

Financial Innovations and Macroeconomic Volatility*

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Abstract

The volatility of US business cycles has declined during the last two decades. During the same period the financial structure of firms has become more volatile. In this paper we develop a model in which financial factors are central for generating economic fluctuations. Innovations in financial markets allow for greater financial flexibility and generate a lower volatility of output together with a higher volatility in the financial structure of firms.

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1 Introduction

The amplitude of US business cycles has declined during the last 20 years, with all macroeconomic variables displaying a lower volatility than in the previous 30 years. In this paper we investigate the extent to which the lower volatility can be explained by innovations in financial markets that allow for greater financial flexibility of firms.

We are motivated by two sets of empirical regularities about the dynamics of the financial structure of firms. First, corporate debt drops dramatically during recessions. This suggests that recessions are periods in which firms must restructure their financial position. If firms cannot compensate the debt reduction with new equity, they must cut production and investment which has further recessionary consequences.

The second regularity is that the change in debt and the issue of new equity in the business sector has become more volatile during the last two decades, in contrast to the lower volatility of the real sector. Because changes in debt and equity issuance are negatively correlated, these findings suggest that firms have become more flexible in the choice of their financial structure. This greater flexibility is, in our framework, the driving force for the milder business cycle.

During the 80s and the 90s various innovations have emerged in the area of firm financing. So far as equity payout policies are concerned, firms have gained greater flexibility in issuing and repurchasing shares. The ability and flexibility to issue debt has also changed as firms have now access to a wider variety of instruments. These two changes are closely related to the empirical regularities discussed above and will play an important role in our analysis.

Financial volatility joint with real stability poses challenges to some of the existing explanations for more stable business cycles. Indeed, if the good fortune of being exposed to milder shocks is the main explanation, then it is not clear, a priori, why financial variables have not also become more stable. If better monetary policies are the main explanation, then it also begs the question through what mechanisms this was achieved without also stabilizing key financial variables. In this paper we use a theoretical framework that can account for the contrasting evolutions in financial and real volatility.

In our model, firms finance investment with equity and debt. Debt contracts are not fully enforceable and the ability to borrow is limited by a no-default constraint which depends on the expected lifetime profitability of the firm. As lifetime profitability varies with the business cycle, so does a

firm's ability to borrow. In this regard, our model is related to Kiyotaki & Moore (1997), Bernanke, Gertler & Gilchrist (1999), and Mendoza & Smith (2005), in the sense that asset prices movements affect the ability to borrow. Our model, however, differs in one important dimension: we allow firms to issue new equity in addition to reinvesting profits. This extra margin plays a central role in our model. In particular, it is the greater flexibility in issuing equity, net of repurchases, that allows for milder business cycles.¹

The paper is structured as follows. In Section 2, we discuss some empirical evidence on real and financial cycles in the US economy. Section 3 presents the model and characterizes some of its analytical properties. After describing the calibration in Section 4, Section 5 studies the impact of financial innovations. Section 6 examines some additional features of the model and 7 concludes.

2 Real and financial cycles in the U.S.

This section presents the main empirical observations that motivate our paper. It describes some features of the real and financial cycles and the extent to which these features have changed in the last two decades.

Figure 1 plots the log of real GDP in the nonfarm business sector. The figure clearly shows the reduction in output volatility during the last 20 years. A similar pattern is also observed in other macroeconomic variables including total factor productivity.

Although the lower business cycle volatility has been emphasized in several studies, the causes of these changes are still under investigation.² In this paper we examine the role of financial markets innovations. The role of financial innovations is also studied in Campbell & Hercowitz (2005), focusing on the residential mortgage market. Our study, instead, focuses on financial

¹There are other studies that allow for equity issuance over the business cycle. See, for example, Choe, Masulis & Nanda (1993), Covas and den Haan (2005), Leary and Roberts (2005), Levy & Hennessy (2005). The main focus of these studies is in the financial behavior of firms, not the macro impact of financial innovations.

²See Kim & Nelson (1999), McConnell & Perez-Quiros (2000), Stock & Watson (2002), Comin and Philippon (2005), Cecchetti, Flores-Lagunes & Krause (2006), and Arias, Hansen & Ohanian (2006). Dynan, Elmendorf & Sichel (2005) document some changes in the US financial market during the same period and Cecchetti, Flores-Lagunes & Krause (2006) provide some cross-country evidence about the relation between financial development and the reduction in macroeconomic volatility.

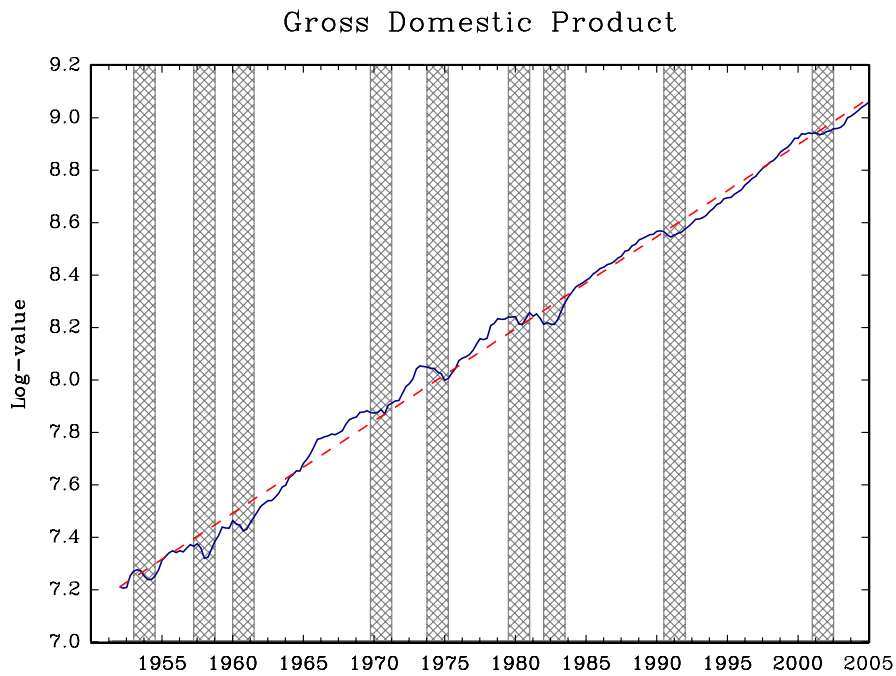


Figure 1: GDP in the nonfarm business sector.

innovations that affect the business sector of the economy. This is motivated by key stylized facts about the dynamics of the financial structure of firms as we now document.

The top panel of Figure 2 plots the credit market liabilities in the nonfarm business sector, as a fraction of GDP produced in this sector. Financial data is from the Flow of Funds Accounts of the Federal Reserve Board. Credit market liabilities include only liabilities that are directly related to credit markets instruments. It does not include, for instance, tax liabilities. We refer to this variable as ‘outstanding debt’.

There are two important patterns to emphasize. The first pattern is that outstanding debt, as a fraction of GDP, has increased during the last 50 years. In the early fifties this ratio was only 35 percent while in 2005 it has reached about 85 percent. The second pattern is the increased volatility of debt. While the debt-to-output ratio has been growing at a relatively stable pace during the fifties and sixties, in the last three decades it has displayed large

