think in a setting in which households own quota parts of a mutual fund who in turn undertakes the risk pooling function. Of course, the reason why the mutual fund and the bank are different institutions is that the latter operates under perfect information. At the same time, there is no intermediation costs associated to the activities of the mutual fund.

[12]This "risk premium" does not refer to the compensation for the risk-aversion of the lender, but rather to a compensation for credit risk.

$$\dot{l}_p(t) = \iota_p(t) iv_p(t) - \delta\beta(t) k_p(t) \tag{2}$$

$$\dot{b}_p(t) = \Big(1 - \iota_p(t)\Big) iv_p(t) - \delta(1 - \beta(t)) k_p(t) \tag{3}$$

$$\lim_{t\to\infty} \quad k_p(t) z_p(t) \geq 0 \tag{4}$$

$$k_p(0) = l_p(0) + b_p(0) \tag{5}$$

where $z_p(t) \equiv \exp\Big(-\int_0^t [r(t) + p] dt\Big)$ is the discount factor; $k_p(t)$ is type p firm's capital; w_p is the rent paid to the manager; $\iota_p(t)$ takes value 1 if the firm opts for bank lending financing rather than bond financing, and 0 otherwise; $iv_p(t)$ is type p firm's gross investment; $l_p(t)$ is bank loans outstanding; $b_p(t)$ is bonds outstanding; $\beta(t) = \frac{l_p(t)}{l_p(t)+b_p(t)}$ is the fraction of bank loan financing relative to total external financing and $k_p(0)$ is type p firm's initial capital stock [13]. Finally, $\vartheta(p, \frac{iv_p(t)}{k_p(t)}) \equiv \phi(\frac{iv_p(t)}{k_p(t)}) + p\varphi$, with $\vartheta_1(.) > 0$ and $\vartheta_2(.) > 0$.

The production technology $AF(k)$ has the usual properties: $AF_k > 0$; $AF_{kk} < 0$ and Inada conditions hold. A is an index for the economy wide productivity level. Both capital and managerial talent are inputs in the production process, but the latter exists in fixed supply. Thus, the production function features DRS. Managerial talent has not been explicitly included in the production function, but the assumption is that each firm needs at least $\frac{1}{N}$ units of it to operate.

Equation (1) is the equation of motion for the capital stock with δ being the depreciation rate. Equation (2) is the law of motion for bank loan financing in each firm and equation (3) is the law of motion for bond issuance. These two equations arise from the assumption that gross investment is entirely financed through external resources.[14] At each moment of time a frac-

[13] Because of the assumption of perfect diversification in debt holdings, the initial value of the state variables (including capital) in the problem for the Pp new firms is equal to the current value of these same variables for the existing $(1-p)P$ firms. In this way, the aggregate capital stock of the economy does not change because of entry and exit of firms.

[14] An alternative could be just to assume that net investment is financed with debt while depreciation is paid out of the firm's cash flow at every moment of time. In fact, if

tion (equal to the depreciation rate weighted by the share of each financing source) of the stock of outstanding debt is paid back.

The Hamiltonian is

$$H_p = z_p\{AF[k_p]-w_p-i^L l_p-i^b b_p-iv_p[\iota_p c^L+(1-\iota_p)\vartheta(\frac{iv_p}{k_p})]-\delta k_p+q_p(iv_p-\delta k_p)\} \tag{6}$$

where for convenience I have omitted the time index t. The FOCs to the optimal control problem for type p firms are

$$\begin{aligned} H_{iv,p} &= q_p - \iota_p c^L - (1-\iota_p)\vartheta(x_p) - (1-\iota_p)x_p\vartheta'(x_p) = 0 && (7) \\ H_{k,p} &= -\dot{\mu}_p; \quad \mu_p = z_p q_p \\ \Rightarrow \quad & AF_{k,p} + (1-\iota_p)x_p^2\vartheta'(x_p) - [\beta i^L + (1-\beta)i^b] - \delta - \delta q_p = \\ & \qquad = (r+p)q_p - \dot{q}_p && (8) \end{aligned}$$

where $x_p \equiv \frac{iv_p}{k_p}$, the investment rate.

The firm's choice of financing method, as represented by the choice variable $\iota_p \in \{0,1\}$, indicates which finance source is being used at time t. This financing decision is determined by the condition:

$$\iota_p(t) = \arg\max_{\{0,1\}}\left(\max_{iv_p(t)} v_p(t)\right) \tag{9}$$

there were no financial frictions there would be no difference between these two schemes. However, as I will show later, when there are costs of issuing debt then the two settings differ in that only the former gives a continuous function for the adjustment cost to investment as long as gross investment is positive (i.e. irreversibility of investment). With the alternative setting there would be a discontinuity in that function at the steady state value of investment, since it would jump discontinuously to zero. Thus the marginal condition for capital could not be derived.

Thus, given the financial frictions, firm's characteristics will play a key role in determining the value of ι_p. Figure 1 plots the net present value of the firm for different types assuming that each firm remains in its steady-state path of investment.[15] As a result, firms of type $p < p^*$ use bond financing and those of type $p > p^*$ use bank lending.

Of course, firms' investment decisions depend on the total financing costs given by interest rate plus origination costs. In this partial equilibrium setting i^L and i^b are given. Thus, in order to understand the feedback between investment and financing decisions of the firm these prices must be made endogenous variables of the model by moving to a general equilibrium analysis. I pursue this task in the next section.

4 The Dynamic General Equilibrium Model

This section embeds the partial equilibrium model of firms' financing decisions presented before into an otherwise standard dynamic general equilibrium model of a closed economy.

There are three agents in the economy: households, firms and financial intermediaries (hereafter called banks).

