# Competition, Markups, and Predictable Returns

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Imperfect competition is an important channel for time-varying risk premia in asset markets. We build a general equilibrium model with monopolistic competition and endogenous firm entry and exit. Endogenous variation in industry concentration generates countercyclical markups, which amplifies macroeconomic risk. The nonlinear relation between the measure of firms and markups endogenously generates countercyclical macroeconomic volatility. With recursive preferences, the volatility dynamics lead to countercyclical risk premia forecastable with measures of competition. Also, the model produces a U-shaped term structure of equity returns.

*Keywords*: Imperfect competition, markups, entry and exit, productivity, business cycle propagation, asset pricing, return predictability, recursive preferences

# 1 Introduction

Economists have long argued that the creation of new businesses is an important engine of growth. In fact, careful measurement reveals that the vast majority of productivity growth occurs as new establishments enter product markets (for recent evidence, see, e.g. Gourio, Messer and Siemer (2014)). The flipside of entry is that old establishments face increased competitive pressure that may eventually drive them out of business. Going back at least to Schumpeter, economists have referred to this process as 'creative destruction'. One striking stylized fact about the intensity of net business creation is that it is highly procyclical.[1] While procyclical variation in the number of competitors is related to changes in profit opportunities, it also suggests that competitive pressure and the price elasticity of demand, should adjust accordingly. Indeed, a long list of contributions documents empirically that markups are countercyclical[2] and that the degree of competitiveness in industries is strongly procyclical.[3]

In this paper, we quantitatively link variation in industry concentration to the predictable component in equity risk premia. We show theoretically and empirically that measures of net business formation and markups forecast the equity premium. To this end, we build a general equilibrium asset pricing model with monopolistic competition and endogenous firm entry and exit. There are two endogenous components of measured productivity in the model, *product innovation* and *process innovation*. Product innovation refers to resources expended for the creation of new products and firms (e.g., Atkeson and Burstein (2014)). Process innovation refers to incumbent firms investing to upgrade their technology in response to the entry threat. Due to spillover effects from process innovation, process innovation provides a powerful low-frequency growth propagation mechanism that leads to sizable endogenous long-run risks as in Kung (2015) and Kung and Schmid (2015).

Product innovation, on the other hand, implies a novel amplification mechanism for shocks at business cycle frequencies. A positive technology shock raises profits and increases firm creation, and vice versa (e.g., firm creation is procyclical). Also, the price elasticity of demand is positively related to the number of competitors in a particular industry. Thus, markups are countercyclical, which magnifies short-run risks. In booms (downturns), markups fall which expands (contracts) production more. Consequently, short-run dividends are very risky and the model produces a U-

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[1]See, e.g., Cooper and Chatterjee (1993), Portier (1995), Devereux, Head and Lapham (1996), Floetotto and Jaimovich (2008), Bilbiie, Ghironi and Melitz (2012)

[2]See, for example, Bils (1987), Rotemberg and Woodford (1991, 1999), Chevalier, Kashyap and Rossi (2003).

[3]Some examples include Bresnahan and Reiss (1991) and Campbell and Hopenhayn (2005)

shaped term structure of equity returns, consistent with the empirical evidence from Binsbergen, Brandt, and Koijen (2012).

We show that in equilibrium the relation between the number of firms and markups is nonlinear. In economic downturns, profits fall, firms exit and industry concentration rises. As a consequence, surviving producers enjoy elevated market power and face steeper demand curves. While this allows firms to charge higher markups in our model, it also makes them more sensitive to aggregate shocks and implies that the amplification mechanism is asymmetric. Markups increase more in recessions than it decreases in booms. Consequently, the model endogenously produces counter-cyclical macroeconomic volatility. With recursive preferences, these volatility dynamics generate a countercyclical equity premium that can be forecasted by measures of industry concentration.

The calibrated model generates an equity premium of around 5% on an annual basis, while simultaneously fitting a wide-range of macroeconomic moments, including those relating to markup and business creation dynamics. The sizable equity premium is primarily compensation for the endogenous long-run risks (e.g., Bansal and Yaron (2004) and Croce (2014)) generated by the process innovation channel as in Kung (2015) and Kung and Schmid (2015). The countercyclical equity premium is attributed to the product innovation channel due to nonlinearities in markup dynamics. The model generates quantitatively significant endogenous variation in risk premia. For example, excess stock return forecasting regressions using the price-dividend ratio produces a $R^2$ of 0.22 at a five-year horizon. The model also predicts that excess stock returns can be forecasted by markups, profit shares, and net business formation, which we find strong empirical support for. In short, our paper highlights how fluctuations in competitive pressure are an important source of time-varying risk premia.

## 1.1 Literature

Our work belongs to several strands of literature. First, the paper is related to the emerging literature linking risk premia and imperfect competition. Second, it connects to research on sources of endogenous return predictability. Third, it contributes to the literature on general equilibrium asset pricing with production.

Our starting point is an innovation-driven model of stochastic endogenous growth following Kung (2015) and Kung and Schmid (2015). Also, Ward (2014) uses a similar framework as Kung and Schmid (2015) to estimate the transition dynamics of the IT revolution. Methodologically, this work builds on the literature on medium-term cycles pioneered by Comin and Gertler (2006)

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and Comin, Gertler and Santacreu (2009). More generally, these papers are a stochastic extension of the endogenous growth models developed by Romer (1990), Aghion and Howitt (1992), and Peretto (1999). We extend the framework from Kung (2015) and Kung and Schmid (2015) to account for entry and exit along the lines of Bilbiie, Ghironi and Melitz (2012) and Floetotto and Jaimovich (2008), and examine the asset pricing implications. We follow the multisector approach from Floetotto and Jaimovich, which yields endogenous countercyclical markups. Opp, Parlour and Walden (2014) obtain time-varying markups in a model of strategic interactions at the industry level.

Our paper is related to a growing literature studying the link between product market competition and stock returns. Hou and Robinson (2006), Bustamante and Donangelo (2014), van Binsbergen (2014), and Loualiche (2014) examine the impact of competition on the cross section of stock returns. Our paper is closely related to Loualiche (2014) who also considers a general equilibrium asset pricing model with recursive preferences and entry and exit. He finds that aggregate shocks to entry rates are an important factor priced in the cross-section of returns. Our work differs from these papers by focusing on the time-series implications and especially on how changes in competition endogenously generate time-varying risk premia. Our approach therefore provides distinct and novel empirical predictions.

Our paper shares its focus with the growing literature on asset pricing in general equilibrium models with production. Papers that use habit preferences include Jermann (1998) and Boldrin, Christiano, and Fisher (2001). More recently, Tallarini (2000), Campanale, Castro, and Clementi (2008), Kuehn (2008, 2009), Ai (2010) and Kaltenbrunner and Lochstoer (2010) explore endogenous long-run consumption risks in real business cycle models with recursive preferences. Gourio (2012, 2013) examines disaster risks. Particularly closely related are recent papers by Croce (2012), Backus, Routledge, and Zin (2007, 2010), Gomes, Kogan, and Yogo (2009), Kogan and Papanikolaou (2010), Garleanu, Kogan, and Panageas (2012), Papanikolaou (2011), and Ai, Croce, and Li (2013) who examine the implications of long-run productivity risk and technological innovation for equity market returns. Our approach differs from their work as technological progress and productivity growth is endogenous in our model through process and product innovation. Furthermore, these papers focus on unconditional asset pricing moments, while we consider return predictability.

Our work is related to papers examining mechanisms that generate return predictability. Dew-Becker (2012) and Kung (2015) generate return predictability by assuming exogenous time-varying processes in risk aversion and the volatility of productivity, respectively. A number of papers

show how predictability can be generated endogenously. Favilukis and Lin (2014a, 2014b), Kuehn, Petrosky-Nadeau and Zhang (2014), Santos and Veronesi (2006) work through frictions in the labor markets. In these papers, wages effectively generate operating leverage and they identify variables related to labor market conditions that can forecast stock returns. Gomes and Schmid (2014) explicitly model financial leverage in general equilibrium and find that credit spreads forecast stock returns through countercyclical leverage. Our channel, which operates through endogenous time-varying markups, is novel and allows us to empirically identify a new set of predictive variables for stock returns linked to time-varying competitive pressure.

Finally, our paper relates to models that try to explain the declining term structure of equity returns documented in Binsbergen, Brandt, and Koijen (2012) and Binsbergen, Hueskes, Koijen, and Vrugt (2012). Belo, Collin-Dusfresne, and Goldstein (2014) show, in an endowment economy, that imposing a stationary and procyclical leverage ratio amplifies short-run risks and increases the procyclicality of short-term dividends, which leads to a downward sloping term structure. Croce, Lettau, and Ludvigson (2014) also generate this result using an endowment economy with limited information. Ai, Croce, Diercks and Li (2014) and Favilukis and Lin (2014a) show how vintage capital and wage rigidities, respectively, are alternative channels in a production-based framework. In contrast to these papers, endogenous countercyclical markups in our model provide a distinct but complimentary amplification mechanism for short-run risks that helps to explain the equity term structure.

The paper is organized as follows. We describe our model in section 2 and examine the main economic mechanisms in section 3. The next section discusses quantitative implications by means of a calibration, and presents empirical evidence supporting our model predictions. Section 5 offers a few concluding remarks.

## 2 Model

In this section, we present a general equilibrium asset pricing model with imperfect competition and endogenous productivity growth. Endogenous innovation impacts productivity growth because of imperfect competition, as markups and the associated profit opportunities provide incentives for new firms to enter (product innovation) and for incumbent firms to invest in their own production technology (process innovation). Cyclical movements in profit opportunities affect the mass of active firms and thus competitive pressure and markups. We also assume a representative household with

recursive preferences.

Overall the model is a real version of the endogenous growth framework of Kung (2014), extended to allow for entry and exit with multiple industries and time-varying markups. We start by briefly describing the household sector, which is quite standard. Then we explain in detail the production sector and the innovation process in our economy, and define the general equilibrium. Also, note that we use calligraphic letters to denote aggregate variables.

## 2.1 Household

The representative agent is assumed to have Epstein-Zin preferences over aggregate consumption $\mathcal{C}_t$ and labor $\mathcal{L}_t$[4]

$$U_t = u\left(\mathcal{C}_t, \mathcal{L}_t\right) + \beta \left( E_t[U_{t+1}^{1-\theta}] \right)^{\frac{1}{1-\theta}}$$

where $\theta = 1 - \frac{1-\gamma}{1-1/\psi}$, $\gamma$ captures the degree of risk aversion, $\psi$ is the elasticity of intertemporal substitution, and $\beta$ is the subjective discount rate. The utility kernel is assumed to be additively separable in consumption and leisure,

$$u\left(\mathcal{C}_t, \mathcal{L}_t\right) = \frac{\mathcal{C}_t^{1-1/\psi}}{1-1/\psi} + \mathcal{Z}_t^{1-1/\psi} \chi_0 \frac{(1-\mathcal{L}_t)^{1-\chi}}{1-\chi}$$

where $\chi$ captures the Frisch elasticity of labor[5], and $\chi_0$ is a scaling parameter. Note that we multiply the second term by an aggregate productivity trend $\mathcal{Z}_t^{1-1/\psi}$ to ensure that utility for leisure does not become trivially small along the balanced growth path.

When $\psi \neq \frac{1}{\gamma}$, the agent cares about news regarding long-run growth prospects. We will assume that $\psi > \frac{1}{\gamma}$ so that the agent has a preference for early resolution of uncertainty and dislikes uncertainty about long-run growth rates.

The household maximizes utility by participating in financial markets and by supplying labor. Specifically, the household can take positions $\Omega_t$ in the stock market, which pays an aggregate dividend $\mathcal{D}_t$, and in the bond market $\mathcal{B}_t$. Accordingly, the budget constraint of the household

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[4]Traditionally, Epstein-Zin preference are defined as $\tilde{U}_t = \left\{ u\left(\mathcal{C}_t, \mathcal{L}_t\right)^{1-1/\psi} + \beta \left( E_t[\tilde{U}_{t+1}^{1-\gamma}] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}$ where $\gamma$ is the coefficient of relative risk aversion and $\psi$ is the intertemporal elasticity of substitution. The functional form above is equivalent when we define $U_t = \tilde{U}_t^{1-1/\psi}$ and $\theta = 1 - \frac{1-\gamma}{1-1/\psi}$ but has the advantage of admitting more general utility kernels $u\left(\mathcal{C}_t, \mathcal{L}_t\right)$ (see Rudebusch and Swanson (2012)).

[5]Given our assumption that the household works 1/3 of his time endowment in the steady state, the steady state Frisch labor supply elasticity is $2/\chi$.

becomes

$$\mathcal{C}_t + \mathcal{Q}_t \Omega_{t+1} + \mathcal{B}_{t+1} = \mathcal{W}_t \mathcal{L}_t + (\mathcal{Q}_t + \mathcal{D}_t)\Omega_t + \mathcal{R}_{f,t}\mathcal{B}_t, \tag{1}$$

where $\mathcal{Q}_t$ is the stock price, $\mathcal{R}_{f,t}$ is the gross risk free rate and $\mathcal{W}_t$ is the wage rate.

These preferences imply the stochastic discount factor (intertemporal marginal rate of substitution)

$$\mathcal{M}_{t+1} = \beta \left( \frac{U_{t+1}}{E_t(U_{t+1}^{1-\theta})^{\frac{1}{1-\theta}}} \right)^{-\theta} \left( \frac{\mathcal{C}_{t+1}}{\mathcal{C}_t} \right)^{-\frac{1}{\psi}}$$

Additionally, the labor supply condition states that at the optimum the household trades off the wage rate against the marginal disutility of providing labor, so that

$$\mathcal{W}_t = \frac{\chi_0 (1 - \mathcal{L}_t)^{-\chi}}{\mathcal{C}_t^{-1/\psi}} \mathcal{Z}_t^{1-1/\psi}.$$

## 2.2 Production Sector

The production sector is composed of three entities: final goods production, intermediate goods production, and the capital producers. The final good aggregates inputs from a continuum of industries, and each industry uses a finite measure of differentiated intermediate goods as inputs. Stationary shocks drive stochastic fluctuations in the profits on intermediate goods. Higher profit opportunities induce new intermediate goods producers to enter (product innovation) and incumbent firms respond by upgrading their technology through R&D (process innovation). The capital sector produces and accumulates both physical and intangible capital and rents it out to the intermediate goods firms.

**Final Goods**  The final goods sector is modeled following Jaimovich and Floetotto (2008). The final good is produced by aggregating sectoral goods which are themselves composites of intermediate goods. We think of each sector as a particular industry and use these labels interchangeably.

More specifically, a representative firm produces the final (consumption) goods in a perfectly competitive market. The firm uses a continuum of sectorial goods $Y_{i,t}$ as inputs in the following CES production technology

$$\mathcal{Y}_t = \left( \int_0^1 Y_{i,t}^{\frac{\nu_1 - 1}{\nu_1}} \, di \right)^{\frac{\nu_1}{\nu_1 - 1}}$$

where $\nu_1$ is the elasticity of substitution between sectorial goods. The profit maximization problem of the firm yields the isoelastic demand for sector $j$ goods,

$$Y_{j,t} = \mathcal{Y}_t \left( \frac{P_{j,t}}{P_{Y,t}} \right)^{-\nu_1}$$

where $P_{Y,t} = \left( \int_0^1 P_{j,t}^{1-\nu_1} \, dj \right)^{\frac{1}{1-\nu_1}}$ is the final goods price index (and the numeraire). We provide the derivations in the appendix.

In turn, each industry $j$ produces sectoral goods using a finite number $N_{j,t}$ of differentiated goods $X_{i,j,t}$. Importantly, the number of differentiated goods in each industry is allowed to vary over time. Because each industry is atomistic, sectorial firms face an isoelastic demand curve with constant price elasticity $\nu_1$. The sectoral goods are aggregated using a CES production technology

$$Y_{j,t} = N_{j,t}^{1-\frac{\nu_2}{\nu_2-1}} \left( \sum_{i=1}^{N_{j,t}} X_{i,j,t}^{\frac{\nu_2-1}{\nu_2}} \right)^{\frac{\nu_2}{\nu_2-1}}$$

where $N_{j,t}$ is the number of firms and $\nu_2$ is the elasticity of substitution between intermediate goods. The multiplicative term $N_{j,t}^{1-\frac{\nu_2}{\nu_2-1}}$ is added to eliminate the variety effect in aggregation.

