

Q: Risk, Rents, or Growth?

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The dramatic stock market crash of March 2020 was preceded by a prolonged rise in Tobin's Q and a productivity slowdown. Do longer stock market booms and sharper corrections reflect structural changes in the US economy? We address this question about Q by estimating an endogenous growth model featuring realistic risk premia and markups. Our baseline estimates highlight the importance of rising market power for explaining increasing valuation ratios despite declining growth prospects with weakening investment and innovation over the past decade. High industry concentration exacerbates economic downturns and stock market corrections triggered by adverse economic shocks. We provide novel forecasts about growth expectations based on current market valuations using our structural model.

Keywords: Tobin's Q, Aggregate demand, Simulated method of moments, Corporate investment, Intangible capital, Innovation, Industry concentration, Price-dividend ratios, Asset valuations, Equity premium

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1 Introduction

The crash of March 2020 marked one of the largest and precipitous stock market corrections in US history. The sell-out ended a stock market boom of unprecedented length that started in the aftermath of the Financial Crisis of 2008. Notably, the boom in equity valuation ratios and Tobin’s Q was accompanied by a significant productivity slowdown. Do these joint observations of longer stock market booms and sharper corrections reflect fundamental structural changes in the US economy?

In this paper, we interpret data on asset market valuations to shed light on structural shifts in the macroeconomy. Asset prices are forward-looking and provide real-time guidance regarding future macroeconomic performance. Specifically, we ask whether movements in valuation ratios such as Tobin’s Q and price-dividend ratios reflect expectations of future risk, economic rents, or growth? To take a step towards answering this question, we provide guidance regarding the determinants of future macroeconomic activity by linking them to asset valuations through the lens of an estimated general equilibrium model.

Our approach is motivated by the recent debate among economists regarding secular trends, and perhaps, a stagnation in macroeconomic activity. Asset valuation ratios have been trending up during the long stock market boom (see, for example, Caballero, Farhi, and Gourinchas (2017), Farhi and Gourio (2018), or Eggertsson, Robbins, and Wold (2018)) until the collapse from the global pandemic in March 2020, while real interest rates have steadily declined. At the same time, weakening capital investment, innovation, and productivity growth have coincided with surging corporate profits and market power (see, for example, Furman (2015), Grullon, Larkin, and Michaely (2019), Gutiérrez and Philippon (2016), Gutiérrez and Philippon (2017), and Alexander and Eberly (2018)).¹ Do rising profits reflect increasing rent extraction by firms in an environment with declining competition (as in Gutiérrez and Philippon (2017)), or higher returns to investment in intangible capital (as, for example, in Crouzet and Eberly (2019b), Crouzet and Eberly (2018) or, Autor, Dorn, Katz, Patterson, and Van Reenen (2017))? Do weakening investment and innovation stem from lower growth expectations or increases in aggregate risk and risk premia (as, for example, in Farhi and Gourio (2018))? Are higher valuation ratios driven by persistently low interest rates, changes in risk premia, or optimistic growth projections (as, for example, in Eggertsson, Robbins, and Wold (2018))? Finally, how do these economic channels interact?

¹See also Philippon (2019) for a forceful survey.

A key challenge to the empirical evaluation of these economic channels is the direct measurement of key variables. Identifying and measuring both the stock and flow of intangible capital is inherently difficult and subject to a broad debate.² Similarly, measuring and identifying the effects of market power at higher levels of aggregation is challenging,³ and so is the estimation of the conditional risk premia. In this paper, we confront these measurement and identification challenges with a complementary approach. We rely on the structural restrictions of our model to (i) relate these variables of interest to an array of observables (e.g., consumption, output, investment, net business formation, etc.) and (ii) endogenously link their joint dynamics in general equilibrium.

To account for and disentangle such potential driving forces, we estimate an innovation-based endogenous growth model with endogenous price markups and realistic aggregate risk premia using the simulated method of moments (SMM) following Hennessy and Whited (2007). In the model, we show that to a first order, Tobin's Q is driven by profitability, which depends on the return on physical and intangible assets, aggregate growth rates, and discount rates, all of which are endogenously determined in equilibrium. The household sector is characterized by a representative investor assumed to have recursive preferences. The production sector is characterized by a set of industries, each featuring oligopolistic firms cognizant of the effect of their pricing strategy on industry demand. Firms invest in both physical and intangible capital, boosting long-term growth prospects due to aggregate spillover effects. Entry costs help pinning down the mass of active firms and determine industry competition. The estimation results illustrate the role of rising market power for quantitatively explaining the recent boom in equity valuation ratios with a slowdown in growth and rising macroeconomic uncertainty. A structural decomposition elucidates the role of equilibrium fluctuations in competition, growth, and risk for shaping recent trends. Based on the decomposition, we provide novel model-based forecasts of future macroeconomic and financial market performance.

The baseline estimates highlight (i) the critical role of declining competition in the presence of strategic interactions among firms and the low aggregate demand in recent years for jointly shaping asset valuations and the current macroeconomic environment, (ii) the relevance of accounting for linkages between competition, growth rates, and risk premia in an economy in which long-term growth rates are endogenously determined by innovative activity, reflected in higher risk premia and higher macroeconomic uncertainty resulting in elevated sensitivity of valuation ratios to shocks in

²See, for example, Corrado, Hulten, and Sichel (2009).

³See, for example, Syverson (2019) for an in-depth discussion.

line with more pronounced stock market declines, and (iii) the role of the rise in intangible capital in shaping the competitive environment. Indeed, we find that the average entry costs into industries almost doubled since the early 2000s relative to the 1980s and 1990s. The associated decline in entry rates can account for the observed rise in industry concentration and markups in recent years. While our estimates attribute weak investment and innovation to rising industry concentration, we find that movements in competition reflect the increasing importance of intangible capital.

Changes in market structure have first order effects on growth and discount rates in a setting where growth is endogenously determined. Declining competition lowers growth expectations and real interest rates, while increasing aggregate uncertainty and risk premia. In our environment, weakening innovation in response to strengthened market power endogenously generates a slowdown in productivity growth. Indeed, changes in competition explain roughly half of the recent slowdown in growth, and contribute similarly to reductions in investment and innovation rates. Similarly, reduced growth expectations and a contraction in aggregate demand both contribute to lower real rates. In contrast, macroeconomic uncertainty and risk premia rise with concentration in our model as markups are endogenously determined by strategic competition among firms, thereby increasing the probability of a sharp correction in stock markets. When there is less competition, incumbent firms enjoying higher market power can be more aggressively undercut by new entrants, raising aggregate volatility and the equity risk premium.⁴ The decline in the riskfree rate dominates the increase in risk premia so that discount rates fall. The drop in discount rates is sufficiently large and persistent so that the valuation ratios rise despite lower long-run growth expectations. On the other hand, we show that in less competitive environments, stock market valuations respond significantly more to shocks. This is reflected in our model-based forecasts, which indicate a substantially larger drop in growth expectations upon a stock market decline in more concentrated economies.

In our economy, fluctuations in growth prospects and volatility have quantitatively important implications for welfare calculations. Our estimates suggest significant welfare costs associated with rises in markups. These findings complement recent work by Edmond, Midrigan, and Xu (2019) and Cavenaile, Celik, and Tian (2019), who find substantial welfare costs from rising markups in environments without aggregate risk. In fact, our estimates are even larger as markup variation amplifies growth dynamics in our model and endogenously generates time-varying volatility that

⁴See Corhay, Kung, and Schmid (2020) for an in-depth analysis of this mechanism.

risk-sensitive households are averse to.

Our benchmark model is silent about nominal variables such as inflation and nominal interest rates, and thus about potential linkages between central bank policy and secular trends. Empirically, however, we document a significant reduction in mean inflation post 2000. Indeed, as discussed widely in the press and documented in the literature⁵, and in spite of a rapidly expanding economy and exceptionally accommodating monetary policy in recent years, inflation has lagged behind, a phenomenon sometimes dubbed the “missing inflation puzzle”. At the same time, valuations in bond markets rose as reflected in declining yields spreads and term premia. To investigate these patterns, we propose an extension of our benchmark model with nominal rigidities and a monetary policy rule. Here, markups not only reflect movements in the competitive environment, but also nominal rigidities, so that markups often deviate significantly from their desired levels (in the flexible price case) and reinforce competitive distortions. In this setup, firms are reluctant to raise prices aggressively in expansions as it is costly to lower prices to target in recessions, when markups are higher than the desired level. Quantitatively, we show that with this interaction, declining competition contributes significantly to the observed fall in inflation. In turn, we find that in such an environment the effects of monetary policy shocks are amplified.

This paper is structured as follows. After a brief overview of the related literature in the next paragraph, we describe our benchmark model in section 2. Section 3 provides an account of recent trends in macroeconomic variables and asset valuations in the data, followed by a description of our empirical estimation strategy. We examine the economic determinants of real trends through the lens our model in section 4, along with welfare calculations and some sensitivity analysis, and extend it to a setting with nominal rigidities in section 5. Section 6 examines in detail the sensitivity of macroeconomic and financial variables to shocks in differentially competitive economies, and provides growth forecasts in the aftermath of the recent stock market collapse. Section 7 provides some concluding remarks.

Related Literature Our paper contributes to a growing literature that attempts to understand the drivers and effects of recent trends in macroeconomic variables and asset prices. Many papers document secular trends in interest rates (Caballero, Farhi, and Gourinchas (2017)), in the labor share (Barkai (2016), Karabarbounis and Neiman (2016), Rognlie (2015), Hartman-Glaser, Lustig, and Xiaolan (2019), Eisfeldt, Falato, and Xiaolan (2019)), in valuation ratios (Gutiérrez and

⁵See, for example in Arias, Erceg, and Trabandt (2016)

Philippon (2017)), and changes in competition (Gutiérrez and Philippon (2017), Grullon, Larkin, and Michaely (2019), De Loecker and Eeckhout (2017)) and intangible investment (Crouzet and Eberly (2019b), Crouzet and Eberly (2018)), among others.

Our approach to attempting an explanation and decomposition of the relevant underlying forces through the lens of a structural model is closely related to and motivated by the recent work of Eggertsson, Robbins, and Wold (2018) and Farhi and Gourio (2018). Both these papers use versions of the standard stochastic growth model augmented with imperfect competition and a device to generate relevant risk premia (long-run risk and disaster risk, respectively) to interpret recent shifts in aggregate activity and asset prices. Their accounts of the evidence differ in that the first paper attributes these movements mostly to rising savings supply and rising market power, while the second paper emphasizes the role of macroeconomic risk, but attributes a smaller role to movements in market power. Our approach differs from these contributions in one critical dimension. Rather than positing exogenously assumed processes for growth rates and markups (a standard assumption in the stochastic growth literature), trend growth prospects and markups are endogenously determined and interact in equilibrium. Our results suggest that these endogenous linkages are quantitatively important. Moreover, rather than relying on a calibration approach, we discipline our inference by structurally estimating our model.

Our results regarding the relevance of rising entry costs mirror recent work by Gutiérrez, Jones, and Philippon (2019), who use Bayesian estimation techniques to back out movements in entry costs in recent years in the US from a DSGE model with endogenous entry similar to the specification we entertain. While our inference regarding rising entry costs is consistent, our work differs in that our estimation is disciplined in a risk-sensitive setting by evidence on risk premia, endogenous innovation, and endogenous markups, while their work disciplines their estimates in a setting with cross-industry heterogeneity which our model abstracts from.

Recent work by Greenwald, Lettau, and Ludvigson (2019) provides a related decomposition and interpretation of trends in asset valuations. Through the lens of a model that allows for movements in factor shares between shareholders and workers, their estimation results attribute a significant part of the rise in asset valuations to a reallocation of rents from workers to shareholders in a slowing economy. While we do not explicitly allow for such a reallocation in our representative agent economy, our results are largely consistent with and support these empirical findings and allow to interpret them through the lens of a model in which shareholders benefit from endogenous

profits and markups, whose effects impact trend growth rates. Intriguingly, however, their setup implies a decline in risk premia over the years.

Our model of endogenous entry, markups, competition, and growth emphasizes firms strategic interactions and thus connects our paper to the growing literature that examines the aggregate asset pricing implications of firms' intangible capital, such as Ai, Croce, and Li (2013), or Crouzet and Eberly (2019a), and of product market imperfections, such Corhay (2017), Lyandres and Palazzo (2016), Loualiche (2016), Opp, Parlour, and Walden (2014), Iraola and Santos (2017), Dou, Ji, and Wu (2019), Wang, Whited, Wu, and Xiao (2019), Neuhann and Sockin (2020), or Chen, Dou, Guo, and Ji (2020). In contrast to these papers, we focus on the determinants of recent trends in asset valuations and their connections to the macroeconomy and growth prospects. In that respect, our work is related to the novel demand based approach to asset pricing pioneered in Kojien and Yogo (2019), as well as Kojien, Richmond, and Yogo (2019), which builds on recent advances in empirical industrial organization and also reflects imperfect competition.

Methodologically, our stochastic endogenous growth model builds on the framework of Kung (2015), Kung and Schmid (2015), and Corhay, Kung, and Schmid (2020). These papers illustrate how the presence of spillovers on the accumulation of R&D capital provide a long-run growth propagation mechanism that generates equilibrium long-run risks. Our paper differs from this strand of literature by illustrating how the presence of strategic interactions in product markets allows to interpret recent secular trends in macroeconomic and asset price data.

2 Economic environment

This section presents the benchmark model that we use to link competition and rents to aggregate growth and risk. Households are characterized by a representative agent and markets are complete. Households accumulate the physical and intangible capital stocks in the economy and rent them out to firms in the production sector. Production consists of two sectors, final goods and intermediate goods. A representative final goods firm produces final goods in two stages. First, a finite measure of differentiated products are packaged together to form an industry good. Second, there are a continuum of industry goods that are combined to form the final goods used for consumption. Each product is produced by an intermediate firm. The intermediate firms are oligopolistic and compete strategically in the industry in a Bertrand-Nash setup. The measure of firms in each

industry and in each period is determined by a free entry condition.

Within the context of our model, we derive an approximate decomposition of Tobin's Q that illuminates the underlying economic drivers in an intuitive way. This decomposition provides guidance for the empirical and quantitative analysis in the remainder of the paper.

2.1 Final goods firm

Final goods are produced by using a constant elasticity of substitution (CES) aggregator to bundle together a continuum of differentiated industry goods, $Y_{j,t}$, on a unit measure, $j \in [0, 1]$:

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

where $\nu_1 > 0$ is the elasticity of substitution between industry goods.

Within a particular industry j , a CES aggregator bundles together a continuum of differentiated products, $X_{ij,t}$, on a measure of firms $i \in [0, N_{j,t}]$:

$$Y_{j,t} = \left(\int_0^{N_{j,t}} X_{ij,t}^{\frac{\nu_2-1}{\nu_2}} di \right)^{\frac{\nu_2}{\nu_2-1}}, \quad (2)$$

where $\nu_2 > 0$ is the elasticity of substitution between products. We focus on a case where the elasticity of substitution is higher within than across industries (i.e., $\nu_2 > \nu_1$).⁶

The representative final goods firm chooses the quantity of products to buy from each firm in order to maximize profits. This yields a demand function for each product i in industry j :

$$\Theta_{j,t}(P_{ij,t}) \equiv \mathcal{Y}_t (P_{ij,t})^{-\nu_2} (P_{j,t})^{\nu_2-\nu_1}, \quad (3)$$

where $P_{ij,t}$ is the price of product i in industry j , and $P_{j,t} \equiv \left(\int_0^{N_{j,t}} P_{ij,t}^{1-\nu_2} di \right)^{\frac{1}{1-\nu_2}}$ is the price index of industry j . Details of the final goods firm's problem is contained in Appendix A.1.

2.2 Industry structure and strategic interaction

There is a continuum of identical industries, each characterized by an oligopolistic market structure. We capture strategic interactions across firms by assuming that firms play each period, a static

⁶This parameter configuration implies countercyclical markups, which is consistent with recent empirical evidence, e.g., see Gilchrist, Schoenle, Sim, and Zakrajšek (2017) and Corhay, Kung, and Schmid (2020).

Bertrand game within their respective industry, that is, firms choose the optimal price for their product, taking the other firms' decisions as given.

The two-stage final goods production that features a continuum of industries allows for a tractable way to embed an industry equilibrium with strategic interactions in a general equilibrium setting. This environment implies that intermediate firms are “large” in their industry (and therefore compete in an oligopolistic fashion), but are “small” relative to the aggregate economy. As a result, intermediate firms influence (and internalize their impact) on industry-level prices, but do not affect aggregate factor prices, such as rental rates and wages, nor national income. Consequently, this structure retains the tractability of the partial equilibrium solution to a single stage game with oligopolistic firms, where factor prices are taken as given, albeit determined endogenously in competitive factor markets in general equilibrium. In addition, our market structure nests the monopolistic competition case with constant price markup when $N_{j,t} \rightarrow \infty$.

2.3 Intermediate goods firm

Product $i \in [0, 1]$ in industry j , $X_{ij,t}$, is produced by using the following technology:

$$X_{ij,t} = K_{ij,t}^\alpha (A_t Z_{ij,t}^\eta \mathcal{Z}_t^{1-\eta} L_{ij,t})^{1-\alpha}, \quad (4)$$

where $K_{ij,t}$ and $Z_{ij,t}$ are the firm-specific physical and intangible capital inputs, respectively, $L_{ij,t}$ is the labor input, and $\mathcal{Z}_t \equiv \int_0^1 \int_0^{N_{j,t}} Z_{ij,t} didj$ is the aggregate stock of intangible capital. The only exogenous forcing process in the benchmark model is the stationary and homoskedastic aggregate productivity shock, A_t , that affects all intermediate firms across all industries symmetrically, and evolves as an AR(1) process in logs:

$$a_t = (1 - \rho)a^* + \rho a_{t-1} + \sigma \epsilon_t, \quad (5)$$

where $\epsilon_t \sim iidN(0, 1)$.

The problem of the intermediate firm is to choose a series of production decisions for labor $L_{ij,t}$, capital $K_{ij,t}$, and technology $Z_{ij,t}$ as well as the sale price of its product, $P_{ij,t}$, in order to maximize the firm's profit in each period:

$$\max_{P_{ij,t}, K_{ij,t}, Z_{ij,t}, L_{ij,t}} D_{ij,t} \equiv P_{ij,t} X_{ij,t} - \mathcal{W}_t L_{ij,t} - R_{k,t} K_{ij,t} - R_{z,t} Z_{ij,t} - f \mathcal{Z}_t, \quad (6)$$

subject to the demand constraint defined in Eq. (3),

$$X_{ij,t} \leq \Theta_t(P_{ij,t}), \quad (7)$$

and taking the pricing and production decisions of the other firms as given. In the profit equation, \mathcal{W}_t is the wage rate, and $R_{k,t}$ and $R_{z,t}$ are the rental rate of physical capital and intangible capital, respectively. The parameter f represents fixed cost of production. A full characterization of an intermediate firm's problem is outlined in Appendix A.2.

