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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, firms have to post collateral to obtain external finance. In a real one-sector model with this type of "collateral constraint", positive news about future productivity implies an increase in stock prices and a relaxation of financing constraints that yield a general economic expansion, i.e. an expectation-driven business cycle. Furthermore, these properties are obtained with standard consumption preferences and capital adjustment costs.

Keywords: news shocks, limited enforcement, collateral constraints, stock prices

JEL codes: E22, E32, E44, E52

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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. Their 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. Beaudry and Portier (2006) used a structural VAR approach to document that this type of shock also plays an important role for business cycle dynamics in general.[1] In the same exercise they showed that news shocks about future TFP generate a positive response of investment, consumption, hours worked, and stock prices.

We explore the implications of shocks to expected future total factor productivity (TFP), "news shocks", in a real business cycle model with limited enforcement of financial contracts. With this type of financial friction, a real one-sector model with standard consumption preferences generates a positive response of investment, consumption, hours worked, and stock prices to shocks to expectations about future TFP. The key difference compared to the previous literature is the last part - that stock prices *increase* in response to positive news. This fundamental characteristic of expectation-driven booms has not previously been successfully modelled in a real one-sector model with two input factors. Empirically, Beaudry and Portier (2004, 2006)

[1] A number of empirical approaches have been used to explore the empirical relevance of news shocks, complementing the results in Beaudry and Portier (2006). Schmitt-Grohe and Uribe (2012) and Fujiwara, Hirose and Shintani (2011) employ Bayesian DSGE estimation to investigate the issue. Both of these papers find that news shock to TFP matter, but to a limited extent. Using survey-based measures of expected future economic activity in a VAR, Leduc and Sill (2012) find substantial and positive effects of shocks to these measures for current economic activity and stock prices. Alexopoulos (2011) provide evidence of the importance of news shocks from a book publications in the field of technology. Comin, Gertler and Santacreu (2009) build a model that emphasize the endogenous decision to implement new technology. Their estimation results indicate that shocks to the expected future technology frontier account for a third of the variation in GDP.

make a strong case that stock prices increase in response to positive news about future TFP, and this characteristic has proven robust to various alternative identification approaches (Barsky and Sims, 2011, and Forni, Gambetti and Sala, 2011). A second important difference compared to the previous literature is that our model generates this positive response of macroeconomic quantities to news shocks without having to assume investment adjustment costs or non-standard consumption preferences.

The technical contribution to the news shock literature of the present paper is the analysis of limited enforcement of financial contracts. Our modelling of optimal financial contracts in this setting builds closely on Lorenzoni and Walentin (2007). Two effects of introducing limited enforcement can be distinguished.

First, the *quantity effect* of limited enforcement is that the funds available to a firm, and thereby its investment, become a function of the value of a "collateral" which in turn depends on the liquidation value of the firm. This introduces a financial channel through which expectations affect the dynamics - more positive expectations in effect expand the current investment opportunities and the next period production capacity. Although the notion of this effect goes back to Minsky and Keynes it has not previously been explored in the recent news shock literature. The quantity effect is not specific to the details of our limited enforcement modelling, but is instead present in a variety of models with financial frictions. In particular, it is present in models where the value of the "collateral" (credit spread) is positively (negatively) affected by future profits, e.g. in Albuquerque and Hopenhayn (2004) and Bernanke, Gertler and Gilchrist (1999).[2]

Second, 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. In a setting with approximately inelastic

[2] Although generally the case, this condition does not hold universally. E.g. it does not necessarily hold in settings where default leads to exclusion from markets as in Ábrahám and Cárceles-Poveda (2006).

labor supply there are decreasing returns to capital. The wedge will then 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.

We illustrate the above two effects in two model specifications that differ in terms of assumptions regarding openness to trade, capital adjustment costs and preferences. To facilitate comparison to previous work, we let our main specification be similar to Jaimovich and Rebelo (2008) and the alternative specification be similar to Christiano, Ilut, Motto and Rostagno (2008; CIMR), except for the presence of limited enforcement. In both of these model specifications the addition of limited enforcement implies that stock prices respond positively to news shocks.