The profit maximization problem of the firm yields the following demand schedule for intermediate firms in industry $j$ (see the appendix for derivations):

$$X_{i,j,t} = \frac{Y_{j,t}}{N_{j,t}} \left( \frac{P_{i,j,t}}{P_{j,t}} \right)^{-\nu_2}$$

where $P_{i,j,t}$ is the price of intermediate good $i$ in industry $j$ and $P_{j,t} = N_{j,t}^{\frac{-1}{1-\nu_2}} \left( \sum_{i=1}^{N_{j,t}} P_{i,j,t}^{1-\nu_2} \right)^{\frac{1}{1-\nu_2}}$ is the sector $j$ price index. In the following, we assume that the elasticity of substitution within industry is higher than across industries, i.e. $\nu_2 > \nu_1$.

**Intermediate Goods**  Intermediate goods production in each industry is characterized by monopolistic competition. In each period, a proportion $\delta_n$ of existing firms becomes obsolete and leaves the economy. The specification of the production technology is similar to Kung (2014). Intermediate goods firms produce $X_{i,j,t}$ using a Cobb-Douglas technology defined over physical capital $K_{i,j,t}$, labor $L_{i,j,t}$, and technology $Z_{i,j,t}$. We think of technology as intangible capital, such as patents. Firms rent their physical and technology from capital producers at a period rental rate of $r_{j,t}^k$ and $r_{j,t}^z$, respectively. Labor input is supplied by the household. We assume that technology

is only partially appropriable and that there are spillovers across firms. The production technology is

$$X_{i,j,t} = K_{i,j,t}^{\alpha} \left( A_t Z_{i,j,t}^{\eta} \mathcal{Z}_t^{1-\eta} L_{i,j,t} \right)^{1-\alpha}$$

where $\mathcal{Z}_t \equiv \int_0^1 \left( \sum_{i=1}^{N_{j,t}} Z_{i,j,t} \right) dj$ is the aggregate stock of technology in the economy and the parameter $\eta \in [0,1]$ captures the degree of technological appropriability. These spillover effects are crucial for generating sustained growth in the economy (e.g. Romer (1990)). Technology increases the efficiency of intermediate good production, so that we interpret that input as process innovation. The variable $A_t$ represents an aggregate technology shock that is common across firms and evolves in logs as an AR(1) process:

$$a_t = (1 - \rho)a^{\star} + \rho a_{t-1} + \sigma \epsilon_t$$

where $a_t \equiv \log(A_t)$, $\epsilon_t \sim N(0,1)$ is i.i.d., and $a^{\star}$ is the unconditional mean of $a_t$.

Dividends for an intermediate goods firm is then given by

$$D_{i,j,t} = \frac{P_{i,j,t}}{P_{Y,t}} X_{i,j,t} - W_{j,t} L_{i,j,t} - r_{j,t}^k K_{i,j,t} - r_{j,t}^z Z_{i,j,t}.$$

The demand faced by an individual firm depends on its relative price and the sectoral demand which in turn depends on the final goods sector. Expressing the inverse demand as a function of final goods variables,

$$X_{i,j,t} = \frac{\mathcal{Y}_t}{N_{j,t}} \left( \tilde{P}_{i,j,t} \right)^{-\nu_2} \left( \tilde{P}_{j,t} \right)^{\nu_2 - \nu_1}$$

where tilde-prices are normalized by the numeraire, i.e. $\tilde{P}_{i,j,t} \equiv \frac{P_{i,j,t}}{P_{Y,t}}$ and $\tilde{P}_{j,t} \equiv \frac{P_{j,t}}{P_{Y,t}}$.

The objective of the intermediate goods firm is to maximize shareholder's wealth, taking input prices and the stochastic discount factor as given:

$$V_{i,j,t} = \max_{\left\{ L_{i,j,t}, K_{i,j,t}, Z_{i,j,t}, \tilde{P}_{i,j,t} \right\}_{t \geq 0}} E_0 \left[ \sum_{s=0}^{\infty} \mathcal{M}_{t,t+s} (1 - \delta_n)^s D_{i,j,s} \right]$$

$$\text{s.t. } X_{i,j,t} = \frac{\mathcal{Y}_t}{N_{j,t}} \left( \tilde{P}_{i,j,t} \right)^{-\nu_2} \left( \tilde{P}_{j,t} \right)^{\nu_2 - \nu_1}$$

where $\mathcal{M}_{t,t+s}$ is the marginal rate of substitution between time $t$ and time $t+s$.

This market structure yields a symmetric equilibrium in the intermediate goods sector. Hence, we can drop the $i$ subscripts in the equations above. As derived in the appendix, the corresponding first order necessary conditions are

$$
\begin{aligned}
r_{j,t}^k &= \frac{\alpha}{\o_{j,t}} \frac{X_{j,t}}{K_{j,t}} \\
r_{j,t}^z &= \frac{\eta(1-\alpha)}{\o_{j,t}} \frac{X_{j,t}}{Z_{j,t}} \\
W_{j,t} &= \frac{(1-\alpha)}{\o_{j,t}} \frac{X_{j,t}}{L_{j,t}} \\
\o_{j,t} &= \frac{-\nu_2\, N_{j,t} + (\nu_2 - \nu_1)}{-(\nu_2 - 1)\, N_{j,t} + (\nu_2 - \nu_1)}
\end{aligned}
$$

where $\o_{j,t}$ is the price markup reflecting monopolistic competition. Note that the price markup depends on the number of active firms $N_{j,t}$ in each industry, and so can be time-varying. We describe how the evolution of the mass of active firms is endogenously determined below.

**Capital producers**   Capital producers operate in a perfectly competitive environment and produce industry-specific capital goods. They specialize in the production of either physical capital or technology.

Physical capital producers lease capital $K_{j,t}^c$ to sector $j$ for production in period $t$ at a rental rate of $r_{j,t}^k$. At the end of the period, they retrieve $(1-\delta_k)K_{j,t}^c$ of depreciated capital. They produce new capital by transforming $I_{j,t}$ units of output bought from the final goods producers into new capital via the technology[6]:

$$
\Phi_{k,j,t}K_{j,t}^c = \left( \frac{\alpha_{1,k}}{1 - \frac{1}{\zeta_k}} \left( \frac{I_{j,t}}{K_{j,t}^c} \right)^{1 - \frac{1}{\zeta_k}} + \alpha_{2,k} \right) K_{j,t}^c
$$

Therefore, the evolution of aggregate physical capital in industry $j$ is

$$
K_{j,t+1}^c = (1 - \delta_k)K_{j,t}^c + \Phi_{k,j,t}K_{j,t}^c
$$

and the dividend is defined as $r_{j,t}^k K_{j,t}^c - I_{j,t}$.

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[6]This functional form for the capital adjustment costs is borrowed from Jermann(1998). The parameters $\alpha_{1,k}$ and $\alpha_{2,k}$ are set to values so that there are no adjustment costs in the deterministic steady state. Specifically, $\alpha_{1,k} = (\Delta\mathcal{Z} - 1 + \delta_k)^{\frac{1}{\zeta_k}}$ and $\alpha_{2,k} = \frac{1}{\zeta_k - 1}(1 - \delta_k - \Delta\mathcal{Z})$.

The optimization problem faced by the representative physical capital producer is to choose $K_{j,t+1}^c$ and $I_{j,t}$ in order to maximize shareholder value:

$$V_{j,t}^k = \max_{\{I_{j,t}, K_{j,t+1}^c\}_{t \geq 0}} E_0 \left[ \sum_{s=0}^{\infty} \mathcal{M}_{t,t+s}(r_{j,s}^k K_{j,s}^c - I_{j,s}) \right]$$
$$\text{s.t.} \ \ K_{j,t+1}^c = (1 - \delta_k)K_{j,t}^c + \Phi_{k,j,t}K_{j,t}^c$$

As shown in the appendix, this optimization problem yields the following first order conditions:

$$Q_{j,t}^k = \Phi_{k,j,t}'^{-1}$$
$$Q_{j,t}^k = E_t \left[ \mathcal{M}_{t,t+1} \left( r_{j,t+1}^k + Q_{j,t+1}^k \left( 1 - \delta_k - \Phi_{k,j,t+1}' \left( \frac{I_{j,t}}{K_{j,t}^c} \right) + \Phi_{k,j,t+1} \right) \right) \right]$$

where $Q_t^k$ is the Lagrange multiplier on the capital accumulation constraint.

The structure of the technology capital producer is similar. More specifically, this sector produces new intangible capital by transforming $S_{j,t}$ units of output bought from the final goods producers into new technology via the technology[7]:

$$\Phi_{k,j,t}Z_{j,t}^c = \left( \frac{\alpha_{1,z}}{1 - \frac{1}{\zeta_z}} \left( \frac{S_{j,t}}{Z_{j,t}^c} \right)^{1 - \frac{1}{\zeta_z}} + \alpha_{2,z} \right) Z_{j,t}^c.$$

We think of $S_{j,t}$ as investment in R&D. In the model, therefore, technology accumulates endogenously.

As with physical capital producers, the optimization problem of the representative technology producer is to maximize shareholder value, so that the first conditions are,

$$Q_{j,t}^z = \Phi_{z,j,t}'^{-1}$$
$$Q_{j,t}^z = E_t \left[ \mathcal{M}_{t,t+1} \left( r_{j,t+1}^z + Q_{j,t+1}^z \left( 1 - \delta_z - \left( \frac{S_{j,t+1}}{Z_{j,t+1}^c} \right) \Phi_{z,j,t+1}' + \Phi_{z,j,t+1} \right) \right) \right]$$
$$Z_{j,t+1}^c = (1 - \delta_z)Z_{j,t}^c + \Phi_{z,j,t}Z_{j,t}^c.$$

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[7]Similarly, the parameters $\alpha_{1,z}$ and $\alpha_{2,z}$ are set to values so that there are no adjustment costs in the deterministic steady state. Specifically, $\alpha_{1,z} = (\Delta \mathcal{Z} - 1 + \delta_z)^{\frac{1}{\zeta_z}}$ and $\alpha_{2,z} = \frac{1}{\zeta_z - 1}(1 - \delta_z - \Delta \mathcal{Z})$.

## 2.3 Entry & Exit

Each period, new firms contemplate entering the intermediate goods sector. Entry into the intermediate goods sector entails the fixed cost $F_{E,j,t} \equiv \kappa_j \mathcal{Z}_t$. A newly created firm will start producing in the following period. Note that these costs are multiplied by the aggregate trend in technology to ensure that the entry costs do not become trivially small along the balanced growth path.

The evolution equation for the number of firms in the intermediate goods sector is

$$N_{j,t+1} = (1 - \delta_n)N_{j,t} + N_{E,j,t}$$

where $N_{E,j,t}$ is the number of new entrants and $\delta_n$ is the fraction of firms, randomly chosen, that become obsolete after each period. The entry condition is:

$$E_t[\mathcal{M}_{t+1}V_{j,t+1}] = F_{E,j,t} \tag{2}$$

where $V_{j,t} = D_{j,t} + (1-\delta_n)E_t[\mathcal{M}_{t+1}V_{j,t+1}]$ is the market value of the representative firm in sector $j$. Movements in profit opportunities and valuations thus lead to fluctuations in the mass of entering firms.

## 2.4 Equilibrium

**Symmetric Equilibrium** We focus on a symmetric equilibrium, in which all sectors and intermediate firms make identical decisions, so that the $i$ and $j$ subscripts can be dropped. Given the symmetric equilibrium, we can express aggregate output as

$$
\begin{aligned}
\mathcal{Y}_t &= \mathcal{N}_t X_t \\
X_t &= K_t^\alpha (A_t Z_t^\eta \mathcal{Z}_t^{1-\eta} L_t)^{1-\alpha}
\end{aligned}
$$

**Aggregation** Aggregate macro quantities are defined as: $\mathcal{I}_t \equiv \int_0^1 I_{j,t}\, dj = I_t$, $\mathcal{S}_t \equiv \int_0^1 S_{j,t}\, dj = S_t$, $\mathcal{Z}_t \equiv \int_0^1 \sum_{i=1}^{\mathcal{N}_t} Z_{i,j,t}\, dj = \mathcal{N}_t Z_t$, $\mathcal{K}_t \equiv \int_0^1 \sum_{i=1}^{\mathcal{N}_t} K_{i,j,t}\, dj = \mathcal{N}_t K_t$. The aggregate dividend coming from the production sector is defined as

$$\mathcal{D}_t = \mathcal{N}_t D_t + (r_t^k \mathcal{K}_t - \mathcal{I}_t) + (r_t^z \mathcal{Z}_t - \mathcal{S}_t)$$

Note that the aggregate dividend includes dividends from the capital and technology sectors.

**Market Clearing**   Imposing the symmetric equilibrium conditions, the market clearing condition for the final goods market is:

$$\mathcal{Y}_t = \mathcal{C}_t + \mathcal{I}_t + \mathcal{S}_t + \mathcal{N}_{E,t} \cdot \mathcal{F}_{E,t}$$

The market clearing condition for the labor market is:

$$\mathcal{L}_t = \sum_{j=1}^{\mathcal{N}_t} L_{j,t}$$

Imposing symmetry, the equation above implies

$$L_t = \frac{\mathcal{L}_t}{\mathcal{N}_t}$$

The market clearing condition for the capital markets implies that the amount of capital rented by firms equals the aggregate supply of capital:

$$\mathcal{K}_t = \mathcal{K}_t^c$$
$$\mathcal{Z}_t = \mathcal{Z}_t^c$$

**Equilibrium**   We can thus define an equilibrium for our economy in a standard way. In a symmetric equilibrium, there is one exogenous state variable, $A_t$, and three endogenous state variables, the physical capital stock $\mathcal{K}_t$, the intangible capital stock $\mathcal{Z}_t$, and the number of intermediate good firms, $\mathcal{N}_t$. Given an initial condition $\{A_0, \mathcal{K}_0, \mathcal{Z}_0, \mathcal{N}_0\}$ and the law of motion for the exogenous state variable $A_t$, an equilibrium is a set of sequences of quantities and prices such that (i) quantities solve producers' and the household's optimization problems and (ii) prices clear markets.

We interpret the stock market return as the claim to the entire stream of future aggregate dividends, $\mathcal{D}_t$.

## 3   Economic mechanisms

Our model departs in two significant ways from the workhorse stochastic growth model in macroeconomics. First, our setup incorporates imperfect competition and the entry and exit of intermediate goods firms. Product innovation, or the variation in the number of firms in a particular sector,

changes the degree of industry competitiveness. Second, rather than assuming an exogenous trend in aggregate productivity, the long-run growth is endogenously determined by firms' investment in their technology, which we refer as process innovation.

In this section, we qualitatively examine how both product and process innovation produce rich model dynamics with only a single homoscedastic technology shock. In particular, in the language of Bansal and Yaron (2004), we document that product innovation provides an *amplification* mechanism for short-run risks while process innovation provides a growth *propagation* mechanism that generates long-run risks. Further, the product innovation channel generates conditional heteroscedasticity in macroeconomic quantities due to nonlinearities in markups.

While we focus on a qualitative examination of our setup here, we provide a detailed quantitative analysis of the model in the next section.

## 3.1 Product Innovation

This subsection describes how business creation combined with imperfect competition provides an short-run amplification mechanism that is asymmetric. This channel is important for generating return predictability and a U-shaped term structure of equity returns.

**Entry & Exit** We start by examining the business creation process through the free entry condition, equation (2). Suppose there is a positive technology shock. As firms become more productive, the value of intermediate goods firms increases. Attracted by higher profit opportunities, new firms enter the market. Firms will enter the market up until the entry condition is satisfied, implying procyclical entry. On the other hand, as the number of firms in the economy grows, product market competition intensifies. Thus, the model is consistent with the empirical evidence that the degree of competitiveness in industries is procyclical, as documented, for example, in Bresnahan and Reiss (1991) and Campbell and Hopenhayn (2005).

