News and Firm Entry: the Role of the Waiting Option*

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September, 2024

Abstract

Firm entry and capital investment both vary over the business cycle. This paper analyzes the role of the firm entry delay option (waiting option) in the joint dynamics of firm entry and investment in a news-driven RBC model. We introduce the waiting option by restricting the number of potential firm entrants and demonstrate that the combination of news shocks and the waiting option effect yields empirically plausible joint dynamics of firm entry and investment over the business cycle. In contrast, the model without the entry delay option produces excessively volatile firm entry. We rationalize our findings using an analytical real-option model of firm entry.

Keywords: entry delay option, firm entry, news shocks, real business cycle

*We are indebted to Kenza Benhima, Raouf Boucekkine, Giovanni Caggiano, Andreas Dibiasi, Frédéric Dufourt, Céline Poilly, Daniele Siena, Fabien Tripier for the comments and prolific discussions. We thank participants of the DEMUR workshops, Aix-Marseille School of Economics seminar and European Economics and Finance Society Conference.
The project leading to this publication has received funding from the French government under the "France 2030" investment plan managed by the French National Research Agency (reference: ANR-17-EURE-0020) and from Excellence Initiative of Aix-Marseille University - A*MIDEX.

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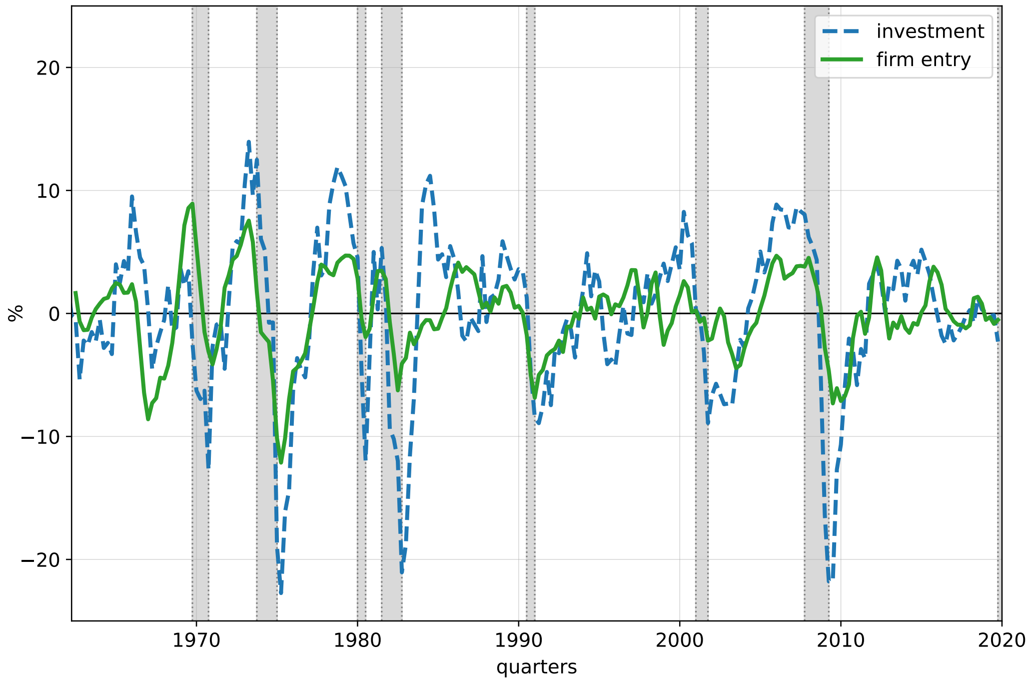
1 Introduction

Firm entry is an important component of the business cycle. The macroeconomic and industrial organization literature emphasizes that firm creation can be interpreted as a particular form of investment (Bilbiie et al., 2012; Lee and Mukoyama, 2018). Yet, the business cycle dynamic of firm entry substantially differs from that of capital investment. Figure 1 illustrates the business cycle fluctuations of firm entry and capital investment in the US. Both series are strongly procyclical, but firm entry is notably less volatile than investment. Business cycle models extended to accommodate investment in both new firms and physical capital have difficulty matching the relatively low volatility of firm entry.[1]

Figure 1: Investment vs. Firm entry volatility



This figure plots quarterly capital investment and firm entry series for the US. Both series are HP-filtered with a filter parameter of 1600. See Appendix A for details on the data. Grey areas indicate recession dates.

In this paper, we analyze the role of the entry delay option (waiting option) in shaping the joint dynamics of firm entry and capital investment in an otherwise

[1]See, for instance, Lewis (2009) and Offick and Winkler (2019); Casares et al. (2020), who discuss this problem and propose mitigating it by incorporating congestion in firm entry. While congestion externalities somewhat dampen the firm entry response to fundamental shocks, they amplify the response to news shocks (Fan et al., 2016)

standard RBC model. We show that the combination of the entry delay option and the news-driven business cycle produces empirically plausible volatility in both firm entry and capital investment. Both ingredients – the waiting option and news shocks – are crucial for our result and work together through the following intuitive mechanism: when potential firm entrants have the valuable entry delay option, news about the future creates an incentive to postpone entry until this news materializes. This mechanism dampens firm entry volatility compared to a model without the waiting option, bringing it to empirically plausible values.

We begin our analysis by documenting that the firm entry response to a productivity *news* shock is relatively weaker than the corresponding capital investment response. At the same time, a conventional productivity shock generates a response of similar magnitude in both firm entry and capital investment. This evidence suggests that the difference in the business cycle volatility between firm entry and capital investment can arise from news-driven fluctuations. Motivated by this evidence, we build a news-driven RBC model with physical capital accumulation, extended to incorporate endogenous firm entry subject to sunk entry cost and the possibility of entry delay, in the spirit of Fajgelbaum et al. (2017).[2]

For the entry delay option to be active within a conventional firm entry model, competition must be restricted to ensure positive future profit opportunities (Dixit and Pindyck, 1994). In an equilibrium with many firm entrants, ensuring positive future profits amounts to limiting the number of potential entrants, thereby relaxing the free entry condition.[3] With a restricted number of potential entrants, the possibility of positive future profits creates a valuable opportunity for entry delay.[4].

Our news-driven RBC model, incorporating waiting to enter and calibrated for the US, successfully reproduces the empirical business cycle volatility in both firm entry and investment series. We contrast our baseline model with the no-waiting-option model (which maintains a restricted number of entrants but shuts down the entry delay option) and with the free-entry model (which allows an unrestricted number of potential entrants). Both models generate excess volatility in firm entry, highlighting

[2]While Fajgelbaum et al. (2017) focus on the effect of endogenous uncertainty under limited information, we examine the waiting option behavior resulting from expected growth rate fluctuations (news shocks) rather than uncertainty fluctuations.

[3]This relaxation is necessary because otherwise, the absence of unexploited profit opportunities would eliminate the incentive to delay entry (Bilbiie et al., 2012)

[4]Several studies in the industrial organization literature have employed the framework with a restricted mass of potential entrants (Sedláček and Sterk, 2017; Clementi and Palazzo, 2016; Smirnyagin, 2023). However, they do not explicitly emphasize the waiting option behavior, which also requires the possibility of entry delay. One exception is Vardishvili et al. (2020), who addresses the role of waiting in the entry and exit of startups.

the crucial role played by the waiting option in the success of our baseline model. Examining the model's response to both a news shock and a productivity shock and isolating the role of the waiting option, we find that the waiting option significantly dampens the firm entry response to news shocks, whereas, in the case of productivity shocks, it has no such dampening effect.

To understand the mechanism behind our quantitative results, we turn to a tractable real-option model of firm entry in the spirit of McDonald and Siegel (1986). Our tractable model features the same firm entry mechanism as our quantitative RBC model. At the same time, the combination of a continuous-time approach and a parsimonious setup enables us to derive an interpretable closed-form solution. Analytically, we show that the effect of news on the incentive to enter consists of two underlying effects: the "firm-value effect" and the "waiting-option effect". These two effects operate in opposing directions when shaping the firm entry response to a news shock. On the one hand, positive news creates a stronger incentive to enter through the "firm-value effect", as it elevates the expected future payoffs, thereby increasing the present value of a firm. On the other hand, positive news weakens the incentive to enter through the "waiting-option effect", as it prompts firms to delay their entry until the news materializes. The overall impact of news on firm entry depends on the relative magnitudes of these two underlying effects. When the firm-value effect dominates, firm entry rises in response to positive news. In contrast, when the waiting-option effect prevails, positive news results in a decrease in firm entry. We show that for projects with sufficiently long duration, the firm-value effect dominates, but the waiting option still dampens the positive firm entry response to good news; this is the case we have in our quantitative RBC model. Finally, we demonstrate that in equilibrium with a restricted number of entrants, the waiting option dampens the volatility of firm entry conditional on news shocks but has no such effect for other shocks, consistent with our quantitative model. Hence, the combination of news-driven fluctuations with the entry delay option presents a plausible mechanism explaining the relatively low volatility of firm entry series compared to capital investment.

Relation to literature. This paper relates to three strands of literature: news-driven business cycle, real option effect, and endogenous firm entry.

First, we contribute to the news-driven business cycle literature by highlighting the role of the entry delay option in shaping the macroeconomic response to productivity news shocks. The seminal contributions, including those of Beaudry and Portier (2004) and Jaimovich and Rebelo (2009), focus on the co-movement between economic aggregates in response to news shocks. Empirically, changes in the expected rate of technological growth, in the form of news shocks, have been documented as a significant source of aggregate fluctuations in the U.S. economy (Beaudry and Portier, 2006; Barsky and Sims, 2011; Görtz and Tsoukalas, 2017; Clements and Galvão, 2021; Cascaldi-Garcia and Vukotić, 2022; Miranda-Agrippino et al., 2022). In particular, news shocks contribute to the dynamics of investment, including inventories (Crouzet and Oh, 2016; Görtz et al., 2022). These papers, however, do not study the cyclical properties of firm entry, despite firm entry often being considered as an alternative form of investment. While Beaudry et al. (2011); Fan et al. (2016); Pavlov (2016) inspect the dynamics of firm entry in the news-driven business cycle model they abstract from the entry delay option. In contrast to this literature, we extend the news-driven business cycle model with endogenous firm entry by relaxing the free-entry condition, thereby reinstating the role of the entry delay option to study the joint dynamics of the two forms of investment: firm entry and capital investment.

Second, our paper relates to the literature studying the irreversibility of investment and the waiting-option effect. Bernanke (1983), McDonald and Siegel (1986), Dixit (1989); Hassler (1996) were among the first to study the role of non-convex adjustment costs in the postponement of investment decisions, notably under uncertainty. A recent vibrant strand of literature on time-varying uncertainty largely incorporates the waiting option to generate wait-and-see behavior (Bloom et al., 2007; Bloom, 2009; Bachmann and Bayer, 2013) and uncertainty traps (Fajgelbaum et al., 2017).[5]. However, uncertainty is not the only factor influencing the waiting option; the expected growth rate also plays a role, even in the deterministic case, as highlighted by Dixit and Pindyck (1994). We explore the role of news about the future, rather than uncertainty, in generating the wait-and-see behavior. The theoretical urban growth literature also argues that positive news about the future may postpone the development of urban land due to the waiting option effect of expected growth (Lange and Teulings, 2024). In contrast, we focus on the firm entry decisions within the real business cycle model.

[5]The concepts of uncertainty shocks and news shocks share a common feature: both shocks affect the expectations of economic agents. News shocks refer to a change in the expected *level* of an economic variable, while uncertainty shock refers to a change in the expected *volatility* of a variable. Berger et al. (2020) relies on this similarity to estimate the effect of uncertainty shocks using an identification strategy borrowed from the news shocks literature.