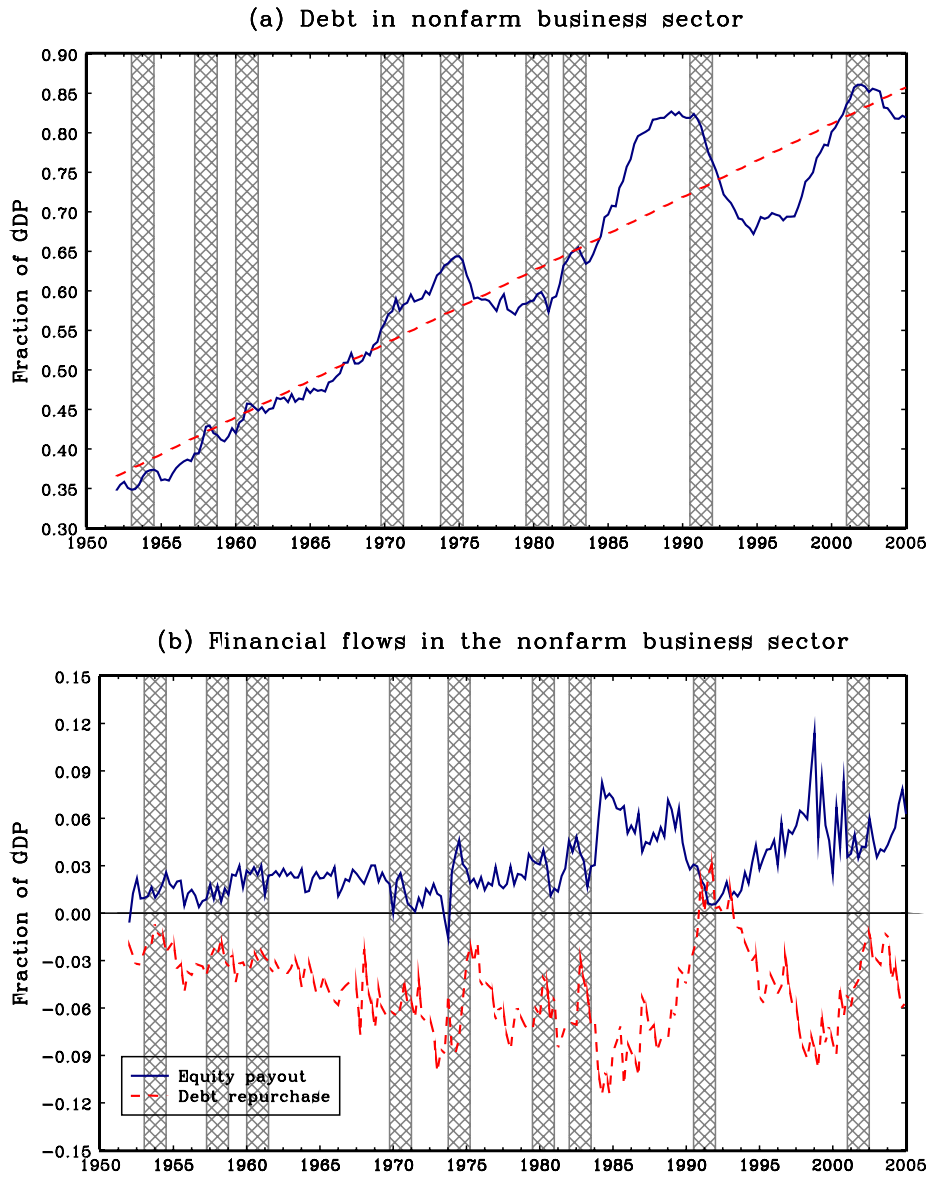


Figure 2: Financial structure in the nonfarm business sector.

swings. Moreover, the debt exposure tends to decline dramatically during or after a recession. This suggests that recessions lead firms to restructure their financial exposure and the magnitude of restructuring is severe when the debt exposure is high.

The bottom panel of Figure 2 plots net payments to equity holders and net debt repurchases in the nonfarm business sector. Both variables are expressed as a fraction of nonfarm business GDP. Equity payout is defined as dividends minus equity issues (net of share repurchases) of nonfinancial corporate businesses, minus net proprietor's investment in nonfarm noncorporate businesses. They capture the net payments from the business sector to business owners (shareholders of corporations and non-corporate business owners). Debt repurchases are defined as the reduction in outstanding debt.

This figure also displays two important features. The first is that both variables have become more volatile during the last two decades. The second is that equity payouts have become negatively correlated with debt repurchases.

The properties of real and financial cycles are further characterized in Table 1. The table reports the standard deviations and cross correlations of three variables: equity payout, debt repurchase, and the log of GDP in the nonfinancial corporate sector and in the nonfarm business sector. Equity payout and debt repurchase are in fractions of value added produced in the sector. The table also reports the standard deviation of net worth. This provides information about the volatility of the stock of internal funds. All variables have been detrended using a band-pass filter that preserves cycles of 1.5-8 years. Alternative detrending using, for instance, the Hodrik-Prescott filter or a linear trend would display similar properties.

The standard deviation of equity payouts, as fraction of GDP, has increased substantially in the most recent period 1984-2005, compared to the earlier period 1952-1983. The increase in volatility is also observed for net worth. This is in sharp contrast to the standard deviation of GDP that has declined by half. The volatility of debt repurchase does not show a clear increase in volatility which seems to contradict the pattern shown in Figure 2. This is because most of the increase in the volatility of debt is at low frequencies, which are captured by the trend.

The cross correlations are consistent with the pattern shown in Figure 2. In particular, firms tend to issue more debt (lower debt repurchase) during booms. This is true in both subperiods. Therefore, the co-movement of debt with output has not changed significantly. Equity payout is positively cor-

Table 1: Business cycles properties of firm financing.

	Corporate sector			Nonfarm business		
	1952-83	1984-05	Late/Early	1952-83	1984-05	Late/Early
<i>Standard deviation</i>						
EquPay	0.56	1.24	2.24	0.69	1.09	1.56
DebtRep	1.53	1.49	0.97	1.09	1.37	1.25
Net Worth	1.18	2.58	2.19	1.12	2.26	2.01
GDP	2.70	1.52	0.56	2.35	1.17	0.50
<i>Correlation</i>						
Corr(EquPay,GDP)	0.42	0.47		-0.03	0.52	
Corr(DebtRep,GDP)	-0.69	-0.63		-0.73	-0.75	
Corr(EquPay,DebtRep)	-0.56	-0.60		-0.12	-0.62	

Notes: Financial data is from the Flow of Funds Accounts of the Federal Reserve Board. *Equity payout* in the corporate sector is net dividends minus net issue of corporate equity. *Equity payout* in the nonfarm business sector is equity payout in the corporate sector minus proprietor's net investment. *Debt repurchase* is the negative of the change in credit market liabilities. Both variables are divided by their sectorial GDP. *Net worth* is the log of net worth, measured at market values, deflated by the price index for the nonfarm value added. *GDP* is the log of sectorial real GDP (corporate or nonfarm business). All variables are detrended with a band-pass filter that preserves cycles of 1.5-8 years (Baxter and King (1999)). See Appendix A for more details.

related with output and negatively correlated with debt repurchases. These correlations are unambiguous especially in the second sample period. Thus, the substitution between debt and equity seems to be a strong empirical regularity.³ Similar cyclical properties are also found by Covas and den Haan (2005) using data from Compustat firms (including those involved in mergers and acquisitions).

We summarize the main empirical facts outlined in this section as follows:

1. *The business cycle volatility has declined during the last 20 years.*
2. *The debt exposure has increased during the last 50 years.*
3. *Debt repurchases are counter-cyclical and equity payouts are pro-cyclical.*
4. *Equity payout and debt repurchases have become more volatile during the last 20 years.*

³The inclusion of a fraction of proprietors' income into equity payouts does not change significantly the statistics reported in Table 1.

The first fact has been emphasized in several empirical studies and is well-known. The others (especially 3 and 4) are less known and explored in the macro literature. Starting in the next section we develop a model that captures the key changes in financial markets described above. The goal is to evaluate the extent to which these innovations have contributed to reducing the real business cycle volatility.

3 Model

We first describe the environment in which an individual firm operates. After characterizing the problem solved by an individual firm, we describe the remaining section of the model and define the general equilibrium.

3.1 Financial and investment decisions of firms

There is a continuum of firms, in the $[0, 1]$ interval, with the following revenue function $\pi(\mathbf{s}_t; k_t, l_t)$. The revenue function is concave in the inputs of capital, k_t , and labor, l_t , and displays decreasing returns to scale in these two inputs. The assumption of decreasing returns implies that the firm generates positive profits and its market value is above the replacement cost of capital. The revenue function also depends on the aggregate state of the economy \mathbf{s}_t as will be made precise below.

