Three Essays in Macro Finance

by

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Abstract

The present thesis is a collection of three essays in Macro Finance. The first essay examines the effects of industry competition on the cross-section of credit spreads and levered equity returns. I build a quantitative model where firms make investment, financing, and default decisions subject to aggregate and firm-specific risk. Firms operate in heterogeneous industries that differ by the intensity of product market competition. Higher competition reduces profit margins and increases default risk for debtholders. Equityholders are protected against default risk due to the option value arising from limited liability. In equilibrium, competitive industries are characterized by higher credit spreads, but lower expected equity returns. I find strong empirical support for these predictions across concentration quintiles. Moreover, the calibrated model generates cross-sectional variation in leverage and valuation ratios in line with the data.

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

The final essay explores the interactions between yield curve dynamics and nominal government debt maturity operations in a New Keynesian model with endogenous bond risk premia. Violations of debt maturity neutrality occur when the yield curve slope is nonzero in a fiscally-led policy regime. When the risk profiles of government liabilities differ, rebalancing the maturity structure changes the government cost of capital. In the fiscal theory, changes in discount rates affect inflation through the intertemporal government budget equation. When the yield curve is upward-sloping (downward-sloping), the fiscal discount rate channel implies that shortening the maturity structure has contractionary (expansionary) effects.

Preface

The research project in chapter 2 was identified and performed solely by the author. The essay in chapter 3 is based on unpublished research with Howard Kung (London Business School) and Lukas Schmid (Duke University). The essay in chapter 4 is based on unpublished research with Howard Kung and Gonzalo Morales (University of Alberta). In each of the co-authored projects, all authors worked on all aspects of the paper. This includes the identification of the research question, the theoretical analysis, the numerical implementation, the empirical work, and the writing of the manuscript. While hard to quantify exactly, my personal share of contribution to chapters 3 and 4 amounts to about 1/3.

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To Laetitia and Charles

Chapter 1

Introduction

This thesis is a collection of three essays at the intersection of Finance and Macroeconomics. Although the topics are diverse, they share the common objective of studying the interplay between asset prices and macroeconomic fluctuations through the lens of dynamic stochastic equilibrium models. In the first essay, I examine the effects of industry competition on the cross-section of asset prices. To study this question, I build and estimate a structural model where firms make optimal production and financing decisions under different competitive environments. In the second essay, I investigate the effects of firm entry dynamics on stock return predictability and business cycle fluctuations. I build and calibrate an endogenous growth model where firms' entry and exits generate time-varying competition. The third essay documents a novel transmission channel for open market operations targeting the average maturity of government debt. The quantitative importance of this new mechanism is examined through the lens of a calibrated New Keynesian model.

Because each essay investigates a different topic, chapters were designed to be self-contained. I thus leave a more exhaustive discussion of the research question and contribution to the introduction specific to each chapter.

Chapter 2

Industry Competition, Credit Spreads, and Levered Equity Returns

2.1 Introduction

Companies generate revenues by competing in product markets. While some firms enjoy monopoly power over the sale of their products, others face fierce competition. The intensity of competition, by affecting a firm's profit opportunities, influences both corporate decisions and asset prices. Recently, a growing number of studies have examined the relationship between product market structure and asset prices. Yet, the existing theoretical literature has largely focused on linking competition to the unlevered equity risk. Also in the data, the effect of competition on equity returns is still debated, while its impact on credit spreads is limited.[1] The goal of this essay is to examine how industry competition *jointly* affects credit spreads and levered equity returns, and to assess the importance of these channels using a quantitative model.

To analyze these issues, I develop a production based asset pricing model that captures the rich interaction between a firm's competitive environment, optimal capital structure, default, and asset prices. The economy is populated by a large number of firms that operate in industries that differ in their degree of product market competition. They hire labor, accumulate capital, and compete with industry rivals in a Cournot-Nash framework. Every period, each firm chooses the optimal capital structure mix by weighting the tax benefits of debt against the costs arising from default. Industry and macroeconomic quantities are obtained by aggregating individual firm decisions. Asset prices are determined in equilibrium by a representative household assumed to have recursive preferences.

[1] A rare exception is the recent empirical work of Valta (2012) who finds a positive relationship between competition and interests charged on bank loans.

I find that industry competition increases equilibrium credit spreads and credit risk premia but decreases equity risk. To understand the economic intuition behind this result, note that in the model, industry competition affects asset prices in several ways. First, competition reduces the firm's exposure to aggregate risk. The intuition is as follows. Because competitive firms face a more elastic demand curve, they increase current and future production more when productivity rises. At the industry level, the firm's rivals also increase production, so that total industry output increases. This leads to an increase in competition and puts a downward pressure on the firm revenues. Therefore in competitive industries, rivals' actions create a procyclical negative externality that acts as a hedge against aggregate shocks. This *competitive externality* channel tend to reduce the risk of firms (both levered and unlevered firms alike).