Finally, our paper contributes to the literature on endogenous firm entry dynamics over the business cycle. Multiple studies address the endogenous fluctuations in the number of firms over the business cycle (Chatterjee and Cooper, 1993; Devereux et al., 1996; Jaimovich and Floetotto, 2008; Bilbiie et al., 2012; Bergin et al., 2018; Bernstein et al., 2021). The equilibrium firm entry in this strand of literature relies on the free-entry condition, which shuts down the waiting option. At the same time, workhorse business cycle models with endogenous firm entry encounter difficulties in accurately replicating the observed moderate volatility of firm entry found in the US data. To address the excessive volatility problem, the literature relies on the congestion externality, where entry costs depend on the number of firms (Lewis, 2009). However, even when applied within a medium-scale DSGE model, this approach only partially resolves the volatility problem (Offick and Winkler, 2019). In contrast to this literature, we relax the free-entry condition and reintroduce the entry delay option into an otherwise standard news-driven RBC model. We show that the assumption of free entry may be especially consequential when entry decisions are affected by news about future productivity.

The paper proceeds as follows. Section 2 provides motivating evidence about the difference in firm entry and investment volatility stemming from news shocks. Section 3 lays out the quantitative news-driven RBC model extended with endogenous firm entry subject to entry delay option. Section 4 describes the quantitative results of the model. Section 5 analyzes the mechanism behind the effect of news on firm entry within an analytical real option model. Section 6 concludes.

2 Motivating evidence

From Figure 1, we see that both capital investment and firm entry are strongly procyclical, with capital investment being roughly two times more volatile than firm entry. What can account for the difference in the magnitudes of business cycle volatilities between these two series? To explore this question, we begin by examining the empirical impulse responses of capital investment and firm entry to two types of shocks: a conventional productivity shock and a productivity news shock. Throughout the paper, we define the (conventional) productivity shock as an innovation to the current productivity level, whereas the productivity news shock, or simply news shock, represents an informational shock about future innovations in the productivity level. Next, we briefly describe the data and the shock identification strategy. Appendix A provides the details.

Firm entry and investment series. For firm entry, we adopt the approach of Brand et al. (2019) to construct a long quarterly series of business creations in the US. This approach combines business formation data from New Business Incorporations by the Bureau of Economic Analysis with data on the Number of Establishment Births by the Bureau of Labor Statistics. For capital investment, we use quarterly real gross private domestic investment series from the US Bureau of Economic Analysis (both series are plotted in Figure 1).

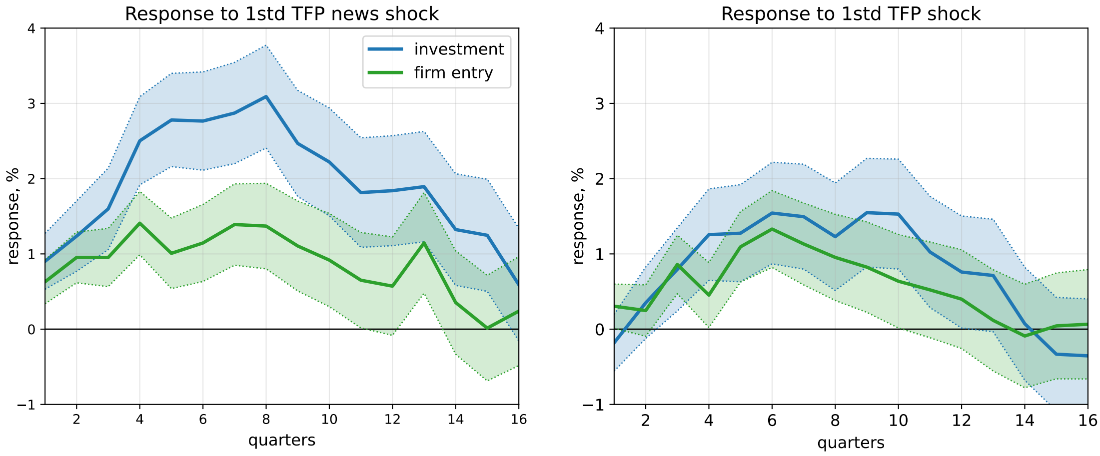
Shock series. We identify a productivity news shock within a structural VAR model using the Barsky and Sims (2011) approach. According to this approach, a news shock does not have a contemporaneous impact on total factor productivity (TFP) but maximizes the forecast error variance of TFP over the long-run horizon (40 quarters). We also identify a conventional productivity shock within this VAR model using the Cholesky decomposition of the variance-covariance matrix of the VAR residuals. This decomposition identifies the productivity shock as the only shock with a contemporaneous impact on TFP. Our VAR model includes three lags and features the SP500, Hours, Output, Consumption, CPI, and utilization-adjusted TFP series from Fernald (2014) with all variables expressed in logarithms.

The period of our analysis spans from 1961Q1 to 2019Q4. Having identified news shock ϵ_t^N and productivity shock ϵ_t^P, we estimate the response of firm entry and capital investment to each of these shocks using the local projection method (Jordà, 2005) with the following specification for the horizon h: $y_{t+h} = \beta_0^h + \beta^h \cdot \epsilon_t^i + X_t + v_{t+h}$ where y_{t+h} is either firm entry or capital investment (both in logarithms), $i = N,\ P$ (either news of productivity shock), and X_t represents the set of control variables. In the baseline, we control for two lags of the dependent variable and a time trend. The corresponding baseline impulse responses are illustrated in Figure 2.

In the left panel, we observe that firm entry is significantly less sensitive to news shocks compared to capital investment. This indicates that news-driven fluctuations could account for the lower volatility of firm entry relative to capital investment. In contrast, conventional productivity shocks cause nearly identical magnitudes of responses for both capital investment and firm entry series (right panel), suggesting that the disparity in business cycle volatility between the two series is unlikely to be caused by productivity shocks.

Robustness. In the robustness check in Appendix A, we control for more variables: both firm entry and capital investment, the shocks themselves, and output; we also include more lags. Our results remain strongly robust to these modifications. In Appendix A, we also employ an alternative measure of news shock, the patent-based

Figure 2: Response to productivity news and contemporaneous productivity shock



Impulse response to 1-standard deviation news and productivity shocks. The local projection specification controls for two lags of the dependent variable and a time trend.

news from Cascaldi-Garcia and Vukotić (2022), and obtain similar results.[6]

Business cycle models accommodating investment in both physical capital and new firms typically produce excessively volatile firm entry series. In this paper, we argue that a combination of news-driven fluctuations and the entry delay option helps to align the RBC model featuring endogenous firm entry more closely with observed data.

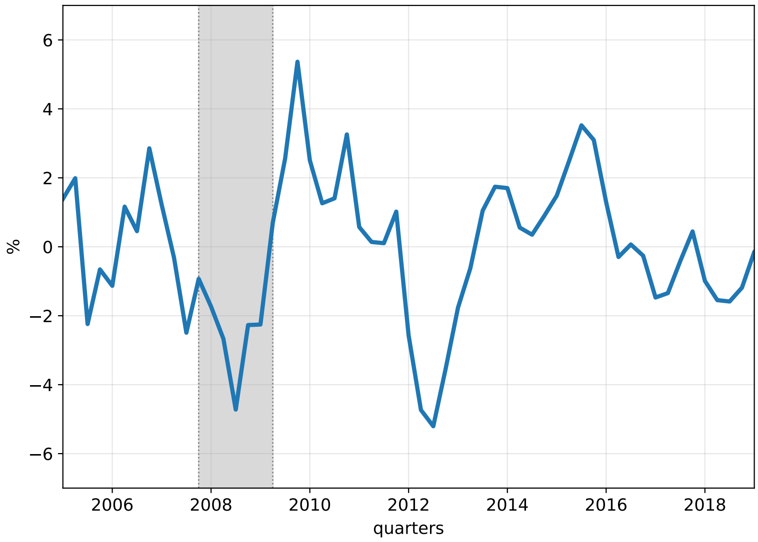
While directly observing waiting option behavior in the data is challenging, one indirect indicator of entry delay behavior is the time from a business application to the actual start of the business. As argued by Smirnyagin (2023), longer waiting times imply stronger entry delay behavior. Figure 3 illustrates the average waiting time in the US from a business application to a business formation.

It shows that, at the business cycle frequency, the average time before starting a business varies significantly, indicating that the value of waiting to enter is time-varying.[7]

[6]Barsky and Sims use the most encompassing definition of news shock, which is widely associated with any unexpected future innovation in productivity. The patent-based news from Cascaldi-Garcia and Vukotić (2022) is more narrow and is related to the technological improvement driven by innovation.

[7]Moreover, the Great Recession is associated with a shorter waiting time, implying that the "wait-and-see" behavior of firm entry is not necessarily countercyclical, contrary to what the literature on time-varying uncertainty suggests. This leaves room for alternative sources of the time-varying entry delay option, including waiting to enter driven by news.

Figure 3: Average waiting time to open a business



This figure plots the average duration from a business application to the formation (detrended with quarterly HP-filter) as reported in the Business Formation Statistics by the US Census. The data range is from 2004Q3 to 2019Q4.

3 News-driven RBC Model

Can news shocks explain the relatively low volatility of the firm entry observed in the US data? We study this question within a news-driven RBC model with an endogenous firm entry featuring the entry delay option. To make the waiting option active, we follow Fajgelbaum et al. (2017) in restricting the number of potential entrants, thus relaxing the free entry condition, and allowing for the profitable possibility of entry delay. Next, we describe the model framework.

3.1 Model description

3.1.1 Total factor productivity process

There are two sources of aggregate fluctuations: conventional productivity shocks and news shocks about future productivity. Let A_t represent the total factor productivity (TFP). The log-deviation of total factor productivity A_t from its stationary value $\bar{A}$ is $a_t = \log A_t - \log \bar{A}$, where a_t is a mean-reverting autocorrelated stochastic process with a drift:

$$a_t = \rho_a a_{t-1} + g_{t-1} + \epsilon_{a,t} \tag{1}$$

The drift g_t is a stationary autoregressive process with zero mean:

$$g_t = \rho_g g_{t-1} + \epsilon_{g,t} \tag{2}$$

The error terms $\epsilon_{a,t}$ and $\epsilon_{g,t}$ are defined as $\epsilon_{a,t} \sim N(0, \sigma_a)$, $\epsilon_{g,t} \sim N(0, \sigma_g)$, with $Corr(\epsilon_{a,t}, \epsilon_{g,s}) = 0$ for all t and s. Productivity shocks $\epsilon_{a,t}$ cause an immediate increase in total factor productivity A_t, which then gradually decays. In contrast, the drift shocks $\epsilon_{g,t}$ do not affect the contemporaneous value of A_t but affect its future values. Therefore, innovations in the drift $\epsilon_{g,t}$ can be interpreted as news shocks (Barsky and Sims, 2012).

3.1.2 Households

The economy is populated by a unit measure of identical households. The representative household maximizes the expected lifetime utility

$$\max_{\{C_s, L_s, K_s\}_{s=t}^{\infty}} E_t \sum_{s=t}^{\infty} \beta^{s-t} u(C_s, L_s) \tag{3}$$

where $\beta \in (0, 1)$ and $u(.)$ is a well-defined utility function such that $u'_C > 0$, $u'_L < 0$, $u''_{CC} < 0$, $u''_{LL} > 0$. Households supply labor hours L_t at a competitive wage rate w_t, buy a consumption good C_t at a unit price, save by investing in physical capital K_t, and then lend this capital to firms at an interest rate r_t. Households own firms and receive dividends D_t. In contrast to a standard RBC model where dividends are typically zero, here they arise due to a combination of decreasing returns to scale and restricted entry subject to entry cost. The household budget constraint is given by:

$$C_t + K_{t+1} = r_t K_t + w_t L_t + (1 - \delta_k) K_t + D_t \tag{4}$$

where δ_k is the capital depreciation rate.

