News shocks, expectation driven business cycles and financial market frictions

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Abstract

This paper explores the booms and busts induced by news shocks in a model economy with financial market frictions. Firms can accumulate capital through either purchase of the existing capital or producing new capital by themselves. Firms need to borrow from financial intermediaries to finance their purchases of capital. With the presence of financial market frictions, firms have to pay an external finance premium which depends inversely on their net values. This provides firms with an incentive to build up capital stocks now to lower the external finance premium in the future. When firms receive news indicating a future technology improvement, they anticipate the need for more capital and so more external finance in the future; they could lower their future external finance costs by building up their capital and net values now. By adding financial market frictions into an otherwise standard RBC model, this paper succeeds in generating a boom when a news shock hits the economy.

1 Introduction

Beaudry and Portier (2004) explore a theory of business cycles (Pigou cycles) in which booms and busts of the economy are caused by agents' expectation of future technology changes. In classical real business cycles models, booms and busts are attributed to the sudden changes of technology levels (technology shocks). Beaudry and Portier introduce a new possible source of business cycles into the literature, stating that fluctuations of the economy may be caused by news shocks: good news about future technology could lead to a boom while an unrealized expectation could generate a bust. Since their seminal paper, interest in news shocks has grown.[1] The challenge faced by all these researchers is that, as shown in Beaudry and Portier (2004), it is difficult to generate a boom of all macroeconomic variables after agents receive news about future technology improvement (Pigou cycles) in classical RBC models. For example, in a classical one-sector RBC model, a news shock always causes consumption and investment to move to the opposite direction.

This paper explores the booms and busts induced by news shocks in a model economy with financial market frictions. In the model economy, firms can accumulate capital either by purchasing existing capital, or by producing new capital themselves, subject to a time-to-build technology constraint as in Prescott and Kydland (1982). Firms need to borrow from financial intermediaries to finance their purchases of capital. With the presence of financial market frictions, firms have to pay an external finance premium which depends inversely on their net values, i.e., firms pay a lower external finance premium when they have higher net values. This provides firms an incentive to build up capital stocks now to lower the external finance premium in the future. When firms receive news indicating a future technology improvement, they anticipate the need for more capital, and therefore more external finance in the future; they can lower their future external finance costs by building up their capital and net values now. By adding financial market frictions into an

[1] For example, Denhaan and Kaltenbrunner (2004), Jaimovich and Rebelo (forthcoming), Christiano, Ilut, Motto, and Rostagno (2008) and Devereux and Engel (2006).

otherwise standard RBC model, this paper succeeds in generating a boom in investment when a news shock hits the economy. However, the boom in the investment comes at the cost of a decrease in the consumption, which is not consistent with the positive comovements among macroeconomic variables observed in the data. This paper further demonstrates that this problem can be solved by incorporating a habit formation in household's preference. The addition of time-to-build has two effects: first, it reduces the volatilities of investment so that the model's simulated moments are more in line with those observed in the data; second, with the time-to-build constraint, the capital price rises sharply when an optimistic expectation drives the demand for existing capital, which leads to a rise in firms' net values, therefore lowering the external finance premium and boosting investment.

The financial market friction is introduced into the model as in Carlstrom and Fuerst (1997) and Bernanke, Gertler, and Gilchrist (1999). A firm combines funds borrowed from bankers and its own net assets to finance capital purchases. There is some friction present in the financial market: the firm's investment return is only observed by itself; and bankers incur a cost to observe it. This asymmetric information creates a moral hazard problem because the firm may misreport the return of the investment. The optimal contract will be constructed in such a way that firms will always report the true return of investment. This financial market friction introduces a wedge between the cost of external funds and the opportunity cost of internal funds, termed "the external finance premium." This premium is an endogenous variable and depends inversely on the net value of firms. Furthermore, firms' net values can be boosted in two ways: firms can increase their net values by producing new capital using their own outputs; or firms' net values could increase due to the capital appreciation. By contrast, Bernanke, Gertler, and Gilchrist (1999) assume that firms cannot produce capital and rely on the capital appreciation to boost their net values. The procyclical behavior in firms' net values in turn implies countercyclical movement in the premium for external funds. This countercyclical movement in the premium serves to amplify investment and hence overall aggregate activity, relative to the case of frictionless financial markets.

The main contribution of this paper is to construct a model which can generate a boom in all macroeconomic variables such as consumption, investment, hours worked and output when a news shock hits the economy. Beaudry and Portier (2004) succeed in generating the positive comovements after a news shock in a two-sector model with durable and non-durable goods. The key assumption they make is that there exists a strong complementarity between the non-durable goods sector and durable goods sector. Denhaan and Kaltenbrunner (2004) argue that models in which expectations induce a boom in both consumption and investment must allow for "idle resources" in the aggregate economy, so that the economy is not at its full capacity when the change in growth expectations occurs. If the amount of "idle resources" can be reduced by an increase in growth expectations, then consumption and investment can increase at the same time. They incorporate labor market matching into their model so that there exists an "idle resource" in the economy: the pool of unemployed. Because the number of vacancies posted by firms depends on firms' expectation about future profits, it follows that whenever profit expectations are suddenly revised upwards, more vacancies are posted, more jobs are generated, and employment rises. This will cause production to increase even though current productivity has remained unchanged. Christiano, Ilut, Motto, and Rostagno (2008) also explore the possibility of generating Pigou cycles in one sector models. They succeed in generating booms of consumption, investment and output by adding investment adjustment costs, variable utilization of capital and habit persistence in preference into a standard one sector model. However, it is not a straightforward matter to get corresponding boom of asset prices in their frameworks. Asset prices slump during the booms when all the other variables rise. To solve this problem, Christiano, Ilut, Motto, and Rostagno (2008) extended their model by adding sticky prices, sticky wages and Taylor-rule monetary policies. The financial market friction introduced in the current paper provides firms with incentives to invest once they expect a technology improvement rather than wait until the realization of the improvement: they can lower their external finance costs in the future by building up their capital stocks now. By contrast, Christiano, Ilut, Motto, and

Rostagno (2008) allow firms to reduce their future investment adjustment costs by increasing current investment levels.

The model in the current paper also succeeds in generating the lead-lag pattern between the external finance premium and output observed in U.S. data. The data show that the external finance premium leads output by three quarters. This lead-lag pattern can only be generated in the model where firms are not capable of producing new capital. In this case, capital appreciation is the only channel through which firms increase their net values and in turn lower their external finance premium. When a news shock hits the economy, agents' expectations of future technology improvement raise demand for new capital. The existing capital becomes more valuable due to the fact that it takes time to build new capital. Since the boom in capital price is caused by the temporary scarcity of the existing capital due to time-to-build, the effect on capital price is the strongest at the moment when the news shock hits the economy. A boom in capital price in turn boosts firms' net values and lowers the external finance premium. Therefore, the slump of the external finance premium leads the boom in output.

The rest of the paper is organized as follows. Section 2 describes the optimal financial contract. Section 3 presents the general equilibrium model with financial market frictions, time-to-build and habit formation. Section 4 describes the calibration. Section 5 evaluates the model by studying the impulse responses and the business cycle moments. The importance of each model feature is analyzed by removing them one a time from the baseline model. Section 6 concludes the paper.

2 The Optimal Financial Contract

This section describes the optimal financial contract problem with the presence of financial market frictions. At the end of period t, fims need to finance the purchase of new capital K_{t+1}, which can be used at period $t+1$. There are two sources of financing: firms' own net worth NV_{t+1} and funds borrowed from financial intermediaries. Given the price of capital Q_t, fims need to borrow $Q_tK_{t+1} - NV_{t+1}$. It is assumed that the return on capital is $\omega R^k_{t+1}Q_tK_{t+1}$, where R^k_{t+1} is the aggregate return on capital and ω is an idiosyncratic shock to the return. The shock ω is assumed to be independent and identically distributed across time and across fims, with a probability density function $f(\omega)$ and a continuous cumulative density function $F(\omega)$. As in Carlstrom and Fuerst (1997) and Bernanke, Gertler, and Gilchrist (1999), the financial market friction is introduced to the model by assuming asymmetric information between firms and financial intermediaries. it is assumed that the idiosyncratic shock ω is private information, which cannot be observed by financial intermediaries unless an auditing cost $\mu\omega R^k_{t+1}Q_tK_{t+1}$ is incurred. To avoid the reputation problem involved in multiperiods contracts, it is assumed that there is enough anonymity in financial markets that only one-period contracts between borrowers and lenders are feasible. Under this circumstance, borrowers have an incentive to misreport their return on capital. To prevent this misreporting, lenders have to audit all the borrowers who default and charge borrowers an interest rate higher than the risk-free rate to cover the audit costs.

