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Expectation Driven Business Cycles with Limited Enforcement*

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Abstract

We explore the implications of shocks to expected future productivity in a setting with limited enforcement of financial contracts. As in Lorenzoni and Walentin (2007) optimal financial contracts under limited enforcement imply that to obtain external finance firms have to post collateral in terms of liquidation value of the firm. In contrast to earlier real one-sector models, we show that a model with this type of "collateral constraint" generates an increase in stock prices in response to positive news about future productivity, as well as the other properties of an expectation driven business cycle, that is, an increase in consumption, investment and hours. The positive stock price response is in line with Beaudry and Portier's (2006) empirical results and the emerging standard view of expectation driven booms.

Keywords: business cycles, news shocks, limited enforcement, stock prices

JEL codes: E22, E32, E44, E51

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1 Introduction

This paper is part of the growing literature following Beaudry and Portier's (2004) work on expectation driven business cycles. The basic idea is that there is a time lag between a technological innovation and its broad implementation, and thereby its effect on total factor productivity. A time period where this type of shock seems *prima facie* present was the IT boom in the late 1990's, but it has been shown that this shock play an important part for business cycle dynamics also in general (Beaudry and Portier (2006) and Schmitt-Grohe and Uribe (2008)).

We explore the implications of shocks to expectations about future total factor productivity ("news shocks") in a real business cycle model with limited enforcement of financial contracts. With this type of financial friction it turns out that a real one-sector model can generate a positive response of investment, consumption, hours worked and stock prices to shocks to expectations about future TFP. The contrast to the extant literature is the last part - that stock prices increase in response to positive news. This fundamental characteristic of expectation driven booms has not been successfully modelled in a real one-sector model before. Empirically, Beaudry and Portier (2004, 2006) make a strong case that stock prices increase in response to positive news about future TFP.

The present paper shares the focus on stock prices with Christiano, Ilut, Motto and Rostagno's (2008) paper on boom-bust cycles (hereafter CIMR). One important limitation of their real model is that it does not generate a positive response of stock prices to news. CIMR solve this problem by adding a monetary dimension with sticky prices and wages to their model and imposing a Taylor rule for the interest rate. We instead address this issue in a purely real model.

The present paper is also related to work by Jaimovich and Rebelo (2008a, 2008b). They construct real models, in closed and open economies respectively, that generate expectation driven business cycles neatly in one-sector settings, but do not get a positive response of stock prices to news. Another related paper is Chen and Song (2008) who explore capital reallocation in a setting with expectation shocks and a collateral constraint on entrepreneurs' financing.[1]

The model in Beaudry and Portier (2004) generates the same type of comovement between expected future productivity and current stock prices as our model. The main difference is that they use a three sector model with complementarities between capital and the intermediate good, and a shock to the productivity of the intermediate goods sector. Our model, on the other hand, has a simple production structure, but limited enforcement of financial contracts.

The technical contribution to the news shock literature of the present paper is the

[1] There are several recent papers exploring various mechanisms to understand expectation driven business cycles: labor market matching (Den Haan and Kaltenbrunner (2009)), vintage capital (Flodén (2006)), international co-movement in response to news shocks (Beaudry, Dupaigne and Portier (2008)) and collateral constraints for financing wages and intermediate goods (Kobayashi, Nakajima and Inaba (2007)). The empirical relevance of news shocks has been explored through Bayesian estimation by Schmitt-Grohe and Uribe (2008) as well as Fujiwara, Hirose and Shintani (2008).

analysis of limited enforcement. Two key effects of limited enforcement can be distinguished. First, as shown in Lorenzoni and Walentin (2007), limited enforcement causes a time-varying wedge between marginal q and average q, the *price effect*. The wedge reflects the tension between available funds and the future profitability of investment. Accordingly, the wedge will increase with expected future productivity if current funds, and thereby investment, do not increase sufficiently to fully offset the direct effect of the increased future productivity on the return to investment. Second, the *quantity effect* of introducing limited enforcement is that the funds available to a firm, and thereby its investment, become a function of the value of a "collateral" which is the expected discounted next period liquidation value of the firm. This introduces an additional channel through which expectations affect the dynamics. Although the notion of this effect goes back to Minsky and Keynes it has not previously been explored in the recent news shock literature.

We illustrate the above two effects in two model specifications that differ in terms of assumptions on openness and capital adjustment costs. For comparison purposes we let one of these specifications be identical to CIMR (2008). The price effect is present in both of these setups, and is crucial in making stock prices (average q) respond positively to news in our variation of CIMR. On the other hand, the relevance of the quantity effect depends strongly on the assumptions regarding preferences and open vs. closed economy. This is because the pledgeable "collateral" is a function of the discount factor, and a positive quantity effect is therefore only present in settings where the stochastic discount factor does not change too much with expected future TFP, and in this way counteracts the effect from future TFP on expected returns. We show that in such settings, e.g. in our other specification, which is a small open economy, investment adjustment costs are not necessary to generate a boom in investment in response to a news shock. In fact, capital adjustment costs work just as well.

The paper proceeds as follows. In section 2 we set up and solve the model. In section 3 we present impulse response functions and elaborate on the intuition for the key results. Section 4 concludes.

2 The model

There are two types of agents: consumers and entrepreneurs, each of unit mass. There are two goods, a perishable consumption good and physical capital. Transformation between consumption good and capital is subject to adjustment costs.

Markets are complete, but there is limited enforcement of financial contracts. All markets are competitive. The modelling of optimal financial contracts are taken from Lorenzoni and Walentin (2007) and we will therefore be slightly brief in the description of that part of the model. The fundamental difference between the present paper and Lorenzoni and Walentin (2007) is that the earlier paper does not analyze news shocks. Furthermore, the assumptions regarding the household preferences and the labor market are different.

Three key mechanisms from the expectation driven business cycle literature are explored.

