Financial Innovations and Macroeconomic Volatility*

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Abstract

The volatility of U.S. business cycles has declined in the last two decades. In this paper we document that, contrary to this, during the same period firms' financial flows have become more volatile. We develop a model with explicit roles for debt and equity financing, and we investigate the importance of financial innovations. We find that innovations allowing for a more flexible use of equity financing can account for a substantial reduction in macroeconomic volatility together with the higher volatility in the financial structure of firms.

JEL classification: E3,G1,G3

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1 Introduction

The amplitude of U.S. business cycles has declined during the last 25 years, with many macroeconomic variables displaying a lower volatility than in the previous 30 years. In contrast to this, firms financial flows have become more volatile. Specifically, the flows of debt and equity financing in the business sector display much greater variability. Because debt financing is negatively correlated to equity financing, these findings suggest that firms have become more flexible in the choice of the financial structure. It seems then natural to ask what types of changes are responsible for the greater financial flexibility, and whether they have contributed to the lower macroeconomic volatility.

During the 1980s and the 1990s 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 have also changed as firms have now access to a wider variety of instruments and to a more competitive intermediation industry.

Financial volatility joint with real stability poses challenges to some candidate explanations for more stable business cycles. Indeed, if the good fortune of being exposed to milder shocks is the only explanation, it is not clear, a priori, why financial variables have not become more stable. If better monetary policies are the main explanation, then a question remains: through what mechanisms was this achieved without also stabilizing key financial variables?

The objective of this paper is to investigate the role played by financial innovations. We start by documenting the cyclical properties of firms' equity and debt flows at an aggregate level, and we describe important changes in firm financing over the last 25 years. We then build a business cycle model with explicit roles for firms' debt and equity financing, and with two types of shocks: 'productivity' and 'credit' shocks. The model is estimated with macroeconomic and financial data, and this allows us to provide answers to two quantitative questions. First, how important are credit shocks relative to more standard productivity shocks in driving the fluctuations of aggregate real and financial variables? Second, how much did financial innovations contribute to the lower volatility of the real sector of the economy and to the higher volatility of the financial flows of firms?

In the 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.[1]

The driving forces of business cycles are productivity and credit shocks. The first is the standard productivity shock as in the typical real business cycle model. The second is a shock that affects the enforcement of debt contracts, and therefore, the borrowing ability of firms. We will refer to this second shock as a 'credit' shock. Because of financial frictions, credit shocks are transmitted to the real sector of the economy through the effect they have on the production and investment decisions of firms. While productivity and credit shocks generate impulses to the real sector of the economy that are qualitatively similar, they have different quantitative implications for the volatility of the real and financial variables depending on the flexibility that firms have in changing their financial structure.

We estimate the model using Bayesian methods. In the estimation we allow for a structural break in the parameter of the financial structure as a way of capturing financial innovations. We start from the assumption that the stochastic structure of the exogenous shocks has not changed over time. Instead, we examine how the changes in the financial sector have modified the propagation mechanism of exogenous shocks in a way that lowers the volatility of the real sector of the economy but increases the volatility of the financial structure of firms. To check the robustness of our findings, we then also allow for structural breaks in the volatilities of the shocks.

Regarding our first quantitative question, standard decomposition of variance shows that credit shocks do contribute non-negligibly to the volatility of the major macroeconomic variables in the first sample period. Regarding the second question, we find that financial innovations can account for a large decline in real macroeconomic volatility and they can easily account for the full increase in the volatility of the financial structure of firms. When we also allow for a break in the volatilities of the shocks, financial innovations

[1] There 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), and Hennessy & Levy (2005). The main focus of these studies is on the financial behavior of firms, not the macro impact of financial innovations.

can account for about 35% of the reduction in output volatility and for sizeable portions of the reduction in the volatility of other real macroeconomic variables.

The lower business cycle volatility has been emphasized in several studies.[2] Some recent papers have also investigated the causes of these changes. Clarida, Gali & Gertler (2000) study the role played by the change in monetary policy rule during the Volcker-Greenspan period. Arias, Hansen & Ohanian (2006) and Justiniano & Primiceri (2006) consider the possibility of changes in the volatility of various exogenous shocks, while Campbell & Hercowitz (2005) study the changes in the mortgage market and the demand for residential investment. Our paper complements these studies by focusing on the role played by financial innovations that took place in the business sector of the economy.

The paper is structured as follows. In Section 2, we consider some empirical evidence on real and financial cycles in the US economy. Section 3 presents the model and characterizes some of its analytical properties. The estimation procedure and the results are presented in Sections 4, 5 and 6. Section 7 conducts a sensitivity analysis.

2 Empirical motivation

This section presents the main empirical observations that motivate the paper. It describes features of the real and financial cycles and the extent to which these features have changed in the last two decades. It also describes some of the changes that have taken place in financial markets that are relevant for the way firms raise funds through equity and debt.

2.1 Real and financial cycles in the U.S.

We first look at the changes in business cycle statistics for the real sector of the economy. Although these changes have been well documented, it is useful to revisit them as they are part of the motivation of this paper. Table 1 reports the standard deviations of the typical macroeconomic variables for the period 1952-2005 and the sub-periods 1952-1983 and 1984-2005. The

[2]See Kim & Nelson (1999), McConnell & Perez-Quiros (2000), Stock & Watson (2002), Comin & Philippon (2005), Cecchetti, Flores-Lagunes & Krause (2006), Dynan, Elmendorf & Sichel (2006).

variables have been logged and detrended using a band-pass filter that preserves cycles of 1.5-8 years (Baxter and King (1999)). As shown in the table, the volatility of all macroeconomic variables has declined between the first and second sample period. It is also worth mentioning that the volatility of all components of domestic investment has declined. Although residential investment is the component of domestic investment with the largest decline, the drop in the volatility of nonresidential investment is also sizable.

Table 1: Standard deviations of major macroeconomic variables.

	1952-2005	*1952-1983*	*1984-2005*	*Late/Early*
Gross domestic product	1.45	1.73	0.89	0.51
Personal consumption	1.14	1.35	0.69	0.51
Non-durable&services	0.79	0.93	0.51	0.55
Durable	4.16	4.96	2.50	0.50
Gross private investment	6.61	7.51	4.94	0.66
Fixed nonresidential	4.63	4.99	4.02	0.81
Fixed residential	8.97	10.90	4.74	0.43
Change in inventories	0.46	0.51	0.38	0.74
Hours of labor	1.75	2.25	1.11	0.49
Total factor productivity	0.67	0.85	0.46	0.54

Notes: Quarterly data detrended with a band-pass filter that preserves cycles of 1.5-8 years (Baxter and King (1999). For hours and total factor produc-. tivity, the data becomes available starting in 1964.1

The lower volatility in the real sector of the economy is in sharp contrast to the volatility increase in the financial flows of firms. Figure 1 plots the net payments to equity holders and the net debt repurchases in the nonfarm business sector. Financial data is from the Flow of Funds Accounts of the Federal Reserve Board. Equity payout is defined as dividends and share repurchases minus equity issues of nonfinancial corporate businesses, minus net proprietor's investment in nonfarm noncorporate businesses. This captures the net payments to business owners (shareholders of corporations and non-corporate business owners). Debt is defined as 'credit market liabilities' which include only liabilities that are directly related to credit markets instruments. It does not include, for instance, tax liabilities. Debt repurchases are simply the reduction in outstanding debt (or increase if negative). Both variables are expressed as a fraction of nonfarm business GDP. See Appendix A for a more detailed description.

There are three important patterns that are clearly visible in the figure. First, both variables have become more volatile during the last two decades. Second, equity payouts are negatively correlated with debt repurchases. This suggests that there is some substitutability between equity and debt financing. Third, while equity payouts tend to increase in booms, debt repurchases increase during or around recessions. This suggests that recessions lead firms to restructure their financial position by cutting debt and reducing the payments made to shareholders.