4.1 Households

The setting is one of infinitely lived representative households that maximize utility derived from consumption goods (C). Households are endowed with a fixed amount of managerial talent. Thus, this factor of production is supplied inelastically to the firms and total endowment in the economy is normalized to 1. Moreover, $\frac{1}{N}$ of the endowment is supplied inelastically to each type

[15] I assume that p_1 and p_N are such that bond financing and bank lending do coexist in this economy.

of firm. Households make their saving decisions through allocating resources between two assets: corporate bonds issued by firms (B) and bank deposits (D). Households are the owners of both firms and banks, which distribute their profits in a lump-sum fashion.

$$\begin{aligned} \max_{\{\alpha,C\}} & \quad \textstyle\int_0^\infty \quad U(C)e^{-\rho t}dt \\ C+\dot{a} & \leq \sum_{p=p_1}^{p_N} w_p + a[\alpha r^d + (1-\alpha)r^b] + \pi^{bank} + \pi^{firm} \\ a & = D+B \\ C & \geq 0 \end{aligned} \tag{10}$$

where ρ is the rate of time preference; w_p is the payment to the fixed factor by type p firms and α is a choice variable and it is the share of bank deposits on total assets. The time index t has been dropped again for convenience.

Notice that due to the assumption of perfect diversification achieved through risk pooling by the mutual fund the risk premium p does not enter the households' budget constraint. A perfectly competitive mutual fund charges

$$i^b = \frac{r^b + p}{1-p} \tag{11}$$

for every dollar of bond financing and it earns $(1-p)i^b - p = r^b$. Thus, this mutual fund pays r^b per dollar of quota part to the households.

The solution to the optimization problem can be framed in the context of an optimal control problem. The Hamiltonian function and the FOCs are:

$$H = e^{-\rho t}\Big[U(C) + \lambda\Big(\sum_{p=p_1}^{p_N} w_p + a[\alpha r^d + (1-\alpha)r^b] + \pi^{bank} + \pi^{firm} - C\Big)\Big]$$

$$H_C = U'(C) - \lambda = 0 \tag{12}$$

$$H_\alpha = \lambda a(r^d - r^b) = 0 \quad \Rightarrow \quad r^d = r^b \tag{13}$$

$$H_a = -\dot{\mu}, \qquad \mu = \lambda e^{-\rho t} \quad \Rightarrow \quad \dot{\lambda} = \lambda\{\rho - [\alpha r^d + (1-\alpha) r^b]\} \tag{14}$$

4.2 Banks

Banks are perfectly competitive. At each moment of time they choose lending to each firm type (l_p) and deposits (D) to maximize per period profits. They receive interest payments on the loans outstanding and they pay interest for the balances held by households at the bank. Their optimization problem is given by:

$$\begin{aligned} \max_{l_p, D} \pi^{bank} &= \sum_{p=p_1}^{p_N} (1-p) i^L l_p - p l_p - r^d D \\ \sum_{p=p_1}^{p_N} l_p &= D \end{aligned}$$

Thus the pricing equation corresponding to a borrower of type p is

$$i^L = \frac{r^d + p}{1 - p} \tag{15}$$

This means that banks never make any losses. Since banks can perfectly observe firms' types they can charge a fair credit-risk premium, perfectly pooling risk and eliminating any source of uncertainty.

As regards the origination cost per unit of loan c^L, banks charge this fee upfront to the borrowers collecting a total of $c^L \sum_{p=p_1}^{p_N} \iota_p i v_p$. Simultaneously, they use this revenue to cover their expenses associated to regulations and administrative costs. Thus this term does not enter in the profit function above and does not affect the pricing decision of the competitive bank.

4.3 Monetary Policy

Monetary policy enters in the model in a very simplistic way: it affects the banks' intermediation costs (i.e. a monetary policy shock will be represented by a shock to c^L). According to the bank lending channel, a monetary policy tightening that reduces reserves and makes banks either re-balance their portfolios of assets (securities versus loans) or seek for non-reservable funds certainly increases the operation costs per unit of loan. This balance sheet adjustment must be costly for banks in terms of worker-hours and administrative costs.

Admittedly, the lack of monetary policy tools and operating instruments in this model results in an extremely simplistic description of the conduct of monetary policy. A more sophisticated version of this model should include a market for reserves as well as micro-foundations of banks' balance sheet adjustments in order to produce the result of an endogenous increase in banks intermediation costs after a negative policy shock. This sophistication would be clearly necessary if the goal of the paper were to assess the importance of the bank lending channel relative to alternative transmission mechanisms, or if it were to study in depth how the bank lending channel works.

However, for the exercise at hand, for which the starting point is an operative bank lending channel, the extra step of adding micro-foundations seems redundant. A more complex version of the model would contribute nothing to the main goal of this study, which is to assess the extent to which the predictions of the bank lending channel and of the balance sheet channel share enough common features as for them to be considered observationally equivalent theories.

4.4 Decentralized Economy Equilibrium

In order to solve for the decentralized economy equilibrium we must impose market clearing conditions for assets

$$a = \sum_{p=p_1}^{p_N} k_p \tag{16}$$

$$\alpha = \frac{\sum_{p=p_1}^{p_N} l_p}{\sum_{p=p_1}^{p_N} k_p} \tag{17}$$

The resource constraint in the market for goods is

$$C + \sum_{p=p_1}^{p_N} iv_p[1 + \iota_p c^L + (1-\iota_p)\vartheta(x)] = \sum_{p=p_1}^{p_N} AF(k_p) \tag{18}$$

Imposing equations (11), (13), (15) and (17) we get $i^b = i^L$, and $r^b = r^d \equiv r$. Using this in (8) and working with (7) to eliminate q,

$$\begin{aligned} AF_{k,p} + (1-\iota_p)x_p^2\vartheta'(x_p) &= (r+p+\delta)\left[1 + \iota_p c^L + (1-\iota_p)\vartheta(x_p) + (1-\iota_p)x_p\vartheta'(x_p))\right] - \\ &\quad -(1-\iota_p)(2\vartheta'(x_p) + x_p\vartheta''(x_p))\dot{x}_p \end{aligned} \tag{19}$$