Habit formation in consumption is helpful in generating an increase in hours worked in response to positive news. It does this by increasing the marginal utility of consumption during the gradual adjustment to a higher consumption level. Similarly, investment adjustment costs (i.e. as a function of I_t/I_{t-1}), as opposed to capital adjustment costs, create a tendency for investment to respond positively earlier and stronger to news about future productivity. A third element from this literature that we explore is habit formation in labor. We consider this a convenient short-cut to fully specified search and hiring frictions in the labor market. It makes hours worked respond positively to news.

Variable capital utilization has been used in news shock modelling by e.g. Jaimovich and Rebelo (2008a). We choose to not include this mechanism in our model. The reason is that our main interest is in expectation driven booms where the price of capital increases. In that case, the standard variable capacity utilization mechanism - that affects the depreciation rate of capital - will not increase capacity utilization, and thereby output, in the anticipation of a TFP increase. In other words, including this mechanism does not help in generating a news shock.

2.1 Setup

Preferences. The preferences of a consumer is described by

$$\mathbb{E}\left[\sum_{t=0}^{\infty}\beta^t\left(\frac{(c_t-b_c c_{t-1})^{1-\sigma_C}}{1-\sigma_C}-\varphi_L\frac{(l_t-b_l l_{t-1})^{1-\sigma_L}}{1-\sigma_L}\right)\right]$$

Consumers choose consumption c, hours worked l, and save in state contingent assets. b_c and b_l are habit parameters. The consumer's problem is in other words quite standard, and will be treated very briefly. The only slightly novel aspect is that we allow for habit formation in labor, following Schmitt-Grohe and Uribe (2008).

Entrepreneurs have finite lives. Each period a fraction γ of entrepreneurs dies and is replaced by an equal mass of young entrepreneurs. The first period of their life entrepreneurs are endowed with l_E units of labor. This gives new entrepreneurs positive initial wealth.

The preferences of entrepreneur i, born at date t, are described by the utility function

$$\mathbb{E}_t\left[\sum_{j=0}^{J_i}\beta_E^j c_{i,t+j}^E\right],$$

where J_i is the random duration of the entrepreneur's life. Entrepreneurs are more impatient than consumers, $\beta_E < \beta$. This assumption, together with the assumption of a finite life for entrepreneurs, guarantees the existence of a steady state where the borrowing constraint is always binding. We will discuss this assumption further below.

Technology. Each period t entrepreneurs have access to a constant returns to scale technology described by the production function $A_t F(k_{i,t}, l_{i,t}) = A_t k_{i,t}^{\alpha} l_{i,t}^{1-\alpha}$, where $k_{i,t}$ is capital installed in period $t-1$. The aggregate productivity parameter A_t follows

$$\log A_t = a_t = \rho a_{t-1} + \varepsilon_t + \eta_{t-p}$$

where ε_t and η_t are Gaussian i.i.d. shocks. Note that η is a "news" shock - it is known p periods before it affects the productivity. ε denotes the "traditional" contemporaneous innovation to TFP. For convenience, as well as comparability to CIMR, we model TFP as a stationary process. We are further motivated in this choice by the empirical finding that news shocks to the stationary part of TFP are the most important shocks in terms of variance decomposition according to Schmitt-Grohe and Uribe's (2008) estimation results.

Aggregate uncertainty is described by the Markov process s_t in the finite state space $\mathcal{S}$, with transition probability $\pi(s_{t+1}|s_t)$. Individual uncertainty is described by the random variable $\chi_{i,t}$, which is equal to 1 in all the periods when entrepreneur i is active, except in the last period of activity, when $\chi_{i,t} = 0$.

In our baseline model we assume convex capital adjustment costs

$$G(I, K) = \frac{\xi}{2}\left(\frac{I_t - \delta K_t}{K_t}\right)^2 K_t$$

and the law of motion for capital is

$$K_{t+1} = (1-\delta) K_t + I_t.$$

In an alternative setup we study the characteristics of a model with convex investment adjustment costs of the type used by Christiano, Eichenbaum and Evans (2005), where the law of motion for capital is the following.

$$K_{t+1} = (1-\delta) K_t + \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \qquad (1)$$

$$\text{where } S(x) = \frac{g}{2}(x-1)^2 \qquad (2)$$

The timing of events is as follows. At the beginning of period t, production is realized and entrepreneur i learns if period t is his last period of activity. Then, entrepreneurs trade used capital. With this timing assumption entrepreneurs are able to liquidate all their capital on their last period of activity. Furthermore, this assumption also helps in modelling the liquidation proceedings in the event an entrepreneur defaults.

Financial contracts. Consider an entrepreneur born at time t. The entrepreneur finances his current and future investment by selling a long-term financial contract $\mathcal{C}_{i,t}$. The contract specifies a sequence of state-contingent transfers $\{d_{i,\tau}\}_{\tau=t}^{\infty}$,[2] for all the periods in which the entrepreneur is alive. The transfers are contingent both on the history of aggregate shocks and on the idiosyncratic termination shock of entrepreneur i. The choice variable $k_{i,\tau+1}$,

[2]The transfer will typically be negative in the first period (initial investment) and can be positive or negative in the following periods, corresponding to dividend payments minus new investment in the firm.

and the transfer $d_{i,\tau}$, are set after the idiosyncratic termination shock is realized. Let q_t^m denote the price of capital and w_t the wage rate in period t. Feasibility requires that the transfers $\{d_{i,\tau}\}$ satisfy:

$$c_{i,\tau}^E + d_{i,\tau} \leq A_\tau F(k_{i,\tau}, l_{i,\tau}) - w_\tau l_{i,\tau} - q_\tau^m (k_{i,\tau+1} - k_{i,\tau}(1-\delta)), \tag{3}$$

for all the periods where the entrepreneur is active.[3]

Limited enforcement. Financial contracts are subject to limited enforcement. The entrepreneur has full control over the firm's assets. In each period, after production takes place, the entrepreneur can choose to divert part or all of the current profits and the capital stock. In this way he can capture up to a fraction $(1-\theta)$ of the firm's *liquidation value*, $v_{i,t}$, which is equal to current profits plus the resale value of the capital stock:

$$v_{i,t} = A_t F(k_{i,t}, l_{i,t}) - w_t l_{i,t} + q_t^m k_{i,t}(1-\delta).$$

The only recourse outside investors have against such behavior is the liquidation of the firm. Upon liquidation, the investors can recover the remaining fraction θ of the firm's liquidation value. After liquidation the entrepreneur can start anew with initial wealth $(1-\theta)v_{i,t}$. That is, the only punishment for a defaulting entrepreneur is the loss of a fraction θ of the firm's liquidation value.