Intermediate firms strategically compete in an oligopolistic industry, therefore firms internalize their impact on the industry price index and the price elasticity of demand will depend on the mass of firms competing in the industry. This will reflect on the firm's optimal production decisions. In particular, the firm's optimal pricing decision yields a markup policy ($\varphi_t \equiv P_t/MC_t$) which depends on the relative size of the firm within the industry, $N_{j,t}^{-1}$:

$$\varphi_{j,t} = \frac{-\nu_2 + (\nu_2 - \nu_1)N_{j,t}^{-1}}{-(\nu_2 - 1) + (\nu_2 - \nu_1)N_{j,t}^{-1}}. \quad (8)$$

In the realistic case, in which the substitutability of goods is higher within industries than across ($\nu_2 > \nu_1$), an increase in the mass of firms decreases markups. Note that when firms become relatively small in their industry, i.e. $N_{j,t}^{-1} \rightarrow 0$, the optimal pricing decision simplifies to the constant markup policy of the standard monopolistic competition case.

The remaining first-order conditions yield conditional factor demands for physical capital, intangible capital, and labor:

$$\mathcal{R}_t^k = \frac{\alpha Y_t}{\varphi_t \mathcal{K}_t}, \quad (9)$$

$$\mathcal{R}_t^z = \frac{\eta(1-\alpha) Y_t}{\varphi_t \mathcal{Z}_t}, \quad (10)$$

$$\mathcal{W}_t = \frac{(1-\alpha) Y_t}{\varphi_t \mathcal{L}_t}. \quad (11)$$

Assuming $\nu_2 > \nu_1$, more competition depresses markups and increases demand for factor inputs, which in turn affects aggregate investment in both physical and intangible capital. In the model, aggregate growth is endogenous and depends on the intensity of aggregate R&D investment. Consequently, endogenous growth provides an important transmission mechanism through

which changes in the price markup have long-lasting effects on the economy.

2.4 Entry and exit

In equilibrium, the degree of competition in an industry is determined endogenously through the entry and exit of firms. In particular, we assume that setting up a new firm in an industry entails a fixed cost $F_{E,t} \equiv \kappa \mathcal{Y}_t$.⁷ These costs are funded by the households each period, and in return, the households are entitled to the future cash flows. We assume that a newly created firm today (time t) starts producing in the following period (time $t + 1$).

Therefore, the measure of firms in an industry evolves as:

$$N_{j,t+1} = (1 - \delta_n)(N_{j,t} + N_{j,t}^E), \quad (12)$$

where $N_{j,t}^E$ is the mass of new entrants and δ_n is the constant fraction of products, randomly chosen each period, that become obsolete.

A free-entry condition endogenously determines the mass of intermediate firms in a particular industry:

$$(1 - \delta_n)E_t[\mathcal{M}_{t,t+1}V_{j,t+1}] = F_{E,t}, \quad (13)$$

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 an intermediate firm. Therefore, changes in expected profit opportunities and discount rates lead to fluctuations in the mass of entering firms.

2.5 Households and preferences

We assume that there is a representative household with Epstein-Zin preferences defined over aggregate consumption, \mathcal{C}_t , and labor, \mathcal{L}_t :

$$U_t = u(\mathcal{C}_t, \mathcal{L}_t) + \beta \left(E_t[U_{t+1}^{1-\theta}] \right)^{\frac{1}{1-\theta}}, \quad (14)$$

⁷Note that these costs are multiplied by the aggregate output to ensure that the entry costs do not become trivially small along the balanced growth path.

where $\theta \equiv 1 - \frac{1-\gamma}{1-1/\psi}$, γ captures the degree of relative risk aversion, ψ is the elasticity of intertemporal substitution, and β is the subjective discount rate. We assume that the utility kernel is additively separable in consumption and leisure:

$$u(\mathcal{C}_t, \mathcal{L}_t) = \frac{\mathcal{C}_t^{1-1/\psi}}{1-1/\psi} + \mathcal{Z}_t^{1-1/\psi} \chi_0 \frac{(1-\mathcal{L}_t)^{1-\chi}}{1-\chi}, \quad (15)$$

where χ captures the Frisch elasticity of labor and χ_0 is a scaling parameter.⁸ We assume that $\psi > \frac{1}{\gamma}$, so that the agent has a preference for early resolution of uncertainty following the long-run risks literature (e.g., Bansal and Yaron (2004)).

The household accumulates the stock of aggregate physical capital, \mathcal{K}_t , by making making investments, \mathcal{I}_t , through the following law of motion:

$$\mathcal{K}_{t+1} = (1 - \delta_k)\mathcal{K}_t + \Phi_k\left(\frac{\mathcal{I}_t}{\mathcal{K}_t}\right)\mathcal{K}_t, \quad (16)$$

where δ_k is the depreciation rate, and $\Phi_k(\cdot)$ captures convex adjustment costs.

The aggregate stock of intangible capital is interpreted as the stock of knowledge in the economy. Increasing the stock of intangible capital makes production more efficient. The household also accumulates the aggregate stock of intangible capital, \mathcal{Z}_t , by making R&D investments, \mathcal{S}_t , through the following law of motion:

$$\mathcal{Z}_{t+1} = (1 - \delta_z)\mathcal{Z}_t + \Phi_z\left(\frac{\mathcal{S}_t}{\mathcal{Z}_t}\right)\mathcal{Z}_t, \quad (17)$$

where δ_z is the depreciation rate for intangible capital.⁹

The household provides capital and labor services in competitive markets, and receives the rental rate $\mathcal{R}_{j,t}$, for $j = k, z$ for capital services and the wage rate \mathcal{W}_t for labor services. The household owns all firms and receives the aggregate payout, Π_t .

The household maximizes lifetime utility, defined recursively in Eq. (14), subject to the budget

⁸We scale 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.

⁹We assume the following functional form for the adjustment cost function: $\Phi_j(x) = \frac{\alpha_{1,j}}{1-\frac{1}{\zeta_j}} (x)^{1-\frac{1}{\zeta_j}} + \alpha_{2,j}$, for $j = k, z$.

constraint:

$$\mathcal{C}_t + \mathcal{I}_t + \mathcal{S}_t = \Pi_t + \mathcal{W}_t \mathcal{L}_t, \quad (18)$$

and the laws of motion for physical and intangible capital (Eqs. (16) and (17), respectively). We relegate the details of the household optimality conditions to Appendix A.3.

The stochastic discount factor implied by these preferences is given by:

$$\mathcal{M}_{t+1} = \beta \left(\frac{U_{t+1}}{E_t(U_{t+1}^{1-\theta})^{\frac{1}{1-\theta}}} \right)^{-\theta} \left(\frac{\mathcal{C}_{t+1}}{\mathcal{C}_t} \right)^{-\frac{1}{\psi}}, \quad (19)$$

where the first term, involving the continuation utility, captures sensitivity regarding uncertainty about long-run growth prospects.

2.6 Aggregation and equilibrium

In the model, there is no heterogeneity among firms, so we focus on the symmetric Nash equilibrium where all firms make identical decisions, and the i , and j subscript can be dropped. Imposing market clearing conditions on all markets, the aggregate quantities are defined as $\mathcal{Z}_t \equiv \int_0^1 \int_0^{\mathcal{N}_t} Z_{ij,t} didj = \mathcal{N}_t Z_t$, $\mathcal{K}_t \equiv \int_0^1 \int_0^{\mathcal{N}_t} K_{ij,t} didj = \mathcal{N}_t K_t$, and $L_t = \frac{\mathcal{L}_t}{\mathcal{N}_t}$. It follows that the aggregate resource constraint is¹⁰

$$\mathcal{Y}_t = \mathcal{C}_t + \mathcal{I}_t + \mathcal{N}_t^E F_t^E + \mathcal{S}_t, \quad (20)$$

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 mass 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.

When studying asset prices, we interpret the aggregate stock market as the total market value of all assets in the economy, which consists of the intermediate firm goods sector as well as the value of the physical and intangible capital. Consequently, the aggregate stock return is a claim

¹⁰We assume that the total fixed cost of production $f \mathcal{Z}_t$ is ultimately consumed by the representative household.

to the entire stream of future aggregate dividends, \mathcal{D}_t^m :¹¹

$$\mathcal{D}_t^m = \mathcal{N}_t D_t - \mathcal{N}_t^E F_t^E + (R_t^k \mathcal{K}_t - \mathcal{I}_t) + (R_t^z \mathcal{Z}_t - \mathcal{S}_t). \quad (21)$$

2.7 Decomposing Q

To provide guidance for our empirical and quantitative work, we derive an approximate expression for Tobin’s Q that illuminates its drivers in an intuitive way.

Total aggregate Tobin’s Q. We define the aggregate Tobin’s Q as the total market value of the firm over the replacement cost of capital. In our setting with intangible capital, the replacement value of capital accounts for the intangible capital stock as well, so that

$$Q_t = \frac{\mathcal{V}_t^m}{q_t^k \mathcal{K}_{t+1} + q_t^z \mathcal{Z}_{t+1}},$$

where q_t^k and q_t^z are the replacement cost of physical and intangible capital, respectively, and \mathcal{V}_t^m is the market value of the claim to the stream of aggregate dividend $\{\mathcal{D}_j^m\}_{j=t}^\infty$ defined in Eq. 21. Note that absent financial frictions in our model, the Modigliani-Miller assumptions apply, so that the market value of firms coincides with the value of their claims to total payouts.

Accordingly, the total market value of firms is defined as the sum of total market value of the intermediate goods sector (\mathcal{V}_t^{int}), and the two investment goods sector (\mathcal{V}_t^k and \mathcal{V}_t^z). Using the first order condition with respect to physical capital and noting that the shadow value of an installed unit of capital – the physical capital “marginal q” – is such that $q_t^k = \Phi'_{z,t}$, standard arguments imply that

$$\mathcal{V}_t^k = q_t^k \mathcal{K}_{t+1},$$

and similarly for intangible capital:

$$\mathcal{V}_t^z = q_t^z \mathcal{Z}_{t+1}.$$

¹¹For more details on the derivation of the aggregate stock market value and dividend, refer to Appendix B.

We can thus rewrite Tobin's Q as:

$$\mathcal{Q}_t = \frac{\mathcal{V}_t^m}{q_t^k \mathcal{K}_{t+1} + q_t^z \mathcal{Z}_{t+1}} = 1 + \frac{\mathcal{V}_t^{int}}{q_t^k \mathcal{K}_{t+1} + q_t^z \mathcal{Z}_{t+1}} \quad (22)$$

$$= 1 + \frac{E_t \left[\sum_{i=1}^{\infty} (1 - \delta_n)^{i-1} M_{t,t+i} D_{t+i} \right]}{q_t^k \mathcal{K}_{t+1} + q_t^z \mathcal{Z}_{t+1}} \quad (23)$$

Since we are interested in the average Tobin's Q in a given sample, we focus on the unconditional average of \mathcal{Q}_t and therefore set $q_t^z = q_t^k = 1$.¹² Defining the firm's total assets by $A_t^{tot} \equiv K_t + Z_t$, the average aggregate Tobin's Q simplifies to:

$$E[\mathcal{Q}_t] = 1 + E \left[\sum_{i=1}^{\infty} (1 - \delta_n)^{i-1} M_{t,t+i} ROA_{t+i} \frac{A_{t+i}^{tot}}{A_{t+1}^{tot}} \right] \quad (24)$$

$$\approx 1 + \sum_{i=1}^{\infty} (1 - \delta_n)^{i-1} \frac{\overline{ROA}}{(1 + \bar{r}_d)^i} (1 + \bar{g})^{i-1} \quad (25)$$

$$\approx 1 + \frac{\overline{ROA}}{\bar{r}_d + \delta_n - \bar{g}} \quad (26)$$

where \bar{r}_d , \bar{g} , and \overline{ROA} denote the aggregate discount rate, the equilibrium growth rate, and profitability (return on assets), respectively.

This approximate expression for Tobin's Q, reminiscent of the Gordon growth formula, suggests that any movements in Q must reflect changes in discount rates and risk, growth rates, or profitability. Profitability can reflect two sources, namely returns to tangible or intangible capital, or rents. This reinforces that inference on the sources of trends in valuations critically depend on identifying and measuring intangible capital. In the following, we will use structural estimation to interpret the data through the lens of our model and disentangle the impact of these channels.

Empirical \hat{Q} . While in the model, it is straightforward to determine Tobin's Q as the total market value of the firm over the replacement cost of capital, empirically, this is complicated through challenges in the measurement of intangible capital. In our quantitative work, we therefore also consider an alternative measure of Tobin's Q, denoted by \hat{Q} , which is arguably closer to empirical work in that we scale market valuations by tangible assets only.

¹²Note that the marginal q's of both the physical and intangible capital are equal to 1 in the steady state. The stochastic steady state values obtained through simulations are also very close to one.

3 Data and Estimation

In this section, we first provide an account of recent trends in macroeconomic variables and asset valuations in the data, followed by a description of the estimation strategy. The sample period starts in 1984, which marks the start of the Great Moderation. We then split our sample period in two equal subperiods, 1984-2000 and 2001-2017, to study secular trends in various macroeconomic and asset pricing moments. While this split is based on the existing literature on secular trends (see, e.g., Farhi and Gourio (2018)), it is also in line with the evidence from more formal structural break tests in the literature (see, e.g., Bretscher (2019) for a recent discussion) which point to shifts in economic activity around 2000.

3.1 Data

Macroeconomic quantities are obtained from the Bureau of Economic Analysis (BEA). Output is defined as real GDP per capita. Consumption is defined as the sum of durable consumption and services. Data on investment, depreciation, and stock (both for the physical and the intangible capital) are obtained from the Fixed Assets table published by the BEA. Physical capital is defined as the sum of non-residential structures and equipment. Intangible capital is defined as the sum of non-residential software and R&D investment. The labor share and profit share data series are defined for the nonfinancial corporate business sector. Labor share is defined as total compensation of employees divided by gross value added. The profit share is defined as profits before tax divided by gross value added.

We use two series to measure the aggregate level of competition. The first is the price markup which is defined as the output price divided by the marginal cost of production. The equilibrium conditions from the firm's profit maximization problem provide a natural way to estimate the price markup from a firm's production inputs. Equations 9-11 say that the optimizing firm equates the marginal cost of each production input to its marginal product. Therefore, one could obtain an estimate of the price markup using any variable production input. For instance, De Loecker and Eeckhout (2017) use Cost of Goods Sold (COGS) from the Compustat database as a measure of variable costs and estimate the markup at the firm-level as follows:

$$\varphi_{it} = \theta_{it} \frac{SALES_{it}}{COGS_{it}}, \quad (27)$$

where θ_{it} is the elasticity of SALES to COGS.

Our benchmark measure of the aggregate price markup relies on the same *production-based* approach.¹³ The main advantage of this approach is that it does not require any assumptions on demand and how firms compete. This method, however, requires the estimation of the output elasticity of at least one variable input of production. To ensure that our findings are not driven by these assumptions, we use an alternative measure of competition which exclusively relies on a *demand-side* approach. In our benchmark model, we assume Bertrand competition so that in the symmetric equilibrium, we can relate the markups to the number of firms (see Eq. 8). This approach does not require any assumptions on the production function and allows us to verify the robustness of our findings. We collect the total number of operating firms from the Business Dynamics Statistics tables published by the US Census Bureau.¹⁴

Aggregate data on dividends, earnings, and asset prices are from Robert Shiller website. Tobin’s Q is calculated following the same methodology as Hall (2001). The one-quarter, one-year, and five-year risk-free rates are defined as the three-month, one-year, and five-year constant maturity Treasury yields. Nominal rates are converted to real rates by subtracting realized inflation. Inflation is defined as core CPI and obtained from the Bureau of Labor Statistics. Our estimate for the expected risk premium is obtained using the Gordon growth formula as in Farhi and Gourio (2018). In particular, the Gordon formula implies:

$$E[r_d - r_f] = E[DP] + E[\Delta d] - E[r_f] \quad (28)$$

where DP is the dividend-price ratio, $E[r_f]$ and $E[\Delta d]$ are the expected future risk-free rate and dividend growth, which we proxy using the mean one-year risk-free rate and mean output growth, respectively.¹⁵

Table 1 reports key macroeconomic and asset pricing moments for each subsample and provides a test for the difference across samples. The estimates in the table confirm the various trends discussed in the literature. Average growth rates have significantly fallen in the last decade or so, in line with a decline in investment and R&D. From a neoclassical perspective, this is somewhat

¹³We thank the authors for making the markup measure available on their website.

¹⁴To obtain a stationary measure, we divide the total number of firms by the total stock of real capital (physical and R&D). We only consider firms with at least 100 employees in the total number of operating firms. Extending the measure to all firms yields similar results.

¹⁵Note that we use the average output growth to stay consistent with the model where all non-stationary variables grow at the same rate along the balanced growth path. Using average dividend growth yields similar results.

puzzling as, at the same time, Tobin’s Q has risen. Similarly, in spite of a slowdown in innovation, the importance of intangible capital to physical capital has grown as well. Along with these changes in real variables, inflation has significantly declined post 2000. This observation is often linked to the “missing inflation puzzle” (see e.g. Arias, Erceg, and Trabandt (2016)) in that, in spite of a rapidly expanding economy and exceptionally accommodating monetary policy in recent years, inflation has lagged behind. A similar pattern emerges for inflation volatility which has decreased by about 40% over the two subsamples.

The labor share, i.e. the share of output paid out to labor, has declined in recent years (see e.g. Barkai (2016), Karabarbounis and Neiman (2016), Rognlie (2015)). As shown in Table 1, this decline has been accompanied by a significant rise in the profit share, which is itself linked to rising markups. Indeed, markups rose by around ten percent since 2000. As similar pattern arises for the total number of operating firms, which has decreased by around 16% between the two subsamples. Asset prices have exhibited similar trends during this period. Valuation ratios beyond Q , such as price-dividend and price-earnings ratios have also increased, accompanied by a pronounced decline in interest rates. At the same time, aggregate risk, as measured by the volatility of output growth or the equity risk premium has risen.