Firms retain the ability to generate profits with probability p . This variable is interpreted as the likelihood that the firm retains the control of a particular market. Uncertainty is resolved at the beginning of the period. In the event of market loss, the firm sells its activities to a new firm at the price L_t and exits. By purchasing the activities of the exiting firm, the new entrant firm starts with the same states as incumbents so that all firms are alike. The law of large numbers implies that in each period there is a fraction $1 - p$ of firms that lose their markets. The probability p is stochastic and follows a first order Markov process with transition probability $\Gamma(p'/p)$. The change in p is the only source of aggregate uncertainty.

The firm raises funds with equity and debt. Debt is preferred to equity because of its tax advantage as in Hennessy and Whited (2005). Given r_t the interest rate and τ the tax rate, the effective cost of debt is $r_t(1 - \tau)$ and the present value of one unit of debt is $1/R_t = 1/[1 + r_t(1 - \tau)]$. The ability to borrow, however, is bounded by the limited enforceability of debt

contracts as the firm can default at the end of the period and divert some of the firm's resources. These resources, denoted by $D(k_t, l_t)$, increase with the scale of production, that is, with the inputs of capital and labor. Let \bar{V}_t be the value of the firm at the end of the period, after paying dividends. This is defined as:

$$\bar{V}_t = E_t \sum_{j=1}^{\infty} \left(\prod_{\ell=1}^{j-1} p_{t+\ell} \right) m_{t+j} \bar{d}_{t+j}$$

where m_{t+j} is the relevant stochastic discount factor, as specified later, and \bar{d}_{j+j} are the net payments to the shareholders.⁴ Appendix B describes in detail the renegotiation process and shows that incentive-compatibility imposes the following constraint:

$$\bar{V}_t \geq \phi \cdot D(k_t, l_t)$$

where ϕ is a parameter that captures the degree of enforcement. Because higher debt reduces the value of the firm for the shareholders (left-hand-side), this constraint imposes a borrowing limit. The value of the firm \bar{V}_t can be interpreted as a collateral and $1/\phi$ the degree to which the firm's assets are collateralizable. As we will see later, one way to capture financial innovations is through the change in ϕ .

The market retention probability p plays a crucial role in the determination of the firm's value because it affects the effective discount factor. In particular, with a persistent fall in p , the retention rates are also expected to be smaller in the future. This reduces the hazard rate $\prod_{\ell=1}^{j-1} p_{t+\ell}$, which in turn reduces the firm's value \bar{V}_t and leads to a tighter constraint: If the firm cannot raise enough equity to reduce the debt exposure and increase the value of the firm, it will be forced to reduce the inputs of capital and labor.

In order to capture the frictions associated with issuing and repurchasing shares as well as paying dividends, we assume that the firm's payout is subject to a quadratic adjustment cost. The cost is:

$$\varphi(d_t) = d_t + \kappa \cdot (d_t - \underline{d})^2$$

where $\kappa \geq 0$ and \underline{d} represents the long-run payout target. Lintner (1956) showed first that managers are concerned about smoothing dividends over time, further confirmed by subsequent studies. The function $\varphi(\cdot)$ also cap-

⁴In the general equilibrium environment we will define below, there will be a unique relevant stochastic discount factor, so that $E_t m_{t+1} = 1/(1+r_t)$.

tures the possible costs associated with share repurchases and equity issuance.⁵

The parameter κ affects the degree of market incompleteness. As we will see, when $\kappa = 0$ the economy is essentially equivalent to a frictionless environment. In this case, debt adjustments triggered by the enforcement constraint can be costlessly accommodated through changes in firm equity. When $\kappa > 0$, the substitution between debt and equity becomes costly and will affect the firm's production decisions. Changes in κ identify the second channel through which financial innovations are captured by our model.

Firm's problem: We write the problem recursively. The states of the firm are capital k and debt b , in addition to the aggregate states that we will define later. Conditional on retaining its market, the firm chooses the input of labor l , the payout d , the new capital k' and the new debt b' . The optimization problem is:

$$V(\mathbf{s}; k, b) = \max_{l, d, k', b'} \left\{ d + \bar{V}(\mathbf{s}; k', b') \right\} \quad (1)$$

subject to:

$$\pi(\mathbf{s}; k, l) + \frac{b'}{R} - b - \varphi(d) - k' = 0$$

$$\bar{V}(\mathbf{s}; k', b') \geq \phi \cdot D(k, l).$$

The function $V(\mathbf{s}; k, b)$ is the value of the firm conditional on market retention and $\bar{V}(\mathbf{s}; k', b')$ is the value at the end of the period (after all relevant choices are made, including the payment of dividends, the choice of next period capital and the repayment of the previous debt). The optimization problem is subject to the budget and enforcement constraints.

⁵The convexity assumption is consistent with the work of Hansen & Torregrosa (1992) and Altinkilic & Hansen (2000), showing that underwriting fees display increasing marginal cost in the size of the offering. Direct costs such as underwriting fees, however, are only part of the cost. The function $\varphi(\cdot)$ also captures the agency problems associated with the issuance or repurchase of shares which are likely to increase more than proportionally with the size of the issuance or repurchase.

The value of the firm at the end of the period is defined as:

$$\bar{V}(\mathbf{s}; k', b') = Em' \left[p' \cdot V(\mathbf{s}; k', b') + (1 - p') \cdot L(\mathbf{s}'; k', b') \right]. \quad (2)$$

The firm retains the market for the intermediate good with probability p' and loses it with probability $1 - p'$. In the latter event the activities of the firm are sold to the new entrant firm at the price $L(\mathbf{s}'; k', b')$. This price depends on the relative bargaining power between the exiting and the new firm. For analytical convenience we assume that the exiting firm has all the bargaining power and extracts the whole net surplus, that is, $L(\mathbf{s}; k, b) = V(\mathbf{s}; k, b) - V(\mathbf{s}; 0, 0)$.⁶ We would like to emphasize that alternative assumptions about the bargaining power would not change the key properties of the model.

In solving the problem, the firm takes as given all prices, including the stochastic discount factor m and the gross interest rate R . The first order conditions can be written as:

$$\pi_l(\mathbf{s}; k, l) = \mu \phi D_l(k, l) \varphi_d(d) \quad (3)$$

$$(1 + \mu)Em' \left(\frac{\pi_k(\mathbf{s}'; k', l')}{\varphi_d(d')} - \mu' \phi D_k(k', l') \right) = \frac{1}{\varphi_d(d)} \quad (4)$$

$$(1 + \mu)Em' \left(\frac{R}{\varphi_d(d')} \right) = \frac{1}{\varphi_d(d)}, \quad (5)$$

where μ is the lagrange multiplier associated with the enforcement constraint and subscripts denote derivatives. The detailed derivation is provided in Appendix C.

These conditions characterize the optimal policy of the firm. To build some intuition, let's consider first the case without adjustment costs, that is, $\kappa = 0$. Thus, $\varphi_d(d) = \varphi_d(d') = 1$ and condition (5) becomes $(1 + \mu)REm' = 1$. This implies that the Lagrange multiplier μ is fully determined by aggregate prices (the discounting m). Then, from conditions (3) and (4) we can see that the production and investment choices of the firm only depend on aggregate

⁶If the two firms do not reach an agreement, the value of the new firm would be $V(\mathbf{s}; 0, 0)$ because it starts with zero capital and debt. This implies that the new firm is unable to produce in the current period because it does not have capital. If the two firms reach an agreement, the value of the new firm would be $V(\mathbf{s}; k, b)$. Therefore, the net surplus from reaching an agreement is $V(\mathbf{s}; k, b) - V(\mathbf{s}; 0, 0)$. This is the price obtained by the exiting firm under the assumption that it has all the bargaining power.

prices. Changes in p affect the investment policy of the firm only if they change the aggregate prices R and m' . But as long as the aggregate prices are not affected, the policy of the firm does not change. Furthermore, we observe that, if the default constraint is not binding in neither the current nor the next period, the Lagrange multiplier is $\mu = \mu' = 0$. Then the first order condition for the choice of labor and capital become $\pi_l(\mathbf{s}; k, l) = 0$ and $Em'\pi_k(\mathbf{s}'; k', l') = 1$, that is, the marginal productivities are equalized to their marginal costs.