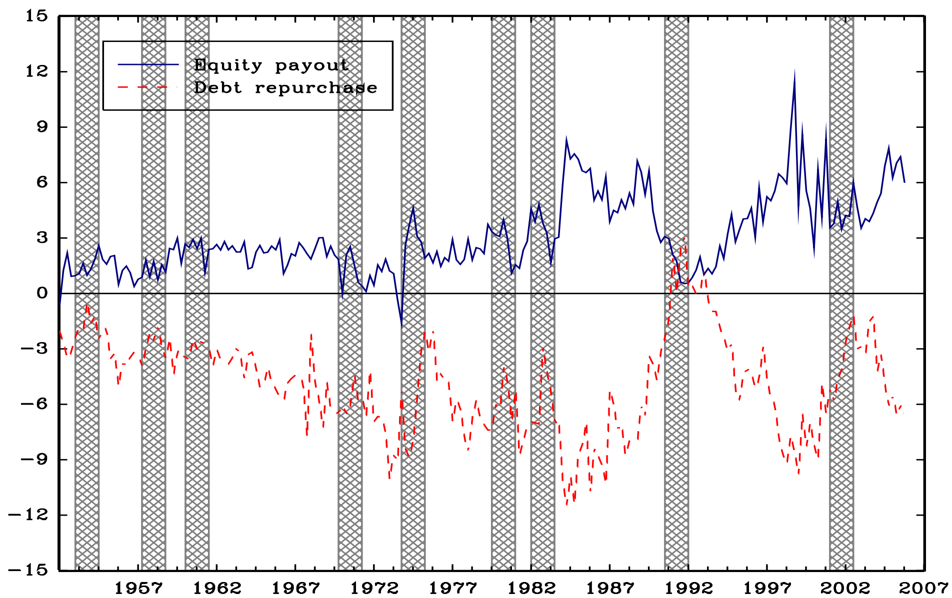

Figure 1: Financial flows in the nonfarm, nonfinancial business sector. Source: Flow of Funds, Federal reserve Board. See notes on Table 2.

The properties of real and financial cycles are further characterized in Table 2. 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 normalized by the value added produced in the sector. For these two variables we do not take logs because some observations are negative. All variables are detrended with 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.

Table 2: Business cycles properties of firm financing in the nonfarm, nonfinancial business sector.

	Corporate			**Corporate & noncorporate**		
	1952-83	*1984-05*	*Late/Early*	*1952-83*	*1984-05*	*Late/Early*
Standard deviation						
EquPay/GDP	0.56	1.24	2.24	0.69	1.09	1.56
DebtRep/GDP	1.53	1.49	0.97	1.09	1.37	1.25
GDP	2.70	1.52	0.56	2.35	1.17	0.50
Correlation						
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 (net of share repurchases). *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. *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.

The standard deviation of equity payout, as a fraction of GDP, has increased substantially in the most recent period 1984-2005, compared to the earlier period 1952-1983. This is in sharp contrast to the standard deviation of GDP that has declined by half. The volatility of debt repurchases, particularly for corporations, does not show a clear increase which seems to contradict the pattern shown in Figure 1. This is because the increase in the volatility of debt is at relatively low frequencies, captured by the trend.

The cross correlations are consistent with the pattern shown in Figure 1. 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 payouts are positively correlated with output and negatively correlated with debt repurchases. These correlations are unambiguous in the second sample period.[3] Thus, the sub-

[3] Baker and Wurgler (2000) suggest that some of the debt-equity substitution is related to leveraged buyout and merger activities. Covas and Den Haan (2006) present some evidence about the cyclicality of debt and equity flows for the subset of listed companies. They also discuss the differences and similarities between their findings and ours.

stitution between debt and equity seems to be a strong empirical regularity.[4]

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

1. *The business cycle volatility has declined during the last 25 years.*

2. *Equity payouts and debt repurchases have become more volatile during the last 25 years.*

3. *Debt repurchases are counter-cyclical and equity payouts are pro-cyclical.*

The first fact has been emphasized in several empirical studies and is well-known. To our knowledge, the other two facts have not been previously documented or explored in the macro literature.

2.2 Changes in U.S. financial markets

Financial markets have gone through tremendous changes in the last 25 years. Some of these changes seem particularly noteworthy for understanding the level of flexibility firms have in adjusting their capital structure. Specifically, several studies examining such changes suggest that firms' flexibility has increased and that capital structures can now be altered at lower costs.

Share repurchases have played an important role. 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 (2002): "*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 significantly the flexibility of equity issuance.

[4]The inclusion of a fraction of proprietors' income into equity payouts of the nonfarm business sector does not change significantly the statistics reported in Table 2.

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.

Kim, Palia & Saunders (2003) provide direct evidence about the behavior of underwriting costs for equity issues. They show that underwriting spreads for equity offerings have been decreasing on average during the 1970-2000 period. Comparing the 1970s with the 1990s, the decline is about 20 percent.

Other structural changes have affected the flexibility in issuing debt. 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. According to The Bond Market Association (2004), ABS issuance overtook the issuance of long term corporate bonds in the third quarter of 2004.

Many see the banking liberalization of the 1980s as an important step for increasing competition in the lending market. This has been especially important for firms more directly dependent on bank loans, namely, small and medium size firms. The 1980s has also seen the development of the market for junk bonds which has been instrumental for increasing the financing flexibility of riskier firms.

To summarize, there are several important financial innovations that offer firms greater flexibility in the choice of their financial structure. The fact that many of these changes took place in the 1980s suggests that they could be potential candidates for explaining, at least in part, the reduced macroeconomic volatility over the last 25 years.

3 Model

We start describing the environment in which an individual firm operates as this is where our model diverges from a more standard business cycle model. We then present the household sector 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 a gross revenue function $F(z_t, k_t, l_t)$. The variable z_t is a productivity shock, k_t is the input of capital, l_t is the input of labor. The revenue function is concave in k_t and 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.

Firms use equity and debt to finance their operations. Debt is in general preferred to equity (pecking order) because of its tax advantage as in Hennessy and Whited (2005). Given $R_t = 1 + r_t$ the gross interest rate, the effective rate is $(1-\tau)R_t$, where τ determines the tax advantage.[5]

The ability to borrow is bounded by the limited enforceability of debt contracts. Let $\overline{V}_t$ be the value of the firm for the shareholders at the end of the period, after paying dividends. This is the market value of equity defined as

$$\overline{V}_t = E_t \sum_{j=1}^{\infty} m_{t+j} d_{t+j},$$

where m_{t+j} is the relevant stochastic discount factor, as derived later, and d_{t+j} are the net payments to the shareholders. The firm's value $\overline{V}_t$ is obviously decreasing in the debt because, everything else equal, debt reduces the future payments that the firm can make to the shareholders.

Limited enforcement implies that firms can default on the debt. In the case of default, the firm diverts the working capital which we assume to be proportional to the payment of wages $w_t l_t$.[6] Appendix B describes in detail the renegotiation process and shows that this leads to the following enforcement constraint:

$$\overline{V}_t \geq A_t + w_t l_t.$$

This constraint imposes that the equity value of the firm (the term on the left hand side), cannot be smaller than the value of defaulting (the expression of the right hand side). The value of defaulting includes two terms. The term $w_t l_t$ is the working capital diverted before defaulting. The term A_t is the value retained by the firm in the renegotiation stage as described in the appendix. It depends on the cost of confiscating the firm and on the bargaining power of the firm.

[5]This is an approximation to $1 + r_t(1-\hat{\tau})$ where $\hat{\tau}$ is the tax advantage from the deductability of interest payments. The approximation is made for analytical simplicity.

[6]Alternative assumptions about the determinants of the working capital generate similar properties. For example, we could assume that working capital depends on both labor and capital. What matters is that the value of default depends on the scale of production. We have chosen the wage payments because this leads to simpler analytical expressions.

We assume that A_t is stochastic and follows an exogenous Markov process. Fluctuations in A_t affect directly the firms' ability to borrow, and therefore, we refer to them as 'credit shocks'. Notice that credit and productivity shocks are the same for all firms, that is, they are aggregate shocks. Hence, we can concentrate on the symmetric equilibrium where all firms are alike, that is, there is a representative firm.

An increase in A_t tightens the enforcement constraint and reduces the borrowing capacity. If the firm cannot raise equity capital and bring back the value of the firm to the pre-shock value, it has to reduce the right-hand-side of the enforcement constraint by cutting employment. Therefore, an increase in A_t reduces the demand for labor and through this it can generate a reduction in output.