The optimal contract is characterized by a threshold value $\overline{\omega}$ such that if $\omega \geq \overline{\omega}$, the borrower pays the lender the fixed amount $\overline{\omega}R^k_{t+1}Q_tK_{t+1}$ and keeps the equity $(\omega - \overline{\omega})R^k_{t+1}Q_tK_{t+1}$. Alternatively, if $\omega < \overline{\omega}$, the borrower cannot pay the contractual return and thus declare default. The lender then audits the borrower who defaults and receives $(1-\mu)\omega R^k_{t+1}Q_tK_{t+1}$, while the borrower is left with nothing.

The value of $\overline{\omega}$ under the optimal contract is determined by the requirement that the lender receive an expected return equal to the opportunity cost of its funds, the risk-free rate R_{t+1}. Accordingly, the loan contract must satisfy

$$[1 - F(\overline{\omega})]\overline{\omega}R^k_{t+1}Q_tK_{t+1} + (1-\mu)\int_0^{\overline{\omega}} \omega R^k_{t+1}Q_tK_{t+1}dF(\omega) = R_{t+1}(Q_tK_{t+1} - NV_{t+1}), \quad (1)$$

where $F(\overline{\omega}) = \int_0^{\overline{\omega}} f(\omega)d\omega$ gives the probability of default. The fist term on the left side of the equation denotes the return from those who do not default and the second term denotes the expected return from those who default. The right side of the equation denotes the lender's opportunity cost of lending.

When the aggregate return on capital R^k_{t+1} fluctuates, the risk-neutral borrower is willing to offer a state-contingent non-default payment that guarantees the lender an expected return equal to the risk-free rate, that is, $\overline{\omega}$ will depend on the realization of R^k_{t+1}. The optimal contracting problem is for the borrower to choose K_{t+1} and $\overline{\omega}$ to maximize the expected return:

$$\int_{\overline{\omega}}^{\infty} \omega R^k_{t+1} Q_t K_{t+1} dF(\omega) - [1 - F(\overline{\omega})]\overline{\omega} R^k_{t+1} Q_t K_{t+1}, \tag{2}$$

subject to the constraint implied by equation Eq. (1).

This optimal contracting problem can be rewritten as:

$$\max_{K_{t+1},\overline{\omega}} (1 - \Gamma(\overline{\omega})) R^k_{t+1} Q_t K_{t+1}, \tag{3}$$

subject to:

$$[\Gamma(\overline{\omega}) - \mu G(\overline{\omega})] R^k_{t+1} Q_t K_{t+1} = R_{t+1}(Q_t K_{t+1} - NV_{t+1}), \tag{4}$$

where $\Gamma(\overline{\omega}) = \int_0^{\overline{\omega}} \omega f(\omega)d\omega + \overline{\omega} \int_{\overline{\omega}}^{\infty} f(\omega)d\omega$ is the lender's expected share of profit; and $\mu G(\overline{\omega}) = \mu \int_0^{\overline{\omega}} \omega f(\omega)d\omega$ is the expected auditing cost. Furthermore, define the external finance premium $s = \frac{R^k_{t+1}}{R_{t+1}}$ and use $k = \frac{Q_t K_{t+1}}{NV_{t+1}}$, the capital/net value ratio as the choice variable. The fist order conditions for the optimal contracting problem may be written as:

$$\overline{\omega}: \quad \Gamma'(\overline{\omega}) - \lambda[\Gamma'(\overline{\omega}) - \mu G'(\overline{\omega})] = 0, \tag{5}$$

$$k: \quad [(1 - \Gamma(\overline{\omega})) + \lambda(\Gamma(\overline{\omega}) - \mu G(\overline{\omega}))]s - \lambda = 0, \tag{6}$$

$$\lambda: \quad (\Gamma(\overline{\omega}) - \mu G(\overline{\omega}))sk - (k - 1) = 0, \tag{7}$$

where λ is the Lagrangian multiplier on the constraint Eq. (4).

From first order condition Eq. (5), λ can be expressed as a function of $\overline{\omega}$,

$$\lambda(\overline{\omega}) = \frac{\Gamma'(\overline{\omega})}{\Gamma'(\overline{\omega}) - \mu G'(\overline{\omega})}, \tag{8}$$

and from the first order condition Eq. (6), the external finance premium s can be expressed as a function of the threshold rate $\overline{\omega}$,

$$s(\overline{\omega}) = \frac{\lambda(\overline{\omega})}{(1 - \Gamma(\overline{\omega})) + \lambda(\overline{\omega})(\Gamma(\overline{\omega}) - \mu G(\overline{\omega}))}, \tag{9}$$

and from the first order condition Eq. (7), the capital/net value ratio k can also be expressed as a function of $\overline{\omega}$,

$$k(\overline{\omega}) = 1 + \frac{\lambda(\overline{\omega})(\Gamma(\overline{\omega}) - \mu G(\overline{\omega}))}{1 - \Gamma(\overline{\omega})}, \tag{10}$$

Bernanke, Gertler, and Gilchrist (1999) prove that $s'(\overline{\omega}) > 0$ and $k'(\overline{\omega}) > 0$ for a certain range of $\overline{\omega}$. Thus, equation Eq. (9) and Eq. (10) together establish the monotonically increasing relationship between the external finance premium s and the borrower's capital/net value ratio k. The underlying intuition is that borrowers with higher net values (lower financial leverage) are less likely to default than those with lower net values (higher financial leverage), therefore, borrowers with higher net values only need to cover a smaller share of the auditing cost, hence pay lower external finance premiums. In the presence of asymmetric information, an optimal financial contract implies that borrower has to pay external finance premium that depends inversely on its net value.

3 The General Equilibrium Model

This section embeds the financial contract problem of Section 2 into general equilibrium models. The baseline model economy is composed of households, firms and financial intermediaries. Firms produce output using labor and capital. Firms can accumulate capital in two ways: they can either use part of their own output to produce new capital subject to a time-to-build technology constraint, or they can increase their capital stock by trading in the market for existing capital. In the latter case, firms need to borrow from the financial intermediaries to finance their capital purchases. Due to the existence of asymmetric information between borrowers and lenders, lenders determine the lending rates based on the financial positions of borrowers. An alternative model is constructed, in which all the model features remain unchanged except one: firms cannot produce their own capital, and they can only accumulate capital by purchasing either the existing capital or purchasing new capital from capital producers. By comparing the impulse responses and business cycle moments in the baseline model and the alternative model, I can explore the pros and cons of these two models, both of which can generate a boom of all macroeconomic variables after agents receive news about future technology improvement (Pigou cycles).

3.1 The Baseline Model

3.1.1 Households

The representative household supplies labor N_t to firms and allocates its income between consumption C_t and savings in financial intermediary D_t. Households' preferences are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\ln(C_t - bC_{t-1}) + \gamma \frac{(1-N_t)^{1-\sigma}}{1-\sigma} \right), \tag{11}$$

where β is the discount factor; σ determines the elasticity of labor supply and γ determines the steady state labor supply. It is assumed that households exhibit internal habit formation, that is, households' preferences depend on their own consumption history. The parameter b measures the strength of habit persistence in consumption preference.

The household budget constraint is given by

$$C_t + D_{t+1} = W_t N_t + R_t D_t, \tag{12}$$

where W_t is the real wage rate, and R_t is the gross real interest rates paid by the financial intermediary.

The household maximizes the utility function Eq. (11) subject to its budget constraint Eq. (12). The first order conditions with respect to consumption, hours worked and savings are:

$$\frac{1}{(C_t - bC_{t-1})} - E_t\left(\frac{b\beta}{C_{t+1} - bC_t}\right) = \lambda_t, \tag{13}$$

$$\lambda_t W_t = \gamma(1 - N_t)^{-\sigma}, \tag{14}$$

$$\lambda_t = \beta E_t(R_{t+1}\lambda_{t+1}), \tag{15}$$

where λ_t is the Lagrangian multiplier associated with the budget constraint Eq. (12). The first term in the first order condition Eq. (13) captures the impact of one extra unit of consumption on current period's utility; the second term in Eq. (13) captures the impact of one extra unit of consumption on the next period's utility. Notice that an increase in current consumption has a negative effect on the next period's utility by raising the criterion by which consumers will judge their preferences. The first order condition Eq. (14) equates the marginal benefits of working an extra hour to the marginal disutility from working an extra hour. First order condition Eq. (15) equates the cost of sacrificing one unit of consumption to the benefit of saving this money in the financial intermediary.