Re-writing the law of motion of capital (1) in terms of x,

$$\dot{k} = k(x-\delta) \tag{20}$$

Thus, for $\iota_p = 0$, (19) gives a well-behaved differential equation for x_p and the system (19)-(20) is a well-behaved dynamic system. That is, for each type p that uses bond financing, and given the interest rate r, we can pin-down the dynamic path of investment, bond financing and the capital stock. This is not the case, however, for firms that use bank financing, i.e. $\iota_p = 1$. [16] Instead, the resource constraint (18) together with the Euler

[16] With $\iota_p = 1$, $q_p = c^L$ is constant, so there's no adjustment costs to investment. With a constant interest rate (i.e. in partial equilibrium) investment would be infinite or zero.

equation for consumption (14) can be used in order to solve for the dynamic paths of investment and the capital stock.

If p^* is the marginal firm type such that for all $p \leq p^*, \iota_p = 0$ (say N_1 firm types: $\{p_1, \ldots, p_{N1}\}$), while for all $p > p^*, \iota_p = 1$ (say $N - N_1$ firm types: $\{p_{N1+1}, \ldots, p_N\}$), then the equilibrium path for this economy is determined by the following system:

$$\dot{x}_p = \frac{(r+p+\delta)[1+\vartheta(x_p)+x_p\vartheta'(x_p)] - AF_{k,p} - x_p^2\vartheta'(x_p)}{2\vartheta'(x_p)+x_p\vartheta''(x_p)} \qquad p \in \{p_1, ..., p_{N1}\} \leq p^* \tag{21}$$

$$AF_{k,p} = (r+p+\delta)(1+c^L), \qquad p \in \{p_{N1+1}, ..., p_N\} > p^* \tag{22}$$

$$\dot{k}_p = k_p(x_p - \delta) \qquad \forall p \tag{23}$$

$$C + \sum_{p=p_1}^{p_N} k_p x_p[1 + \iota_p c^L + (1-\iota_p)\vartheta(x_p)] = \sum_{p=p_1}^{p_N} AF(k_p) \tag{24}$$

$$\dot{C} = \frac{U'(C)}{U''(C)}(\rho - r) \tag{25}$$

$$k_p(0) = \kappa_p, \qquad \lim_{t\to\infty} k_p(t) z_p(t) \geq 0 \qquad \forall p$$

The strategy to solve this system relies on using equations (22) and (23) to eliminate k_p and x_p for $p \in \{p_{N1+1}, ..., p_{N-1}\}$ (i.e. for all firms that use bank financing but one, say type p_N) from (24). First, using equation (22), $k_p = f_p(k_{pN})$ and $\dot{k}_p = f_p'\dot{k}_{pN}$ can be found for $p \in \{p_{N1+1}, ..., p_{N-1}\}$, where $f_p(.)$ is some known function. Second, using equation (23), $x_p = g_p(k_{pN}, \dot{k}_{pN})$ can be derived for $p \in \{p_{N1+1}, ..., p_{N-1}\}$, where $g_p(.)$ is some known function. Using these expressions in the resource constraint (24) yields:

$x_{pN} = h\left(k_{pN}, f_{pN1+1}...f_{pN-1}, g_{pN1+1}...g_{pN-1}, k_{p1}...k_{pN1}, C\right)\dot{k}_{pN}$

where $h(.)$ is some known function. Finally, plugging this expression for x_{pN} into $\dot{k}_{pN} = k_{pN}(x_{pN} - \delta)$ (from equation (23) for $p = p_N$), a equation of motion for k_{pN} is obtained:

$\dot{k}_{pN} = m\left(k_{pN}, h(.)\right)$

where $m(.)$ is some known function. Finally, equation (22) can be used to eliminate the interest rate throughout: $r = r(k_{pN}, p_N)$. Therefore, system (21)-(25) can be re-expressed as system (26)-(30):

$$\dot{x}_p = \frac{(r(k_{pN}, p_N) + p + \delta)[1 + \vartheta(x_p) + x_p\vartheta'(x_p)] - AF_{k,p} - x_p^2\vartheta'(x_p)}{2\vartheta'(x_p) + x_p\vartheta''(x_p)} \qquad p \in \{p_1, ..., p_{N1}\} \leq p^* \quad (26)$$

$$\dot{k}_p = k_p(x_p - \delta) \qquad p \in \{p_1, ..., p_{N1}\} \leq p^* \quad (27)$$

$$\dot{k}_N = m\left(k_{pN}, f_{pN1+1}...f_{pN-1}, g_{pN1+1}...g_{pN-1}, k_{p1}...k_{pN1}, C\right) \quad (28)$$

$$\dot{C} = \frac{U'(C)}{U''(C)}(\rho - r(k_{pN}, p_N)) \quad (29)$$

$$k_p(0) = \kappa_p, \qquad \lim_{t\to\infty} k_p(t)z_p(t) \geq 0 \qquad p \in \{p_1, ..., p_{N1}\} \cup \{p_N\} \quad (30)$$

The solution consists of the functions describing the time paths of x_p and k_p for the subset of N_1 firm types that use bond financing, and k_{pN} and C. [17]

5 Monetary Policy Shocks and the Bank Lending Channel

In this section we find the solution to the boundary value problem stated in equations (26)-(30). Due to the high order dimensionality of the system we would not gain much insight by using a phase diagram to characterize the qualitative dynamics of this economy. Rather we prefer to obtain a numerical approximation to the exact solution by using Miranda and Fackler (2002) CompEcon toolbox to solve boundary value problems. In short, the method relies on a polynomial approximation to the unknown functions of time, where the coefficients of the polynomial that give the "best fit" are

[17] This is a system of $2N_1 + 2$ equations in $2N_1 + 2$ unknowns, with $2N_1 + 2$ boundary conditions.

found by the collocation method.[18]

In carrying out this numerical implementation we reduce the number of firm types to just $N = 3$. This is enough to summarize the heterogeneity among borrowers with only three different types of agents: those who always use bank lending (p_3), those who always use bond financing (p_1) and those in between (p_2).