3.2 Parameterization

We study the quantitative implications of the model for the period starting in 1984, that is, after the onset of the episode commonly referred to as the “Great Moderation”. As discussed, we then split our dataset into two subsamples of equal length, namely one spanning the years 1984-2000, and the other covering 2001-2017. Accordingly, we estimate our key model parameters separately for each of those subperiods. Our estimation strategy relies on a simulated method of moments (SMM) procedure following Hennessy and Whited (2007) that estimates seven key parameters using seven identifying moments. We focus on these parameters because they are often mentioned as potential candidates for the observed secular trends in macroeconomic and asset pricing variables.

Estimated parameters The first estimated parameter is the subjective discount factor, β . Estimated differences in β over the two periods capture shifts in aggregate demand and policy interventions possibly affecting the real rate. In the model, both entry and growth are endogenous and are impacted by firms’ valuation. Thus, it is crucial to control for these effects in our

quantitative analysis by allowing the subjective discount factor to vary across periods. Although β jointly affects many variables in our model, we primarily identify it using the average one-year real risk-free rate. The observed secular trends might also be explained by the changing nature of intangible capital in firm's production function. Indeed, Table 1 provides evidence that the ratio of intangible capital to physical capital has been steadily increasing over time. So we also include the share of technology in production, η , in our estimation. The next estimated parameter is the entry cost parameter, κ . In equilibrium, the degree of competition in an industry is determined by a free entry condition that equates a firm's future profits opportunities to the cost of entry. Thus, κ drives the steady state mass of firms in the industry and therefore the level of competition. We identify this parameter using the average price markup.

The trend in investment rate and R&D intensity can be due to a change in their respective depreciation rates over time. Thus, we also estimate δ_k , and δ_z for each subsample period. In addition, to account for changes in aggregate productivity unexplained by the other parameters, we include a scale parameter a^* which directly affects the endogenous steady state growth rate and use the average output growth as another identifying moment. Finally, we also allow for the price of risk to vary in each period by estimating the preference parameter driving the relative risk aversion of the representative household. The parameter γ primarily affects the equity risk premium, which is exactly identified using the price earning ratio (given the growth rate of dividends and the level of risk-free rate) as shown in expression 28.

We estimate the parameters using the SMM approach. More specifically, we find the values for the vector of parameters $\hat{\Theta} = [a^*, \beta, \eta, \gamma, \bar{\kappa}, \delta_k, \delta_z]$ that minimizes the distance between the vector of identifying moments from the data described earlier and the corresponding moments generated from model simulations:

$$\hat{\Theta} = \underset{\Theta}{\operatorname{argmin}} [\hat{m} - m(\Theta)]' W [\hat{m} - m(\Theta)], \quad (29)$$

where W is a weighting matrix, \hat{m} is a vector of empirical moments, and $m(\Theta)$ is the vector of model-implied moments obtained by assuming a value of Θ for the structural parameters.¹⁶ We follow the literature and set W equal to the inverse of the covariance matrix of the moments. To estimate the covariance matrix of the moments, we use the influence function approach of Erickson

¹⁶Model moments are computed over 100 samples of length similar to the data, with a burning-in period of 400 quarters.

and Whited (2000).¹⁷

The seven identifying moments and the estimated parameters are summarized in Table 2. Panel A shows that the estimated model quantitatively captures the recent trends in macroeconomic activity and asset valuations quite well. Panel B documents the associated changes in parameter estimates across samples. The decline in growth rates is accompanied with a drop in the level of productivity, while the decline in the interest rates is in line with a fall in aggregate demand, captured through the increase in the parameter β . The rise in the intangible share η , whose estimated value almost doubles in recent years relative to the eighties and nineties, helps account for the observed increase in intangible relative to physical capital. The estimated risk aversion, which captures changes in risk premia unaccounted for by the other parameters, has increased over the two sample periods. The estimated entry cost parameter, $\bar{\kappa}$, has significantly increased since 2000, which has increased industry concentration and markups.

Calibrated parameters The remaining parameters are harder to identify, so we calibrate them to standard values from the existing literature or to match steady-state evidence. Table 3 summarizes the parameter values for the benchmark model. The preference parameter controlling the intertemporal elasticity of substitution, ψ , is calibrated to 2, a standard value in the long-run risks literature (e.g. Bansal and Yaron (2004)). Note that our estimated preference parameters imply that the representative agent prefers an early resolution of uncertainty (i.e. $\psi > 1/\gamma$), which implies that the price of risk for low-frequency consumption growth uncertainty is positive. This assumption is key to generate a sizable equity risk premium. The labor elasticity parameter χ is set to 3, which implies a Frisch elasticity of labor supply in the steady state of 2/3.

The capital share α is set to 0.3, which is a standard value in the macroeconomics literature and designed to match steady-state evidence. The parameters driving the convexity of the capital and R&D adjustment costs are set to 0.85 and 1.50, respectively. The exogenous firm exit shock δ_n is set to 2%, in line with Bilbiie, Ghironi, and Melitz (2012). The elasticity parameter that determines the substitutability of goods across industries, ν_1 , and within industries ν_2 is set to 1.15 and 6.50, respectively in line with the estimation in Corhay, Kung, and Schmid (2020). The fixed cost parameter f is chosen to be consistent with the average market-to-book ratio. Finally, the persistence parameter, ρ , and volatility parameter, σ , corresponding to the aggregate productivity

¹⁷Note that we convert all series at the annual frequency to compute the covariance matrix because some series are only available annually. We also perform the same transformation for our simulated model data.

shock are calibrated to annualized values of 0.95 and 1.50%, designed to match the dynamics of R&D intensity, as in Kung (2015).

4 Decomposing Real Trends

We now use our estimated model as a laboratory to quantitatively examine and isolate the driving forces behind recent trends in macroeconomic activity and asset valuations. We start by providing a structural decomposition of the changes in moments into the marginal contributions of each estimated parameter, both regarding moments targeted in the estimation as well as non-targeted moments. Based on such a decomposition, we can use our framework to extract information from asset valuations about future growth, risk, and welfare in the context of rising market power. Finally, we consider a number of alternative specifications and provide a sensitivity analysis with respect to the measurement and identification of the trends.

4.1 Structural decomposition

The estimated model is used to quantify the marginal contribution of each estimated parameter to changes in the target moments over the two periods. Because growth, markups, and risk premia are endogenously determined, all parameters are jointly identified and investigating the marginal contribution of a given parameter is challenging. We carry out two types of numerical exercises to study the drivers of secular trends. In the first, we set the value of a particular parameter of interest to that estimated on the 2001-2017 sample, while keeping all other parameters to their values estimated on the 1984-2000 sample. In these exercises, the parameter a^* is adjusted to keep the scale comparable across samples. We first decompose changes in targeted moments, and then look at a broader set of implications. In the second numerical exercise, the model is re-estimated over the 2001-2017 subsample period using the same target moments, except that the average markups, the intangible capital share, and risk aversion are constrained to be the same as the values from the 1984-2000 period. The idea of the second exercise is that differences between the benchmark calibration and the counterfactual that control for the rise in markups, intangible share, and risk premia help provide us with a quantitative measure of these effects.

Table 4 presents the contribution of each estimated parameter to the changes in moments across sample periods for our first numerical exercise. The results show that the secular trend in growth

rates is mainly driven by four parameters, namely the mean of the stationary productivity shock a^* , the time discount rate β , the intangible share η , and the entry cost κ . The downward revision in average productivity in the second part of the sample lowers output growth. In contrast, the increase in β , lowers both real rates and aggregate demand for consumption goods, leading to a reallocation of resources towards investment, boosting output growth. Similar to the increase in β , the rise in the intangible share contributes to an increase in growth. The rising intangible share increases the aggregate return to intangible capital due a positive spillover effect from innovation, and therefore increases growth. An important contribution to the lower growth rates in the recent period is the increase in entry costs. Table 4 suggests that κ explains more than a third of the recent drop in growth rates and highlights the relevance of movements in the competitive environment for expected growth. Rising barriers to entry lowers the mass of competitors in industries and leads to an increase in concentration. This allows incumbents to charge higher markups, which leads to a drop in both investment and innovation, ultimately depressing growth prospects. The estimation also suggests that the remaining parameters, risk aversion and the capital depreciation rates, had a negligible contribution in explaining the recent slowdown of output growth.

Inspecting the drivers of the secular decline in interest rates, paints a similar picture. While the drop in β had a significant effect on the risk-free rate, the recent rise in entry costs had a quantitatively similar effect. As discussed earlier, equilibrium growth is endogenously determined by investment and innovation, due to aggregate spillover effects from the accumulation of intangible capital that directly link trend growth to aggregate innovation rates. When competition falls, markups rise, which depress the demand for factor inputs, leading to a drop in investment and innovation, depressing growth prospects, and therefore, real interest rates. The estimates in Table 4 suggests that the recent decline in competition was an important driver of the recent fall in both growth and interest rates. Additionally, changes in macroeconomic uncertainty and risk aversion also impacted risk free rates, through a stronger precautionary savings motive.

Our setup allows us to look at a broader set of moments beyond those targeted in the estimation. That is, we can assess the drivers of movements in profit and labor shares, overall productivity growth, investment and innovation, as well as volatility and the equity premium, among others, through the lens of our model. Table 5 reports the results. We report fluctuations in variables characterizing the competitive environment, macroeconomic implications, and asset pricing implications.

In the light of the empirical trends, concentration (as measured by the Herfindahl-Hirschman index) and profit shares have been trending upwards, which is captured by the model well. At the same time, the model also captures the observed decline in the overall mass of firms. The bulk of these movements is accounted for by rising barriers to entry in the form of entry costs. The fall in competition also is important for explaining the slowdown in productivity growth, investment and innovation along with the increase in macroeconomic volatility and risk premia. The rise in the intangible capital share has quantitatively important effects, but often with a counterfactual sign. Accounting for the drop in aggregate demand is important for generating an increase in valuation ratios, but the aggregate demand channel by itself has the opposite implications for the rest of the trends (i.e., higher β increases investment and growth prospects and reduces industry concentration and markups). Rising risk aversion is an important driver of the rising equity premium, but otherwise has mild effects on macroeconomic variables.

As shown earlier, the model captures quantitatively well the secular decline in interest rates. Table 5 shows that the model also predicts a rise in the equity risk premium in recent years. Our estimates suggest that the persistent rise in macroeconomic uncertainty is quantitatively important for explaining the higher equity premium in the second period. Importantly, the estimated change in competition is the main contributor for the change in macroeconomic risk. This happens because as industries are more concentrated, firms enjoying greater market power charge higher markups, but can be more aggressively undercut by new entrants, exposing their cash flows, investment, and pricing decisions more to entry risk. In equilibrium, less competition is therefore associated with higher macroeconomic uncertainty, reflected in a larger equity premium.

The decline of the real interest rate ultimately dominates the increase in risk premia such that overall discount rates fall. The persistent drop in discount rates is sufficiently large to offset lower expected growth so that valuation ratios rise. In particular, the model quantitatively matches the recent rise in the price-earnings ratio. This quantitative success highlights the importance of accounting for endogenous links between market power, growth, and risk to explain how profit opportunities shape firms' investment and innovation strategies, but also their risk exposure, and valuations.

Overall, the structural estimation highlights the importance of declining competition in explaining secular declines not just in average growth, but also in investment and innovation. To explain these trends, it is important to allow markups to impact growth in equilibrium, which is

a central ingredient in our model. If trend growth were exogenous, rising markups would have a minimal impact on the long-term outlook of the economy as we show in section 4.2.1. Similarly, if markups were exogenous, they would have a modest effect on growth and fluctuations. In contrast, markups in our benchmark model endogenously depend on the state of the economy due to strategic interactions among firms, providing an amplification mechanism.

Our second numerical exercise looks at the secular trends in variables of interests when markups, intangible capital share, and risk aversion, respectively, are assumed to stay constant over the two sample periods. Results are reported in Table 6. Overall, the conclusions reinforce the picture emerging from the first numerical exercise. Failing to account for the rise in markups implies counterfactual trends for several variables such as a decrease in both profitability, Tobin’s Q, and aggregate risk. The rising intangible share also has quantitatively important effects, as failing to account for it, would imply an increase in the profit share significantly higher than otherwise observed. Similarly, investment and innovation would have fallen even more. In contrast, changes in risk aversion have quantitatively mild effects.

4.1.1 Implications for Welfare

Recent work, such as Edmond, Midrigan, and Xu (2019) and Cavenaile, Celik, and Tian (2019), has examined the movements in markups from a welfare perspective, and pointed to significant welfare costs. These calculations are based on deterministic and stationary environments in which trends do not interact with risk premia. As we have documented so far, the recent trends also include a persistent rise in macroeconomic uncertainty with a higher risk of sharp stock market corrections, which agents with Epstein-Zin preferences are averse to. We complement this literature by evaluating the welfare implications of secular trends with these additional endogenous risk and growth margins.

We implement welfare cost calculations as in Croce, Nguyen, and Schmid (2012). For two consumption bundle processes, $\{u^1\}$ and $\{u^2\}$, we express the relative welfare costs as the additional fraction λ of lifetime utility required to make the representative agent indifferent between the two, that is, so that $U_0(\{u^1\}) = U_0(\{u^2\})(1 + \lambda)$. With homogeneity, this is akin to requiring that $\frac{U_0(\{u^1\})}{u_0^1} u_0^1 = \frac{U_0(\{u^2\})}{u_0^2} u_0^2 (1 + \lambda)$, which shows that the welfare costs depend both on the utility-consumption ratio and the initial level of our two utility kernel profiles. We are going to compare the life-time utility of an agent that starts initially at the same utility kernel level, i.e. $u_0^1 = u_0^2$,

but in an economy with different characteristics (e.g., different entry costs, risk aversion, etc.). Denoting unconditional averages with bars, we can approximate the welfare costs as

$$\lambda \approx \ln(\overline{U_0(\{u^1\})/u_0^1}) - \ln(\overline{U_0(\{u^2\})/u_0^2}). \quad (30)$$

Welfare costs (or gains, if negative) in our model thus both reflect changes in growth and risk.

Table 7 reports the results. We compute the welfare implications of changing the parameters driving changes in the intangible share, risk, and competition to their estimated values for the 2001-2017 sample, while keeping parameters at their estimated values for the 1984-2000 sample. First, notably, changing the intangible share alone implies substantial welfare gains in the context of our model. These stem from both a boost in growth, as well as a reduction in risk. In the model, an increase in the intangible share fosters innovation, also benefits investment through rising productivity growth. These welfare gains are mirrored by a reduction of the equity premium. In contrast, significant welfare costs are associated with higher risk aversion. While, in equilibrium, higher risk aversion leaves volatility unchanged, it comes with slower growth. Taken together, a higher equity premium is reflected in high welfare costs. Similarly, higher barriers to entry in the form of rising entry costs come with large welfare costs and a higher equity premium, stemming from lower growth and higher risk in this case. In our risk-sensitive setting, movements in consumption volatility are propagated to the volatility of the utility kernel, as the latter reflects continuation utilities as well. This contributes to amplifications in welfare costs.

While the literature has suggested high welfare costs of rising markups related to recent trends, the welfare implications are even larger through the lens of our model. This reflects the endogenous relation between macroeconomic risk, markups, and growth in our endogenous growth model that features a risk-sensitive household. While rising barriers to entry allow incumbent firms to consolidate market power by charging higher markups, it also makes firms more exposed to entry risk, which increases aggregate uncertainty. Higher markups also depresses factor demands for physical and intangible capital, leading to a slowdown in investment and innovation, ultimately reflected in lower growth prospects. Our model suggests that accounting for these linkages is important for assessing the welfare implications of recent trends.

4.2 Alternative Specifications

We next consider a number of alternative specifications that give some perspective on our benchmark results. First, we consider a model nested with ours, namely the standard stochastic growth model, which we obtain by fixing productivity growth and markups exogenously. This allows to illustrate the impact of endogenous linkages between the growth, rents, and risks. Second, for robustness, we consider alternative empirical proxies for some of our target moments. We also study a specification where parameters are allowed to vary over time.

4.2.1 Trends with exogenous growth and markups

Our model suggests quantitatively significant linkages between growth, competition, and risk. To further illustrate the importance of the endogenous feedback between these channels, we now consider a special case of our benchmark model in which both trend growth and markups are specified exogenously. This specification is much closer to the standard stochastic growth model. The process for log total factor productivity growth, $z_t^e \equiv \log(Z_t^e)$, follows:

$$\begin{aligned} z_{t+1}^e - z_t^e &= \Delta \bar{z}^e + x_t \\ x_t &= \rho_x x_{t-1} + \sigma_x e_{xt}, \end{aligned}$$

where e_{xt} is a iid shock, which follows a standard normal distribution. This specification assumes a constant mass of firms, implying a constant markup.

The results are in Table 8, in the column labeled “exogenous”. We re-estimate the exogenous model to match the same target moments of the 1984-2001 sample and consider a counterfactual economy where the markup exogenously increases to its 2001-2017 level. By construction, the increase in markup explains the same change in the HHI and the labor share as in the benchmark model. However, it has no impact on growth. This specification misses the endogenous feedback and amplification present in the benchmark model, so that aggregate volatility is unaffected. Nevertheless, a change in markups affects the incentives for investment, dividends, and thus consumption dynamics. A slight increase in consumption risk is accompanied by a modest fall in interest rates and an increase in the equity premium. Nonetheless, the welfare costs are substantially muted, and in fact negligible relative to those in the benchmark model. This illustrates, and to some extent quantifies, the importance of accounting for endogenous linkages between growth,

risk, and competition. Thus, the exogenous growth model misses important link between risk, rents and growth that is captured by our benchmark model. In our view, this allows us to more succinctly identify the economic sources of the recent shifts in trends.

4.2.2 Measurement and Sensitivity

This subsection provides some sensitivity with respect to the measurement of moments, as well as trends.

Alternative Moments One manifestation of the change in the U.S. macroeconomic environment documented in the literature is the decline in the labor share. While our benchmark estimation is consistent with that pattern, we have so far assumed that the capital share parameter α was constant across the two samples. To verify the robustness of our results, we now allow the parameter α to adjust over subsamples. Similarly, our benchmark estimation relies on a representation of the competitive environment in terms of markups, whose measurement is controversial (see, for example Syverson (2019) or Basu (2019)). Accordingly, we re-estimate our model using the total number of firms as a proxy for competition, as detailed in section 3.