These results no longer hold when $\kappa > 0$. In this case changes in the value of the firm lead to changes in the production choices. In particular, a fall in the value of the firm will make the default constraint tighter which is captured by an increase in μ . In the first period this leads to a reduction in the demand of labor l . Then, starting from the next period, the input of capital also falls. In equilibrium, of course, the changes in the firms' policies also affect the aggregate prices R and m' . To derive the aggregate effects we need to close the model and characterize the general equilibrium.

3.2 Full model and general equilibrium

We now describe the remaining sections of the model and define the general equilibrium. First we specify the market structure and technology leading to the revenue function $\pi(\mathbf{s}; k, l)$. We then close the model with the specification of the household sector.

Production and market structure: Each firm produces an intermediate good x_i that is used in the production of final goods according to:

$$Y = \left(\int_0^1 x_i^\eta di \right)^{\frac{1}{\eta}}.$$

The inverse demand function for the intermediate good i is:

$$p_i = Y^{1-\eta} x_i^{\eta-1}$$

where p_i is the price in units of the final good and $1/(1-\eta)$ is the elasticity of demand.

The intermediate good is produced with the inputs of capital and labor, according to:

$$x_i = (k_i^\theta l_i^{1-\theta})^\nu$$

where $\nu \geq 1$ determines the return to scale in production. We will consider both cases of constant return ($\nu = 1$) and increasing return ($\nu > 1$). The model with increasing returns captures, in a simple form, the presence of fix factors and variable capacity utilization. Capital depreciates at rate δ .

Given w the wage rate, the resources of firm i after production and after the payment of wages can be written as:

$$\pi(\mathbf{s}; k_i, l_i) = (1 - \delta)k_i + Y^{1-\eta}(k_i^\theta l_i^{1-\theta})^{\nu\eta} - wl_i$$

where the term $Y^{1-\eta}(k_i^\theta l_i^{1-\theta})^{\nu\eta}$ is the monopoly revenue $p_i x_i$, after substituting the demand and production functions.

The assumption made in the previous section that the revenue function displays decreasing returns is obtained by imposing $\eta\nu < 1$. In equilibrium, $k_i = K$ and $l_i = L$ for all firms, and therefore, $Y = (K^\theta L^{1-\theta})^\nu$. This implies that the aggregate production function is homogenous of degree ν .

Household sector: There is a continuum of homogeneous households with lifetime utility $E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, h_t)$, where c_t is consumption, h_t is labor, and β is the subjective discount factor. Households are the owners (shareholders) of firms. In addition to equity shares, they own non-contingent bonds. The budget constraint is:

$$w_t h_t + b_t + s_t(\bar{d}_t + p_t q_t) + G_t = \frac{b_{t+1}}{1 + r_t} + s_{t+1} q_t + c_t + T_t$$

where w_t and r_t are the wage and interest rates, b_t is the one-period bond, s_t the equity shares, \bar{d}_t the equity payment received from their portfolio of shares, q_t is the market price of surviving firms after the payment of dividends. The variable G_t are the net capital gains generated by the creation of new firms and T_t are lump sum taxes. Taxes are used to finance the tax exemption of interests paid by firms.

Each household owns a diversified portfolio of shares, and therefore, they only face the aggregate risk. Because only a fraction p_t survives to the next period, the price q_t is multiplied by this probability. The ownership of new firms is shared among all existing households independently of their previous ownership. The mass of new firms is $1 - p_t$. A new firm acquires the equity capital from an exiting firm by paying the liquidation value L_t . Therefore, the net capital gains are given by $G_t = (1 - p_t)(d_t + q_t - L_t)$. The payout received from incumbent firms is $\bar{d}_t = p_t d_t + (1 - p_t)L_t$.

The first order conditions with respect to labor, h_t , next period bonds, b_{t+1} , and next period shares, s_{t+1} , are:

$$w_t U_c(c_t, h_t) + U_h(c_t, h_t) = 0 \quad (6)$$

$$U_c(c_t, h_t) - \beta(1 + r_t) E U_c(c_{t+1}, h_{t+1}) = 0 \quad (7)$$

$$U_c(c_t, h_t) q_t - \beta E(\bar{d}_{t+1} + p_t q_{t+1}) U_c(c_{t+1}, h_{t+1}) = 0. \quad (8)$$

These are standard optimizing conditions for the household's problem. The first two conditions are key to determine the supply of labor and the risk-free interest rate. The last condition determines the market price of shares. After re-arranging and using forward substitution, the price can be written as:

$$q_t = E_t \sum_{j=1}^{\infty} \left(\frac{(\prod_{\ell=1}^{j-1} p_{t+\ell}) \cdot \beta^j \cdot U_c(c_{t+j}, h_{t+j})}{U_c(c_t, h_t)} \right) \bar{d}_{t+j}.$$

Firms' optimization is consistent with households' optimization. Therefore, conditional on survival, the stochastic discount factor is equal to $m_{t+j} = \beta^j U_c(c_{t+j}, h_{t+j}) / U_c(c_t, h_t)$.

General equilibrium: We can now provide the definition of a recursive general equilibrium. The sufficient set of aggregate states are given by the survival probability p , the aggregate capital K , and the aggregate bonds B .

Definition 3.1 (Recursive equilibrium) *A recursive competitive equilibrium is defined as a set of functions for (i) households' policies $c(\mathbf{s})$ and $h(\mathbf{s})$; (ii) firms' policies $d(\mathbf{s}; k, b)$, $k(\mathbf{s}; k, b)$ and $b(\mathbf{s}; k, b)$; (iii) firms' value $V(\mathbf{s}; k, b)$; (iv) aggregate prices $w(\mathbf{s})$, $r(\mathbf{s})$ and $m(\mathbf{s}, \mathbf{s}')$; (v) law of motion for the aggregate states $\mathbf{s}' = H(\mathbf{s})$. Such that: (i) household's policies satisfy the optimality conditions (6)-(7); (ii) firms' policy are optimal and $V(\mathbf{s}; k, b)$ satisfies the Bellman's equation (1); (iii) the wage and interest rates are the equilibrium clearing price in the labor and bond markets and $m(\mathbf{s}, \mathbf{s}') = \beta U_c(c_{t+1}, h_{t+1}) / U_c(c_t, h_t)$; (iv) the law of motion $H(\mathbf{s})$ is consistent with individual decisions and the stochastic process for p .*

3.3 Some characterization of the equilibrium

To illustrate some of the properties of the model, it will be convenient to look at some special cases in which the equilibrium can be characterized analytically. First, we show that for a deterministic steady state with constant p , the default constraint is always binding. Second, if $\kappa = 0$, changes in the survival probability p have no effect on the real variables of the economy.

Proposition 3.1 *The no-default constraint binds in a deterministic steady state.*

In a deterministic steady state $m = 1/(1+r)$ and $\varphi_d(d) = \varphi_d(d')$. Then, the first order condition for debt, equation (5), can be written as

$$1 + \mu = \frac{1+r}{R} > 1$$

where the inequality derives from the definition of $R = 1 + r(1 - \tau)$. Due to the tax advantage in debt, the shareholders would like to issue debt to pay out dividends. The debt constraint puts a limit to this. In a model with uncertainty, however, the constraint may not be always binding because firms may reduce their borrowing in anticipation of future shocks, unless τ is sufficiently high.

Proposition 3.2 *With $\kappa = 0$, changes in p have no effect on l and k' .*

When $\kappa = 0$, we have that $\varphi_d(d) = \varphi_d(d') = 1$. Therefore, the first order conditions (3)-(5), can be written as:

$$\pi_l(\mathbf{s}; k, l) = \mu\phi D(k, l)$$

$$(1 + \mu)Em' \left[\pi_k(\mathbf{s}'; k', l') - \mu'\phi D_k(k', l') \right] = 1$$

$$(1 + \mu)REm' = 1$$

Clearly, the retention probability does not enter the first order conditions. Therefore, the only way in which p can affect the production and investment policy of the firm is through the change in the multiplier μ or the equilibrium prices. But suppose that the equilibrium prices r , w and m do not change.