Second, competition decreases the *value* of the firm by reducing the level of operating cash flows.[2] In the model, shareholders declare bankruptcy as soon as equity becomes negative. Since competitive firms are on average less valuable, they are more likely to default. In addition, default is more likely to happen in recessions when firm continuation values are low. Taken together, the increased likelihood of default at times when recovery rates are low and the price of risk is high makes corporate bonds issued by competitive firms less desirable to investors. Competition thus increases equilibrium credit spreads. On the other side, equity holders in competitive industries own a more valuable option to default because the limited liability acts as an insurance against bad states of the world.[3] This reduces the risk of equity. In short, the *default option* channel of competition increases credit spreads, but decreases equity risk.

Third, competition decreases the use of financial leverage. The intuition is readily understood. Debt financing is relatively more expensive in competitive industries, therefore competitive firms use more equity. The lower quantity of debt mitigates the effect of competition on credit spreads. However, I find that the reduction in leverage is not sufficient to make credit spreads lower in competitive industries. This happens because the cost of default, i.e. the value lost in bankruptcy, in endogenously lower for competitive firms (these firms are less valuable). In the end, competitive firms issue less, but more expensive debt. The effect of competition on leverage also affects equity risk. In particular, since less competitive firms use more financial leverage, their equity risk gets higher. Consequently, the *leverage* channel of competition leads to a further increase in equity risk in concentrated industries.

To assess the quantitative importance of these channels, I calibrate the model to match a broad set of aggregate and industry moments. In the model, the only cross-sectional difference across industries is a parameter driving industry concentration. I estimate these to match

[2]This holds for both equity and the unlevered firm value. In addition, although the reduction in risk tends to increase firm valuation through a discount rate channel, I find that the cash-flow channel dominates so that competition decreases the firm value. This result is consistent with empirical evidence.

[3]This result comes from the fact that competitive firms are relatively more exposed to idiosyncratic risk, which makes default *non-risky*. If default was triggered by higher exposure to aggregate risk, a higher likelihood of default risk could potentially increase shareholders' risk.

a measure of market power obtained from industries sorted on concentration. Therefore, all remaining cross-sectional differences entirely stem from differences in industry competition.

I find that competition has significant effects on corporate decisions and asset prices. In the model, the difference in credit spreads between the high- and low-competition quintile is large, around 57bps. I test this prediction in the data using a panel of publicly traded corporate bond transactions and find strong empirical evidence. Firms in competitive industries pay 25bps more on their debt.[4] These results are statistically significant and are robust to various measures of competition and controls. In economic terms, this represents $1.4M of additional annual interest payments for firms in more competitive environment.[5] These estimates are consistent with Valta (2012) who finds that competitive firms pay higher interests on bank loans. The higher cost of debt leads competitive industries to use less financial leverage. In the model the difference in market leverage between the high- and low-competition quintile is -2.3%. These results accord with MacKay and Phillips (2005) who find that the average book leverage in more competitive industries is *lower* than in concentrated industries. More recently, Xu (2012) reaches similar conclusions using import penetration as an instrumental variables for competition. I further confirm these findings using summary statistics from my data sample. In short, the model prediction that competition leads firms to use less, but more expensive debt is strongly supported in the data, both qualitatively and quantitatively.

The model also provides quantitative predictions for the effects of competition on the cross-section of stock returns. I find that firms in the lowest competition quintile have a lower equity premium (-0.76%). Also, firms in more competitive industries have lower CAPM beta (-0.14). These predictions are consistent with recent empirical evidence by Bustamante and Donangelo (2015) who find a positive relationship between excess stock returns, CAPM betas and industry concentration.[6] The concentration premium arises because competition affects the firm's exposure to industry rivals, the value of the option to default and the incentive to use leverage. Decomposing the concentration premium, I find that about 20% comes from the competitive externality effect, and 80% from the default and leverage channels. This highlights the importance of accounting for leverage and default in explaining the interaction between equity returns and industry competition. In contrast to equity risk, the model predicts that debt is *riskier* in competitive industries.[7] The reason for this result is that although competitive firms have lower cash-flow risk, they default more. Since default occurs at times when the price of risk is high, this effect ultimately dominates and debt in competitive

[4]This estimate might seem low compared to the model predictions. However, as discussed later, data estimates are likely to be a lower bound measure of the effect of competition on credit spreads because my sample is biased towards the largest firms in the population.

[5]These values are obtained assuming a debt face value of $541M (the average face value in the sample).