2.2 Optimal financial contracts

Before turning to the competitive equilibrium, we concentrate on the decision problem of a single entrepreneur. We begin by spelling out some results from consumers' optimization and introducing preliminary definitions that will simplify the analysis. Then we give a recursive characterization of the optimal financial contract and show that, under constant returns to scale and given the notion of limited enforcement introduced above, the optimal financial contract is linear.

2.2.1 Preliminaries

Consumers. We will study equilibria where consumers always have positive consumption, $c_t > 0$. Therefore, the price of a sequence of state-contingent transfers $\{d_{i,t+s}\}_{s=0}^\infty$ is discounted using the consumer's discount factor, $m(X', X)$. This factor is defined by

$$m(X', X) = \beta \frac{\lambda_{C,t+1}}{\lambda_{C,t}}$$

[3] In the first period of activity the constraint is:

$$c_{i,t}^E + d_{i,t} \leq A_t F(k_{i,t}, l_{i,t}) - w_t l_{i,t} - q_\tau^m (k_{i,t+1} - k_{i,t}(1-\delta)) + w_t l_E,$$

with $k_{i,t} = 0$.

where λ_C denotes the marginal utility of consumption and can be written as

$$\lambda_{C,t} = (c_t - b_c c_{t-1})^{-\sigma_c} - b_c \beta E_t (c_{t+1} - b_c c_t)^{-\sigma_c}$$

The consumer's first order condition with respect to labor supply implies:

$$w_t = \frac{\varphi_L (l_t - b_l l_{t-1})^{\sigma_L} - \beta \varphi_L b_l E_t (l_{t+1} - b_l l_t)^{\sigma_L}}{\lambda_{C,t}}$$

Entrepreneurs. An entrepreneur born at date t will choose the financial contract $\mathcal{C}_{i,t}$ to maximize his expected utility subject to feasibility, (3), to the intertemporal budget constraint:

$$\sum_{s=0}^{\infty} \prod_{r=1}^{s} \mathbb{E}_t \left[m(X_{\tau+r}, X_{\tau+r-1}) d_{i,t+s} \right] \geq 0,$$

and to the condition that future promised transfers are credible. The last condition is satisfied if, at each date, the entrepreneur prefers repayment to diversion and default. This condition is stated formally below. For a recursive formulation of the problem it is useful to define the net present market value of the firm's liabilities at date τ:

$$b_{i,\tau} = \sum_{s=0}^{\infty} \left(\mathbb{E}_\tau \left[d_{i\tau} \right] + \prod_{r=1}^{s} \mathbb{E}_\tau \left[m(X_{\tau+r}, X_{\tau+r-1}) d_{i\tau+s} \right] \right).$$

The entrepreneur's problem can be simplified by exploiting the assumption of constant returns to scale. Under constant returns to scale the liquidation value of the firm can be written as:

$$v_{i,t} = R_t k_{i,t} = \max_{l_{i,t}} \left\{ A_t F(k_{i,t}, l_{i,t}) - w_t l_{i,t} + q_t^m k_{i,t} (1 - \delta) \right\},$$

where R_t, the gross return on capital, is taken as given by the single entrepreneur and is a function of the prices w_t and q_t^m. Also, constant returns to scale for adjustment costs, and the presence of a competitive market for used capital, imply that there exists a price of capital, q_t^m, which is taken as given by the single entrepreneur, such that

$$q_t^m = 1 + \xi \frac{I_t - \delta K_t}{K_t}$$

In the setup with investment adjustment costs we instead have:[4]

$$q_t^m = \frac{1 - \beta_E E_t \left[\frac{\phi_{t+1}}{\phi_t} q_{t+1}^m \right] \left[S' \left(\frac{I_{t+1}}{I_t} \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right]}{1 - S\left(\frac{I_t}{I_{t-1}} \right) - S' \left(\frac{I_t}{I_{t-1}} \right) \left(\frac{I_t}{I_{t-1}} \right)}. \tag{4}$$

[4] The derivation of this expression revolves around noting that investment in $t+1$ can be decreased by $S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2$ units with an unchanged capital stock in $t+2$. The expression for q_t^m is identical to its counterpart in CMR except that the discount factor of the entrepreneur, instead of the consumer, is used.

Combining the definitions above, the feasibility constraint (3) can be written as:

$$c_{i,\tau}^E + d_{i,\tau} + q_\tau^m k_{i,\tau+1} \leq v_{i,\tau}. \tag{5}$$

2.3 Recursive characterization of entrepreneur's problem

We study recursive competitive equilibria, where the state of the economy is captured by a vector of aggregate state variables $X_t \in \mathcal{X}$, including the exogenous state s_t, with transition probability $H(X_{t+1}|X_t)$. The vector X_t will be defined and discussed in section 2.4. For now, consider an entrepreneur, who takes as given the law of motion for X_t. The state X_t determines the wage rate, w_t, and the price of capital, q_t^m. Therefore, it also determines the gross rate of return, R_t. Let this dependence be captured by the functions $R(X_t)$ and $q^m(X_t)$.

Now we can use a recursive approach to characterize the optimal financial contract. The individual state variables for the entrepreneur are given by $v_{i,t}$, $b_{i,t}$, and $\chi_{i,t}$. Define $W(v, b; \chi, X)$ as the expected utility, in state X, of an entrepreneur who controls a firm with liquidation value v and outstanding liabilities b.[5] The expected utility W is defined at the time when production has already taken place and the idiosyncratic termination shock has been observed. Also, W is defined after the default decision has taken place, assuming that the entrepreneur does not default in the current period. For now, we will assume that the entrepreneur's problem has a solution in each state $X \in \mathcal{X}$, and the expected utility W is finite. This will be the case in the recursive equilibria we study below.