Next, we show that in our model how changes in the number of competitors in an industry lead to time-varying markups.

**Markups** In the classic Dixit-Stiglitz CES aggregator, an individual firm is atomistic. Therefore, a single firm will not affect the sectoral price level, $P_{j,t}$. The firm faces a constant price elasticity of demand and charges a constant markup equal to $\frac{\nu_2}{\nu_2-1}$.

In contrast, in our model the measure of firms within each sector is finite. Consequently, the

intermediate producer takes into account its effect on the sectoral price index. This implies that the price elasticity of demand in a sector depends on the number of firms. As we show in the appendix, intermediate firms' cost minimization problem implies that the price markup is[8]

$$\emptyset_t \quad = \quad \frac{-\nu_2 \mathcal{N}_t + (\nu_2 - \nu_1)}{-(\nu_2 - 1)\mathcal{N}_t + (\nu_2 - \nu_1)}.$$

Thus, equilibrium markups depend on the number of active firms and thus, the degree of competition. Taking the derivative of the markup with respect to $\mathcal{N}_t$, we find

$$\frac{\partial \emptyset_t}{\partial \mathcal{N}_t} = \frac{\nu_1 - \nu_2}{\left[-(\nu_2 - 1)\mathcal{N}_t + (\nu_2 - \nu_1)\right]^2} < 0. \tag{3}$$

Assuming that the elasticity of substitution within industries is higher than across sectors ($\nu_2 > \nu_1$) implies that markups decrease as the number of firms increases, and thus are countercyclical in the model. This implication is consistent with the empirical evidence documented e.g. in Bils (1987), Rotemberg and Woodford (1991, 1999) and Chevalier, Kashyap and Rossi (2003). Moreover, countercyclical markups amplifiy short-run risks as in booms (downturns), markups are higher which expands (contracts) production more. Riskier short-run cash flows allows the model to generate a downward sloping equity term structure initially.

The expression for the derivative of the markup with respect to the number of firms $\mathcal{N}_t$ implies that the sensitivity of markups to a marginal entrant depends on the number of firms in the industry. The nonlinear relation between markups and $\mathcal{N}_t$ is illustrated in figure 1. Adding a new firm to an already highly competitive industry (high $\mathcal{N}_t$) will have little impact on product market competition. In contrast, a marginal entrant will have a large impact on markups when the number of firms are low. Consequently, markups will rise more recessions than it falls in booms, which leads to countercyclical macroeconomic volatility.

## 3.2  Process Innovation

This subsection illustrates the long-run growth propagation mechanism through process innovation. This channel generates endogenous long-run risks.

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[8]The standard constant markup specification is a particular case in which $N_t \to \infty$.

**Endogenous Productivity**  The aggregate production technology can be expressed as

$$
\begin{aligned}
\mathcal{Y}_t &= \mathcal{N}_t K_t^\alpha (A_t Z_t^\eta \mathcal{Z}_t^{1-\eta} L_t)^{1-\alpha} \\
&= \mathcal{N}_t \left( \frac{\mathcal{K}_t}{\mathcal{N}_t} \right)^\alpha \left[ A_t \left( \frac{\mathcal{Z}_t}{\mathcal{N}_t} \right)^\eta \mathcal{Z}_t^{1-\eta} \left( \frac{\mathcal{L}_t}{\mathcal{N}_t} \right) \right]^{1-\alpha} \\
&= \mathcal{K}_t^\alpha \left[ \mathcal{Z}_{p,t} \mathcal{L}_t \right]^{1-\alpha}
\end{aligned}
$$

where $\mathcal{Z}_{p,t} \equiv A_t \mathcal{Z}_t \mathcal{N}_t^{-\eta}$ is measured TFP, which is composed of three components. $A_t$ is an exogenous component while $\mathcal{Z}_t$, the stock of intangible capital, is endogenously accumulated through process innovation (i.e., R&D), and the mass of active firms $\mathcal{N}_t$, endogenously created through product innovation. Due to the spillover effect from process innovation, $\mathcal{Z}_t$ grows and is the endogenous trend component.

To filter out the cyclical components of productivity, we can take conditional expectations of the log TFP growth rate:

$$
\begin{aligned}
E_t[\Delta z_{p,t+1}] &= E[\Delta a_{t+1} + \Delta z_{t+1} - \eta \, \Delta n_{t+1}] \\
&\approx \Delta z_{t+1},
\end{aligned}
$$

where the second approximation is recognizing that $a_{t+1}$ and $n_{t+1}$ are persistent stationary processes, so $\Delta a_{t+1}$ and $\Delta n_{t+1}$ are approximately iid. Thus, as in Kung (2015) and Kung and Schmid (2015), low-frequency components in growth are driven by the accumulation of intangible capital, which they also find strong empirical support for. With recursive preferences, these low-frequency movements in productivity lead to sizable risk premia in asset markets.

# 4  Quantitative Implications

In this section, we present quantitative results from a calibrated version of our model. We calibrate it to the replicate salient features of industry and business cycles and use it to gauge the quantitative significance of our mechanisms for risk premia. We also provide empirical evidence supporting the model predictions.

In order to quantitatively isolate the contributions of process innovation, product innovation and time-varying markups on aggregate risk and risk premia, we find it instructive to compare our benchmark model to another nested model. In the following, we refer to the benchmark model as

model A. Model B features a CES aggregator, and abstracts away from entry and exit, so that the mass of firms and hence markups are constant.

The models are calibrated at quarterly frequency. The empirical moments correspond to the U.S. postwar sample from 1948 to 2013. The model is solved using third-order perturbation methods.[9]

**Calibration**   We begin with a description of the calibration and the construction of the key empirical data series, such as entry rates, markups, R&D, and intangible capital stock.

Following Bils (1987), Rotemberg and Woodford (1999) and Campello (2003), we construct an empirical price markup series by exploiting firms' first order condition with respect to $L_t$, imposing the symmetry condition,

$$\emptyset_t \quad = \quad (1 - \alpha)\frac{\mathcal{Y}_t}{\mathcal{L}_t W_t} = (1 - \alpha)\frac{1}{\mathcal{S}_{L,t}}$$

and adjusting for potential nonlinearities in the empirical counterparts. Here, $\mathcal{S}_{L,t}$ is the labor share in the model. We discuss further details about the construction of the markup measure in the appendix.

For entry rates, we use two empirical counterparts. First, we use the index of net business formation (NBF). This index is one of the two series published by the BEA to measure the dynamics of firm entry and exit at the aggregate level. It combines a variety of indicators into an approximate index and is a good proxy for $n_t$. The other is the number of new business incorporations (INC), obtained from the U.S. Basic Economics Database. Both series have similar dyanmics. Below, we provide a number of robustness checks with respect to both measures.

Finally, our empirical series for $\mathcal{S}_t$ measures private business R&D investment and comes from the National Science Foundation (NSF). The Bureau of Labor Statistics (BLS) constructs the R&D stock by accumulating these R&D expenditures and allowing for depreciation, much in the same way as the physical capital stock is constructed. We thus use the R&D stock as our empirical counterpart for the stock of technology $\mathcal{Z}_t$. For consistency, we use the same depreciation rate $\delta_n$ in our calibration as does the BLS in its calculations. The remaining empirical series are standard in the macroeconomics and growth literature. Additional details are collected in the appendix.

Table 1 presents the quarterly calibration. Panel A reports the values for the preference parameters. The elasticity of intertemporal substitution $\psi$ is set to 1.8 and the coefficient of relative

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[9]We prune simulations using the Kim, Kim, Schaumburg and Sims (2008) procedure to avoid generating explosive paths in simulations.

risk aversion $\gamma$ is set to 10.0, both of which are standard values in the long-run risks literature (e.g. Bansal, Kiku, and Yaron (2008)). The labor elasticity parameter $\chi$, is set to 3. This implies a Frisch elasticity of labor supply of 2/3, which is consistent with estimates from the microeconomics literature (e.g. Pistaferri (2003)). $\chi_0$ is set so that the representative household works 1/3 of her time endownment in the steady state. The subjective discount factor $\beta$ is calibrated to 0.995 to be consistent with the level of the real risk-free rate.

Panel B reports the calibration of the technological parameters. The capital share $\alpha$ is set to 0.33, and the depreciation rate of capital $\delta_k$ is set to 2.0%. These two parameters are calibrated to standard values in the macroeconomics literature (e.g. Comin, and Gertler (2006)). The parameters related to R&D are calibrated following Kung (2014). The depreciation rate of the R&D capital stock $\delta_z$ is set to 3.75%, implying an annualized depreciation rate of 15%. The physical and R&D capital adjustment cost parameters $\zeta_k$ and $\zeta_z$ are both set at 0.738 to be consistent with the relative volatility of R&D investment growth to physical investment growth. The degree of technological appropriability $\eta$ is calibrated to 0.065, in line with Kung (2014). The exogenous firm exit shock $\delta_n$ is set to 1%, slightly lower than in Bilbiie, Ghironi, and Melitz (2012). The price elasticity accross ($\nu_1$) and within ($\nu_2$) industries are calibrated to 1.05 and 75, respectively to be consistent with estimates from Jaimovich and Floetotto (2008). $\kappa$ is set to ensure an aggregate price markup of 20% in the deterministic steady state.

Panel C reports the parameter values for the exogenous technology process. The volatility parameter $\sigma$ is set at 1.24% to match the unconditional volatility of measured productivity growth. The persistence parameter $\rho$ is calibrated to 0.985 to match the first autocorrelation of expected productivity growth. $a^\star$ is chosen to generate an average output growth of 2.0%.

## 4.1 Quantitative Results

We now report quantitative results based on our calibration. We start by discussing the nature of macroeconomic dynamics and then present quantitative predictions for asset returns and empirical tests.

### 4.1.1 Implications for Growth and Cycles

Aggregate cycles in the model reflect movements at the industry level. New firms enter, obsolete products exit, competitive pressure and markups adjust, and measured productivity fluctuates. Productivity dynamics in turn shape macroeconomic cycles.

**Industry Cycles**  Table 2 reports basic industry moments from the benchmark model. The average markup and the mean profit share are broadly consistent with the data. Similarly, the model quantitatively captures industry cycles well by closely matching the volatilities and first autocorrelations of markups, intangible capital growth, profit shares and net entry rates. The last panel confirms the negative relation between the mass of firms and entry rates.

Figure 2 illustrates the underlying dynamics by plotting the responses of key variables to a positive one standard deviation exogenous technology shock. We focus on two model specifications, namely the benchmark model and model B (constant mass of firms and a constant markup). In the benchmark model, a positive technology shock raises valuations and thus triggers entry, as shown in the top left panel, and the mass of firms increases, as documented in the top right panel. In our benchmark model, firms take their effect on competitor firms into account when setting prices, so that increasing competitive pressure leads to falling markups, as shown in the lower left panel. Importantly, as the lower right panel illustrates, the entry margin significantly amplifies investment in technology. This is because in response to falling markups, demand for intermediate goods increase. To satisfy the higher demand, firms produce more and increase demand for both physical and technology capital.

In table 3, we report results from predictive regressions of aggregate growth rates on entry rates. Qualitatively, the model predicts that a rise in entry rates forecasts higher growth. Indeed, we empirically find that entry positively forecasts higher growth rates of output, consumption, and investment. While the signs are consistent with the model prediction throughout, statistical significance obtains only for shorter horizons, consistent with the notion that entry rates are highly cyclical. This suggests that variations in entry rates are an important determinant of business cycles fluctuations, which we examine next.

**Business Cycles**  Table 4 reports the main business cycle statistics for models A, and B. While all of them are calibrated to match the mean and volatility of consumption growth, the cyclical behavior across models differs considerably.

The benchmark model quantitatively captures basic features of macroeconomic fluctuations in the data well. It produces consumption volatility, investment volatility and R&D volatility that are similar to their empirical counterparts. While investment volatility falls a bit short of the empirical analogue, Kung (2014) shows that incorporating sticky nominal prices and interest rate shocks in such a framework can help to explain the remaining volatility. The model generates

volatile movements in labor markets, even overshooting the volatility of hours worked slightly. This is noteworthy, as standard macroeconomic models typically find it challenging to generate labor market fluctuations of the orders of magnitude observed in the data.

The quantitative success of the benchmark model contrasts starkly to the simulated moments from the nested model B. Without entry and exit investment and R&D volatility are significantly reduced. Thus, entry and exit combined with countercyclical markups serve as a quantitatively significant amplification mechanism for shocks at business cycle frequencies.

The amplification mechanism is illustrated in figure 3, which plots the impulse response functions of aggregate quantities. Upon impact of a positive exogenous productivity shock, output, investment and consumption all rise, and significantly more so than in a specification without the entry margin. The lower two panels show that both the responses of realized and and expected consumption growth are amplified in the benchmark model. Accordingly, the amplification mechanism increases the quantity of priced risk in the economy, since the stochastic discount factor in the model reflects both realized and predictable movements in consumption growth, given the assumption of Epstein-Zin preferences.

The intuition for the amplification result is as follows. With procyclical entry, the model predicts countercyclical markups, so that falling markups in expansions triggers higher demand for intermediate goods from the final good producer, further stimulating investment in capital and technology, and thus output. Similarly, rising markups in downturns dampen the demand for intermediate goods, and deepens recessions further.

Table 5 provides empirical support for the model predictions regarding the cyclical behavior of entry rates, number of firms, and markups. The correlation of aggregate quantities and our empirical markup series is negative while the number of firms and entry rates are procyclical.

**Asymmetric Cycles**   Fig. 4 plots the *difference* between the response of quantities to a positive shock and to a negative shock of the same magnitude. Any deviation from a zero difference reflects an asymmetry in responses at some horizon. Observe that model B, with constant firm mass and markups, generates no differential response at any horizon. That specification thus predicts symmetric cycles. This is quite different in our benchmark model. It features differential responses at all horizons. The number of firms increases relatively more in expansions than it falls in recessions. Similarly, markups fall relatively more in upswings than they rise in downturns. On the other hand, investment, consumption and output rise by relatively less in good times than they

fall in bad times, so that recessions are deeper in our benchmark economy.

The source of asymmetry in the model comes from the nonlinear relation between markups and the number of firms, which is highlighted in figure 5. This figure plots responses of quantities in the benchmark conditional on high and low number of firms. Note that the figure shows that both realized and expected consumption growth fall by relatively more in a scenario with a low mass of incumbent firms (i.e., during a recession). Consequently, this asymmetry implies conditional heteroscedasticity in fundamentals, including consumption growth. If we fit our simulated data to the consumption process of Bansal and Yaron (2004), we obtain:

$$z_{t+1} = 0.961\, z_t + 0.433\, \sigma_t e_{t+1}$$

$$g_{t+1} = z_t + \sigma_t \eta_{t+1}$$

$$\sigma_{t+1}^2 = 0.0046^2 + 0.975\, (\sigma_t^2 - 0.0046^2) + 0.184 \times 10^{-6}\, w_{t+1}$$

where $g_{t+1}$ is the realized consumption growth, $z_t$ is the expected consumption growth, $\sigma_t$ is the conditional volatility of $g_{t+1}$ and $e_{t+1}$, $\eta_{t+1}$, and $w_{t+1}$ are i.i.d. shocks. To compare with Bansal and Yaron (2004), we time aggregate their model to a quarterly frequency, and obtain:

$$z_{t+1} = 0.939\, z_t + 0.151\, \sigma_t e_{t+1}$$

$$g_{t+1} = z_t + \sigma_t \eta_{t+1}$$

$$\sigma_{t+1}^2 = 0.0022^2 + 0.962\, (\sigma_t^2 - 0.0022^2) + 8.282 \times 10^{-6}\, w_{t+1}$$

Note that our endogenous consumption volatility dynamics closely matches the exogenous specification of Bansal and Yaron (2004). Quantitatively, our model generates significant time-varying volatility. Consistent with Kung (2015) and Kung and Schmid (2015), the model also generates significant long-run risks through the process innovation channel.