[6]In contrast, Hou and Robinson (2006) find that competition *increases* expected returns using the population of firms in Compustat. A likely reason for this difference is that concentration measures based on public firms are biased because the decision of firms to be publicly listed is affected by the structure of the industry (e.g. Bustamante and Donangelo (2015)).

[7]The credit spread premium for competitive firms is higher by a factor of 1.2. Formally, the credit spreads premium is defined as the difference between the yield on a risky bond minus the yield of riskless security that pays the expected bond payoff.

industries is riskier.

The previous results have highlighted the importance of idiosyncratic cash-flow shocks in driving cross-sectional differences in credit spreads across competition quintiles. I extend the benchmark model with time-varying volatility for idiosyncratic shocks and find that credit spreads in competitive industries are more sensitive to change in idiosyncratic volatility. To understand the intuition, it is useful to remember that corporate debt can be modeled as a default-free bond minus a put option on the firm assets (e.g. Merton (1974)). Tougher competition, by reducing the firm value, brings the firm closer to default, i.e. the strike price. The sensitivity of the put option to change in volatility is thus amplified for more competitive firms. I confirm this prediction in the data. Using a moving standard deviation of abnormal returns as proxy for idiosyncratic volatility, I find that a 1% increase in idiosyncratic volatility is associated to an additional 21bps increase in credit spreads in competitive industries. In terms of portfolio performance, a corporate bond portfolio of debt issued by competitive firms loose an additional 1.49% return for each 1% increase in idiosyncratic volatility. These results are robust to different measures of competition and various controls, including firm fixed effects.[8]

2.1.1 Literature review

The present essay contributes to the literature that links product market competition to firm risk and stock returns. Early empirical work by Hou and Robinson (2006) finds that competition increases expected stock returns using Compustat-based measures. Bustamante and Donangelo (2015) reach opposite conclusions, using broader measures of concentration that include private firms. The later explain this discrepancy by noting that the decision to be publicly listed depends on industry characteristics, which can bias concentration measures. Aguerrevere (2009) examines how competition affects equity risk in a simultaneous-move oligopoly. Bena and Garlappi (2011), and Carlson, Dockner, Fisher, and Giammarino (2014) considers risk dynamics in a leader-follower equilibrium. Bustamante and Donangelo (2015), and Loualiche (2014) studies the effects of entry on the cross-section of stock returns. Corhay, Kung, and Schmid (2015) links competition to time-varying risk premia and return predictability. My work fills an important gap in this literature by analyzing how product market structure jointly affects the pricing and risk of corporate debt and levered equity.[9]

The literature in corporate finance and IO examining the interactions between capital structure and product markets is vast. While most prior studies have focused on the impact of capital structure on firm strategies in product markets,[10] a growing research (e.g. MacKay and Phillips (2005)) has highlighted the importance of industry competition on capital structure.

[8] These calculations are obtained by computing the realized return on a bond whose characteristics are set to the sample average and assuming a 1% increase in idiosyncratic volatility.

[9] Other related papers include Garlappi (2004), Hackbarth and Morellec (2008), Hoberg and Phillips (2010), Ortiz-Molina and Phillips (2014), Bustamante (2015).

[10] Some examples are Brander and Lewis (1986), Bolton and Scharfstein (1990), Chevalier (1995), Phillips (1995), Lambrecht (2001), and Campello (2003).

Xu (2012) shows empirically that higher industry competition decreases the use of leverage. Valta (2012) shows that more competitive firm face a higher cost of bank loans. This essay contributes by investigating the effects of industry competition on the quantity and pricing of debt in a joint framework. In addition, the quantitative model provides structural evidence that differences in industry concentration have first order effects on corporate policies and asset prices.[11]

My work also builds on the literature in economics and finance embedding dynamic capital structure decision[12] into equilibrium asset pricing models. Hackbarth, Miao, and Morellec (2006) highlights the importance of macroeconomic conditions for firm financing conditions and credit spreads in a risk-neutral framework. Building on their work, several papers have tried to rationalize the credit spread puzzle by generating variation in the market price of risk over the business cycle. Chen, Collin-Dufresne, and Goldstein (2009) accomplishes this using the habits formation model of Campbell and Cochrane (1999), while Bhamra, Kuehn, and Strebulaev (2009) adopts the long-run risks framework of Bansal and Yaron (2004). Chen (2010) shows how countercyclical variations in default losses helps generating a significant bond risk premia.[13] In these papers, the state-price density or endowment process is assumed to be exogenous.

