Macroeconomic Effects of Financial Shocks*

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Abstract

In this paper we document the cyclical properties of U.S. firms' financial flows. Debt payouts are countercyclical and equity payouts are procyclical. We develop a model with explicit roles for debt and equity financing and we study its business cycle implications. Standard productivity shocks can only partially explain the observed variations in real variables and financial flows. We show that financial shocks that affect firms' capacity to borrow can bring the model much closer to the data. The recent events in the financial sector show up clearly in our model as a tightening of firms' financing conditions in 2008 and as a cause for a downturn in GDP growth. The model also suggests that the downturns in 1990 and 2001 were strongly influenced by changes in the credit conditions.

*Some material in this paper was previously incorporated in our companion paper "Financial Innovations and Macroeconomic Volatility."

1 Introduction

Recent economic events starting with the subprime crisis in the summer of 2007 suggest that the financial sector plays an important role in the transmission and as a source of business cycles. While there is a long tradition in macroeconomics to consider financial accelerators, quantitative model building has not focused much on matching simultaneously real aggregates and aggregate flows related to debt and equity financing. Moreover, financial shocks have played a relatively minor role in the business cycle literature. In this paper we attempt to make some progress along these lines.

We start by documenting the cyclical properties of firms' equity and debt flows at an aggregate level. We then build a business cycle model with explicit roles for firms' debt and equity financing. We show that the model driven solely by measured productivity shocks fails to match business cycle volatilities and the behavior of equity and debt flows. Augmenting the model with credit shocks that directly affect firms' ability to borrow brings the model much closer to the data—not only for financial flows but also for some of the real business cycle quantities. When we further characterize these credit shocks, we find that the model implies a worsening of firms' ability to borrow in 2008, which is in line with the standard interpretation of economic events since the summer of 2007. Moreover, the model implies that economic downturns in 1990 and 2001 were strongly influenced by changes in the credit conditions.

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.[1]

The paper is structured as follows. In Section 2 we consider some em-

[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 in the quantitative impact of financial frictions for the propagation of aggregate shocks to the macro economy.

pirical evidence on real and financial cycles in the US economy. Section 3 presents the model and characterizes some of its analytical properties. Model calibration and quantitative findings are presented in Sections 4.

2 Real and financial cycles in the U.S.

This section presents the main empirical observations that motivate the paper. It describes the properties of real and financial business cycles.

We start by reporting the business cycle properties of firms' aggregate financial flows. To our knowledge, these properties have not been previously documented and explored in the macro literature. 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 noncorporate business owners). Debt is defined as 'Credit Market Instruments' 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.

Two patterns are visible in the figure, very strongly so for the second half of the period considered. First, equity payouts are negatively correlated with debt repurchases. This suggests that there is some substitutability between equity and debt financing. Second, 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.

The properties of real and financial cycles are further characterized in Table 1. The table reports the standard deviations and correlations with GDP for equity payouts and debt repurchases in the nonfinancial corporate sector and in the nonfinancial corporate and noncorporate sectors combined. Statistics for a number of key business cycle variables are also presented. Equity payouts and debt repurchases are normalized by the value added produced in the sector. For these two variables we do not take logs because

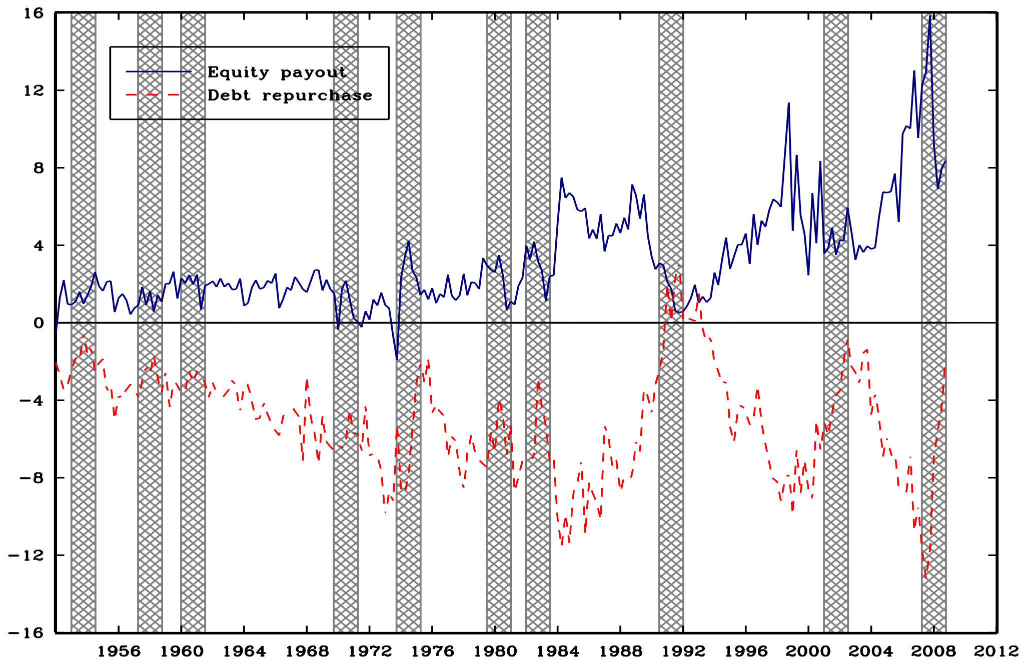

Figure 1: Financial flows in the nonfarm, nonfinancial business sector. Source: Flow of Funds, Federal reserve Board.

some observations are negative. All variables are detrended with a band-pass filter that preserves cycles of 1.5-8 years (Baxter and King (1999)).

We focus on the period after 1984 for two related reasons. First, it has been widely documented in relation with the so called Great Moderation that 1984 corresponds to a break in the volatility in many business cycle variables. Second, as documented in Jermann and Quadrini (2008), this time period also saw major changes in U.S. financial markets. In particular, spurred by regulatory clarifications, share repurchases had become more common, and this seemed to have had a major impact on firms' payout policies and financial flexibility. Therefore, by concentrating on the period after 1984 we do not have to address the causes of the structural break that arose in the early 1980s.

The reported correlations in the table for equity payouts and debt repurchases with output confirm the properties we highlighted in the previous figure. As is clear in the table, equity payouts are procyclical and debt repurchases are countercyclical, and this property holds for the nonfinancial

Table 1: Business cycles properties of macroeconomic and financial variables, 1984:1-2008:4.

	Std(Variable)	$\frac{\text{Std(Variable)}}{\text{Std(GDP)}}$	Corr(Variable,GDP)
Macroeconomic variables			
GDP	0.85		
Consumption (N.D.& S.)	0.50	0.59	0.83
Investment	3.98	4.68	0.85
Hours	1.18	1.39	0.81
TFP	0.50	0.59	0.41
Financial variables			
EquPay/GDP (Corporate)	1.27	1.49	0.44
DebtRep/GDP (Corporate)	1.42	1.67	-0.65
EquPay/GDP (Corp.&Noncorp.)	1.08	1.27	0.50
DebtRep/GDP (Corp.&Noncorp.)	1.34	1.58	-0.77

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. The macroeconomic variables have been logged. 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.

corporate sector alone, as well as for the total nonfinancial business sector. The business cycle properties of the real variables are well known, and we will get back to them when comparing our model to the data.

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 $F(z_t, k_t, l_t) = e^{z_t} k_t^{\theta} l_t^{1-\theta}$. The variable z_t is a productivity shock, k_t is the input of capital depreciating at rate δ and l_t is the input of labor.

Firms use equity and debt to finance their operations. Debt is in general preferred to equity (pecking order) because of its tax advantage as, for example, in Hennessy and Whited (2005). Given r_t the interest rate, the effective gross rate for the firm is $R_t = (1-\tau)(1+r_t)$, where τ determines the tax advantage.[2]

The ability to borrow is bounded by the limited enforceability of debt contracts as firms can default on their obligations. Let $\overline{V}_t$ be the value of the firm at the end of the period, after paying dividends. This is the 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 which will be derived later, and d_{t+j} are the net payments to the shareholders. The firm's value $\overline{V}_t$ is typically decreasing in the debt, because, everything else equal, debt reduces the future payments that can be made to the shareholders.

Default arises after the realization of revenues. In case of default, the firm has the ability to retain the revenues $F(z_t, k_t, l_t)$, as these are liquid funds that can be easily diverted, and renegotiates the debt.

To determine the renegotiation outcome, we assume that the lender can sell the firm but there is some loss of value in dong so. More specifically, we make the following assumptions: (i) Liquidation requires a cost ζ_t. This cost is stochastic and follows a Markov process; (ii) Only a fraction $\psi < 1$ of the equity value of the firm is recovered through the sale.