From the third condition we see that the unchanged sequence of prices implies that the sequence of multipliers μ does not change either. The first two conditions then imply that the production and investment choices of the firm do not change. Considering the consumer problem, it can be easily seen that p drops out of the budget constraint in equilibrium. That is, the losses of exiting firms are perfectly offset by the capital gains generated by the entrance of new firms. Moreover, changes in debt issuance and dividend payouts associated with changes in p cancel each other out because there is no cost associated with changing equity payouts. For these reasons, the conjecture unchanged sequence of prices is an equilibrium outcome and the financial restructuring does not affect the real sector of the economy.⁷

This result no longer holds when $\kappa > 0$, that is, when the substitution between equity and debt is costly. Intuitively, a fall in the value of the firm induced by a persistent fall in p requires a reduction in debt. To maintain the same production and investment, the firm needs to increase equity. Because this is costly, the adjustment is done only gradually. In the short-run, then, the firm is forced to reduce capital and labor. This mechanism will be shown numerically in the next section, after the calibration of the model.

4 Quantitative properties

We parameterize the model on a quarterly basis and set the discount rate to $\beta = 0.99$. The utility function takes the form $U(c, h) = \ln(c) + \alpha \cdot \ln(1 - l)$ where α is chosen to have an average working time of 0.25. The tax rate is set to $\tau = 0.3$.

For the parametrization of the revenue function we start by setting the return to scale parameter to $\nu = 1.5$. As we will show in the sensitivity analysis, this parameter is important for the volatility of measured TFP but it does not affect in important ways the cyclical properties of other variables and the impact of financial innovations. Next we choose the elasticity parameter η which affects the price markup. In the model, the markup over the average cost is on average equal to $1/\nu\eta - 1$. The values commonly used in macro studies range between 10 to 20 percent. We use the intermediate value of 15

⁷This neutrality result depends critically on the particular specification of the liquidation value $L(\mathbf{s}; k, b) = V(\mathbf{s}; k, b) - V(\mathbf{s}; 0, 0)$. This result does not hold for alternative specifications of the liquidation value even if $\kappa = 0$. However, because the effect would be small, it would not change significantly the quantitative results.

percent, that is, $\nu\eta = 0.85$. Given $\nu = 1.5$, this implies $\eta = 0.567$. Then θ is chosen to have a capital income share of 40 percent. The required value is $\theta = 1 - 0.6/\eta\nu = 0.294$. Capital depreciates at rate $\delta = 0.025$.

To insure that the firm's problem is concave, we assume that the value of diversion is linear, that is, $D(k, l) = \chi \cdot k + (1 - \chi) \cdot l$. The parameter χ is such that about half of the divertible funds are associated with the use of capital and half with the use of labor. The sensitivity analysis will clarify the role played by χ . The enforcement parameter ϕ is chosen to replicate the average ratio of debt over GDP in the nonfarm business sector in the 1952-83 period. The average yearly value is 0.55.

The probability of market survival can take two values, that is, $p = \bar{p} \pm \Delta$, with symmetric transition matrix. The persistence probability is set to $\Gamma(p/p) = 0.9$. This implies that recessions arise on average every 20 quarters, which is the approximate frequency over the post-war period. The average retention probability is set to $\bar{p} = 0.975$. This implies an annual exit rate of about 10 percent, which is the approximate value for the whole US economy as reported by the OECD (2001).⁸

At this point there are only two parameters left. The variability of the shock, Δ , and the cost parameter, κ . They are chosen jointly to replicate the standard deviation of GDP and the standard deviation of net worth during the first sample period 1952-83 (see Table 1). In the model the net worth is defined as $\pi - b$. The full set of parameter values is reported in Table 2.

4.1 Response to shocks

Suppose that the probability of market retention has been at the high level $\bar{p} + \Delta = 0.988$ for a long period of time and the economy has converged to the long-term equilibrium. Starting from this equilibrium, the probability drops to $p = 0.962$ and stays at this level for several periods (although agents understand that there is a probability of switching). The top panel of Figure 3 plots the response of output and measured TFP.

The computation of TFP requires some explanation. The aggregate production function in the model is $Y = (K^\theta L^{1-\theta})^\nu$, and therefore, the actual

⁸When weighted by the size of firms, the exit probability is smaller than 10 percent. However, the exit rate in our model should be interpreted more broadly than firms' exit. It also includes the partial sales of business activities. When interpreted in this broader sense, the 10 percent annual probability is not unreasonable.

Table 2: Calibration.

<i>Description</i>	<i>Parameter values</i>
Discount factor	$\beta = 0.99$
Utility parameter	$\alpha = 0.318$
Production technology	$\theta = 0.294, \nu = 1.5, \delta = 0.025$
Elasticity parameter	$\eta = 0.567$
Market survival	$p = 0.975 \pm 0.013, \Gamma(p/p) = 0.9$
Default parameters	$\chi = 0.2, \phi = 3.36$
Cost of equities	$\kappa = 0.25$
Tax rate	$\tau = 0.3$

TFP is constant and equal to 1. However, following the standard accounting procedure, we compute the TFP assuming that the production function takes the standard Cobb-Douglas form, that is, $Y = \hat{z}K^{\hat{\theta}}L^{1-\hat{\theta}}$, where $\hat{\theta} \neq \theta$ is the capital income share. The variable \hat{z} is what we identify as measured TFP. Because this representation ignores the increasing returns, the variable \hat{z} is not constant. This variable is determined by:

$$\hat{z} = \frac{(K^{\theta}L^{1-\theta})^{\nu}}{K^{\hat{\theta}}L^{1-\hat{\theta}}}$$

which in general increases with the scale of production.

As can be seen from the top panel of Figure 3, the drop in the probability of market retention generates a large fall in measured TFP and output. After the initial drop, output stabilizes at a lower level. The long-term drop is a consequence of the convex adjustment cost. After a negative shock, the firm replaces debt with equity until a new shock arrives. When the positive shock arrives, the firm increases its leverage by paying more dividends, but this is costly. To save on this cost, there is an incentive to keep less equity (compared to the case of no adjustment cost). But with lower equity the firm invests less.

The response to a positive shock, shown in the bottom panel of Figure 3, is symmetric to the response after a negative shock. With a high p the firm is able to increase its leverage until a negative shock hits. Because of the possibility of a lower p , requiring a lower leverage, the firm expects to

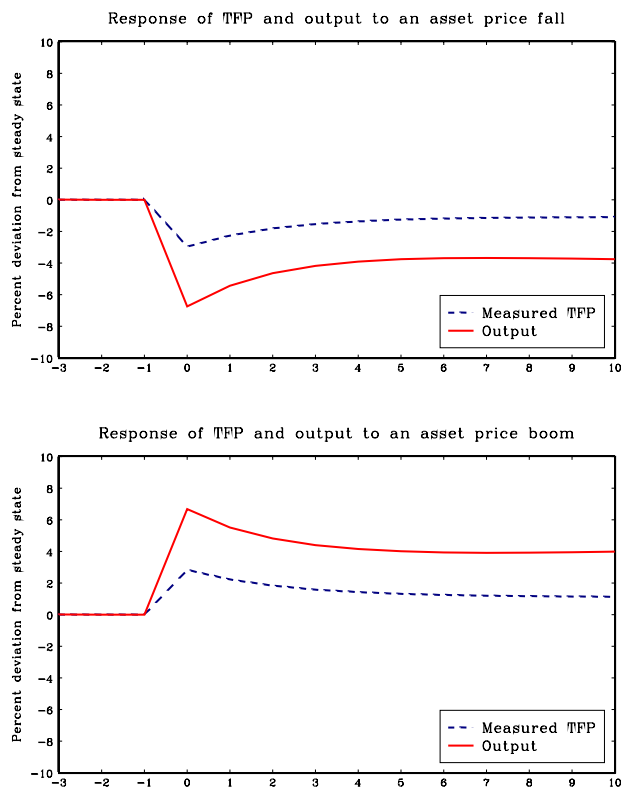


Figure 3: Macroeconomic dynamics after a shock.

reduce its payout at some point in the future, which is also costly. To reduce this cost, the firm has an incentive to retain more equity. By retaining more equity (compared to the case of no adjustment cost) the firm invests more.

5 Financial innovations and business cycles

We now study how financial markets innovations affect the properties of the business cycle. We provide first some background information about the changes that have taken place in the financial markets and how these changes are mapped in our model. We then show the business cycle implications predicted by the model.