3.1.2 Firms (also capital producers themselves)

Firms produce output according to the production function given by

$$Y_t = A_t N_t^{\alpha} K_t^{1-\alpha}, \tag{16}$$

where A_t is exogenous technology, N_t is the amount of labor used, K_t is the capital stock, and α is the labor's share of the income.

Firms can accumulate capital in two ways: they can either use part of their own output to produce new capital subject to a time-to-build technology constraint or they can purchase existing capital in the market. As in Prescott and Kydland (1982), starting a project at date t requires investment of resources at dates t, $t+1$, ... , $t+J-1$, with the capital finally being ready for use at date $t+J$. Let $s_{j,t}$ denote the number of projects j periods from completion at date t. The laws of motion that describe the evolution of the incomplete projects are given by

$$s_{j-1,t+1} = s_{j,t}, \qquad j = 2, ...J \tag{17}$$

It is assumed that a fixed fraction ϕ_j of resources are expended for a project j periods from completion. The total investment expenditure at date t is given by

$$I_t = \sum_{j=1}^{J} \phi_j s_{j,t}, \tag{18}$$

with $0 \leq \phi_j \leq 1$, and $\sum_{j=1}^{J} \phi_j = 1$.

Alternatively, firms can increase their capital stock by purchasing existing capital in the market. Let K_t^m denote the purchase of existing capital. Assume all the existing capital after the depreciation will be sold in the market; then the law of motion of the capital stock is given by

$$K_{t+1} = K_t^m + s_{1,t}, \tag{19}$$

Firms need to borrow from financial intermediaries to finance capital purchases. At the end of period t, firms purchase existing capital K_t^m in the market at price Q_t. The purchase of the capital is partly financed with firms' net value NV_{t+1} and partly financed by borrowing from the financial intermediary B_{t+1}, that is,

$$Q_t K_t^m = NV_{t+1} + B_{t+1}, \tag{20}$$

The solution to the optimal contracting problem shown in Section 2 demonstrates that the external finance premium is an increasing function of the capital/net value ratio, that is:

$$E_t(R_{t+1}^k) = f\left(\frac{Q_t K_t^m}{NV_{t+1}}\right) E_t(R_{t+1}) = \left(\frac{Q_t K_t^m}{NV_{t+1}}\right)^{\eta} E_t(R_{t+1}), \tag{21}$$

where $E_t(R_{t+1}^k)$ denotes the expected cost of external finance between t and $t+1$; $E_t(R_{t+1})$ denotes the expected risk free rate; $f(.)$ is called the external finance premium, which measures the wedge between the cost of external finance and the risk free rate; Q_t is the price of the existing capital; and NV_{t+1} denotes firms' net value at the end of period t. The borrower's financial position is summarized by its capital/net value ratio. A relative high capital/net value ratio indicates high financial leverage, that is, a low net value relative to the total funds needed to finance the capital purchase. According to the solution to the optimal financial contract, the parameter η, the elasticity of the external finance premium with respect to financial leverage, should be positive.

The firm's objective is to maximize the expected discounted profits

$$\max E_0 \sum_{t=0}^{\infty} \Delta_{0,t} \left[A_t N_t^{\alpha} K_t^{1-\alpha} + Q_t(1-\delta)K_t - E_{t-1}(R_t^k)(Q_{t-1}K_{t-1}^m - NV_t) - \sum_{j=1}^{J} \phi_j s_{j,t} - W_t N_t \right], \tag{22}$$

where $\Delta_{0,t}$ is the stochastic discount factor that represents household's relative valuation of cash across time. $\Delta_{0,t}$ is defined as:

$$\Delta_{0,t} = \beta^t U_1(C_t, N_t) = \Pi_{s=0}^{t}\left(\frac{1}{R_s}\right), \tag{23}$$

where $U_1(C_t, N_t)$ is the marginal utility of consumption. The second equation in Eq. (23) is derived from the household's first order condition Eq. (15).

At each period t, a firm's cash inflow includes the income from the sales of its output and its stock of existing capital after the depreciation. A firm's cash outflow includes the repayment of loan, the expenditure on the capital projects including the project started at the current period and all projects still incomplete, and the wage payment. After substituting K_{t-1}^m with $K_t - s_{1,t-1}$, the firm is assumed to maximize the objective function in Eq. (22) with respect to N_t, $K_{t,}$ $s_{J,t}$ subject to laws of motions described in Eq. (17)). The corresponding first order conditions are:

$$W_t = \alpha A_t N_t^{\alpha-1} K_t^{1-\alpha}, \tag{24}$$

$$E_t(R_{t+1}^k) = E_t\left[\frac{(1-\alpha)(Y_{t+1}/K_{t+1}) + Q_{t+1}(1-\delta)}{Q_t}\right], \tag{25}$$

$$E_t\left(\frac{R_{t+J}^k Q_{t+J-1}}{\Pi_{s=t+1}^{t+J-1} R_s}\right) = \phi_J + E_t\left(\frac{\phi_{J-1}}{\Pi_{s=t+1}^{t+1} R_s}\right) + ... + E_t\left(\frac{\phi_1}{\Pi_{s=t+1}^{t+J-1} R_s}\right), \tag{26}$$

First order condition Eq. (24) equates the real wage rate to the marginal product of labor; Equation Eq. (25) demonstrates that the expected rate of return on capital can be decomposed into two parts: the expected marginal increase in the production of outputs and capital appreciation. Firms will adjust their capital purchases so that the expected rate of return on capital equals the expected marginal cost of finance. In the model without financial market imperfections, the expected real return on capital will be equated to the expected real risk-free interest rate $E_t(R_{t+1})$. Equation Eq. (26) shows that the price of existing capital must adjust so that the firm is indifferent between starting a new capital project by itself and purchasing existing capital in the market. To increase its stock of capital at period $t+J$, the firm can either purchase a unit of existing capital at period $t+J-1$, or start a new capital project at period t. In the latter case, the firm will incur a cost of ϕ_J at current period t, and an expected cost of $E_t(\frac{\phi_{J-1}}{R^k_{t+1}})$ at period $t+1$, and so on. Notice that the left-hand side of equation Eq. (26) is the expected cost of purchasing a unit of existing capital at period $t+J-1$, discounted to the present value; the right-hand side of equation Eq. (26) denotes all the costs incurred by the firm to build up a unit of one-period-to-complete capital project, discounted to the present value. Since both of these options provide the firm with one unit of ready-to-use capital at period $t+J$, the expected costs incurred should be equal to each other.

The profits earned by firms will be accumulated in net values over time. Following Bernanke, Gertler, and Gilchrist (1999), it is assumed that each firm has a constant probability of surviving to the next period. This assumption is intended to preclude the possibility that the entrepreneurs will ultimately accumulate enough wealth to be fully self-financing. Firms that do not survive will consume the residual equity. The evolution of the aggregate net value of firms can be described as:

$$NV_{t+1} = \mu \left[R^k_t Q_{t-1} K_t - E_{t-1}(R^k_t)(Q_{t-1}K^m_{t-1} - NV_t) \right], \tag{27}$$

where μ is the probability of surviving; $R^k_t Q_{t-1} K_t$ is the realized return on capital; $E_{t-1}(R^k_t)$ is the rate of return on capital anticipated in the previous period, which is also the actual external financing cost; and $(Q_{t-1}K^m_{t-1} - NV_t)$ is the funds borrowed from the financial intermediary. Equation Eq. (27) suggests that there exist two sources of changes in firms' net values: the first source is the wedge between the realized and the expected rate of return on capital. When the economy is hit by a positive shock, the realized rate of return on capital is greater than the expected one, which boosts firms' net values. The second source is the wedge between the capital purchased K^m_{t-1} and the total capital used in the production K_t. When firms produce more capital by themselves, this wedge will widen; therefore, firms' net values increase. According to equation Eq. (21), an increase in the net value lowers the producer's external finance premium and in turn spurs borrowing and capital investment. The rise in capital demand fuels the boom of the capital price, which further raises the producer's net value and reduces the external finance premium. This mechanism is called "financial accelerator".