Because of the loss of value in liquidating the firm, both parties have an interest in renegotiating the debt. The net surplus from reaching an agrement is $(1-\psi)\overline{V}_t + \zeta_t$. Without loss of generality (see Appendix B) we assume that the firm has the whole bargaining power, and therefore, the value retained in the renegotiation stage is $(1-\psi)\overline{V}_t + \zeta_t$. Thus, the total value from defaulting is $F(z_t, k_t, l_t) + (1-\psi)\overline{V}_t + \zeta_t$, that is, the retained revenues plus the renegotiation value. Enforcement requires that the value of the firm $\overline{V}_t$ is at least as big as the value of defaulting, that is,

$$\overline{V}_t \geq F(z_t, k_t, l_t) + (1-\psi)\overline{V}_t + \zeta_t. \tag{1}$$

Rearranging terms, the enforcement constraint can be rewritten as:

$$\overline{V}_t \geq \phi F(z_t, k_t, l_t) + \xi_t. \tag{2}$$

[2] 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.

where $\phi = 1/\psi$ and $\xi_t = \zeta_t/\psi$. For a more detailed description of the timing of the renegotiation process leading to this enforcement constraint see Appendix B.

The ability to borrow depends on both ϕ and ξ_t. Higher recoverable values (lower ϕ or lower ξ_t) increase the collateral value of the firm, and therefore, it allows for more debt. Because the capacity to borrow fluctuates stochastically through the changes in ξ_t, we refer to the stochastic component of this variable as "credit shock". More specifically, an increase in ξ_t tightens the enforcement constraint and reduces the borrowing capacity. If the firm cannot raise equity capital and increase the equity value of the firm to the new required level, it has to reduce the right-hand-side of the enforcement constraint by cutting employment and, starting from the next period, the input of capital.[3]

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

[3]As an alternative specification we could assume that the shock is on the recoverable value of equity, affecting ϕ. As we will see in the sensitivity analysis, this specification does not change the key properties of the model but it will make the characterization of some analytical properties more difficult. 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.

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.[4]

The parameter κ is key for determining the impact of market incompleteness. When $\kappa = 0$, the economy is essentially equivalent to a frictionless economy. In this case, debt adjustments triggered by the credit shocks can be quickly accommodated through changes in firm equity. When $\kappa > 0$, the substitution between debt and equity becomes costly and firms readjust the sources 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, which we will make precise 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:

$$V(\mathbf{s}; k, b) = \max_{d,l,k',b'} \left\{ d + Em'V(\mathbf{s}'; k', b') \right\} \quad (3)$$

subject to:

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

$$Em'V(\mathbf{s}'; k', b') \geq \phi F(z,k,l) + \xi$$

The problem is subject to the budget and the enforcement constraints. The function $V(\mathbf{s}; k, b)$ is the cum-dividend (fundamental) market value of the firm and m' is the stochastic discount factor. The variables w and R are, respectively, 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.

[4]As an alternative to the adjustment cost on equity payouts, we could use a quadratic cost on the change of debt. Our sensitivity analysis reported below shows that this doesn't change our main results. Therefore, our model can be interpreted more broadly as capturing the rigidities in the adjustment of all sources of funds, not only equity.

Taking the first-order conditions we get:

$$F_l(z,k,l) = w \cdot \left(\frac{1}{1-\phi\mu\varphi_d(d)}\right), \tag{4}$$

$$(1+\mu)E\,m'\left(\frac{\varphi_d(d)}{\varphi_d(d')}\right)\Big[1-\delta+\big(1-\phi\mu'\varphi_d(d')\big)F_k(z',k',l')\Big] = 1, \tag{5}$$

$$(1+\mu)RE\,m'\left(\frac{\varphi_d(d)}{\varphi_d(d')}\right) = 1, \tag{6}$$

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 (6) becomes $(1+\mu)REm' = 1$. 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 ξ. From conditions (4) and (5) we can see that the production and investment choices of the firm only depend on aggregate prices. Changes in ξ 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 ξ, 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. The model collapses, essentially, to the standard RBC model driven by productivity shocks only.

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

3.2 Households sector and general equilibrium

There is a continuum of homogeneous households maximizing the expected 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:

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

where w_t and r_t are the wage and interest rates, b_t is the one-period bond, s_t the equity shares, d_t the equity payout received from the ownership of shares, q_t is the market price of shares, and $T_t = B'/(1-\tau)(1+r_t) - B'/(1+r_t)$ 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:

$$w_t U_c(c_t, l_t) + U_h(c_t, l_t) = 0 \tag{7}$$

$$U_c(c_t, l_t) - \beta(1+r_t)EU_c(c_{t+1}, l_{t+1}) = 0 \tag{8}$$

$$U_c(c_t, l_t)q_t - \beta E(d_{t+1} + q_{t+1})U_c(c_{t+1}, l_{t+1}) = 0. \tag{9}$$

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 $m_{t+j} = \beta^j U_c(c_{t+j}, l_{t+j})/U_c(c_t, l_t)$.

We can now provide the definition of a recursive general equilibrium. The set of aggregate states $\mathbf{s}$ are given by the current realization of productivity z, the current realization of the credit shock ξ, the aggregate capital K, and the aggregate bonds B, that is, $\mathbf{s} = (z, \xi, K, B)$.

Definition 3.1 (Recursive equilibrium) *A recursive competitive equilibrium is defined as a set of functions for (i) households' policies $c(\mathbf{s})$ and $l(\mathbf{s})$; (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 (7)-(8); (ii) firms' policies are optimal and*

$V(\mathbf{s}; k, b)$ satisfies the Bellman's equation (3); (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 ξ.

3.3 Some characterization of the equilibrium

To illustrate some of the properties of the model, it will be convenient to look at two special cases in which the equilibrium can be characterized analytically. First, we show that for a deterministic steady state with constant z and ξ, the default constraint is always binding. Second, if $\kappa = 0$, changes in ξ (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 $m = 1/(1+r)$. Because in the steady state $\varphi_d(d) = \varphi_d(d') = 1$, the first order condition for debt, equation (6), simplifies to $(1+\mu)Rm = 1$. Substituting the above definition of m, this condition can be written as $R = (1+r)/(1+\mu)$. Remembering that $R = (1-\tau)(1+r)$, we then have $(1-\tau)(1+\mu) = 1$, implying that $\mu > 0$ if $\tau > 0$. Thus, as long as there is a tax advantage in issuing debt, 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 ξ have no effect on l and k'.*

When $\kappa = 0$ we have that $\varphi_d(d) = \varphi_d(d') = 1$. Therefore, the first order condition (6) can be written as $(1+\mu)REm' = 1$. From the household's first order condition (8) we have that $(1+r)Em' = 1$. Combining the two conditions and using $R = (1-\tau)(1+r)$ we get $(1+\mu)(1-\tau) = 1$. Therefore, μ is constant. Now consider an innovation in ξ and conjecture that the sequence of prices w, R and m' do not change. Because ξ does not enter the optimality conditions (5)-(6) and μ stays constant, changes in ξ 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 fluctuations in ξ cancel each other out in the household's budget constraint. Therefore, the conjectured unchanged sequence of prices is an equilibrium outcome.

We have then established that, when $\kappa = 0$, business cycle movements are only driven by fluctuations in aggregate productivity z and the economy is essentially equivalent to a standard RBC model. The enforcement constraint does not affect the transmission of a productivity shock to the economy's real variables. There is one small difference with respect to the standard RBC model due to the debt's subsidy. This distorts somewhat the deterministic steady state. However, it has not effects on the dynamic properties of the model in response to credit shocks. In fact, when $\kappa = 0$, the key first order conditions become:

$$wU_c(c,l) + U_l(c,l) = 0$$

$$(1-\phi\mu)F_l(z,k,l) = w,$$

$$(1+\mu)E\left(\frac{\beta U_c(c',l')}{U_c(c,l)}\right)\Big[1-\delta+(1-\phi\mu)F_k(z',k',l')\Big] = 1.$$

These conditions are equivalent to the first order conditions for the standard RBC model with the exception of some wedges in the optimality conditions for labor and capital. These wedges, captured by the variable $\mu = \tau/(1-\tau)$, remain constant over the business cycle. Therefore, they affect the steady state but not the business cycle properties. It can be verified that the model would converge exactly to the RBC model also in its steady state level if $\tau = 0$.