The present paper shares the focus on stock prices with 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. We thereby provide an alternative to the claim by CIMR that it is inappropriate monetary policy that causes the boom-bust pattern in response to news shocks. This difference in results has important policy implications.

Our work is also related to Jaimovich and Rebelo (2008, 2009; JR). Those two papers contain real models, in open and closed economy set-ups respectively, that generate expectation-driven business cycles in one-sector settings, except that they do not get a positive response of stock prices to news. In contrast to our model, they need non-standard preferences, a variation on the specification in Greenwood, Hercowitz and Huffman (1988; GHH), that imply small short-run wealth effects on labor supply, to get a positive response of hours worked.

There are two papers that share our focus on news shocks and constraints on entrepreneurs' financing. Kobayashi, Nakajima and Inaba (2011) set up a model with collateral constraints for intra-period financing of four different input factors. They allow for all inputs to be rented on a spot market, although payment is required in advance. There are two important differences in terms of implications compared to the present paper: i) In their full model, consumption decreases in the periods leading up to the realization of the anticipated TFP increase, in contrast to Beaudry and Portier's (2006) empirical results. ii) Entrepreneurs reduce their holding of the collateral in response to good news. Chen and Song (2012) instead explores capital reallocation in a setting with news shocks and constraints on entrepreneurs' financing.

Finally, Jermann and Quadrini (2007) is in the same limited enforcement spirit as the present paper, but in a regime-switching model where capital reallocation plays an important part. A survey of the news shock literature is provided in Lorenzoni (2011).[3]

The paper proceeds as follows. In section 2, we set up and solve the model. In section 3, we present impulse response functions and provide intuition for the main results. Section 4 shows robustness of the results to alternative calibrations and an alternative specification. Section 5 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. All markets are competitive.

Financial markets are complete, but there is limited enforcement of financial con-

[3] There are several recent papers exploring various mechanisms to understand expectation-driven business cycles. Some examples are: labor market matching (Den Haan and Kaltenbrunner, 2009), vintage capital (Flodén, 2006), international comovement in response to news shocks (Beaudry, Dupaigne and Portier, 2011).

tracts. The modelling of optimal financial contracts follows Lorenzoni and Walentin (2007). The key difference between the present paper and Lorenzoni and Walentin (2007) is that the latter paper does not analyze news shocks. Furthermore, the assumptions regarding household preferences and the labor market are different. In particular, we assume habit formation in labor supply as argued for both theoretically and empirically by Bower (1991). We mainly consider this a convenient short-cut to a fully specified search and matching model of the labor market. It makes hours worked respond positively to news and is similar to the labor adjustment costs that are used in Jaimovich and Rebelo (2008, 2009).

Let us briefly mention some mechanisms that have been used in the news shock literature, but that we do not need. Variable capital utilization has been assumed by e.g. Jaimovich and Rebelo (2009). We do 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 driven expansion. We do not assume habit formation in consumption (as CIMR), nor do we assume GHH/JR preferences that imply low wealth effects on labor supply, as Jaimovich and Rebelo (2008, 2009). GHH/JR preferences would strengthen the response of hours worked to news also in our model, but is not needed to induce comovement.

2.1 Setup

Preferences. The preferences of a consumer is described by

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

Consumers choose consumption c, hours worked l, and save in state contingent assets. σ_C denotes the inverse intertemporal elasticity of substitution, b_L denotes the degree of habit formation for labor, σ_L is the inverse Frisch elasticity and φ_L is a scaling parameter for labor supply. 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.

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 the conditions for this result further below. Linear utility in consumption for entrepreneurs is assumed to facilitate aggregation.

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_t is a "news shock" - it is known p periods before it affects the productivity. ε_t denotes the "traditional" contemporaneous innovation to TFP. For convenience, as well as comparability to CIMR, we model TFP as a stationary process.

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.[4] Then investment is made using the following law of motion for capital

$$k_{i,t+1} = (1-\delta)\, k_{i,t} + i_{i,t}.$$

We assume convex capital adjustment costs of the form

$$G\left(i_{i,t}, k_{i,t}\right) = \frac{\xi}{2}\left(\frac{i_{i,t}-\delta k_{i,t}}{k_{i,t}}\right)^2 k_{i,t}$$

Aggregate uncertainty is described by the Markov process s_t in the finite state space $\mathcal{S}$, with transition probability $\pi\left(s_{t+1}|s_t\right)$. 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 $\chi_{i,t} = 0$.