Maximizing (3) subject to (4) is a standard household optimization program in the RBC model. The corresponding first order conditions are given by: 1) the Euler equation: $u'_C(C_t, L_t) = \beta E_t\{(r_{t+1} + 1 - \delta) \cdot u'_C(C_{t+1}, L_{t+1})\}$ and 2) the labor supply equation: $u'_L(C_t, L_t) = -w_t \cdot u'_C(C_t, L_t)$.

3.1.3 Number of firms

In each period, there are P potential entrants, and a fraction λ_t of them enters produciton at time t ($\lambda_t \in [0,\ 1]$). Here, P is a finite positive number. The finite number of potential entrants ensures that the free-entry condition does not necessarily hold, potentially activating the waiting option.[8] The number of actual firm entrants is given by $N_t^e = \lambda_t P$. Let N_t be the number of firms operating at time t. The law of motion governing the number of firms is given by:

$$N_{t+1} = (1 - \delta_n) \cdot (N_t + \lambda_t P) \tag{5}$$

with $\delta_n \in [0,\ 1]$ denoting the probability of firm exit.

3.1.4 Firm problem

All firms are identical and operate within a competitive goods market. Each firm produces output y_t that can serve as both consumption or capital good. Each firm hires capital k_t and labor l_t at the competitive market to produce output according to the decreasing returns-to-scale technology given by:

$$y_t = y(k_t, l_t) = A_t (k_t^{\alpha} l_t^{1-\alpha})^{\omega} \tag{6}$$

Here, ω is the returns-to-scale parameter and α is the capital intensity of the production technology. The decreasing returns to scale bring back the meaningful notion of firm size into the RBC model. The firm profit is given by:

$$\pi_t = A_t (k_t^{\alpha} l_t^{1-\alpha})^{\omega} - w_t l_t - r_t k_t - f \tag{7}$$

where f denotes fixed costs paid by the operating firm regardless of the production level. This fixed cost makes the firm entry decision irreversible (see Fajgelbaum et al. (2017)).[9]

The present value of a firm is given by its expected discounted stream of profits:

$$F_t = E_t \sum_{s=t}^{\infty} (1 - \delta_n)^{s-t} Q_{t,s} \pi_s \tag{8}$$

[8] The restricted number of potential entrants is the only deviation from the perfect competition we introduce into the model. We assume that the number of firms is still large enough to ensure that each firm can be viewed as "atomistic". For this reason, we abstract from the issues of strategic market entry and capture under oligopoly, discussed in the industrial organization literature (Spence, 1977; Gilbert and Newbery, 1982; Dixit, 1980; Lieberman and Montgomery, 1988; Tirole, 1988).

[9] Bilbiie et al. (2012) point out the difficulty of various models in replicating strong pro-cyclicality of profits observed in the data. In our model, profits result from the decreasing returns-to-scale assumption and are perfectly pro-cyclical since decreasing returns-to-scale imply $\pi_t = (1 - \omega) y_t - f$. Moreover, our model features constant markups $1/\omega$ computed as an inverse of the real marginal cost.

where $Q_{t,s}$ is a stochastic discount factor defined as $Q_{t,s} \equiv \beta^{s-t} u'_C(C_s, L_s)/u'_C(C_t, L_t)$, which corresponds to the stochastic discount factor of a household between periods t and s. The term $(1-\delta_n)^{s-t}$ is the probability that a firm survives until the period s.

Each period, firms choose labor l_t and capital k_t to maximize the expected discounted stream of profits. The resulting first-order conditions are standard and give rise to the labor and capital demand equations: $y_l(k_t, l_t) = w_t$ and $y_k(k_t, l_t) = r_t$.

3.1.5 Entrant problem

All potential entrants are ex-ante identical. Each potential entrant chooses between immediate entry and postponement of the entry decision until the next period. The value function of a potential entrant is defined as

$$V_t = \max\{F_t^E, F_t^W\} \tag{9}$$

$$F_t^E = E_t(1-\delta_n)Q_{t,t+1}F_{t+1} \tag{10}$$

$$F_t^W = E_t Q_{t,t+1} V_{t+1} \tag{11}$$

where F_t^E is the value in case of entry in period t, and F_t^W is the value in case of postponement of the entry decision for one additional period. In the case of entry, a new firm is created and starts production in the next period. The value of entry is the expected discounted next-period firm value, as production by the new firm starts in the period following the entry period. In the case of waiting, the corresponding value is the expected discounted next-period value of a potential entrant. A potential entrant decides to start a firm if the value of immediate entry, F_t^E, exceeds the value of waiting, F_t^W. Conversely, the entrant chooses to wait if F_t^E is smaller than F_t^W. When F_t^E equals F_t^W, the potential entrant is indifferent between waiting and entering.

If the number of potential entrants is sufficiently large, that is, as $P \to \infty$, then the free-entry condition $F_t^E = F_t^W$ should hold for all t. In this case, the value of waiting is zero at all times. To see this, note that with free entry, we can express $V_t = F_t^E = F_t^W = E_t Q_{t,t+1} V_{t+1}$. By iterating forward, we find $V_t = \lim_{k\to\infty} E_t Q_{t,t+k} V_{t+k} = 0$.[10] Restricting the number of potential entrants leaves the profit opportunities unexploited, at least in some periods, which, in turn, activates the waiting option. With the waiting option, the individual entry rule becomes stricter, as the value of entry must now be greater than the value of waiting, which is greater or equal to zero $F_t^E \geq F_t^W \geq 0$.

[10] Bilbiie et al. (2012) use similar reasoning to show that the free-entry condition shuts down the waiting option channel in their model.

3.1.6 Equilibrium

Definition 1. *An intertemporal competitive equilibrium consists of consumption* $\{C_t\}_{t=0}^{\infty}$*, labor* $\{L_t\}_{t=0}^{\infty}$*, capital* $\{K_t\}_{t=0}^{\infty}$*, firm-specific capital* $\{k_t\}_{t=0}^{\infty}$*, firm-specific labor* $\{l_t\}_{t=0}^{\infty}$*, number of firms* $\{N_t\}_{t=0}^{\infty}$*, the fraction of firm entrants* $\{\lambda_t\}_{t=0}^{\infty}$*, wages* $\{w_t\}_{t=0}^{\infty}$*, interest rates* $\{r_t\}_{t=0}^{\infty}$ *and the value functions* $\{F_t\}_{t=0}^{\infty}$*,* $\{F_t^E\}_{t=0}^{\infty}$*,* $\{F_t^W\}_{t=0}^{\infty}$*,* $\{V_t\}_{t=0}^{\infty}$ *such that*

1. *This path is consistent with the optimal behavior of households, firms, and potential entrants*

2. *The factor markets clear, that is* $K_t = k_t N_t$ *and* $L_t = l_t N_t$ *for all* t

3. *Share of entrants* λ_t *is consistent with individual entry decisions*[11]

$$\lambda_t = \begin{cases} 0, & \text{if } F_t^E < F_t^W \\ (0,\ 1) & \text{if } F_t^E = F_t^W \\ 1 & \text{if } F_t^E > F_t^W \end{cases} \tag{12}$$

   and the firm dynamics equation 5 is satisfied.

4. *The economy's resource constraint holds*

$$C_t + K_{t+1} + f \cdot N_t = N_t A_t (k_t^{\alpha} l_t^{1-\alpha})^{\omega} + (1 - \delta_k) K_t \tag{13}$$

3.2 Calibration

One period in the model corresponds to one quarter in the data. We calibrate the parameters of the TFP process to match a set of four empirical moments: the variance of the TFP series, the first-order autocovariance of the TFP series, and the share of forecast error variance of TFP attributed to news shocks at middle- and long-run horizons. We compute the variance and first-order autocovariance of TFP from the linearly detrended, utilization-adjusted TFP series constructed by Fernald (2014). We take the forecast error variance shares attributed to news from Barsky and Sims (2011)[12]. The calibrated parameter values are $\rho_a = 0.97$, $\rho_g = 0.9$, $\sigma_a = 0.009$, and

[11] Note that while all potential entrants are ex-ante identical, only a fraction of them enters ex-post in equilibrium. This structure borrows from the information acquisition literature, including works by Grossman and Stiglitz (1980), Benhabib et al. (2016), Fajgelbaum et al. (2017), and allows for a clear definition of equilibrium without imposing any additional assumptions.

[12] We use $h = 8$ as a middle-run horizon and $h = 40$ as a long-run horizon. The forecast error variance shares, which are 0.126 and 0.454 respectively, are taken from Table 1 of Barsky and Sims (2011).

$\sigma_g = 0.001$. We normalize $\bar{A} = 1$.

We parameterize the utility function as Greenwood–Hercowitz–Huffman (GHH) utility (Greenwood et al. (1988)) with a relative risk aversion of 1: $U(C_t, L_t) = ln\left(C_t - \frac{L_t^{1+1/\varphi}}{1+1/\varphi}\right)$. The GHH form of the utility function allows for avoiding the recessionary effects of good news by eliminating the effect of consumption on the labor supply schedule, as discussed in detail by Jaimovich and Rebelo (2009).

We set $\varphi = 0.54$, corresponding to the Frisch elasticity over the intensive margin as reported by Chetty et al. (2011). We set the returns-to-scale parameter to $\omega = 0.89$, consistent with the value-added returns-to-scale estimate provided by Basu and Fernald (1997). The Cobb-Douglass production function parameter is $\alpha = 0.275$, ensuring that $\omega(1-\alpha)$ matches the average labor share from 1950 to 2019 as reported by the Penn World Tables. The discount rate $\beta = 0.987$ is selected to match the US average yearly real interest rate of 3.7% from 1961 to 2021, as reported by the World Bank. Following Kydland and Prescott (1982), we set the quarterly depreciation rate of capital δ to 2.5%. We calibrate the quarterly firm exit rate $\delta_n = 0.026$ based on the average yearly firm exit rate of 10.4% from the Business Dynamics Statistics Datasets by the United States Census Bureau between 1978 and 2021[13].

We normalize the number of potential entrants in each period to $P = 1$ and calibrate the fixed cost to match the targeted ratio of potential entrants to actual entrants in the steady state[14]. The targeted ratio of potential entrants to actual entrants is 14.241, representing the maximum ratio of business applications to projected business formations within four quarters as reported by the Business Formation Statistics (BFS) of the US Census.[15] Table 1 summarizes the model calibration.

We solve the model numerically using the policy function algorithm similar to Fajgelbaum et al. (2017). The solution details are provided in Appendix B. Next, we turn to the quantitative assessment of the model.

[13]While we are using the firm entry series by combining data from the Bureau of Economic Analysis and the Bureau of Labor Statistics, this dataset does not include information on firm exit rates. To calibrate the firm exit rate, we use the Business Dynamics Statistics dataset, where the firm exit rate is available at a yearly frequency. We then assess the robustness of our main results to changes in this parameter.

[14]Rescaling the number of potential entrants requires recalibrating the entry cost to achieve the same firm entry outcome, as discussed in Fajgelbaum et al. (2017).

[15]Business applications refer to the number of applications for the tax ID, while business formations indicate the number of new businesses identified by the first instance of payroll tax liability.