4 Quantitative analysis

In this section we study the quantitative properties of the model. We start by showing that the model driven only by productivity shocks fails to replicate some of the features of U.S. business cycles. We then show that adding credit shocks not only improves the model's predictions for the financial flows, but also helps the model replicating the business cycle moments of certain macroeconomic variables, in particular working hours. Finally, we use the model to recover the series of credit shocks needed to replicate debt flows for the period 1984-2008. Driven by these shocks, as well as measured productivity shocks, the model does a good job matching the GDP downturn in 2008, as well as the downturns of 1990 and 2001. This suggests that tighter credit conditions have been important drivers of these episodes. Finally, we show that the series for equity payouts generated by the model matches its empirical counterpart very closely.

4.1 Calibration

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 utility function takes the form $U(c, l) = \ln(c) + \alpha \cdot \ln(1-l)$ where $\alpha = 1.9265$ is chosen to have steady state hours equal to 0.3. The Cobb-Douglas parameter in the production function is set to $\theta = 0.36$ and the depreciation to $\delta = 0.025$. All these parameter values are standard in the literature and the quantitative properties of the model are not very sensitive to changing them. The tax advantage parameter is set to $\tau = 0.006163$. In terms of tax deductibility of interests this corresponds to 35 percent.

The parameter ϕ is chosen to match the average leverage, that is, the ratio of debt, b, over the capital stock, k. The chosen value of $\phi = 3.7823$ implies that the steady state leverage in the model is 0.46. This corresponds to the average leverage obtained from the Flow of Funds for the Nonfarm Nonfinancial Corporate and Noncorporate Business during the period 1984-2008.[5]

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

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

After linearly detrending the empirical Solow residuals over the period 1984-2008, we estimate the persistence $\rho_z = 0.9$ and the standard deviation of the innovations $\sigma_z = 0.0041$.

The credit shock is specified as $\xi_t = e^{x_t}$, with

$$x_{t+1} = \rho_x x_t + \varepsilon_{t+1} \qquad \varepsilon \sim N(0, \sigma_x).$$

[5] Leverage is measured as total liabilities divided by total assets. See Tables B.102 and B.103 in the Flow of Funds.

which involves two parameters, rho_x and σ_x. These two parameters and the adjustment cost parameter in the dividend function, κ, cannot be calibrated using steady state targets. The steady state equilibrium is invariant to the values of ρ_x, σ_x and κ. Therefore, we have to use business cycle moments.

Our strategy is to select parameter values to match some properties of equity and debt flows without directly fitting the volatility of output or other real macroeconomic variables. In particular, we use the simulated methods of moments technique to best fit the following four moments calculated over the period 1984-2008: (i) the standard deviation of Equity Payouts; (ii) the standard deviation of Debt Repurchases; (iii) the correlation of Equity Payouts with GDP; and (iv) the correlation of Debt Repurchases with GDP.

Denote by $\overline{M}$ the vector containing the four moments calculated from the data, that is,

$$\overline{M} = \begin{pmatrix} \text{Std}(EquPay) \\ \text{Std}(DebtPay) \\ \text{Corr}(EquPay, Gdp) \\ \text{Corr}(DebtPay, Gdp) \end{pmatrix}$$

Furthermore, denote by $M(\rho_x, \sigma_x, \kappa)$ the corresponding moments generated by the model given the particular values of the parameters ρ_x, σ_x and κ. Parameter values are chosen to minimize

$$\left[M(\rho_x, \sigma_x, \kappa) - \overline{M}\right]^T \cdot W \cdot \left[M(\rho_x, \sigma_x, \kappa) - \overline{M}\right],$$

where W is a weighting matrix computed from the data as, for instance, in Jonsson and Klein (1996). The empirical data as well as the data generated by the model are detrended with a band-pass filter that preserves cycles of 1.5-8 years (Baxter and King (1999)).

To keep the model stationary, we restrict ρ_x to be bounded by 0.995. This constraint ends up binding. The values obtained for these parameters are $\rho_x = 0.995$, $\sigma_x = 0.028055$ and $\kappa = 0.3299$. We have also considered fitting different subsets of three of the four moments considered here with results that are not fundamentally different (see the sensitivity analysis below).

While it is not a priori clear what a good empirical counterpart for the adjustment cost parameter κ is, the value used in our calibration implies a very small loss due to the adjustment cost friction. Indeed, with $\kappa = 0.3299$, the percentage loss at a 2 standard deviation distance for the payout from its steady state level is roughly one quarter of a percent. Everything else equal, as κ is increased, the firm will occasionally choose policies for which the enforcement constraint becomes slack. For our parametrization, the constraint is slack only 1% of the time. The full set of parameters values are reported in Table 2.

Table 2: Parametrization.

Calibrated parameters	
Discount factor, β	0.9825
Tax advantage, τ	0.0062
Utility parameter, α	1.9265
Production technology, θ	0.3600
Depreciation rate, δ	0.0250
Enforcement parameter, ϕ	3.7823
Productivity shock persistence and volatility , ρ_z and σ_z	0.9000, 0.0041
Credit shock persistence and volatility , ρ_x and σ_x	0.9950, 0.0280
Payout cost parameter, κ	0.3299

4.2 Findings

The quantitative performance of the model is first shown for the case with only productivity shocks. Then we illustrate how the addition of credit shocks improves the performance of the model.

4.2.1 Productivity shocks only

The model driven only by productivity shocks fails along a number of dimensions. Consider first the well known implications of the basic RBC model, which is obtained by setting $\kappa = 0$. The statistics are reported in the last column of Table 3. While this model does a reasonable job with the main aggregates, its fit is far from perfect. For example, the model implies a perfect correlation between output and productivity shocks (TFP), this correlation is only 0.41 in the data. This suggests that standard productivity cannot be the only driver of output movements. The correlations of output with debt and equity flows generated by the model are also very different from their empirical counterparts. In particular, equity payouts in the model are mildly countercyclical while they are procyclical in the data. Finally, hours worked are too smooth in the model. Impulse responses are displayed in Figure 2.

Introducing financial frictions into the benchmark model by setting the payout adjustment cost parameter to the estimated value of $\kappa = 0.3299$, has a relatively minor effect on business cycle properties. However, financial flows are further dampened, and thus the distance between model and data is further increased. Given that both sides of the enforcement constraint (2) contain endogenous variables, the effect of productivity shocks on output can theoretically be amplified or dampened. For our benchmark calibration, shocks are dampened through the financial friction.

4.2.2 Credit and productivity shocks

Adding credit shocks leads to a substantial improvement in the model's ability to match financial and real variables. Among the four moments targeted by the SMM selection of the three parameters ρ_x, σ_x, and κ, the model matches reasonably well the two correlations and the volatility of debt flows. The model implied standard deviation of equity payouts of 0.73% falls somewhat short of its empirical counterpart, 1.08%. The implied output volatility is almost the same as in the model with only productivity shocks and no financial frictions. As discussed before, financial friction, that is, $\kappa > 0$, reduces output volatility, while, as shown here, adding the credit shocks makes a positive contribution to output volatility. Despite the fact that output volatility is not increased (compared to the frictionless case), the model with credit shocks does substantially better in generating volatility in hours worked. Finally, and less surprisingly, compared to the perfect correlation between output and TFP in the model with only productivity shocks, the model with credit shocks implies a more reasonable correlation of 0.68. Figure 3 displays the impulse response functions following a tightening of the enforcement constraint induced by a one standard deviation credit shock.

4.2.3 Implied credit shock series

Having demonstrated that the model with financial frictions and credit shocks does a reasonable job reproducing volatility levels and cross-correlations of macroeconomic and financial variables, we now compare paths of some key series generated by the model with their empirical counterparts.

We run the following experiment. Conditional on the empirical realizations of the Solow residuals for the period 1984-2008, we compute the model implied realizations of the credit shocks needed to perfectly match the empirical series of debt repurchase. All series have been linearly detrended but are otherwise unfiltered. Having matched one of the financial flows series to the data, we compare the paths for output and other variables generated by the model to their empirical counterparts.

As a starting point, the lower panel of Figure 4 shows that the model driven only by productivity shocks does a poor job matching actual GDP. Indeed, throughout the 1990s, the model implies output falling relative to trend, while the data shows the opposite.[6] Productivity shocks are also not able to produce the substantial decline in output observed during the most recent recession in 2008. The top panels show that the performance of the model in replicating the financial flows is also poor.[7]

Let's consider now the case with both productivity and credit shocks. The sequence of productivity shocks are as described before. The sequence of credit shock is determined to replicate exactly the path of debt repurchases observed in the data. Figure 5 plots the paths of the financial flows and GDP in the model driven by the two sequences of productivity and credit shocks.