For the numerical solution it is also necessary to specify functional forms and parameter values. Table 1 shows the functional forms while Table 2 shows the parameter values. When possible, these parameters have been assigned values that are standard in the continuous-time neoclassical growth literature. Several robustness checks have been run without finding significant changes in the qualitative results obtained.[19]

The financial friction in bond financing depends on the underwriting fees and costly state verification parameters ϕ, θ and φ (see Tables 1 and 2). These parameters were chosen in combination with probability p_2, such that in steady-state the optimal finance choice for this type of firms is, initially, bank financing (i.e. $\iota_{p2} = 1$).[20] This allows studying how the financing method used by firms of type p_2 changes after a monetary policy shock (i.e. in this model, a shock to c^L).

[18]For a system of dimension d, the collocation method finds the $n \times d$ coefficients of the n-degree polynomial by requiring the approximation to the solution function to satisfy the system of differential equations at $n - 1$ prescribed time nodes. This yields $d \times (n - 1)$ nonlinear equations. The boundary conditions, that must also be satisfied by the approximated solution function, add d more equations for a total of $n \times d$ equations. The $n \times d$ nonlinear system can be solved by standard nonlinear solvers such as the Newton method or the more computationally efficient Broyden method. See Miranda and Fackler (2002, Ch 6, p 146).

[19]The results from various robustness checks are available from the author upon request.

[20]In steady-state $v_{p2}(0|\iota = 1) = 93.4731 > v_{p2}(0|\iota = 0) = 93.4652$.

5.1 Financing Decisions and Firm's Size

Equation (19) yields the result that the steady-state level of capital stock is decreasing in the firm type p. A higher p means a higher probability of default and thus, both banks and the mutual fund adjust the interest rate they charge on loans accordingly. Higher interest rates, of course, lead to lower investment and smaller firms' sizes as measured by their capital stock. Thus, high-risk firms that must use bank lending are also the smallest ones (i.e. p_3 type), while low-risk firms that can undercut financing costs by issuing direct debt are the biggest ones (i.e. p_1 type).

This relationship between firms' size and financing decision is in fact "imposed" on to the model through its initial assumptions, making it consistent with empirical evidence presented by Petersen and Rajan (1994,1995) and Cantillo and Wright (2000) among others. Several other papers also use this same type of relationship between firms' sizes and their financing decisions in either theoretical models or empirical applications (Bolton and Freixas, 2000; Oliner and Rudebusch, 1996a, 1996b; Gertler and Gilchrist, 1994; Bernanke, Gertler and Gilchrist, 1996).

5.2 Effects of an Unexpected Monetary Policy Shock

The simulation exercise performed here consists of a temporary 10% positive shock to banks' intermediation cost c^L. This intends to capture a shock to banks loan supply schedules after a monetary tightening. The intermediation cost is kept at this higher value during some period of time, after which it returns to its original value. [21]

Given the calibration used (see Tables 1 and 2), a small temporary shock

[21] In this exercise, the boundary conditions for the system are given by the pre-shock steady-state values of capital for each type. The transversality condition $\lim_{t\to\infty} z(t)k(t)$ is replaced by a stricter condition that $k(T) = k^{SS}$ (SS=steady-state) for T large enough.

is enough for a firm of type 2 to find it profitable to switch to bond financing: $v_{p2}(0|\iota = 1) = 93.4177 < v_{p2}(0|\iota = 0) = 93.4724$. This is the result pointed first by Kashyap, Stein and Wilcox (1993), by which borrowers seek alternative financing sources as banks' intermediation costs increase, making the aggregate financing mix $\frac{\sum_p l_p}{\sum_p k_p}$ to fall. Figure 2 displays the time paths of aggregate consumption, investment and output after the monetary tightening. The recessionary impact of the monetary policy described here is also in line with Kashyap, Stein and Wilcox (1993) empirical estimation of the real effects of a shock to the aggregate financing mix. As in their model, these real effects are the consequence of the imperfect substitutability between alternative financing sources for the firm. A borrower that previously found it optimal to use bank lending cannot overcome the shortage of bank credit after the monetary tight without incurring in higher financing costs.

One argument opposed to Kashyap, et al (1993) empirical findings is that firms do not actually switch after a monetary policy contraction. Oliner and Rudebusch (1996a) present some evidence showing that even though the aggregate financing mix falls after a monetary contraction, this does not hold when looking at disaggregated data on the financing mix for different firm sizes. That is, the financing mix does not change at the level of the individual firms. They explain that this apparent contradiction between aggregate and disaggregated data results is due to a compositional effect that drives the aggregate behavior of the financing mix. Their reasoning is that if monetary policy affects firm activity through a mechanism other than the bank lending channel, so that the financing mix is not altered at the level of the individual firm, and small (bank-dependent) firms happens to be hit more severely than large firms, then bank lending will fall disproportionately more than total external financing generating the behavior observed for the aggregate financing mix.

Kashyap, Stein and Wilcox (1996) contend that Oliner and Rudebusch's findings of no switching[22] only show that looking at the aggregate financing mix is not such a good identification strategy, but that this does not necessarily challenge the bank lending channel. Kashyap et al (1996) argue that many small firms that have no access to alternative sources of funds other than bank credit never switch. However, the lack of switching would actually reinforce the bank lending channel. Figure 3 illustrates Kashyap, et al (1996) point. In this exercise p_2 has been increased from $p_2 = 0.12$ to $p_2 = 0.15$, a level that guarantees no switching. Thus, for each of the three firm types (i.e. sizes) there is no change in the financing choices of the individual firms after the monetary policy shock. As Oliner and Rudebusch (1996a) suggest, the aggregate financing mix response is due entirely to a disproportionate effect of the policy shock over small firms. However, as Kashyap, et al (1996) argue, the explanation for this differential response of small firms may lay precisely on the bank lending channel.