Table 6 highlights that our time-varying macroeconomic volatility is also countercyclical. Using our markup series, we split the data sample into high and low markup episodes. This procedure allows us to compute moments conditional on markups. Given the countercyclicality of our markup measure, it is perhaps not surprising that average output, consumption and investment is lower in high markup episodes. More interestingly, however, we find that the volatilities conditional on high markups are also higher. In line with the discussion above, the model is consistent with these findings.

### 4.1.2 Asset Pricing Implications

In our production economy, the endogenous consumption and cash flow dynamics will be reflected in aggregate risk premia and their dynamics. Intuitively, we expect two effects. First, the entry margin endogenously amplifies movements in realized consumption growth. Second, R&D decisions of firms propagates technology shocks to long-run consumption growth, which generates endogenous persistence in expected consumption growth. With Epstein-Zin preferences, both shocks to realized and expected consumption growth are priced, hence we expect that the amplification and propagation mechanisms will give rise to a sizable *unconditional* equity premium. Second, since quantity of risk is time-varying and depends negatively on the mass of firms, we expect a countercyclical *conditional* equity premium.

We now use our calibration to assess the quantitative significance of these dynamics for risk premia and to generate empirical predictions. We discuss and quantify these implications in turn and present empirical evidence supporting the model predictions.

**Equity Premium**   Table 7 reports the basic asset pricing implications of the benchmark model and the alternative specification. Absent entry and exit, the risk free rate is about double its empirical counterpart (model B), while the benchmark model (model A) replicates a low and stable risk free rate. While we calibrate the endogenous average growth rate to coincide across all models, the amplification mechanism working through the entry margin coupled with countercyclical markups creates higher persistent uncertainty. Higher uncertainty increases the precautionary savings motive, driving down interest rates to realistic levels in our benchmark economy.

The higher uncertainty also leads to a significantly higher and realistic equity premium. This is because product innovation provides an amplification mechanism for short-run risks while process innovation provides a growth propagation mechanism that generates endogenous long-run risks. While stock return volatility falls short of the empirical target, Ai, Croce and Li (2013) report that empirically, the productivity driven fraction of return volatility is around just 6%, which is close to our quantitative finding.

Consistent with the existence of sizeable risk premia, the benchmark model also generates quantitatively realistic implications for the level and the volatility of the price-dividend ratio.

**Competition and asset prices**   Imperfect competition and variations in competitive pressure is a key mechanism driving risk premia in our setup. We now provide some comparative statics of

risk and risk premia with respect to average competitive pressure. We do this by reporting some sensitivity analysis of simulated data with respect to the sectoral elasticity of substitution between goods, $\nu_2$. Fig. 6 reports the results by plotting key industry, macro and asset pricing moments for different values of $\nu_2$.

Raising the sectoral elasticity of substitution between goods, $\nu_2$, has two main effects on markups. First, by facilitating substitution between intermediate goods, it increases competition and therefore, holding all else constant, lowers markups. Second, by the virtue of our expression for the markup, equation (3), it raises the sensitivity of markups with respect to the number of incumbent firms, and thus, all else equal, makes markups more volatile. The first effect is an important determinant of the average growth rate of the economy, while the latter affects the volatility of growth.

With respect to the first effect, increasing $\nu_2$ has two opposing implications. First, decreasing the average markup, holding all else equal, lowers monopoly profits in the intermediate sector. Second, a lower average markup increases the demand for intermediate goods inputs, which raises monopoly profits. In our benchmark calibration, the second effect dominates, and therefore more intense competition, and a higher average markup raises steady-state growth. On the other hand, a more volatile demand for intermediate goods inputs triggered by increasingly volatile markups leads to a more volatile growth path. This effect is exacerbated by increasingly cyclical entry as profit opportunities become more sensitive to aggregate conditions. The net effect is a riskier economy, which translates into a higher risk premium.

**Term structure of equity returns** An emerging literature starting with van Binsbergen, Brandt, and Koijen (2012) provides evidence that the term structure of expected equity returns is downward sloping, at least in the short-run. This is in contrast to the implications of the baseline long-run risks model (Bansal and Yaron (2004)) or the habits model (Campbell and Cochrane (1999)). The empirical finding reflects the notion that dividends are very risky in the short-run.

Our benchmark model is qualitatively consistent with these findings. We compute the current price $\mathcal{Q}_{t,t+k}$ of a claim to the aggregate dividend at horizon $k$ as $\mathcal{Q}_{t,t+k} = E[\mathcal{M}_{t,t+k}\mathcal{D}_{t+k}]$ and compute its unconditional expected return accordingly.

The left panel of figure 7 shows that the term structures of (unlevered) equity returns for the benchmark model and the model without entry and exit. Consistent with the standard long-run risks model, the model absent entry and exit produces an upward sloping term structure. In the

benchmark model, countercyclical markups substantially amplify short-run risks and increase the procyclicality of short-term cash flows, which leads to a downward-sloping equity term structure for roughly the first five years. Note also that the risk premia on the very short-term strips are significantly higher than those at medium to long horizons, consistent with the data.

These cash flow dynamics are illustrated in the right panel of figure 7, which plots the impulse response function of the aggregate dividend growth rate to a positive exogenous technology shock in the benchmark model and the model without entry and exit. Both models generate a persistent increase in dividend growth at longer maturities through the process innovation channel. Thus, long-run cash flows are risky as reflected by the high long-horizon risk premia. On the other hand, industry and markup dynamics render short-run dividends significantly more risky in the benchmark model. Intuitively, dividends spike upwards on impact as new firms enter more slowly in response to attractive profit opportunities. When competitive pressure rises, markups and dividends start falling until the aggregate demand for capital and R&D increases, triggering low-frequency movements in productivity that drive up dividends again.

**Return predictibility**   The previous sections establish how the endogenous short- and long-run risks in our benchmark model produce a realistic unconditional equity premium. This section documents that the endogenous countercyclical volatility due to nonlinearities in markups implies countercyclical variation in the conditional equity premium consistent with the data. We show that excess equity returns are forecastable by measures of markups and net business formation, which we verify empirically.

Table 8 presents our main predictability results. Panel A first verifies standard long-horizon predictability regressions projecting future aggregate returns on current log price-dividend ratios in our data sample, and shows statistically significant and negative slope coefficients, and $R^2$'s increasing with horizons up to five years. Perhaps more interestingly, we run the same regressions with simulated data from our benchmark model using a sample of equal length as the empirical counterpart. The top right panel reports the results. Consistent with the data, we find statistically significant and negative slope coefficients, with $R^2$'s increasing with horizons up to five years and of similar magnitude as the data. Notably, the $R^2$'s in our model simulations match their empirical counterparts remarkably well.

These predictability results in the model imply that the model generates endogenous conditional heteroscedasticity, as shocks to the forcing process, $A_t$, are assumed to be homoscedastic. Figure

8 confirms this. It shows the impulse response functions of the conditional risk premium and the conditional variance of excess returns to a positive exogenous technology shock, both in the benchmark model and in model absent entry and exit. While in model B neither the risk premium nor the conditional variance respond, they both persistently fall on impact in the benchmark model. With the entry margin and countercyclical markups, the risk premium and its variance are countercyclical, mirroring the endogenous countercyclical consumption volatility.

Our predictability results are related to the degree of competition, which we confirm in the remaining panels in table 8. Moreover, we present novel empirical evidence supporting this prediction. We use two measures of entry, our markup series, and the profit share as predictive variables. Panels B to E report the results from projecting future aggregate returns on these variables for horizons up to 5 years, in the model and in the data. In the model, the proxies for entry forecast aggregate returns with a statistically significant negative sign, while markups and profit shares forecast them with a statistically significant positive sign. We verify this empirical prediction in the data. The empirically estimated slope coefficients all have the predicted sign, and except for the profit share regressions, are statistically significant. We thus provide novel evidence on return predictability related to time-varying competitive pressure.

It is well-known that statistical inference in predictive regressions is complicated through small sample biases. To illustrate that the sources of predictability in our model is robust to these concerns, we repeat the predictability regressions in a long sample of 200,000 quarters. For simplicity, we only report evidence from projecting returns on log price-dividend ratios. Table 9 shows the results from these regressions across model specifications. In case of the model without entry and exit, the explanatory power of the regressions are identically equal to zero. In contrast, the benchmark model produces $R^2$ that are still sizeable and increasing with horizon.

## 4.2 Extensions

Given the importance of markup dynamics for our asset pricing results, we next consider two extensions of the model that address properties of markups recently emphasized in the literature. Countercyclical movements in both price and wage markups are often recognized as the main source of fluctuations at higher frequency (e.g. Christiano, Eichenbaum and Evans (2005)). The objective of this section is to investigate which features of markups appear relevant through the lens of asset pricing. In a first extension, we consider price markup shocks, in a way often considered in the DSGE literature (e.g. Smets and Wouters (2003), Justiniano, Primiceri, and Tambalotti (2010)).

Second, in addition to price markups, we consider wage markups, whose relevance has recently been pointed out in the context of New Keynesian macroeconomic models (e.g. Gali, Gertler, and Lopez-Salido (2007)). The two extensions also allow us to gain further intuition about the mechanisms underlying the risk premia and predictability results in the benchmark model.

### 4.2.1 Markup Shocks

In this section, we show that we need two ingredients to jointly generate a countercyclical risk premium: markups need to be countercyclical and conditionally heteroskedastic.

We start by considering exogenously stochastic price markups. To that end, we solve the version of the model without entry and exit and specify the markup process as

$$\log(\text{\o}_t) \quad = \quad (1 - \rho_\text{\o}) \log(\text{\o}) + \rho_\text{\o} \log(\text{\o}_{t-1}) + \sigma_\text{\o} u_t$$

where $u_t$ is a standard normal i.i.d. shock that has a contemporaneous correlation of $\varrho$ with $\epsilon_t$. We investigate three cases, (i) constant price markups, (ii) uncorrelated time-varying markups, and (iii) countercyclical markups. We set $\text{\o}$, $\rho_\text{\o}$, and $\sigma_\text{\o}$ to match the unconditional mean, first autocorrelation, and unconditional standard deviation of $\text{\o}_t$ in the benchmark model.

Panels A, B, and C in table 10 report the main quantitative implications for asset returns and price-dividend ratios. The results are instructive. Panel B shows that introducing uncorrelated stochastic markups has a 40 bps impact on the risk premia and increases significantly the volatility of the price dividend ratio. Consistent with the intuition developed earlier, the additional risk raises the precautionary savings motive and lowers the risk-free rate. When markups are exogenously countercyclical, panel C shows that the risk premium goes up by close to one percent. In line with the intuition explained in the benchmark case, countercyclical markups amplifiy uncertainty.

While countercyclical markups increase uncertainty, it does not generate predictability if the dynamics are symmetric. Table 11 illustrates this point by reporting the results from projecting future returns on log price-dividend ratios in models with exogenous markups. The results in panels A, B, and C show that none of these specifications generate any predictability. The missing ingredient is the asymmetry or conditional heteroscedasticity in markups that is generated endogenously in our benchmark model.

To illustrate the importance of this asymmetry for predictibility, we solve a version of the model where the volatility of technology shocks is affected by the level of markups. In particular,

we assume

$$a_t = (1 - \rho_a)a^\star + \rho_a a_{t-1} + \sigma_t \epsilon_t$$

$$\sigma_t = \sigma(1 + \kappa_\emptyset \hat{\emptyset}_t)$$

where $\kappa_\emptyset > 0$ captures the effects of markups on the conditional volatility of productivity shocks. We choose $\kappa_\emptyset$ to approximately replicate the asymmetry generated by the benchmark model. Results from the simulation are reported in Tables 10 and 11, panel D. While the average risk premium is barely affected, markup induced heteroskedasticity generates excess stock return predictability.

### 4.2.2   Wage Markups

In addition to price markups, imperfect competition in labor markets reflected in wage markups plays an important role in current DSGE models. The dynamics of wage markups is currently subject to a debate after an influential paper by Gali, Gertler, and Lopez-Salido (2007) which argues that they should be countercyclical. In this section, we quantitatively explore the implications of dynamic wage markups for asset returns.

Formally, the wage markup is defined as the ratio of the real wage to the households marginal rate of substitution between labor and consumption,

$$\log(\emptyset_t^w) = \log(W_t) - \log\left(\frac{\chi_0(1 - \mathcal{L}_t)^{-\chi}}{\mathcal{C}_t^{-1/\psi}} \mathcal{Z}_t^{1-1/\psi}\right)$$

reflecting imperfect competition in the labor supply market. We specify the wage markup process exogenously as an AR(1) process in logs

$$\log(\emptyset_t^w) = (1 - \rho_\emptyset^w)\log(\emptyset^w) + \rho_\emptyset^w \log(\emptyset_{t-1}^w) + \sigma_\emptyset^w u_t^w$$

where $u_t^w$ is a standard normal i.i.d. shock that has a contemporaneous correlation of $\varrho^w$ with $\epsilon_t$.

We augment the benchmark model with wage markups and compare asset pricing moments and predictability results for two additional specifications: (i) uncorrelated time-varying markups, and (ii) countercyclical wage markup. We calibrate the markup process to match the standard deviation and first autocorrelation of the wage markup reported in Gali, Jordi, Gertler, and Lopez-Salido (2007): $\rho_\emptyset^w = 0.96$, and $\sigma_\emptyset^w = 2.88\%$. Whenever applicable, we set $\varrho^w = -0.45$ in order to replicate the $-0.79$ correlation between wage markups and output documented in Gali, Jordi, Gertler, and

Lopez-Salido (2007). The steady state markup is set to 1.2 (see e.g., Comin and Gertler, 2006).

The main asset pricing implications are collected in table 12 and predictability results are reported in table 13. Accounting for wage markups in addition to endogenous countercyclical price markups amplifies priced risk and raises risk premia. On the other hand, introducing wage markups only sharpens predictability when the dynamics are countercyclical.

# 5    Conclusion

We build a general equilibrium model with monopolistic competition and endogenous firm entry and exit. Endogenous R&D accumulation (process innovation) generates substantial long-run risks and therefore, a sizable equity premium. Also, our model structure implies a negative and nonlinear relation between the number of firms and markups. Consequently, variation in entry and exit of firms (product innovation), generates countercyclical and asymmetric markups. Countercyclical markups amplifiy short-run risks, which allows the model to generate a downward sloping equity term structure up to roughly five years. Asymmetric markup dynamics produce countercyclical consumption volatility, and with recursive preferences, this implies a countercyclical equity premium. The model also predicts that the equity premium is forecastable with measures of markups and the intensity of new firm creation, which we verify in the data. In short, our paper highlights how fluctuations in competitive pressure is an important source of time-varying risk premia.

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# 7    Appendix A: Data Sources

Quarterly data for consumption, capital investment, and GDP are from the Bureau of Economic Analysis (BEA). Annual data on private business R&D investment are from the survey conducted by the National Science Foundation. Annual data on the stock of private business R&D are from the Bureau of Labor Statistics. Real annual capital stock data is obtained from the Penn World Table. Quarterly productivity data are from Fernald (2009) (Federal Reserve Bank of San Francisco) and is measured as Business sector total factor productivity. The labor share and average weekly hours are obtained from the Bureau of Labor Statistics (BLS). The monthly index of net business formation (NBF) and number of new business incorporations (INC) are from the U.S. Basic Economics Database. Consumption is measured as expenditures on nondurable goods and services. Capital investment is measured as private fixed investment. Output is measured as GDP. The labor share is defined as the business sector labor share. Average weekly hours is measured for production and nonsupervisory employees of the total private sector. The variables are converted to real using the Consumer Price Index (CPI), which is obtained from the Center for Research in Security Prices (CRSP). Annual data are converted into quarterly data by linear interpolation. The inflation rate is computed by taking the log return on the CPI index. The sample period is for 1948-2013, except for the average weekly hours series which starts in 1964 and the NBF and INC series that were discontinued in 1993.