As shown in the upper right panel, the model matches extremely well the empirical path for equity payouts. Notice that this series was not directly targeted in backing up the sequence of the credit shocks. We only targeted the sequence of debt repurchases (plotted in the upper left panel).

The path of output implied by the model is shown in the lower panel of Figure 5. The model captures many of the dynamic features of recent U.S. GDP. In particular, the model generates a sharp downturn in 2008 at a time when debt repurchases display a dramatic surge. The model also captures very well the GDP downturn in 1990, as well as part of the downturn in 2001. The overall picture that emerges is that for the last three recessions, credit shocks seem to have played an important role.

Another way to illustrate the importance of financial tightness is by plotting the series for the credit shock (the variable x_t). As can be seen from the

[6]This is consistent with McGrattan and Prescott (2007) who show that the standard RBC model cannot capture the macroeconomic expansion of the 1990s due to its inability to match working hours.

[7]Setting $\kappa = 0$ makes equity payouts and debt repurchases more volatile. However, the model's ability to match their empirical counterparts does not improve relative to the figures presented here.

upper panel of Figure 6, the implied credit shocks show tightening financial conditions in 1990, 2001 and 2008.

The most important reason the consideration of credit shocks improves the performance of the model in terms of GDP is because it can better capture the dynamic path of working hours. This is shown in the lower panel of Figure 6. The panel also reports the path of working hours generated by the model with only productivity shocks (dashed/red line). Clearly, the addition of credit shocks generates much larger fluctuations in working hours. More importantly, it generates large drops in labor during the three recessions, as well as an upward trend during the 1990s.

5 Sensitivity analysis

To explore the sensitivity of our quantitative findings to various assumptions, we report here on the implications of several alternative calibrations and model versions. Overall, our findings are quite robust to these variations.

Cases 1 to 4 consider different calibrations. In particular, in each of these cases the three parameters associated with the credit shock process and the payout adjustment cost, ρ_x, σ_x and κ, are set so as to match 3 moments. Case 1 considers equity payout volatility and the correlations of the two financial flow variables with output, case 2, considers the volatilty of debt repurchases and the two correlations. As shown in Table 4A, in both cases the models display more volatile output and hours worked than the benchmark calibration. For the implied paths of equity payouts and GDP there are also some differences, in particular these two cases do not match equity payouts as well as the benchmark. In cases 3 and 4 the calibration targets the standard deviation of output as well as two additional moments related to the financial flows. The differences when compared to Cases 1 and 2 are relatively minor.

Case 5 considers an alternative specification for the enforcement constraint. Specifically, instead of the constraint considered in the main text

$$\overline{V}_t \geq \phi F(z_t, k_t, l_t) + \xi_t,$$

we now consider

$$\overline{V}_t \geq \phi_t F(z_t, k_t, l_t), \tag{10}$$

where ϕ_t is now the credit shock. As stated previously, the advantage of the specification used in the main text is that, due to the additive separability of the credit shock, we can show that if the adjustment cost parameter $\kappa = 0$, then credit shocks have no real effects (see Proposition 3.2 in section 3.3). As is clear from Table 4B and Figure 7B, results are almost unaffected by changing the constraint in this way. Note that the parameters ρ_x, σ_x and κ have been re-estimated in the same way as for the benchmark case.

Case 6 assumes that the adjustment cost is on the change of debt as opposed to the equity payout. More specifically, changing the level of debt gives rise to the cost $\kappa(b_{t+1} - b_t)^2$. The budget constraint becomes:

$$b_t + \kappa(b_{t+1} - b_t)^2 + d_t + k_{t+1} = (1 - \delta)k_t + F(z_t, k_t, l_t) - w_t l_t + \frac{b_{t+1}}{R_t}$$

As can be seen from the budget constraint, the adjustment cost on the debt replaces the adjustment cost on dividends. With this change, the theoretical properties established analytically in Section 3 also apply to this case. The key quantitative results are reported as Case 6 in Table 4B and Figure 7B.

6 Conclusion

Are financial frictions and shocks in the financial sector important for macroeconomic fluctuations? Our analysis in this paper suggest that they are. Models driven solely by productivity shocks have a number of known shortcomings in matching second moments of key business cycle variables. In our model we explicitly incorporate debt and equity flows and we further show that productivity shocks are not sufficient to generate realistic movements in financial flows. Shocks to firms' ability to borrow, combined with some rigidities in the ability to rearrange the financial structures of firms, are shown to bring the model closer to the data.

When we use the model to interpret recent economic events, the following picture emerges. The events in the financial sector starting in late 2007 show up clearly in our model as a tightening of firms' financing conditions and as a cause for a sharp downturn in GDP growth. In addition, tighter financial conditions also seem to have been important drivers of the two previous GDP downturns in 1990 and 2001.

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

Firms start the period with debt b_t. Before producing they choose the labor input, l_t, investment, $i_t = k_{t+1} - (1-\delta)k_t$, and raise additional funds to make payments to shareholders, d_t, and workers, $w_t l_t$. After raising these additional funds, the total liabilities are $b_t + d_t + w_t l_t + i_t$. At the end of the period, firms receive the revenue $F(z_t, k_t, l_t)$, which is used in partial repayment of the debt. Therefore, the net liabilities at the end of the period are $b_t + d_t + w_t l_t + i_t - F(z_t, l_t)$. These liabilities will be carried out to the next period with the addition of the interests. Thus, the next period debt will be:

$$b_{t+1} = \Big[b_t + d_t + w_t l_t + i_t - F(z_t, l_t)\Big] R_t$$

where R_t is the gross interest rate. This is the budget constraint for the firm.

Default arises after receiving the revenue $F(z_t, k_t, l_t)$, which can be easily diverted. In case of default, the lender has the right to sell the firm but only a fraction ψ of the equity value is recovered, that is, the lender can recover only the value $\psi \overline{V}_t$. Furthermore, in order to sell the firm, the lender has to pay a cost ζ_t. This cost is assumed to be stochastic.

Denote by η the bargaining power of the firm and $1-\eta$ 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 $F(z_t, k_t, l_t) + \overline{V}_t - e_t$ and the lender gets e_t. Without agreement, the firm gets the threat value $F(z_t, k_t, l_t)$ and the lender gets the liquidation value $\psi\overline{V}_t - \zeta_t$. Therefore, the net value of reaching an agreement for the firm is $\overline{V}_t - e_t$ and for the lender is $e_t - \psi\overline{V}_t + \zeta_t$. The bargaining problem solves:

$$\max_{e_t} \left\{ (\overline{V}_t - e_t)^{\eta}(e_t - \psi\overline{V}_t + \zeta_t)^{1-\eta} \right\}$$

Taking the first order conditions and solving we get $e_t = \overline{V}_t[1 - \eta(1-\psi)] - \eta\zeta_t$.

Incentive-compatibility requires that the value of not defaulting, $\overline{V}_t$, is not smaller than the value of defaulting, $F(z_t, k_t, l_t) + \overline{V}_t - e_t$. Therefore, the enforcement constraint is $\overline{V}_t \geq F(z_t, k_t, l_t) + \overline{V}_t - e_t$. Using $e_t = \overline{V}_t[1 - \eta(1-\psi)] - \eta\zeta_t$ derived above, the enforcement constraint can be written as:

$$\overline{V}_t \geq F(z_t, k_t, l_t) + \eta(1-\psi)\overline{V}_t + \eta\zeta_t$$

Collecting terms and rearranging we get:

$$\overline{V}_t \geq \phi F(z_t, k_t, l_t) + \xi_t,$$

where $\phi = 1/[1 - \eta(1-\phi)]$ and $\eta\xi_t = \zeta_t/[1 - \eta(1-\phi)]$.

If we assume that the bargaining power of the firm is $\eta = 1$ we get the enforcement constrained used in the main text of the paper. However, the assumption that $\eta = 1$ is without loss of generality.

C First order conditions

Consider the optimization problem (3) and let λ and μ be the Lagrange multipliers associate with the two constraints. Taking derivatives we get:

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

The envelope conditions are:

$$\begin{aligned}
V_k(\mathbf{s}; k, b) &= \lambda\Big[1 - \delta + F_k(z,k,l)\Big] - \mu\phi F_k(z,k,l) \\
V_b(\mathbf{s}; k, b) &= -\lambda
\end{aligned}$$

Using the first condition to eliminate λ and substituting the envelope conditions we get (4)-(6).