There is a second argument against the bank lending channel rooted in the evidence presented by Gertler and Gilchrist (1994), Oliner and Rudebusch (1996a,1996b) and Bernanke, Gertler and Gilchrist (1996). After a monetary contraction these authors find a redirection of all forms of credit from small firms towards large firms. This observation is independent of the financing choice of each type of firms and it is consistent with no changes in the financing mix at the level of the firm. This is the "flight to quality" story (Bernanke, et al 1996) that provides strong support to a balance sheet channel of monetary policy in which banks play no special role. In their view the bank lending channel cannot provide an equally satisfactory explanation of the facts.

However, Figure 4 shows that this model actually can reconcile the theory of the bank lending channel with the data. Figure 4 displays the results

[22] In fact, Kashyap et al (1996) show that certain firm types do switch to commercial paper after a monetary policy shock.

from the same exercise carried out in Figure 2 except that now it plots firm level variables.[23] The dynamics of investment and financing of small (p_3) and large firms (p_1) clearly reflects a pattern consistent with the "flight-to-quality" story involving a shift of business (i.e. production, investment and credit) away from small and towards large firms.

The driving force for this result is the equilibrium response of the interest rate in general equilibrium. In a general equilibrium setting, as small firms cut back on production and financing after being affected by higher intermediation costs, they free-up resources that can be then used by other production units not directly affected (initially) by the monetary contraction. Higher intermediation costs also imply lower wealth and thus lower consumption, which makes even more resources available for investment in larger firms. As more resources are made available, the relative price of current period goods in terms of future goods (i.e. the real interest rate) decreases. Large firms not affected directly by the policy shock take advantage of the lower financing costs and they increase production. Thus, after the monetary policy shock there is a temporary fall in the real interest rate that produces a reallocation of resources toward larger firms.[24] Again, a reallocation of investment from small to large firms is consistent with the "flight to quality" hypothesis, but from this exercise we conclude that this observation

[23]Aggregate consumption has also been included in this graph because it conveys important information on the transition of the equilibrium interest rate.

[24]This clearly contrasts with the traditional interest rate channel of monetary policy. In the traditional view, a positive shock to nominal interest rates generates an increase in real rates due to price rigidities. There is however two pieces of evidence that seems to back up the idea of falling real rates during a policy tight: first, King and Watson (1996) and Seppala and Xie (2005) show that real interest rates are countercyclical, so countercyclical monetary policy generates real interest rate responses in line with those observed in this model; second, Mishkin (2004) argue that even nominal rates could decline after a slow down in the growth rate of money supply due to income, price level and expected inflation effects (see pp.114-117).

not only should not be used to make a case against the bank lending channel, but also it actually provides support to this model.

There is one piece of the empirical evidence in support of a balance sheet channel that apparently a model consistent with the bank lending mechanism cannot account for. Bernanke, et al (1996) and also Gertler and Gilchrist (1994) point that the "flight to quality" phenomenon holds even within the group of bank-dependent borrowers. That is, after a monetary tightening large firms increase their access to bank credit at the expense of smaller firms. Still, this should not be taken as evidence against the bank lending view. The two theories are not mutually exclusive and thus this piece of evidence may be showing just that. But more importantly, further investigation could show that the evidence of a "flight to quality" within bank credit is also consistent with the bank lending view. For this purpose it would be enough to show that banks engage in some sort of price discrimination among their customers, something that is not unlikely. It might be profitable for banks to shift the bulk of the adjustment following a policy shock to smaller firms, which have a more inelastic demand due to higher switching costs and less outside financing opportunities, while still offering the same credit conditions as before the shock to their larger customers.[25]

Finally, a prediction of the balance sheet channel with strong support in the data is the asymmetric response over the cycle of small firms variables (investment, short-term debt and sales) to a monetary policy contraction (see Gertler and Gilchrist, 1994, Figure IV p. 333). The idea is that if monetary policy works through worsening the balance sheet positions of small credit-constrained firms, then this mechanism should be stronger during downturns, when their net worth is already low. When net worth decreases, informational problems worsen driving agency costs up. Thus, external financing premia for

[25]Including price discrimination by banks in the model is beyond the scope of the paper, so I do not pursue this argument further here.

these firms rise by more during a recession, increasing their financing costs. During a boom, monetary policy is not likely to have such an strong impact on the external finance premium of small firms as their credit constraints are not likely to bind in good times. Large firms, on the other hand, should not experience such an asymmetric effect as their credit constraints are never binding after a monetary shock, even during bad times. Again, the common wisdom is that the simple story behind the bank lending view cannot account for the rich dynamics of the disaggregated level variables. However, as we show next the predictions of this model of the bank lending channel are also consistent with this asymmetric response for small firms (p_3 type).

The explanation also relies on the external finance premium for small bank-dependent borrowers increasing during recessions. However, in this model with no role for borrowers' net worth, we must keep in mind that the external finance premium for bank borrowers corresponds to banks' price-cost markups. Aliaga-Díaz and Olivero (2006), Mandelman (2005) and Chen, Higgins and Mason (2005) present different types of evidence showing that banks price setting behavior results in markups that are countercyclical. They show that this is true for the US even after controlling for several other obvious determinants of markups such as credit risk, term structure of interest rates and monetary policy. Therefore, Figure 5 matches the evidence of asymmetric response of small firms by complementing a contractionary monetary policy with countercyclical intermediation costs in banking. For the purpose of this exercise banks' intermediation costs are modelled as a function of the total factor productivity (TFP) index: $c^L(A), \quad \partial c^L/\partial A$.