3.1.3 News Shocks

As in Beaudry and Portier (2004) and Christiano, Ilut, Motto, and Rostagno (2008), productivity follows the following process:

$$\log(A_t) = (1-\rho)\log(A) + \rho\log(A_{t-1}) + \psi_{t-p} + \xi_t, \tag{28}$$

where ψ_{t-p} is called news shock, which is a signal received at period $t-p$ indicating a change in the future productivity. A signal received at period $t-p$ will change agents' expectation of future productivity at period t. The term ξ_t is a conventional technology shock. ψ_{t-p} and ξ_t are assumed to be uncorrelated over time and with each other, and normally distributed with standard deviation σ_ψ and σ_ξ.

3.1.4 Equilibrium

An equilibrium for this economy is an allocation $\{C_t, N_t, K_t^m, D_t, s_{J,t}, Y_t\}_{t=0}^{\infty}$ and sequences of prices $\{Q_t, R_t, R_t^k, W_t\}_{t=0}^{\infty}$ that satisfy the following conditions: households satisfy the first order conditions Eq. (13)-Eq. (15), and firms satisfy Eq. (24)-Eq. (26). In the meanwhile, all markets should clear: the goods market is in equilibrium if output equals consumption demand by households and investment expenditures by firms; the labor market is in equilibrium if firms' demand for labor equals labor supply of all households to the market; the financial market is in equilibrium when savings by households are equal to demand for external funds by firms.

Equations A1-A14 in appendix A summarize the equilibrium of the model. The model can be solved by first log-linearizing A1-A14 around steady state and applying a QZ decomposition method.[2]

3.2 The Alternative Model

This subsection presents a variant of the baseline model: keeping the other model features the same, I assume that firms now can only accumulate capital by purchasing it from capital producers.

3.2.1 Firms (purchasing capital from capital producers)

Firms still need to finance their capital purchases by borrowing from financial intermediaries. The financial market frictions still exist so that firms have to pay an external finance premium based on their capital/net value ratios.

The firm's objective is to maximize the expected discounted profits

$$\max E_0 \sum_{t=0}^{\infty} \Delta_{0,t} \left[A_t N_t^{\alpha} K_t^{1-\alpha} + Q_t(1-\delta)K_t - E_{t-1}(R_t^k)(Q_{t-1}K_t - NV_t) - W_t N_t \right], \tag{29}$$

where all the notations are the same as described in previous subsection. The corresponding first order conditions are:

$$W_t = \alpha A_t N_t^{\alpha-1} K_t^{1-\alpha}, \tag{30}$$

$$E_t(R_{t+1}^k) = E_t \left[\frac{(1-\alpha)(Y_{t+1}/K_{t+1}) + Q_{t+1}(1-\delta)}{Q_t} \right], \tag{31}$$

Notice that these two first order conditions are the same as in Eq. (24) and Eq. (25).

Two different assumptions concerning firms' capital accumulation behaviours mainly affect the evolution of firms' net value. When firms are assumed to accumulate capital through trading with each other or purchasing from capital producers, firms' net value evolves as fol-

[2] See Sims(2002) for more discussion of the QZ decomposition.

lows:

$$NV_{t+1} = \mu \left[R_t^k Q_{t-1} K_t - E_{t-1}(R_t^k)(Q_{t-1}K_t - NV_t) \right], \tag{32}$$

Notice that firms choose to purchase K_t units of capital at price Q_{t-1} at period $t-1$. They borrow $(Q_{t-1}K_t - NV_t)$ from financial intermediaries at the cost of paying an interest rate $E_{t-1}(R_t^k)$ depending on their capital/net value ratios. $R_t^k Q_{t-1} K_t$ measures the realized return on capital, where all the capital used in production, K_t , is purchased in the market. By contrast, when firms are assumed to be able to produce capital using their own outputs, firms' net value evolves as follows:

$$NV_{t+1} = \mu \left[R_t^k Q_{t-1} K_t - E_{t-1}(R_t^k)(Q_{t-1}K_{t-1}^m - NV_t) \right], \tag{33}$$

Now, of all the capital used in the production at period t, K_t, only the part K_{t-1}^m needs to be purchased in the market, the rest $(K_t - K_{t-1}^m)$ is produced by the firm itself. The capital produced by the firm itself increases the firm's net value directly. By contrast, when firms are assumed to purchase all the capital in the market, the main source of changes in firms' net value is the wedge between the realized and the expected rate of return on capital.

3.2.2 Capital Producers

Capital producers generate new capital using outputs produced by firms subject to a time-to-build technology constraint as described previously. The capital producer maximizes the following expected discounted profit

$$\max E_0 \sum_{t=0}^{\infty} \Delta_{0,t} \left[Q_t s_{1,t} - \sum_{j=1}^{J} \phi_j s_{j,t} \right], \tag{34}$$

subject to laws of motions described in Eq. (17). The corresponding first order condition is:

$$E_t \left(\frac{Q_{t+J-1}}{\Pi_{s=t+1}^{t+J-1} R_s} \right) = \phi_J + E_t \left(\frac{\phi_{J-1}}{\Pi_{s=t+1}^{t+1} R_s} \right) + ... + E_t \left(\frac{\phi_1}{\Pi_{s=t+1}^{t+J-1} R_s} \right) \tag{35}$$

4 Calibration

The values of parameters are either borrowed from the literature or calibrated to match certain long-run averages observed in the U.S. economy. The discount factor β is set to 0.99 so that the steady-state annualized risk-free rate is about 4%. Following Gomme and Rupert (2007), the parameter determining the labor's share of income α is set to 0.717. The depreciation rate of capital δ is set to 0.025. The parameter σ is set to be 2 so that the elasticity of labor supply is unity. The parameter γ is chosen so that steady-state hours worked account for 1/3 of the disposable time.

As in Prescott and Kydland (1982), assume it takes four quarters to complete an investment project, and each period 1/4 of the total resources are used. Thus $J = 4$ and $\phi_j = 1/4$ for $j = 1, 2, 3, 4$. The parameter b, measuring the strength of habit persistence in preferences, is set to 0.73 as in Boldrin, Christiano, and Fisher (2001).

Following Bernanke, Gertler, and Gilchrist (1999), the steady-state ratio of capital to net value K/NV is set to be 2, which indicates that half of firms' assets are borrowed; the steady-state annual external finance premium is set to be 4%, which approximates the historical average of the high yield spread.[3] The firms' probability of surviving $\mu = 93.12\%$ can be derived from the evolution of firms' net value Eq. (27). The parameter η, the elasticity of external finance premium with respect to the capital/net value ratio is set to 0.05, which is also used in Bernanke, Gertler, and Gilchrist (1999).

The parameter governing the persistence of technology shocks is set to be 0.964 as in Gomme and Rupert (2007). The time lag between the arrival of news on the productivity improvement and the realization of this news is assumed to be 4 quarters, that is, p = 4. In the absence of evidence to guide the choice of the standard deviation of news shocks, it is assumed that news shocks are perfectly informative so that all agents' expectations on future technology improvements are fully realized. In this case, the standard deviation of

[3] The high yield spread is measured as the difference between the high yield bond rate and the corresponding rate for the highest quality bonds.

technology shocks is zero, and the standard deviation of news shocks is exactly equal to the standard deviation of realized technology innovations, which is estimated to be 0.0082 by Gomme and Rupert (2007). Table Table 1 summarizes the calibrated parameters.

5 Findings

5.1 Impulse Responses

In this section, I am interested in studying two problems: first, whether the model can generate a boom of all macroeconomic variables after agents receive news about future technology improvement; and second, whether the model can explain the countercyclical movement and the lead-lag pattern of the external finance premium. I explore the impulse responses of selected variables to news shocks in models with different combinations of model features. Assume that all agents in the economy receive news at period 1 indicating a future technology improvement at period 5. At period 5, the expected technology improvement is realized.

First, I study the scenario in which firms can produce capital by themselves. Figure 1 plots the responses of selected variables to a one standard deviation innovation to the news shock in the model with and without the financial accelerator. In the presence of financial market frictions (as shown in lines with stars), macroeconomic variables such as consumption, investment, output, capital prices and net values all experience a boom after agents receive a signal indicating future improvement of technology; in the meantime, the external finance premium drops.