5.1 Changes in financial markets

We describe two sets of changes. The first is in the direction of increasing the borrowing capability of firms. The second allows for greater flexibility in equity financing. In our model, the first change is captured by a reduction in the enforcement parameter ϕ . The second by a smaller κ .

Collateralization: Recent financial market developments have made it easier for firms to pledge their assets to lenders, that is, to relax their collateral constraints and increase their leverage. As a major financial innovation, Asset Backed Securities (ABS) created through the process of securitization have become an effective way of debt collateralization. Securitization began in the late 70s as a way to finance residential mortgages. By the second half of the 80s, securitization was used for automobiles, manufactured housing and equipment leasing, as well as for credit cards. Growth has been fast since then and ABS are today an important component of firm financing. According to The Bond Market Association (2004), ABS issuance overtook the issuance of long term corporate bonds in the third quarter of 2004.

Cost and flexibility of equity issues: Our simple specification of the adjustment cost in the equity payout encompasses both direct and indirect costs of changing the equity of the firm. There is a number of studies suggesting that these costs have changed during the last two decades.

Starting in the early 1980s, share repurchases have become more common. One change that has favored this is the SEC adoption of a safe harbor rule (Rule 10b-18) in 1982. This rule guarantees that, under certain conditions, the SEC would not file manipulation charges against companies that repurchased shares on the open market. According to Allen and Michaely: *“Evidence suggests that the rise in the popularity of repurchases increased overall payout and increased firms financial flexibility”*.

One of the changes that have contributed to lowering the cost of new issues, is the ability to make ‘shelf’ offerings under Rule 415. This was introduced in 1983. Under a shelf offering, a firm can issue at short notice, up to a given limit, during a period of 2 years. The study by Bhagat, Marr & Thompson (1985) finds that this additional flexibility has allowed firms to lower offering costs by 13 percent in syndicated issues and 51 percent in non-syndicated issues. More generally, this rule has increased the flexibility of firms in issuing new shares.

Another important change is the development of the venture capital market and the introduction of new trading markets such as NASDAQ. This has facilitated the access to the equity market of small and medium size firms, increasing their overall financial flexibility.

Kim, Palia & Saunders (2003) provide some direct evidence about the behavior of underwriting cost for new equity issues. They show that underwriting spreads for seasoned equity offerings have been on average decreasing during the period 1980-2000. The comparison of cross sectional average spreads in 1980 and 2000 shows a decline of about 20 percent.

5.2 Business cycle implications

The two sets of innovations described above are captured in our model with changes in the parameters ϕ and κ . A reduction in ϕ allows the firm to take more debt. A reduction in κ allows for greater flexibility in equity finance, that is, greater flexibility in shares repurchases, new issues and dividends.

To evaluate the effect of these innovations we conduct the following exercise. We change ϕ and κ to replicate the average leverage and volatility of net worth in the nonfarm business sector in the most recent period 1984-2005. In the baseline model these two parameters were chosen to replicate the average leverage and volatility of net worth during the early period 1952-83, that is, 0.55 and 1.12 respectively. These values have changed to 0.75 and 2.26 for the most recent period 1984-05. All the other parameters are kept unchanged.

The responses of output for the baseline model and the new parametrization are reported in the top panels of Figure 4. The continuous line is for the baseline model (early period) and the dashed line is for the new parametrization (late period). As can be seen, the sensitivity of aggregate output falls dramatically with the new values of ϕ and κ .

To disentangle the effect deriving from the higher leverage (lower ϕ) and from the greater flexibility in equity financing (lower κ), the lower sections of Figure 4 plot the impulse responses when we change only one of the two parameters. The response of output does not change substantially with the different value of ϕ .⁹ On the other hand, the response of output with a

⁹For some parametrizations, the response of output may actually increase with a lower ϕ , and thus higher leverage would contribute to greater macroeconomic volatility. A related point was made by Iacoviello & Minetti (2003) who show that house prices respond more strongly to interest rate shocks if leverage is high.

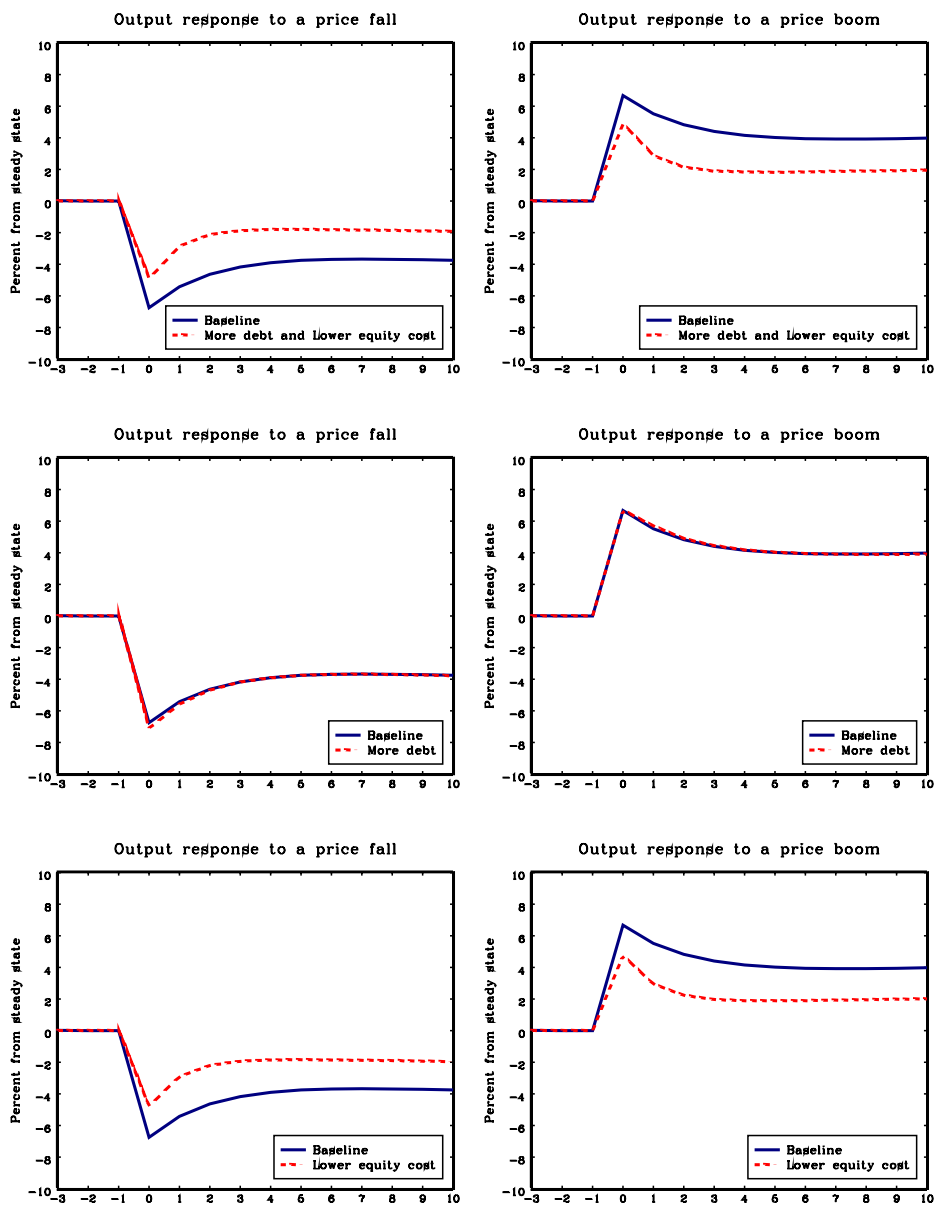


Figure 4: Financial development and macroeconomic dynamics.

lower κ is almost identical to the response obtained with the simultaneous change of ϕ and κ . This finding suggests that it is not the greater ability to borrow that has contributed to the lower macroeconomic volatility. Rather, it derives from innovations allowing for greater flexibility in equity financing.

Table 3 reports standard business cycle statistics computed on model simulated data, for the early and later periods. As described above, we change ϕ and κ so that the model replicates the higher leverage and the greater volatility of net worth observed in the second part of the sample period. Therefore, the comparison of these numbers provides an assessment of the macroeconomic changes induced by financial markets innovations as predicted by the model.