The exercise in Figure 5 consists of comparing the response to a monetary tightening when the economy is in a high growth state to the one that takes place when the economy is in a low growth state. High (low) growth states in the model are artificially generated with a +(-)0.7% temporary TFP shock.[26] Since there is no growth in this model, positive or negative TFP shocks correspond to states in which the economy is above or below trend, respectively. The time paths for investment and external financing after a temporary monetary policy shock under each one of the two growth regimes are displayed in Figure 5. The full line corresponds to a monetary policy shock in a low growth state while the dotted line denotes the response to a policy shock in a high growth state. The bottom two panels in Figure 5 display the response of small firms' variables conditional on the state of the economy (i.e. controlling for the TFP index).

More evidently for external financing, but also clear for the case of investment, small firms (i.e. p_3 type firms) display a marked asymmetry in their response to a monetary tightening. The countercyclical bank intermediation costs reinforce the effects of the monetary policy shock during recessions while it tends to ameliorate its strength during booms. There is no reason for bigger firms to display this type of asymmetry. The top two panels in Figure 5 show that investment and external debt outstanding follow a similar pattern in good and in bad times after the monetary tightening.

6 Conclusions

A considerable amount of work in the literature on the transmission channels of monetary policy has been devoted to the task of developing empirical identification strategies to disentangle the two alternative theories of the credit channel: the bank lending channel and the balance sheet channel.

The theory of a balance sheet channel relying on borrowers' net worth has been proved very successful at replicating the real world data. This transmission mechanism also results very appealing from a theoretical standpoint,

[26]The magnitude of this shock (0.7% of its value) is close to the standard deviation of the TFP index over the business cycle.

as it fits nicely in the informational asymmetries paradigm of credit markets.

One might be tempted to use the empirical success of the balance sheet channel to automatically reject the alternative view. This seems to be the consensus reached by the profession (Walsh, 1998). In particular, it has been stressed that only the balance sheet channel can account for the rich dynamics of several variables at the firm level (see Oliner and Rudebusch, 1996b). However, here we show that a simple dynamic general equilibrium model augmented with a bank lending channel, where there is no role for firms' balance sheets, can still successfully reproduce the qualitative dynamics of firm level data. In a qualitative exercise the model predictions can track well firms' financing choices, a differential access to credit markets across firm sizes and the compositional effects in changes of the financing mix after a monetary policy tightening, all of them empirical regularities attributed to the balance sheet channel and the "flight to quality" hypothesis.

Therefore, this paper calls for further identification efforts in assessing the relative (quantitative) contribution of each one of the two channels in the transmission of monetary policy.

The balance sheet channel assigns no role to bank credit as an independent force in the transmission mechanism of monetary policy. However, on the one hand, Kashyap and Stein (2000) show that monetary policy shocks do limit the ability of certain banks to extend credit. On the other, with small firms representing a share as high as 90% of total industry sales in certain sectors of the economy (Gertler and Gilchrist, 1994) and with bank loans ranging from 50% to 100% of total external financing for these firms, it seems important to assess the extent to which even small shocks to bank loan supply schedules can still provide an effective transmission channel of monetary policy.

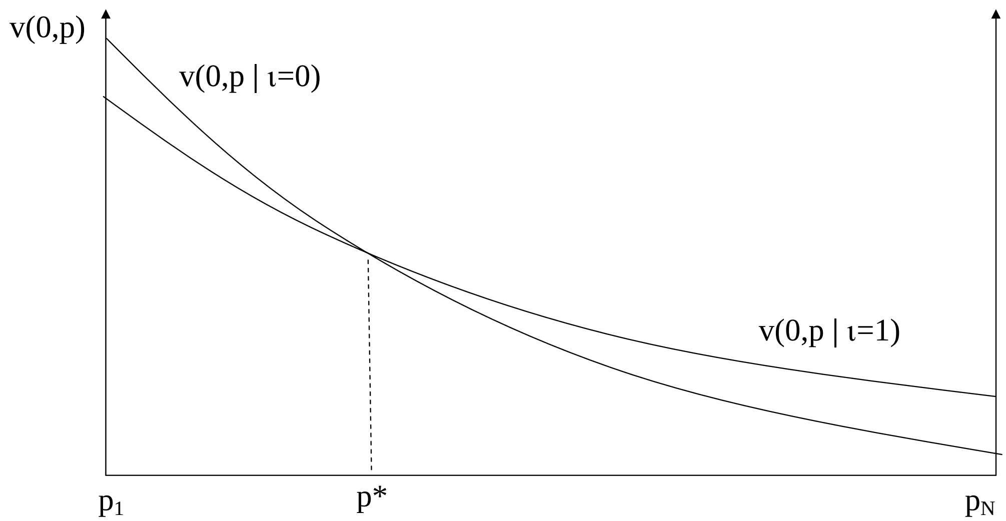

Figure 1: Firms' Financing Decisions

Table 1: Functional Forms

$AF(k)$	Ak^{γ}
$U(C)$	$\frac{C^{1-\sigma}}{1-\sigma}$
$\vartheta(x)$	$\varphi p + \phi x^{\theta}$