In all periods prior to the last period of activity, i.e. for $\chi = 1$, W satisfies the Bellman equation:

$$W(v, b; 1, X) = \max_{\substack{c^E, d \\ k', b'(.)}} c^E + \beta_E \mathbb{E}[W(v', b'; \chi', X')|X] \tag{P}$$

$s.t.$

$$c^E + d + q^m(X) k' \leq v, \tag{6}$$

$$b = d + \mathbb{E}[m(X', X) b'(\chi', X')|X], \tag{7}$$

$$v'(X') = R(X') k' \quad \forall X', \tag{8}$$

$$W(v'(X'), b'(\chi', X'); \chi', X') \geq W((1-\theta) v'(X'), 0; \chi', X') \; \forall \chi', X', \tag{9}$$

where the conditional expectation $\mathbb{E}[.|X]$ is computed according to the transition $H(X'|X)$, with χ' independent of X'.

Problem (P) can be interpreted as follows. At each date, an entrepreneur who does not default has to decide how to allocate the firm's resources, v, to its potential uses: payments to insiders, c^E, payment to outsiders, d, or investment in physical capital, $q^m k'$. This is captured by the feasibility constraint (6). Moreover, the entrepreneur has to satisfy the "promise keeping" constraint (7): current and future payments to outsiders have to cover the current liabilities of the firm, b. The current payments are d, the future payments are

[5] For a newborn entrepreneur, v is the entrepreneur's initial labor income, and b is zero.

captured by the market discounted value of the firm's liabilities in the following period, $b'(\chi', X')$. These liabilities are allowed to be contingent on the realization of the idiosyncratic termination shock χ' and of the aggregate state X'. Constraint (8) simply says that the liquidation value of the firm in the next period will be given by the total returns on the firm's installed capital k'. Finally, the no-default constraint (9) ensures that, in all next period states of the world, the future liabilities b' are credible. The no-default constraint take this form, given that the entrepreneur has the option to default and start anew with a fraction $(1-\theta)$ of the firm's liquidation value v' and zero liabilities.

An entrepreneur in his last period of activity will simply liquidate all capital and pay existing liabilities. Therefore, for $\chi = 0$ we have:

$$W(v, b; 0, X) = v - b.$$

As shown in Lorenzoni and Walentin (2007), also for surviving entrepreneurs the value function satisfies

$$W(v, b; \chi, X) = W(v - b, 0; \chi, X) \tag{10}$$

The no-default condition can accordingly be written as

$$b \leq \theta v. \tag{11}$$

Equation (10) allows us to replace constraint (9) with constraint (11). The latter can be interpreted as a "collateral constraint", where the total value of the entrepreneur's liabilities are bounded from above by a fraction θ of the liquidation value of the firm. Using this replacement we note that problem (P) is linear and we obtain the following proposition.

Proposition 1 *The value function $W(.,.;\chi, X)$ is linear in its first two arguments and takes the form:*

$$\begin{aligned} W(v, b; 1, X) &= \phi(X)(v - b), \\ W(v, b; 0, X) &= v - b. \end{aligned}$$

There is an optimal policy for k', c^E, d and b' which is linear in $v - b$.

Entrepreneurial net worth, $n \equiv v - b$, represents the difference between the liquidation value of the firm and the value of the claims issued to outsiders. Proposition 1 shows that the expected utility of the entrepreneur is a linear function of the entrepreneurial net worth. The factor ϕ, which determines the marginal value of the entrepreneurial net worth, depends on current and future prices, and hence it is dependent on X.

The following proposition gives a further characterization of the optimal solution.

Proposition 2 *For a given law of motion $H(X'|X)$, let $\phi(X)$ be defined by the recursion:*

$$\phi(X) = \max\left\{ \frac{\beta_E (1-\theta) \mathbb{E}[(\gamma + (1-\gamma)\phi(X')) R(X') | X]}{q^m(X) - \theta \mathbb{E}[m(X', X) R(X') | X]}, 1 \right\}. \tag{12}$$

Suppose that

$$m\left(X', X\right)\phi\left(X\right) \geq \beta_E \phi\left(X'\right) \tag{13}$$

for all pairs X, X' *such that* $H\left(X'|X\right) > 0$. *Then, the optimal policy for the individual entrepreneur involves: (i)* $k' > 0$, *(ii)* $c^E = 0$ *if* $\phi\left(X\right) > 1$, *and (iii)* $b\left(1, X'\right) = \theta v\left(X'\right)$ *if* $m\left(X', X\right)\phi\left(X\right) > \beta_E \phi\left(X'\right)$.

A central result of this proposition is point (iii), which characterizes the state pairs X, X' where it is optimal to borrow as much as possible against the revenue realized in state X' and use the proceeds to invest today.

2.4 Equilibrium

We are now in a position to define a recursive competitive equilibrium. The aggregate state is given by

$$X = \left(K, B, s\right),$$

where K is the aggregate capital stock and B represents the aggregate liabilities of the entrepreneurs who are not in their last period of activity.[6] Recall that s denotes the aggregate technology.

A recursive competitive equilibrium is given by a transition probability, $H\left(X'|X\right)$, such that the optimal behavior of consumers and entrepreneurs is consistent with this transition probability and the goods market, labor market, and capital market clear. The formal definition is given in the Appendix.

A crucial property of this model is that the entrepreneur's problem is linear, and we obtain optimal policies that are linear in entrepreneurial net worth, $v_{i,t} - b_{i,t}$. Given the linearity of the optimal policies it is straightforward to aggregate the behavior of the entrepreneurial sector. We illustrate the aggregation properties of the model in the case where the collateral constraint is always binding. This is the case where the condition

$$m\left(X', X\right)\phi\left(X\right) > \beta_E \phi\left(X'\right) \tag{14}$$

holds for every pair X, X' such that $H\left(X'|X\right) > 0$. Lorenzoni and Walentin (2007) showed that, in economies with "small" productivity shocks, such an equilibrium exists. This case will be the basis for the numerical analysis in the next section.