This mechanism relies on the assumption that firms are unable to substitute quickly debt with equity. To formalize the rigidities affecting the substitution between debt and equity, we assume that the firm's payout is subject to a quadratic adjustment cost:

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

where $\kappa \geq 0$ and $\bar{d}$ represents the long-run payout target (steady state).

This cost should not be interpreted necessarily as a pecuniary cost. It is a simple way of modeling the speed with which firms can change the source of funds when the financial conditions change. Of course, the possible pecuniary costs associated with share repurchases and equity issuance can also be incorporated in the function $\varphi(.)$. The convexity assumption would then be 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.

Another way of thinking about the adjustment cost is that it captures the preferences of managers for dividend smoothing. Lintner (1956) showed first that managers are concerned about smoothing dividends over time, a fact further confirmed by subsequent studies. This could derive from agency problems associated with the issuance or repurchase of shares as emphasized by several studies in finance. The explicit modeling of these agency conflicts, however, is beyond the scope of this paper.[7]

[7] Instead of the adjustment cost on equity payouts, a quadratic cost on the change of debt would imply very similar properties. Therefore, our model can be interpreted more broadly as capturing the rigidities in the adjustment of all sources of funds, not only equity.

The parameter κ is key for determining the impact of market incompleteness. As we will see, when $\kappa = 0$, the economy is essentially equivalent to a frictionless economy. In this case, debt adjustments triggered by the enforcement constraint can be quickly accommodated through changes in firm equity. When $\kappa > 0$, the substitution between debt and equity becomes costly and firms readjust the source of funds slowly. This implies that, in the short-run, shocks have an impact on the production decision of firms.

Firm's problem: We now write the problem of the firm recursively. The individual states are the capital stock, k, and the debt, b. The aggregate states, specified later, are denoted by $\mathbf{s}$.

The firm chooses the input of labor, l, the equity payout, d, the new capital, k', and the new debt, b'. The optimization problem is:

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

subject to:

$$F(z, k, l) - wl + \frac{b'}{(1-\tau)R} - b - \varphi(d) - k' = 0$$

$$Em'V(\mathbf{s}'; k', b') \geq A + wl$$

The optimization problem is subject to the budget and the enforcement constraints. The function $V(\mathbf{s}; k, b)$ is the market value of the firm and m' is the stochastic discount factor. The variables d, w and R are, respectively, the equity payout, the wage rate and the gross interest rate. The stochastic discount factor, the wage and interest rate are determined in the general equilibrium and are taken as given by an individual firm.

Taking the first-order conditions we get:

$$F_l(z, k, l) = w \cdot \Big(1 + \mu\varphi_d(d)\Big), \tag{2}$$

$$(1+\mu)E\, m' \left(\frac{\varphi_d(d)}{\varphi_d(d')}\right) F_k(z', k', l') = 1, \tag{3}$$

$$(1+\mu)(1-\tau)RE\,m'\left(\frac{\varphi_d(d)}{\varphi_d(d')}\right)=1, \tag{4}$$

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

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 (4) becomes $(1+\mu)(1-\tau)REm'=1$. This implies that the Lagrange multiplier μ is fully determined by aggregate prices, R and Em'.

Consider a credit shock captured by a change in A. From conditions (2) and (3) we can see that the production and investment choices of the firm only depend on aggregate prices. Changes in A affect the policies of the firm only if they change the aggregate prices R, Em' and w. But as long as the prices are not affected, the production and investment policies do not change.

These properties are key for understanding the behavior of the aggregate economy we will study later: If the policies of the firms are not affected by changes in A, the general equilibrium prices will not change either. We will then be able to show that, when $\kappa=0$, credit shocks are irrelevant for the real sector of the economy. They only affect the financial structure of firms.

This result no longer holds when $\kappa>0$. In this case μ responds directly to the change in A and this changes the policies of the firm even if the prices do not change. Therefore, credit shocks will have real macroeconomic effects.

Things are different with productivity shocks. Let's consider again the case with $\kappa=0$. In this case conditions (2) and (3) are affected directly by the productivity shock because it affects the marginal revenues from labor and capital. Therefore, even if the aggregate prices do not change, the demand for labor and investment will respond. This, in turn, will induce general equilibrium effects that are typical of the standard real business cycle model.

With a positive value of κ, the impact of a productivity shock is somewhat altered in the way we will see later. But in general, we can infer that, the higher is the value of κ, the more important is the relative contribution of credit shocks to business cycle fluctuations. In the limiting case of $\kappa=0$, only the productivity shocks matter.

3.2 Closing the 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 gross revenue function $F(z,k,l)$. We then specify the household sector.

Production and market structure: The modeling of the market structure and technology is similar to Farmer (1999). Each firm produces an intermediate good x_i that is used in the production of final goods

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

The inverse demand function is $v_i = Y^{1-\eta} x_i^{\eta-1}$, where v_i is the price of the intermediate good and $1/(1-\eta)$ is the elasticity of demand.

The intermediate good is produced with capital and labor according to:

$$x_i = e^z \left(k_i^\theta l_i^{1-\theta}\right)^\nu$$

where z is the aggregate productivity and $\nu \geq 1$ determines the returns to scale in production. By allowing ν to be bigger than 1 (increasing returns), the model can generate endogenous fluctuations in productivity. Increasing returns capture, in a parsimonious way and for a short-run horizon, the presence of fixed factors and variable capacity utilization. The assumption of increasing returns is not important for the qualitative results of the paper, except for the ability to generate endogenous fluctuations in measured TFP.

After substituting the demand and production functions in the monopoly revenue $v_i x_i$, we get:

$$F(z, k_i, l_i) = (1-\delta)k_i + Y^{1-\eta}\left[e^z (k_i^\theta l_i^{1-\theta})^\nu\right]^\eta,$$

with δ the capital depreciation rate. The individual revenue function depends not only on the production inputs k_i and l_i but also on aggregate productivity z and aggregate production Y. We have not included Y as an explicit argument of the individual revenue function to simplify the notation.

The decreasing returns property of the revenue function is obtained by imposing $\nu\eta < 1$. In equilibrium, $k_i = K$ and $l_i = L$ for all firms and $Y = e^z (K^\theta L^{1-\theta})^\nu$. Therefore, the aggregate production function is homogenous of degree ν. There is a limit to the value of ν dictated by a stability condition. We check this condition locally using the linearized system.

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

The household's budget constraint is:

$$w_t l_t + b_t + s_t(d_t + q_t) = \frac{b_{t+1}}{R_t} + s_{t+1} q_t + c_t + T_t$$

where w_t and R_t are the wage and gross interest rates, b_t is the one-period bond, s_t the equity shares, d_t the equity payout received from the ownership of shares, q_t is the market price of shares, and $T_t = (B'/R)[\tau/(1-\tau)]$ are lump-sum taxes financing the tax benefits received by firms on debt.

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

$$w_t U_c(c_t, l_t) + U_h(c_t, l_t) = 0 \tag{5}$$

$$U_c(c_t, l_t) - \beta R_t E U_c(c_{t+1}, l_{t+1}) = 0 \tag{6}$$

$$U_c(c_t, l_t) q_t - \beta E(d_{t+1} + q_{t+1}) U_c(c_{t+1}, l_{t+1}) = 0. \tag{7}$$

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, this price is:

$$q_t = E_t \sum_{j=1}^{\infty} \left(\frac{\beta^j \cdot U_c(c_{t+j}, l_{t+j})}{U_c(c_t, l_t)} \right) d_{t+j}.$$

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

General equilibrium: We can now provide the definition of a recursive general equilibrium. The set of aggregate states $\mathbf{s}$ are given by the sufficient set of past and current realizations of productivity, $\mathbf{z}$, the sufficient set of current and past realizations of credit shocks $\mathbf{A}$, the aggregate capital K, and the aggregate bonds B, that is, $\mathbf{s} = (\mathbf{z}, \mathbf{A}, K, B)$. We allow past realizations of the exogenous shocks to be part of the sufficient set of states because we have not restricted the Markov processes for the shocks to be of order 1.