In a recent paper, Gilchrist and Zakrajšek (2011) show that corporate bond risk premia contains important information about the business cycles. Motivated by these findings, a growing body of literature now attempts to connect corporate bond risk premium to the economy. This is especially important as most of the production-based asset pricing literature has focused on linking the macroeconomy to equity risk premia.[14] Recent contributions include Gomes, Jermann, and Schmid (2013) who incorporate long-term nominal debt into a standard DSGE model to quantify the importance of nominal rigidity through a debt deflation channel. Miao and Wang (2010) adopts a similar setup and shows how long-term debt amplifies business cycle fluctuations. Several other papers have proved successful at generating significant credit risk premium in production models: Gourio (2013) uses disaster risk, Gomes and Schmid (2010) model heterogeneous firms, and Favilukis, Lin, and Zhao (2013) highlights the importance of labor frictions. My work contributes to this literature by departing from the assumption of perfect competition and by examining how the product market structure affects credit spreads in the cross-section.[15]

[11] Also related is Miao (2005) that investigates the interaction between industry dynamics and capital structure in a model with entry and exits. Other papers examine the effect of competition on other corporate decision such as investment (e.g. Simintzi (2013), and Frésard and Valta (2014)).

[12] See Strebulaev and Whited (2011) for a recent literature review.

[13] Other related studies include Almeida and Philippon (2007), Davydenko and Strebulaev (2007), Elkamhi, Ericsson, and Jiang (2011).

[14] Some examples are Jermann (1998), Boldrin, Christiano, and Fisher (2001), Kaltenbrunner and Lochstoer (2010), Kung and Schmid (2015)

[15] More broadly, the essay also relates to the macroeconomic literature studying the effects of financial constraints in quantitative general equilibrium business cycle models. Early examples in the literature are Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999). More recent work includes Christiano, Motto, and Rostagno (2010) and Jermann and Quadrini (2012).

Finally, this essay relates to studies linking equity volatility to corporate credit spreads, e.g. Campbell and Taksler (2003). A series of recent paper documents the tight connection between competition and idiosyncratic volatility (e.g. Gaspar and Massa (2006) and Irvine and Pontiff (2009)). In this essay, I contribute to the literature by showing, both theoretically and empirically, how competition can amplify credit spread's exposure to idiosyncratic risk. Importantly, I also document that the increased exposure to idiosyncratic volatility translates into lower equity risk premium for competitive industries.

The chapter is organized as follows. Section 2 develops a simple two-period model where I derive closed form solution on the effects of competition on asset prices. Section 3 extends the simple model into a quantitative model. In section 4, I discuss the baseline calibration. Section 5 investigates some of the model's quantitative implications for the cross-section of asset prices. Section 6 presents several empirical tests and is followed by a few concluding remarks in section 7.

2.2 A simple model

This section develops a simple, two-period model to highlight some of the key economic channels through which competition affects the pricing of equity and debt. These ingredients are then incorporated in a more quantitative setting in the next section.

2.2.1 Economic environment

Consider an oligopolistic industry that is populated by n value-maximizing firms. These firms strategically compete in the product markets in a Cournot-Nash setup as in Aguerrevere (2009). In particular, it is assumed that firms play a static Cournot game in each period. They choose the quantity of output to maximize the value of the firm, taking production decisions of other firms as given. For simplicity, I assume the existence of a risk-neutral representative investor whose time discount factor β is used to price all securities. The timeline of events is as follows. In period 0, the firm hires labor after observing the realization of an aggregate technology shock. The firm finances itself by issuing one-period debt and equity. In period 1, the firm makes optimal production decisions after which it is hit by an idiosyncratic shock. Shareholders then have the option to declare bankruptcy. If no default occurs, the firm pays its debt obligations, and distribute all residual claim as dividend. The firm then disappears from the economy.

To be more specific, each firm in the industry produces an identical good $y_{i,t}$. The total demand for the industry is given by the following downward-sloping demand curve,

$$Y_t = P_t^{-\nu}\, \mathcal{Y}_t \tag{2.1}$$

where ν is the elasticity of demand for the industry good, P_t is the equilibrium industry good price, $Y_t = \sum_{i=1}^{n} y_i$ is the total industry output, and $\mathcal{Y}_t$ is an aggregate demand term, taken

as given by the firm.[16]

The firm produces output using labor l_t that is rented in competitive markets at a wage rate of W_t. The production technology is assumed to be linear in labor,

$$y_t = A\, l_t \tag{2.2}$$

where A is a persistent (i.e. lasts two periods) technology shock capturing all systematic risk in the economy.