Condition (14) implies that, in each state X, the state-contingent liabilities are set to their maximum level for each future value of X', i.e. $b'\left(\chi', X'\right) = \theta v'\left(X'\right)$. Therefore, the optimal level of investment is given by:

$$k' = \frac{1}{q^m\left(X\right) - \theta \mathbb{E}\left[m\left(X', X\right) R\left(X'\right)|X\right]}\left(v - b\right). \tag{15}$$

Consider an economy that enters period t with an aggregate stock of capital K_t, in the hands of old entrepreneurs. The agents who invest in period t are: a mass $(1-\gamma)$ of

[6] In our alternative specification with investment adjustment costs, in addition $lag(K)$ is part of the state. In the specification with habit preferences $lag(C)$ and $lag(L)$ are part of the state vector.

the old entrepreneurs, who have $v_{i,t} = R_t k_{i,t}$ and $b_{i,t} = \theta R_t k_{i,t}$, and a mass γ of newborn entrepreneurs with $v_{i,t} = w_t l_E$. Therefore, the aggregate entrepreneurial net worth of investing entrepreneurs is:

$$N_t = (1-\gamma)(1-\theta) R_t K_t + \gamma w_t l_E.$$

Using the optimal policy (15) and aggregating we obtain:

$$K_{t+1} = \frac{1}{q_t^m - \theta \mathbb{E}_t [m_{t+1} R_{t+1}]} N_t.$$

From these two equations we get the following law of motion for the aggregate capital stock

$$K_{t+1} = \frac{(1-\gamma)(1-\theta) R_t K_t + \gamma w_t l_E}{q_t^m - \theta \mathbb{E}_t [m_{t+1} R_{t+1}]}. \tag{16}$$

The proof of existence of both a deterministic steady state and a recursive competitive equilibrium where the collateral constraint is always binding is given in Lorenzoni and Walentin (2007). The differences in the assumptions on the economic environment made here do not induce any major changes in that proof, so it is left out.

2.5 Asset prices

We are now in a position to define the *financial value* of a representative firm. The value of the firm is simply the sum of all the claims on the firm's future profits, held by insiders and outsiders. This leads us to the following expression for the ex-dividend value of a continuing firm:

$$p_{i,t} = W\left(v_{i,t}, b_{i,t}; \chi_{i,t}, X_t\right) + b_{i,t} - d_{i,t}.$$

Where W corresponds to the net present value of the payments to the insider and $b_{i,t}$ corresponds to the net present value of the payments to outsiders.

Normalizing the financial value of the firm by the total capital invested we obtain our definition of *average q*

$$q_{i,t} \equiv \frac{p_{i,t}}{k_{i,t+1}}.$$

For continuing entrepreneurs, it is possible to show that $q_{i,t}$ is the same for all agents, and we denote it simply by q_t.

Proposition 3 *Average q is greater than or equal to marginal q,* $q_t \geq q_t^m$*, with a strict inequality if the financial constraint is binding.*

Proof. Given that $\phi_t \geq 1$ we have

$$p_{i,t} = \phi_t (v_{i,t} - b_{i,t}) + b_{i,t} - d_{i,t} \geq v_{i,t} - d_{i,t} = q_t^m k_{i,t+1}.$$

■

Notice that, absent financial constraints we have $\phi_t = 1$ and $q_t = q_t^m$. In this case the investment part of the model boils down to the Hayashi (1982) model. On the other hand, in presence of financial frictions there is a wedge between the value of the entrepreneur's claims in case of liquidation $(v_{i,t} - b_{i,t})$ and the value of the claims he holds to future profits. In other words, the fact that $\phi_t > 1$ creates a wedge between q_t^m and q_t.

For later analysis it is convenient to define the net risk-free interest rate r^f, even if contracts in the model are state contingent and have state contingent interest rates. r^f is the inverse of the probability weighted average of the consumer's state contingent discount factor:

$$r^f(X) = \frac{1}{\mathbb{E}[m(X', X)]} - 1$$

Finally, define the external finance premium as

$$f(X) \equiv \frac{\mathbb{E}[m(X', X) R(X')]}{q^m(X)} - 1$$

This reflects the premium that consumers ("outsiders") would be willing to pay to be able to invest directly in the physical capital of firms.

2.6 Goods Market Clearing and Small Open Economy Aspects

One of the specifications we will consider is a small open economy (the closed economy is a simple special case of this). In modelling this we follow Jaimovich and Rebelo (2008b). Allowing for goods trade implies that the goods market clearing condition includes a net export term NX_t:

$$Y_t = C_t + I_t + C_t^E + NX_t$$

We must also keep track of the net foreign asset position F_t :

$$F_{t+1} = (1 + r_t)F_t + NX_t$$

Finally, we assume the following equation relating the interest rate r_t^* that domestic agents face when borrowing abroad to the net foreign asset position F_t of the country:[7]

$$r_t^* = 1/\beta - 1 + \chi\left[\exp\left(\bar{F} - F_t\right) - 1\right]$$

which in steady state implies that $r^* = 1/\beta - 1$. The domestic and foreign interest rates are equalized because of an uncovered interest rate assumption.

3 News Shock Dynamics

3.1 Calibration

We calibrate the model to a quarterly time period. To match an annual risk-free rate of 3% implies $\beta = 0.9925$. To satisfy equation (13) we set $\beta_E < \beta$, more specifically, $\beta_E = 0.99$.

[7] This specification is from Schmitt-Grohe and Uribe (2003).