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:

$$wU_c(c,l) + U_l(c,l) = 0 \tag{11}$$

$$U_c(c,l) = \frac{\beta R}{1-\tau} EU_c(c',l') \tag{12}$$

$$wl + b - \frac{b'}{R} + d - c = 0 \tag{13}$$

$$F_l(z,k,l) = w\Big(\frac{1}{1-\mu\phi\varphi_d(d)}\Big) \tag{14}$$

$$(1+\mu)E\,m(c,l,c'l')\left(\frac{\varphi_d(d)}{\varphi_d(d')}\right)\left[1-\delta+\Big(1-\mu'\phi\varphi_d(d')\Big)F_k(z',k',l')\right] = 1 \tag{15}$$

$$(1+\mu)RE\,m(c,l,c',l')\left(\frac{\varphi_d(d)}{\varphi_d(d')}\right) = 1 \tag{16}$$

$$F(z,k,l) - wl - b + \frac{b'}{R} - k' - \varphi(d) = 0 \tag{17}$$

$$Em(c,l,c',l')V' = \phi F(z,k,l) + \xi \tag{18}$$

$$V = d + Em(c,l,c',l')V' \tag{19}$$

Equations (11)-(13) are the first order conditions for households and their budget constraint. Equations (14)-(16) are the first order conditions for firms and (17)-(19) are the budget constraint, the enforcement constraint and the value function.

We have nine dynamic equations. After linearizing around the steady state, we can solve these equations 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, z_t, ξ_t, k_t, b_t.

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Table 3
Business cycle properties

	1984-2008	Benchmark $\kappa = 0.3299$ $\rho x = .995$, $\sigma = .028055$	Only productivity shocks $\kappa = 0.3299$	Only productivity shocks $\kappa = 0$
GDP (Y)	0.85%	0.67%	0.49%	0.69%
σ(j)				
EquPay / Y	1.08%	**0.73%**	0.29%	0.93%
DebRep / Y	1.34%	**1.44%**	0.46%	0.91%
Consumption	0.50%	0.20%	0.18%	0.22%
Investment	3.98%	2.27%	1.48%	2.24%
Hours	1.18%	0.75%	0.23%	0.34%
corr(j, Y)				
EquPay / Y	0.50	**0.55**	-0.23	-0.15
DebRep / Y	-0.77	**-0.66**	-0.07	-0.22
Consumption	0.83	0.86	0.98	0.94
Investment	0.85	0.99	1.00	0.99
Hours	0.81	0.72	0.34	0.99
TFP	0.41	0.68	0.93	1.00

(Band-pass filter 1.5-8 years)

Table 4A

Business cycle properties Sensitivity Analysis	Data 1984-2008	Benchmark κ = 0.3299 ρx =.995 σ=.028055	Case 1 κ = 0.1397 ρx =.55175 σ=.067125	Case 2 κ = 0.711 ρx =.879 σ=.03825	Case 3 κ = 0.605 ρx =.7165 σ=.605
GDP (Y)	0.85%	0.67%	0.99%	0.79%	**0.84%**
σ(j)					
EquPay / Y	1.08%	**0.73%**	**1.08%**	0.37%	0.35%
DebRep / Y	1.34%	**1.44%**	2.19%	**1.34%**	**1.34%**
Consumption	0.50%	0.20%	0.21%	0.20%	0.19%
Investment	3.98%	2.27%	3.75%	2.81%	3.11%
Hours	1.18%	0.75%	1.33%	1.06%	1.15%
corr(j, Y)					
EquPay / Y	0.50	**0.55**	**0.50**	**0.50**	0.32
DebRep / Y	-0.77	**-0.66**	**-0.77**	**-0.77**	**-0.78**
Consumption	0.83	0.86	0.64	0.78	0.69
Investment	0.85	0.99	0.99	0.99	0.99
Hours	0.81	0.72	0.88	0.81	0.83
TFP	0.41	0.68	0.53	0.51	0.49

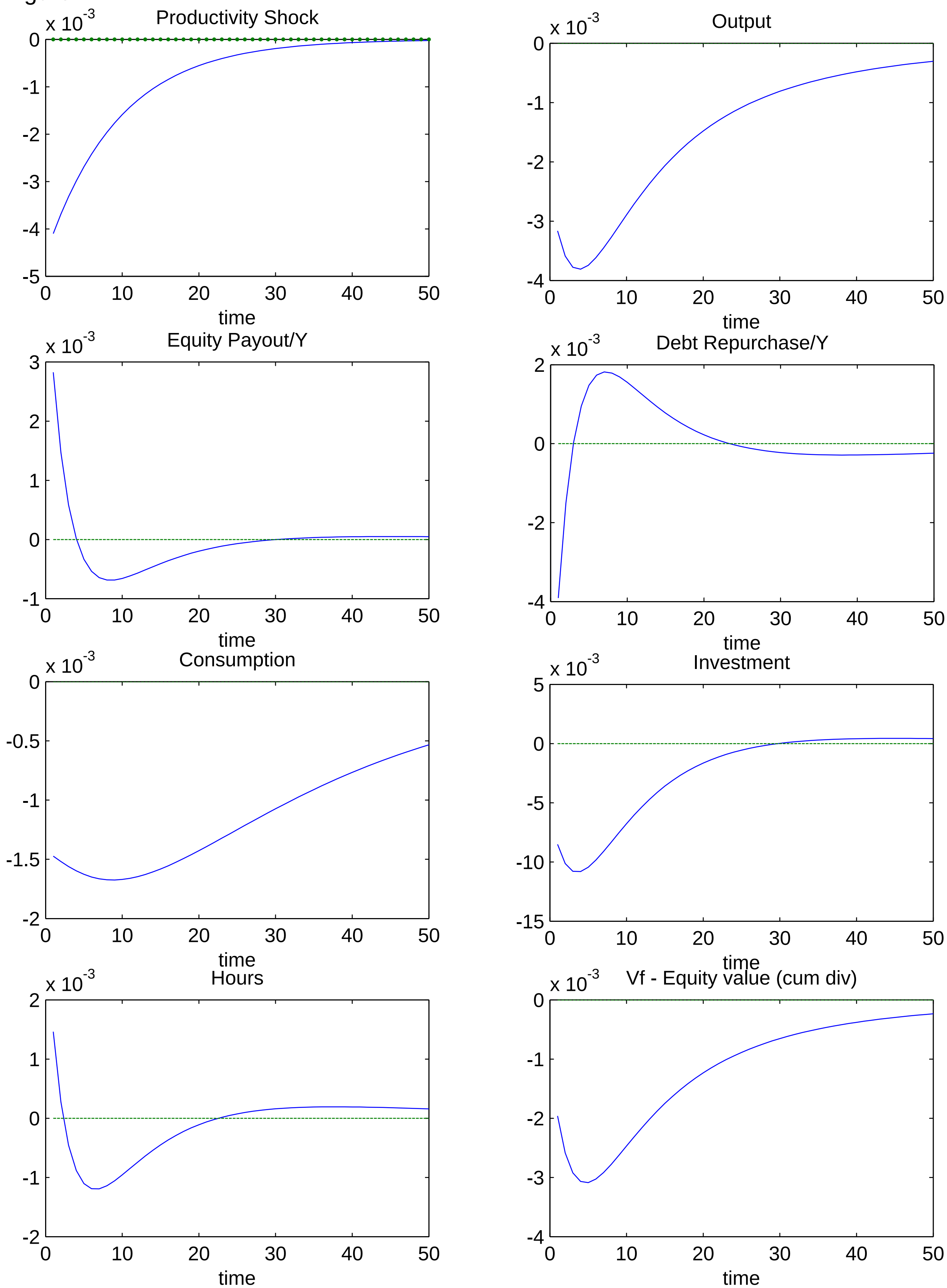
(Band-pass filter 1.5-8 years
Moments in bold face are targeted in the calibration)

Table 4B

Business cycle properties Sensitivity Analysis	Data 1984-2008	Benchmark κ = 0.3299 ρx =.995 σ=.028055	Case 4 κ = 0.1366 ρx =.7257 σ=.05122	Case 5 Model with Stochastic Φ	Case 6 Model with Debt Adjustment Cost
GDP (Y)	0.85%	0.67%	**0.85%**	0.63%	0.68%
σ(j)					
EquPay / Y	1.08%	**0.73%**	**1.08%**	**0.73%**	**1.32%**
DebRep / Y	1.34%	**1.44%**	1.98%	**1.49%**	**1.07%**
Consumption	0.50%	0.20%	0.20%	0.15%	0.26%
Investment	3.98%	2.27%	3.10%	2.36%	2.22%
Hours	1.18%	0.75%	1.05%	0.71%	0.65%
corr(j, Y)					
EquPay / Y	0.50	**0.55**	**0.50**	**0.48**	**0.31**
DebRep / Y	-0.77	**-0.66**	-0.71	**-0.63**	**-0.63**
Consumption	0.83	0.86	0.73	0.61	0.82
Investment	0.85	0.99	0.99	0.99	0.98
Hours	0.81	0.72	0.84	0.71	0.77
TFP	0.41	0.68	0.62	0.69	0.80