In period 0, the firm decides on its optimal capital structure by issuing one-period defaultable debt b and equity (negative dividends). Debt is attractive because of the tax deductibility of interest rates but is costly because default entails dead-weight costs. In particular, when the value of the firm becomes negative, shareholders walks away with a payoff of zero, and debtholders get nothing. Denoting the unit price of debt by q, the value of corporate debt to investors is,

$$q = \beta\Phi(z^\star)(1 + C) \tag{2.3}$$

where $\Phi(z^\star)$ is the probability of survival of the firm (to be determined later), and C is the coupon payment. Essentially, Eq. 2.3 says that the value of debt today is the expected payoff, discounted by the state-price density, β.

2.2.2 Individual firm's problem

The objective of the firm is to maximize the market value to shareholders V_j, by choosing labor, and the optimal capital structure:

$$V_j = \max_{l_0, l_1, i, b} \; d_0 + \beta E_0[\max\{d_1, 0\}] \tag{2.4}$$

subject to the total demand for the industry good (Eq. 2.1), the market value of corporate debt (Eq. 2.3), and production decisions of other firms. Note that the second max operator captures the limited liability option of shareholders. The firm dividends are defined as the free cash-flows generated by the firm. Because of the finite nature of the firm, there will be no debt issuance in period 1. The real dividend in each period is given by,[17]

$$d_0 = P_0 y_0 - W_0 l_0 + qb \tag{2.5}$$

$$d_1 = P_1 y_1 - W_1 l_1 - z\,\bar{l} - (1 + C(1-\tau))b_1 \tag{2.6}$$

where $(1-\tau)$ captures the tax advantage of interest payments, and z is a mean-zero, idiosyncratic shock assumed to be uniformly distributed on $[-a/2, a/2]$. The idiosyncratic shock z

[16] To facilitate the exposition, the i-subscript is dropped, unless it is necessary to avoid confusion.

[17] All nominal variables, except for the output price, are normalized by the equilibrium industry price. It is assumed to be taken as given by the individual firm.

is multiplied by the average size of a firm in the industry, $\bar{l} = \frac{1}{n}\sum_{i=1}^{n} l_{i,t}$ to avoid that competitive industries be mechanically more exposed to z shocks. In the following, I denote the cumulative distribution of z by $\Phi(.)$, and the associated probability distribution function by $\phi(.)$. The idiosyncratic cash-flow shock z captures, in a reduced form, all heterogeneity across firms and is the key ingredient that drives firms to default. In particular, the bankruptcy decision consists of a threshold rule where shareholders declare bankruptcy as soon as z is larger than a default threshold $z^\star$, where $z^\star$ is such that $d_1(z^\star) = 0$.

2.2.3 Equilibrium

In the model, all firms are the same except for their idiosyncratic shock realization. Because this cost enters as a fixed cost, all firms make identical decisions. Therefore the model admits a unique symmetric Nash equilibrium, where all firms maximize their firm value, taking rivals' actions as given. To close the labor market, I assume that the total labor supply in the industry is equal to 1. I leave the derivation of the solution to the appendix.

The equilibrium is described by a set of three equations, one optimality condition for labor, one for debt, and an optimal default threshold. This implies the following equilibrium profit margin:

$$PM = \frac{h}{\nu} \tag{2.7}$$

where $h = \sum_{i=1}^{n}(y_{i,t}/Y_t)^2$ is the industry Herfindahl-Hirschman concentration index. h^{-1} is a measure of industry competition. Note that the firm profit margin is increasing in industry concentration. Intuitively, when competition is tougher, a single firm has less control on the industry price P_t, and faces a more elastic demand curve.[18] Therefore higher competition drives each individual firm to produce more. At the industry level, all firms produce more so that the increased industry production puts a downward pressure on revenues and reduces the firm profits.

2.2.4 Competition, corporate policies and asset prices

This section examines the effect of industry competition on equilibrium corporate policies, credit spreads and equity. Proposition 1 summarizes several key results.

Proposition 1. *An increase in industry competition: (i) increases the expected default probability, (ii) decreases financial leverage, (iii) decreases equity value, and (iv) increases credit spreads.*[19]

Proof. See appendix □

[18] To be more specific, the elasticity of demand for an individual firm is $\eta_{y_j,P} = \frac{\nu}{h}$.

[19] Note that I'm working under the assumption that $\beta > 0$, $C > 0$, $\tau > 0$, $\nu > 1$. Also, note that these results hold quite generally for all distribution functions $\Phi(.)$ such that $\frac{\Phi(z)}{\phi(z)}$ is increasing in z. This is the case for most standard distribution function such as normal, uniform, etc.