We let $\alpha = 0.33$, $\delta = 0.0125$ and $\rho = 0.95$ as standard RBC parameter values. We set φ_L to get a steady state value of around $L = 0.30$.[8] As in Lorenzoni and Walentin we let the capital adjustment cost parameter ε equal 8.5. We use $\sigma_C = 1$, i.e. log utility of consumption, as a natural benchmark. Similarly we assume log disutility of labor, $\sigma_L = 1$. For habit formation in consumption we follow CIMR in setting $b_c = 0.63$. For habit in labor we use $b_l = 0.88$.

Regarding the financial side we set $\theta = 0.3$ based on evidence in Fazzari *et al.* (1988) who show that firms finance 30% of their investment using external funds. Matching a 2% annual steady state finance premium, following Bernanke, Gertler and Gilchrist (2000), implies $l_E = 0.05$ and $\gamma = 0.015$.[9]

In the small open economy version we calibrate parameters to get a reasonably stable real interest rate, so as to represent developed economies whose borrowing terms do not change dramatically with their net foreign asset position. In particular we set $\bar{F}$ to get steady state net exports of 2% of GDP and $\chi = 0.001$.

For the alternative setting with investment adjustment costs we follow CIMR and set $g = 15.1$.

3.2 Impulse response functions

3.2.1 The empirical benchmark

Beaudry and Portier (2006) present VAR evidence in terms of impulse response functions to a news shock to the non-stationary level of TFP showing that stock prices, consumption, investment and hours worked respond positively. This evidence is representative of what is becoming the standard view of an expectation driven business cycle. Qualitatively similar results have been found for Germany by Haertel and Lucke (2007) who also show that news shocks Granger cause patents.

Recall that the extant literature, and in particular Jaimovich and Rebelo (2008a, 2008b) and CIMR, have successfully built models that generate positive responses of the macro variables to news shocks about future TFP. The remaining challenge that we focus on below is how to get stock prices, as well as these macro variables, to respond positively to news shock in a real model.

3.2.2 Impulse responses

In the figures below we present impulse responses of the key variables to a positive stationary TFP news shock. We set the number of quarters between the news shock and the actual change in productivity to $p = 4$ quarters.

[8] We vary the value of φ_L between various model specifications to keep L constant.

[9] The model is parametrized so that the labor input of entrepreneurs have negligible impact on aggregate labor supply. It is constant and accounts for one quarter of a percent ($l_E\gamma/\bar{L}$) of the steady state labor supply.

We calculate impulse responses for two different model specifications. The first specification is similar to Jaimovich and Rebelo (2008b) and is an illustration mainly of the quantity effect of limited enforcement. The price effect is also present, but is not crucial for the results in this specification. To understand the quantity effect, note from equation (16) that investment is an increasing function of $\mathbb{E}_t\left[m_{t+1}R_{t+1}\right]$. For a closed economy model with log utility an increase in expected future productivity $\mathbb{E}_t\left[a_{t+p}\right]$ would decrease the discount factor $\mathbb{E}_t\left[m_{t+p}\right]$ more than it would increase the expected return to capital $\mathbb{E}_t\left[R_{t+p}\right]$. To mute the effect of the decrease in the discount factor on investment we use a small open economy setting. To show the strength of the quantity effect we choose to have capital adjustment costs, as opposed to resorting to investment adjustment costs.[10]

Impulse responses for this specification are presented in Figure 1. Note how consumption, investment, hours and stock prices all increase in response to the positive news shock. In addition, even the price of capital, q^m, increases, although stock prices, q, increase more. To understand the price effect, note from Proposition 3 that the wedge between q^m and q is driven by the marginal value of wealth of entrepreneurs, ϕ, which in turn depends on the expected future return on investment (see equation (12)) and therefore increases initially. The increase in both stock prices and capital prices is in complete contrast to extant theoretical work on real one-sector models that deliver investment booms in response to positive news. Finally, note that net exports decrease so that consumption and investment can increase faster than output in anticipation of the increase in TFP.

The main weakness of this specification is that to get hours worked to respond positively to news we need to assume substantial labor rigidities in the form of strong habit formation in labor: $b_l \geq 0.88$ is required to get hours to increase. But the result that investment and stock prices increase in response to news shocks is very general in terms of parameter values.

The second model specification illustrates the price effect. To isolate the effects of limited enforcement we use assumptions that are identical to CIMR: closed economy, investment adjustment costs and habit formation in consumption but not in labor.[11] The impulse responses are presented in Figure 2. The initial increase in consumption, investment and hours are in line with the empirical evidence as well as earlier models, e.g. CIMR. The key difference to the latter is that we get an increase in stock prices at the impact of a positive news shock. The mechanism that generates the stock price increase is the price effect, i.e. the increase in the wedge between the cost of capital q^m and the stock price q. As can be seen in the figure ϕ, which determines the wedge, increases following a positive news shock. On the other hand, the price of capital q^m falls because of the investment adjustment cost specification. The stock price q is affected by both these opposing factors, the price effect dominates, and q therefore increases.

The fact that the law of motion for capital in our model is derived from a financial

[10] It is interesting to note that the same qualitative results (i.e. positive response of key variables to news shocks) go through with investment adjustment costs. Even quantitatively the results are similar.

[11] The qualitative results are unchanged if we allow for habit formation in labor.

constraint makes no qualitative difference for the macro variables compared to CIMR's model. This also means that we get the same problematic size in the interest rate swings as CIMR.

4 Conclusion

In this paper we have analyzed the effects of shocks to expectations about future productivity in a real business cycle model with limited enforcement of financial contracts. We set up a real one-sector model that delivers a positive response of stock prices, as well as the key macro variables, to an expectation shock. This had not been achieved in the extant literature. Furthermore, we showed that this result holds for different assumptions on preferences, capital adjustment costs and open vs. closed economies.

The implications of limited enforcement in the presence of news shock can be considered as two effects. A key insight is that limited enforcement drives a wedge between the price of physical capital and stock prices. This wedge is increasing in the difference between the available funding and the first best capital stock. In general this difference, and therefore also the wedge, increases in response to positive news about future TFP. We call this the price effect. It can generate an increase in stock prices even in model specifications that imply a decrease in the price of capital in response to positive news.