Table 1: Model calibration

(a) Panel A: Parameters taken from the literature and data

Symbol	Parameter name	Parameter value	Source
φ	Inv. Frisch elasticity	0.54	Chetty et al. (2011)
ω	Returns to scale	0.89	Basu and Fernald (1997)
α	Technology parameter	0.275	Penn World Tables (labor share)
β	Discount factor	0.987	World Bank (interest rate)
δ	Capital depreciation	0.025	Kydland and Prescott (1982)
δ_n	Firm exit rate	0.026	U.S. Census
$\bar{A}$	Steady-state TFP	1	normalization
$\bar{P}$	Potential entrants	1	normalization

(b) Panel B: Parameters chosen to match targets

Symbol	Name	Parameter value
ρ_a	TFP autocorrelation	0.97
σ_a	TFP st. deviation	0.009
ρ_g	TFP growth autocorrelation	0.9
σ_g	TFP growth st. deviation	0.001
f	Fixed cost parameter	0.1

(c) Panel C: Targets

Target description	Target value	Target data source
Variance of TFP	0.0031	Fernald (2014)
Autocovariance of the TFP	0.0030	Fernald (2014)
TFP share attr. to news at h=8 quarters	0.126	Barsky and Sims (2011)
TFP share attr. to news at h=40 quarters	0.454	Barsky and Sims (2011)
Ratio of potential to actual entrants	14.241	US Census

4 Quantitative results

Now we assess the model's ability to account for the joint volatility of capital investment and firm entry series, both unconditionally and in response to shocks. For this purpose, we conduct corresponding unconditional and conditional model simulations (see Appendix B for details of the simulation algorithm). To isolate the role of the waiting option, we also run an additional counterfactual simulation where we shut down the waiting option effect by using the alternative entry rule $F_t^E \geq 0$ (as opposed to $F_t^E \geq F_t^W$ of the baseline model).

4.1 Business cycle moments

We begin by comparing the business cycle moments generated in our baseline model with those in the US data, as well as with the counterfactual model without the waiting option (but with a restricted number of potential entrants).[16] Table 2 reports the corresponding business cycle moments of the main macroeconomic variables as well as firm entry. Our baseline model reasonably matches the volatility and persistence of output, consumption, and capital investment, but falls short of capturing the volatility of hours, which is a recognized limitation in RBC models (King and Rebelo, 1999).

Notably, our baseline model matches the empirical volatility and persistence of the firm entry series. The quantitative success of the model in matching the volatility of firm entry is attributed to two features: a limited number of potential entrants and the presence of a waiting option. To illustrate, let us examine an alternative simulation in which we shut down the waiting option but maintain the limited number of potential entrants. Remarkably, without the waiting option, firm entry volatility nearly doubles, and the persistence of firm entry increases, diverging from the patterns observed in the data. Besides, suppressing the waiting option marginally degrades the quantitative performance of output and investment series.

Additionally, we consider another counterfactual scenario where we shut down the waiting option and eliminate the restriction on the number of potential entrants, essentially reverting to a "free entry" model. Simulating this model generates even greater volatility in firm entry, significantly exceeding the volatility observed in the US data.

Finally, Table 2 reports the business cycle moments in a standard RBC model, as computed in the seminal paper by King and Rebelo (1999). We see that the behavior of standard macroeconomic variables in our model is in line with the standard RBC model. Specifically, consumption is less volatile than output, output is approximately three times less volatile than capital investment, and the volatility of hours is dampened compared to the data.

[16] The data sources are reported in Appendix A.

Table 2: Unconditional business cycle moments

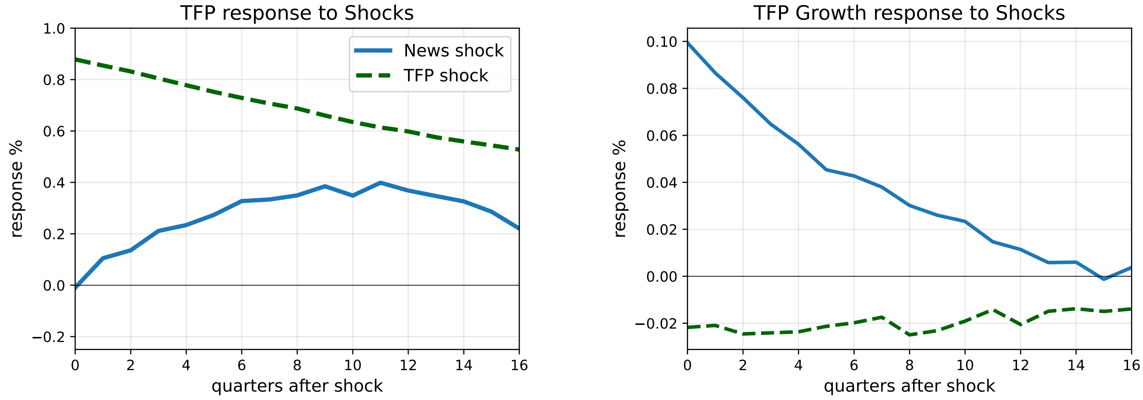
	Y	C	I	L	λ
Standard Deviation					
US Data	1.41	1.14	6.35	1.79	3.98
Baseline model	1.60	0.94	6.94	0.56	3.57
No waiting option	1.66	1.10	7.61	0.58	6.29
Free entry model	1.82	1.26	5.45	0.64	23.61
Standard RBC (King and Rebelo, 1999)	1.39	0.61	4.09	0.67	-
Autocorrelation (1st order)					
US Data	0.87	0.87	0.82	0.91	0.68
Baseline model	0.74	0.79	0.71	0.74	0.78
No waiting option	0.76	0.81	0.71	0.76	0.89
Free entry model	0.82	0.92	0.72	0.76	0.01
Standard RBC (King and Rebelo, 1999)	0.72	0.79	0.71	0.71	-

This table displays business-cycle moments for quarterly output (Y), consumption (C), investment (I), hours worked (L), and firm entry (λ). The model moments are calculated from HP-filtered series produced via model simulations. The HP filter parameter is set to 1600. The period used for data moments is 1961Q1:2019Q4. The moments for the standard RBC model are taken from King and Rebelo (1999).

4.2 Impulse response and the role of waiting option

Next, we will examine the model response of firm entry and capital investment to a news shock and a conventional productivity shock (TFP shock). But before doing so, it is important to clarify the difference between these two shocks, which is key to understanding our results. The fundamental distinction between news and productivity shocks lies in their effect on the subsequent dynamics of TFP. As depicted in the left panel of Figure 4, the impact of a news shock on TFP unfolds progressively over time, with no immediate contemporaneous effect. In contrast, a conventional productivity shock (TFP shock) generates a maximum change in TFP upon impact, followed by subsequent gradual attenuation.

Figure 4: News shock vs. TFP shock

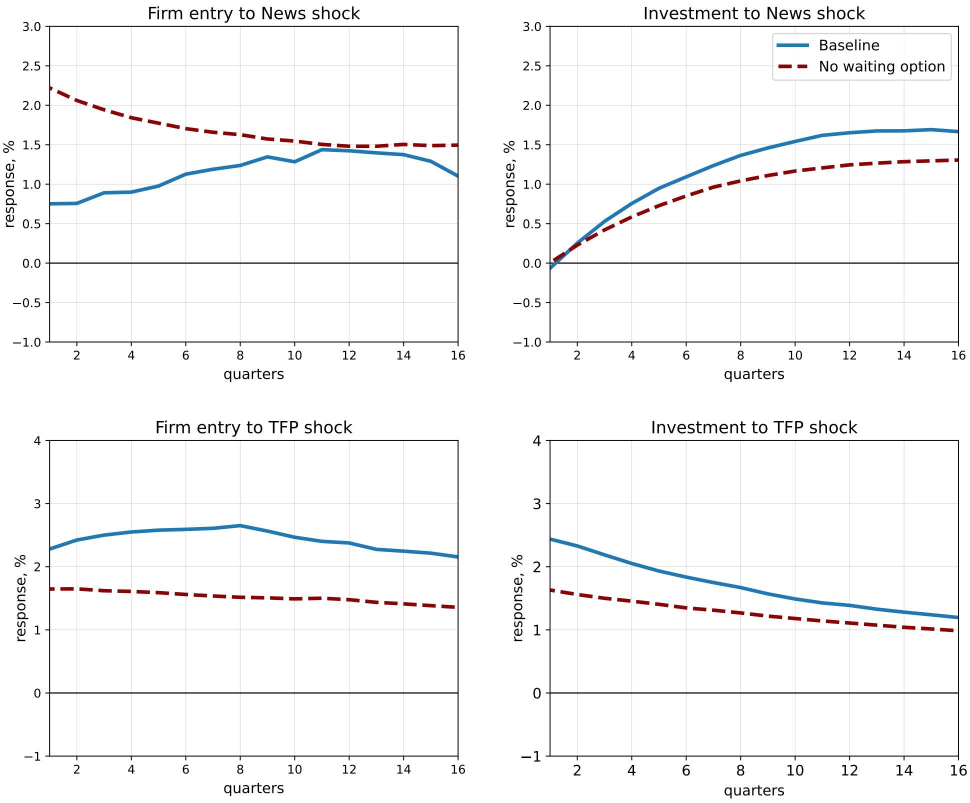


This figure shows the generalized impulse response of total factor productivity (TFP) and its growth rate to a productivity news shock and a conventional productivity shock (TFP shock).

The distinct TFP paths following each of these two shocks have significant implications for the TFP growth rate. As the right panel of Figure 4 shows, following a positive news shock, the TFP growth rate is positive and large, whereas, after a positive productivity shock, the TFP growth rate is negative (but rather small due to large TFP persistence). This distinction is crucial for the role of the waiting-option effect in shaping the firm entry response to each of these two shocks. The reason is that the waiting option is sensitive to the *growth rate* of productivity rather than its level, as we will show analytically in the next section.

Figure 5 shows the impulse response of firm entry and capital investment to a news shock and a productivity shock in the baseline model. It also depicts the counterfactual response with no waiting option effect (while keeping the restricted number of potential entrants). When comparing the baseline response with the no-waiting-option response, we observe that the presence of a waiting option strongly dampens the response of firm entry to a news shock but somewhat amplifies its response to a conventional productivity shock. Why does the waiting option dampen the firm entry response to a news shock but amplify the response to a conventional productivity shock? The answer lies in the dynamics of the TFP growth following each of these shocks. Following a positive news shock, the expected future TFP exceeds the current TFP, making waiting more appealing. In contrast, after a positive productivity shock, the expected future TFP falls below the present TFP, diminishing the attractiveness of waiting. In the next section, we will further explain this mechanism within an analytical real option model. Note that the firm entry delay option somewhat amplifies the response of capital investment to both shocks due to the presence

Figure 5: Model response to news shock and TFP shock



The black line in this figure shows the model's generalized impulse response of firm entry and capital investment to a news shock and a conventional productivity shock. The green line plots the counterfactual impulse response obtained under the firm entry rule which excludes the waiting option $F_t^E \geq 0$ (as opposed to $F_t^E \geq F_t^W$ of the baseline model). See Appendix B for the impulse response computation details.

of equilibrium effects and non-linearities.

Addtitional excersises. In Appendix B, we report the impulse response of other macroeconomic variables – output, consumption, and hours – to news and productivity shocks. Similarly to capital investment, the entry delay option somewhat alters the equilibrium dynamics of these variables. However, as we saw above, this alteration does not worsen the model's performance in matching the key business cycle moments.

In addition, in Appendix B, we evaluate the sensitivity of the firm entry response to news shocks to changes in various model parameters: exit rate, labor supply elasticity, TFP volatility, mass of potential entrants, and alternative CRRA preferences. We also perform welfare analysis, which reveals that the presence of an entry delay option leads to suboptimally low entry.

5 Understanding the role of waiting option

So far, we have shown quantitatively that incorporating the entry delay option into firm-entry decisions within the news-driven RBC model reduces the responsiveness of firm entry to news shocks. The entry delay option substantially improves the quantitative performance of the model in replicating the volatility of firm entry observed in the US data. However, what precisely is the mechanism through which the waiting option shapes firm entry dynamics? In this section, we develop intuition about our quantitative results using an analytical real-option model in the spirit of McDonald and Siegel (1986). Specifically, we demonstrate that (i) following a news shock, the presence of an entry delay option diminishes firms' incentive to enter compared to the case with no such option, and (ii) while the volatility of firm entry conditional on a news shock is reduced by the presence of the waiting option, no such effect occurs for other shocks.