To understand the intuition behind these results note that, as shown in Eq. 2.7, competition erodes firms' profit margins. This makes competitive firms more exposed to idiosyncratic cash-flows shocks and increases the expected probability of default. Creditors are rational and discount the value of corporate bonds issued by competitive firms. Consequently, equilibrium credit spreads rise. In response to the more expensive cost of debt, shareholders cut on leverage. However, the reduction in leverage is not sufficient to decrease credit spreads because equity holders in competitive industries endogenously face a lower cost of default. This happens because the cost of default is determined by the value of the firm lost in bankruptcy and competitive firms are, on average, less valuable. In the end, competitive firms earn lower profits, default more, and generate less tax shield from leverage, making their equity value lower.

Another measure of interest is equity risk. More formally, equity risk can be measured by the firm conditional beta β_i, calculated as the elasticity of equity with respect to the systematic shock A.[20] It can be shown that the conditional beta is composed of three components (see appendix for details),

$$\beta_i = 1 - \underbrace{\frac{\beta \int_{z^\star}^{\overline{z}} z \, d\Phi(z)}{V_j}}_{\text{Default option}} + \underbrace{\frac{\beta \tau C}{1+(1-\tau)C} \frac{\Phi(z^\star) z^\star}{V_j}}_{\text{Tax shield}} \tag{2.8}$$

The first term is the equity beta of an unlevered firm without idiosyncratic shocks. It is equal to one because in this case, the firm value is linear in A. The second term captures the effect of default on equity risk. This term is negative, that is, the option to default decreases equity beta. The intuition is that the limited liability of shareholders acts as an insurance against bad states of the world, making equity safer. Finally, the third term captures the risk coming from the expected tax-shield. This term contributes positively to β_i because the net benefit of debt is procyclical.

In contrast to credit spreads, industry competition *decreases* equity risk. The reason for this result is two-fold. First, because competitive firms face a higher likelihood of default, their limited liability option is more valuable. This decreases equity risk through a *default option* channel. Second, because competition reduces the use of debt, they are less exposed to the risk stemming from the expected tax-shield. This further decreases equity risk through a *leverage* channel. So far, we have abstracted from investment, a key ingredient in the benchmark model. Allowing firms to invest in extra capacity leads to an additional effect of competition which I refer to as the *competitive externality* channel. I discuss this third channel in the next section.

[20] To be more precise, the risk premium on the asset is $\beta_i \times \lambda$, where λ is the market price of the systematic risk. In this simple model, the price of risk is null because of the risk-neutrality assumption. Therefore exposure to the A shock is not risky per se. The model could easily be augmented to have a positive price of risk without changing the qualitative results. To keep exposition as simple as possible I abstract from this and keep referring to β_i as capturing equity risk.

2.2.5 Investment

The previous section illustrates how competition, by reducing the *level* of profits, makes firm more exposed to idiosyncratic cash-flow shocks. Competition increases credit spreads because the likelihood of default is higher. Yet, it reduces equity risk because the default option becomes more valuable and competitive firms use less financial leverage. In this section, I discuss how allowing for investment gives rise to another effect of competition on asset prices; namely, competition decreases the *riskiness* of the firm cash flows.

The intuition is as follows. Firms in competitive industries face a more elastic demand curve. Consequently, they increase investment relatively more in response to positive news about productivity. At the industry level, all firms adopt a similar strategy such that total industry output increases. This puts a downward pressure on the output price (see Eq. 2.1). In the end, competitive firms produce more and sell at a cheaper price. Because the marginal product of capital is decreasing, competitive industries are characterized by less procyclical profits. Therefore when investment is allowed, feedback effects from industry rivals curtail potential profit opportunities from investment, and decreases the firm exposure to aggregate risk. I refer to this effect as the *competitive externality* channel.[21]

The simple model has highlighted several channels through which competition affects levered equity returns and credit spreads. In the next section, I build a production-based asset pricing model to quantitatively assess the strengths of each these channels.

2.3 Benchmark model

I now extend the simple two-period model into a quantitative dynamic stochastic general equilibrium model. The economy is composed various industries in which firms compete in product markets. These firms issue debt and equity and are owned by risk-averse investors. Figure 2.1 gives an overview of the economic environment. The goal here is to test whether the channels highlighted previously are quantitatively sufficient to explain the cross-sectional differences in industries sorted on industry concentration.