Monthly nominal return and yield data are from CRSP. The real market return is constructed by taking the nominal value-weighted return on the New York Stock Exchange (NYSE) and American Stock Exchange (AMEX) and deflating it using the CPI. The real risk-free rate is constructed by using the nominal average one-month yields on treasury bills and taking out expected inflation[10]. Aggregate market and dividend values are from CRSP. The price dividend ratio is constructed by dividing the current aggregate stock market value by the sum of the dividends paid over the preceding 12 months.

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[10]The monthly time series for expected inflation is obtained using an AR(4).

## 7.1 Markup measure

Solving the intermediate producer problem links the price markup to the inverse of the marginal cost of production $MC_t$,

$$\o_t \;\; = \;\; \frac{1}{MC_t}$$

In equilibrium, $MC_t$ is equal to the ratio of marginal cost over marginal product of each production input (see the cost mininization problem). Since data on wages are available at the aggregate level, the labor input margin has been the preferred choice in the literature. Using the first order condition with respect to $L_t$ and imposing the symmetry condition,

$$\o_t \;\; = \;\; (1-\alpha)\frac{\mathcal{Y}_t}{\mathcal{L}_t W_t} = (1-\alpha)\frac{1}{\mathcal{S}_{L,t}}$$

where $\mathcal{S}_{L,t}$ is the labor share.

The inverse of the labor share should thus be a good proxy for the price markup. However, there are many reasons why standard assumptions may lead to biased estimates of the markup (see Rotemberg and Woodford (1999)). In this paper, we follow Campello (2003) by focusing on non-linearities in the cost of labor[11]. More specifically, when deriving the cost function, we assumed that the firm was able to hire all workers at the marginal wage. In practice however, the total wage paid $W(L_t)$, is likely to be convex in hours (e.g. Bils (1987)). This creates a wedge between the average and marginal wage that makes the labor share a biased estimate of the real marginal cost. Denoting this wedge by $\omega_t = W'(L_t)/(W(L_t)/L_t)$, the markup becomes,

$$\o_t \;\; = \;\; (1-\alpha)\frac{1}{S_{L,t}}\,\omega_t^{-1}$$

Log-linearizing this expression around the steady state,

$$\hat{\o}_t \;\; = \;\; -\hat{s}_{L,t} - \omega_L \hat{l}_t$$

where $\omega_L$ is the steady state elacticity of $\omega_t$ with respect to average hours. Bils (1987) proposes a

---

[11]Rotemberg and Woodford (1999) presents several other reasons that makes marginal costs more procyclical than the labor share (e.g. non-Cobb-Douglas production technology, overhead labor, etc.). For robustness, we tried additional corrections. Overall, they make markups even more countercyclical, and further strengthen our empirical results.

simple model of overtime. Assuming a 50% overtime premium[12] he estimates the elasticity $\omega_L$ to be 1.4. We use this value to build our overtime measure of the price markups. We set the steady state values for $L_t$ and $S_{L,t}$ to 40 hours and $100$[13], respectively and linearly detrend the series.

# 8    Appendix B: Derivation of demand schedule

**Final goods sector**    The final goods firm solves the following profit maximization problem

$$\max_{\{Y_{j,t}\}_{j\in[0,1]}} P_{Y,t} \left( \int_0^1 Y_{j,t}^{\frac{\nu_1-1}{\nu_1}} \, dj \right)^{\frac{\nu_1}{\nu_1-1}} - \int_0^1 P_{j,t} Y_{j,t} \, dj$$

where $P_{Y,t}$ is the price of the final good (taken as given), $Y_{j,t}$ is the input bought from sector $j$ and $P_{j,t}$ is the price of that input $j \in [0,1]$,

The first-order condition with respect to $Y_{j,t}$ is

$$P_{Y,t} \left( \int_0^1 Y_{j,t}^{\frac{\nu_1-1}{\nu_1}} \, dj \right)^{\frac{\nu_1}{\nu_1-1}-1} Y_{j,t}^{-\frac{1}{\nu_1}} - P_{j,t} = 0$$

which can be rewritten as

$$Y_{j,t} = \mathcal{Y}_t \left( \frac{P_{j,t}}{P_{Y,t}} \right)^{-\nu_1} \tag{4}$$

Using the expression above, for any two intermediate goods $j, k \in [0,1]$,

$$Y_{j,t} = Y_{k,t} \left( \frac{P_{j,t}}{P_{k,t}} \right)^{-\nu_1} \tag{5}$$

Since markets are perfectly competitive in the final goods sector, the zero profit condition must hold:

$$P_{Y,t} Y_t = \int_0^1 P_{j,t} Y_{j,t} \, dj \tag{6}$$

---

[12]This is the statutory premium in the United States.
[13]The Bureau of labor statistics use 100 as the index for the labor share in 2009. Our results stay robust to change in this value.

Substituting (9) into (6) gives

$$Y_{j,t} = P_{Y,t} \mathcal{Y}_t \frac{P_{j,t}^{-\nu_1}}{\int_0^1 P_{j,t}^{1-\nu_1} \, dj} \tag{7}$$

Substitute (8) into (7) to obtain the price index

$$P_{Y,t} = \left( \int_0^1 P_{j,t}^{1-\nu_1} \, dj \right)^{\frac{1}{1-\nu_1}}$$

Since each sector is atomistic, their actions will not affect $\mathcal{Y}_t$ nor $P_{Y,t}$. Thus, each of these sectors will face an isoelastic demand curve with price elasticity $\nu_1$.

**Sectorial goods sector**  The representative sectorial firm $j$ solves the following profit maximization problem

$$\max_{\{X_{i,j,t}\}_{i=1,N_{j,t}}} P_{j,t} N_{j,t}^{1-\frac{\nu_2}{\nu_2-1}} \left( \sum_{i=1}^{N_{j,t}} X_{i,j,t}^{\frac{\nu_2-1}{\nu_2}} \right)^{\frac{\nu_2}{\nu_2-1}} - \sum_{i=1}^{N_{j,t}} P_{i,j,t} X_{i,j,t}$$

where $P_{j,t}$ is the aggregate price in sector $j$ (taken as given by the firm), $X_{i,j,t}$ is intermediate good input produced by firm $i$ in sector $j$, and $N_{j,t}$ is the number of firms in sector $j$.

The first-order condition with respect to $X_{i,j,t}$ is

$$P_{j,t} N_{j,t}^{1-\frac{\nu_2}{\nu_2-1}} \left( \sum_{i=1}^{N_{j,t}} X_{i,j,t}^{\frac{\nu_2-1}{\nu_2}} \right)^{\frac{\nu_2}{\nu_2-1}-1} X_{i,j,t}^{-\frac{1}{\nu_2}} - P_{i,j,t} = 0$$

which can be rewritten as

$$X_{i,j,t} = \frac{Y_{j,t}}{N_{j,t}} \left( \frac{P_{i,j,t}}{P_{j,t}} \right)^{-\nu_2} \tag{8}$$

Using the expression above, for any two intermediate goods $i$, and $k$,

$$X_{i,j,t} = X_{k,j,t} \left( \frac{P_{i,j,t}}{P_{k,j,t}} \right)^{-\nu_2} \tag{9}$$

Now, raising both sides of the equation to the power of $\frac{\nu_2-1}{\nu_2}$, summing over $i$ and raising both sides to the power of $\frac{\nu_2}{\nu_2-1}$, we get

$$\left(\sum_{i=1}^{N_{j,t}} X_{i,j,t}^{\frac{\nu_2-1}{\nu_2}}\right)^{\frac{\nu_2}{\nu_2-1}} = X_{k,j,t}\frac{\left(\sum_{i=1}^{N_{j,t}} P_{i,j,t}^{1-\nu_2}\right)^{\frac{\nu_2}{\nu_2-1}}}{P_{k,j,t}^{-\nu_2}} \tag{10}$$

Substituting for the production function in the left-hand side and rearranging the terms,

$$\frac{Y_{j,t}}{\mathcal{N}_t}\frac{P_{k,j,t}^{-\nu_2}}{X_{k,j,t}} = \mathcal{N}_t^{-\frac{\nu_2}{\nu_2-1}}\left(\sum_{i=1}^{N_{j,t}} P_{i,j,t}^{1-\nu_2}\right)^{\frac{-\nu_2}{\nu_2-1}} \tag{11}$$

Using the first order condition with respect to $X_{i,j,t}$, the left-hand side is equal to $P_{j,t}^{-\nu_2}$. Therefore, the sectoral price index is

$$P_{j,t} = N_{j,t}^{\frac{-1}{1-\nu_2}}\left(\sum_{i=1}^{N_{j,t}} P_{i,j,t}^{1-\nu_2}\right)^{\frac{1}{1-\nu_2}}$$

## 8.1 Individual firm problem

Using the demand faced by an individual firm $i$ in sector $j$, and the demand faced by sector $j$, the demand faced by firm $(i,j)$ can be expressed as

$$\begin{aligned}
X_{i,j,t} &= \frac{\mathcal{Y}_t}{N_{j,t}}\left(\frac{P_{i,j,t}}{P_{j,t}}\right)^{-\nu_2}\left(\frac{P_{j,t}}{P_{Y,t}}\right)^{-\nu_1} & (12)\\
&= \frac{\mathcal{Y}_t}{N_{j,t}}\left(\tilde{P}_{i,j,t}\right)^{-\nu_2}\left(\tilde{P}_{j,t}\right)^{\nu_2-\nu_1} & (13)
\end{aligned}$$

where $\tilde{P}_{i,j,t} \equiv \frac{P_{i,j,t}}{P_{Y,t}}$ and $\tilde{P}_{j,t} \equiv \frac{P_{j,t}}{P_{Y,t}}$.

The (real) source of funds constraint is

$$D_{i,j,t} = \tilde{P}_{i,j,t}X_{i,j,t} - W_{j,t}L_{i,j,t} - r_t^k K_{i,j,t} - r_t^z Z_{i,j,t}$$

Taking the input prices and the pricing kernel as given, intermediate firm $(i,j)$'s problem is to

maximize shareholder's wealth subject to the firm demand emanating from the rest of the economy:

$$V_{i,j,t} = \max_{\{L_{i,j,t},K_{i,j,t},Z_{i,j,t},\tilde{P}_{i,j,t}\}_{t\geqslant 0}} E_0\left[\sum_{s=0}^{\infty} M_{t,t+s}(1-\delta_n)^s D_{i,j,s}\right]$$

$$\text{s.t. } X_{i,j,t} = \frac{\mathcal{Y}_t}{N_{j,t}}\left(\tilde{P}_{i,j,t}\right)^{-\nu_2}\left(\tilde{P}_{j,t}\right)^{\nu_2-\nu_1}$$

where $M_{t,t+s}$ is the marginal rate of substitution between time $t$ and time $t+s$. Note that each sector is atomistic and take the final goods price as given. However, the measure of each firm within a sector is not zero and individual firms will take into account the impact of their price setting on the sectorial price. Further, note that there is no intertemporal decisions. The objective of the firm thus simplifies to a profit maximixation problem with constraint.

The Lagrangian of the problem is

$$\begin{aligned}
\mathcal{V}_{i,j,t} &= \tilde{P}_{i,j,t}K_{i,j,t}^{\alpha}\left(A_t Z_{i,j,t}^{\eta}\mathcal{Z}_t^{1-\eta}L_{i,j,t}\right)^{1-\alpha} - W_{j,t}L_{i,j,t} - r_{j,t}^k K_{i,j,t} - r_{j,t}^z Z_{i,j,t} \\
&\quad + \Lambda_{j,t}^d\left(K_{i,j,t}^{\alpha}\left(A_t Z_{i,j,t}^{\eta}\mathcal{Z}_t^{1-\eta}L_{i,j,t}\right)^{1-\alpha} - \frac{\mathcal{Y}_t}{N_{j,t}}\left(\tilde{P}_{i,j,t}\right)^{-\nu_2}\left(\tilde{P}_{j,t}\right)^{\nu_2-\nu_1}\right)
\end{aligned}$$

The corresponding first order necessary conditions are

$$\begin{aligned}
r_{j,t}^k &= \alpha\frac{X_{i,j,t}}{K_{i,t}}(\tilde{P}_{i,j,t}+\Lambda_t^d) \\
r_{j,t}^z &= \eta(1-\alpha)\frac{X_{i,j,t}}{Z_{i,j,t}}(\tilde{P}_{i,j,t}+\Lambda_t^d) \\
W_{j,t} &= (1-\alpha)\frac{X_{i,j,t}}{L_{i,j,t}}(\tilde{P}_{i,j,t}+\Lambda_t^d) \\
X_{i,j,t} &= \Lambda_{j,t}^d\frac{\mathcal{Y}_t}{N_{j,t}}\left[-\nu_2\tilde{P}_{i,j,t}^{-\nu_2-1}\tilde{P}_{j,t}^{\nu_2-\nu_1} + (\nu_2-\nu_1)\tilde{P}_{i,j,t}^{-\nu_2}\tilde{P}_{j,t}^{\nu_2-\nu_1-1}\frac{\partial\tilde{P}_{j,t}}{\partial P_{i,j,t}}\right]
\end{aligned}$$

where $\Lambda_{j,t}^d$ is the Lagrange multiplier on the inverse demand function.

In the standard Dixit-Stiglitz aggregator, $\frac{\partial\tilde{P}_{j,t}}{\partial P_{i,j,t}} = 0$. This happens because each individual firm is atomistic and has no influence on the aggregate price. In our setup, it will be non-zero because the the measure of firm within an industry is strictly positive. Using the definition of the price index,

$$\frac{\partial\tilde{P}_{j,t}}{\partial P_{i,j,t}} = \frac{1}{N_{j,t}}\left(\frac{P_{i,j,t}}{P_{j,t}}\right)^{-\nu_2}$$

Imposing the symmetry condition, i.e. $\tilde{P}_{j,t} = \tilde{P}_{i,j,t} = 1$, and $\mathcal{Y}_t = N_{j,t}X_{j,t}$, our set of equilibrium conditions simplifies to:

$$
\begin{aligned}
r_{j,t}^k &= \alpha \frac{X_{j,t}}{K_{j,t}}(1 + \Lambda_{j,t}^d) \\
r_{j,t}^z &= \eta(1 - \alpha)\frac{X_{j,t}}{Z_{j,t}}(1 + \Lambda_{j,t}^d) \\
W_{j,t} &= (1 - \alpha)\frac{X_{j,t}}{L_{j,t}}(1 + \Lambda_{j,t}^d) \\
\Lambda_{j,t}^d &= \left[-\nu_2 + (\nu_2 - \nu_1)\frac{1}{N_{j,t}}\right]^{-1}
\end{aligned}
$$

The price markup is defined as the ratio of the optimal price set by the firm over the marginal cost of production. The marginal cost of production is obtained by solving the following cost minimization problem:

$$
\begin{aligned}
\min_{K_{i,j,t},Z_{i,j,t},L_{i,j,t}} \quad & r_{j,t}^k K_{i,j,t} + r_{j,t}^z Z_{i,j,t} + W_{j,t}L_{i,j,t} \\
\text{s.t.} \quad & K_{i,j,t}^\alpha (A_t Z_{i,j,t}^\eta \mathcal{Z}_t^{1-\eta} L_{i,j,t})^{1-\alpha} = X^\star
\end{aligned}
$$

In Lagrangian form,

$$
\mathcal{V}_{i,j,t} = r_{j,t}^k K_{i,j,t} + r_t^z Z_{i,j,t} + W_t L_{i,j,t} + \lambda_{i,j,t}\left(X^\star - K_{i,j,t}^\alpha(A_t Z_{i,j,t}^\eta \mathcal{Z}_t^{1-\eta} L_{i,j,t})^{1-\alpha}\right)
$$

where $\lambda_{i,j,t}$ is the Lagrange multiplier on the production objective. It is also the marginal cost of production of intermediate firms. Taking the first order conditions,

$$
\begin{aligned}
r_{j,t}^k &= \alpha \lambda_{i,j,t} \frac{X_{i,j,t}}{K_{i,j,t}} \\
r_{j,t}^z &= \eta(1 - \alpha)\lambda_{i,j,t}\frac{X_{i,j,t}}{Z_{i,j,t}} \\
W_{j,t} &= (1 - \alpha)\lambda_{i,j,t}\frac{X_{i,j,t}}{L_{i,j,t}}
\end{aligned}
$$