The results are in Table 8, in the columns labeled “capital share” and “n-proxy”. We assess the effects of changes in the competitive environment on trends in these specifications. Estimating α to match the labor share barely affects our inference, in that the change in markups is identical. Nonetheless, it amplifies the macroeconomic effects slightly. Indeed, the decline in growth is slightly larger, which is also reflected in somewhat higher welfare costs of rising markups. On the other hand, when proxying for the competitive environment by the total number of firms, the rise in markups becomes somewhat lower, but still substantial. Accordingly, the effects on growth, risk, and welfare are a bit smaller. Overall, however, our inference that the effects of changes in competition are substantial is unaffected.

Time Series Tests Thus far, our empirical approach has focused on estimating shifts in deep parameters in the economy across the 1984-2000 and the 2001-2017 samples. In reality, changes in these parameters could have been more gradual. To check whether our conclusions are robust to allowing for possible slow movements in parameters, we model our key parameters as stochastic processes. More specifically, we model a generic parameter, say θ , as $\theta_t \equiv \bar{\theta}e^{x_{\theta,t}}$, where $x_{\theta,t} = \rho_{\theta}x_{\theta,t-1} + \sigma_{\theta}\epsilon_{\theta,t}$. After estimating $\bar{\theta}$ on the basis of the early subsample as for the benchmark

model, we extract the realized shocks $\hat{\epsilon}_{\theta,t}$ to match moments for the late subsample. To infer the impact of a parameter changes on the observed trend, we simulate the model with only one source of estimated shocks active at a time, setting the remaining ones to zero.

Table 9 reports the results. We focus on movements in κ , a^* , and β .¹⁸ Overall, these results support our previous inference regarding the critical role of entry costs in explaining shifts in macroeconomic and financial market activity. Indeed, quantitatively, stochastic movements in entry costs explain the bulk of the changes in moments across the samples, with the other parameters often implying the wrong sign.

5 Decomposing Nominal Trends

Our benchmark model provides a structural decomposition of changes in trends of a number of relevant macroeconomic and financial market variables. However, the model is necessarily silent about nominal variables such as inflation and nominal interest rates, and thus about potential linkages between central bank policy and secular trends. Referring back to the empirical evidence on trends in Table 1, we see also a significant reduction in mean inflation post 2000. Indeed, as documented for example in Arias, Erceg, and Trabandt (2016), in spite of a rapidly expanding economy and exceptionally accommodating monetary policy in recent years, inflation has lagged behind, a phenomenon sometimes dubbed the “missing inflation puzzle”. At the same time, as shown in Table 1, asset valuations in bond markets rose as reflected in declining yields. In this section, we propose an extension of our benchmark model with nominal rigidities and a monetary policy rule to investigate whether some of these movements in nominal variables can also be plausibly attributed to forces such as declining competition. In this extended framework, markups vary because of two channels. Desired markups vary endogenously because of changes in competition due to strategic interactions among firms as featured in the benchmark model. Markups also vary endogenously *relative* to the desired markup because of lagging price adjustment.

5.1 Extended Model with Nominal Rigidities

In this section, we extend the benchmark model to account for nominal rigidities. The only change to the firm’s problem is that now we assume that firms face quadratic adjustment costs when

¹⁸Results for the remaining parameters are available on request.

changing its nominal price following Rotemberg (1982). The intermediate firm's problem becomes:

$$V_{ij,t} = \max_{P_{ij,t}, K_{ij,t}, Z_{ij,t}, L_{ij,t}} D_{ij,t} + (1 - \delta_n) E_t [M_{t,t+1} V_{ij,t+1}], \quad (31)$$

subject to the demand constraint defined in Eq. (3) and the source of fund constraint:

$$X_{ij,t} \leq \Theta_t(P_{ij,t}) \quad (32)$$

$$D_{ij,t} = P_{ij,t} X_{ij,t} - W_t L_{ij,t} - R_{k,t} K_{ij,t} - R_{z,t} Z_{ij,t} - f Z_t - \frac{\Phi_P}{2} \left(\frac{P_{ij,t}}{P_{ij,t-1} \bar{\Pi}} - 1 \right)^2 \frac{\mathcal{Y}_t}{\mathcal{N}_t} \quad (33)$$

where Φ_P captures the magnitude of the nominal rigidities and $\bar{\Pi}$ is the rate of inflation in the steady state. Note that the benchmark model is the particular case where $\Phi_P = 0$.

We assume a central bank that follows a Taylor rule that depends on the lagged nominal interest rate, as well as output and inflation deviations:

$$\hat{r}_{t+1}^{\$} = \rho_r \hat{r}_t^{\$} + (1 - \rho_r) (\rho_\pi \hat{\pi}_t + \rho_y \hat{y}_t) + \sigma_r \epsilon_t^r \quad (34)$$

where $r_{t+1}^{\$}$ is the one-quarter nominal rate, π_t is log-inflation, y_t is the log of normalized output, ϵ_t^r is a monetary policy shock, and hat-variables are in deviations from the steady state. The firm's optimization problem and optimal decisions are outlined in Appendix A.4.

The firm's optimal decisions in the presence of nominal rigidities are the same as before, except for the output pricing decision. More specifically, the optimal time-varying markup policy φ_t^* not only depends on the level of competition in the industry (as proxied by N_t), but also on nominal rigidities:

$$\begin{aligned} (\varphi_t^*)^{-1} &= \frac{-(\nu_2 - 1) N_t + (\nu_2 - \nu_1)}{-\nu_2 N_t + (\nu_2 - \nu_1)} \quad (35) \\ &+ \Phi_P \frac{-\left(\frac{\Pi_{j,t}}{\bar{\Pi}} - 1\right) \frac{\Pi_{j,t}}{\bar{\Pi}} + E_t \left[(1 - \delta_n) M_{t,t+1} \left(\frac{\Pi_{j,t+1}}{\bar{\Pi}} - 1\right) \frac{\Pi_{j,t+1}}{\bar{\Pi}} \Delta \mathcal{Y}_{t+1} \Delta \mathcal{N}_{t+1} \right]}{1 - \nu_2 + (\nu_2 - \nu_1) N_t^{-1}}. \end{aligned}$$

When prices are sticky, firms are unable to adjust their nominal product prices quickly to changes in productivity, or, more broadly, external shocks. Therefore, markups are too low relative to the desired markup in expansions and too high in recessions, further increasing the counter-cyclicality of markups arising from strategic competition.

5.2 Structural Decomposition

To provide a structural decomposition of the recent trends into the underlying drivers, we first estimate the extended model over both the 1984-2001 and the 2001-2017 samples and add inflation as a target moment. Rather than estimating the parameters of the monetary policy rule, we choose them in line with the choices in Kung (2015) and Basu and Bundick (2017).¹⁹ Table 10 presents the parameter estimates along with the implied moments. The extended model fits well both the benchmark target moments as well as mean inflation across samples. Importantly, it captures the decline in inflation in the later sample well. The estimates of the baseline parameters do not change much in comparison to the benchmark model, and the estimation yields plausible inflation targets. Most notably, however, in spite of the substantial decline in mean inflation in the later sample, the estimated inflation targets are almost identical, suggesting an important change in the endogenous dynamics of inflation.

Table 11 reports the results from our structural decomposition for non-target moments. Overall, the parameter contributions to changes in (non-inflation) moments are similar to those from the benchmark specification documented in Table 5. The contribution of rising barriers to entry, however, is stronger. This is consistent with our earlier discussion, in that nominal rigidities amplify the countercyclical movements in markups. We illustrate this amplification in Figure 1 which compares the impulse response functions to a negative productivity shock in a low and a high competition environment. Overall, the response functions for the high markup environment are significantly more pronounced than for the low markup environment.

Declining competition significantly contributes to the decline in mean inflation. Incumbent firms with greater market power face a less elastic demand curve, making desired markups more sensitive to changes in economic conditions. With sticky prices, markup fluctuations affect inflation at the first-order through the New Keynesian Phillips Curve (NKPC). Bianchi, Kung, and Tirsikh (2018) show that the risk-adjusted NKPC includes a nominal pricing bias term that depends on the covariance between the stochastic discount factor and inflation. As evident in figure 1, inflation in the model is countercyclical, therefore the covariance term is positive. In an economy with high price markup, however, both the covariance terms and the inflation volatility drop, which lowers average inflation.

¹⁹Specifically, we set $\Phi_P = 35$, $\rho_r = 0.5$, $\rho_\pi = 1.5$, and $\rho_y = 0.1$. Moreover, the parameters driving the monetary policy shocks are: $\rho_\zeta = 0.6$, and $\sigma_\zeta = 0.15\%$.

Intuitively, firms are worried of setting a price that is too high (relative to the desired markup) during high marginal utility states. This risk-based mechanism also explains why higher risk aversion also contributes to lower inflation in Table 11. Importantly, in high markup environments, the countercyclicality of markups is amplified along with countercyclical aggregate volatility.²⁰

In short, the secular decline in inflation, or the “missing inflation puzzle”, through the lens of the model can be attributed to the interplay between nominal rigidities and risk premia, largely absent in standard macroeconomic frameworks. Note that the rising intangible share decreases aggregate volatility and risk premia leading to an increase in mean inflation rather than a decline. This corroborates the importance of accounting for rising markups in conjunction with risk when explaining the trend in inflation.

5.2.1 Implications for Monetary Policy

The different behavior of inflation across samples suggests that the transmission of monetary policy varies depending on the degree of industry competition. The impulse responses to an expansionary monetary policy shock in both a high and low markup environments are plotted in Figure 2. Following the shock, the nominal short rate drops while the rate of inflation increases. In a low competition environment, however, the impact of a monetary policy shock on inflation is lower as firms are worried of setting a price that is too high relative to the desired markup during high marginal utility states. This occurs in spite of a more aggressive response of the nominal interest rate. Therefore the associated real interest rate decreases more leading to a larger increase in investment and growth. Monetary policy shocks also increases stock market valuations, but significantly more so when competition is low. Our model is thus consistent with the anecdotal evidence that in recent years, stock market valuations exhibited elevated sensitivity with respect to monetary policy announcements.

6 Interpreting Valuation Ratios

Our estimates suggest significant changes in the aggregate economic environment since 2000. Valuation ratios, such as Tobin’s Q, embed information on investors’ expectations regarding future risk, rents, and growth, in real time. We now use our model to glean information on what move-

²⁰See Corhay, Kung, and Schmid (2020) for empirical evidence and a detailed analysis of the link between countercyclical markups and volatility.

ments in valuation ratios tell us about future economic performance. We start by using valuation ratios to predict future growth rates, profitability, and consumption risk across samples, to extract information about the sensitivity of future macroeconomic performance embedded in movements in asset prices. With these estimates at hand, we are in a position to provide growth forecasts regarding growth expectations given the dramatic drop in asset valuations witnessed in March 2020. Underlying our estimates is the observation that, within the context of the model, asset valuations have become much more sensitive to shocks in a less competitive environment, so that the risk of the observed large correction has sharply increased in the recent sample. We illustrate this result by means of impulse response functions below.

Table 12 reports a first set of results. We report the results of predictive regressions of future consumption growth, profitability, and consumption volatility on $\log Q$. The horizon is four quarters ahead and the specification captures the percentage movements in future growth, rents, and risk, upon percentage movements in valuation ratios. Here, we measure profitability as the return on assets, net of investment. Realized consumption growth volatility is computed in two steps as in Bansal, Kiku, Yaron, et al. (2012). First, realized consumption growth is fitted to an AR(1) process. Second, realized annual volatility is obtained by summing the absolute value of the errors over the next four quarters.

Financial market data are forward looking and are therefore significant predictors of future growth, profitability, and risk. That predictive power increases in the later sample for growth and profitability, as reflected in the higher R^2 's. In contrast, the informational content of valuation ratios for future macroeconomic uncertainty has declined over time. To track the sources of this increased informational content of valuation ratios, we also run predictive regressions in a counterfactual experiment in which we use entry costs as estimated in the late sample, but fix all parameters at the early sample values. The results are reported in the last column, labeled 1984-2000*. The regression coefficients for growth are almost identical to those in the late sample case. In addition, both the regression coefficient for profitability and risk also increases in this alternative economy. Overall, these results bring corroborating evidence that changes in competition are the driving force for explaining the differences in predictability across the sample periods.

Stock Market Crash To put these results into context, our setup allows to make growth forecasts given the recent dramatic drop in asset valuations in March 2020. Considering the most recent peak in the S&P 500 of late February, stock market valuations in the US indicate a drop

in Tobin’s Q in the range of around 20 percent in March. Through the lens of our model, that drop translates into a predicted decline of average consumption growth over the next five years of 3.47 percent. A more extreme scenario in stock market declines of, say, 25 percent would raise this number to 4.34 percent, while a more favorable scenario of a 15 percent stock market decline would lower it to 2.61 percent. These are substantial numbers, but in the range of the magnitudes obtained directly empirically from aggregate equity market futures in Gormsen and Koijen (2020). On the other hand, given the estimates in Table 12, our model suggests that a stock market crash of a similar magnitude would have indicated a significantly muted effect on future growth in a more competitive environment.

The significant decline in future growth indicated by a stock market crash of the observed magnitude in our current environment reflects the observation that asset valuations and fundamentals have become substantially more sensitive to shocks than in previous decades. In a less competitive environment with higher markups, which our model identifies as a realistic depiction of the current economic environment, stock market valuations are more sensitive to shocks than previously irrespective of the source of shocks. Figures 3 and 4 illustrate this pattern. Figure 3 plots the impulse responses with respect to a standard representation of a negative demand shock, which we model as a shock to the discount rate, following, e.g. Albuquerque, Eichenbaum, Luo, and Rebelo (2016). More specifically, here we entertain a specification with $\beta_t \equiv \beta e^{x_t}$, where we set $x_t = \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}$. As the figure indicates, a negative demand shock leads to a much more pronounced decline in valuations as well as real activity in a low competition environment. On top of that, in such an environment, inflation falls rather than rises. A similar pattern obtains in case of an adverse uncertainty shock associated with a sudden increase of uncertainty, that we model as stochastic volatility in productivity in that $\sigma_t \equiv \sigma e^{x_t}$, where $x_t = \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}$. Qualitatively, the responses are similar than in the case of a demand shock, but the quantitative effects are even stronger.

The recent stock market crash is often ascribed to an interaction of demand and supply effects, as described, for example, in Baldwin and Weder di Mauro (2020). Our model suggests that the interaction of demand and supply effects indeed have powerful quantitative effects giving raise to the possibility of significant stock market declines in response to shocks, as shown in figure 5. We plot the impulse responses to a combined negative demand and supply shock, in which both discount rates and exogenous productivity fall simultaneously. While, qualitatively, the

responses mirror those of the individual shocks, their combined strength is significantly stronger when considered together. In particular, the decline in stock market valuations is strong and persistent, which is consistent with the current narrative of the recent stock market crash. A similar pattern obtains in case of a joint supply and uncertainty shock, as documented in figure 6.

7 Conclusion

We examine trends in macroeconomic activity and asset valuations over the past three decades by estimating an endogenous growth model featuring realistic variation in market power and risk premia. The model endogenously links the trends to expectations about growth prospects, profit margins, real rates, and risk premia, all of which are affected by industry competition in equilibrium. Changes in market power affect price markup and investment policies due to strategic interactions among firms. Our baseline estimates suggest that a decline in competition coupled with weakening aggregate demand are important for simultaneously explaining rising valuation ratios despite a stagnating productivity growth, weakening investment and innovation rates, and a rising impact of intangible capital. Standard neoclassical models that ignore the endogenous feedback between markups and the state of the economy are likely to underestimate the role of declining market power for explaining the aforementioned trends.

An extended model highlights how nominal rigidities amplify the effects of changing competition on macroeconomic fluctuations and growth through the markup channel. We illustrate how the interaction between sticky prices and fluctuating competition can provide a potential explanation for missing inflation and rising valuation in bond markets in recent years. We use our estimated model to provide guidance regarding future economic performance through predictive regressions. In particular, the model indicates that asset valuations and economic activity are more responsive to shocks in the current environment, increasing the likelihood of sharp contractions. Our estimates suggests that a sudden drop in stock market valuations predicts substantially bleaker growth prospects in an environment with weak competition.

In our model, we adopt an aggregate perspective, and abstract from potentially rich cross-sectional heterogeneity in the linkages between risk, rents, and growth. At the industry level, such heterogeneity especially in the relationship between concentration and efficiency is well documented (see Crouzet and Eberly (2019b)). Our structural approach is initially motivated by concerns

regarding measurement of market power and aggregation (as discussed in Syverson (2019)) that are most prevalent at the aggregate level. We view extending our structural estimation approach to account for cross-industry heterogeneity (along the lines of Gutiérrez, Jones, and Philippon (2019), for example) as an important challenge for future research.

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Table 1: Summary statistics

	1984-2000	2001-2017	Difference	p -value	Trend
$E[\Delta y]$	2.38%	1.08%	-1.30%	0.028	0.014**
$\sigma[\Delta y]$	2.10%	2.37%	0.27%	0.326	-
$E[\text{Tobin's Q}]$	1.32	1.73	0.41	0.162	0.009***
$E[\text{Net IK}]$	2.75%	1.78%	-0.97%	0.008	-0.042***
$E[\text{Net SZ}]$	7.25%	4.17%	-3.08%	0.000	-0.147***
$E[\delta_{k,t}]$	1.79%	1.72%	-0.08%	0.001	-0.004**
$E[\delta_{z,t}]$	7.02%	7.27%	0.25%	0.027	0.010*
$E[Z/K]$	6.28%	10.82%	4.54%	0.000	0.265***
$E[\pi]$	3.20%	2.06%	-1.14%	0.015	-0.018***
$\sigma[\pi]$	0.53%	0.32%	-0.21%	0.000	-
$E[\text{Labor Share}]$	0.636	0.597	-0.039	0.000	-0.001***
$E[\text{Profit Share}]$	9.10%	12.96%	3.87%	0.002	0.058***
$E[\text{Markup}]$	37.56%	47.75%	10.20%	0.002	0.676***
$E[n]$	1.693	1.537	-0.156	0.002	-0.010***
$E[PE]$	19.41	24.52	5.11	0.069	0.263
$E[PD]$	42.86	53.06	10.20	0.257	0.787**
$E[r_f^{(1)}]$	3.13%	-0.48%	-3.60%	0.000	-0.048***
$E[y^{\$(5Y)} - y^{\$(1Q)}]$	0.97%	1.05%	0.08%	0.763	-0.002
$E[r_d]$	5.14%	3.02%	-2.12%	0.002	-0.111***
$E[r_d - r_f^{(1)}]$	2.01%	3.50%	1.48%	0.015	0.081***

This table reports a series of macroeconomic variables from the data. The first two columns report the statistics for each subsample and the third column reports the difference between the 2001-2017 subsample and the 1984-2000 subsample. The column p -value tests the difference between the subsamples. The trend column reports the coefficient estimate from fitting the variables to a trend. ***, **, * denote significance at the 1%, 5%, and 10%, respectively. All p -value and standard errors are corrected for Newey-West. The p -value for the standard deviation is obtained by performing a two-sample variance comparison test. Growth rates and asset pricing moments are annualized percentage rates.