Table 3: Business cycle statistics before and after financial innovations.

	Early period (1952-1983)		Late period (1984-2005)		Late/Early	
	<i>Data</i>	<i>Model</i>	<i>Data</i>	<i>Model</i>	<i>Data</i>	<i>Model</i>
<i>Real variables</i>						
Output	1.70	1.72	0.86	1.02	0.51	0.59
TFP	0.83	0.75	0.43	0.44	0.52	0.59
Labor	2.21	1.63	1.10	0.97	0.50	0.59
Investment	7.36	9.09	4.79	5.36	0.65	0.59
Consumption	0.93	0.34	0.49	0.18	0.53	0.53
<i>Financial variables</i>						
Net Worth	1.12	1.12	2.26	2.25	2.01	2.01
DebtRep	1.09	4.20	1.37	5.84	1.25	1.39
EquiPay	0.69	2.51	1.09	4.85	1.56	1.93
Equity Return		0.87		0.97		1.11

Notes: Artificial data is generated by simulating the model for 10,000 periods. Both artificial and real data is detrended using a band-pass filter that preserve cycles of 1.5-8 years.

The combined reduction in κ and ϕ lowers the volatility of output as well as the volatility of other macroeconomic variables. Quantitatively, the model is roughly able to replicate the lower macroeconomic volatility observed in the data. The model also generates greater variability for debt repurchases and equity payouts as fractions of output. The scale of the volatility increase, as shown in the last column of the table, is similar to the data. However, the absolute volatility of these two variables is higher than in the data.¹⁰

¹⁰Remember that the change in κ between the two periods was chosen to match the

Finally, it is also worth pointing out that the volatility of equity returns does not increase much in the later period. Therefore, the model is also consistent with the empirical observation that the volatility of aggregate equity returns has not changed significantly. Indeed, the CRSP value-weighted return at the quarterly frequency has a standard deviation in the later period (1984-05) that equals 1.06 times the standard deviation of the early period (1952-83). In the model this ratio is 1.11. Of course, given the simple specifications of the stochastic discount factor and the capital accumulation, the model cannot generate the amount of volatility observed in the aggregate stock market.

5.3 Sensitivity analysis

In this section we conduct a sensitivity analysis with respect to two parameters: the return to scale parameter, ν , and the fraction of divertible (liquid) funds associated with the use of capital, χ . We also consider an alternative specification of the default function.

The top section of Table 4 reports the business cycle statistics when the production function has constant returns to scale, that is, $\nu = 1$. In changing ν we also change the elasticity parameter to $\eta = 0.85$ so that the markup over the average cost remains 15 percent. All the other parameters remain unchanged. As can be seen from the table, the volatility of the real variables is lower with $\nu = 1$. This could be corrected by increasing the volatility of p . What matters here, however, is the drop in the volatility of real variables induced by financial innovations. As can be seen in the last column, the drop in real volatility is not very different from the baseline model with $\nu = 1.5$. The only exception is, of course, the volatility of measured TFP. When the production function displays constant returns to scale, TFP is no longer mis-measured. Therefore, the assumption of increasing returns helps us in capturing an extra feature of the data—the lower TFP volatility—but it is not crucial for the main results of the paper.

The middle section of Table 4 reports the business cycle statistics when we increase the share of capital in the repudiation function from $\chi = 0.2$ to $\chi = 0.4$. This implies that about 27 percent of divertible funds are associated with the use of labor and 73 percent with the use of capital. In the baseline model they were both 50 percent. In changing χ we also change ϕ (the volatility of the stock of net worth, not the flows of equity payout and debt repurchase.

Table 4: Business cycle statistics. Sensitivity analysis.

	Early period <i>(1952-1983)</i>	Late period <i>(1984-2005)</i>	Late/Early
Constant return to scale, $\nu = 1$			
<i>Real variables</i>			
Output	0.85	0.47	0.55
TFP	0.00	0.00	–
Labor	1.21	0.67	0.55
Investment	4.72	2.47	0.52
Consumption	0.18	0.08	0.44
<i>Financial variables</i>			
Net Worth	1.49	2.57	1.72
DebtRep	4.29	6.11	1.42
EquPay	3.09	5.46	1.76
Equity Return	0.83	0.92	1.11
Higher share of k in repudiation, $\chi = 0.4$			
<i>Real variables</i>			
Output	1.69	0.76	0.45
TFP	0.73	0.33	0.45
Labor	1.60	0.73	0.46
Investment	10.25	4.21	0.41
Consumption	0.39	0.14	0.36
<i>Financial variables</i>			
Net Worth	1.55	2.67	1.72
DebtRep	5.24	6.59	1.26
EquPay	3.63	5.83	1.61
Equity Return	0.91	0.95	1.04
Default value proportional to output			
<i>Real variables</i>			
Output	0.98	0.70	0.71
TFP	0.43	0.30	0.70
Labor	0.93	0.67	0.72
Investment	4.84	3.49	0.72
Consumption	0.21	0.13	0.62
<i>Financial variables</i>			
Net Worth	0.75	1.77	2.36
DebtRep	2.59	4.39	1.69
EquPay	1.65	3.72	2.25
Equity Return	0.84	0.92	1.09

Notes: Artificial data is generated by simulating the model for 10,000 periods. Both artificial and real data is detrended using a band-pass filter that preserve cycles of 1.5-8 years.

enforcement parameter) so that the average leverage is as in the baseline model. Also in this case we observe that financial innovations lead to a large drop in macroeconomic volatility.

In the bottom section of Table 4 we report the business cycle statistics for an alternative specification of the default function. In particular, we assume that the value of defaulting is proportional to output, that is, $\phi \cdot (k^\theta l^{1-\theta})^\nu$. As can be seen from the table, financial innovations lead to a sizable drop in business cycle volatility, as in the other cases.

A further specification of the repudiation value would be $\phi k'$, that is, proportional to the new input of capital. This specification would generate similar results as those reported in Table 3. The reason we did not use this formulation is because it generates the unattractive property that first period consumption increases after a negative shock. This does not happen with the specification of the repudiation value used in the quantitative section.

6 Technology shocks

The analysis conducted so far has considered only shocks affecting asset prices but has abstracted from technology shocks. What would be the impact of financial innovations when the main driving force of the business cycle are standard technology shocks? In this section we address this question by replacing the shock to the retention probability p with standard TFP shocks.

The production function is specified as $x = z(k^\theta l^{1-\theta})^\nu$. In the previous sections, the variable z was a constant. We now assume that z follows a two-state symmetric Markov process with persistence probability $\Gamma(z/z) = 0.9$. The variability of z is chosen to replicate the standard deviation of GDP in the first sample period 1952-83. All parameters are as in the baseline calibration. The only exception is the volatility of the retention probability Δ which is set to zero, and therefore, $p = \bar{p}$.

To evaluate the impact of financial innovations, we reduce the values of ϕ and κ as we did in Section 5. As shown in Table 5, financial innovations lead to greater, not lower volatility. Therefore, when the main driving force of the business cycle are standard productivity shocks, the type of financial innovations discussed earlier generate greater macroeconomic volatility.

This result can be explained as follows. Within this model, financial frictions reduce the financial flexibility of firms. With lower flexibility, firms react more slowly to productivity changes. Financial innovations increase

Table 5: Business cycle statistics with TFP shocks.

	Early period (1952-1983)		Late period (1984-2005)		Late/Early	
	<i>Data</i>	<i>Model</i>	<i>Data</i>	<i>Model</i>	<i>Data</i>	<i>Model</i>
<i>Real variables</i>						
Output	1.70	1.71	0.86	1.94	0.51	1.13
TFP	0.83	1.21	0.43	1.30	0.52	1.07
Labor	2.21	0.84	1.10	1.06	0.50	1.26
Investment	7.36	7.93	4.79	9.05	0.65	1.14
Consumption	0.93	0.45	0.49	0.50	0.53	1.11
<i>Financial variables</i>						
Net Worth	1.12	0.64	2.26	0.85	2.01	1.32
DebtRep	1.09	0.71	1.37	1.17	1.25	1.64
EquPay	0.69	0.82	1.09	1.17	1.56	1.43
Equity Return		0.15		0.17		1.13

Notes: Artificial data is generated by simulating the model for 10,000 periods. Both artificial and real data is detrended using a band-pass filter that preserve cycles of 1.5-8 years.

their flexibility, and allow them to react faster to these changes. As a result, innovations lead to greater business cycle volatility.