From the individual firm problem (FOC w.r.t. $L_{i,j,t}$), we know that

$$
W_{j,t} = (1 - \alpha)\frac{X_{i,j,t}}{L_{i,j,t}}(\tilde{P}_{i,j,t} + \Lambda_{i,j,t}^d)
$$

Putting the two FOCs w.r.t. to labour together and defining the price markup $\o_{i,j,t}$ as $\tilde{P}_{i,j,t}/\lambda_{i,j,t}$,

$$\o_{i,j,t} \quad = \quad \left(1 + \frac{\Lambda^d_{i,j,t}}{\tilde{P}_{i,j,t}}\right)^{-1}$$

Imposing the symmetry condition $\tilde{P}_{j,t} = 1$ and using the expression for $\Lambda^d_{j,t}$, the price markup is

$$\o_{i,j,t} \quad = \quad \frac{-\nu_2\,N_{j,t} + (\nu_2 - \nu_1)}{-(\nu_2 - 1)\,N_{j,t} + (\nu_2 - \nu_1)}$$

## 8.2  Capital producer problem

The period profit of capital producers is $r^k_{j,t}\mathcal{K}^c_{j,t} - \mathcal{I}_{j,t}$. The optimization problem faced by the representative physical capital producer is to choose $\mathcal{K}^c_{j,t+1}$ and $\mathcal{I}_{j,t}$ in order to maximize the present value of revenues, given the capital accumulation constraint:

$$V^k_{j,t} = \max_{\{\mathcal{I}_{j,t},\mathcal{K}^c_{j,t+1}\}_{t\geqslant 0}} E_0\left[\sum_{s=0}^{\infty} M_{t,t+s}(r^k_{j,s}\mathcal{K}^c_{j,s} - \mathcal{I}_{j,s})\right]$$
$$\text{s.t.} \quad \mathcal{K}^c_{j,t+1} = (1 - \delta_k)\mathcal{K}^c_{j,t} + \Phi_{k,j,t}\mathcal{K}^c_{j,t}$$

The Lagrangian in recursive form is,

$$\mathcal{V}_{j,t} = r^k_{j,t}\mathcal{K}^c_{j,t} - \mathcal{I}_{j,t} + E_t\left[M_{t,t+1}\mathcal{V}_{j,t+1}\right] + Q^k_{j,t}\left((1 - \delta_k)\mathcal{K}^c_{j,t} + \Phi_{k,j,t}\mathcal{K}^c_{j,t} - \mathcal{K}^c_{j,t+1}\right)$$

The first order conditions are:

$$Q^k_{j,t} \quad = \quad \Phi'_k\left(\frac{\mathcal{I}_{j,t}}{\mathcal{K}_{j,t}}\right)^{-1}$$
$$Q^k_{j,t} \quad = \quad E_t\left[M_{t,t+1}\frac{\partial\mathcal{V}_{j,t+1}}{\partial\mathcal{K}^c_{j,t+1}}\right]$$

Using the enveloppe theorem,

$$\frac{\partial\mathcal{V}_{j,t}}{\partial\mathcal{K}^c_{j,t}} = \left(r^k_{j,t} + Q^k_{j,t}\left(1 - \delta_k - \left(\frac{\mathcal{I}_{j,t}}{\mathcal{K}^c_{j,t}}\right)\Phi'_{k,j,t} + \Phi_{k,j,t}\right)\right)$$

The set of equilibrium conditions for the representative capital producer is

$$
\begin{aligned}
Q_{j,t}^k &= \Phi_{k,j,t}'^{-1} \\
Q_{j,t}^k &= E_t \left[ M_{t,t+1} \left( r_{j,t+1}^k + Q_{j,t+1}^k \left( 1 - \delta_k - \left( \frac{\mathcal{I}_{j,t+1}}{\mathcal{K}_{j,t+1}^c} \right) \Phi_{k,j,t+1}' + \Phi_{k,j,t+1} \right) \right) \right] \\
\mathcal{K}_{j,t+1}^c &= (1 - \delta_k)\mathcal{K}_{j,t}^c + \Phi_{k,j,t}\mathcal{K}_{j,t}^c
\end{aligned}
$$

The equilibrium conditions for the technology sector are derived is the same way,

$$
\begin{aligned}
Q_{j,t}^z &= \Phi_{z,j,t}'^{-1} \\
Q_{j,t}^z &= E_t \left[ M_{t,t+1} \left( r_{j,t+1}^z + Q_{j,t+1}^z \left( 1 - \delta_z - \left( \frac{\mathcal{S}_{j,t+1}}{\mathcal{Z}_{j,t+1}^c} \right) \Phi_{z,j,t+1}' + \Phi_{z,j,t+1} \right) \right) \right] \\
\mathcal{Z}_{j,t+1}^c &= (1 - \delta_z)\mathcal{Z}_{j,t}^c + \Phi_{z,j,t}\mathcal{Z}_{j,t}^c
\end{aligned}
$$

where $\mathcal{S}_{j,t}$ is the aggregate investment in R&D in sector $j$.

Table 1: Quarterly Calibration

| Parameter | Description | Model |
|---|---|---|
| A. Preferences | | |
| $\beta$ | Subjective discount factor | 0.995 |
| $\psi$ | Elasticity of intertemporal substitution | 1.8 |
| $\gamma$ | Risk aversion | 10 |
| $\chi$ | Labor elasticity | 3 |
| B. Production | | |
| $\alpha$ | Capital share | 0.33 |
| $\eta$ | Degree of technological appropriability | 0.065 |
| $\delta_k$ | Depreciation rate of capital stock | 2.0% |
| $\delta_k$ | Depreciation rate of R&D stock | 3.75% |
| $\delta_n$ | Firm obsolescence rate | 1.0% |
| $\zeta_k$ | Capital adjustment cost parameter | 0.738 |
| $\zeta_z$ | R&D capital adjustment cost parameter | 0.738 |
| $\nu_1$ | Price elasticity accross industries | 1.05 |
| $\nu_2$ | Price elasticity within industries | 75 |
| C. Productivity | | |
| $\rho$ | Persistence of $a_t$ | 0.985 |
| $\sigma$ | Conditional volatility of $a_t$ | 1.24% |

This table reports the parameter values used in the benchmark quarterly calibration of the model. The table is divided into three categories: Preferences, Production, and Productivity parameters.

Table 2: Industry moments

|  | Data | Model |
|---|---|---|
| **A. Means** | | |
| $E[\log(\text{ø})]$ (%) | 13.39 | 15.92 |
| $E[\text{Profit Share}]$ (%) | 7.04 | 10.98 |
| **B. Standard deviations** | | |
| $\sigma[\log(\text{ø})]$ (%) | 2.30 | 2.69 |
| $\sigma[\Delta z_p]$ (%) | 1.74 | 2.55 |
| $\sigma[\Delta z]$ (%) | 1.05 | 0.87 |
| $\sigma[\text{Profit Share}]$ (%) | 2.18 | 2.37 |
| $\sigma[NE]$ | 0.06 | 0.05 |
| **C. Autocorrelations** | | |
| $AC1[\log(\text{ø})]$ | 0.900 | 0.998 |
| $AC1[\Delta z_p]$ | 0.159 | 0.107 |
| $AC1[\Delta z]$ | 0.958 | 0.985 |
| $AC1[\text{Profit Share}]$ | 0.955 | 0.998 |
| $AC1[NE]$ | 0.701 | 0.696 |
| **D. Correlations** | | |
| $\text{corr}(\log(\text{ø}), N)$ | -0.139 | -0.213 |
| $\text{corr}(\log(\text{ø}), NE)$ | -0.101 | -0.023 |

This table presents the means, standard deviations, autocorrelations, for key macroeconomic variables from the data and the model. The model is calibrated at a quarterly frequency using the benchmark calibration. The growth rate of technology has been annualized ($\Delta z_p$). To obtain a stationary, unit-free measure of entry, $\log(NE)$ is filtered using a Hodrick-Prescott filter with a smoothing parameter of 1,600.

Table 3: Forecasts with growth of new incorporations

|  | Data | | | Model | | |
|---|---|---|---|---|---|---|
|  | Horizon (in quarters) | | | | | |
|  | 1 | 4 | 8 | 1 | 4 | 8 |
| A. Output |  |  |  |  |  |  |
| $\beta$ | 0.235 | 0.429 | 0.108 | 1.224 | 4.784 | 9.585 |
| S.E. | 0.034 | 0.107 | 0.165 | 0.725 | 2.603 | 5.464 |
| $R^2$ | 0.242 | 0.118 | 0.004 | 0.010 | 0.029 | 0.044 |
| B. Consumption |  |  |  |  |  |  |
| $\beta$ | 0.071 | 0.206 | 0.157 | 3.310 | 12.041 | 21.516 |
| S.E. | 0.013 | 0.049 | 0.064 | 0.293 | 1.782 | 4.476 |
| $R^2$ | 0.012 | 0.125 | 0.036 | 0.247 | 0.265 | 0.237 |
| C. Investment |  |  |  |  |  |  |
| $\beta$ | 1.277 | 1.980 | 0.225 | 1.625 | 5.819 | 10.761 |
| S.E. | 0.213 | 0.549 | 0.785 | 1.084 | 3.606 | 7.136 |
| $R^2$ | 0.268 | 0.119 | 0.001 | 0.009 | 0.025 | 0.036 |

This table presents output growth, consumption growth, and investment growth forecasts for horizons of one, four, and eight quarters using the growth in net business formation from the data and the model. The $n$-quarter regressions, $\frac{1}{n}(x_{t,t+1} + \cdots + x_{t+n-1,t+n}) = \alpha + \beta \Delta n_t + \epsilon_{t+1}$, are estimated using overlapping quarterly data and Newey-West standard errors are used to correct for heteroscedasticity.

Table 4: Business cycle moments

|  | Data | A. | B. |
|---|---|---|---|
| **First Moment** |  |  |  |
| $E(\Delta c)$ | 2.00 | 2.00 | 2.00 |
| **Second Moment** |  |  |  |
| $\sigma_{\Delta c}/\sigma_{\Delta y}$ | 0.64 | 0.49 | 1.11 |
| $\sigma_{\Delta i}/\sigma_{\Delta c}$ | 4.38 | 3.00 | 0.99 |
| $\sigma_{\Delta s}/\sigma_{\Delta c}$ | 3.44 | 2.77 | 0.92 |
| $\sigma(\Delta c)$ | 1.10 | 1.10 | 1.10 |
| $\sigma(l)$ | 1.52 | 2.24 | 0.98 |

This table reports simulated moments for two specifications of the model. Column A reports model moments for the benchmark model. Column B reports model moments for the model without entry and exit. To keep the comparison fair, we recalibrate $a^\star$ and $\sigma$ to match the first and second moments of realized consumption growth. The risk premiums are levered following Boldrin, Christiano, and Fisher (2001). Growth rate moments are annualized percentage. Moments for log-hours ($l$) are reported in percentage of total time endowment.

Table 5: Industry cycles

|  | Data | Model |
|---|---|---|
| **A. Markups** | | |
| corr($\phi, Y$) | -0.174 | -0.137 |
| corr($\phi, C$) | -0.283 | -0.213 |
| corr($\phi, I$) | -0.164 | -0.134 |
| **B. Number of firms** | | |
| corr($N, Y$) | 0.708 | 0.656 |
| corr($N, C$) | 0.638 | 0.944 |
| corr($N, I$) | 0.701 | 0.634 |
| **C. Entry** | | |
| corr($NE, Y$) | 0.449 | 0.838 |
| corr($NE, C$) | 0.397 | 0.255 |
| corr($NE, I$) | 0.487 | 0.851 |

This table reports correlations for key macro variables with aggregate markups ($\phi$), the number of firms (NBF: Index of net business formation, and entry (INC: total number of new incorporations) for the data and the model. The model is calibrated at a quarterly frequency and all reported statistics are computed after applying an Hodrick-Prescott filter with a smoothing parameter of 1,600 to the log of all non-stationary variables.

Table 6: Summary statistics sorted on markups

| | Data | | Model | |
|---|---|---|---|---|
| | low $\varnothing_t$ | high $\varnothing_t$ | low $\varnothing_t$ | high $\varnothing_t$ |
| **A. Output** | | | | |
| mean | 0.436 | -0.019 | 0.199 | -0.303 |
| std | 1.030 | 1.970 | 1.336 | 1.433 |
| min | -1.275 | -3.798 | -5.197 | -5.919 |
| max | 2.319 | 3.536 | 5.076 | 5.399 |
| **B. Consumption** | | | | |
| mean | 0.450 | -0.158 | 0.202 | -0.301 |
| std | 0.748 | 0.805 | 0.600 | 0.831 |
| min | -0.543 | -1.406 | -2.023 | -3.413 |
| max | 1.820 | 1.083 | 2.258 | 2.696 |
| **C. Investment** | | | | |
| mean | 1.335 | -0.753 | 0.288 | -0.448 |
| std | 4.434 | 9.411 | 1.881 | 2.455 |
| min | -9.264 | -21.177 | -7.219 | -10.329 |
| max | 8.562 | 11.827 | 7.026 | 8.815 |

This table presents summary statistics for output, consumption, and investment by sorting the data on the level of markup. All non-stationary data are detrended using a Hodrick-Prescott filter with a smoothing parameter of 1,600. All units are percentage deviation from trend.

Table 7: Asset pricing moments

| | Data | A. | B. |
|---|---|---|---|
| **First Moment** | | | |
| $E(r_f)$ | 1.62 | 1.34 | 2.89 |
| $E(r_d - r_f)$ | 5.84 | 5.16 | 0.55 |
| $E[pd]$ | 3.43 | 3.77 | 4.43 |
| **Second Moment** | | | |
| $\sigma(r_f)$ | 0.67 | 0.60 | 0.06 |
| $\sigma(r_d - r_f)$ | 17.87 | 6.57 | 2.62 |
| $\sigma[pd]$ | 0.37 | 0.29 | 0.02 |

This table reports simulated moments for two specifications of the model. Column A reports model moments for the benchmark model. Column B reports model moments for the model without entry and exit. To keep the comparison fair, we recalibrate $a^\star$ and $\sigma$ to match the first and second moments of realized consumption growth. The risk premiums are levered following Boldrin, Christiano, and Fisher (2001). Returns are in annualized percentage units.