Table 2: Parameter estimates

	Panel A: Moments			
	Data		Model	
	1984-2000	2001-2017	1984-2000	2001-2017
Mean output growth	2.38%	1.08%	2.38%	1.08%
Mean risk-free rate	3.13%	-0.48%	3.13%	-0.48%
Mean markup	37.56%	47.75%	37.68%	47.87%
$E[\delta_k]$	1.79%	1.72%	1.79%	1.72%
$E[\delta_z]$	7.02%	7.27%	7.02%	7.27%
Mean Z/K	6.28%	10.82%	6.28%	10.82%
Mean PE	19.41	24.54	19.38	24.48

	Panel B: Parameter estimates						
	a^*	β	η	γ	$\bar{\kappa}$	δ_k	δ_z
1984-2000	1.030	0.988	0.072	8.467	2.301	1.79%	7.02%
	(0.004)	(0.001)	(0.001)	(0.193)	(0.002)	(0.001)	(0.007)
2001-2017	0.272	0.994	0.155	9.813	4.078	1.72%	7.27%
	(0.005)	(0.001)	(0.002)	(0.382)	(0.008)	(0.001)	(0.003)
Difference	-0.758	0.005	0.083	1.346	1.776	-0.07%	0.25%

This table reports the results of the moment matching procedure for each subsample. Structural parameters are estimated by matching simulated moments from the model to the corresponding empirical moments. Panel A reports the simulated moments and the empirical targets. Panel B reports the estimated structural parameters for each subsample as well as the difference between the estimates of the 2001-2017 subsample and those of the 1984-2000 subsample. Standard errors are reported below each estimated parameter in parentheses. a^* is the unconditional mean of a . β is the subjective discount factor. η is the share of technology in the production function. γ is the risk aversion. $\bar{\kappa}$ is the entry cost parameter. δ_k and δ_z are the depreciation rate of physical capital and R&D capital, respectively.

Table 3: Parameter Values

Parameter	Description	Value (1984-2000/2001-2017)
A. Preferences		
β	Subjective discount factor	0.988/0.994
ψ	Elasticity of intertemporal substitution	2.00
γ	Risk aversion	8.467/9.813
χ	Labor elasticity	3.0
B. Production		
α	Capital share	0.30
η	Degree of technological appropriability	0.072/0.155
δ_k	Depreciation rate of capital stock	1.79%/1.72%
δ_k	Depreciation rate of R&D stock	7.02%/7.27%
δ_n	Firm obsolescence rate	2.00%
ζ_k	Capital adjustment cost parameter	1.50
ζ_z	R&D capital adjustment cost parameter	0.85
ν_1	Price elasticity accross industries	1.15
ν_2	Price elasticity within industries	6.50
κ	Fixed cost of entry	2.30/4.08
f	Fixed cost of production	0.05
C. Productivity		
a^*	Unconditional mean of a_t	1.03/0.27
ρ^4	Persistence of a_t	0.95
σ	Conditional volatility of a_t	1.50%

This table summarizes the parameter values used in the benchmark calibration of the model. The table is divided into three categories: Preferences, Production, and Productivity parameters. Parameters separated by / are estimated in each subsample. Details on the subsample parameter estimation can be found in Table 2.

Table 4: Comparative statics - target moments

	A. Target moment		B. Parameter contribution							
	1984-2000	2001-2017	Difference	a^*	β	η	γ	κ	δ_k	δ_z
$E[\Delta y]$	2.38%	1.08%	-1.30%	-2.44%	1.28%	0.32%	-0.14%	-0.51%	-0.11%	0.03%
$E[r_f]$	3.13%	-0.48%	-3.61%	-0.08%	-2.86%	0.33%	-0.56%	-0.50%	0.09%	-0.07%
$E[\varphi]$	137.56%	147.75%	10.19%	2.10%	-1.53%	-0.43%	0.04%	10.70%	0.19%	-0.05%
$E[\delta_k]$	1.79%	1.72%	-0.07%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.07%	0.00%
$E[\delta_z]$	7.02%	7.27%	0.25%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.25%
$E[Z/K]$	6.28%	10.82%	4.54%	-0.56%	-1.03%	6.62%	-0.08%	-0.14%	-0.23%	-0.25%
$E[PE]$	19.38	24.48	5.10	-9.86	21.18	1.20	-1.94	-2.32	-0.20	-0.07

This table investigates the contribution of each estimated parameter to matching the target moments. Panel A reports the target moments for the two subsamples as well as their difference. Panel B reports the contribution of each parameter to the target moments. The marginal contribution of each parameter is obtained by setting the parameter value to that of the 2001-2017 sample, while keeping all other parameters to their 1984-2000 values and adjusting for the scale. All moments are obtained from model simulated data. Growth rates and asset pricing moments are annualized percentage rates.

Table 5: Comparative statics - non target moments

		A. Model moment				B. Parameter contribution					
		1984-2000	2001-2017	Difference	α^*	β	η	γ	κ	δ_k	δ_z
A. Competition proxies											
HHI	0.53	0.64	0.11	0.02	-0.02	-0.00	0.00	0.11	0.00	0.00	-0.00
n	0.63	0.45	-0.18	-0.03	0.03	0.01	-0.00	-0.19	-0.00	0.00	0.00
Profit Share	12.56%	15.84%	3.28%	1.56%	-0.29%	-4.84%	0.05%	7.00%	0.22%	0.00	-0.04%
B. Macro moments											
$E[\Delta y]$	2.38%	1.08%	-1.30%	-2.44%	1.28%	0.32%	-0.14%	-0.51%	-0.11%	0.03%	0.03%
$\sigma[\Delta y]$	3.01%	3.00%	-0.01%	-0.12%	0.10%	-0.08%	-0.00%	0.09%	-0.02%	0.02%	0.02%
$E[\Delta tfp]$	2.38%	1.08%	-1.30%	-2.44%	1.28%	0.32%	-0.14%	-0.51%	-0.11%	0.03%	0.03%
$\sigma[\Delta tfp]$	2.47%	2.42%	-0.04%	-0.09%	0.03%	-0.04%	-0.00%	0.06%	-0.02%	0.02%	0.02%
Net I/K	2.40%	1.10%	-1.31%	-2.45%	1.29%	0.32%	-0.15%	-0.51%	-0.11%	0.03%	0.03%
Net S/Z	2.40%	1.09%	-1.31%	-2.45%	1.29%	0.32%	-0.15%	-0.51%	-0.11%	0.03%	0.03%
Labor Share	0.51	0.47	-0.04	-0.01	0.01	0.00	-0.00	-0.04	-0.00	0.00	0.00
C. Asset prices											
$E[r_f^{(1)}]$	3.13%	-0.48%	-3.61%	-0.08%	-2.86%	0.33%	-0.56%	-0.50%	0.09%	0.09%	-0.07%
$E[r_d - r_f]$	4.14%	5.34%	1.20%	-1.14%	1.34%	-0.22%	0.75%	0.43%	-0.15%	0.10%	0.10%
$E[r_d]$	7.55%	5.16%	-2.38%	-1.31%	-1.45%	0.08%	0.23%	-0.06%	-0.07%	0.04%	0.04%
$E[PD]$	19.38	24.48	5.10	-9.86	21.18	1.20	-1.94	-2.32	-0.20	-0.07%	-0.07%
$E[Q]$	1.00	1.07	0.07	-0.03	0.03	-0.17	0.00	0.24	-0.00	0.00	0.00
$E[Q]$	1.00	1.12	0.12	-0.03	0.02	-0.11	0.00	0.25	-0.01	-0.00	-0.00
$\sigma[r_d - r_f]$	5.03%	5.13%	0.10%	-0.14%	0.08%	0.04%	0.00%	0.12%	-0.02%	0.03%	0.03%

This table investigates the contribution of each estimated parameter to model moments not targeted in the estimation. Panel A reports the moments for the two subsamples as well as their difference. Panel B reports the contribution of each parameter to the magnitude of the moments. The marginal contribution of each parameter is obtained by setting the parameter value to that of the 2001-2017 sample, while keeping all other parameters to their 1984-2000 values and adjusting for the scale. All moments are obtained from model simulated data. Growth rates and asset pricing moments are annualized percentage rates.

Table 6: Counterfactual experiments

	I. No change markup			II. No change intangibles			III. No change risk		
	1984-2000	2001-2017	Contribution	1984-2000	2001-2017	Contribution	1984-2000	2001-2017	Contribution
HHI	0.53	0.53	0.11	0.53	0.64	-0.00	0.53	0.64	0.00
n	0.63	0.64	-0.19	0.63	0.45	0.00	0.63	0.45	-0.00
Profit Share	12.56%	8.91%	6.93%	12.56%	19.27%	-3.42%	12.56%	15.78%	0.06%
Labor Share	0.51	0.51	-0.04	0.51	0.47	0.00	0.51	0.47	-0.00
Net I/Y	3.42%	1.73%	-0.24%	3.42%	1.41%	0.08%	3.42%	1.80%	-0.31%
Net S/Y	0.23%	0.23%	-0.02%	0.23%	0.12%	0.09%	0.23%	0.24%	-0.03%
$E[\dot{Q}]$	1.00	0.84	0.23	1.00	1.20	-0.13	1.00	1.07	0.00
$E[\dot{Q}]$	1.00	0.88	0.24	1.00	1.20	-0.08	1.00	1.11	0.00
$\sigma[\Delta y]$	3.01%	2.90%	0.11%	3.01%	3.08%	-0.08%	3.01%	3.00%	-0.00%
$\sigma[r_d - r_f]$	5.03%	5.00%	0.13%	5.03%	5.15%	-0.02%	5.03%	5.13%	-0.00%

This table measures the quantitative importance of the rise in markups (Panel I), the rise in intangibles (Panel II), and the rise in risk (Panel III), in explaining the change in non-targeted moments across samples. The contribution of each of these forces is obtained by running counterfactual experiments. The first column of each panel reports the simulated moments for the 1984-2000 sample. The second column of each panel reports simulated moments for a counterfactual economy that matches all the target moments of the 2001-2017 subsample period, except for the price markup (for Panel I) or the share of intangibles (for Panel II), which are assumed to stay equal to their 1984-2000 values. For Panel III, the second column is obtained assuming that the coefficient of risk aversion γ stays equal to its 1984-2000 value. The third column of each panel measures the relative importance of the force in explaining the changes in moments over the two subsample periods. It is obtained by taking the difference between the simulated moments from the benchmark model (where the force has an effect) and those of the associated counterfactual experiment (where the force is muted). Growth rates and asset pricing moments are annualized percentage rates.

Table 7: Welfare costs

	η	γ	κ
Welfare costs	-22.22%	23.25%	27.36%
$E[r_d - r_f]$	-0.22%	0.75%	0.43%
$E[\Delta c]$	0.32%	-0.14%	-0.51%
$\sigma[\Delta c]$	-0.01%	-0.00%	0.02%
$\sigma[\Delta u]$	-0.13%	-0.00%	0.11%

This table measures the effect of the change in the R&D share (η), the risk aversion coefficient (γ), and the entry costs (κ) on welfare. The values are obtained by setting the parameter value to that of the 2001-2017 sample, while keeping all other parameters to their 1984-2000 values and adjusting for the scale. Δu is the growth rate of the utility kernel. All moments are obtained from model simulated data. Growth rates and asset pricing moments are annualized percentage rates.

Table 8: Alternative specifications

	Benchmark	Exogenous	Capital share	n -proxy
Markup	10.19%	10.19%	10.19%	8.24%
HHI	0.11	0.11	0.11	0.09
Labor Share	-0.04	-0.04	-0.04	-0.03
Q	0.22	0.21	0.24	0.20
$E[\Delta y]$	-0.51%	0.00%	-0.52%	-0.40%
$\sigma[\Delta y]$	0.09%	0.00%	0.09%	0.07%
$E[r_f]$	-0.50%	-0.03%	-0.50%	-0.39%
$E[r_d - r_f]$	0.43%	0.20%	0.43%	0.34%
Welfare cost	27.36%	0.99%	27.86%	21.42%

This table reports the effects of rising markups on secular trends for various alternative specifications. The first column reports simulated moments obtained from the benchmark model. The second column reports simulated moments from a (re-estimated) alternative model where both growth and markup are exogenous. The third column reports moments from the benchmark model where the capital share parameter α is estimated to match the change in the labor share in the data. The fourth column uses the total number of firms as a proxy for competition instead of the price markup. Growth rates and asset pricing moments are annualized percentage rates.

Table 9: Comparative statics - stochastic parameter

	A. Model moment		B. Parameter contribution			
	1984-2000	2001-2017	Difference	a^*	β	κ
A. Competition proxies						
HHI	0.53	0.63	0.10	-0.00	-0.01	0.11
n	0.63	0.46	-0.17	0.00	0.02	-0.19
Profit Share	12.67%	19.24%	6.58%	-0.01%	-0.63%	7.21%
Labor Share	0.51	0.47	-0.03	0.00	0.00	-0.04
B. Macro moments						
$E[\Delta y]$	2.38%	1.08%	-1.30%	0.04%	0.57%	-1.90%
$\sigma[\Delta y]$	2.76%	2.76%	0.00%	0.00%	0.01%	-0.00%
$E[\Delta tfp]$	2.37%	1.11%	-1.26%	0.04%	0.57%	-1.87%
$\sigma[\Delta tfp]$	2.12%	2.13%	0.01%	0.00%	-0.00%	0.01%
Net I/K	2.33%	1.64%	-0.68%	0.02%	0.46%	-1.17%
Net S/Z	3.13%	-0.48%	-3.61%	0.01%	-0.47%	-3.16%
C. Asset prices						
$E[r_f^{(1)}]$	3.13%	-0.48%	-3.61%	0.01%	-0.47%	-3.16%
$E[r_d - r_f]$	4.43%	14.34%	9.91%	0.03%	0.94%	8.94%
$E[r_d]$	7.85%	12.37%	4.52%	0.04%	0.52%	3.96%
$E[PD]$	19.22	12.71	-6.51	0.04	2.53	-9.10
$E[Q]$	1.00	1.02	0.02	0.00	0.00	0.02
$E[Q]$	1.00	1.02	0.02	0.00	0.00	0.02
$\sigma[r_d - r_f]$	5.38%	5.46%	0.09%	-0.00%	-0.01%	0.10%

This table investigates the contribution of each estimated parameter to model moments for the benchmark model. In contrast to the other tables, we allow each parameter of interest to be time-varying and estimate the shocks necessary to replicate the two sub-sample moments. We look at three parameters, κ , a , and β

Table 10: Parameter estimates - model with nominal rigidities

Panel A: Moments				
	Data		Model	
	1984-2000	2001-2017	1984-2000	2001-2017
Mean output growth	2.38%	1.08%	2.38%	1.08%
Mean risk-free rate	3.13%	-0.48%	3.13%	-0.48%
Mean markup	37.56%	47.75%	37.56%	47.75%
$E[\delta_k]$	1.79%	1.72%	1.79%	1.72%
$E[\delta_z]$	7.02%	7.27%	7.02%	7.27%
Mean Z/K	6.28%	10.82%	6.28%	10.82%
Mean PE	19.41	24.54	19.43	24.53
Mean inflation	3.20%	2.06%	3.20%	2.06%

Panel B: Parameter estimates								
	a^*	β	η	γ	Π^*	$\bar{\kappa}$	δ_k	δ_z
1984-2000	1.016	0.988	0.072	8.636	1.025	2.074	1.79%	7.02%
	(0.009)	(0.001)	(0.002)	(0.388)	(0.001)	(0.005)	(0.002)	(0.023)
2001-2017	0.261	0.994	0.156	10.112	1.028	3.743	1.72%	7.27%
	(0.012)	(0.001)	(0.005)	(0.899)	(0.003)	(0.004)	(0.005)	(0.011)
Difference	-0.755	0.005	0.084	1.476	0.002	1.669	-0.07%	0.25%

This table reports the results of the moment matching procedure for each subsample for the model with nominal rigidities. Structural parameters are estimated by matching simulated moments from the model to the corresponding empirical moments. Panel A reports the simulated moments and the empirical targets. Panel B reports the estimated structural parameters for each subsample as well as the difference between the estimates of the 2001-2017 subsample and those of the 1984-2000 subsample. Standard errors are reported below each estimated parameter in parentheses. a^* is the unconditional mean of a . β is the subjective discount factor. η is the share of technology in the production function. γ is the risk aversion. $\bar{\kappa}$ is the entry cost parameter. Π^* is the gross inflation rate target. δ_k and δ_z are the depreciation rate of physical capital and R&D capital, respectively.