Table 2: Parameter Values

γ	ρ	σ	δ	A	c^L	φ	ϕ	θ	p_1	p_2	p_3
0.66	0.06	2	0.1	1	0.05	0.405	2	4	0.05	0.12	0.2

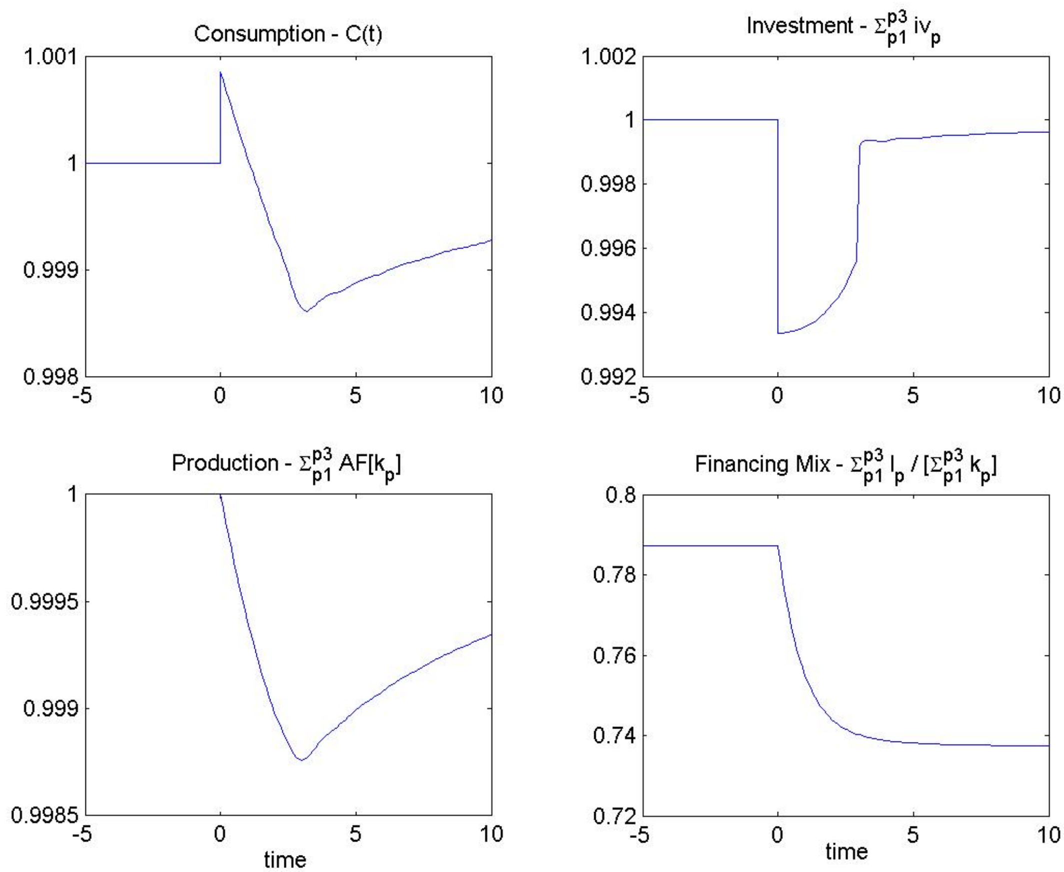

Figure 2: The Aggregate Financing Mix and the Bank Lending Channel

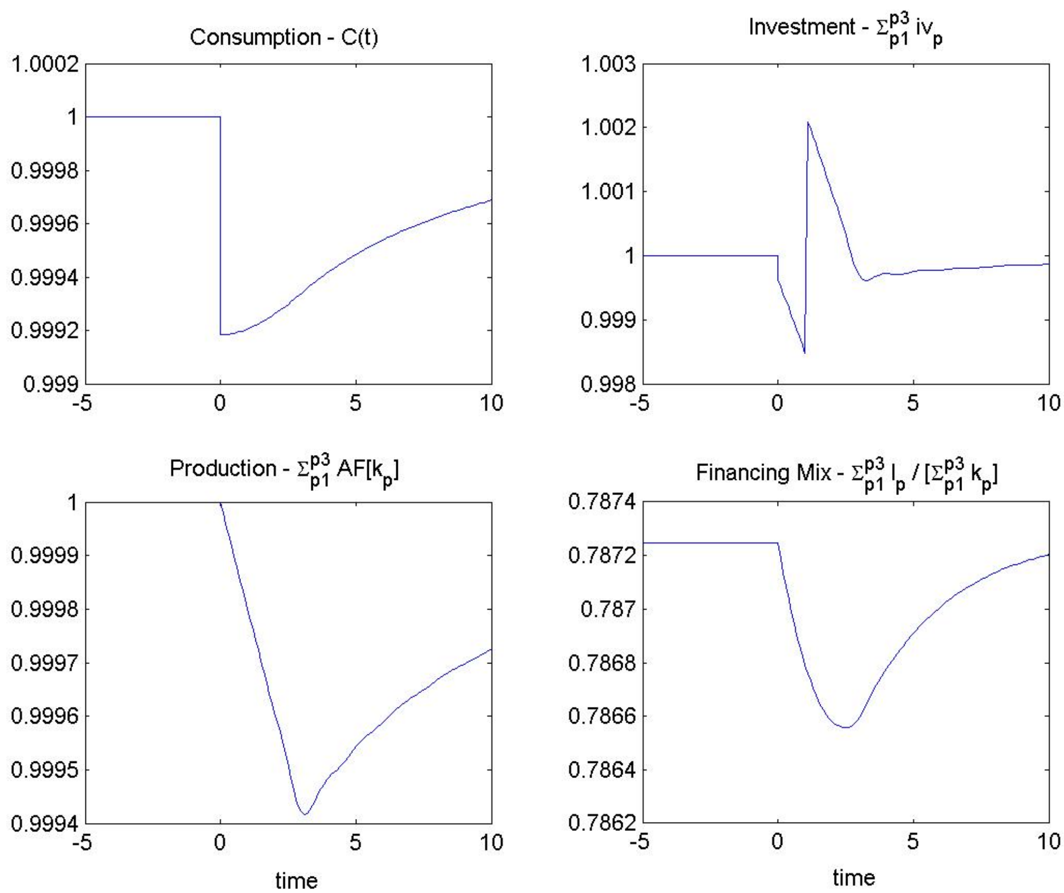

Figure 3: Compositional Effects versus Switching