Definition 3.1 (Recursive equilibrium) *A recursive competitive equilibrium is defined as a set of functions for (i) households' policies* $c(\mathbf{s})$ *and* $l(\mathbf{s})$*; (ii) firms' policies* $d(\mathbf{s}; k, b)$*,* $l(\mathbf{s}; k, b)$*,* $k(\mathbf{s}; k, b)$ *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 (5)-(6); (ii) firms' policies are optimal and* $V(\mathbf{s}; k, b)$ *satisfies the Bellman's equation (1); (iii) the wage and interest rates are the equilibrium clearing prices in the labor and bond markets and* $m(\mathbf{s}, \mathbf{s}') = \beta U_c(c_{t+1}, l_{t+1})/U_c(c_t, l_t)$*; (iv) the law of motion* $H(\mathbf{s})$ *is consistent with individual decisions and the stochastic processes of* z *and* A*.*

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 z and A, the default constraint is always binding. Second, if $\kappa = 0$, changes in A (credit shocks) have no effect on the real sector of the economy.

Proposition 3.1 *The enforcement constraint binds in the steady state.*

In a deterministic steady state $m = 1/R$. Because in the steady state $\varphi_d(d) = \varphi_d(d') = 1$, the first order condition for debt, equation (4), can be rewritten as $m = 1/[(1 + \mu)(1 - \tau)R]$. This implies that $\mu = \tau/(1 - \tau)$. Therefore, as long as there is tax advantage in issuing debt, that is, $\tau > 0$, the enforcement constraint is binding in a steady state.

With uncertainty, however, the constraint may not be binding at all times because firms may reduce their borrowing in anticipation of future shocks. In this case the constraint is always binding if τ is sufficiently large.

Let's consider now the stochastic economy concentrating on the special case in which $\kappa = 0$. We have the following proposition:

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

When $\kappa = 0$, we have that $\varphi_d(d) = \varphi_d(d') = 0$. Therefore, the first order condition (4) can be written as $(1 + \mu)(1 - \tau)REm' = 1$. From the household's first order condition (6) we have that $REm' = 1$. This implies that μ is constant and equal to $\tau/(1-\tau)$. Now consider an innovation in A and conjecture that the sequence of prices w, R and m do not change. Because A

does not enter the optimality conditions (3)-(4) and μ stays constant, changes in A would not affect the production and investment policies of the firm.

Consider now the consumer problem. Changes in debt issuance and equity payout associated with changes in A cancel each other out because there is no cost associated with changing equity payout. For these reasons, the conjectured unchanged sequence of prices is an equilibrium outcome. Therefore, with $\kappa = 0$, business cycle movements are only driven by fluctuations in the aggregate productivity z as a standard RBC model.[8]

This result no longer holds when $\kappa > 0$, that is, when the substitution between equity and debt is costly. Intuitively, an increase in A requires a reduction in debt. Because this requires a reduction in d_t, which is costly, the adjustment is done only gradually. In the short-run the firm is forced to reduce labor. This mechanism will be examined in the quantitative analysis.

4 Estimation

In this section we study the quantitative properties of the model to address two main questions. First, what are the relative contributions of the two shocks, z and A, to the US business cycle? Second, did financial innovations contribute to the lower business cycle volatility observed in the US economy during the last two decades?

To address these questions we parameterize the model in two sequential steps. First we use the standard calibration technique for the parameters that can be pinned down using steady state targets. The remaining parameters are estimated using Bayesian methods. In doing so we follow the approach described in An and Schorfheide (2007).

We choose to calibrate the first set of parameters because they are standard in the business cycle literature and/or they can be pinned down unambiguously by steady state targets. By doing so, we can concentrate on the estimation of a smaller set of parameters. This is without loss of generality because it is equivalent to estimating the whole set of parameters after setting the priors for the first subset concentrated around the calibration values.

Among the estimated parameters is the one characterizing the financial

[8]The fact that the production function displays increasing returns and there is a constant wedge between the interest and discount rates does not change the cyclical properties of the model compared to a standard RBC model. Increasing returns amplify the impact of productivity shocks on aggregate variables but do not change the comovements.

structure, that is, κ. To evaluate the importance of financial innovations we allow for a structural change in this parameter. Given a date in which the structural change takes place, we have two distinct values: before the structural break, κ_1, and after the break, κ_2. All the other parameters are assumed to remain constant over the entire sample period. The date for the structural break is determined as the one maximizing the posterior likelihood.

Calibrated parameters: The period in the model is a quarter. We set $\beta = 0.9825$, implying that the annual steady state return from holding shares is 7.32 percent. The tax advantage parameter is set to $\tau = 0.0062$. In terms of tax deductibility of interests this corresponds to 35 percent. 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 0.3.

Because of monopolistic competition, the price charged by each firm is characterized by an average markup equal to $1/\nu\eta - 1$. We use a value of 10 percent, that is, $\nu\eta = 0.9$, which is the value commonly used in macro studies. Unfortunately, this condition allows us to calibrate only the product of ν and η. To determine the individual values of these two parameters, we could include ν among the set of estimated parameters. However, the identification of ν is very weak. Therefore, we decided to fix ν to 1.5 but then we conduct a sensitivity analysis, that is, we re-estimate the model for different values of ν.

The parameter θ is determined to obtain an average share of wages in output of 64 percent. In the model, the share of wages is equal to $\nu\eta(1 - \theta)/(1 + \mu)$ and in the steady state $\mu = \tau$. Given $\nu\eta = 0.9$ and $\tau = 0.0062$, this condition implies $\theta = 0.2845$. The depreciation of capital is set to 0.015.

The productivity and credit shocks are assumed to be independent. Productivity follows the autoregressive process:

$$z_{t+1} = \rho_z z_t + \epsilon_{t+1}, \qquad \epsilon \sim N(0, \sigma_z)$$

For the credit shock we define $A_t = \bar{A}e^{x_t}$, where x_t follows the process:

$$x_{t+1} = \rho_x x_t + \varepsilon_{t+1}$$

with

$$\varepsilon_{t+1} = \rho_\varepsilon \varepsilon_t + \varrho_{t+1}, \qquad \varrho \sim N(0, \sigma_\varepsilon)$$

We are basically assuming that the credit shock is AR(2). The inclusion of a second order term is to allow for greater persistence.[9]

All the parameters of the shocks are estimated, with the exception of $\bar{A}$, that is, the steady state value of A. This is chosen to have a steady state leverage (debt over capital) of 40 percent, which is about the average leverage obtained from the Flow of Funds for the Nonfarm Nonfinancial Corporate Business during the period 1952-2005.[10] The sensitivity analysis will clarify the role played by this parameter.

Estimated parameters: We are left with 7 parameters: those characterizing the process for the shocks, ρ_z, σ_z, ρ_x, ρ_ε, σ_ε, and those characterizing the financial structure, κ_1 and κ_2. Given the break date for κ, we estimate these parameters using Bayesian methods. We then choose the best break date as the one associated with the highest posterior likelihood.

Because in the model we have only two shocks, z and x, we can use at most two data series for the estimation. We choose GDP and the equity payout ratio. The first variable captures the cyclical properties of the real side of the economy while the second captures the cyclical properties of the financial side. To correct for long term trends, we use the first differences of the log of GDP and the equity payout ratio. For the equity payout we do not take logs because some of the observations are negative.[11]

To generate the artificial series, we solve the model numerically after log-linearizing around the steady state. This is possible because the enforcement constraint is always binding in the neighborhood of the steady state equilibrium.[12] The set of dynamic equations are listed in the appendix. Because of the structural break, we have two dynamic systems: the first associated with

[9]We have also allowed the productivity shock to be AR(2) but the results did not change in important ways. We have also tried a process where the growth rate of z follows a AR(1), which is common in models that are structurally estimated. Again, we did not find significant differences in the results. For the credit shock, however, the second order term matters, and therefore, we kept it.

[10]The leverage is measured as total liabilities divided by total assets. This is equal to 0.4 for the Nonfinancial Corporate Business (table B.102) and 0.366 for the Nonfarm Nonfinancial Business (table B.102 and B.103).

[11]Because our model displays zero growth on average, to make the data and artificial series comparable, we de-mean the data.

[12]Outside the steady state, there is no guarantee that the enforcement constraint is binding, that is, the lagrange multiplier μ remains positive. We have checked the simulations data and found that μ remains positive most of the times.

κ_1 and the second associated with κ_2. Both systems are linearized around the common steady state since the value of κ does not affect the steady state.