Table 11: Comparative statics - non target moments - model with nominal rigidities

	A. Model moment			B. Parameter contribution							
	1984-2000	2001-2017	Difference	a^*	β	η	γ	Π^*	κ	δ_k	δ_z
A. Competition proxies											
HHI	0.51	0.61	0.10	0.02	-0.02	-0.00	-0.00	-0.00	0.11	0.00	-0.00
n	0.68	0.49	-0.19	-0.03	0.04	0.01	0.00	0.00	-0.20	-0.00	0.00
Profit Share	11.94%	15.33%	3.39%	1.44%	-0.14%	-5.05%	0.13%	-0.00%	7.21%	0.21%	-0.05%
Labor Share	0.51	0.47	-0.04	-0.01	0.00	0.00	-0.00	0.00	-0.04	-0.00	0.00
B. Macro moments											
$E[\Delta y]$	2.38%	1.08%	-1.30%	-2.36%	1.28%	0.34%	-0.17%	0.00%	-0.60%	-0.10%	0.04%
$\sigma[\Delta y]$	3.01%	2.99%	-0.02%	-0.13%	0.10%	-0.10%	0.00%	0.00%	0.10%	-0.02%	0.02%
$E[\pi]$	3.20%	2.06%	-1.14%	1.47%	-2.27%	0.93%	-1.34%	0.95%	-1.11%	0.23%	-0.15%
$\sigma[\pi]$	1.62%	1.40%	-0.22%	0.09%	-0.09%	0.02%	0.00%	-0.00%	-0.15%	-0.00%	-0.07%
Net I/K	2.40%	1.10%	-1.31%	-2.37%	1.29%	0.34%	-0.17%	0.00%	-0.60%	-0.10%	0.04%
Net S/Z	3.13%	-0.48%	-3.61%	-0.02%	-2.88%	0.35%	-0.62%	0.00%	-0.49%	0.10%	-0.07%
C. Asset prices											
$E[r_f^{(1)}]$	3.13%	-0.48%	-3.61%	-0.02%	-2.88%	0.35%	-0.62%	0.00%	-0.49%	0.10%	-0.07%
$E[y^{\$(5Y)} - y^{\$(1Q)}]$	0.95%	1.06%	0.10%	0.08%	0.11%	0.19%	0.24%	0.05%	-0.17%	0.05%	-0.03%
$E[r_d - r_f]$	4.11%	5.29%	1.17%	-1.17%	1.34%	-0.25%	0.80%	-0.00%	0.38%	-0.15%	0.12%
$E[r_d]$	7.55%	5.16%	-2.38%	-1.27%	-1.45%	0.08%	0.23%	-0.00%	-0.10%	-0.06%	0.05%
$E[PD]$	19.43	24.53	5.09	-9.50	21.26	1.35	-2.10	0.00	-2.52	-0.19	-0.08
$E[Q]$	0.91	0.98	0.06	-0.02	0.03	-0.16	0.00	0.00	0.23	-0.00	0.00
$E[\hat{Q}]$	0.87	0.98	0.10	-0.02	0.02	-0.10	0.00	0.00	0.22	-0.01	-0.00
$\sigma[r_d - r_f]$	4.98%	5.02%	0.03%	-0.19%	0.08%	0.03%	0.00%	0.00%	0.10%	-0.03%	0.04%
PC slope	0.13	0.11	-0.02	0.02	-0.02	0.04	-0.00	-0.00	-0.05	0.00	-0.01

This table investigates the contribution of each estimated parameter to model moments for the model with nominal rigidities. Panel A reports the moments for the two subsamples as well as their difference. Panel B reports the contribution of each parameter to the magnitude of the moments. The marginal contribution of each parameter is obtained by setting the parameter value to that of the 2001-2017 sample, while keeping all other parameters to their 1984-2000 values. All moments are obtained from model simulated data. Growth rates and asset pricing moments are annualized percentage rates.

Table 12: Predictions using Q

	2001-2017	1984-2000	1984-2000*
<u>A. Growth</u>			
β	0.569	0.473	0.554
$S.E.$	0.002	0.002	0.002
R^2	0.712	0.678	0.686
<u>B. ROA</u>			
β	0.233	0.128	0.156
$S.E.$	0.001	0.000	0.000
R^2	0.874	0.862	0.875
<u>C. Volatility</u>			
β	-0.122	-0.171	-0.220
$S.E.$	0.005	0.004	0.005
R^2	0.155	0.222	0.306

This table presents a series of four quarters ahead predictive regressions using the log-Tobin's Q , i.e., $z_{t+1,t+4} = \alpha + \beta \log(Q_t) + \epsilon_t$. Each panel reports the results for different dependent variable variables z_t : Panel A uses output growth, panel B the return on assets, net of investment, and panel C the log-realized consumption growth volatility. Realized consumption growth volatility is computed in two steps as in Bansal, Kiku, Yaron, et al. (2012). First, realized consumption growth is fitted to an AR(1) process. Second, realized annual volatility is obtained by summing the absolute value of the errors over the next four quarters. β reports the slope coefficient, $S.E.$ is the associated standard error. Column 1984-2000 and 2001-2017 reports the results using the estimated parameters for the first and second subsample. Column 1984-2000* reports the results for a counterfactual setting in which we use entry costs as estimated in the late sample, but fix all parameters to those of the early sample values.

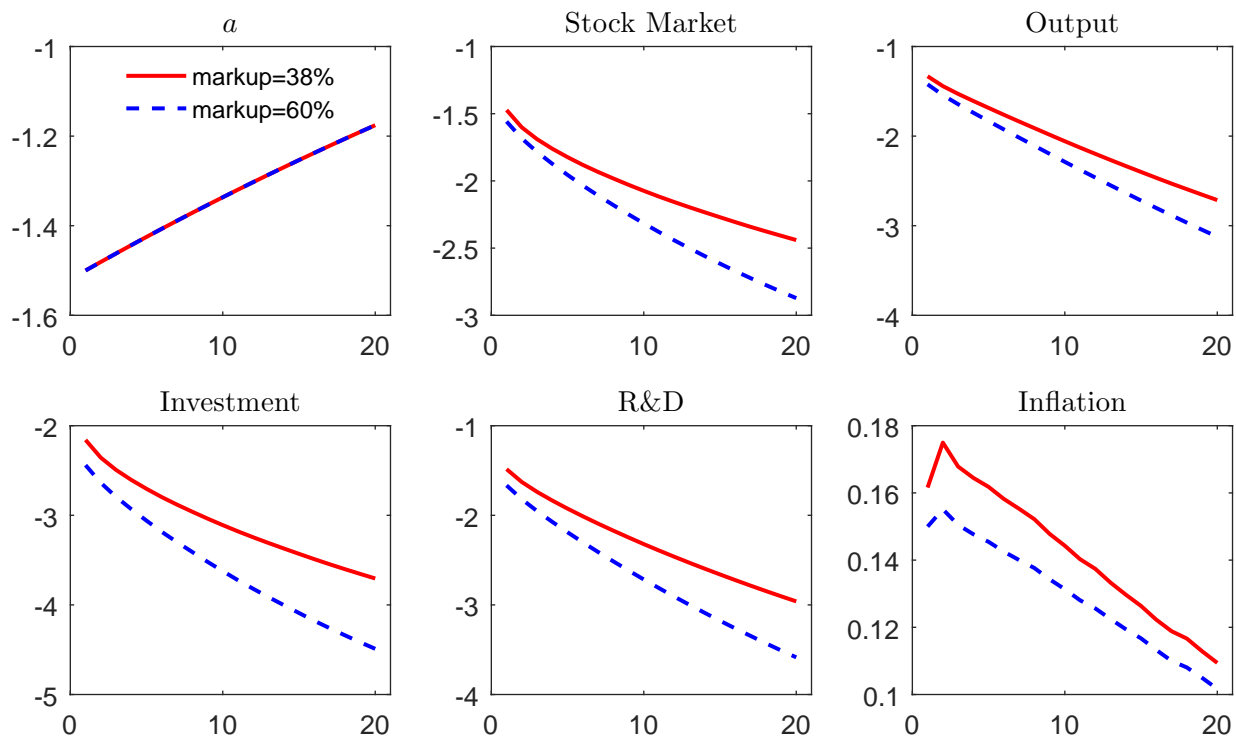


Figure 1: This figure compares the impulse-response functions to a negative productivity shock for two calibrations of the model with nominal rigidities. The red solid line uses the parameter estimates for the 2001-2017 sample period with a level of markup of 38%, consistent with the estimate for the 1984-2000 sample. The dashed blue line uses the same parameters except for the entry cost that is set to match a price markup of 60%, consistent with the estimate for 2017. The plots reports responses for productivity, the aggregate stock market, output, investment, R&D investment, and inflation. All values on the y -axis are in percentage log-deviation from the deterministic trend.

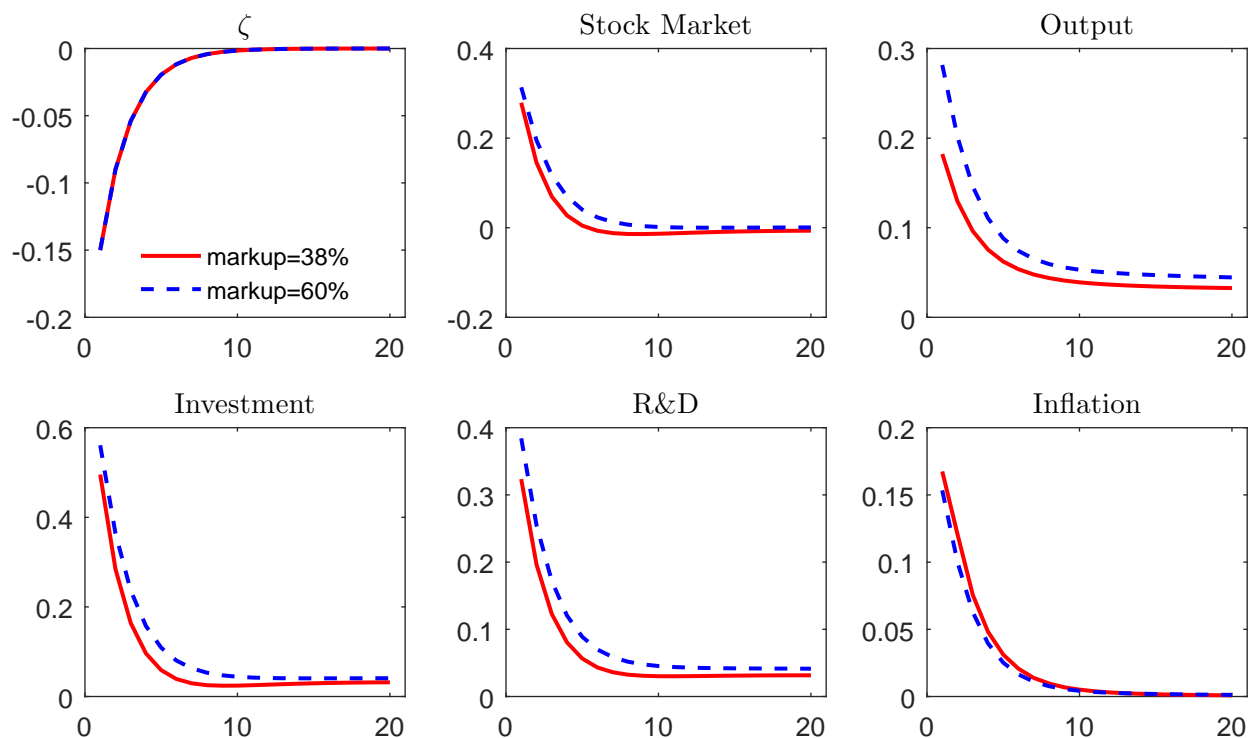


Figure 2: This figure compares the impulse-response functions to an accommodating monetary policy shock for two calibrations of the model with nominal rigidities. The red solid line uses the parameter estimates for the 2001-2017 sample period with a level of markup of 38%, consistent with the estimate for the 1984-2000 sample. The dashed blue line uses the same parameters except for the entry cost that is set to match a price markup of 60%, consistent with the estimate for 2017. The plots reports responses for productivity, the aggregate stock market, output, investment, R&D investment, and inflation. All values on the y -axis are in percentage log-deviation from the deterministic trend.

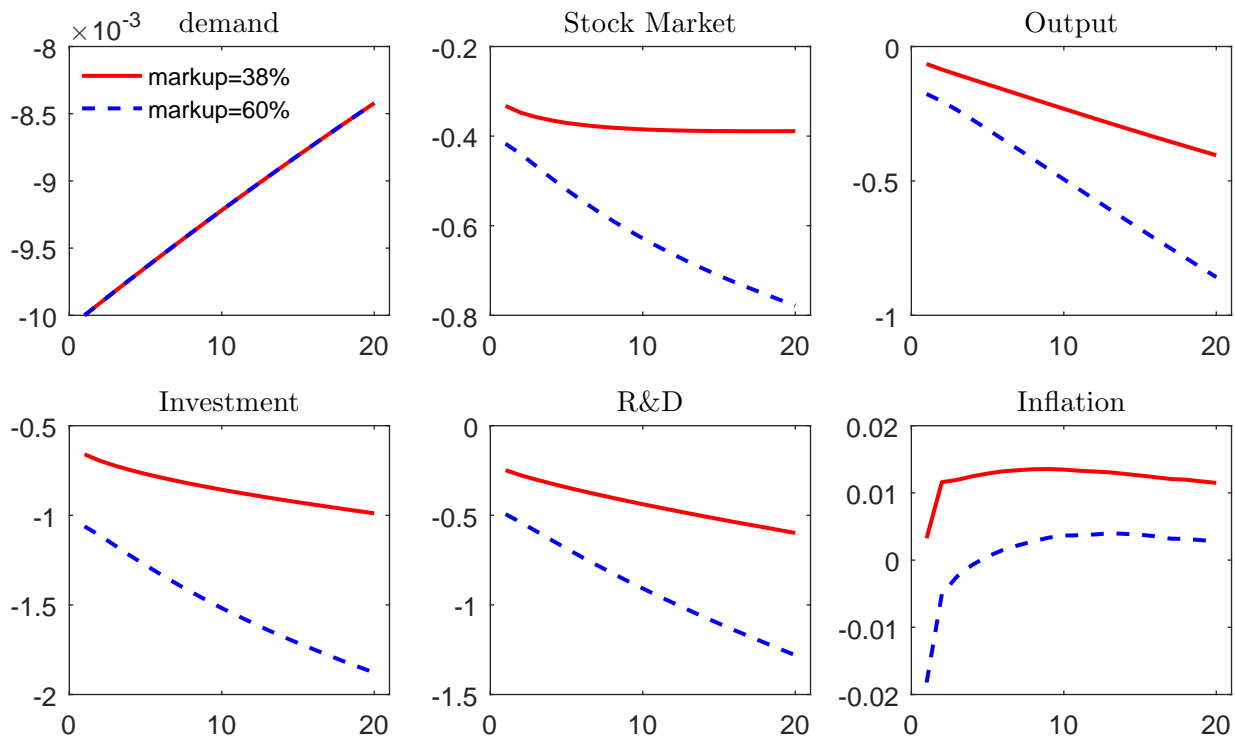


Figure 3: This figure compares the impulse-response functions to a negative demand shock for two calibrations of the model with nominal rigidities. The negative demand-shock ($\epsilon_x < 0$) is obtained by assuming that the subjective discount rate is defined as $\beta_t \equiv \beta e^{x_t}$, where $x_t = \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}$. The calibration is $\rho_x = 0.991$, and $\sigma_x = 0.01\%$. The red solid line uses the parameter estimates for the 2001-2017 sample period with a level of markup of 38%, consistent with the estimate for the 1984-2000 sample. The dashed blue line uses the same parameters except for the entry cost that is set to match a price markup of 60%, consistent with the estimate for 2017. The plots reports responses for productivity, the aggregate stock market, output, investment, R&D investment, and inflation. All values on the y -axis are in percentage log-deviation from the deterministic trend.

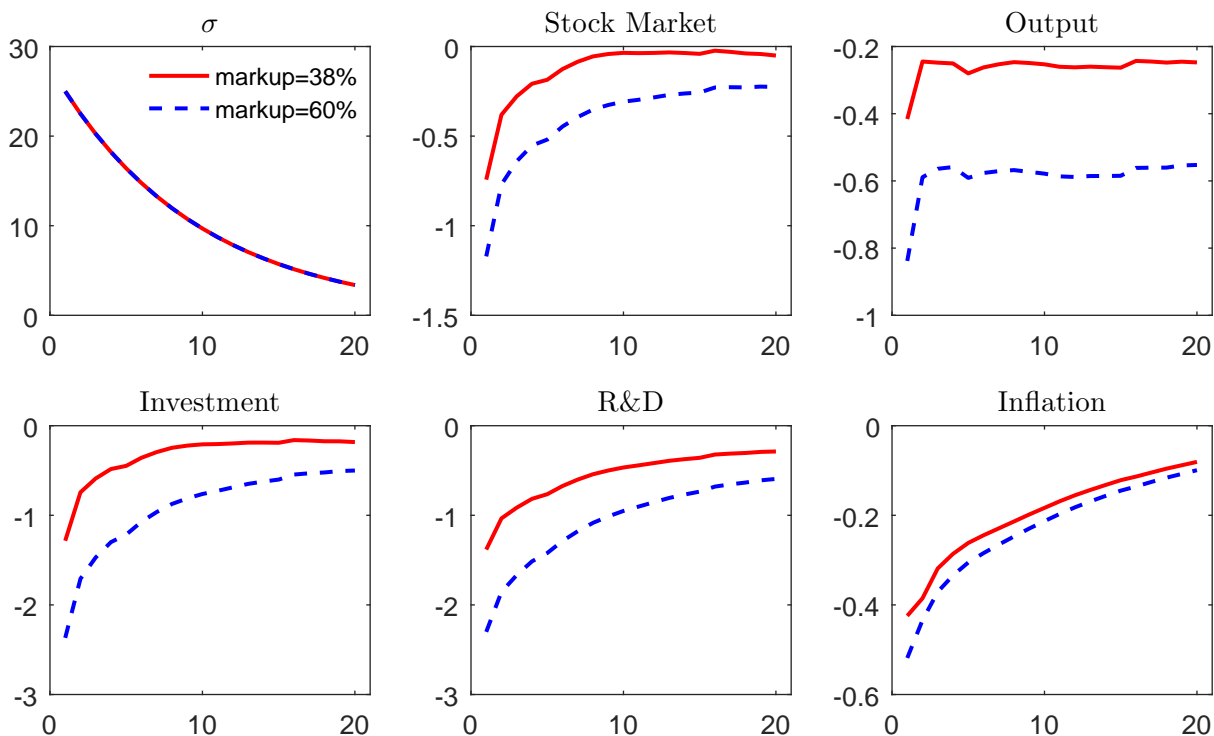


Figure 4: This figure compares the impulse-response functions to a 25% increase in uncertainty for two calibrations of the model with nominal rigidities. The positive uncertainty shock ($\epsilon_x > 0$) is obtained by assuming that the volatility of exogenous productivity is defined as $\sigma_t \equiv \sigma e^{x_t}$, where $x_t = \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}$. The calibration is $\rho_x = 0.9$, and $\sigma_x = 2.5\%$. The red solid line uses the parameter estimates for the 2001-2017 sample period with a level of markup of 38%, consistent with the estimate for the 1984-2000 sample. The dashed blue line uses the same parameters except for the entry cost that is set to match a price markup of 60%, consistent with the estimate for 2017. The plots reports responses for productivity, the aggregate stock market, output, investment, R&D investment, and inflation. All values on the y -axis are in percentage log-deviation from the deterministic trend.