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 $\{d_{i,\tau}\}_{\tau=t}^{\infty}$,[5] 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. Let q_t^m denote the price of capital and w_t the wage rate in period t. Feasibility requires

[4] 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.

[5] 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.

that the transfers $\{d_{i,\tau}\}$ satisfy:

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

for all the periods where the entrepreneur is active.[6]

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:

$$v_{i,t} = A_{t} F\left(k_{i,t}, l_{i,t}\right) - w_{t} l_{i,t} + q_{t}^{m} k_{i,t}\left(1-\delta\right).$$

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

[6] In the first period of activity the constraint instead is:

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

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

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, $m(X', X)$ where X denotes the aggregate state vector which is further described below. The discount factor is defined by

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

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

$$\lambda_{C,t} = c_t^{-\sigma_c}$$

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, (1), to the intertemporal budget constraint:

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

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:

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

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:

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

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

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

Combining the definitions above, the feasibility constraint (1) can be written as:

$$c_{i,\tau}^E + d_{i,\tau} + q_\tau^m k_{i,\tau+1} \leq v_{i,\tau}. \tag{2}$$

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 $H\left(X_{t+1}|X_t\right)$. 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 $q^m\left(X_t\right)$ and $R\left(X_t\right)$.

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 $W\left(v, b; \chi, X\right)$ as the expected utility, in state X, of an entrepreneur who controls a firm with liquidation value v and outstanding liabilities b.[7] 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:

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

$s.t.$

$$c^E + d + q^m(X) k' \leq v, \tag{3}$$

$$b = d + \mathbb{E}[m(X', X) b'(\chi', X') | X], \tag{4}$$

$$v'(X') = R(X') k' \quad \forall X', \tag{5}$$

$$W(v'(X'), b'(\chi', X'); \chi', X') \geq W((1-\theta) v'(X'), 0; \chi', X') \ \forall \chi', X', \tag{6}$$

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 (3). Moreover, the entrepreneur has to satisfy the "promise keeping" constraint (4): 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 captured by the market discounted value of

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

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 (5) 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 (6) 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

$$W(v, b; \chi, X) = W(v - b, 0; \chi, X) \tag{7}$$

The no-default condition can accordingly be written as

$$b \leq \theta v. \tag{8}$$

Equation (7) allows us to replace constraint (6) with constraint (8). 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:*

$$W(v,b;1,X) = \phi(X)(v-b),$$
$$W(v,b;0,X) = v-b.$$

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:*

$$\phi(X) = \max\left\{\frac{\beta_E(1-\theta)\mathbb{E}[(\gamma+(1-\gamma)\phi(X'))R(X')|X]}{q^m(X)-\theta\mathbb{E}[m(X',X)R(X')|X]}, 1\right\}. \tag{9}$$

Suppose that

$$m(X',X)\phi(X) \geq \beta_E\phi(X') \tag{10}$$

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

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. The fact that entrepreneurs end up promising to pay a fixed fraction (θ) of the firm value to outside financiers in every future state makes the interpretation of the financial contract as "equity" obvious.

2.4 Equilibrium

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

$$X = (K, B, lag(L), s),$$

where K is the aggregate capital stock, B denotes the aggregate liabilities of the entrepreneurs who are not in their last period of activity. Lagged labor are part of the state vector because of habit formation in labor supply. Recall that s denotes the aggregate technology.

A recursive competitive equilibrium is given by a transition probability, $H(X'|X)$, 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 (10) holds for every pair X, X' such that $H(X'|X) > 0$. Lorenzoni and Walentin (2007) showed that, in economies with "small" productivity shocks, such an equilibrium exists. This case will be the basis for our numerical analysis.

Condition (10) implies that, in each state X, the state-contingent liabilities are set to their maximum level for each future value of X', i.e. $b'(\chi', X') = \theta v'(X')$.