Table 8: Stock Return Predictability

| | Data | | | | | Model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Horizon (in years) | | | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| **A. Log Price-Dividend Ratio** | | | | | | | | | | |
| $\beta^{(n)}$ | -0.132 | -0.231 | -0.292 | -0.340 | -0.430 | -0.062 | -0.120 | -0.172 | -0.221 | -0.265 |
| S.E. | 0.041 | 0.078 | 0.099 | 0.112 | 0.135 | 0.022 | 0.039 | 0.054 | 0.066 | 0.076 |
| $R^2$ | 0.090 | 0.157 | 0.193 | 0.214 | 0.254 | 0.051 | 0.097 | 0.140 | 0.179 | 0.215 |
| **B. Net Business Formation** | | | | | | | | | | |
| $\beta^{(n)}$ | -0.770 | -1.006 | -1.059 | -1.255 | -1.790 | -0.054 | -0.103 | -0.148 | -0.189 | -0.227 |
| S.E. | 0.248 | 0.385 | 0.375 | 0.411 | 0.590 | 0.017 | 0.031 | 0.042 | 0.050 | 0.058 |
| $R^2$ | 0.121 | 0.122 | 0.108 | 0.121 | 0.166 | 0.062 | 0.117 | 0.167 | 0.212 | 0.252 |
| **C. Growth in New Incorporations** | | | | | | | | | | |
| $\beta^{(n)}$ | -0.396 | -0.866 | -1.049 | -1.219 | -1.323 | -0.666 | -1.271 | -1.828 | -2.333 | -2.798 |
| S.E. | 0.248 | 0.449 | 0.634 | 0.656 | 0.717 | 0.216 | 0.386 | 0.520 | 0.632 | 0.728 |
| $R^2$ | 0.008 | 0.024 | 0.028 | 0.031 | 0.024 | 0.060 | 0.115 | 0.164 | 0.208 | 0.248 |
| **D. Markup** | | | | | | | | | | |
| $\beta^{(n)}$ | 1.516 | 2.571 | 2.747 | 3.529 | 4.185 | 0.303 | 0.580 | 0.834 | 1.068 | 1.284 |
| S.E. | 0.651 | 1.052 | 1.301 | 1.577 | 2.016 | 0.112 | 0.199 | 0.269 | 0.328 | 0.379 |
| $R^2$ | 0.043 | 0.075 | 0.071 | 0.102 | 0.116 | 0.048 | 0.091 | 0.131 | 0.167 | 0.201 |
| **E. Profit Share** | | | | | | | | | | |
| $\beta^{(n)}$ | 0.298 | 0.733 | 0.943 | 1.678 | 2.135 | 0.340 | 0.651 | 0.937 | 1.199 | 1.442 |
| S.E. | 0.620 | 1.056 | 1.554 | 2.375 | 3.060 | 0.126 | 0.224 | 0.302 | 0.369 | 0.426 |
| $R^2$ | 0.001 | 0.005 | 0.007 | 0.018 | 0.022 | 0.048 | 0.091 | 0.130 | 0.167 | 0.201 |

This table reports excess stock return forecasts for horizons of one to five years, i.e. $r_{t,t+n}^{ex} - y_t^{(n)} = \alpha_n + \beta \, x_t + \epsilon_{t+1}$, where $x_t$ is the predicting variables. The different panels present forecasting regressions using different predicting variables: the log price-dividend ratio (panel A), the linearly detrended index of net business formation (panel B), the growth in new incorporations (panel C), price markups (panel D), and the profit share (panel E). The forecasting regressions use overlapping quarterly data. Newey-West standard errors are used to correct for heteroscedasticity. The estimates from the model regression are averaged across 100 simulations that are equivalent in length to the data sample. The sample is 1948-2013 for Panel A and E, 1948-1993 for panel B and C, and 1964-2013 for panel D. The risk premiums are levered following Boldrin, Christiano, and Fisher (2001).

Table 9: Stock Return Predictability in the Long Sample

| | Horizon (in years) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| **A. Benchmark** | | | | | |
| $\beta^{(n)}$ | -0.039 | -0.075 | -0.108 | -0.139 | -0.168 |
| $R^2$ | 0.032 | 0.062 | 0.089 | 0.114 | 0.138 |
| **B. No Entry/Exits** | | | | | |
| $\beta^{(n)}$ | -0.018 | -0.029 | -0.043 | -0.051 | -0.051 |
| $R^2$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

This table reports excess stock return forecasts in the long sample for horizons of one to five years using the log-price-dividend ratio: $r_{t,t+n}^{ex} - y_t^{(n)} = \alpha_n + \beta \ \log(P_t/D_t) + \epsilon_{t+1}$. Panel A presents the forecasting regressions for the benchmark model with time-varying markup, panel B presents the regression results for the model without entry and exit and constant price markup. The forecasting regressions use overlapping quarterly data. The risk premiums are levered following Boldrin, Christiano, and Fisher (2001).

Table 10: Asset pricing moments: exogenous markups

|  | A. | B. | C. | D. |
|---|---|---|---|---|
| **First Moment** | | | | |
| $E(r_f)$ | 2.89 | 2.55 | 2.22 | 2.15 |
| $E(r_d - r_f)$ | 0.55 | 0.98 | 1.51 | 1.53 |
| $E(pd)$ | 4.43 | 4.40 | 4.30 | 4.28 |
| **Second Moment** | | | | |
| $\sigma(r_f)$ | 0.06 | 0.17 | 0.19 | 0.33 |
| $\sigma(r_d - r_f)$ | 2.62 | 2.92 | 3.40 | 3.45 |
| $\sigma(pd)$ | 0.02 | 0.17 | 0.16 | 0.22 |

This table reports asset pricing moments for four specifications of the model with exogenous markups. Column A reports model moments for the model with constant markups ($\rho_\o = 0$, $\sigma_\o = 0$, $\varrho = 0$, and $\kappa_\o = 0$). Column B reports model moments for the time-varying markup model ($\rho_\o = 0.997$, $\sigma_\o = 0.17\%$, $\varrho = 0$, and $\kappa_\o = 0$). Column C reports model moments for the model with countercyclical markups ($\rho_\o = 0.997$, $\sigma_\o = 0.17\%$, $\varrho = -0.5$, and $\kappa_\o = 0$). Column D reports moment for the model with countercyclical markups and business cycle asymmetry ($\rho_\o = 0.997$, $\sigma_\o = 0.17\%$, $\varrho = -0.5$, and $\kappa_\o = 15$). The risk premiums are levered following Boldrin, Christiano, and Fisher (2001).

Table 11: Stock return predictability: exogenous markups

| | Horizon (in years) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| **A. Constant markup** | | | | | |
| $\beta^{(n)}$ | -0.018 | -0.029 | -0.043 | -0.051 | -0.051 |
| $R^2$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **B. Time-varying, uncorrelated $\o_t$** | | | | | |
| $\beta^{(n)}$ | 0.001 | 0.002 | 0.003 | 0.004 | 0.005 |
| $R^2$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **C. Countercyclical $\o_t$** | | | | | |
| $\beta^{(n)}$ | 0.002 | 0.004 | 0.005 | 0.007 | 0.009 |
| $R^2$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **D. Countercyclical and heteroskedastic $\o_t$** | | | | | |
| $\beta^{(n)}$ | -0.022 | -0.044 | -0.066 | -0.087 | -0.109 |
| $R^2$ | 0.015 | 0.029 | 0.043 | 0.057 | 0.070 |

This table reports long sample excess stock return forecasts in the model with exogenous price markup for horizons of one to five years using the log-price-dividend ratio: $r_{t,t+n}^{ex} - y_t^{(n)} = \alpha_n + \beta \, \log(P_t/D_t) + \epsilon_{t+1}$. Panel A reports the forecasting regressions for the model with constant markups ($\rho_\o = 0$, $\sigma_\o = 0$, $\varrho = 0$, and $\kappa_\o = 0$). Panel B reports the forecasting regressions for the time-varying markup model ($\rho_\o = 0.997$, $\sigma_\o = 0.17\%$, $\varrho = 0$, and $\kappa_\o = 0$). Panel C reports the forecasting regressions for the model with countercyclical markups ($\rho_\o = 0.997$, $\sigma_\o = 0.17\%$, $\varrho = -0.5$, and $\kappa_\o = 0$). Panel D reports the forecasting regressions for the model with countercyclical markups and business cycle asymmetry ($\rho_\o = 0.997$, $\sigma_\o = 0.17\%$, $\varrho = -0.5$, and $\kappa_\o = 15$). The risk premiums are levered following Boldrin, Christiano, and Fisher (2001).

Table 12: Asset pricing moments: wage markup

|  | A. | B. | C. |
|---|---|---|---|
| **First Moment** | | | |
| $E(r_f)$ | 1.34 | 0.62 | 0.00 |
| $E(r_d - r_f)$ | 5.16 | 5.63 | 6.94 |
| $E(pd)$ | 3.77 | 3.59 | 3.32 |
| **Second Moment** | | | |
| $\sigma(r_f)$ | 0.60 | 0.72 | 0.90 |
| $\sigma(r_d - r_f)$ | 6.57 | 7.02 | 7.90 |
| $\sigma(pd)$ | 0.29 | 0.33 | 0.37 |

This table reports asset pricing moments for four specifications of the model with wage markups as well as the benchmark model. Column A reports moments for the benchmark model. Column B reports model moments for the benchmark model with time-varying, uncorrelated wage markup ($\sigma_\phi^w = 2.88\%$, $\rho_\phi^w = 0.96$, and $\varrho^w = 0$). Column C reports moments for the benchmark model with countercyclical wage markup ($\sigma_\phi^w = 2.88\%$, $\rho_\phi^w = 0.96$, and $\varrho^w = -0.45$). Column D reports model moments for the model with constant price markup and countercyclical wage markup ($\sigma_\phi^w = 2.88\%$, $\rho_\phi^w = 0.96$, and $\varrho^w = -0.45$). The risk premiums are levered following Boldrin, Christiano, and Fisher (2001).

Table 13: Stock return predictability: wage markup

| | Horizon (in years) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| **A. Benchmark** | | | | | |
| $\beta^{(n)}$ | -0.039 | -0.075 | -0.108 | -0.139 | -0.168 |
| $R^2$ | 0.032 | 0.062 | 0.089 | 0.114 | 0.138 |
| **B. Time-varying, uncorrelated $\phi_t^w$** | | | | | |
| $\beta^{(n)}$ | -0.054 | -0.105 | -0.152 | -0.196 | -0.238 |
| $R^2$ | 0.043 | 0.082 | 0.119 | 0.153 | 0.184 |
| **C. Countercyclical $\phi_t^w$** | | | | | |
| $\beta^{(n)}$ | -0.173 | -0.333 | -0.480 | -0.615 | -0.740 |
| $R^2$ | 0.119 | 0.215 | 0.294 | 0.357 | 0.408 |

This table reports long sample excess stock return forecasts in the model with exogenous wage markup for horizons of one to five years using the log-price-dividend ratio: $r_{t,t+n}^{ex} - y_t^{(n)} = \alpha_n + \beta \ \log(P_t/D_t) + \epsilon_{t+1}$. Panel A reports the forecasting regressions for the benchmark model. Panel B reports the forecasting regressions for the benchmark model with time-varying, uncorrelated wage markup ($\sigma_\phi^w = 2.88\%$, $\rho_\phi^w = 0.96$, and $\varrho^w = 0$). Panel C reports the forecasting regressions for the benchmark model with countercyclical wage markup ($\sigma_\phi^w = 2.88\%$, $\rho_\phi^w = 0.96$, and $\varrho^w = -0.45$). Panel D reports the forecasting regressions for the model with constant price markup and countercyclical wage markup ($\sigma_\phi^w = 2.88\%$, $\rho_\phi^w = 0.96$, and $\varrho^w = -0.45$). The risk premiums are levered following Boldrin, Christiano, and Fisher (2001).
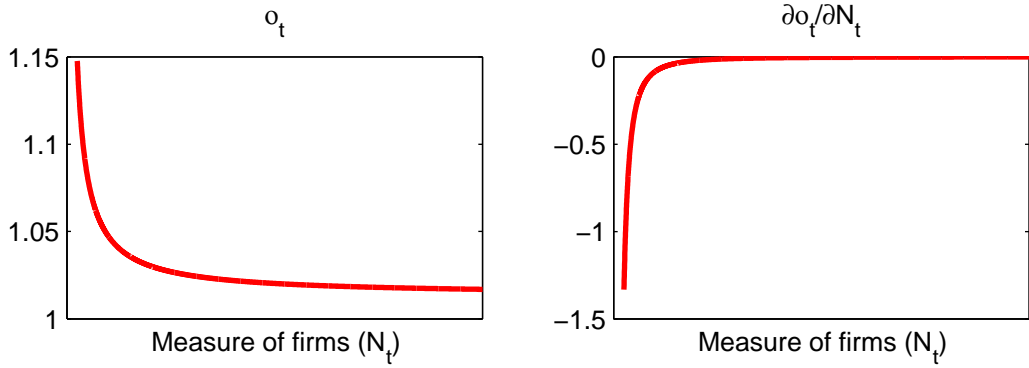
Figure 1: This figure plots the markup (left) and the first derivative of the markup with respect to $\mathcal{N}_t$ (left) as a function of the number of firms ($\mathcal{N}_t$) for the benchmark calibration of the model.
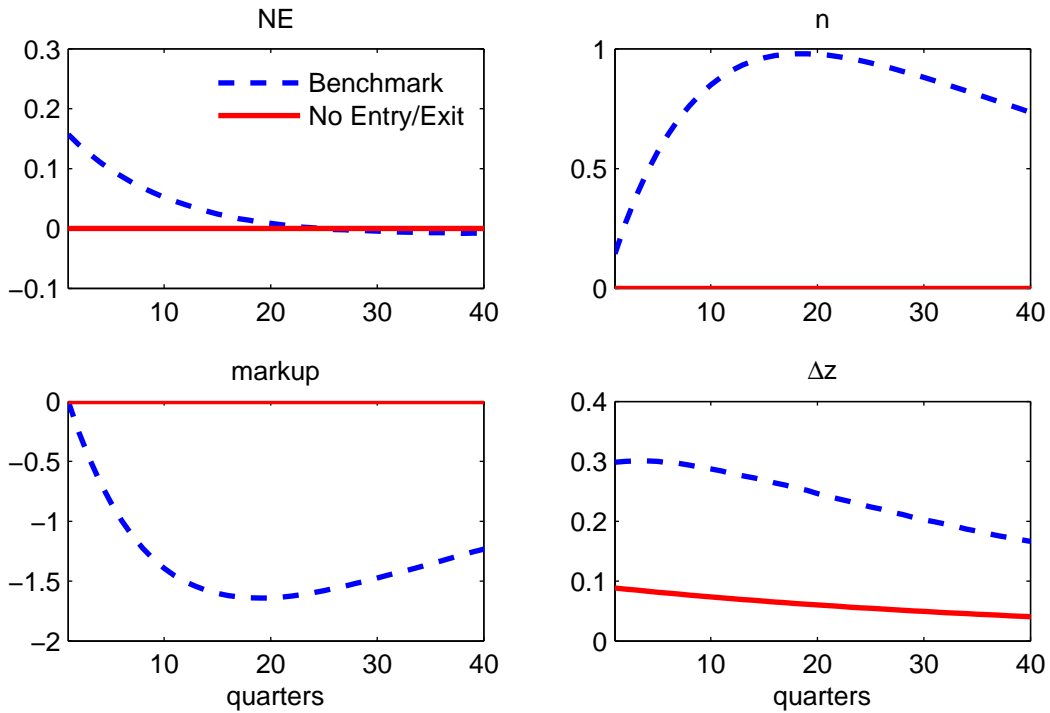