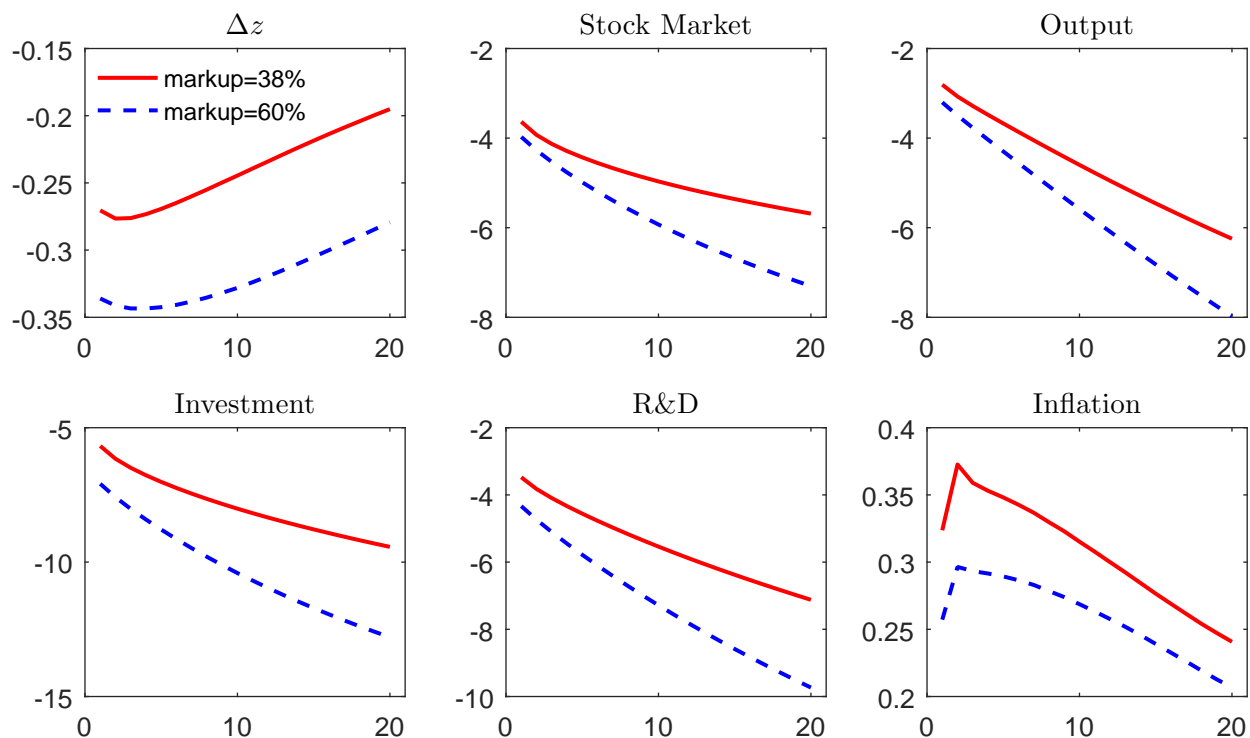


Figure 5: This figure compares the impulse-response functions to a joint negative demand and supply shock for two calibrations of the model with nominal rigidities. The negative demand-shock ($\epsilon_x < 0$) is obtained by assuming that the subjective discount rate is defined as $\beta_t \equiv \beta e^{x_t}$, where $x_t = \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}$. The calibration is $\rho_x = 0.991$, and $\sigma_x = 0.01\%$. The red solid line uses the parameter estimates for the 2001-2017 sample period with a level of markup of 38%, consistent with the estimate for the 1984-2000 sample. The dashed blue line uses the same parameters except for the entry cost that is set to match a price markup of 60%, consistent with the estimate for 2017. The plots reports responses for productivity, the aggregate stock market, output, investment, R&D investment, and inflation. The magnitude of each shock is equal to minus 2 standard deviations. All values on the y -axis are in percentage log-deviation from the deterministic trend.

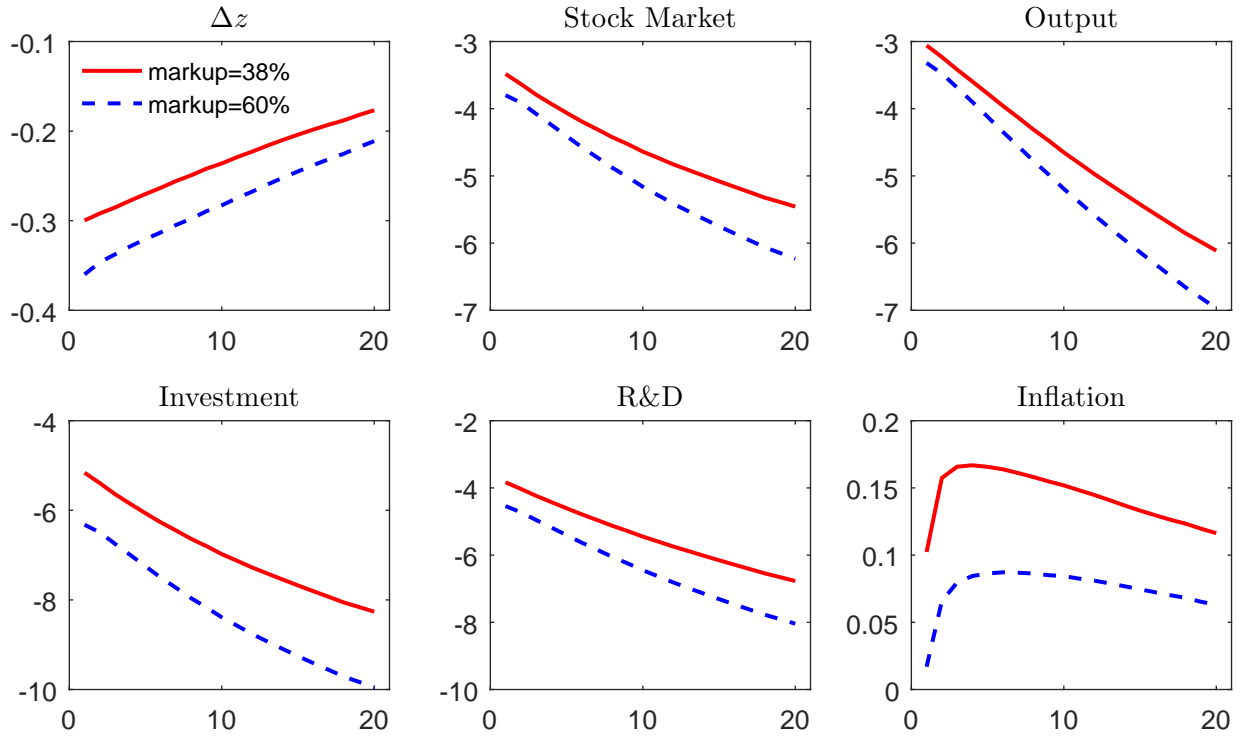


Figure 6: This figure compares the impulse-response functions to a joint increase in uncertainty and a recession for two calibrations of the model with nominal rigidities. The positive uncertainty shock ($\epsilon_x > 0$) is obtained by assuming that the volatility of exogenous productivity is defined as $\sigma_t \equiv \sigma e^{x_t}$, where $x_t = \rho_x x_{t-1} + \sigma_x \epsilon_{x,t}$. The calibration is $\rho_x = 0.962$, and $\sigma_x = 1.73\%$. The red solid line uses the parameter estimates for the 2001-2017 sample period with a level of markup of 38%, consistent with the estimate for the 1984-2000 sample. The dashed blue line uses the same parameters except for the entry cost that is set to match a price markup of 60%, consistent with the estimate for 2017. The plots reports responses for productivity, the aggregate stock market, output, investment, R&D investment, and inflation. The magnitude of the productivity shock is equal to minus 2 standard deviations and that of the uncertainty shock to plus 5 standard deviations. All values on the y -axis are in percentage log-deviation from the deterministic trend.

Appendix A. Optimality conditions

A.1 Final goods sector

The final goods firm's problem consists of choosing the optimal bundle of products $\{X_{ij,t}\}_{j \in [0,1], i \in [0, N_{j,t}]}$, in order to maximize the firm's profit. The production function is:

$$\begin{aligned} \mathcal{Y}_t &= \left(\int_0^1 Y_{j,t}^{\frac{\nu_1-1}{\nu_1}} dj \right)^{\frac{\nu_1}{\nu_1-1}} \\ Y_{j,t} &= \left(\int_0^{N_{j,t}} X_{ij,t}^{\frac{\nu_2-1}{\nu_2}} di \right)^{\frac{\nu_2}{\nu_2-1}} \end{aligned}$$

The problem is solved in two steps. First, we derive the optimal demand for products $X_{ij,t}$ within industry j to maximize industry output $Y_{j,t}$ for any given expenditure level $\xi_{j,t}$:

$$\int_0^{N_{j,t}} P_{ij,t} X_{ij,t} di = \xi_{j,t} \quad (\text{A.1})$$

The Lagrangian of the problem is:

$$\mathcal{L}_{\xi,j,t} = \max_{\{X_{ij,t}\}_{i \in [0, N_{j,t}]}} \left(\int_0^{N_{j,t}} X_{ij,t}^{\frac{\nu_2-1}{\nu_2}} di \right)^{\frac{\nu_2}{\nu_2-1}} + \Lambda_{j,t}^{\xi} \left(\xi_{j,t} - \int_0^{N_{j,t}} P_{ij,t} X_{ij,t} di \right)$$

where $\Lambda_{j,t}^{\xi}$ is the associated Lagrange multiplier. The first order necessary conditions are:

$$\left(\int_0^{N_{j,t}} X_{ij,t}^{\frac{\nu_2-1}{\nu_2}} di \right)^{\frac{\nu_2}{\nu_2-1}-1} X_{ij,t}^{-\frac{1}{\nu_2}} = \Lambda_{j,t}^{\xi} P_{ij,t}, \quad \text{for } i \in [0, N_{j,t}]$$

Using the expression above, for any two products i , and k ,

$$X_{ij,t} = X_{kj,t} \left(\frac{P_{ij,t}}{P_{kj,t}} \right)^{-\nu_2} \quad (\text{A.2})$$

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

$$\left(\int_0^{N_{j,t}} X_{ij,t}^{\frac{\nu_2-1}{\nu_2}} di \right)^{\frac{\nu_2}{\nu_2-1}} = X_{kj,t} \frac{\left(\int_0^{N_{j,t}} P_{ij,t}^{1-\nu_2} di \right)^{\frac{\nu_2}{\nu_2-1}}}{P_{kj,t}^{-\nu_2}}$$

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

$$Y_{j,t} \frac{P_{kj,t}^{-\nu_2}}{X_{kj,t}} = \left(\int_0^{N_{j,t}} P_{ij,t}^{1-\nu_2} di \right)^{\frac{-\nu_2}{1-\nu_2}} \quad (\text{A.3})$$

The industry j price index is the price $P_{j,t}$ such that $P_{j,t}Y_{j,t} = \xi_{j,t}$. Using the expenditure function, Eq. A.1, along with Eq. A.2, we get

$$\frac{X_{kj,t}}{P_{kj,t}^{-\nu_2}} \int_0^{N_{j,t}} P_{ij,t}^{1-\nu_2} di = \xi_{j,t} = P_{j,t}Y_{j,t} \quad (\text{A.4})$$

Putting Eq. A.3 together with Eq. A.4, we obtain the expression for the industry price index $P_{j,t}$:

$$P_{j,t} = \left(\int_0^{N_{j,t}} P_{ij,t}^{1-\nu_2} di \right)^{\frac{1}{1-\nu_2}}$$

Therefore the demand for intermediate firm (i, j) output is:

$$X_{ij,t} = Y_{j,t} \left(\frac{P_{ij,t}}{P_{j,t}} \right)^{-\nu_2} \quad (\text{A.5})$$

In the second step, we derive the optimal demand for each industry good $Y_{j,t}$ in order to maximize the final goods firm profit, that is

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

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

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

$$Y_{j,t} = \mathcal{Y}_t \left(\frac{P_{j,t}}{P_{Y,t}} \right)^{-\nu_1} \quad (\text{A.6})$$

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

$$Y_{j,t} = Y_{k,t} \left(\frac{P_{j,t}}{P_{k,t}} \right)^{-\nu_1} \quad (\text{A.7})$$

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

$$P_{Y,t} Y_t = \int_0^1 P_{j,t} Y_{j,t} dj \quad (\text{A.8})$$

Substituting (A.7) into (A.8) gives

$$Y_{j,t} = P_{Y,t} \mathcal{Y}_t \frac{P_{j,t}^{-\nu_1}}{\int_0^1 P_{j,t}^{1-\nu_1} dj} \quad (\text{A.9})$$

Substitute (A.6) into (A.9) to obtain the price index

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

In the following, we use the aggregate price index as our numéraire, i.e., $P_{Y,t} = 1$.

A.2 Intermediate firms

Using the demand faced by a firm i in sector j (Eq. A.5), and the demand faced by industry j (Eq. A.6), the demand faced by firm (i,j) can be expressed as

$$X_{ij,t} = \mathcal{Y}_t (P_{ij,t})^{-\nu_2} (P_{j,t})^{\nu_2 - \nu_1} \quad (\text{A.10})$$

The (real) source of funds constraint is

$$D_{ij,t} = P_{ij,t} X_{ij,t} - \mathcal{W}_t L_{ij,t} - \mathcal{R}_t^k K_{ij,t} - \mathcal{R}_t^z Z_{ij,t} - f Z_t$$

Taking the input prices, the pricing and production decisions of the other firms in the industry, and the pricing kernel as given, firm (i,j) 's problem is to maximize shareholder's wealth subject

to the firm demand emanating from the rest of the economy:

$$\begin{aligned}
V_{ij,t} &= \max_{\{L_{ij,t}, K_{ij,t}, Z_{ij,t}, P_{ij,t}\}_{t \geq 0}} E_t \left[\sum_{s=0}^{\infty} M_{t,t+s} (1 - \delta_n)^s D_{i,j,t+s} \right] \\
\text{s.t. } X_{ij,t} &= \mathcal{Y}_t (P_{ij,t})^{-\nu_2} (P_{j,t})^{\nu_2 - \nu_1} \\
P_{j,t} &= \left(\int_0^{N_{j,t}} P_{ij,t}^{1-\nu_2} di \right)^{\frac{1}{1-\nu_2}}
\end{aligned}$$

where $M_{t,t+s}$ is the marginal rate of substitution between time t and time $t + s$.

The Lagrangian of the problem is

$$\begin{aligned}
\mathcal{Q}_{ij,t} &= P_{ij,t} K_{ij,t}^\alpha (A_t Z_{ij,t}^\eta \bar{Z}_t^{1-\eta} L_{ij,t})^{1-\alpha} - \mathcal{W}_t L_{ij,t} - \mathcal{R}_t^k K_{ij,t} - \mathcal{R}_t^z Z_{ij,t} - f \bar{Z}_t \\
&\quad + \Lambda_{ij,t}^d \left(K_{ij,t}^\alpha (A_t Z_{ij,t}^\eta \bar{Z}_t^{1-\eta} L_{ij,t})^{1-\alpha} - \mathcal{Y}_t (P_{ij,t})^{-\nu_2} (P_{j,t})^{\nu_2 - \nu_1} \right)
\end{aligned}$$

The corresponding first order necessary conditions are

$$\begin{aligned}
\mathcal{R}_t^k &= \alpha \frac{X_{ij,t}}{K_{ij,t}} (P_{ij,t} + \Lambda_{ij,t}^d) \\
\mathcal{R}_t^z &= \eta (1 - \alpha) \frac{X_{ij,t}}{Z_{ij,t}} (P_{ij,t} + \Lambda_{ij,t}^d) \\
\mathcal{W}_t &= (1 - \alpha) \frac{X_{ij,t}}{L_{ij,t}} (P_{ij,t} + \Lambda_{ij,t}^d) \\
X_{ij,t} &= \Lambda_{ij,t}^d \mathcal{Y}_t \left[-\nu_2 P_{ij,t}^{-\nu_2 - 1} P_{j,t}^{\nu_2 - \nu_1} + (\nu_2 - \nu_1) P_{ij,t}^{-\nu_2} P_{j,t}^{\nu_2 - \nu_1 - 1} \frac{\partial P_{j,t}}{\partial P_{ij,t}} \right]
\end{aligned}$$

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

Using the definition of the industry price index and because the industry goods market is oligopolistic:

$$\frac{\partial P_{j,t}}{\partial P_{ij,t}} = \left(\frac{P_{ij,t}}{P_{j,t}} \right)^{-\nu_2}$$

Imposing the symmetry condition across industries implies that $P_{j,t} = 1$. In addition, the symmetry across firms within an industry implies that $P_{ij,t} = P_t = N_{j,t}^{\frac{1}{\nu_2 - 1}}$, so that $Y_{j,t} = N_{j,t}^{\frac{\nu_2}{\nu_2 - 1}} X_{j,t}$ and the i

subscript can be dropped. Our set of equilibrium conditions simplifies to:

$$\begin{aligned}
\mathcal{R}_t^k &= P_t \alpha \frac{Y_{j,t}}{N_{j,t} K_{j,t}} \left(1 + \frac{\Lambda_{j,t}^d}{P_t} \right) \\
\mathcal{R}_t^z &= P_t \eta (1 - \alpha) \frac{Y_{j,t}}{N_{j,t} Z_{j,t}} \left(1 + \frac{\Lambda_{j,t}^d}{P_t} \right) \\
\mathcal{W}_t &= P_t (1 - \alpha) \frac{Y_{j,t}}{N_{j,t} L_{j,t}} \left(1 + \frac{\Lambda_{j,t}^d}{P_t} \right) \\
1 &= \frac{\Lambda_{j,t}^d}{P_t} [-\nu_2 + (\nu_2 - \nu_1) N_{j,t}^{-1}]
\end{aligned}$$

Further, defining the price markup, φ_t , as the price set by the firm over the marginal cost of production, we have:

$$\varphi_t = \frac{P_t}{\frac{\mathcal{W}_t}{(1-\alpha) \frac{Y_{j,t}}{N_{j,t} L_{j,t}}}} = \left(1 + \frac{\Lambda_{j,t}^d}{P_t} \right)^{-1} = \frac{-\nu_2 N_{j,t} + (\nu_2 - \nu_1)}{-(\nu_2 - 1) N_{j,t} + (\nu_2 - \nu_1)}.$$

A.3 Household

The representative household maximizes utility by participating in financial markets, investing in capital and technology, and supplying labor. The household position in the stock market is denoted by Ω_t , and her position in the government bond market by \mathcal{B}_t . The household owns a stock of physical and intangible capital, that are rented to firms for a period return of \mathcal{R}_t^k and \mathcal{R}_t^z , respectively. Using the fact that all intermediate firms are symmetric, the (real) budget constraint of the household is

$$\mathcal{C}_t + (\mathcal{N}_t + \mathcal{N}_{E,t})(V_t - D_t) \Omega_{t+1} + \mathcal{B}_{t+1} + \mathcal{I}_t + \mathcal{S}_t = \mathcal{W}_t \mathcal{L}_t + \mathcal{N}_t f \mathcal{Z}_t + \mathcal{N}_t V_t \Omega_t + \mathcal{R}_{f,t} \mathcal{B}_t + \mathcal{R}_t^k \mathcal{K}_t + \mathcal{R}_t^z \mathcal{Z}_t,$$

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

Setting up the household problem in Lagrangian form:

$$\begin{aligned}
\mathcal{U}_t &= \max u(\mathcal{C}_t, \mathcal{L}_t) + \beta \left(E_t [\mathcal{U}_{t+1}^{1-\theta}] \right)^{\frac{1}{1-\theta}} \\
&+ \Lambda_t \left(\mathcal{W}_t \mathcal{L}_t + \mathcal{N}_t f \mathcal{Z}_t + \mathcal{N}_t V_t \Omega_t + \mathcal{R}_{f,t} \mathcal{B}_t + \mathcal{R}_t^k \mathcal{K}_t + \mathcal{R}_t^z \mathcal{Z}_t - \mathcal{C}_t - (\mathcal{N}_t + \mathcal{N}_{E,t})(V_t - D_t) \Omega_{t+1} - \mathcal{B}_{t+1} - \mathcal{I}_t - \mathcal{S}_t \right) \\
&+ \Lambda_t^K \left((1 - \delta_k) \mathcal{K}_t + \Phi_{k,t} \mathcal{K}_t - \mathcal{K}_{t+1} \right) \\
&+ \Lambda_t^Z \left((1 - \delta_z) \mathcal{Z}_t + \Phi_{z,t} \mathcal{Z}_t - \mathcal{Z}_{t+1} \right)
\end{aligned}$$

where Λ_t , Λ_t^K , and Λ_t^Z are the Lagrange multipliers on the budget constraint, physical accumulation and intangible capital accumulation, respectively.