In any Bayesian estimation, the choice of the prior densities are important for the results. Not having prior information about the 7 parameters we are estimating, we assume that the prior densities are uniform. In this way, we impose as few restrictions as possible. The boundaries are dictated by technical conditions. For the persistence of the shocks, ρ_z, ρ_x, ρ_ε, we set the bounds to -0.999 and 0.999. The range for the standard deviations σ_z and σ_ε are sufficiently large so that there are no constraints in practise. Finally, the uniform densities for κ_1 and κ_2 take values in $[0.001, 5]$. With $\kappa = 0.001$ the model is almost identical to the frictionless model. Allowing for a higher upper bond would not make a significant difference.

Table 3 reports the full set of parameters, calibrated and estimated. For the subset of the estimated parameters the table reports the prior densities, the mode and the cutoff values for the 5 and 95 percentiles in the posterior distribution. This is constructed by simulation using the Random-Walk Metropolis algorithm as described in An and Schorfheide (2007).

Table 3: Parametrization.

Calibrated parameters				
Discount factor, β	0.9825			
Tax advantage, τ	0.0062			
Utility parameter, α	0.4			
Production technology, θ	0.2845			
Return to scale, ν	1.5			
Price mark-up, $\nu\eta$	0.9			
Depreciation rate, δ	0.015			
Enforcement parameter, $\bar{A}$	6.1			
Estimated parameters	*Prior*	*Mode*	*Below 5%*	*Below 95%*
Productivity persistence, ρ_z	U[-0.999,0.999]	0.945	0.928	0.962
Productivity volatility, σ_z	U[0.00001,0.5]	0.0031	0.0028	0.0034
Credit shock persistence, ρ_x	U[-0.999,0.999]	0.921	0.889	0.951
Credit shock persistence, ρ_ε	U[-0.999,0.999]	0.921	0.885	0.948
Credit shock volatility, σ_ε	U[0.00001,0.5]	0.0013	0.0012	0.0015
Adjustment cost period 1, κ_1	U[0.001,5]	3.292	2.829	4.024
Adjustment cost period 2, κ_2	U[0.001,5]	0.001	0.001	0.024

5 Results

The first finding is that the date of the break that gives the highest posterior likelihood is the first quarter of 1984. This is similar to the date of the structural break found in many other studies. Regarding the change in the parameter of the financial structure, we find that the mode value of κ falls by a large margin. This is consistent with the view that innovations in the financial sector have increased the financial flexibility of firms.

Table 4 reports the standard deviations of several variables for the first and second sample periods. The numbers reported in the table are averages of the standard deviations associated with each of the 100,000 draws of parameters from the posterior distribution.

Table 4: Business cycle statistics before and after the break in 1984.1.

	Early period (1952-1983)		**Late period** (1984-2005)		**Late/Early**	
	Data	*Model*	*Data*	*Model*	*Data*	*Model*
Real variables						
Output	1.15	1.20	0.50	0.65	0.43	0.54
TFP	0.58	0.66	0.41	0.45	0.71	0.68
Labor	0.84	0.87	0.55	0.32	0.65	0.37
Investment	4.66	6.99	2.94	3.41	0.63	0.49
Consumption	0.72	0.31	0.48	0.19	0.67	0.62
Financial variables						
DebtRep/Output	1.44	1.42	1.63	3.16	1.13	2.22
EquPay/Output	0.94	0.86	1.66	2.90	1.77	3.38

Notes: For the real variables, the numbers are standard deviations of the growth rates. For the financial variables the numbers are standard deviations of first differences. Artificial data is generated by averaging the standard deviations associated with 100,000 draws of parameters from the posterior distribution.

There is a sizable reduction in volatility among all macroeconomic variables. Overall, financial innovations can account for a substantial reduction in the actual volatility of the real sector of the economy. At the same time, the model generates a large increase in the volatility of the financial variables. This derives only from the change in the financial parameter κ. All the other parameters including those characterizing the stochastic properties of the two shocks remain unaltered between the two subperiods.

These results are derived from a model with two independent shocks. It is then natural to ask what are the relative contributions of these two shocks to generating business cycle fluctuations. We can also ask whether their relative contributions have changed between the two subperiods. This question is addressed by computing the fraction of the variance of the various macroeconomic variables induced by each of the two shocks. Table 5 reports the variance decomposition statistics. As in the previous table, the numbers are computed by averaging the statistics associated with each of the 100,000 draws of parameters from the posterior distribution.

Table 5: Decomposition of variance before and after the break in 1984.1.

	Early period *(1952-1983)*		**Late period** *(1984-2005)*	
	A shock	*z shock*	*A shock*	*z shock*
Real variables				
Output	0.13	0.87	0.01	0.99
TFP	0.07	0.93	0.01	0.99
Labor	0.23	0.77	0.01	0.99
Investment	0.22	0.78	0.01	0.99
Consumption	0.19	0.81	0.01	0.99
Financial variables				
DebtRep/Output	0.29	0.71	0.59	0.41
EquPay/Output	0.93	0.07	0.68	0.32

Notes: The statistics are generated by averaging the numbers obtained for each of the 100,000 draws of parameters from the posterior distribution.

The contribution of credit shocks to the variance of the real variables in the first sample period is not negligible. It is 13% for output and more than 20% for labor and investment. However, it essentially disappears after the break. For the volatility of the financial variables, debt and equity payouts, credit shocks contribute significantly in both subperiods.

To better understand these results, Figures 2 and 3 plot the impulse responses to the two shocks in both subperiods. The parameters are set to the mode values. From a qualitative point of view, the responses of the macroeconomic variables to a credit shock share some common features with the responses to a productivity shock. Output, productivity, labor, investment and consumption all experience a persistent expansion. The primary impact of a decrease in A (positive credit shock) is to increase the demand for labor which induces an increase in wages and output with the exception of the first period. The increase in output, in turn, generates both higher consumption and higher savings (investment). The initial decline comes from the fact that the credit shock is hump-shaped, which is made possible by the AR(2) structure of the shock. This implies that the direct impact described above is initially small. At the same time, households anticipate the forthcoming expansion and this generates a wealth effect on the supply of labor.

It is worth emphasizing that the specification of the default value is important for generating these responses, in particular, for consumption. It is important that l_t enters directly the right-hand-side of the enforcement constraint. This can be achieved by assuming that the default value depends on the compensation of labor, as we did, or by some other function of l_t. For example, we would obtain very similar results if the value of default depends on production, so as to equal $A_t + e^{z_t}(k_t^{\theta} l_t^{1-\theta})^{\nu}$.[13] However, this could change if l_t does not enter directly the right-hand-side of the enforcement constraint. For instance, if we assume that the default value depends only on the new stock of capital, so as to equal $A_t + k_{t+1}$, then credit shocks will typically generate countercyclical consumption impulses at impact. Indeed, a decrease in A would raise k_{t+1}. The higher investment would then generate a decrease in consumption, which through the complementarity with leisure, induces higher supply of labor and lower wages. Because of this, we have opted for a specification of the default value where l_t enters directly.

Concerning the changes in the impulse responses before and after the structural break, the responses to credit shocks decline by a large margin. The responses to productivity shocks also fall. The decline in the response to productivity shocks can be explained as follows. After a productivity improvement, the value of the firm increases. This relaxes the enforcement constraint which could allow the firm to borrow more and increase payouts to shareholders. However, if the firm cannot adjust the debt quickly, this will generate a larger change in the demand of labor similarly to the case of a positive credit shock. Therefore, in this context, financial frictions act as an amplification mechanism. As the value of κ becomes smaller, the amplification of productivity shocks become also smaller.

[13] We have estimated the model with production entering the left-hand-side of the enforcement constraints. Because the results are essentially equivalent we have decided to work with the current specification because it leads to simpler analytical expressions.