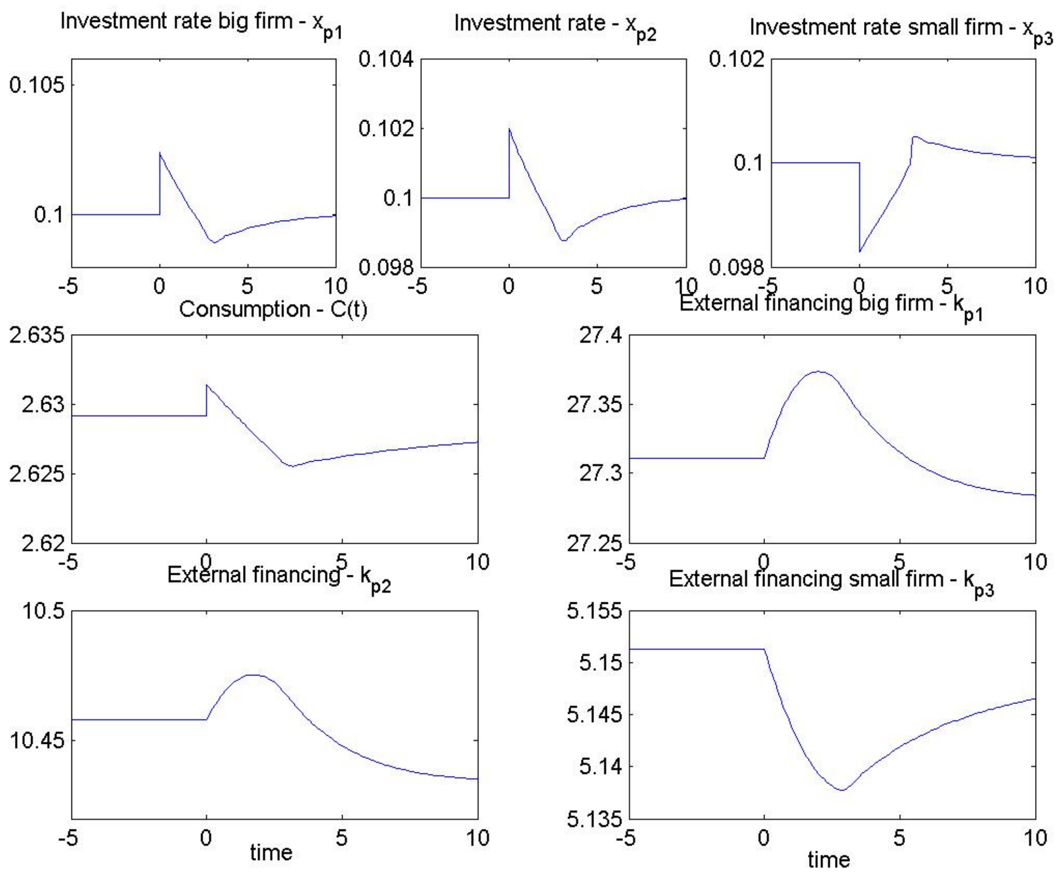

Figure 4: Differential Effect of Monetary Policy Across Firm Sizes

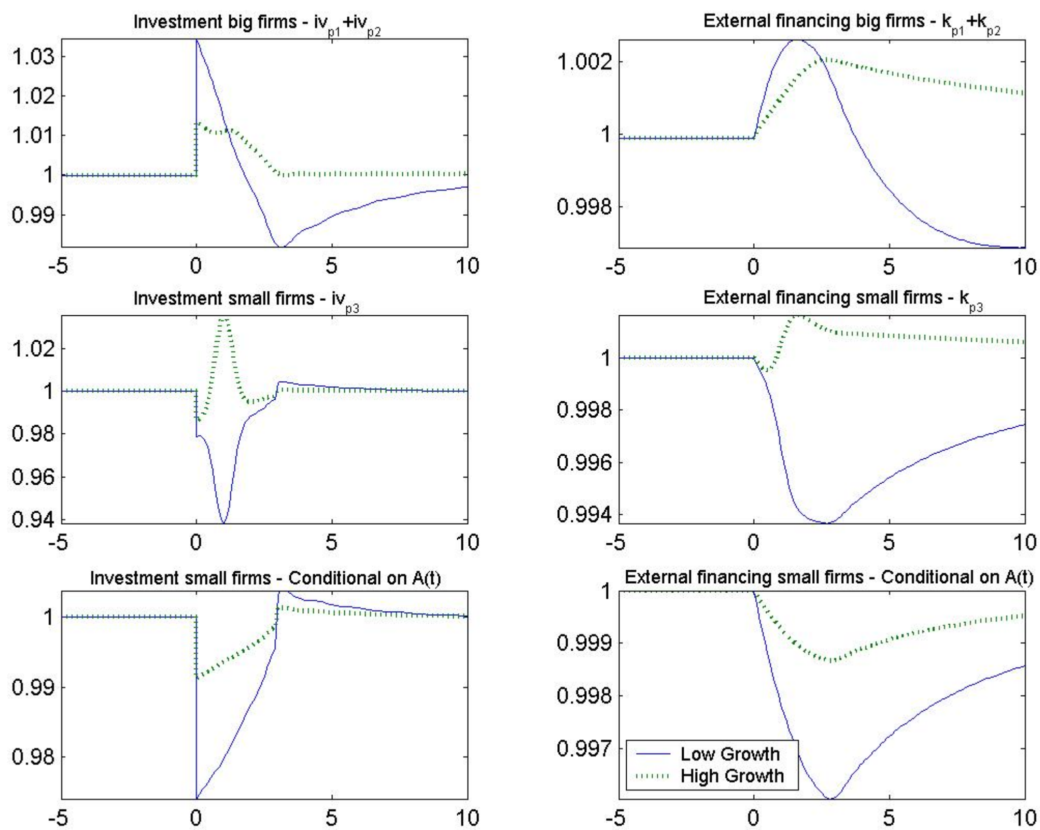

Figure 5: Asymmetric Effects of Monetary Policy Over the Cycle

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