Taking first order conditions with respect to \mathcal{I}_t , \mathcal{S}_t , \mathcal{K}_{t+1} , \mathcal{Z}_{t+1} , Ω_{t+1} , \mathcal{B}_{t+1} , and \mathcal{L}_t yield four intertemporal Euler equations and one intratemporal condition for labor supply:

$$\begin{aligned}
1 &= E_t \left[\mathcal{M}_{t,t+1} \frac{\mathcal{R}_{t+1}^k + \Phi_{k,t+1}'^{-1} \left(1 - \delta_k - \Phi_{k,t+1}' \left(\frac{\mathcal{I}_t}{\mathcal{K}_t} \right) + \Phi_{k,t+1} \right)}{\Phi_{k,t}'^{-1}} \right] \\
1 &= E_t \left[\mathcal{M}_{t,t+1} \frac{\mathcal{R}_{t+1}^z + \Phi_{z,t+1}'^{-1} \left(1 - \delta_z - \Phi_{z,t+1}' \left(\frac{\mathcal{S}_t}{\mathcal{Z}_t} \right) + \Phi_{z,t+1} \right)}{\Phi_{z,t}'^{-1}} \right] \\
1 &= E_t \left[\mathcal{M}_{t,t+1} \frac{\mathcal{N}_{t+1} V_{t+1}}{(\mathcal{N}_t + \mathcal{N}_{E,t})(V_t - D_t)} \right] \\
1 &= E_t [\mathcal{M}_{t,t+1} R_{f,t+1}] \\
\mathcal{W}_t &= \frac{\chi_0 (1 - \mathcal{L}_t)^{-\chi}}{\mathcal{C}_t^{-1/\psi}} \mathcal{Z}_t^{1-1/\psi}
\end{aligned}$$

where $\Phi_{k,t}' = \frac{\partial \Phi_{k,t}}{\partial \mathcal{K}_t}$, $\Phi_{z,t}' = \frac{\partial \Phi_{z,t}}{\partial \mathcal{Z}_t}$, and \mathcal{M}_{t+1} is the one-period stochastic discount factor:

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

Using the evolution of the mass of firms in an industry, the cum-dividend value of a firm simplifies to:

$$V_t = D_t + (1 - \delta_n) E_t [\mathcal{M}_{t,t+1} V_{t+1}]$$

The aggregate resource constraint is obtained after imposing market clearing in financial markets (i.e. $\Omega_t = 1$ and $\mathcal{B}_t = 0$), goods markets and production input markets as well as using the symmetric nature of the economy. We obtain,

$$\mathcal{C}_t + \mathcal{N}_{E,t}(V_t - D_t) + \mathcal{I}_t + \mathcal{S}_t = \mathcal{W}_t \mathcal{L}_t + \mathcal{N}_t D_t + \mathcal{R}_t^k \mathcal{K}_t + \mathcal{R}_t^z \mathcal{Z}_t$$

which after replacing for D_t , and using the free entry condition (i.e. $V_t - D_t = \mathcal{F}_{E,t}$), simplifies to:

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

A.4 Intermediate firms - nominal rigidities

The intermediate firm problem with nominal rigidities is the same as before except that the firm price becomes a state variable at the firm level. The (real) source of funds constraint is

$$D_{ij,t} = P_{ij,t}X_{ij,t} - \mathcal{W}_t L_{ij,t} - R_{k,t}K_{ij,t} - R_{z,t}Z_{ij,t} - fZ_t - \frac{\Phi_P}{2} \left(\frac{P_{ij,t}}{P_{ij,t-1}\bar{\Pi}} - 1 \right)^2 \frac{\mathcal{Y}_t}{\mathcal{N}_t}$$

Taking the input prices, the pricing and production decisions of the other firms in the industry, and the pricing kernel as given, firm (i,j) 's problem is to maximize shareholder's wealth subject to the firm demand emanating from the rest of the economy:

$$\begin{aligned} V_{ij,t} &= \max_{\{L_{ij,t}, K_{ij,t}, Z_{ij,t}, P_{ij,t}\}_{t \geq 0}} E_t \left[\sum_{s=0}^{\infty} M_{t,t+s} (1 - \delta_n)^s D_{i,j,t+s} \right] \\ \text{s.t. } X_{ij,t} &= \mathcal{Y}_t (P_{ij,t})^{-\nu_2} (P_{j,t})^{\nu_2 - \nu_1} \\ P_{j,t} &= \left(\int_0^{N_{j,t}} P_{ij,t}^{1-\nu_2} di \right)^{\frac{1}{1-\nu_2}} \end{aligned}$$

where $M_{t,t+s}$ is the real marginal rate of substitution between time t and time $t+s$.

The Lagrangian of the problem is

$$\begin{aligned} \mathcal{L}_{ij} &= \sum_{s=0}^{\infty} (1 - \delta_n)^s M_{t,t+s} \left\{ P_{ij,t+s} K_{ij,t+s}^\alpha (A_{t+s} Z_{ij,t+s}^\eta Z_{t+s}^{1-\eta} L_{ij,t+s})^{1-\alpha} \right. \\ &\quad - \mathcal{W}_{t+s} L_{ij,t+s} - \mathcal{R}_{t+s}^k K_{ij,t+s} - \mathcal{R}_{t+s}^z Z_{ij,t+s} - fZ_{t+s} - \frac{\Phi_P}{2} \left(\frac{P_{ij,t+s}}{P_{ij,t-1+s}\bar{\Pi}} - 1 \right)^2 \frac{\mathcal{Y}_{t+s}}{\mathcal{N}_{t+s}} \\ &\quad \left. + \Lambda_{ij,t+s}^d \left(K_{ij,t+s}^\alpha (A_{t+s} Z_{ij,t+s}^\eta Z_{t+s}^{1-\eta} L_{ij,t+s})^{1-\alpha} - \mathcal{Y}_{t+s} (P_{ij,t+s})^{-\nu_2} (P_{j,t+s})^{\nu_2 - \nu_1} \right) \right\} \end{aligned}$$

The first order conditions (FOCs) with respect to $L_{ij,t}$, $K_{ij,t}$, and $Z_{ij,t}$ are the same as before. The FOC w.r.t. $P_{ij,t}$ becomes

$$\begin{aligned} X_{ij,t} - \Phi_P \left(\frac{P_{ij,t}}{P_{ij,t-1}\bar{\Pi}} - 1 \right) \frac{\mathcal{Y}_t/\mathcal{N}_t}{P_{ij,t-1}\bar{\Pi}} + \Phi_P (1 - \delta_n) E_t \left[M_{t,t+1} \left(\frac{P_{ij,t+1}}{P_{ij,t}\bar{\Pi}} - 1 \right) \frac{P_{ij,t+1}}{P_{ij,t}^2 \bar{\Pi}} \mathcal{Y}_{t+1}/\mathcal{N}_{t+1} \right] \\ = \Lambda_{ij,t}^d \mathcal{Y}_t \left[-\nu_2 P_{ij,t}^{-\nu_2-1} P_{j,t}^{\nu_2-\nu_1} + (\nu_2 - \nu_1) P_{ij,t}^{-\nu_2} P_{j,t}^{\nu_2-\nu_1-1} \frac{\partial P_{j,t}}{\partial P_{ij,t}} \right] \end{aligned}$$

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

Using the definition of the industry price index and because the industry goods market is oligopolis-

tic, we have:

$$\frac{\partial P_{j,t}}{\partial P_{ij,t}} = \left(\frac{P_{ij,t}}{P_{j,t}} \right)^{-\nu_2}.$$

Imposing the symmetry condition across industries implies that $P_{j,t} = P_t$. In addition, the symmetry across firms within an industry implies that $P_{ij,t} = P_t N_t^{\frac{1}{\nu_2-1}}$, so that $Y_t = N_t^{\frac{\nu_2}{\nu_2-1}} X_t$ and the i subscript can be dropped. Using P_t as the numéraire. The price-setting equation becomes:

$$\begin{aligned} P_{ij,t} X_t - \Phi_P \left(\frac{\Pi_{j,t}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t}}{\bar{\Pi}} \mathcal{Y}_t / \mathcal{N}_t + \Phi_P E_t \left[(1 - \delta_n) M_{t,t+1} \left(\frac{\Pi_{j,t+1}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t+1}}{\bar{\Pi}} \mathcal{Y}_{t+1} / \mathcal{N}_{t+1} \right] \\ = \frac{\Lambda_{ij,t}^d}{P_{ij,t}} P_{ij,t} X_t [-\nu_2 + (\nu_2 - \nu_1) N_t^{-1}], \text{ or,} \\ \frac{\Lambda_{ij,t}^d}{P_{ij,t}} = \frac{1 - \Phi_P \left(\frac{\Pi_{j,t}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t}}{\bar{\Pi}} + \Phi_P E_t \left[(1 - \delta_n) M_{t,t+1} \left(\frac{\Pi_{j,t+1}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t+1}}{\bar{\Pi}} \Delta \mathcal{Y}_{t+1} / \Delta \mathcal{N}_{t+1} \right]}{-\nu_2 + (\nu_2 - \nu_1) N_t^{-1}}, \end{aligned}$$

Where we used the fact that $P_{j,t} X_t = \mathcal{Y}_t / \mathcal{N}_t$, and where $\Pi_{j,t} = \Pi_t \Delta N_t^{\frac{1}{\nu_2-1}}$.

As before, the price markup, φ_t^* , is defined as the price set by the firm over the marginal cost of production. It follows that φ_t^* satisfies:

$$\begin{aligned} (\varphi_t^*)^{-1} &= \left(1 + \frac{\Lambda_{j,t}^d}{P_{j,t}} \right) \\ &= 1 + \frac{1 - \Phi_P \left(\frac{\Pi_{j,t}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t}}{\bar{\Pi}} + \Phi_P E_t \left[(1 - \delta_n) M_{t,t+1} \left(\frac{\Pi_{j,t+1}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t+1}}{\bar{\Pi}} \Delta \mathcal{Y}_{t+1} / \Delta \mathcal{N}_{t+1} \right]}{-\nu_2 + (\nu_2 - \nu_1) N_t^{-1}} \\ &= \frac{-(\nu_2 - 1) N_t + (\nu_2 - \nu_1)}{-\nu_2 N_t + (\nu_2 - \nu_1)} \\ &\quad + \Phi_P \frac{- \left(\frac{\Pi_{j,t}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t}}{\bar{\Pi}} + E_t \left[(1 - \delta_n) M_{t,t+1} \left(\frac{\Pi_{j,t+1}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t+1}}{\bar{\Pi}} \Delta \mathcal{Y}_{t+1} / \Delta \mathcal{N}_{t+1} \right]}{-\nu_2 + (\nu_2 - \nu_1) N_t^{-1}}. \end{aligned}$$

Note that markups are now time-varying for two reasons: (i) time-varying industry competition (N_t), and (ii) nominal rigidities. Importantly, the second term highlights how the two components interact with each other.

Appendix B. Aggregate dividend definition

The total ex-dividend market value of equity, \mathcal{Q}_t^m , is defined as the sum of the ex-dividend market value of the intermediate goods sector, and the investment goods sector, that is:

$$\mathcal{V}_t^m = \mathcal{V}_t^{int} + \mathcal{V}_t^k + \mathcal{V}_t^z,$$

where

$$\begin{aligned} \mathcal{V}_t^{int} &= (\mathcal{N}_t + \mathcal{N}_{E,t})(V_t - D_t) \\ &= E_t [M_{t,t+1} \mathcal{N}_{t+1} V_{t+1}] \\ &= E_t [M_{t,t+1} (\mathcal{N}_{t+1} D_{t+1} - \mathcal{N}_{E,t+1} (V_{t+1} - D_{t+1}) + (\mathcal{N}_{t+1} + \mathcal{N}_{E,t+1})(V_{t+1} - D_{t+1}))] \\ &= E_t [M_{t,t+1} (\mathcal{N}_{t+1} D_{t+1} - \mathcal{N}_{E,t+1} (V_{t+1} - D_{t+1}) + \mathcal{V}_{t+1}^{int})], \\ \mathcal{V}_t^k &= E_t [M_{t,t+1} (R_{t+1}^k \mathcal{K}_{t+1} - \mathcal{I}_{t+1} + \mathcal{V}_{t+1}^k)], \text{ and} \\ \mathcal{V}_t^z &= E_t [M_{t,t+1} (R_{t+1}^z \mathcal{Z}_{t+1} - \mathcal{S}_{t+1} + \mathcal{V}_{t+1}^z)]. \end{aligned}$$

Therefore, the total market value of equity can be rewritten recursively as follows:

$$\begin{aligned} \mathcal{V}_t^m &= E [M_{t,t+1} (\mathcal{D}_{t+1}^m + \mathcal{V}_{t+1}^m)], \text{ where} \\ \mathcal{D}_t^m &= \mathcal{N}_t D_t - \mathcal{N}_t^E F_t^E + (R_t^k \mathcal{K}_t - \mathcal{I}_t) + (R_t^z \mathcal{Z}_t - \mathcal{S}_t), \end{aligned}$$

where we used the free-entry condition, which implies that $F_t^E = V_t - D_t$.

Appendix C. Derivation of the NKPC

In this section we derive the New-Keynesian Philips Curve (NKPC). Denoting the real marginal cost by $MC_t = \frac{\mathcal{W}_t}{\frac{(1-\alpha)Y_t}{\varphi_t \mathcal{L}_t}}$ and using the first order condition with respect to labor to replace for $(\varphi_t^*)^{-1}$, the optimal price setting condition of the firm becomes:

$$MC_t = \frac{-(\nu_2 - 1) + (\nu_2 - \nu_1) N_t^{-1}}{-\nu_2 + (\nu_2 - \nu_1) N_t^{-1}} - \left(\frac{\Pi_{j,t}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t}}{\bar{\Pi}} + E_t \left[(1 - \delta_n) M_{t,t+1} \left(\frac{\Pi_{j,t+1}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t+1}}{\bar{\Pi}} \Delta \bar{\mathcal{Y}}_{t+1} \right] + \Phi_P \frac{-\left(\frac{\Pi_{j,t}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t}}{\bar{\Pi}} + E_t \left[(1 - \delta_n) M_{t,t+1} \left(\frac{\Pi_{j,t+1}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t+1}}{\bar{\Pi}} \Delta \bar{\mathcal{Y}}_{t+1} \right]}{-\nu_2 + (\nu_2 - \nu_1) N_t^{-1}}.$$

where $\bar{\mathcal{Y}}_t \equiv \mathcal{Y}_t / \mathcal{N}_t$ is the average output per firm. Re-arranging the terms, we obtain:

$$(\nu_2 - (\nu_2 - \nu_1) N_t^{-1}) MC_t - (\nu_2 - 1) - (\nu_2 - \nu_1) N_t^{-1} = + \Phi_P \left(\frac{\Pi_{j,t}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t}}{\bar{\Pi}} - \Phi_P E_t \left[(1 - \delta_n) M_{t,t+1} \left(\frac{\Pi_{j,t+1}}{\bar{\Pi}} - 1 \right) \frac{\Pi_{j,t+1}}{\bar{\Pi}} \Delta \bar{\mathcal{Y}}_{t+1} \right].$$

We denote the industry concentration index by $H_t = N_t^{-1}$. We also denote log-variables in deviation from the steady state with lower case, hat variables. Taking a first order log-approximation around the deterministic steady state, we get:

$$\hat{\pi}_t = \kappa_{mc} \widehat{mc}_t - \kappa_h \hat{h}_t + M^* E_t [\hat{\pi}_{t+1}].$$

where

$$\begin{aligned} \kappa_{mc} &= \frac{(\nu_2 - 1) + (\nu_2 - \nu_1) H}{\Phi_P} \\ \kappa_h &= \frac{(\nu_2 - \nu_1)(MC + 1)H}{\Phi_P} \\ M^* &= (1 - \delta_n) \beta \Delta Y^{1-1/\psi} \end{aligned}$$

A couple of things are noteworthy. First, in the monopolistic competition case, $H = \kappa_h = 0$ and the traditional NKPC obtains. Second, in the presence of time-varying markups, inflation dynamics are impacted by changes in the competitive environment. In particular, changes in competition dampens the inflation response to marginal costs. To see this, consider an economic recession. Marginal costs are high, which pushes inflation up via the NKPC. Recessions, however

are also times of high concentration. This increase in market power dampens the increase in inflation through the κ_h term, making inflation less responsive to marginal costs. Importantly, the magnitude of κ_h increases with the average level of concentration, H , which makes the dampening effect stronger as competition decreases. This effect explains why both the volatility of inflation and the slope of the NKPC decreases as competition decreases. It also explains why inflation responses are smaller despite real responses (e.g., output) being stronger in the high markup calibration of the model.