2.3.1 Firms

This section describes the economic environment faced by an individual firm i operating in an industry j. The industry is composed of n_j firms which compete for the sale of an identical industry good. As before, competition in product markets is captured by assuming that firms play a Cournot game in each period. The number of firms n_j is the only difference across industries and captures differences in industry competition. In particular, higher n_j industries are characterized by tougher competition. For simplicity, I assume that n_j is fixed. The total

[21] The idea that rivals' actions can reduce own-firm risk arises in other setups. For instance, Carlson, Dockner, Fisher, and Giammarino (2014) obtain similar results in dynamic duopoly model where firms have the option to invest in additional capacity (intensive margin). More recently, Bustamante and Donangelo (2015) uses procyclical entry threat (extensive margin).

demand for industry goods, $Y_{j,t}$, obeys the following inverse demand curve,

$$Y_{j,t} = \tilde{P}_{j,t}^{-\nu} \, \mathcal{Y}_t \tag{2.9}$$

where $\mathcal{Y}_t$ is an aggregate demand term, $Y_{j,t} = \sum_{i=1}^{n_j} y_{i,j,t}$ is the total industry output, $\tilde{P}_{j,t} = P_{j,t}/\mathcal{P}_t$ is the price of the industry good, relative to the economy price index $\mathcal{P}_t$, and ν is the elasticity of demand for industry goods. For now, I take this demand function as given. At the end of the section, I provide an industry structure to rationalize this specification.

Technology Intermediate firm i in industry j uses capital $k_{i,j,t}$ and labor $l_{i,j,t}$ as input in a Cobb-Douglas production technology:

$$y_{i,j,t} = k_{i,j,t}^{\alpha} \left(A_t l_{i,j,t}\right)^{1-\alpha} \tag{2.10}$$

where A_t represents an aggregate productivity shock common across firms, and is composed of a short- and long-run risk components:[22]

$$\Delta a_{t+1} = \mu + g_t + \sigma_a \epsilon_{a,t+1} \tag{2.11}$$

$$g_t = \rho_g g_{t-1} + \sigma_g \epsilon_{gt} \tag{2.12}$$

where $\Delta a_t = \ln(A_t) - \ln(A_{t-1})$, and ϵ_{at} and ϵ_{gt} are uncorrelated standard normal shocks i.i.d. shocks. The low-frequency component in productivity, g_t, is used to generate sizeable risk premia as in Bansal and Yaron (2004).

Firm's operating profit The firm hires $l_{i,j,t}$ units of labor from households at a competitive wage of $W_t \mathcal{P}_t$. Each unit of goods is sold to customers at a unit price of $P_{j,t}$. Following Gomes, Jermann, and Schmid (2013), heterogeneity accross firms is captured by assuming that operating profits are hit by an idiosyncratic, mean zero, i.i.d. shock $z_{i,j,t}$. These shocks summarize, in a reduced form, all idiosyncratic risk affecting a firm's cash flows. The real operating profit before tax is

$$\Pi_{i,j,t} = \tilde{P}_{j,t} \, y_{i,j,t} - W_t \, l_{i,j,t} - z_{i,j,t} \, \bar{k}_{j,t} \tag{2.13}$$

where $\bar{k}_{j,t}$ is the average capital stock in the industry.[23] In the following, I denote by $\Phi(.)$ and $\phi(.)$ the cumulative and density distribution function of the idiosyncratic shock z which is defined over the support $[\underline{z}, \bar{z}]$. Eq. 2.13 means that operating profits are equal to total sales, minus the total cost of labor, minus a firm-specific shock, assumed to be uncorrelated

[22] Other studies using this type of productivity process include Croce (2014), Kung (2015), and Kung and Schmid (2015).

[23] One needs to multiply $z_{i,j,t}$ by some non-stationary variables to avoid that idiosyncratic risk becomes trivially small along the balanced growth path. Furthermore, multiplying by the average size of a firm avoids that competitive industries be mechanically more exposed to idiosyncratic shocks.

both serially and cross-sectionally.

Financing Each period, after observing realizations of all shocks, the owner of the intermediate firm decides on whether to default or not. If no default occurs, the firm chooses its optimal capital structure by issuing new debt, $b_{i,j,t+1}$, and equity to finance its operations. In case of default, the owner walks away with a payoff of zero[24] and creditors take over the firm after paying some bankruptcy cost.

Before issuing new debt, the firm is required to pay the interest and the principal due on its outstanding one-period debt,

$$((1-\tau)C+1)\, b_{i,j,t} \tag{2.14}$$

where $b_{i,j,t}$ is the total amount of real corporate debt issued at $t-1$, C is the coupon payment on existing debt, and τ is the corporate tax rate. When no default occurs, the firm issues new debt $b_{i,j,t+1}$ at a market price of $q_{i,j,t}$ per unit of debt. Finally, all costs associated with adjustments to leverage are captured by a cost function $\psi_b(b_{i,j,t}, b_{i,j,t+1})$.[25] Therefore the net cash flow from debt financing activities is

$$b_{i,j,t+1}q_{i,j,t} - ((1-\tau)C+1)\, b_{i,j,t} - \psi_b(b_{i,j,t}, b_{i,j,t+1}) \tag{2.15}$$