(Band-pass filter 1.5-8 years
Moments in bold face are targeted in the calibration)

Figure 2



Productivity Shock
x 10^-3
time
Output
x 10^-3
time
Equity Payout/Y
x 10^-3
time
Debt Repurchase/Y
x 10^-3
time
Consumption
x 10^-3
time
Investment
x 10^-3
time
Hours
x 10^-3
time
Vf - Equity value (cum div)
x 10^-3
time

Figure 3

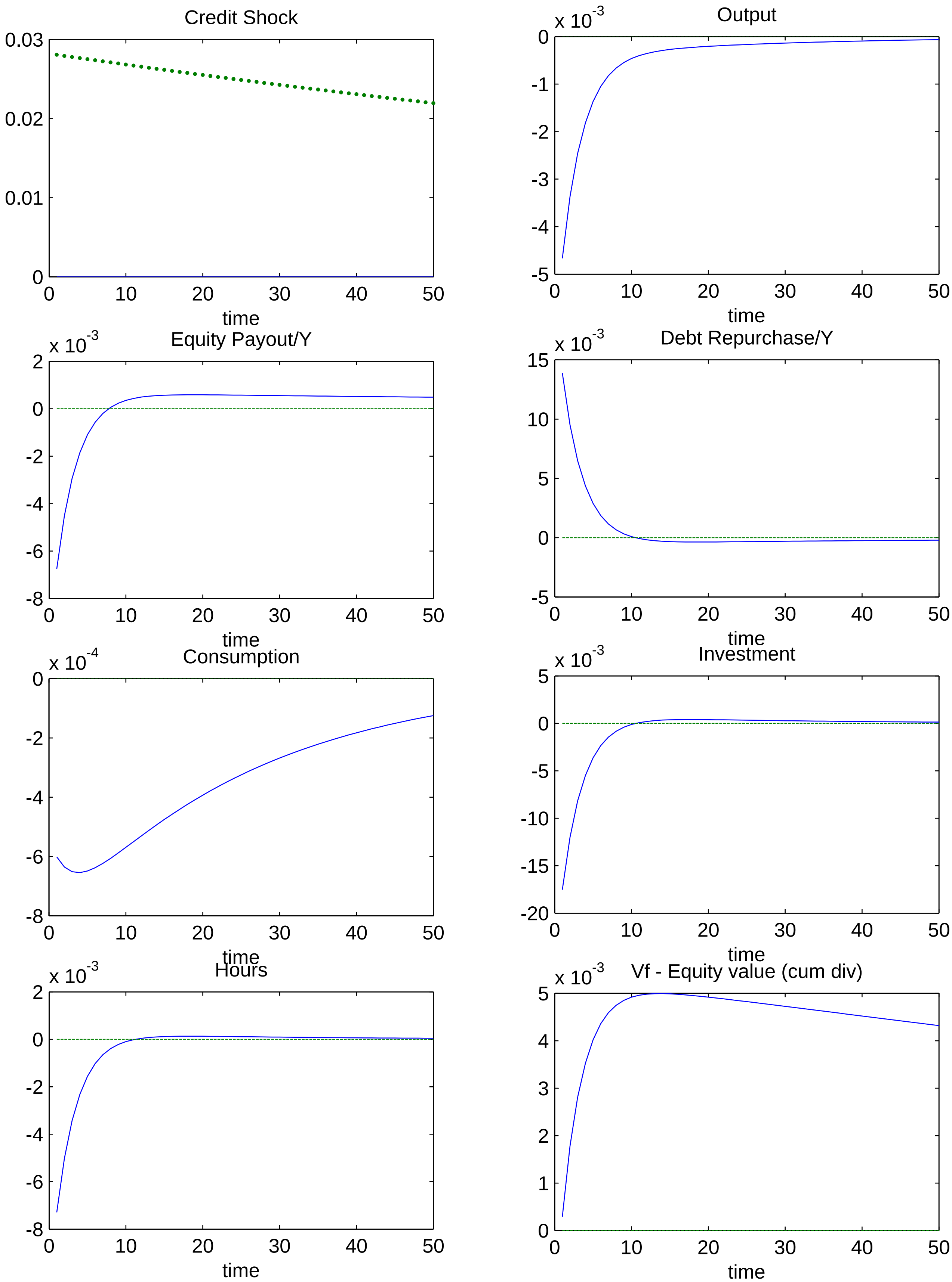

Credit Shock
0.03
0.02
0.01
0
0 10 20 30 40 50
time
Output
x 10^-3
0
-1
-2
-3
-4
-5
0 10 20 30 40 50
time
Equity Payout/Y
x 10^-3
2
0
-2
-4
-6
-8
0 10 20 30 40 50
time
Debt Repurchase/Y
x 10^-3
15
10
5
0
-5
0 10 20 30 40 50
time
Consumption
x 10^-4
0
-2
-4
-6
-8
0 10 20 30 40 50
time
Investment
x 10^-3
5
0
-5
-10
-15
-20
0 10 20 30 40 50
time
Hours
x 10^-3
2
0
-2
-4
-6
-8
0 10 20 30 40 50
time
Vf - Equity value (cum div)
x 10^-3
5
4
3
2
1
0
0 10 20 30 40 50
time