Beaudry and Portier (2004) demonstrated that it is difficult to generate a boom in both consumption and investment in classical RBC models when agents receive news about future technology improvement. The baseline model in the current paper succeeds in generating the boom by adding financial market frictions, time-to-build and habit formation into an otherwise standard RBC model. It is important to understand the contribution of each of these three features. First, the introduction of time-to-build generates a boom in firms' net values by boosting the capital price when a news shock hits the economy. Intuitively, agents' expectations of future technology improvement raise demand for the new capital. Since it takes time to build new capital, the existing capital becomes more valuable. The underlying mechanism is as follows: according to equation Eq. (27), the expression determining firms' net value, the net value will increase with the widening of the wedge between R_t^k, the realized capital return and $E_{t-1}(R_t^k)$, the external financing cost. Further, based on equation Eq. (25), the expression determining the expected return on capital, the wedge between R_t^k and $E_{t-1}(R_t^k)$ will widen when the capital price rises unexpectedly. According to equation Eq. (26), the expression governing the capital price, the capital price is determined by the expected real interest rates with different terms. Figure 1 shows that the real interest rate experiences a hike every four periods. An increase of real interest rates raises the cost of producing new capital, therefore boosting the price of existing capital. As shown in Figure 1, the capital price shoots up when the news shock hits the economy, then it falls gradually. This pattern will repeat every four periods. When the capital price increases, the firm's net value will be boosted; when the capital price falls, the net value also decreases. According to equation Eq. (21), the expression determining the external finance premium, an increase in firms' net value helps lower the external finance premium, which boosts the investment.

The hikes in real interest rate deserve more discussion. As shown in Figure 2, when habit formation is removed from the model, consumption experiences a jump every four periods after a news shock hits the economy. According to first order conditions determining households' optimal behaviours Eq. (13) and Eq. (15), every jump in consumption leads to a hike in the real interest rate. Further study of Figure 2 shows that the periodical jump in consumption is caused by the periodical start of the new capital project. Since starting a project requires the investment of resources at the next three periods, firms that already have projects under construction do not have extra resources to start another new project.

This explains why hikes emerge in new capital projects every four periods. Furthermore, the periodical start of new capital projects leads to periodical completion of capital projects and periodical increase in capital stock. Every time firms finish their ongoing projects, they will adjust their new capital startups. It is at this time point that consumption and investment jump to new levels.

Figure 1 also demonstrates an upward trend in the firms' net value, besides the fluctuations caused by time-to-build. This can be explained by firms' accumulation of self-owned capital. As shown in equation Eq. (27), the production of self-owned capital can increase firms' productive capital, K_t , without increasing borrowing from financial intermediaries. Thus, firms' production of capital boosts their net value directly. The gradual increase in firms' net value leads to a gradual decrease in the external finance premium. The low external finance premium further boosts investment.

The presence of financial market frictions is the key factor in generating a boom in investment after agents expect a future technology improvement. As shown by the solid lines in Figure 1, the model without financial market frictions (set $\eta = 0$) fails to generate a boom in the investment. In the model without financial market frictions, news about the future technology improvement instantaneously increases consumption and leisure through a wealth effect. Thus, hours worked decreases, as does output. The only way consumption can be increased while hours worked are decreased is by decreasing investment. By contrast, in the model with financial market frictions, firms increase investment since they have incentives to do so: they can build up capital stocks now to lower the external finance premium in the future. When firms receive news indicating a future technology improvement, they expect a future rise in the external finance for capital purchases; they could lower their future external finance costs by building up their own capitals and net values now since the external finance premium depends inversely on the net value. By building up their own capital, they rely less on the purchase of the existing capital and avoid paying relatively high external finance costs. Thus, they can accumulate their net value more quickly. Furthermore, a rise in firms' net value lowers the external finance premium it has to pay and further boosts the investment.

The purpose of adding habit formation into the model is to induce an increase in consumption after a news shock. As shown in Figure 3 which displays the responses of selected variables to a one standard deviation innovation to the news shock in the model with and without habit formations. Without habit formation in preferences, households are willing to lower their current consumption and therefore more resources can be used in investment without a large increase in the hours worked and outputs. By contrast, introduction of habit formation increases households' desire to smooth consumption over time. Since households expect an increase of consumption in the future due to the anticipated technology improvement, they would rather start to increase their consumption gradually once they receive the news indicating the future technology improvement. Since there are incentives to increase both the consumption and the investment, output has to increase, as does the hours worked.

In the baseline model, firms have two channels to boost their net values: capital appreciation and new capital production. Next, I study the alternative model in which firms are not capable of producing new capital, and only purchase capital in the market. Figure 4 plots the responses of selected variables to a one standard deviation innovation to the news shock in the model where firms cannot build capital using their outputs. The solid lines correspond to the baseline parameters, where η, the elasticity of external finance premium with respect to the capital/net value ratio, is set to 0.05. Notice that the model fails to generate a boom in investment when agents receive news about the future technology improvement. Without the capability of producing capital using their own outputs, firms' net value can only be raised through the capital appreciation. Although a time-to-build technology constraint does generate a short period of boom in capital price, it only has a moderate effect on the net value, so the effect on the external finance premium is small. Only when a much greater elasticity of external finance premium with respect to the capital/net value ratio is assumed, can the model generate a low enough external finance premium and provide enough incentives for firms to increase capital purchases. The lines with stars depict the responses in the model where η, the elasticity of external finance premium with respect to the capital/net value ratio, is set to 0.25. Firms have incentives to increase capital purchases before the realization of the expected technology improvement, because they expect that an increase in the capital purchase will cause a boom in capital price due to the time-to-build constraint; a boom in the capital price will further boost firms' net values, and therefore lower the external finance premium. The drop in the external finance premium will in turn stimulate the investment.

It is natural to raise the question: can a model without the time-to-build technology constraint still generate a boom in all macroeconomic variables, especially the investment, when agents receive news indicating future technology improvement? Figure 5 plots the responses of selected variables to a one standard deviation innovation to the news shock in the model where the time-to-build technology constraint is removed. Without the time-to-build constraint, the capital price remains constant. Firms can only boost their net values through building their own capital. As shown by the solid lines in Figure 5, the model without time-to-build fails to generate the boom in investment after agents expect a future technology improvement. Only when the elasticity of the external finance premium with respect to the capital/net value ratio is greater than 0.08, can the model generate a boom in investment. The results in Figure 4 and Figure 5 demonstrate that both firms' capability of building their own capital and time-to-build contribute to the baseline model's success in generating a boom in investment.

5.2 Business Cycle Moments

Table 2-Table 4 display the business cycle moments for U.S. economy, the baseline model and the alternative model respectively. The detailed description of data can be found in Appendix C. All data have been detrended by taking logarithms and Hodrick-Prescott filtering. The simulated moments are averages over 1000 replications of 120 observations (the same number of observations as in U.S. data).

The baseline model's prediction for the volatility of output and the external finance premium is virtually the same as that seen in data. The volatility of consumption is less than that of output; in fact, the model predicts that consumption is too smooth relative to the data. The volatility of investment is greater than that of output, although the model predicts too much volatility in investment. The standard deviation of hours worked is about two thirds of that seen in the data. The baseline model matches the strong positive contemporaneous correlations between output and investment, and between output and hours worked. Furthermore, the model predicts that investment and hours worked are coincident with the cycle. The model predicts a slightly negative contemporaneous correlation between output and external finance premium, which is consistent with that seen in the data. However, the model's predictions are at odds with the data in the following two areas: first, the model predicts that consumption lags output, while they move coincidently in that data. Second, the model predicts that the external finance premium lags the output, while the data indicate that the premium leads the output. This result is consistent with the impulse responses to news shock in the baseline model as shown in Figure 1): when agents receive news indicating future technology improvement, output rises smoothly; four quarters after the news shock, the realization of the technology improvement boosts output to a peak. Meanwhile, the external finance premium spikes down periodically, which can be explained by the periodical completion of new capital projects. In the baseline model where firms are assumed to be capable of producing new capital, firms' net values are boosted each time their new capital projects are completed, which in turn leads to drops in the external finance premium. Notice that the realized technology improvement at period 5 generates a boom in new capital projects, and these new capital projects will be completed at period 9, which leads to a slump of the external finance premium at that moment. This explains why the external finance premium lags output by four quarters in the baseline model.