We also explored the importance of the quantity effect, i.e. the additional feedback from expected future productivity to today's investment that limited enforcement implies. Because this effect works through a collateral value, consisting of the expected discounted liquidation value of the firm, it is only present for settings where the stochastic discount factor does not change too much with the growth rate of the TFP. One example of such a setting is a small open economy. In that setup our model generates a positive response of consumption, investment, hours and stock prices to shocks to expected future productivity, even without assuming investment adjustment costs.

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Appendix

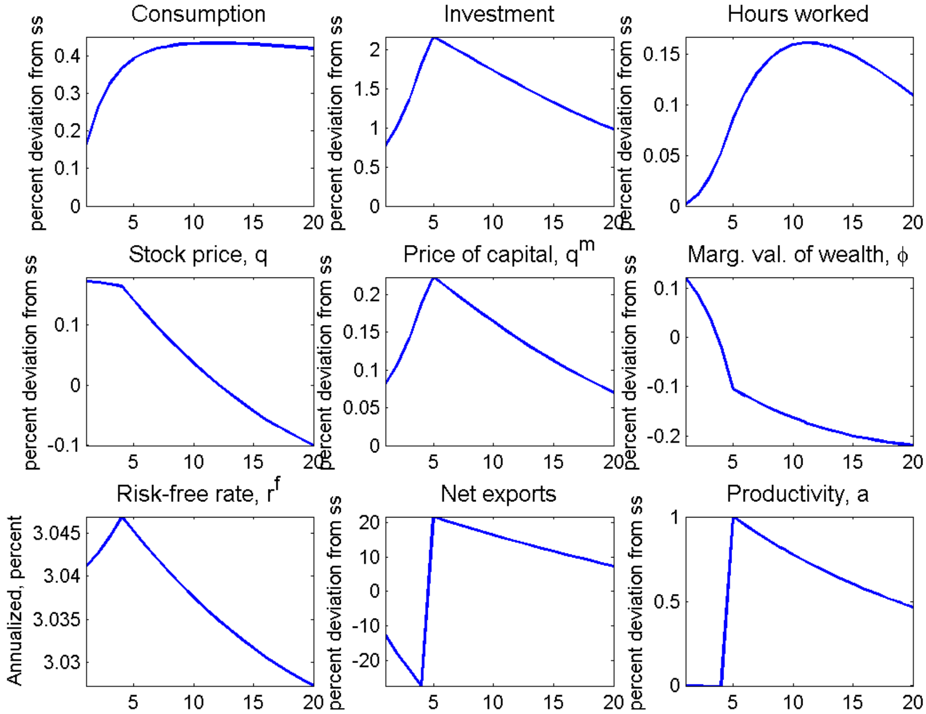

Figure 1. Impulse responses to a η shock to future TFP, $E_t\{a_{t+4}\}$. Small open economy, habit formation in labor, capital adjustment costs.

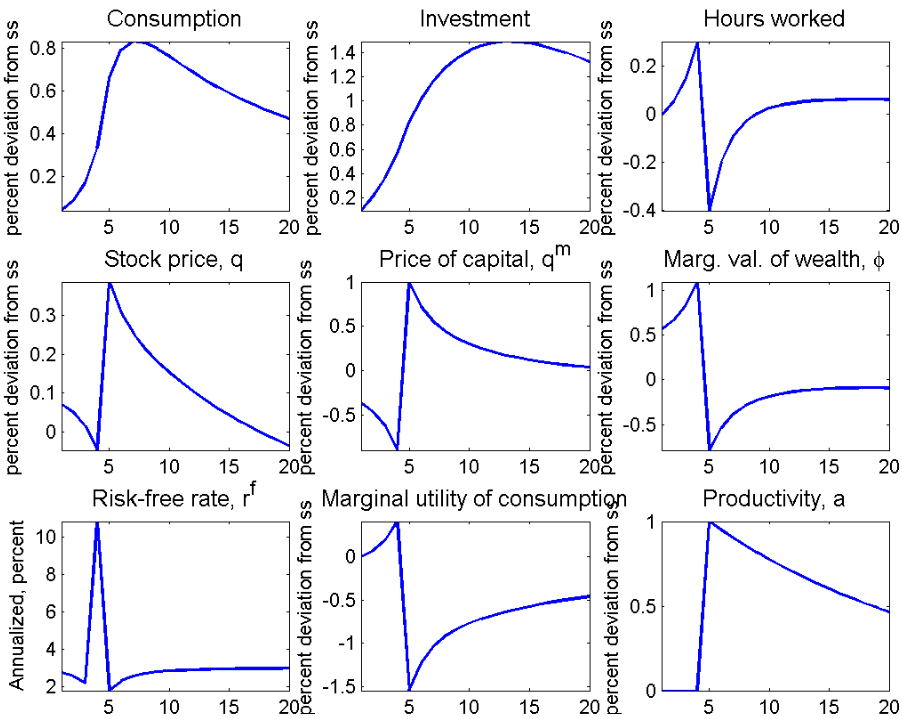

Figure 2. Impulse responses to a η shock to future TFP, $E_t\{a_{t+4}\}$. Investment adjustment costs, closed economy.