Therefore, the optimal level of investment is given by:

$$k' = \frac{1}{q^m(X) - \theta \mathbb{E}\left[m(X', X) R(X') | X\right]} (v - b). \tag{11}$$

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 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 (11) and aggregating we obtain:

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

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

$$K_{t+1} = \frac{(1-\gamma)(1-\theta) R_t K_t + \gamma w_t l_E}{q_t^m - \theta \mathbb{E}_t\left[m_{t+1} R_{t+1}\right]}. \tag{12}$$

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 between the model in that paper and the ones made here do not induce any substantive changes in the proof, so it is left out.

2.5 Asset prices

We can now 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. Recall from section 2.3 that it turns out that the optimal financial contract takes the form of an equity contract, so $p_{i,t}$ is interpreted as the stock price.

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 firms, 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

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

■

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 positive premium $f(X)$ reflects 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

We model a small open economy. In modelling this aspect we follow Jaimovich and Rebelo (2008). The goods market clearing condition is:

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

where NX_t denotes net exports. The law of motion for the net foreign asset position F_t is:

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

Finally, we assume the following relation between the interest rate r_t^* that domestic agents face when borrowing abroad and the net foreign asset position of the country:

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

This relationship, and $\omega > 0$, induce stationary of net foreign assets. Absence of arbitrage implies that the domestic and foreign interest rates are equalized at each point in time.

3 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 (10) we set $\beta_E < \beta$, more specifically, $\beta_E = 0.99$. Following standard RBC parameter values we set $\alpha = 0.33$, $\delta = 0.0125$ and $\rho = 0.95$. We set φ_L to get a steady state value of around $L = 0.30$. As in Lorenzoni and Walentin (2007) we set the capital adjustment cost parameter ξ 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 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 $\gamma = 0.015$.[8]

In the small open economy dimension 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 equal to 4% of GDP (as in Jaimovich and Rebelo, 2008) and the parameter for international interest rate sensitivity, ω, to 0.001.

[8] The model is parameterized 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 of the steady state labor supply.

3.2 The empirical benchmark

Beaudry and Portier (2006) present VAR evidence in terms of impulse response functions to a news shock to 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 in addition show that news shocks Granger cause patents. For a contrarian view based on a different identification, see Barsky and Sims (2011) and, using a factor model approach, Forni, Gambetti and Sala (2011). The results in these two papers differ from Beaudry and Portier (2006) in that they indicate that hours and investment respond negatively to news shocks on impact. Nevertheless, the positive response of stock prices to news - the main focus of the present paper - is robust to these alternative approaches.

Recall that there are several papers in the literature that set up models that successfully generate the positive responses of the above macro variables to news shocks about future TFP. The remaining challenge that we focus on in this paper is how to get stock prices, as well as these macroeconomic variables, to respond positively to news shock in a real model.

3.3 Impulse response functions

In Figure 1 we present impulse responses of the key variables to a positive stationary shock to expected future TFP. We set the number of quarters between the news shock and the actual change in productivity to $p = 4$ quarters.[9] Note how consumption, investment, hours and stock prices all increase at impact in response to the positive news shock. In addition, the price of capital, q^m, increases, although stock prices, q,

[9] To save space we do not display the contemporaneous TFP shock IRFs, but simply note that they imply positive responses of all key variables.

increase more.[10] Note that net exports decrease so that consumption and investment can increase faster than output (and hours) in anticipation of the increase in TFP.

The result that news shocks generate an increase in consumption, investment and stock prices is quite robust. We elaborate on issues of robustness in the next section. The increase in both stock prices and capital prices is in complete contrast to previous theoretical work on real one-sector models that deliver an increase of macroeconomic variables in response to news shocks.

We will now outline the intuition for these results, emphasizing two effects: the (investment) quantity effect and the (stock) price effect. The quantity effect of limited enforcement is central for the news shock dynamics of our model. To understand the quantity effect, note from equation (12) that investment is an increasing function of the discounted expected return on capital, $E_t\left[m_{t+1}R_{t+1}\right]$. This implies that a positive quantity effect requires shocks to expected future productivity, $E_t\left[a_{t+p}\right]$, to increase the expected return to capital, $E_t\left[R_{t+p}\right]$, more than they decrease the discount factor, $E_t\left[m_{t+p}\right]$. In our open economy setting the discount factor, $E_t\left[m_{t+p}\right]$, (or equivalently, the risk-free interest rate) is approximately unchanged so this requirement is fulfilled. Investment accordingly increase substantially in anticipation of the increase in TFP.