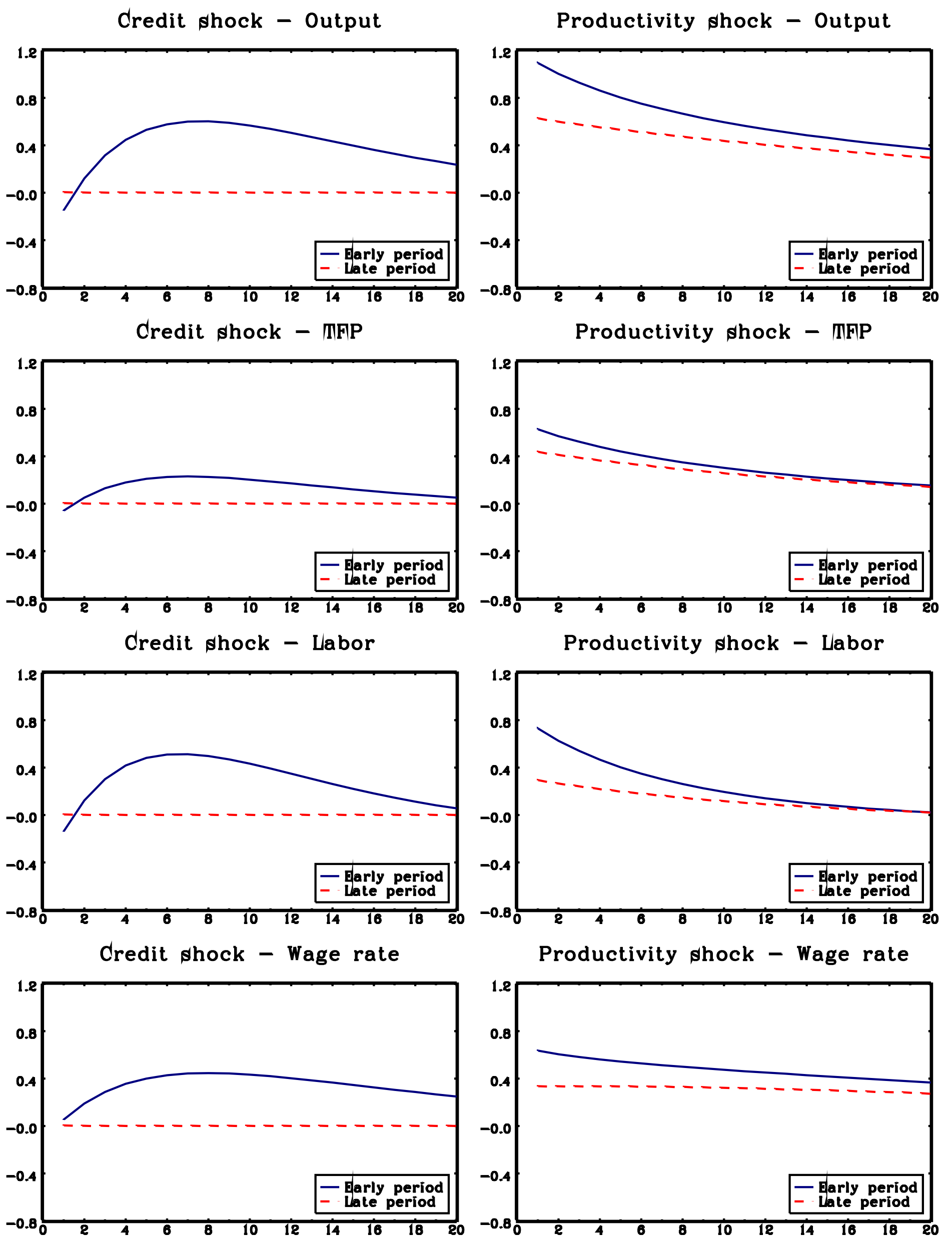

Figure 2: Impulse responses to shocks. Parameters set to the mode values.

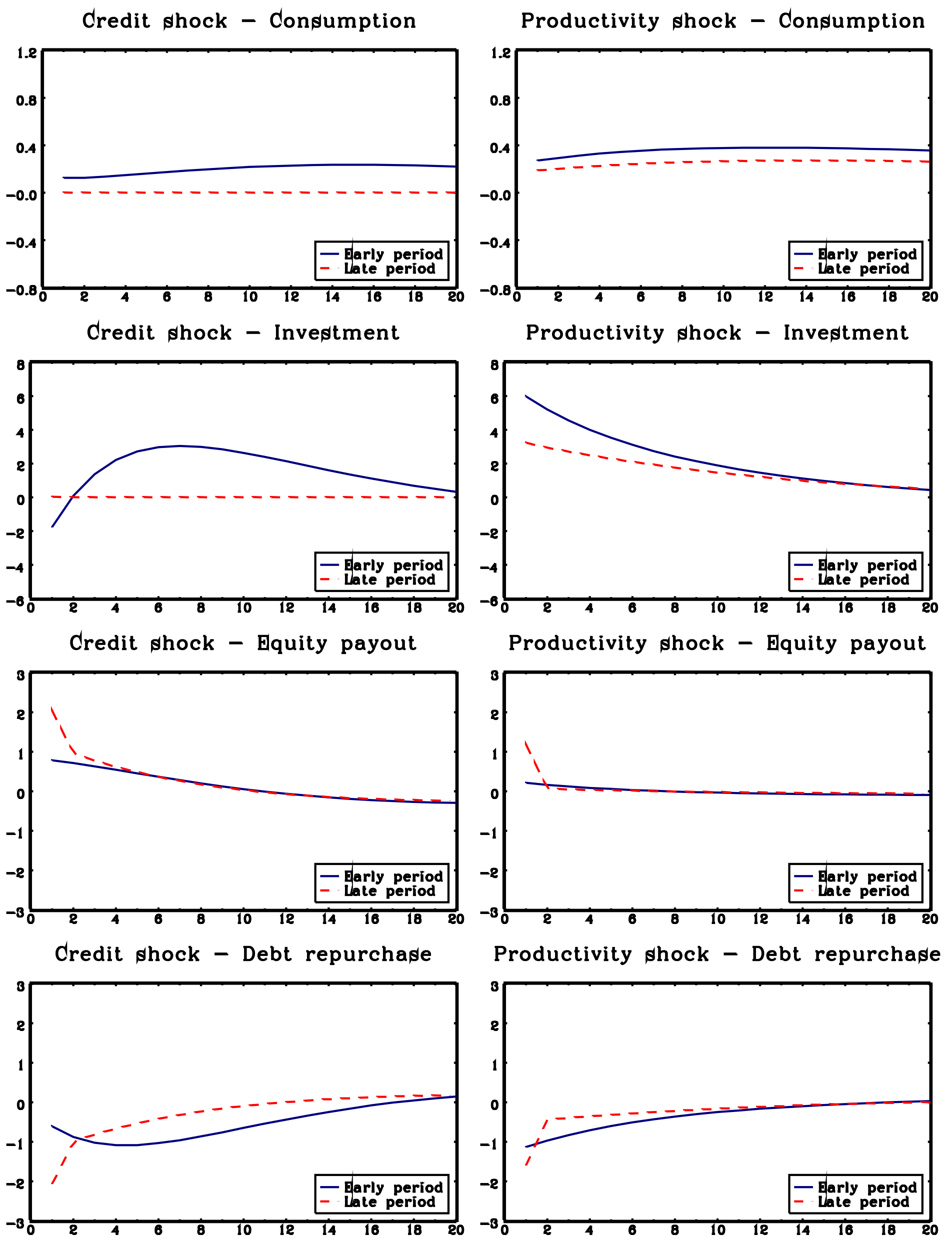

Figure 3: Impulse responses to shocks. Parameters set to the mode values.

6 Good luck versus financial innovations

In the quantitative exercise conducted in the previous section we have assumed that κ is the only parameter changing between the two periods. In other words, we made the assumption that financial innovations are the only structural break taking place between the two periods. By doing so, we are not allowing for other competing explanations. The goal of this section is to show that, even if we allow for additional structural breaks, the change in the financial structure is still an important factor contributing to the lower macroeconomic volatility.

Of course, we cannot account for all possible explanations that have been suggested in the literature. However, there is one explanation we can easily account for. This is the 'good luck' story, that is, the possibility that the reduction in the volatility of the macro-economy results from the reduction in the volatility of the exogenous shocks and, in particular, in the volatility of productivity shocks. Strictly speaking, attributing the causes of the great moderation to the decline in the volatility of shocks is not an explanation, but it can be interpreted as capturing all other mechanisms we cannot account for because they are not explicitly modeled.