Equations determining the equilibrium
Equlibrium capital stock and factor prices

$$
\begin{aligned}
K_{t+1} &= \frac{(1-\gamma)(1-\theta) R_t K_t + \gamma w_t l_E}{q_t^m - \theta E_t [m_{t+1} R_{t+1}]} \\
q_t^m &= 1 + \xi \frac{I_t - \delta K_t}{K_t} \\
R_t &= \alpha A_t K_t^{\alpha-1} L_t^{1-\alpha} + q_t^m (1-\delta) \\
w_t &= (1-\alpha) A_t K_t^{\alpha} L_t^{-\alpha}
\end{aligned}
$$

Financial variables

$$
\begin{aligned}
\phi_t &= \frac{\beta_E (1-\theta) E_t \left[\left(\gamma + (1-\gamma) \phi_{t+1} \right) R_{t+1} \right]}{q_t^m - \theta E_t [m_{t+1} R_{t+1}]} \\
q_t &= \beta_E (1-\theta) E_t \left[\left\{ \gamma + (1-\gamma) \phi_{t+1} \right\} R_{t+1} \right] + \theta E_t [m_{t+1} R_{t+1}] \\
Wedge_t &= q_t - q_t^m
\end{aligned}
$$

Household's marginal utility and the state contingent market discount factor

$$
\begin{aligned}
\lambda_{c,t} &\equiv u'(c_t) = (c_t - b_c c_{t-1})^{-\sigma_c} - b_c \beta E_t (c_{t+1} - b_c c_t)^{-\sigma_c} \\
m_{t+1} &= \beta \frac{u'(c_{t+1})}{u'(c_t)}
\end{aligned}
$$

Labor market clearing

$$
w_t = \frac{\varphi_L (L_t - b_l L_{t-1})^{\sigma_L} - \beta \varphi_L b_l E_t (L_{t+1} - b_l L_t)^{\sigma_L}}{\lambda_{c,t}}
$$

Risk-free interest rate

$$
r_t^f = \frac{1}{E_t m_{t+1}} - 1
$$

Output

$$
Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}
$$

Entrepreneurial consumption

$$
C_t^E = \gamma N_t = \gamma (1-\theta) R_t K_t
$$

Law of motion for capital in setup with capital adjustment costs

$$
K_{t+1} = (1-\delta) K_t + I_t
$$

Goods market clearing:

$$
Y_t = C_t + I_t + C_t^E + NX_t
$$

Net foreign asset position:

$$
F_{t+1} = (1 + r_t) F_t + NX_t
$$

The international interest rate r_t:

$$
r_t = 1/\beta - 1 + \chi \left[\exp\left(\bar{F} - F_t \right) - 1 \right]
$$

Technology

$$a_t = \rho a_{t-1} + \varepsilon_t + \eta_{t-p}$$

Equations that apply for alternative specifications

Investment adjustment costs instead of capital adjustment costs imply:

$$\begin{aligned} K_{t+1} &= (1-\delta) K_t + \left(1 - S\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \\ \text{where } S(x) &= \frac{g}{2}(x-1)^2 \end{aligned}$$

and

$$q_t^m = \frac{1 - \beta_E E_t \left[\frac{\phi_{t+1}}{\phi_t} q_{t+1}^m\right] \left[S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right]}{1 - S\left(\frac{I_t}{I_{t-1}}\right) - S'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right)}$$

Goods market clearing, closed economy

$$Y_t = C_t + I_t + C_t^E$$

Definition of Recursive Competitive Equilibrium

A recursive competitive equilibrium, with linear policies for the entrepreneurs, is given by:

(i) a transition probability $H(X'|X)$, where $X = \{K, lag(K), B, lag(C), lag(L), s\}$;

(ii) pricing functions $R(X), m(X', X), q^m(X), w(X)$;

(iii) policy functions for the entrepreneur $c^E(v, b, \chi, X), k'(v, b, \chi, X), d(v, b, \chi, X)$ and $b'(\chi', X'; v, b, \chi, X)$, that are linear in $v - b$; and[12]

(iv) policy functions for the consumer $c(X)$ and $l(X)$

which satisfy the following conditions:

(a) the policies in (iii) are optimal for problem (P) in section 2.3, given the transition H;

(b) the policies in (iv) are optimal for the consumer's problem outlined in section 2.2.1, given the transition H;

(c) the functions $R(X), m(X', X), q^m(X)$ and $w(X)$ satisfy the following equations (these conditions embed market clearing in the used capital market and in the labor market):

$$
\begin{aligned}
R(X) &= A(s) F_1(K, L) + q^m(X)(1-\delta), \\
m(X'|X) &= \beta \frac{\lambda_c(X')}{\lambda_c(X)} \\
\text{where } \lambda_c(X) &= \left(\frac{1}{C - b * lag(C)} - b\beta E_t \left\{ \frac{1}{C' - bC} \right\} \right) \\
q^m(X) &= \frac{1 - \beta_E E_t \left[\frac{\phi(X')}{\phi(X)} q^m(X') \right] \left[S'\left(\frac{I'}{I}\right) \left(\frac{I'}{I}\right)^2 \right]}{1 - S\left(\frac{I}{lag(I)}\right) - S'\left(\frac{I}{lag(I)}\right)\left(\frac{I}{lag(I)}\right)} \\
\text{where } \phi(X) &= \max\left\{ \frac{\beta_E (1-\theta) \mathbb{E}\left[(\gamma + (1-\gamma)\phi(X')) R(X') | X \right]}{q^m(X) - \theta \mathbb{E}\left[m(X', X) R(X') | X \right]}, 1 \right\} \\
V &= R(X) K, \\
w(X) &= A(s) F_2(K, L);
\end{aligned}
$$

(d) the following inequality is satisfied (this condition ensures market clearing in the consumption goods market, with $c_t > 0$)

$$
\begin{aligned}
& A(s) F(K, L) - S\left(\frac{I}{lag(I)}\right) + \\
- \quad & \gamma c^E(R(X) K, B, 0, X) - (1-\gamma) c^E(R(X) K, B, 1, X) + \\
- \quad & \gamma d(R(X) K, B, 0, X) - (1-\gamma) d(R(X) K, B, 0, X) > 0
\end{aligned}
$$

(e) the transition for s' is consistent with $\pi(s'|s)$; the transition probabilities for K' and B' are consistent with the following:

$$
\begin{aligned}
K' &= k'(R(X) K, B, 1, X) \text{ with probability } 1, \\
B' &= (1-\gamma) b'(1, \{K', B', s'\}; V, B, 1, X) - \gamma w(X) l_E \text{ with probability } \pi(s'|s).
\end{aligned}
$$

[12] The first two arguments of the b' function reflect the state contingent nature of the optimal contract chosen in state (v, b, χ, X).

The restriction to policy functions that are linear in $v - b$ is justified, given Proposition 1.

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