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 (9)) and therefore increases initially. When the TFP increase is realized, in period 5, marginal value of wealth of entrepreneurs, ϕ, decrease as they become less constrained. This implies that the wedge, and therefore also stock prices, fall.

[10] It is interesting to note that the same qualitative results - i.e. positive responses of key variables to news shocks - go through also with investment adjustment costs. Even quantitatively the results are similar. The only notable difference is that a negative price effect obtains as ϕ decrease at impact.

Results are also qualitatively unchanged if we assume habit formation in consumption. Unsurpricingly, with consumption habit the changes in consumption become more gradual, but this is the only major difference compared to our main specification.

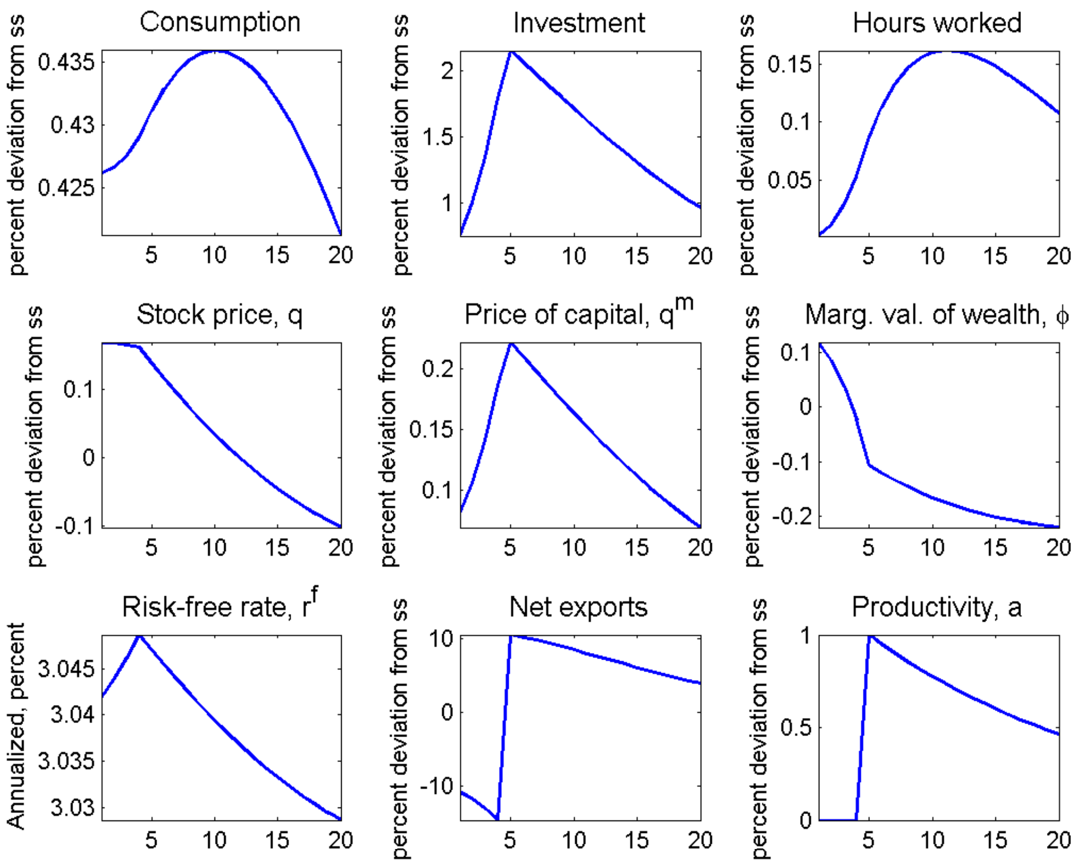

Figure 1. Impulse responses to a η shock to future TFP, $E_t\{a_{t+4}\}$. Small open economy, habit formation in labor, capital adjustment costs.