We re-estimate the model as we did in the previous section but we allow for a structural change not only in κ but also in σ_z and σ_ε. Notice that the volatility of the shock does not affect the steady state. Therefore, the two dynamic systems associated with each regime are linearized around the same steady state. The parameter we estimate are reported in Table 6. The calibrated parameters take the same values as in the previous section.

Table 6: Estimated parameters.

Parameter	*Prior*	*Mode*	*Below 5%*	*Below 95%*
Productivity persistence, ρ_z	U[-0.999,0.999]	0.902	0.879	0.924
Credit shock persistence, ρ_x	U[-0.999,0.999]	0.955	0.896	0.982
Credit shock persistence, ρ_ε	U[-0.999,0.999]	0.955	0.896	0.981
Volatility of z period 1, $\sigma_{z,1}$	U[0.00001,0.5]	0.0042	0.0038	0.0049
Volatility of z period 2, $\sigma_{z,2}$	U[0.00001,0.5]	0.0022	0.0020	0.0026
Volatility of A period 1, $\sigma_{\varepsilon,1}$	U[0.00001,0.5]	0.0013	0.0012	0.0015
Volatility of A period 2, $\sigma_{\varepsilon,2}$	U[0.00001,0.5]	0.0005	0.0004	0.0006
Adjustment cost period 1, κ_1	U[0.01,5]	4.716	4.172	4.998
Adjustment cost period 2, κ_2	U[0.01,5]	0.001	0.001	0.001

The top panel of Table 7 reports the standard deviations generated by the estimated model. As can be seen, by allowing for changes in the volatility of the shocks, in addition to changes in κ, the model can reproduce the business cycle statistics quite closely. The model can account for all the reduction in the volatility of GDP and the increase in the volatility of equity payout. These are the two series used in the estimation.

Table 7: Business cycle statistics before and after the break in 1984.1.

	Early period *(1952-1983)*		**Late period** *(1984-2005)*		**Late/Early**	
	Data	*Model*	*Data*	*Model*	*Data*	*Model*
A) Structural break in κ, σ_z, σ_ε						
Real variables						
Output	1.15	1.25	0.50	0.52	0.43	0.42
TFP	0.58	0.76	0.41	0.35	0.71	0.46
Labor	0.84	0.80	0.55	0.28	0.65	0.35
Investment	4.66	7.27	2.94	2.99	0.63	0.41
Consumption	0.72	0.35	0.48	0.12	0.67	0.33
Financial variables						
DebtRep/Output	1.44	1.35	1.63	2.01	1.13	1.49
EquPay/Output	0.94	0.95	1.66	1.83	1.77	1.93
B) Structural break only in κ						
Real variables						
Output	1.14	1.25	0.50	0.10	0.43	0.80
TFP	0.58	0.76	0.41	0.67	0.71	0.88
Labor	0.84	0.80	0.55	0.53	0.65	0.66
Investment	4.66	7.27	2.94	5.72	0.63	0.79
Consumption	0.72	0.35	0.48	0.22	0.67	0.64
Financial variables						
DebtRep/Output	1.44	1.35	1.63	4.78	1.13	3.53
EquPay/Output	0.94	0.95	1.66	4.49	1.77	4.73

Notes: For the real variables, the numbers are standard deviations of the growth rates. For the financial variables the numbers are standard deviations of first differences. Artificial data is generated by averaging the standard deviations associated with 100,000 draws of parameters from the posterior distribution.

This is not surprising: if we allow more degrees of freedom, we get a better fit. What is important, however, is that we can now decompose the contribution of 'financial innovations' versus 'good luck'. To do this we conduct a counterfactual experiment where we assume that κ is the only parameter to change between the two periods. The business cycle statistics computed under this assumption are reported in the bottom section of Table 7. The change in κ accounts for 35% of the reduction in output volatility and for sizeable portions of the reduction in the volatility of other macroeconomic variables. This is less than what we obtained in the previous section when we estimated the model allowing only for a change in κ. However, it is still a significant contribution.

What we conclude from this exercise is that financial innovations have contributed significantly to the great moderation but it is not necessarily the only factor. It is in this sense that our theory is complementary, not substitute, to other theories proposed in the literature, such as changes in monetary policy.

7 Sensitivity analysis

Enforcement parameter. The first sensitivity analysis is with respect to the enforcement parameter $\bar{A}$. This determines the average leverage of firms, that is, b/k. In the baseline model $\bar{A}$ was set to have a steady state leverage of 40 percent. We now re-estimate the model after choosing $\bar{A}$ to have steady state leverages of 20 percent and 60 percent. The business cycle statistics are reported in Table 8.

For economy of space we only report the statistics for the counterfactual experiment in which we change only κ, although in the estimation we also allow for a break in σ_z and σ_ε. The business cycle statistics obtained with the additional break in the volatility of the shocks are similar to the ones obtained with the baseline calibration of $\bar{A}$.

The value of $\bar{A}$ does affect the quantitative contribution of financial innovations to the lower volatility of the macro-economy. Lower is the leverage and higher is the contribution.

The last point we would like to make is that the model with only a structural change in κ generates excessive fluctuations in the financial variables. However, these are counterfactual simulations where we keep the volatility of the shocks constant. In our estimation we also allow σ_z and σ_ε to change. Once we allow for the additional break, the model replicates quite well the business cycle statistics for both real and financial variables.

Table 8: Sensitivity with respect to $\bar{A}$.

	Early period *(1952-1983)*		**Late period** *(1984-2005)*		**Late/Early**	
	Data	*Model*	*Data*	*Model*	*Data*	*Model*
A) Leverage=0.2 - Structural break only in κ						
Real variables						
Output	1.15	1.27	0.50	0.94	0.43	0.74
TFP	0.58	0.75	0.41	0.63	0.71	0.83
Labor	0.84	0.84	0.55	0.50	0.65	0.59
Investment	4.66	7.46	2.94	5.36	0.63	0.72
Consumption	0.72	0.34	0.48	0.20	0.67	0.61
Financial variables						
DebtRep/Output	1.44	1.43	1.63	4.74	1.13	3.32
EquPay/Output	0.94	0.95	1.66	4.47	1.77	4.69
B) Leverage=0.6 - Structural break only in κ						
Real variables						
Output	1.14	1.23	0.50	1.10	0.43	0.89
TFP	0.58	0.78	0.41	0.74	0.71	0.94
Labor	0.84	0.74	0.55	0.58	0.65	0.78
Investment	4.66	7.01	2.94	6.27	0.63	0.89
Consumption	0.72	0.36	0.48	0.24	0.67	0.67
Financial variables						
DebtRep/Output	1.44	1.25	1.63	5.04	1.13	4.03
EquPay/Output	0.94	0.95	1.66	4.74	1.77	5.01

Notes: For the real variables, the numbers are standard deviations of the growth rates. For the financial variables the numbers are standard deviations of first differences. Artificial data is generated by averaging the standard deviations associated with 100,000 draws of parameters from the posterior distribution.

Return to scale. Consider now the sensitivity with respect to the return to scale ν. With increasing returns, the model can generate endogenous fluctuations in productivity. Therefore, it can also generate a decline in the volatility of measured TFP after financial innovations even if the volatility of the productivity shock does not change. As stated earlier, the case $\nu > 1$ is interpreted as capturing, in a simple form, the presence of fixed factors that cannot be changed in the short-run. It is a parsimonious way of incorporating variations in capacity utilization.

Table 9 reports the business cycle statistics generated by the estimated model with $\nu = 1.25$ and with $\nu = 1.75$. When we change ν we also change $\bar{A}$ so that the steady state leverage remains the same. In the estimation we allow for a structural break in both, the parameter of the financial structure κ and in the volatility of the shocks, σ_z and σ_ε. However, to economize on space, we only report the statistics for the counterfactual simulation in which only κ changes. This is the relevant simulation to evaluate the contribution of financial innovations to the reduction in business cycle volatility.

The contribution of financial innovations increases with higher returns to scale. When $\nu = 1.75$, changes in κ can account for about half of the volatility decline in the real variables. With $\nu = 1.25$, the contribution of financial innovations is about half the contribution in the baseline calibration with $\nu = 1.5$.