Figure 4: Data (thick line) versus Model with TFP shocks only

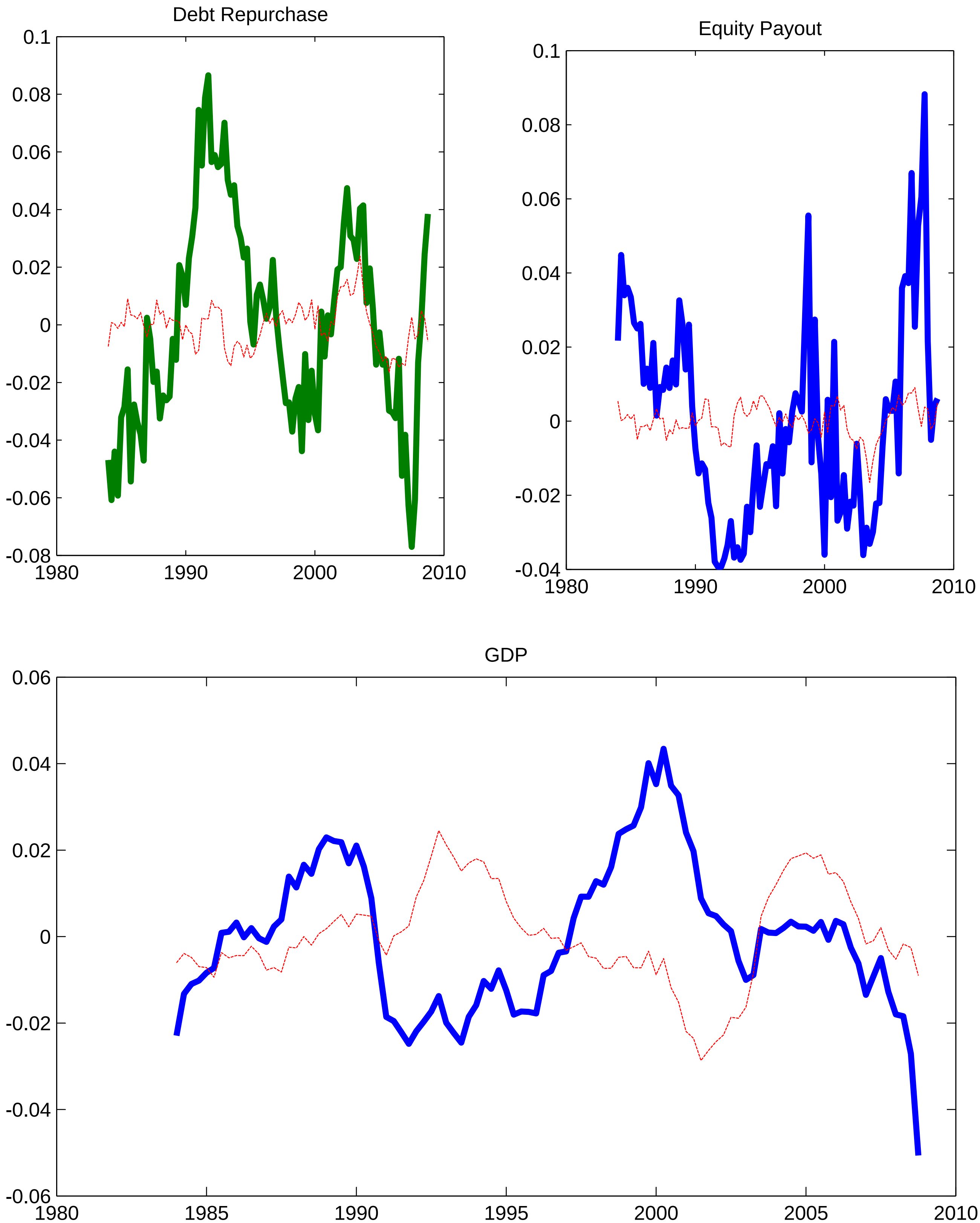


Figure 5: Data (thick line) versus Model

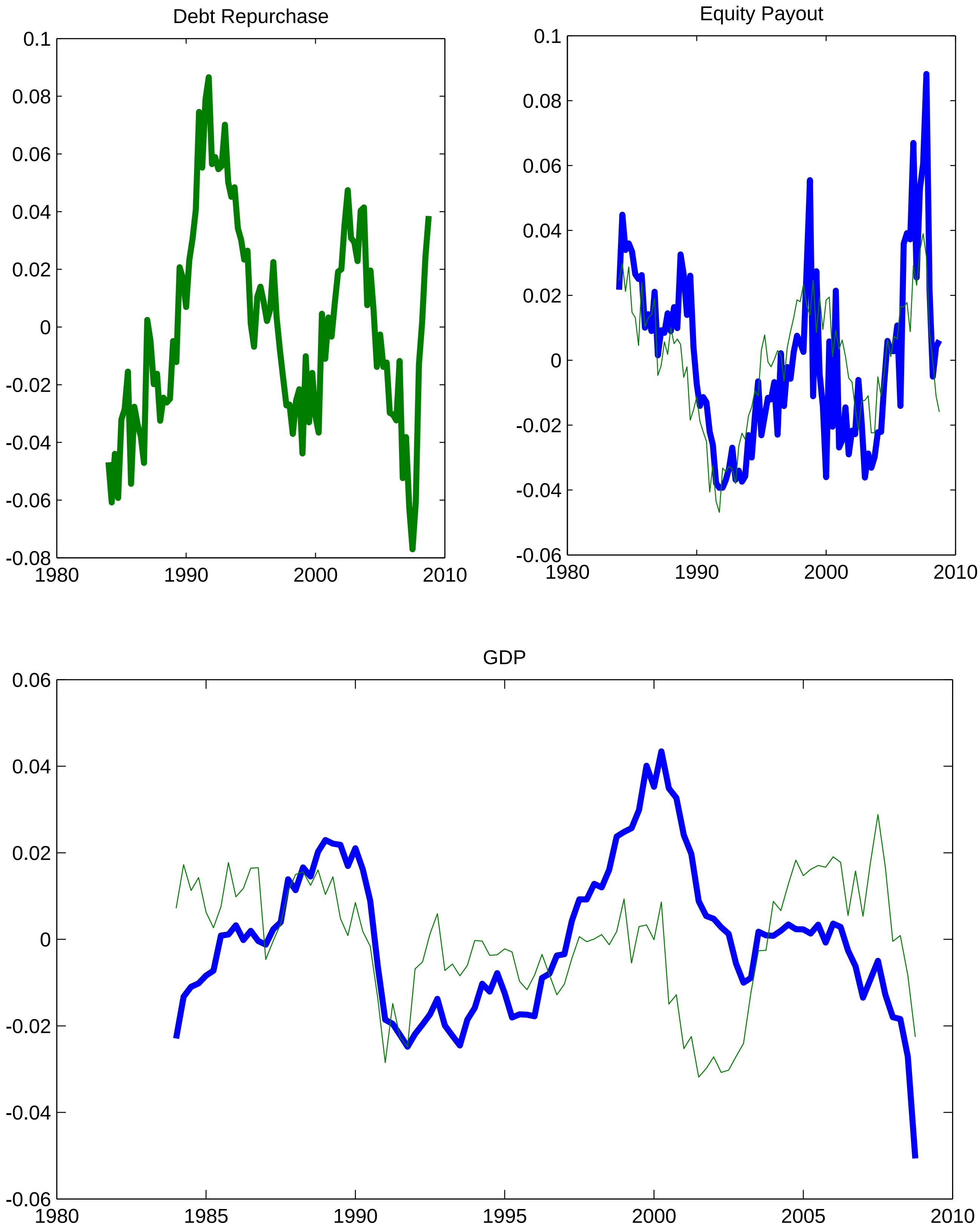
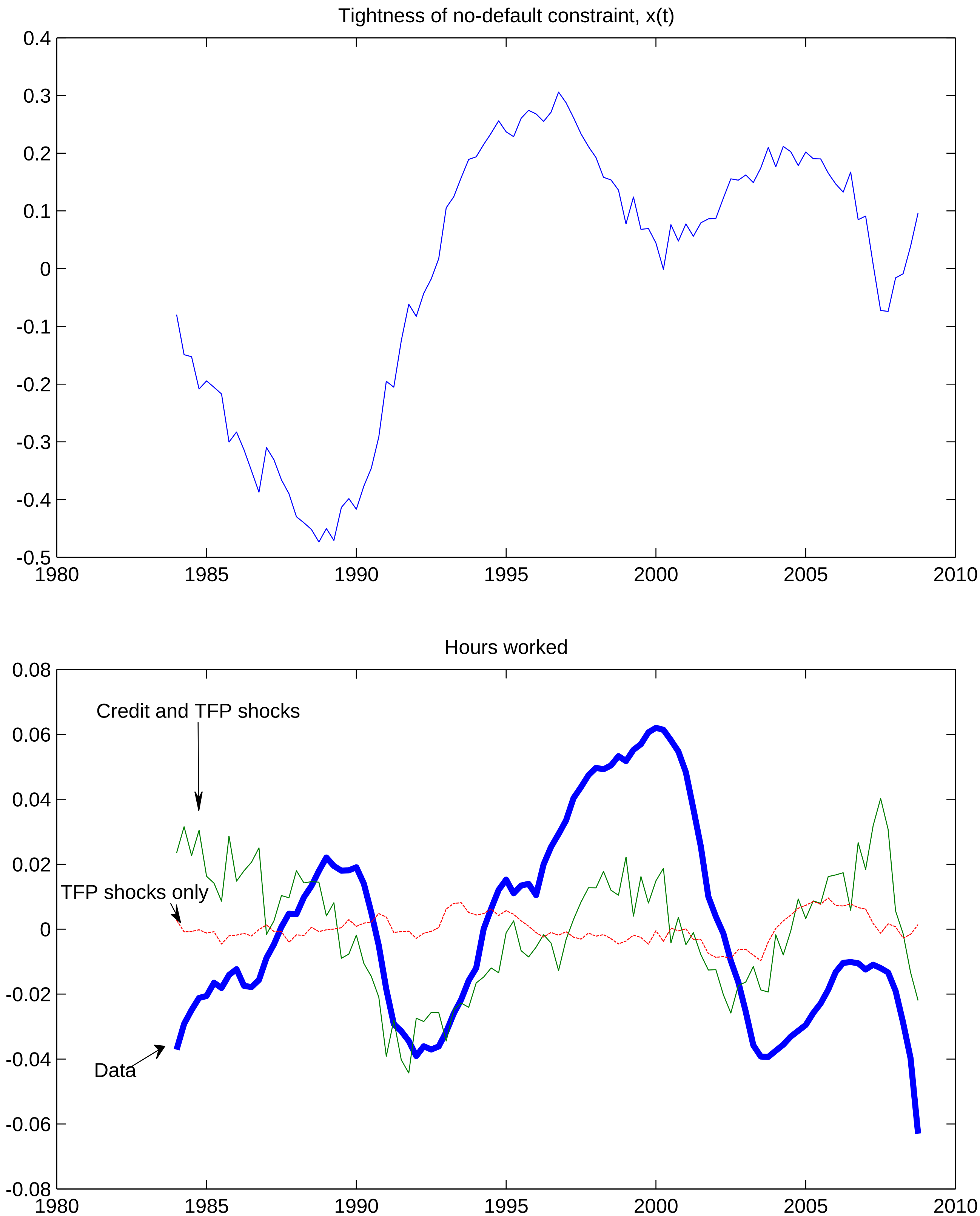
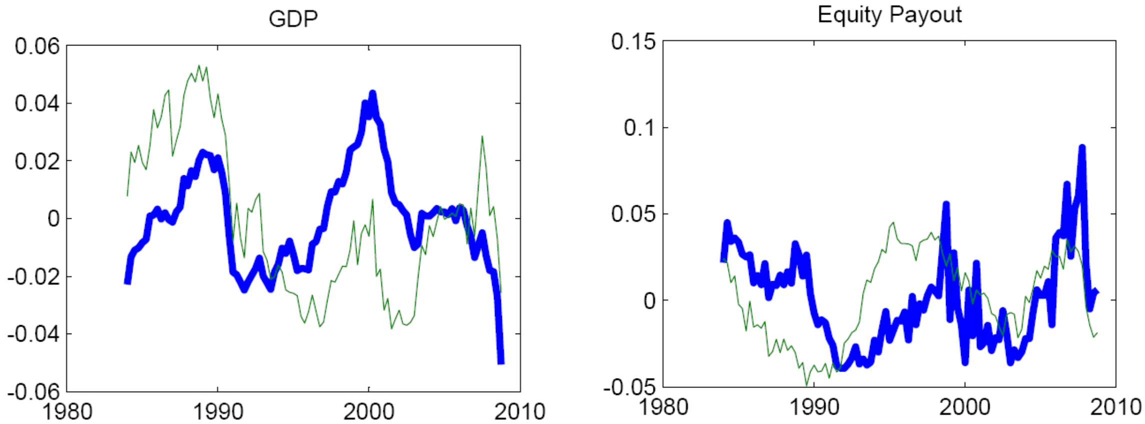