5.1 Waiting option and incentive to enter

We begin by considering the problem of a single potential entrant, similar to the one described in Section 4.[17] A potential entrant contemplates the opportunity to start a firm, which requires the payment of a sunk entry cost of I. Once the entry cost is paid, the firm starts operating and receives a stream of stochastic payoffs X_t throughout the period T, where T represents the lifespan of the firm.

The expected present value of a firm entering at date t and the corresponding payoff process are given by:

$$F_t = E_t\left[\int_t^{t+T} e^{-r(s-t)} X_s ds\right] \tag{14}$$

$$dX_t = \mu dt + \sigma d\mathcal{E}_t,\ d\mathcal{E}_t \sim \mathcal{N}(0, dt) \tag{15}$$

where r denotes the rate of time discounting, and E_t denotes the expectation at date t over possible future realizations of payoff X_s. Payoff follows a drift-diffusion process; $\mathcal{E}_t$ denotes the Wiener process, and the initial value X_0 is given. The diffusion parameter σ represents the uncertainty regarding the future payoff level, while the

[17] To provide an analytical characterization of the waiting option, we switch to continuous time.

drift term μ indicates the expected growth rate of payoff. Similarly to our quantitative model, news about the future corresponds to changes in the growth rate μ.

The potential entrant tracks the firm value F_t and decides whether to enter or wait. The value function of the potential entrant is given by:

$$V(F_t) = \max\{\underbrace{F_t - I}_{\text{enter}}, \underbrace{E_t e^{-rdt} V(F_{t+dt})}_{\text{wait}}\} \tag{16}$$

When comparing Equation 16 with the entrant problem outlined in Equations 9-11 of Section 3, it is apparent that they are nearly equivalent, both representing the firm entry problem under uncertain future payoffs and the possibility of an entry delay.

Let the optimal entry threshold be denoted as $F^\star$. This threshold describes the optimal policy governing firm entry: wait if $F_t < F^\star$ and enter if $F_t \geq F^\star$. As is detailed in Appendix C, solving the entrant problem demonstrates that the optimal entry threshold is given by $F^\star = I + W_t$. That is, for entry to be considered optimal, the expected present value of a firm should exceed the entry costs by (at least) W_t. The wedge W_t arises due to the possibility of an entry delay and represents the value of the waiting option, that is, the additional compensation a potential entrant requires to forego the option of delaying entry.

Now we introduce the notion of the incentive to enter. Let the incentive to enter, denoted as I_t (with a time subscript), be the maximum entry cost that a potential entrant is willing to pay to start a firm immediately, given the current firm value F_t. The incentive to enter obtains by substituting F_t for $F^\star$ and is given by

$$I_t = \underbrace{F_t}_{\text{firm value}} - \underbrace{W_t}_{\text{waiting value}} \tag{17}$$

where firm value and waiting value have closed-form solutions:

$$F_t = \mathcal{A}(r,T)X_t + \mathcal{B}(r,T)\mu \tag{18}$$

$$W_t = \frac{\mathcal{A}(r,T)}{2r}(\mu + \sqrt{\mu^2 + 2r\sigma^2}) \tag{19}$$

with $\mathcal{A}(r,T) = \frac{1-e^{-rT}}{r} \geq 0$ and $\mathcal{B}(r,T) = \frac{1-e^{-rT}(rT+1)}{r^2} \geq 0$ depending on the discount rate r and the firm lifespan T. See Appendix C for detailed derivations.

The incentive to enter measures the willingness to start a firm immediately. A high incentive to enter indicates that a potential entrant is willing to pay a significant entry cost to start operating immediately. Equation (17) implies that the impact of news (or any other shock) on the incentive to enter comprises two underlying effects: the impact of a shock on firm value F_t, and on the waiting value W_t. We refer to the first effect as "the firm-value effect" and the second effect as "the waiting-option effect".

The following Proposition characterizes the impact of news on the incentive to enter through these two underlying effects:

Proposition 1 (Firm value/waiting option effects of news). *Let the effect of news on the incentive to enter be denoted by $\frac{\partial I_t}{\partial \mu}$. This effect amounts to the difference between the firm value effect and the waiting option effect $\frac{\partial I_t}{\partial \mu} = \frac{\partial F_t}{\partial \mu} - \frac{\partial W_t}{\partial \mu}$.*

The firm value effect is always positive, i.e., $\frac{\partial F_t}{\partial \mu} \geq 0$. The waiting option effect is also always positive, i.e., $\frac{\partial W_t}{\partial \mu} \geq 0$. For long-duration projects (T is large) firm value effect dominates the waiting option effect.

For the proof, we refer the interested reader to Appendix C. Proposition 1 indicates that both the firm value effect and the waiting option effect of news are positive, suggesting that the overall impact of news on the incentive to enter, represented by $\frac{\partial I_t}{\partial \mu}$, hinges on the dominance of either force. The presence of a waiting option diminishes and might even potentially reverse the effect of news on the incentive to enter. For long-lived projects the firm value effect dominates and the overall effect of news on the incentive to enter is positive though still dampened by the presence of a waiting option; this is the case of our quantitative model in the previous section, where $T \to \infty$.

5.2 Equilibrium firm entry

So far, we have illustrated the behavior of a single potential entrant facing an exogenous stream of payoff X_t. Now, we explore the role of the waiting option in a setting where multiple firms can enter the market. To this end, we assume that there are $\bar{n}$ potential entrants contemplating entry. In equilibrium, only a subset of them, $n \leq \bar{n}$, actually enters the market. The existence of an upper limit on the number of potential firm entrants distinguishes our setup from free entry models. Henceforth, we assume that the total economy's payoff, denoted as X_t, is distributed among n firms. As a result, each firm faces a payoff of $x_t = \frac{X_t}{n}$. Consequently, the dynamics of each firm's payoff can be represented as a drift-diffusion process:

$$dx_t = \tilde{\mu} dt + \tilde{\sigma} d\mathcal{E} \tag{20}$$

where $\tilde{\mu} = \frac{\mu}{n}$ and $\tilde{\sigma} = \frac{\sigma}{n}$, reflecting the scaled-down drift and volatility terms due to the division of payoff by the number of operating firms, n. Given the firm-specific drift-diffusion process, the problem faced by potential entrants remains equivalent to the one described above.

The individual firm value, denoted as f_t, and the waiting option value, denoted by w_t, are obtained by replacing X_t, μ, and σ with x_t, $\tilde{\mu}$, and $\tilde{\sigma}$ in Equations (18) and (19). This substitution results in:

$$f_t = \frac{F_t}{n} \tag{21}$$

$$w_t = \frac{W_t}{n} \tag{22}$$

where F_t and W_t are the aggregate firm value and waiting value, respectively, and they do not depend on the number of entrants, n.

Let the entry cost be the same for every firm and denoted as I. New firms enter as long as the difference between the firm value and the waiting value is greater than or equal to the entry cost ($f_t - w_t \geq I$), and the number of firms is less than or equal to the maximum number of potential entrants ($n \leq \bar{n}$). In other words, firm entry ceases either because all potential entrants have entered and $n = \bar{n}$, or because it is no longer optimal to enter ($f_t - w_t < I$). Next, we establish the equilibrium number of entrants in this economy.

Proposition 2 (Equilibrium number of entrants)**.** *Let $F_t - W_t > I$, that is, it is optimal to have at least one firm, $n \geq 1$. Then, the equilibrium firm entry is*

$$n = \begin{cases} \frac{F_t - W_t}{I} & \text{for } \frac{F_t - W_t}{I} \leq \bar{n} \\ \bar{n} & \text{otherwise} \end{cases} \tag{23}$$

This equilibrium is unique.

See proof in Appendix C.

Equation (23) demonstrates that the equilibrium number of firms depends positively on the economy-wide incentive to enter, defined as $I_t = F_t - W_t$. When the aggregate incentive to enter is low, equilibrium firm entry is also low, and vice versa. In Appendix C we show that the the waiting option W_t becomes zero only if the number of potential entrants is unrestricted. Restricting the number of potential entrants by $\bar{n}$ results in non-zero waiting value due to the unexploited profit opportunities.

Finally, we characterize the effect of the waiting option on the volatility of firm entry. Assume that the number of potential entrants, denoted as $\bar{n}$, is sufficiently large to yield an equilibrium firm entry given by $n = \frac{F_t - W_t}{I}$ at the present moment t (but not necessarily in the future periods). Consider the following small independent variations in the level of payoff, its growth rate, and risk: dX_t, $d\mu$, $d\sigma$. The corresponding variation in firm entry is:[18]

$$dn = \frac{1}{I} \cdot \underbrace{\left(\frac{\partial F_t}{\partial \mu} - \frac{\partial W_t}{\partial \mu}\right) d\mu}_{\text{news shock}} + \frac{1}{I} \cdot \underbrace{\frac{\partial F_t}{\partial X_t} dX_t}_{\text{productivity shock}} - \frac{1}{I} \cdot \underbrace{\frac{\partial W_t}{\partial \sigma} d\sigma}_{\text{uncertainty shock}}$$

Applying the variance operator, we obtain the volatility of firm entry:

$$Var(n) = \frac{1}{I^2} \left\{ \left(\frac{\partial F_t}{\partial \mu} - \frac{\partial W_t}{\partial \mu}\right)^2 Var(d\mu) + \left(\frac{\partial F_t}{\partial X_t}\right)^2 Var(dX_t) + \left(\frac{\partial W_t}{\partial \sigma}\right)^2 Var(d\sigma) \right\}$$

The above equations establish a connection between the volatility of firm entry and the volatility of the payoff level, growth rate, and risk. We see that the firm entry volatility induced by news shocks (changes in the growth rate $d\mu$) is shaped by the difference between the firm-value effect and the waiting-option effect of news. The presence of the waiting option ($\frac{\partial W_t}{\partial \mu} > 0$) dampens the response of firm entry to news shocks.

At the same time, the waiting option does not affect the firm entry response to a contemporaneous payoff shock dX_t, which corresponds to a conventional productivity shock in our quantitative RBC model. The reason is that a shock to the payoff level does not induce the change in the growth rate necessary to create additional waiting value.[19] As a result, the firm entry response to the payoff level shock is shaped uniquely by the firm-value effect, and the waiting option plays no role. In contrast, the firm entry volatility induced by risk shocks $d\sigma$ (uncertainty shocks) depends uniquely on the waiting-option effect and does not depend on the firm-value effect. The reason is that firms are risk-neutral, meaning that the waiting option is the only channel through which uncertainty affects the firm entry behavior in this model.

To summarize, the ability of the waiting option to dampen firm entry volatility pertains only to news-driven fluctuations. Other potential sources of fluctuations do not allow the waiting option to exert a dampening effect. Therefore, the larger the

[18] $\frac{\partial W_t}{\partial X_t} = 0$ since the value of waiting does not depend on the current level of payoff; $\frac{\partial F_t}{\partial \sigma} = 0$ since firm value does not depend on uncertainty. See Equations 18, 19.

[19] Here, the current payoff innovations are fully permanent and do not affect the growth rate. In the RBC model of the previous section, the calibrated productivity process is persistent but not fully permanent, and as a result, a positive productivity shock induces a slightly negative subsequent growth rate.

share of news shocks in the business cycle, the less volatile firm entry becomes.