The fact that financial innovations do not lead to milder business cycles when productivity shocks are the only source of fluctuations doesn't rule out the importance of these shocks. If one were to build a model where productivity shocks lead to larger asset price movements, financial innovations could then have a stabilizing effect.

7 Conclusion

During the last two decades, the volatility of the US business cycle has declined significantly. This paper investigates the role played by financial innovations. It develops a general equilibrium model where business cycle fluctuations are driven by asset price shocks that are propagated to the real sector of the economy through financial markets frictions. By dampening the real impact of these shocks, financial innovations lead to lower macroeconomic volatility. Our theory is consistent with the observation that, although the real sector of the economy has become less volatile, the volatility of the financial structure of firms has increased during the last two decades.

Appendix

A Data sources

Financial data is from the Flow of Funds Accounts compiled by the Federal Reserve Board. Outstanding debt is ‘Credit Market Instruments’ of Nonfarm Nonfinancial Corporate Business (B.102, line 22) and Nonfarm Noncorporate Business (B.103, line 24). This includes mainly Corporate Bonds (for the corporate part), mortgages and bank loans (for corporate and noncorporate); it doesn’t include trade and tax payables. Debt Repurchases are defined as the negative of ‘Net Increases in Liabilities’ for the Nonfinancial Corporate Business (F.102, line 36) and for the Noncorporate Business (F103, line 21). Equity Payout in the Nonfinancial Corporate Business is ‘Net Dividends’ (F.102, line 3) minus ‘Net New Equity Issue’ (F.102, line 38). Equity Payout in the Noncorporate Sector is the negative of ‘Proprietors’ Net Investment’ (F103, line 29). Net Worth is as reported by the Flow of Funds in the Nonfinancial Corporate Business (B.102, line 32) and in the Noncorporate Business (B.103, line 31). All macro variables are from the Bureau of Economic Analysis (BEA).

B Enforcement constraint

In addition to k_t , production requires working capital. Higher is the scale of production, captured by the production inputs k_t and l_t , and bigger is the required working capital. We denote it by $f_t = D(k_t, l_t)$. Working capital consists of liquid funds that are used at the beginning of the period and are recovered at the end of the period when all transactions are completed. For simplicity we assume that the firm borrows these funds at the beginning of the period and returns them at the end of the period. Because this is an intra-period loan, there are no interests.

The firm could divert these funds at the end of the period and default. Default will lead to the renegotiation of the loan. Suppose that in case of default the lender can confiscate the firm and recover $\psi \bar{V}_t$, that is, a fraction of the firm’s value ($\psi < 1$). Denote by β the bargaining power of the firm and $1 - \beta$ the bargaining power of the lender. Bargaining is over the repayment of the debt, which we denote by \hat{f}_t . If they reach an agreement, the firm gets $f_t - \hat{f}_t + \bar{V}_t$ and the lender gets \hat{f}_t . If there is no agreement, the firm gets

the threat value f_t and the lender gets the threat value $\psi\bar{V}_t$. Therefore, the net value for the firm is $\bar{V}_t - \hat{f}_t$ and the net value for the lender is $\hat{f}_t - \psi\bar{V}_t$. The bargaining problem solves:

$$\max_{\hat{f}_t} \left\{ (\bar{V}_t - \hat{f}_t)^\beta (\hat{f}_t - \psi\bar{V}_t)^{1-\beta} \right\}$$

Taking the first order conditions and solving we get $\hat{f}_t = [1 - \beta(1 - \psi)]\bar{V}_t$.

Incentive-compatibility requires that the value of not defaulting, \bar{V}_t , is not smaller than the value of defaulting, $f_t - \hat{f}_t + \bar{V}_t$. Using $\hat{f}_t = [1 - \beta(1 - \psi)]\bar{V}_t$, this condition can be written as $\bar{V}_t \geq f_t + \beta(1 - \psi)\bar{V}_t$. Collecting terms and rearranging we get

$$\bar{V}_t \geq \left[\frac{1}{1 - \beta(1 - \psi)} \right] f_t$$

Define $\phi = 1/[1 - \alpha(1 - \psi)]$. Remembering that $f_t = D(k_t, l_t)$, the enforcement constraint can be written as $\bar{V}_t \geq \phi D(k_t, l_t)$. It is worth noticing that lower values of ϕ can be interpreted either as a decrease in the bargaining power of firms, β , or as an increase in the recovery rate, ψ . Both changes lead to greater enforcement of debt contracts.

C First order conditions

Consider the optimization problem (1) and let λ and μ be the Lagrange multipliers associate with the two constraints. Taking derivatives we get:

$$\begin{aligned} l : \quad & \lambda\pi_l(\mathbf{s}; k, l) - \mu\phi D_l(k, l) = 0 \\ d : \quad & 1 - \lambda\varphi_d(d) = 0 \\ k' : \quad & (1 + \mu)\bar{V}_k(\mathbf{s}; k', b') - \lambda = 0 \\ b' : \quad & (1 + \mu)\bar{V}_b(\mathbf{s}; k', b') + \frac{\lambda}{R} = 0 \end{aligned}$$

Given the definition of $\bar{V}(\mathbf{s}; k', b')$ provided in (2) and taking into account the liquidation value $L(\mathbf{s}; k, b) = V(\mathbf{s}; k, b) - V(\mathbf{s}; 0, 0)$, the derivatives are:

$$\begin{aligned} \bar{V}_k(\mathbf{s}; k', b') &= Em'V_k(\mathbf{s}'; k', b') \\ \bar{V}_b(\mathbf{s}; k', b') &= Em'V_b(\mathbf{s}'; k', b') \end{aligned}$$

The envelope conditions are:

$$\begin{aligned} V_k(\mathbf{s}; k, b) &= \lambda \pi_k(\mathbf{s}; k, l) - \mu \phi D_k(k, l) \\ V_b(\mathbf{s}; k, b) &= -\lambda \end{aligned}$$

Using the first condition to eliminate λ and substituting the envelope conditions we get conditions (3)-(5).

D Solution strategy

Consider the following equations:

$$wU_c(c, h) + U_h(c, h) = 0 \quad (9)$$

$$U_c(c, h) - \beta(1+r)EU_c(c', h') = 0 \quad (10)$$

$$wh + b - \frac{b'}{1+r} + d - c - T = 0 \quad (11)$$

$$\pi_l(\mathbf{s}; k, l) - \mu \phi D_l(k, l) \varphi_d(d) = 0 \quad (12)$$

$$(1 + \mu) \bar{V}_k(\mathbf{s}; k', b') - \frac{1}{\varphi_d(d)} = 0 \quad (13)$$

$$(1 + \mu) \bar{V}_b(\mathbf{s}; k', b') + \frac{1}{\varphi_d(d)R} = 0 \quad (14)$$

$$\bar{V}(\mathbf{s}; k', b') \geq \phi D(k, l) \quad (15)$$

$$\pi(\mathbf{s}; k, l) - b + \frac{b'}{R} - k' - \varphi(d) = 0 \quad (16)$$

Equations (9)-(11) are the first order conditions for households and the budget constraint. Equations (12)-(14) are the first order conditions for firms. The last two equations are the enforcement and budget constraints.

The computational procedure is based on the following observation: If we knew the terms $\bar{V}(\mathbf{s}; k', b')$, $\bar{V}_k(\mathbf{s}; k', b')$, $\bar{V}_b(\mathbf{s}; k', b')$, and $E\beta U_c(c', h')$, we could solve the eight conditions (9)-(16) for the unknowns $c, h, w, r, \mu, d, b', k'$.

The numerical procedure is then based on the approximation of these four functions. We create a two-dimensional grid for k and b . For each value of the shock p , we guess the values of the four functions at each grid point. The grid points are joined with bilinear functions so that the approximated functions are continuous. At this point we solve for the eight variables at each grid point and update the initial guesses until convergence.

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