4 Robustness

In this section we document the robustness of the results. We start with documenting the robustness of the model's ability to generate an expectation-driven boom with respect to parameter values. Then we present an alternative model specification. We conclude with a more general analysis of the sensitivity of the price and quantity effects.

4.1 Parameter values

We document the parameter values that are consistent with a positive effect of TFP news shocks on all the relevant macro variables as well as stock prices. We measure this as being above the steady state value from when a news shock occurs to when the increase in TFP is materialized, i.e. after $p = 4$ periods in the benchmark specification. The exercise is performed by varying one parameter at a time, keeping the other parameters at the values specified in section 3.1.[11] Four parameters that can take any value without affecting the qualitative results are excluded from the table: α, β_e, δ and L_e. There is disagreement in the empirical literature regarding the sign of the impact response of hours to news shocks – Beaudry and Portier (2006) and Haertel and Lucke (2007) find a positive response while Barsky and Sims (2011) and Forni, Gambetti and Sala (2011) document a negative response. We therefore also present the parameter values that imply positive effects for all the variables, except hours worked.

In Table 1, the first column shows that if we abstract from hours worked, the restrictions on the parameters needed for a positive response the remaining variables to news shocks are extremely mild. The second column shows that when we also include hours worked, there are reasonably strict restrictions on a couple of parameters, mainly ρ, σ_C and b_L.[12] [13] Note that the parameters close to the key mechanism of our model, the quantity effect, are almost unrestricted. By this we mean the fraction of the liquidation value that investors can recover in case of entrepreneurial diversion, θ, and the size of the capital adjustment costs, ξ. It is comforting that our result does not depend on the exact calibration of these parameters.

[11] The only exception to this approach is β. For that parameter we also vary β_e and set $\beta_e = \beta - 0.025$ to keep the "collateral constraint" binding.

[12] One way to increase the robustness to parameter values of the model in generating a positive response of hours worked is to use GHH/JR preferences that limits the short run wealth effect on labor supply. We prefer to keep the consumption preferences standard.

[13] An interesting aspect, outside the scope of the present paper, is the non-monotone effect of the interest rate elasticity parameter ω on hours worked.

	All variables except hours	All variables
p	≤ 10	≤ 4
β	≥ 0.85	≥ 0.9892
ρ	any	≤ 0.955
ξ	≥ 0.275	$0.275 - 31$
σ_C	any	≤ 1.05
σ_L	any	≥ 0.35
b_L	any	≥ 0.88
θ	≥ 0.025	≥ 0.16
ω	≤ 0.035	$0 - 0.00125, 0.025 - 0.035$

Table 1: Robustness to parameter values in main specification. Values consistent with sustained positive response to news shocks are shown.

As a separate exercise we explore how the value of θ affect the volatility of stock prices and investment. As one might conjecture from (12), it turns out that a higher θ, i.e. stronger enforcement, generates slightly higher volatility (in response to contemporaneous and expected shocks to TFP, respectively) of both these variables. The intuition for this result is that better enforcement makes more credit and higher leverage for entrepreneurs possible. Investment therefore responds more to a change in the price of capital. The qualitative result coincides with what Walentin (2011) finds for household leverage, but contradicts Cooley, Marimon and Quadrini (2004), although their definition of "better enforcement" is slightly different.

4.2 Alternative model specification

To illustrate the price effect in isolation we present an alternative model specification that is identical to the real model in CIMR, with the exception that we assume limited enforcement. We use key assumptions that are identical to CIMR: closed economy, investment adjustment costs and habit formation in consumption but not in labor.[14]

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

Preferences are defined by

$$\mathbb{E}\left[\sum_{t=0}^{\infty}\beta^{t}\left(\frac{\left(c_{t}-b_{C}c_{t-1}\right)^{1-\sigma_{C}}}{1-\sigma_{C}}-\varphi_{L}\frac{l_{t}^{1+\sigma_{L}}}{1+\sigma_{L}}\right)\right]$$