6 Conclusion

This paper analyzes the role of the entry delay option in shaping the business cycle dynamics of firm entry within a news-driven RBC model. We show that the combination of the waiting option and a news-driven business cycle can explain the relatively low observed volatility of firm entry compared to capital investment.

Our news-driven RBC model features both firm entry and capital investment, enabling us to compare the behavior of these two series. We demonstrate that the firm entry delay option is a crucial component for jointly matching the business cycle volatility of firm entry and capital investment. Without the entry delay option, the model produces excessive volatility of firm entry even with a restricted number of potential entrants. Furthermore, we show that the presence of a waiting option dampens the response of firm entry to a news shock but has no such effect in the case of productivity shocks.

To understand our quantitative results, we then analytically characterize the mechanism behind the waiting-option effect of news shocks within a tractable real-option model. We demonstrate that the impact of news on firm entry amounts to the difference between two underlying effects: the firm-value effect and the waiting-option effect. Positive news increases both the firm value and the value of waiting, with the latter causing a dampening of the firm entry response to the news shock. Additionally, we illustrate that this dampening effect occurs exclusively for news shocks and not for other types of shocks.

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News and firm entry over the business cycle: the role of waiting option
Appendix

Anastasiia Antonova and Mykhailo Matvieiev

A Motivating evidence appendix

A.1 Data description

In this appendix, we describe the data used for calibration, computation of empirical business cycle moments, identification of a productivity news shock, and local projection estimation.

Total factor productivity. Utilization-adjusted TFP series are from Fernald (2014). Retrieved from https://www.johnfernald.net/TFP.

Firm entry. Firm entry variable is the number of new businesses formed within a given quarter. Following Brand et al. (2019) we construct a long quarterly series of business creation. The first part, covering the period 1948Q1 to 1994Q4, uses "New Business Incorporations" data from the Survey of Current Business by the Bureau of Economic Analysis (available at the Federal Reserve Bank of St. Louis https://fraser.stlouisfed.org/). We convert this monthly data to quarterly by summing up the number of new businesses created in all months within a quarter. The second part, spanning 1995Q1 to 2021Q1, uses "Number of Establishments Births" data from the Bureau of Labor Statistics.

SP500. Real SP500 stock price index is from Robert Shiller website. Available at monthly frequency. We convert it to quarterly frequency by taking the last month of observation for each quarter.

The following variables are all retrieved from FRED, Federal Reserve Bank of St. Louis https://fred.stlouisfed.org/.

Consumption. Real Personal Consumption Expenditures from the U.S. Bureau of Economic Analysis

Investment. Real Gross Private Domestic Investment from the U.S. Bureau of Economic Analysis

Output. Real Gross Domestic Product from the U.S. Bureau of Economic Analysis

Hours. Nonfarm Business Sector: Hours Worked for All Employed Persons from the U.S. Bureau of Labor Statistics

CPI. Personal Consumption Expenditures: Chain-type Price Index from the U.S. Bureau of Economic Analysis

All series are transformed into logarithms.

A.2 Estimation strategy

We identify productivity news shock within a structural VAR model using the identification strategy of Barsky and Sims (2011). We now describe the strategy. Consider a reduced-form VAR model $\boldsymbol{y_t} = V\boldsymbol{y_{t_1}} + \boldsymbol{u_t}$, where $\boldsymbol{y_t}$ is a vector of variables and $\boldsymbol{u_t}$ are reduced form innovations. Note that VAR of any order can be represented as VAR(1). Next, we follow Barsky and Sims (2011) notation. VAR can be represented as a moving average form as:

$$\boldsymbol{y_t} = B(L)\boldsymbol{u_t}$$

where $B(L)$ is a corresponding lag-polynomial. The reduced form innovations are related to structural innovations as $\boldsymbol{u_t} = A\boldsymbol{\epsilon_t}$. The variance-covariance matrix of $\boldsymbol{u_t}$ is $\Sigma = A'A$. Note, that matrix A is not unique and depends on the imposed identification.

For some arbitrary A satisfying $\Sigma = A'A$, the matrix AD is such that $D'D = I$ also satisfies this condition. The forecast error at horizon h is $\boldsymbol{y_{t+h}} - E_{t-1}\boldsymbol{y_{t+h}} = \sum\limits_{s=0}^{h} B_s AD\boldsymbol{\epsilon_{t+h-s}}$. The share of forecast error variance in variable i attributed to structural shock j is

$$\Omega_{i,j}(h) = \frac{\boldsymbol{e_i'}(\sum\limits_{s=0}^{h} B_s AD\boldsymbol{e_j}\boldsymbol{e_j'}D'A'B_s')\boldsymbol{e_i}}{\boldsymbol{e_i'}(\sum\limits_{s=0}^{h} B_s ADD'A'B_s')\boldsymbol{e_i}}$$

where $\boldsymbol{e_i}$ is a selection vector with i-th element equal 1 and the rest equal zero. Let A be the Choleski decomposition and denoting $\boldsymbol{\gamma} = D\boldsymbol{e_j}$ (j-th column of D); the forecast error variance share becomes a function of $\boldsymbol{\gamma}$. News shock is identified by solving the maximization problem

$$\begin{aligned}
\boldsymbol{\gamma}^\star &= \sum_{h=0}^{H} \Omega_{1,2}(h) \\
s.t.\ \boldsymbol{\gamma}'\boldsymbol{\gamma} &= 1 \\
A_{1,j} &= 0 \ for\ j > 1\ and\ \gamma(1,1) = 0
\end{aligned}$$

Where the productivity variable is denoted by 1 (ordered first) and news shock is denoted by 2 (ordered second). The first constraint ensures that D is an orthonormal matrix. The second and third constraints ensure that the news shock does not have a contemporaneous effect on productivity.

The identification of a contemporaneous productivity shock is via a standard Choleski decomposition of the variance-covariance matrix in a VAR, with the productivity variable and productivity shock ordered first, which is equivalent to setting $D = I$.

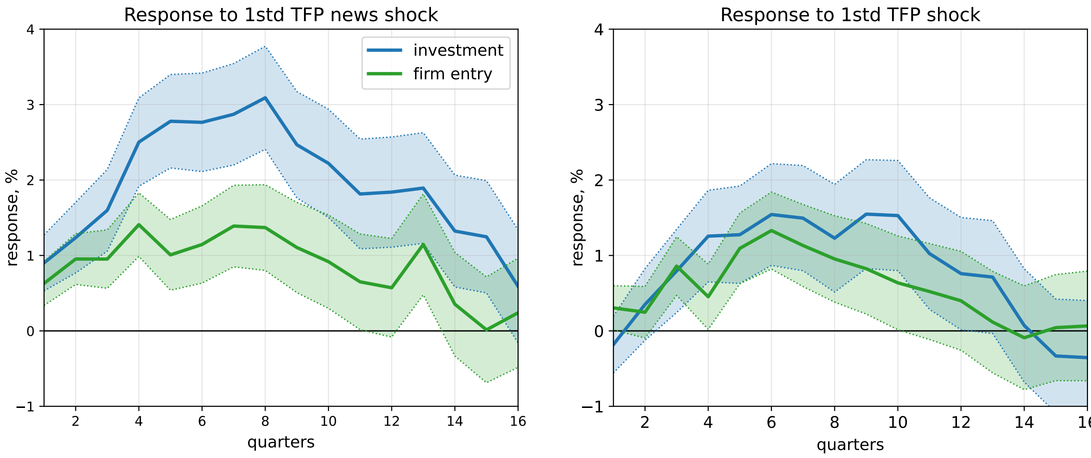
Having identified news shock ϵ_t^N and productivity shock ϵ_t^P, we estimate the response of firm entry and investment to each of these shocks using the local projection method (Jordà (2005)) with the following specification for the horizon h

$$y_{t+h} = \beta_0^h + \beta^h \cdot \epsilon_t^i + X_t + v_{t+h}$$

where $i = N,\ P$ and X_t represents the set of control variables.

A.3 Additional controls

Figure A.1: Response to productivity news and contemporaneous productivity shock

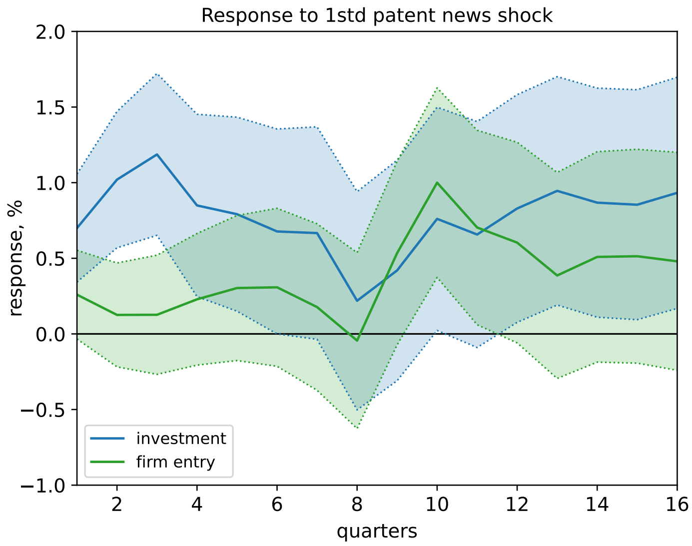


Impulse response to 1-standard deviation news and productivity shocks. The local projection specification controls for three lags of the firm entry and capital investments, three lags of productivity and news shocks, three lags of output, and a time trend.

A.4 Patent-based news

As a robustness check, we estimate the response of firm entry and investment to patent-based news shocks. We measure patent-based news shocks using data on patent grants from Cascaldi-Garcia and Vukotić (2022). Even though the response size differs from that to TFP news shocks, the investment series still exhibits a stronger reaction to this shock.

Figure A.2: Response to patent-based news



Patent-based news shock is from Cascaldi-Garcia and Vukotić (2022)

B Model appendix

B.1 Model solution algorithm

Our solution algorithm is similar to the one applied by Fajgelbaum et al. (2017). The state of the economy at time t is given by $(K_t,\ A_t,\ g_t,\ N_t)$. We solve the model by iterating over consumption policy $C(K, A, g, N)$ and firm entry policy $\lambda(K, A, g, N)$ until convergence. Within each step of these two policy iterations, we find the corresponding firm value and potential entrant value by iterating the corresponding value functions. Our iteration algorithm (for outer loops) consists of iterating over a Coleman-Reffett operator (Coleman (1990), Reffett (1996)). Our iteration for inner loops (step 3) relies on the standard value function iteration.

The numerical algorithm is as follows:

1. Guess initial n-policy and C-policy: $\lambda^0(K, A, g, N)$ and $C^0(K, A, g, N)$

2. For the current step policies $\lambda^i(K, A, g, N)$ and $C^i(K, A, g, N)$ and using the fact that all consumers and firms are identical, find $C^{i+1}(K, A, g, N)$ that solves the following equation

$$U'_C(C_t^{i+1}, L_t^i) = \beta E\{U'_C(C_{t+1}^i, L_{t+1}^i)(MPK(A_{t+1}, \frac{K_{t+1}^{i+1}}{N_{t+1}^i}, \frac{L_{t+1}^i}{N_{t+1}^i}) + (1-\delta_k))\} \quad \text{(B.1)}$$

where MPK is the marginal product of capital

$$MPK(A,k,l) = A\alpha\omega k^{\alpha\omega-1} l^{\omega(1-\alpha)}$$

and the next period capital K_{t+1}^{i+1} is

$$K_{t+1}^{i+1} = N_t A_t \left(\frac{K_t}{N_t}\right)^{\alpha\omega} \left(\frac{L_t}{N_t}\right)^{(1-\alpha)\omega} + (1-\delta_k)K_t - C_t^{i+1} - \lambda_t P \times I_t^E$$

Since both productivity shock and news shock are normally distributed, we approximate the expectation on the right hand side of (B.1) with the appropriate Gauss–Hermite quadrature. We solve the equation (B.1) using a non-linear solver.