Table 4 exhibits the business cycle moments for the alternative model in which firms are not capable of producing new capital. The elasticity of external finance premium with respect to the capital/net value ratio, η, is set to 0.25. Compared with the baseline model, the alternative model performs better in matching the volatilities of investment and consumption, but worse in matching the volatilities in output, hours and external finance premium. The alternative model improves a little in matching the coincident movement of consumption: the alternative model predicts that consumption lags the cycle by two quarters, while the baseline model predicts that consumption lags the cycle by five quarters. The most prominent improvement of the alternative model is generating a leading external finance premium. The alternative model predicts that the external finance premium leads the output by four quarters, which is very close to the three quarters leading periods observed in the data. This result is consistent with the impulse responses to news shock in the alternative model as shown in Figure 4: the external finance premium slumps immediately after the news shock hits the economy, and moves back to the steady-state gradually. In the meantime, output reaches a peak four quarters later when the expected technology improvement materializes. In the alternative model where firms cannot produce new capital, capital appreciation is the only channel through which firms increase their net values and in turn lower their external finance premium. Since the boom in capital price is caused by the temporary scarcity of the existing capital due to time-to-build, the effect on capital price is the strongest when the news shock hits the economy. This explains why the external finance premium slumps immediately after the news shock hits the economy.

6 Conclusion

This paper highlights the role that financial market frictions play in the propagation of news shocks. It is difficult to generate a boom driven by agents' expectation of future technology improvement in a standard real business cycle model. Beaudry and Portier (2004) succeed in generating the positive comovements after a news shock in a two-sector model with durable and non-durable goods. The key assumption they make is that there exists a strong complementarity between the non-durable goods sector and the durable goods sector. By adding financial market frictions, habit formation and time-to-build into an otherwise standard RBC model, this paper succeeds in generating a boom when a news shock hits the economy. Due to the presence of financial market frictions, firms' external finance cost depends inversely on their net values. Firms' net values can be boosted through either building up new capital or through appreciation of existing capital. With time-to-build, capital price increases when an optimistic expectation drives the demand for existing capital; firms also have an incentive to build up their capital stocks now to lower the external finance premium in the future. An increase in firms' net values lowers their external finance premium and in turn boosts the investment. The purpose of adding habit formation into the model is to induce an increase in consumption after a news shock.

The data shows that the external finance premium leads output by three quarters. This lead-lag pattern can only be generated in the model where firms are not capable of producing new capital. When a news shock hits the economy, agents' expectations of future technology improvement raise demand for new capital. The existing capital becomes more valuable due to the fact that it takes time to build new capital. Since the boom in capital price is caused by the temporary scarcity of the existing capital due to time-to-build, the effect on capital price is the strongest at the moment when the news shock hits the economy. A boom in capital price in turn boosts firms' net values and lowers the external finance premium. Therefore, the slump of the external finance premium leads the boom in output. By contrast, when firms are capable of producing new capital, their net values will be boosted periodically by the completion of new capital projects. Since the bulk of the new capital projects will be completed after the realization of technology improvement, the peak of firms' net values lags output, therefore the external finance premium also lags output.

The analysis in this paper shows that the effect of financial market frictions depends on whether or not firms have the capability to produce new capital using their own outputs, and on the elasticity of the external finance premium with respect to the capital/net value ratio.

When firms are capable of producing new capital, they can accumulate net values much faster so that a small elasticity of the external finance premium with respect to the capital/net value ratio is enough to generate a boom. By contrast, when firms cannot produce new capital by themselves, they rely on capital appreciation to raise net values. In this case, their net values increase only moderately, so that a much greater elasticity of the external finance premium with respect to the capital/net value ratio is needed to generate a boom. This observation arouses interest in conducting further empirical research on the elasticity of the external finance premium with respect to the capital/net value ratio.

Appendix

A A Summary of All the Equations Describing the Model Equilibrium

(1) Households' decisions

$$\frac{1}{(C_t - bC_{t-1})} - E_t\left(\frac{b\beta}{C_{t+1} - bC_t}\right) = \lambda_t \tag{A1}$$

$$\lambda_t W_t = \gamma(1 - N_t)^{-\sigma} \tag{A2}$$

$$\lambda_t = \beta E_t(R_{t+1}\lambda_{t+1}) \tag{A3}$$

(2) Firms' decisions

$$W_t = \alpha A_t N_t^{\alpha-1} K_t^{1-\alpha} \tag{A4}$$

$$E_t(R_{t+1}^k) = E_t\left[\frac{(1-\alpha)(Y_{t+1}/K_{t+1}) + Q_{t+1}(1-\delta)}{Q_t}\right] \tag{A5}$$

$$E_t\left(\frac{R_{t+J}^k Q_{t+J-1}}{\Pi_{s=t+1}^{t+J-1} R_s^k}\right) = \phi_J + E_t\left(\frac{\phi_{J-1}}{\Pi_{s=t+1}^{t+1} R_s^k}\right) + ... + E_t\left(\frac{\phi_1}{\Pi_{s=t+1}^{t+J-1} R_s^k}\right) \tag{A6}$$

$$E_t(R_{t+1}^k) = \left(\frac{Q_t K_t^m}{NV_{t+1}}\right)^{\eta} E_t(R_{t+1}) \tag{A7}$$

$$NV_{t+1} = \mu\left[R_t^k Q_{t-1} K_t - E_{t-1}(R_t^k)(Q_{t-1}K_{t-1}^m - NV_t)\right] \tag{A8}$$

(3) Productions, resource constraints and capital goods accumulations:

$$Y_t = A_t N_t^{\alpha} K_t^{1-\alpha} \tag{A9}$$

$$Y_t = C_t + I_t \tag{A10}$$

$$K_{t+1} = K_t^m + s_{1,t} \tag{A11}$$

$$I_t = \sum_{j=1}^{J} \phi_j s_{j,t} \tag{A12}$$

$$s_{j-1,t+1} = s_{j,t} \qquad j = 2, ...J \tag{A13}$$

(4) Technology process:

$$\log(A_t) = (1-\rho)\log(A) + \rho\log(A_{t-1}) + \psi_{t-p} + \xi_t \tag{A14}$$

B Data Description

The following U.S. data from 1976:1q to 2006:4q are extracted from DRI Basic Economics (Citibase). The names of the series used here correspond to the names in the database.

GCN: personal consumption of non-durable goods

GCS: personal consumption of service

GCD: personal consumption of durable goods

GPI: gross domestic private investment

GDPQ: gross domestic product

GDP: nominal gross domestic product

P16: population above 16 years old

LBMN: hours of all persons in private business sector

The macroeconomic variables defined in the paper are connected to the above data as follows:

GDP deflator = GDP/GDPQ

Real per capita consumption C_t = (GCN+GCS)/P16/GDP deflator

Real per capita investment I_t = (GCD+GPI)/P16/GDP deflator

Real per capita output Y_t = GDPQ/P16

Per capita hours worked N_t = LBMN/P16

External finance premium is measured by high yield spread. The high yield spread is measured as the difference between the high yield bond rate and the corresponding rate for the highest quality bonds, where the high yield bond rate is measured by Merrill Lynch U.S. High Yield Master II Index and the rate for highest quality bonds is measured by Moody's Seasoned Aaa Corporate Bond Yield.