8 Conclusion

In this paper we document that while the volatility of the U.S. business cycle has declined in the last two decades, the financial flows of firms have become more volatile. To investigate the role played by financial innovations, the paper develops a business cycle model with explicit roles for debt and equity financing. The model is driven by two types of shocks—productivity and credit—and financial frictions play a central role for the amplification of shocks. In the model, financial innovations reduce the importance of financial frictions and, as a result, they lead to lower macroeconomic volatility but greater volatility in the financial structure of firms as in the data.

While we have shown our model to be quite successful along a number of dimensions, our analysis has not explicitly considered all aspects of the so-called Great Moderation. In particular, although the volatilities of all components of investment (nonresidential, residential and inventories) have

Table 9: Sensitivity with respect to ν.

	Early period *(1952-1983)*		**Late period** *(1984-2005)*		**Late/Early**	
	Data	*Model*	*Data*	*Model*	*Data*	*Model*
A) $\nu = 1.25$ **- Structural break only in** κ						
Real variables						
Output	1.15	1.23	0.50	1.13	0.43	0.92
TFP	0.58	0.78	0.41	0.76	0.71	0.97
Labor	0.84	0.77	0.55	0.60	0.65	0.79
Investment	4.66	7.06	2.94	6.49	0.63	0.92
Consumption	0.72	0.33	0.48	0.25	0.67	0.75
Financial variables						
DebtRep/Output	1.44	1.30	1.63	6.06	1.13	4.67
EquPay/Output	0.94	0.95	1.66	5.77	1.77	6.09
B) $\nu = 1.75$ **- Structural break only in** κ						
Real variables						
Output	1.14	1.29	0.50	0.81	0.43	0.63
TFP	0.58	0.77	0.41	0.54	0.71	0.70
Labor	0.84	0.83	0.55	0.43	0.65	0.51
Investment	4.66	7.48	2.94	4.61	0.63	0.61
Consumption	0.72	0.39	0.48	0.18	0.67	0.46
Financial variables						
DebtRep/Output	1.44	1.46	1.63	3.67	1.13	2.51
EquPay/Output	0.94	0.97	1.66	3.41	1.77	3.52

Notes: For the real variables, the numbers are standard deviations of the growth rates. For the financial variables the numbers are standard deviations of first differences. Artificial data is generated by averaging the standard deviations associated with 100,000 draws of parameters from the posterior distribution.

declined in the second sample period, the decline has been especially large for the volatility of residential investment. We have studied a model where all types of investments are pooled in one single aggregate chosen by the business sector. This is consistent with the idea that real estate businesses face the same financial decisions and instruments as other businesses. However, one can imagine extending our analysis to explicitly model households' real estate transactions by incorporating mechanisms that are similar to those we have studied in this paper. Households would also face some rigidities in changing their financial structure, and financial innovations would reduce these rigidities.

Indeed, many of the financial changes or innovations that have taken place during the last two decades have changed dramatically the financing options open to households. Two of these changes are particularly important: the rapid expansion of credit cards and equity lines of credit. These instruments provide a buffer against unexpected borrowing needs which is very important for increasing the financial flexibility of households. The existing literature has mostly emphasized the role that these instruments create for increasing the household's total borrowing. What we would like to emphasize here is that they have also increased the financial flexibility of households. This greater flexibility then could imply lower volatility of households expenditures for those items that are more directly related to households' financing, namely, durable consumption and real estate investment.

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 'Credit Market Instruments' for the Nonfinancial Corporate Business (F.102, line 39) and for the Noncorporate Business (F103, line 22). 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). Total assets and liabilities are as reported by the Flow of Funds in the Nonfinancial Corporate Business (B.102, line 1 and 21) and in the Noncorporate Business (B.103, line 1 and 23). All macro variables are from the Bureau of Economic Analysis (BEA).

B Enforcement constraint

In addition to k_t, production requires working capital. Denote the working capital by D_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. The firm borrows these funds at the beginning of the period and returns them at the end of the period. This is in addition to the debt b_{t+1}. 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 leads to the renegotiation of the loan. Suppose that in case of default the lender can confiscate the firm and sell it at the market value $\overline{V}_t$. However, in order to do so, the lender has to pay a cost ξ_t. Denote by ψ_t the bargaining power of the firm and $1-\psi_t$ the bargaining power of the lender. Bargaining is over the repayment of the debt, which we denote by e_t. By reaching an agrement, the firm gets $D_t + \overline{V}_t - e_t$ and the lender gets e_t. Without agreement, the firm gets the threat value D_t and the lender gets the threat value $\overline{V}_t - \xi_t$. Therefore, the net value of reaching an agreement for the firm is $\overline{V}_t - e_t$ and for the lender is $e_t - \overline{V}_t + \xi_t$. The bargaining problem solves:

$$\max_{e_t} \left\{ (\overline{V}_t - e_t)^{\psi_t} (e_t - \overline{V}_t + \xi_{t+1})^{1-\psi_t} \right\}$$

Taking the first order conditions and solving we get $e_t = \overline{V}_t - \psi_t \xi_t$.

Incentive-compatibility requires that the value of not defaulting, $\overline{V}_t$, is not smaller than the value of defaulting, $D_t + \overline{V}_t - e_t$. Using $e_t = \overline{V}_t - \psi_t \xi_t$, this can be written as $\overline{V}_t \geq D_t + \psi_t \xi_t$. Collecting terms and rearranging we get

$$\overline{V}_t \geq \psi_t \xi_t + D_t$$

Defining $A_t = \psi_t \xi_t$ and remembering that the working capital is assumed to equal the wage payments, that is, $D_t = w_t l_t$, the enforcement constraint becomes:

$$\overline{V}_t \geq A_t + w_t l_t$$

Higher values of A_t, can derive either from higher bargaining power of firms, ψ, or higher cost of liquidation, ξ. Both changes lead to lower enforcement of debt contracts. Also notice that alternative assumptions about the working capital requires only a change in the right-hand-side of the constraint.

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:

$$\begin{aligned}
l: &\quad \lambda F_l(z,k,l) - \mu w = 0 \\
d: &\quad 1 - \lambda \varphi_d(d) = 0 \\
k': &\quad (1+\mu) E m' V_k(\mathbf{s}'; k', b') - \lambda = 0 \\
b': &\quad (1+\mu) E m' V_b(\mathbf{s}'; k', b') + \frac{\lambda}{(1-\tau)R} = 0
\end{aligned}$$

The envelope conditions are:

$$\begin{aligned}
V_k(\mathbf{s}; k, b) &= \lambda F_k(z,k,l) \\
V_b(\mathbf{s}; k, b) &= -\lambda
\end{aligned}$$

Using the first condition to eliminate λ and substituting the envelope conditions we get (2)-(4).

D Numerical solution

We solve the model after log-linearizing the dynamic system around the steady state. The system of dynamic equations is as follows:

$$w U_c(c,l) + U_l(c,l) = 0 \qquad (8)$$

$$U_c(c,l) - \beta R E U_c(c',l') = 0 \tag{9}$$

$$wl + b - \frac{b'}{(1-\tau)R} + d - c = 0 \tag{10}$$

$$F_l(z,k,l) - w\Big(1 + \mu\varphi_d(d)\Big) = 0 \tag{11}$$

$$(1+\mu)E\, m' \left(\frac{\varphi_d(d)}{\varphi_d(d')}\right) F_k(z',k',l') = 1 \tag{12}$$

$$(1+\mu)(1-\tau)RE\, m' \left(\frac{\varphi_d(d)}{\varphi_d(d')}\right) = 1 \tag{13}$$

$$F(z,k,l) - b + \frac{b'}{(1-\tau)R} - k' - \varphi(d) = 0 \tag{14}$$

$$Em'V' - A - wl = 0 \tag{15}$$

$$V - d - Em'V' = 0 \tag{16}$$

Equations (8)-(10) are the first order conditions for households and their budget constraint. Equations (11)-(13) are the first order conditions for firms and (14)-(16) are the budget constraint, the enforcement constraint and the value function.

These are nine dynamic equations which, together with the definition of the discount factor, $m' = \beta U_c(c',l')/U_c(c,l)$, are used to solve the model. After linearizing around the steady state, we can solve for the variables c_t, d_t, l_t, w_t, R_t, V_t, μ_t, k_{t+1}, b_{t+1}, as linear functions of the states, $\mathbf{z}_t$, $\mathbf{A}_t$, k_t, b_t.

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