Figure 6

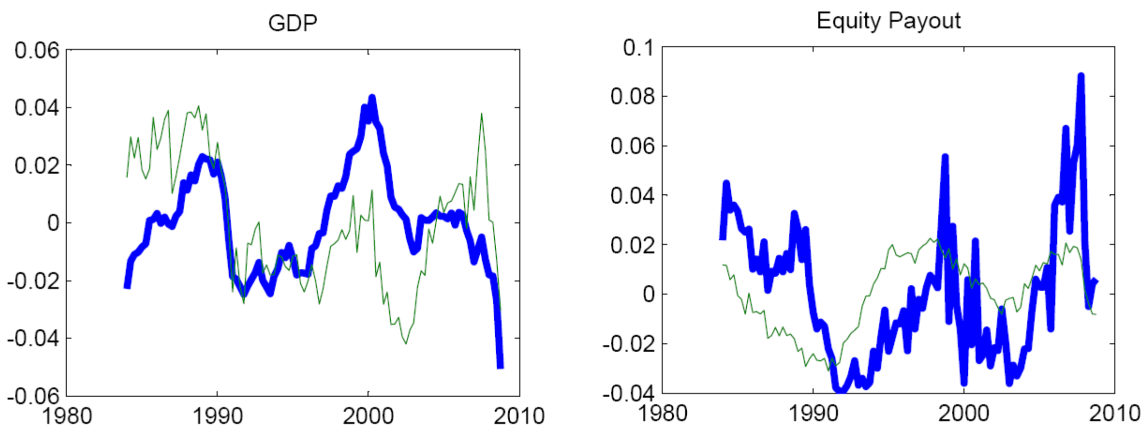


Tightness of no-default constraint, x(t)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1980
1985
1990
1995
2000
2005
2010
Hours worked
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
Credit and TFP shocks
TFP shocks only
Data

Figure 7A: Data (thick line) versus Model, Case 1



Case 2



Case 3

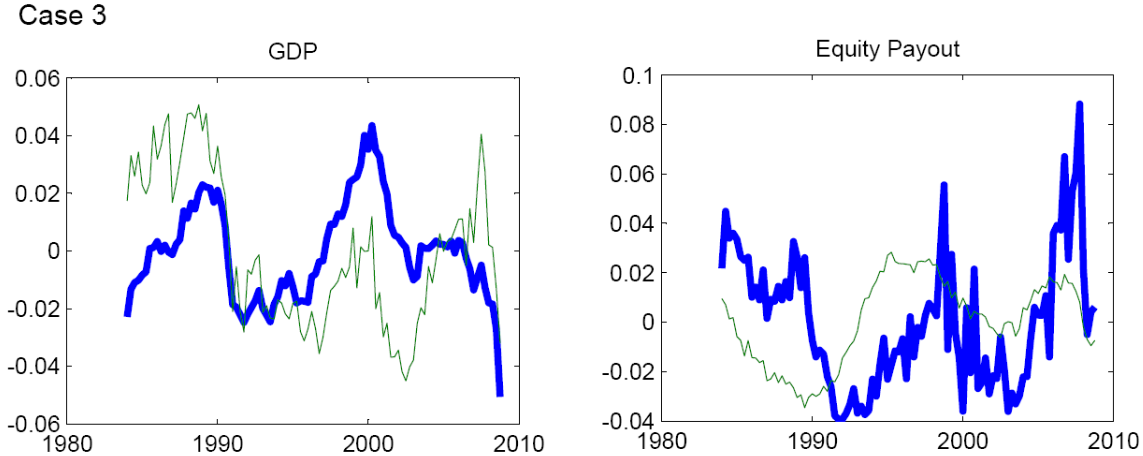
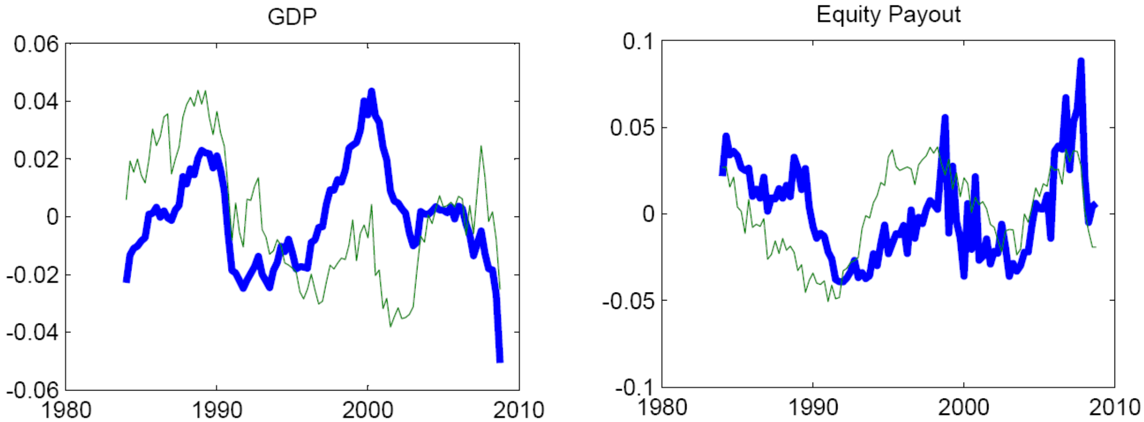
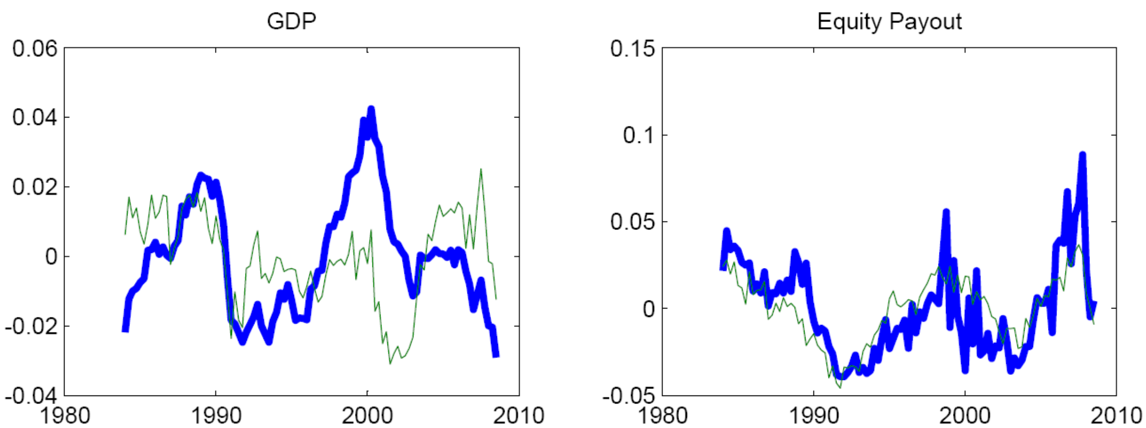


Figure 7B: Case 4



Case 5



Case 6