Table 1: Calibrated values of parameters

Parameter	**Description**	**Calibrated Value**
β	discount factor	0.99
α	labor's share of income	0.717
δ	depreciation rate	0.025
σ	determinant of the elasticity of labor supply	2
γ	leisure weight in the utility	1.128
ϕ_j	percentage of resources used on projects each period	0.25
b	strength of habit persistence	0.73
μ	firms' probability of surviving	0.9312
η	elasticity of external finance premium w.r.t capital/net value ratio	0.05
ρ	persistence of technology shock	0.964
σ_ψ	standard deviation of news shock	0.0082
σ_ξ	standard deviation of technology shock	0.00

Table 2: Business Cycle Moments: U.S. Economy

	Standard Deviation	Cross Correlation of GDP with												
		x_{t-6}	x_{t-5}	x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}	x_{t+5}	x_{t+6}
Gross domestic product	1.43	-0.14	0.00	0.21	0.40	0.64	0.81	**1.00**	0.81	0.64	0.40	0.21	0.00	-0.14
Consumption	0.71	-0.24	-0.18	-0.12	0.02	0.25	0.43	**0.68**	0.64	0.62	0.49	0.35	0.15	0.07
Investment	4.61	-0.08	0.07	0.31	0.49	0.68	0.81	**0.93**	0.70	0.50	0.27	0.10	-0.06	-0.20
Hours worked	1.66	-0.29	-0.13	0.07	0.27	0.47	0.63	**0.80**	0.85	0.81	0.70	0.52	0.34	0.14
External finance premium	0.25	-0.44	-0.54	-0.58	**-0.60**	-0.56	-0.45	**-0.21**	0.04	0.29	0.43	0.59	0.65	0.67

Table 3: Business Cycle Moments: Baseline Model

	Standard Deviation	Cross Correlation of GDP with												
		x_{t-6}	x_{t-5}	x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}	x_{t+5}	x_{t+6}
Gross domestic product	1.40	-0.09	0.03	0.17	0.40	0.58	0.80	**1.00**	0.80	0.58	0.40	0.17	0.03	-0.09
Consumption	0.35	-0.51	-0.46	-0.36	-0.25	-0.12	0.04	**0.20**	0.29	0.36	0.42	0.48	0.49	0.48
Investment	7.56	0.02	0.12	0.26	0.46	0.65	0.83	**0.98**	0.77	0.55	0.33	0.10	-0.05	-0.17
Hours worked	0.97	0.06	0.18	0.36	0.57	0.71	0.82	**0.88**	0.71	0.51	0.27	0.00	-0.10	-0.20
External finance premium	0.23	0.00	-0.04	-0.08	-0.10	-0.14	-0.17	**-0.20**	-0.27	-0.32	-0.37	**-0.40**	-0.38	-0.36

Table 4: Business Cycle Moments: Alternative Model

	Standard Deviation	Cross Correlation of GDP with												
		x_{t-6}	x_{t-5}	x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}	x_{t+5}	x_{t+6}
Gross domestic product	1.20	-0.14	-0.01	0.16	0.40	0.61	0.82	**1.00**	0.82	0.61	0.40	0.16	-0.01	-0.14
Consumption	0.47	-0.52	-0.49	-0.42	-0.25	0.02	0.26	**0.53**	0.65	0.78	0.75	0.72	0.67	0.59
Investment	5.67	0.02	0.16	0.33	0.53	0.70	0.84	**0.95**	0.70	0.43	0.16	-0.10	-0.26	-0.38
Hours worked	0.79	0.18	0.38	0.66	0.72	0.73	0.69	**0.56**	0.35	0.13	-0.12	-0.40	-0.43	-0.45
External finance premium	0.32	-0.49	-0.65	**-0.78**	-0.68	-0.57	-0.45	**-0.26**	-0.07	0.11	0.28	0.35	0.40	0.42

Figure 1: Responses of selected variables to news shocks in the model in which firms can produce capital. The solid lines: the model without financial market frictions; the lines with stars: the model with financial market frictions.

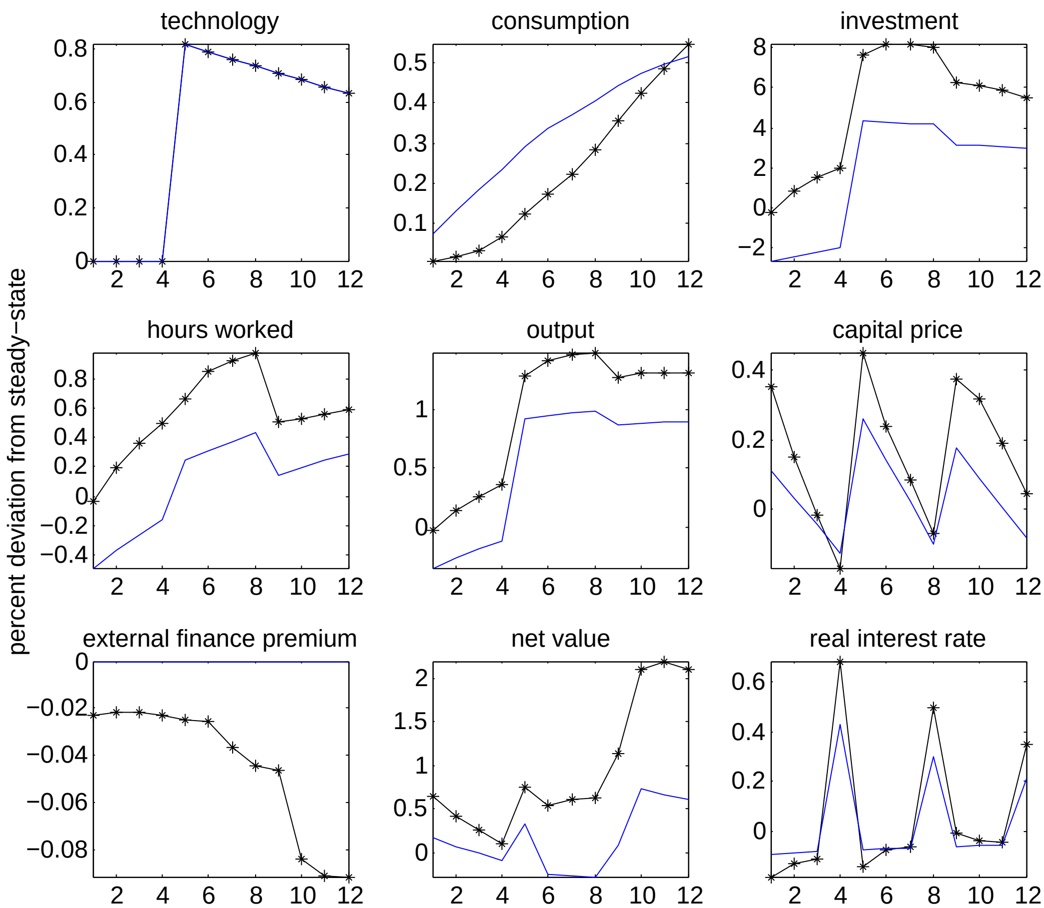


Figure 2: Responses of selected variables to news shocks in the model in which firms can produce capital. The parameter governing the strength of habit persistence, b, is set to zero.

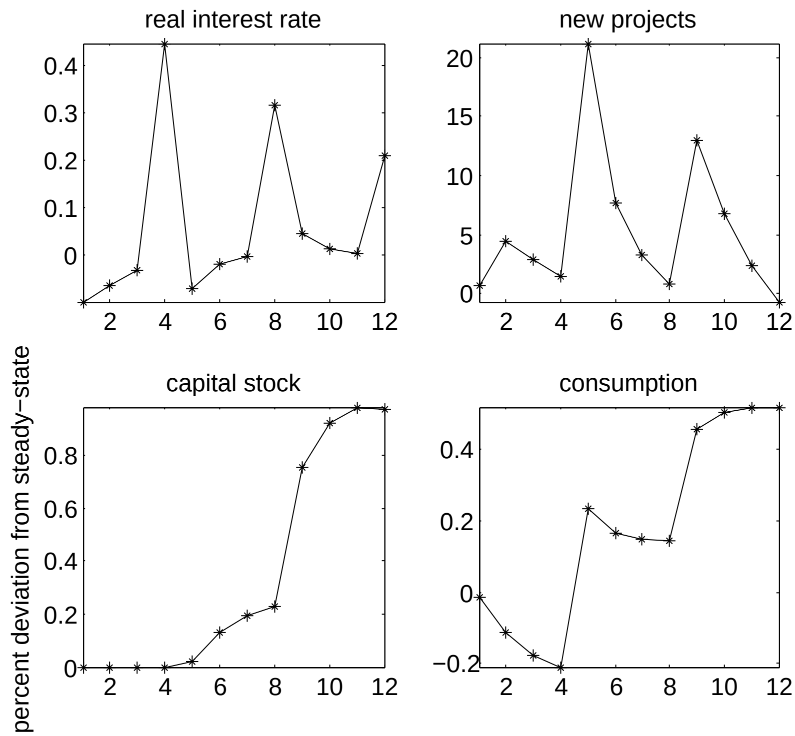


Figure 3: Responses of selected variables to news shocks in the model in which firms can produce capital. The solid lines: without habit formation, $b = 0$; the lines with stars: with habit formation, $b = 0.73$.