3. Given the updated C-policy $C^{i+1}(K,A,g,N)$ and the current step λ-policy $\lambda^i(K,A,g,N)$, compute $F(k_t,K_t,A_t,g_t,N_t)$, $F^E(K_t,A_t,g_t,N_t)$ and $V(K_t,A_t,g_t,N_t)$ by iterating over the corresponding value functions until convergence.

4. Using the updated value functions from the previous step, update the firm entry policy $\lambda^{i+1}(K,A,g,N)$.

5. Return to the step 2 and repeat until both λ-policy and C-policy converge.

B.2 Model simulation algorithm

Here we describe the algorithm for model simulation.

1. Simulate the model for $t0 = 1000$ periods

2. Draw shock realizations $\{\epsilon_{g,t}\}_{t=t0+1}^{t0+H}$, $\{\epsilon_{a,t}\}_{t=t0+1}^{t0+H}$ from the respective distributions, where H is the impulse response horizon

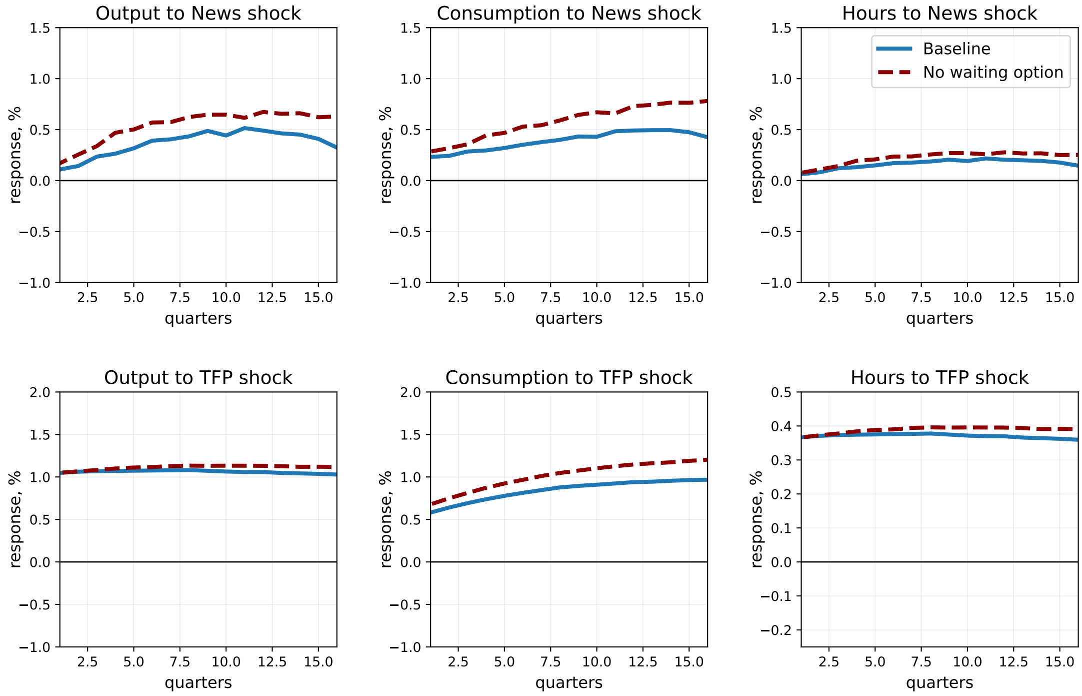
3. Create two simulations (to compute generalized IRF): in the simulation 1 set $\epsilon_{g,t0} = \sigma_g$, and in the simulation 2 set $\epsilon_{g,t0} = 0$ (for the TFP shock do the same but for the $\epsilon_{a,t0}$)

4. Compute the simulated paths for each of two simulations using the shocks from step 2

5. Compute the deviations of the paths obtained via simulation 1 from the paths obtained via simulation 2 to get the generalized impulse responses

6. Go to step 1 and repeat the procedure $N = 10000$ times. Then compute the average across simulations

Figure B.1: Model response to news shock and TFP shock



The green line plots the counterfactual impulse responses obtained under the firm entry rule that excludes the waiting option $F_t^E \geq 0$ (as opposed to $F_t^E \geq F_t^W$ in the baseline model). See Appendix B for the impulse response computation details.

B.3 IRF

B.4 Socially optimal firm entry rule

The restricted number of potential entrants makes equilibrium firm entry suboptimal from a social planner's perspective. Now, we describe the social planner's problem and derive the firm entry rule consistent with socially optimal firm entry. For the current analysis, we also allow the fixed cost to depend on the number of firms, considering the congestion externality frequently discussed in the literature.

The social planner maximizes household welfare subject to the resource constraint

$$W \equiv \max_{\{C_s, L_s, K_s, N_s\}_{s=t}^{\infty}} E_t \sum_{s=t}^{\infty} \beta^{s-t} u(C_s, L_s)$$

$$s.\ t.\ C_t + K_{t+1} + N_t \times f(N_t) = A_t N_t^{1-\omega} (K_t^{\alpha} L_t^{1-\alpha})^{\omega} + (1 - \delta_k) K_t$$

The first order condition with respect to the number of firms N_t is

$$N_t \times f'(N_t) + f(N_t) = (1-\omega) \cdot \frac{Y_t}{N_t} \tag{B.2}$$

The interpretation of Equation (B.2) is straightforward: per-firm profit should compensate for the additional fixed cost associated with an increased number of firms. Equation (B.2) yields the socially optimal number of firms N_t for a given output level Y_t.

Next, we demonstrate that the socially optimal firm entry choice is nearly equivalent to the free-entry condition. To maintain consistency with the market-based entry rules outlined in the previous section, we construct the socially optimal rule in terms of the entry value F_t^E. The following proposition establishes the socially optimal firm entry rule.

Proposition (Welfare optimal firm entry). *Socially optimal firm entry rule is*

$$F_t^E \geq E_t \sum_{s=t+1}^{\infty} (1-\delta_n)^{s-t} Q_{t,s} N_s f'(N_s) \geq 0$$

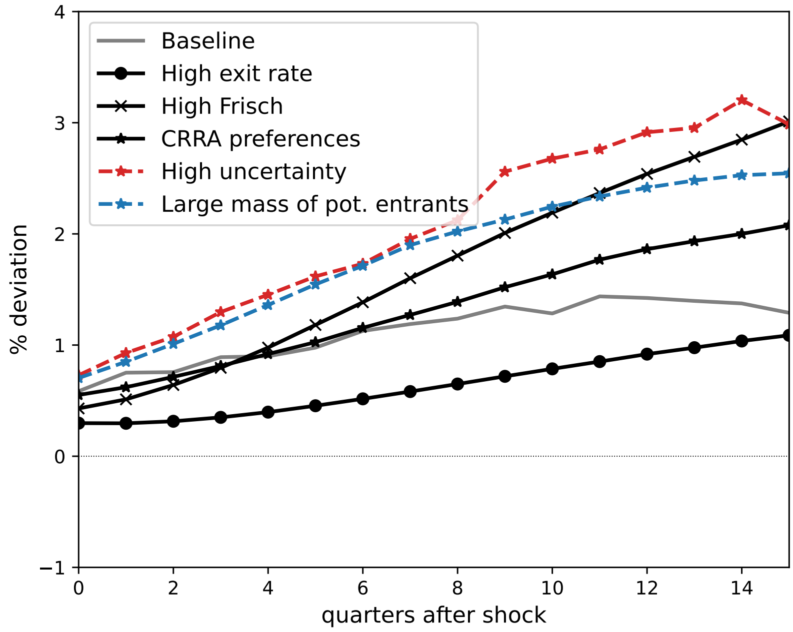
Proof. First, consider the case without congestion externality, that is $f'(N_t) = 0$. The condition for the welfare-maximizing number of firms becomes $f(N_t) = (1-\omega) \cdot \frac{Y_t}{N_t}$ for all t, which corresponds to the free-entry condition $F_t^E = 0$. To see this, observe that $\pi_t = (1-\omega) \cdot \frac{Y_t}{N_t}$ is per-firm profit since this is the output not going to the factors of production. The firm value then is $E_t(1-\delta_n)Q_{t,t+1}F_{t+1} = E_t \sum_{s=t+1}^{\infty}(1-\delta_n)^{s-t}Q_{t,s}\pi_s = E_t \sum_{s=t+1}^{\infty}(1-\delta_n)^{s-t}Q_{t,s}f(N_t) = I_t^E$, where the last equality follows from the definition of entry cost as a discounted sum of fixed costs. To recap, without congestion externality socially optimal firm entry is determined by the free-entry condition: $F_t^E = E_t(1-\delta_n)Q_{t,t+1}F_{t+1} - I_t^E \geq 0$. With the congestion externality, the socially optimal number of entrants is determined by $F_t^E = E_t \sum_{s=t+1}^{\infty}(1-\delta_n)^{s-t}Q_{t,s}N_s f'(N_s) > 0$. The last inequality follows from $f' > 0$.

Let us compare the socially optimal entry rule given by Proposition with the free-entry condition $F_t^E = 0$. Consider the case without congestion $f' = 0$, such that the socially optimal entry rule from Proposition becomes $F_t^E = 0$, which coincides with the free-entry condition. Not surprisingly, free entry is socially optimal if congestion is absent. Congestion effect $f' > 0$ introduces a negative externality in the individual firm entry decisions. With congestion, the socially optimal entry rule is $F_t^E > 0$, implying that the socially optimal number of entrants is lower than the free-entry condition implies. Quantitatively, the model-based welfare losses from not following the socially optimal firm entry rule are equivalent to a permanent decrease in consumption of about 2%.

B.5 Sensitivity checks

Now we check the sensitivity of the firm entry response to news shock to the calibration of model parameters. We check the sensitivity of the model firm entry response to changes in model design and calibration: high exit rate ($\delta_n = 0.06$), high Frisch elasticity ($\phi = 2$), CRRA preferences (with risk aversion parameter of 2), high uncertainty ("High uncertainty" corresponds to $3 \times \sigma$), large number of potential entrants ($2 \cdot P$); all IRFs are computed using the generalized IRF simulation

Figure B.2: Firm entry response to a news shock. Sensitivity to calibration



C Theoretical appendix

C.1 Model derivations and solution

The expected present value of a firm that enters at date t is:

$$F_t = E_t \left[\int_t^{t+T} e^{-r(s-t)} X_s ds \right] \tag{C.1}$$

Payoff X_t follows

$$dX_t = \mu dt + \sigma d\mathcal{E}_t, \; d\mathcal{E}_t \sim \mathcal{N}(0, dt) \tag{C.2}$$

Given the dynamics of payoff X_t (Equation C.2), we evaluate the expression for the firm value F_t (Equation C.1), yielding:

$$F_t = \mathcal{A}(r,T)X_t + \mathcal{B}(r,T)\mu \tag{C.3}$$

Here, $\mathcal{A}(r,T) = \frac{1-e^{-rT}}{r} \geq 0$ and $\mathcal{B}(r,T) = \frac{1-e^{-rT}(rT+1)}{r^2} \geq 0$ depend on the discount rate r and the firm lifespan T.

From Equation (C.3), it is evident that the firm value F_t is also a drift-diffusion process:

$$dF_t = \mathcal{A}(r,T)dX_t = \mu\mathcal{A}(r,T)dt + \sigma\mathcal{A}(r,T)d\mathcal{E}_t \tag{C.4}$$

The potential entrant tracks the firm value F_t and determines the optimal timing for entry. Let us denote the value function of a potential entrant by $V(F_t)$. For a potential entrant who decides to postpone her entry by at least a small period dt, the value function should satisfy:

$$V(F_t) = E_t e^{-rdt} V(F_{t+dt}) \tag{C.5}$$

This equation indicates that in the waiting region, the potential entrant's value today must equal her expected discounted value tomorrow as she receives zero payoff while waiting to enter.