The investment adjustment costs are of the type introduced by Christiano, Eichenbaum and Evans (2005), where the law of motion for capital is the following:

$$k_{i,t+1} = (1-\delta)\,k_{i,t}+\left(1-S\left(\frac{i_{i,t}}{i_{i,t-1}}\right)\right)i_{i,t} \quad (13)$$

$$\text{where } S(x) = \frac{g}{2}(x-1)^{2} \quad (14)$$

This implies that the price of capital is:

$$q_{t}^{m}=\frac{1-\beta_{E}E_{t}\left[\frac{\phi_{t+1}}{\phi_{t}}q_{t+1}^{m}\right]\left[S'\left(\frac{I_{t+1}}{I_{t}}\right)\left(\frac{I_{t+1}}{I_{t}}\right)^{2}\right]}{1-S\left(\frac{I_{t}}{I_{t-1}}\right)-S'\left(\frac{I_{t}}{I_{t-1}}\right)\left(\frac{I_{t}}{I_{t-1}}\right)}. \quad (15)$$

and $I_t = i_{i,t}$ and $I_{t+1} = i_{i,t+1}$ because of trade in capital between entrepreneurs.

We use CIMR's calibration of the investment adjustment cost parameter $g = 15.1$ and the consumption habit parameter $b_c = 0.63$. We adjust the value of φ_L to keep $L = 0.30$ as in the main specification. All other parameter values are as previously stated in section 3.1.

The impulse responses for the alternative specification are presented in Figure 2. The initial increase in consumption, investment and hours are in line with the empirical evidence, as well as with previous models, e.g. CIMR. The key difference versus 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 Figure 2 the marginal value of entrepreneurial wealth, ϕ, which determines the wedge, increases in response to a positive news shock. This increase comes from the fact that the future return of capital increased. On the other hand, the price of capital q^m falls because of the investment adjustment costs. The stock price q is affected by these two 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 constraint makes very little difference for the macroeconomic dynamics compared to CIMR's model, a perhaps surprising result. This also means that we get the same problematic size in the interest rate swings as CIMR.