Figure 2: This figure plots the impulse response functions for entry ($NE$), the number of firms ($n$), the price markup, and the growth of technology ($\Delta z$) to a positive one standard deviation productivity shock for the benchmark model (dashed line), and the model without entry and exit (solid line). The parameters used to solve the no entry/exit model are the same as the benchmark model except for $a^\star$ that is modified to ensure an average growth rate of 2%, and $\sigma$ that is modified to get a consumption growth volatility of 1.10%. All values on the $y$-axis are in annualized percentage log-deviation from the steady state.
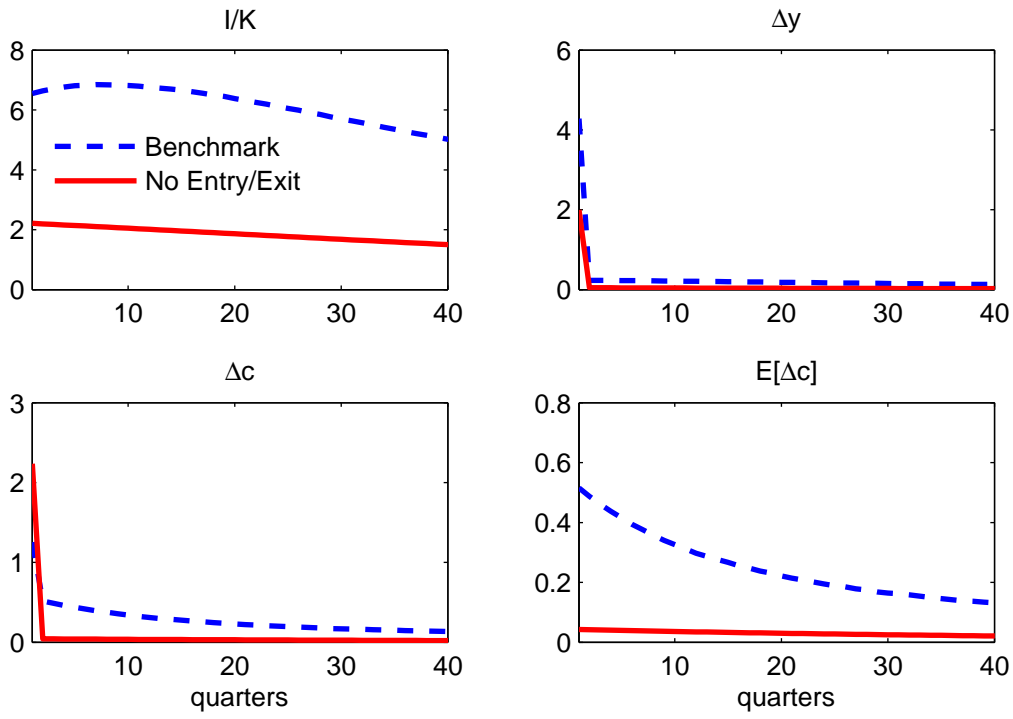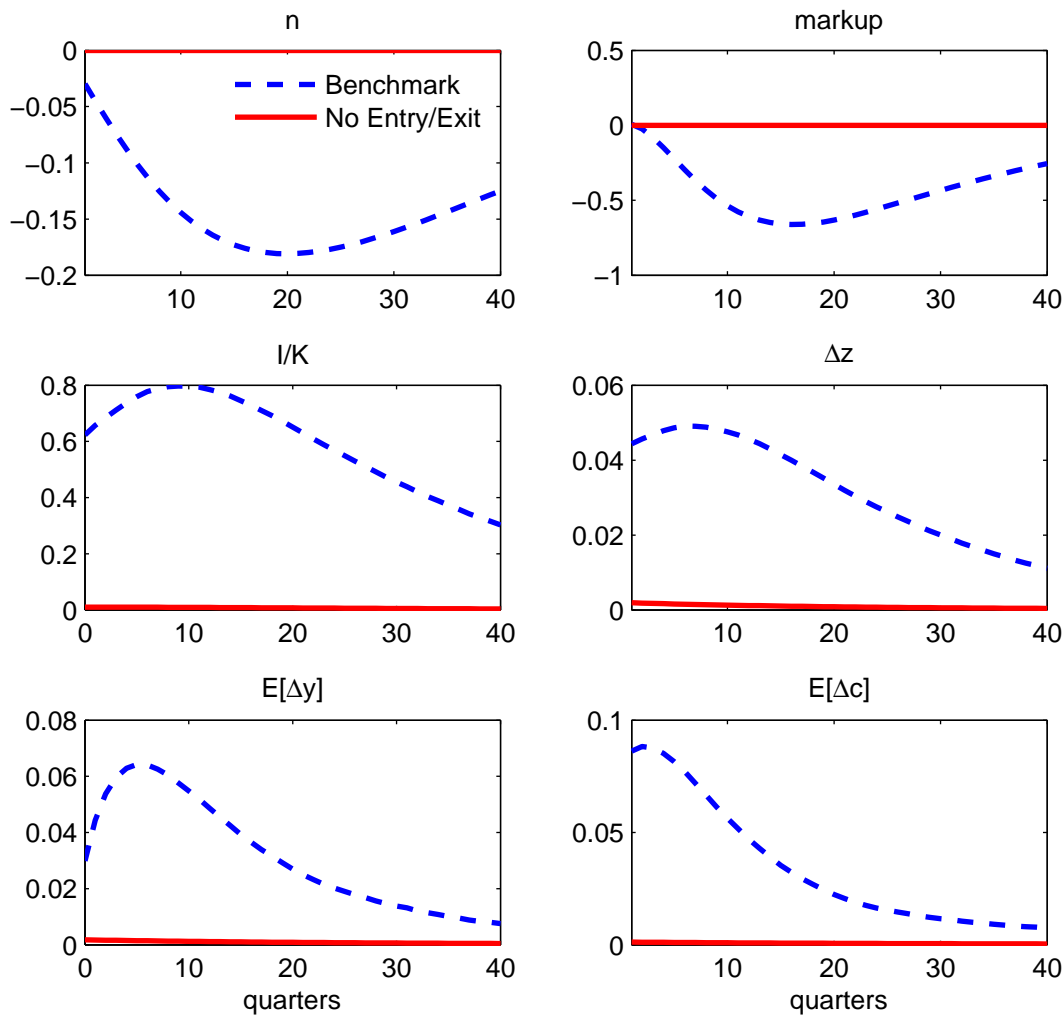
Figure 3: This figure plots the impulse response functions for the investment-to-capital ratio ($I/K$), output growth ($\Delta y$), consumption growth ($\Delta c$), and expected consumption growth ($E[\Delta c]$) to a positive one standard deviation productivity shock for the benchmark model (dashed line), and the model without entry and exit (solid line). The parameters used to solve the no entry/exit model are the same as the benchmark model except for $a^\star$ that is modified to ensure an average growth rate of 2%, and $\sigma$ that is modified to get a consumption growth volatility of 1.10%. All values on the $y$-axis are in annualized percentage log-deviation from the steady state.
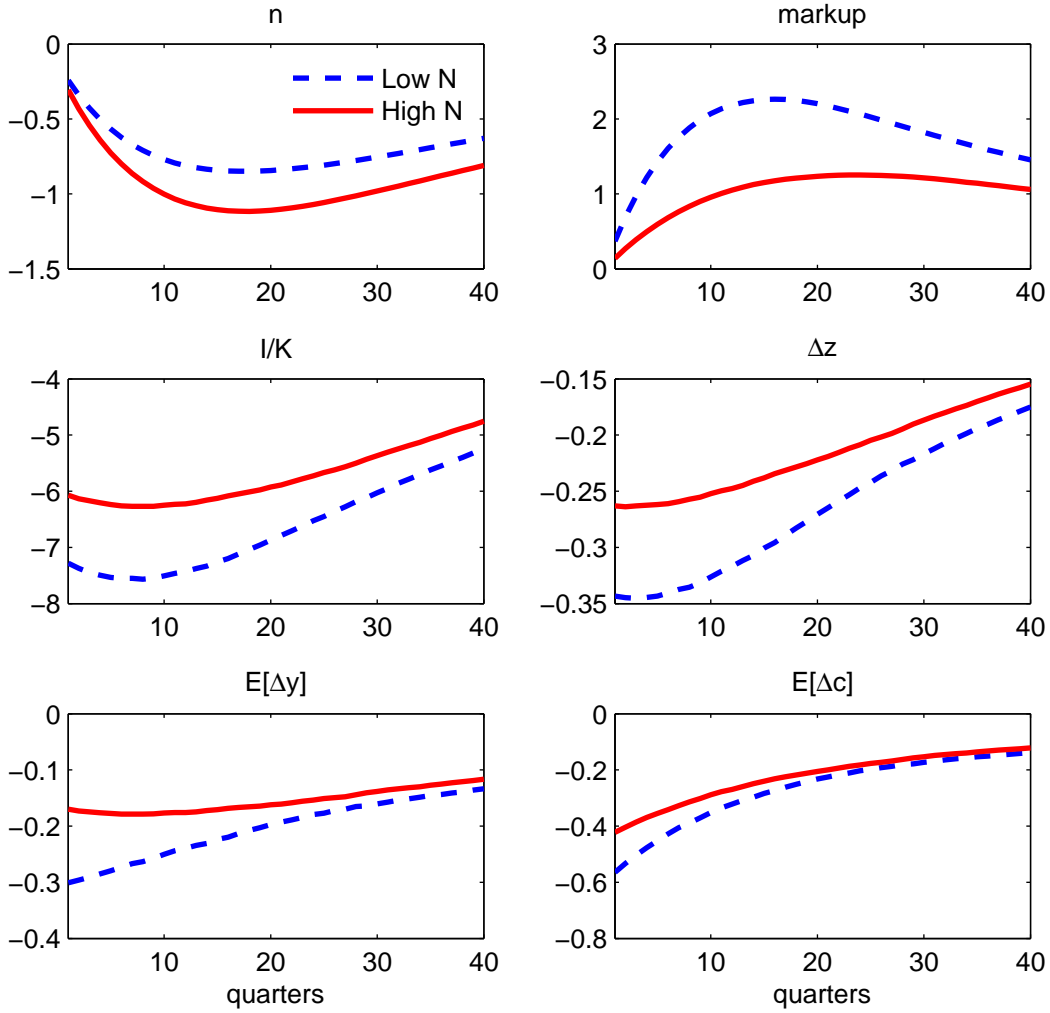
Figure 4: This figure plots the asymmetry in impulse response functions for the number of firms ($n_t$), the price markup, the investment-to-capital ratio ($I/K$), the growth in technology ($\Delta z$), and the expected growth rate of output ($E[\Delta y]$) and consumption ($E[\Delta c]$) in the benchmark model (dashed line), and the model without entry and exit (solid line). The graphs are obtained by taking the difference between minus the response to a two standard deviation negative productivity shock and the response to a positive two standard devitation shock. The parameters used to solve the no entry/exit model are the same as the benchmark model except for $a^\star$ that is modified to ensure an average growth rate of 2%, and $\sigma$ that is modified to get a consumption growth volatility of 1.10%. All values on the $y$-axis are in annualized percentage log-deviation from the steady state.

Figure 5: This figure plots the impulse response functions for the number of firms ($n_t$), the price markup, the investment-to-capital ratio ($I/K$), the growth in technology ($\Delta z$), and the expected growth rate of output ($E[\Delta y]$) and consumption ($E[\Delta c]$) in the benchmark model to a negative one standard deviation technology shock as a function of the number of firms in the economy, $\mathcal{N}_t$. The high $\mathcal{N}$ (low $\mathcal{N}$) case corresponds to the average responses accross 250 draws in the highest (lowest) quintile sorted on $\mathcal{N}_t$. The data for the sorting is obtained by simulating the economy for 50 periods prior to the realization of the negative technology shock. All values on the $y$-axis are in annualized percentage log-deviation from the steady state.
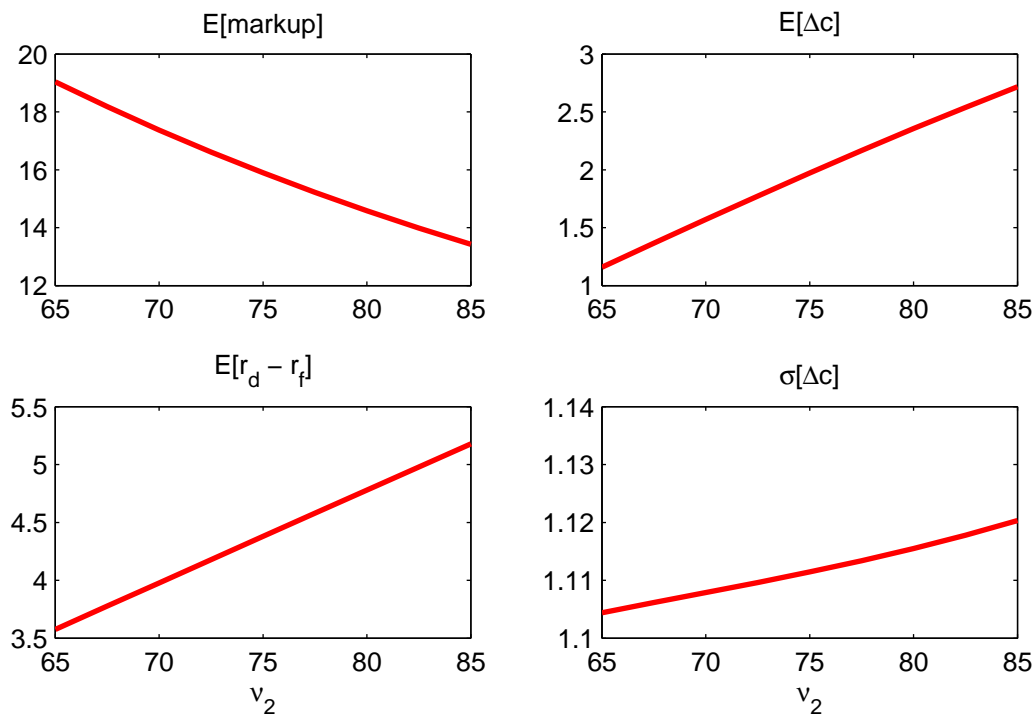
Figure 6: This figure plots the impact of varying the degree of competition within industry $\nu_2$ on the average markup, the average output growth, the average equity premium, and the volatility of output growth. Values on y-axis are in annualized percentage units for expected consumption growth and the equity premium and in percentage units for the price markup.
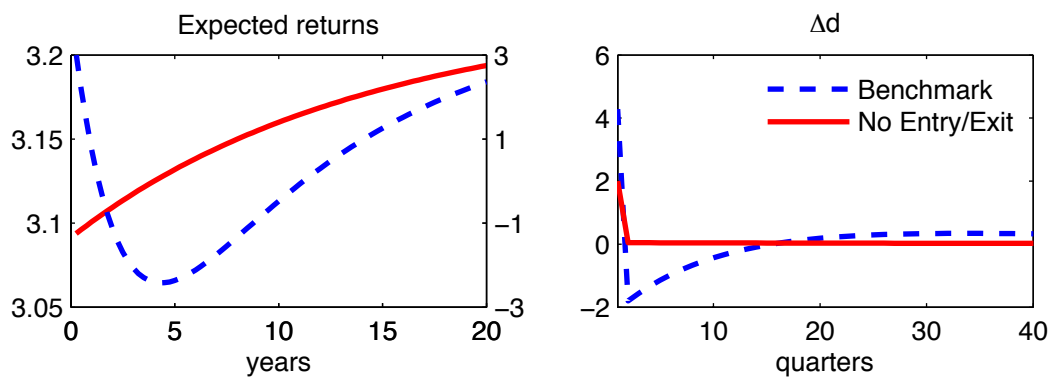


Figure 7: This figure plots the term structure of equity returns (left) and the response of dividend growth to a positive technology shock (right) in the benchmark model and in the model without entry and exit (constant markups). The parameters used to solve the no entry/exit model are the same as the benchmark model except for $a^\star$ that is modified to ensure an average growth rate of 2%, and $\sigma$ that is modified to get a consumption growth volatility of 1.10%. All values on the $y$-axis are in annualized percentage.
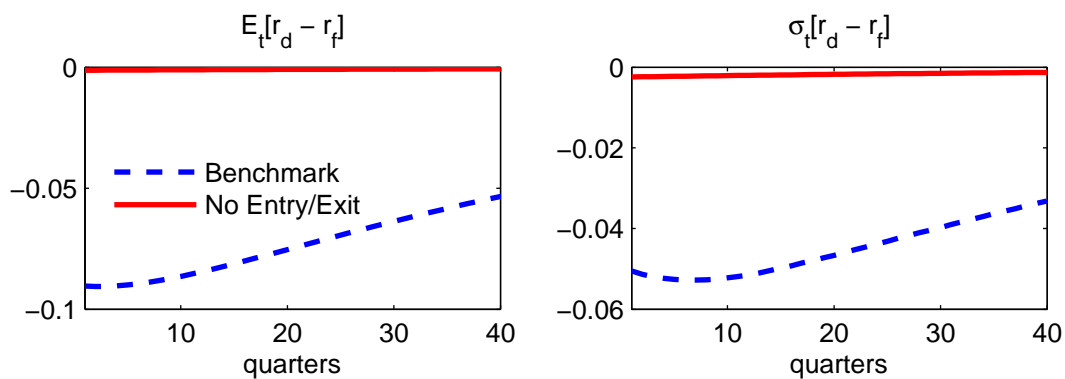
Figure 8: This figure plots the impulse response functions for the conditional risk premium ($E_t[r_d - r_f]$), and the conditional variance of the risk premium ($\sigma^2[r_d - r_f]$) to a positive one standard deviation productivity shock for the benchmark model (dashed line), and the model without entry and exit (solid line). The parameters used to solve the no entry/exit model are the same as the benchmark model except for $a^\star$ that is modified to ensure an average growth rate of 2%, and $\sigma$ that is modified to get a consumption growth volatility of 1.10%. All values on the $y$-axis are in annualized percentage log-deviation from the steady state.