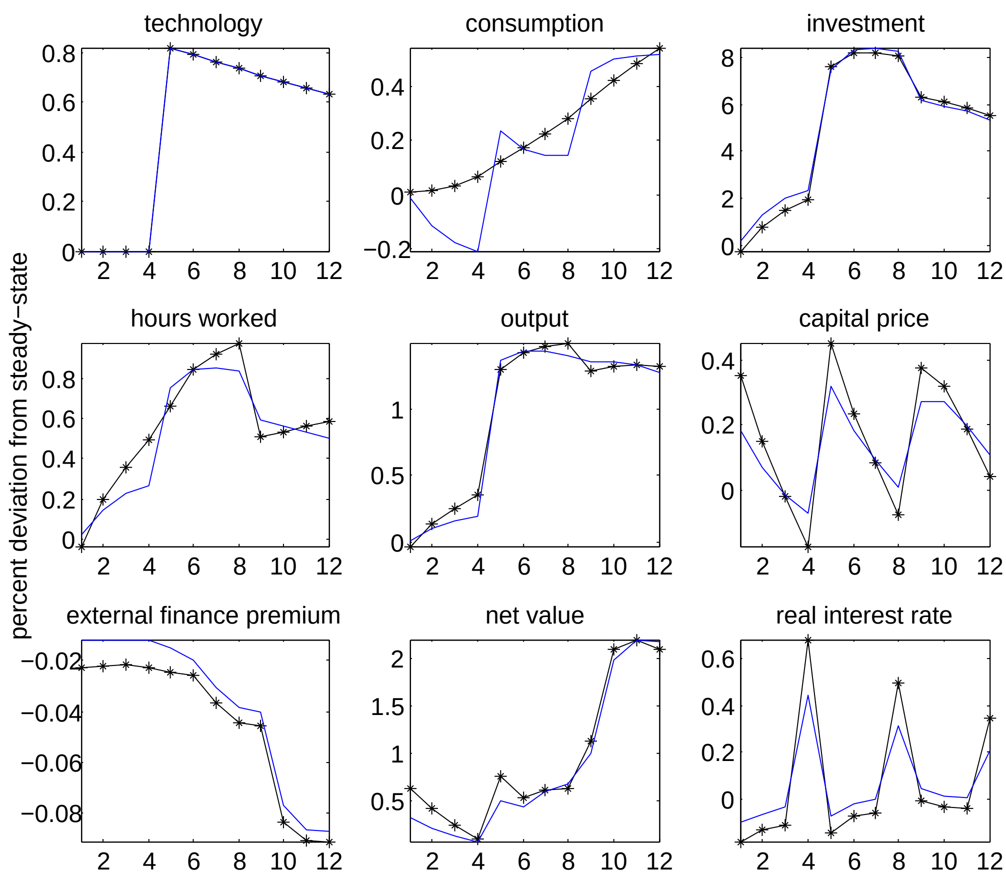


Figure 4: Responses of selected variables to news shocks in the model in which firms can only purchase capital in the market. The solid lines: $\eta = 0.05$;the lines with stars: $\eta = 0.25$.

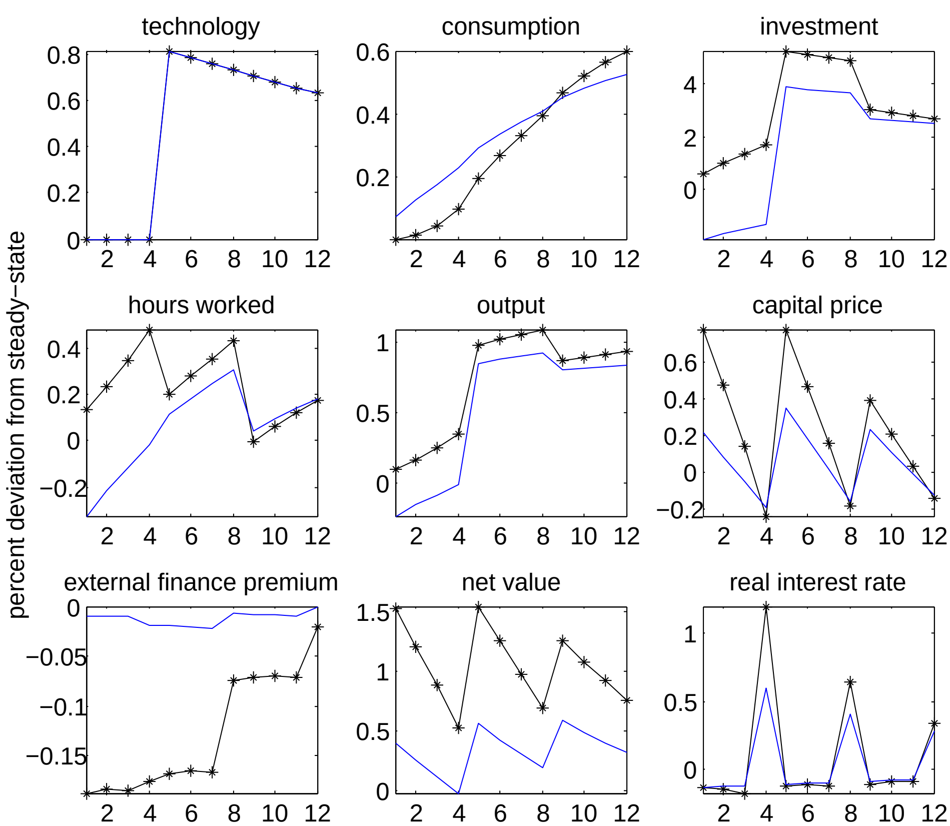
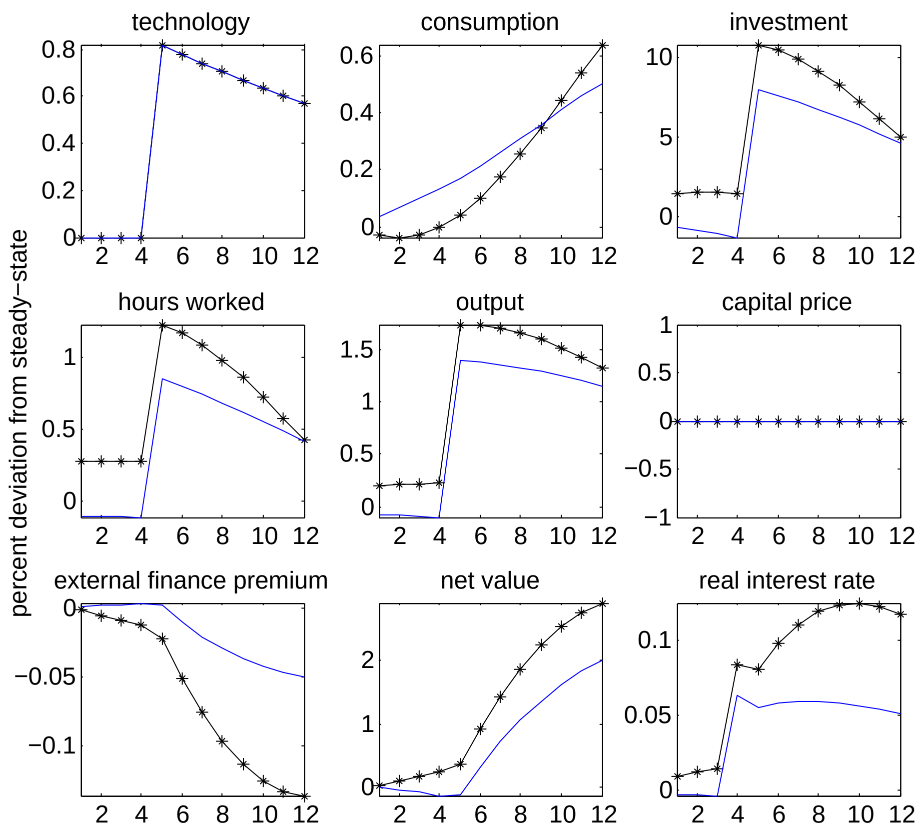


Figure 5: Responses of selected variables to news shocks in the model without the time-to-build technology constraint. The solid lines: $\eta = 0.05$;the lines with stars: $\eta = 0.08$.



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