Given the dynamics of F_t from Equation (C.3) and the value function from Equation (C.5), we obtain the differential equation for the entrant's value function, also known as the Hamilton-Jacobi-Bellman (HJB) equation

$$rV(F_t) = \mu\mathcal{A}(r,T)V'(F_t) + \frac{1}{2}\sigma^2\mathcal{A}^2(r,T)V''(F_t) \tag{C.6}$$

Heuristic HJB equation derivation. Letting $dV(F_t) = V(F_{t+dt}) - V(F_t)$ and approximating $e^{rdt} \approx 1 + rdt$ in Equation C.5, we arrive at the well-known Bellman equation describing the dynamics of an investor's value function $rV(F_t) = \frac{E_t dV(F_t)}{dt}$. Given that F_t is a drift-diffusion process, the application of Itô lemma to the right-hand side of this expression yields the second-order differential equation for the investor's value function, Equation (C.6). ∎

Equation (C.6), together with a set of boundary conditions standard in the real option literature (Stokey, 2008), yields a unique solution $V(F_t)$ *and* the optimal entry threshold value of the firm $F^\star$. These boundary conditions are: 1) the zero-value condition $V(F_t) \to 0$ as $F_t \to -\infty$, 2) the value matching condition $V(F^\star) = F^\star - I$ and 3) the smooth-pasting condition $V'(F^\star) = 1$. The optimal entry threshold $F^\star$ is the main object of our interest as it describes the optimal policy governing firm entry: wait if $F_t < F^\star$ and enter if $F_t \geq F^\star$.

Proposition (Firm entry threshold). *The optimal entry threshold is*

$$F^\star = I + W_t \tag{C.7}$$

where W_t is given by

$$W_t = \frac{\mathcal{A}(r,T)}{2r}(\mu + \sqrt{\mu^2 + 2r\sigma^2}) \tag{C.8}$$

Proof. The proof is constructive. The general solution of Equation (C.6) takes the form $V(F_t) = C_1 e^{a_1 F_t} + C_2 e^{a_2 F_t}$ where $a_1 = \frac{-\mu - \sqrt{\mu^2+2r\sigma^2}}{\mathcal{A}(r,T)\sigma^2}$, $a_2 = \frac{-\mu+\sqrt{\mu^2+2r\sigma^2}}{\mathcal{A}(r,T)\sigma^2}$, and C_1 and C_2 are arbitrary constants. To obtain a solution specific to a potential entrant problem, we apply a set of boundary conditions. The first condition refers to the behavior of $V(F_t)$ as $F_t \to -\infty$. In this case, it's optimal to never start producing, which results in the potential entrant's value being zero and implies that $C_1 = 0$. The other two conditions concern the behavior of the investor's value function at the (unknown) optimal entry point $F_t = F^\star$. At the entry point, we have the value matching condition $V(F^\star) = F^\star - I$, which states that the potential entrant's value should match the value of the firm minus entry costs. Moreover, we have the smooth pasting condition $V'(F^\star) = 1$, which states that the potential entrant's value should be smooth around the entry point. These conditions pin down the second constant C_2 and the optimal entry threshold value $F^\star$. Applying them, we obtain the firm value at the optimal entry threshold is $F^\star = I + \frac{1}{a_2} = I + W_t$ where $W_t = \frac{1}{a_2} = \frac{\mathcal{A}(r,T)}{2r}(\mu + \sqrt{\mu^2 + 2r\sigma^2})$.■

Definition 2 (Incentive to enter)**.** *For a given firm value F_t and a waiting option value W_t, the incentive to enter I_t is the maximum entry cost that a potential entrant is willing to pay to start a firm immediately. Formally,*

$$I_t = F_t - W_t \tag{C.9}$$

where F_t and W_t are defined by Equations (C.3) and (C.8), respectively.

C.2 Effect of news on incentive to enter

Proposition (Firm value/waiting option effects of news)**.** *Let the effect of news on the incentive to enter be denoted by $\frac{\partial I_t}{\partial \mu}$. This effect amounts to the difference between the firm value effect and the waiting option effect:*

$$\frac{\partial I_t}{\partial \mu} = \frac{\partial F_t}{\partial \mu} - \frac{\partial W_t}{\partial \mu} \tag{C.10}$$

where $\frac{\partial F_t}{\partial \mu} = \mathcal{B}(r,T)$ and $\frac{\partial W_t}{\partial \mu} = \frac{\mathcal{A}(r,T)}{2r} \cdot \left(\frac{\mu}{\sqrt{\mu^2+2r\sigma^2}} + 1\right)$.

The firm value effect is always positive, i.e., $\frac{\partial F_t}{\partial \mu} \geq 0$. The waiting option effect is also always positive, i.e., $\frac{\partial W_t}{\partial \mu} \geq 0$.

Proof. Firm value effect $\frac{\partial F}{\partial \mu} = \frac{1-e^{-rT}(rT+1)}{r^2}$ attains its minimum when $rT = 1$. At this point, $\frac{\partial F}{\partial \mu} = \frac{1}{r^2} \cdot (1 - \frac{1}{e}) > 0$. Hence, the firm value effect is always positive. Waiting option effect is obviously positive: $\frac{\partial W}{\partial \mu} = \frac{1-e^{-rT}}{2r^2}\left(1 + \frac{\mu}{\sqrt{\mu^2+2r\sigma^2}}\right) \geq 0.$■

C.3 Project lifespan and project uncertainty

Next, we characterize how the relative strength of the firm-value effect and the waiting-option effect of news depends on the project lifespan T and uncertainty σ.

Corollary 1 (Project lifespan and the impact of news). *For projects with a long enough lifespan, the impact of news on the incentive to enter is positive - the firm value effect dominates the waiting option effect. Specifically, there exists a finite $\bar{T}$ such that for all $T > \bar{T}$, we have $\frac{\partial I_t}{\partial \mu} \geq 0$.*

Proof. When $T \to 0$, $\frac{\partial I}{\partial \mu} = 0$. For $T \leq T^\star = \frac{1}{r} \cdot \left[1 - \frac{1}{2} \cdot \left(1 - \frac{\mu}{\sqrt{\mu^2+2r\sigma^2}}\right)\right]$ the effect of news $\frac{\partial I}{\partial \mu}$ decreases with T. For $T > T^\star$, the effect monotonically grows. As $T \to \infty$, we have $\frac{\partial I}{\partial \mu} = \frac{1}{2r^2}\left(1 - \frac{\mu}{\sqrt{\mu^2+2r\sigma^2}}\right) \geq 0$. This means that exists $\bar{T} \in [0,\ \infty)$ such that for all $T > \bar{T}$, the effect of news is positive. ■

Next, we establish the role of uncertainty in shaping the effect of news for infinitely-lived projects.

Corollary 2 (Uncertainty and the effect of news). *For infinitely-lived projects ($T \to \infty$) strictly positive uncertainty is required to have a non-trivial effect of news on the incentive to enter. When there is no uncertainty $\sigma = 0$, we have:*

1. *In case of a positive growth rate $\mu \geq 0$, news does not affect firm entry, as the firm value effect is fully offset by the waiting option effect. That is $\frac{\partial I_t}{\partial \mu} = 0$*
2. *In case of negative growth rate $\mu < 0$, only the firm value effect of news is present (with no waiting option), that is $\frac{\partial I_t}{\partial \mu} = \frac{\partial F_t}{\partial \mu}$*

Proof. Note that when $T \to \infty$, we have $\mathcal{A}(r,T) = \frac{1}{r}$ and $\mathcal{B}(r,T) = \frac{1}{r^2}$. Then, for $\sigma = 0$, we have $\frac{\partial I_t}{\partial \mu} = 0$ for positive μ and $\frac{\partial I_t}{\partial \mu} = \mathcal{B}(r,T)$ for negative μ.

C.4 Restricted number of entrants and equilibrium with waiting option

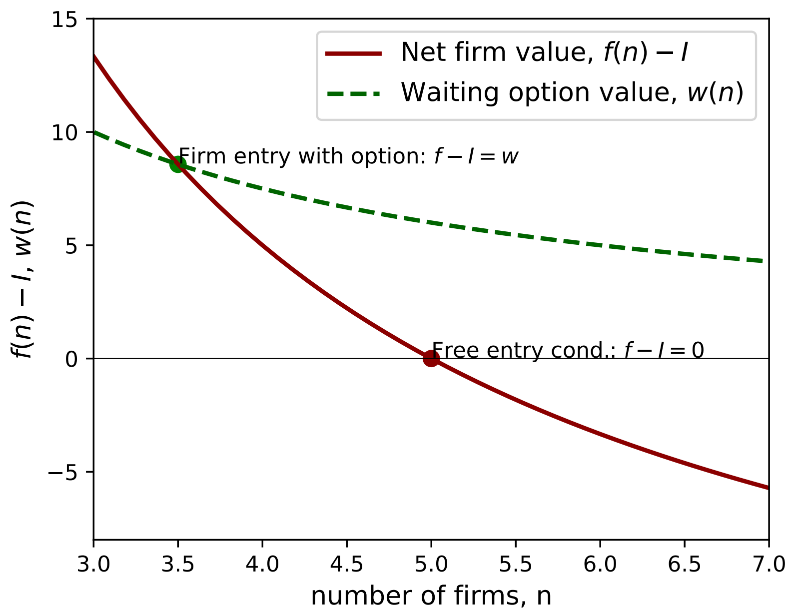
Proposition (Equilibrium number of entrants). *Let $F_t - W_t > I$, that is, it is optimal to have at least one firm, $n \geq 1$. Then, the equilibrium firm entry is*

$$n = \begin{cases} \frac{F_t - W_t}{I} & \textit{for } \frac{F_t-W_t}{I} \leq \bar{n} \\ \bar{n} & \textit{otherwise} \end{cases} \tag{C.11}$$

This equilibrium is unique.

Proof. The uniqueness follows from the fact that for $n = 1$, $\phi(n) = \frac{F_t}{n} - \frac{W_t}{n} - I > 0$ by assumption, and $\phi(n)$ is monotonically decreasing for $n > 1$. ■

Figure C.1: Equilibrium firm entry with waiting option



For this plot we use values $F_t = 100$, $W_t = 30$, and $I = 20$

In Figure C.1, it is evident that despite having a sufficiently high number of potential entrants to reach the unrestricted equilibrium (the intersection of the two lines), the number of entrants in this equilibrium is smaller than what the free entry condition $\frac{F_t}{n} - I = 0$ suggests (the intersection of net firm value with zero).

The following proposition states that when there are no limitations on firm entry in *any possible state of the world*, the waiting option is eliminated, giving rise to a standard free entry condition.

Proposition (**Zero waiting option**). *If the number of potential entrants is large enough to ensure $f_t - I = w_t$ in every possible state of the economy, the value of the waiting option becomes zero, that is $w_t = 0$ and the free entry condition is restored.*

Proof. The optimal entry point $f^\star = I + w_t$. Together with the condition $f_t - I = w_t$, this implies $f^\star = f_t$. Thus, the optimal entry value equals the current firm value in every period. At the optimal entry point, the value matching condition holds, implying that $f_t - I = V(f_t)$. The value function has the form $V(f_t) = C_2 e^{a_2 f_t}$ where $a_2 > 0$ is a function of model parameters. The condition $f^\star = f_t$ pins down the constant $C_2 = 0$ since the only way for $f_t - I = V(f_t)$ to hold for all f_t is to have $C_2 = 0$, which yields $V(f_t) = w_t = 0$. ∎