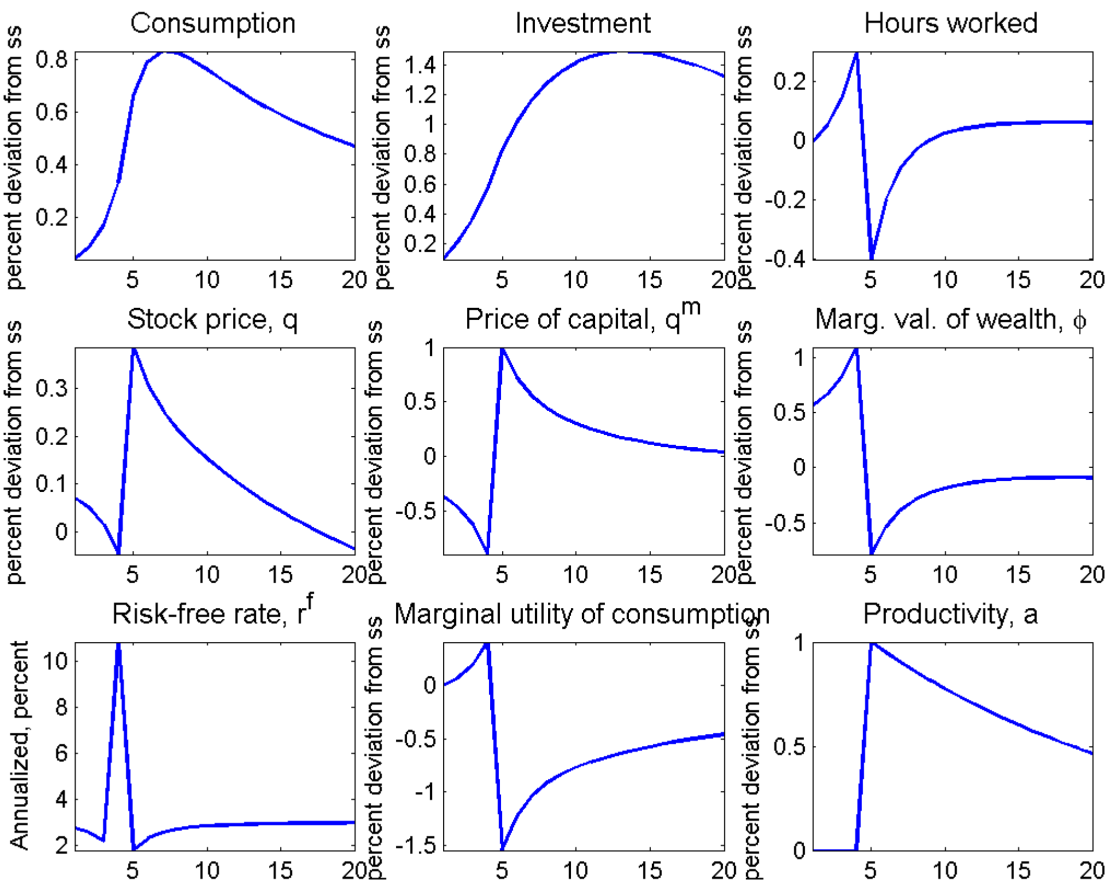

Figure 2. Impulse responses to a η shock to future TFP, $E_t\{a_{t+4}\}$. Closed economy, habit formation in consumption, investment adjustment costs.

4.3 Sensitivity of effects

The sign of the quantity effect depends on the strength of the response of the interest rate (stochastic discount factor) to news shocks, and will turn negative if the interest rate responds too strongly to news shocks. In an open economy a high elasticity of the international interest rate to the country's net foreign asset position, ω, would make the interest rate too responsive. Similarly, in a closed economy this would be the case if the degree of intertemporal substitution, $1/\sigma_c$ is low.

The price effect, i.e. that the wedge between the price of capital and the stock price responds positively to news about future productivity, is quite robust to different parameterizations. Three important exceptions to this robustness are investment adjustment costs in an open economy setting, very high depreciation rate, δ, or high capital adjustment costs, ξ.

5 Conclusion

In this paper we have analyzed the effects of shocks to expectations about future productivity in a business cycle model with limited enforcement of financial contracts. We constructed a real one-sector model with two inputs, capital and labor, that delivers a positive response of stock prices, as well as the key macro variables, to an expectation shock. This had not been achieved previously in the literature. Furthermore, we showed that this result holds for different assumptions on preferences, capital adjustment costs and open vs. closed economies, as well as for a wide set of parameter values. The fact that a real model can deliver a stock market boom in response to positive news shocks also has important policy implications, as it implies that it is not necessarily loose monetary policy that causes expectation-driven booms in asset prices and the economy in general, as argued by CIMR.

The implications of limited enforcement in the presence of news shock can be considered as two effects. In our main model specification the key effect is 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 price of capital increases and 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 with standard consumption preferences (no habit formation, no GHH/JR preferences) and without investment adjustment costs or variable capital utilization.

Limited enforcement also 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. 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, as in our variation of the real model in CIMR.

More generally, the present paper have shown that financial frictions – which we modelled by limited enforcement – in some settings are necessary for generating expectation-driven business cycles.

Appendix

Equations determining the equilibrium

Equilibrium 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

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

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

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

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^* (which is equal to r_t^f in equilibrium):

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

Technology

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

Equations that apply only for the alternative specification

Habit formation in consumption, but not in labor imply:

$$\lambda_{c,t} = u'(c_t) = (c_t - b_c c_{t-1})^{-\sigma_c} - b_c \beta E_t (c_{t+1} - b_c c_t)^{-\sigma_c}$$

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

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

Finally, the alternative specification is a closed economy so the international interest rate, r_t^*, and the net foreign asset position, F_t, are not defined.

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 $X = \{K, B, lag(L), s\}$;

(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[15]

(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):

$$\begin{aligned} R(X) &= A(s) F_1(K, L) + q^m(X)(1-\delta), \\ m(X'|X) &= \beta \frac{\lambda_c(X')}{\lambda_c(X)} \\ \text{where } \lambda_c(X) &= \frac{1}{C(X)} \\ q^m(X) &= 1 + \xi \frac{I - \delta K}{K} \\ V &= R(X) K, \\ w(X) &= A(s) F_2(K, L); \end{aligned}$$

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

[15] 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.

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

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

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

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