Investment The firm accumulates capital for production in the next period through capital investment, $I_{i,j,t}$. The stock of productive capital accumulates as follow,

$$k_{i,j,t+1} = (1-\delta_k)k_{i,j,t} + \Gamma\left(\frac{I_{i,j,t}}{k_{i,j,t}}\right) k_{i,j,t} \tag{2.16}$$

where δ_k is the depreciation rate of capital, and $\Gamma\,(.)$ captures the idea that capital accumulation is subject to adjustment costs. As in reality, it is assumed that the firm can deduct depreciated capital from taxable income. The net cash flows from investment activities is

$$-I_{i,j,t} + \tau\delta_k k_{i,j,t} \tag{2.17}$$

Equity value Equity holders have the right to the firm dividends so long as the firm is in operation. The dividend is equal to firm free cash-flows that is, the operating profit, net of

[24] In practice, shareholders can receive a positive amount in case of default (e.g. Garlappi and Yan (2011)). Accounting for this has no bearing on the main results.

[25] One could obtain financing frictions in other ways. For instance Jermann and Quadrini (2012) assume quadratic adjustment costs for dividends, and Gomes, Jermann, and Schmid (2013) use long-term nominal debt.

cash flows from financing and investment activities,

$$D_{i,j,t} = (1-\tau)\Pi_{i,j,t} - I_{i,j,t} + \tau\delta_k k_{i,j,t} - ((1-\tau)C+1)\, b_{i,j,t} + q_{i,j,t} b_{i,j,t+1} - \psi_{b,i,j,t} \tag{2.18}$$

The objective of the firm manager is to maximize the equity value defined as the present value of dividends, subject to the capital accumulation equation and the inverse demand for the firm goods. Denoting the vector of aggregate state variables and production decisions of rivals by $\Upsilon_{j,t} \equiv \left\{\bar{k}_{j,t}, \mathcal{Y}_t, g_t, \Delta a_t, \{y_{k,j,t}\}_{k=1,k\neq j}^{n_j}\right\}$, the firm problem is

$$\begin{aligned} E\left(b_{i,j,t}, k_{i,j,t}, z_{i,j,t}, \Upsilon_{j,t}\right) = \max\left\{\max_{\digamma_{i,j,t}} D_{i,j,t} + E_t\left[M_{t,t+1} E\left(b_{i,j,t+1}, k_{i,j,t+1}, z_{i,j,t+1}, \Upsilon_{j,t+1}\right)\right], 0\right\} \\ \text{s.t.} \quad k_{i,j,t+1} = (1-\delta_k)k_{i,j,t} + \Gamma\left(\frac{I_{i,j,t}}{k_{i,j,t}}\right) k_{i,j,t} \\ Y_{j,t} = \tilde{P}_{j,t}^{-\nu}\, \mathcal{Y}_t \end{aligned} \tag{2.19}$$

where $\digamma_{i,j,s} \equiv \{b_{i,j,s+1}, I_{i,j,s}, k_{i,j,s+1}, l_{i,j,s}\}$ is a vector containing all the firm controls, and $M_{t,t+s}$ is the equilibrium stochastic discount factor. Note that the first max operator captures the limited liability of shareholders, and the second max operator relates to the optimal decision of the manager.

Default decision When the value of the firm becomes negative, shareholders declare bankruptcy and leave with a payoff of zero. Let's define $V\left(b_{i,j,t}, k_{i,j,t}, z_{i,j,t}, \Upsilon_{j,t}\right)$ to be the present discounted value of dividends (the term inside the first max in Eq. 2.19). The default decision consists in finding the threshold value $z^\star_{i,j,t}$ such that $V\left(b_{i,j,t}, k_{i,j,t}, z^\star_{i,j,t}, \Upsilon_{j,t}\right) = 0$ and declaring bankruptcy when $z_{i,j,t} > z^\star_{i,j,t}$. The assumption that $z_{i,j,t}$ enters as an i.i.d. fixed cost makes the value of the firm additive in $z_{i,j,t}$[26] and we can solve easily for $z^\star_{i,j,t}$,

$$z^\star_{i,j,t} = \frac{V\left(b_{i,j,t}, k_{i,j,t}, 0, \Upsilon_{j,t}\right)}{(1-\tau)\bar{k}_{j,t}} \tag{2.20}$$

Eq. 2.20 highlights the fact that the optimal default threshold depends on the firm valuation. This will be important to generate countercyclical default rates as in the data.

Debt value When the firm defaults, creditors gain control over the firm assets after paying a one time cost of $\xi_t\%$ of the firm value. They become owner of an unlevered firm and collect the firm's profit in the current period. Corporate bonds are held by the representative household and are thus valued using the household equilibrium pricing kernel $M_{t,t+1}$. The value of newly issued debt to creditors is

[26] In particular, $V\left(b_{i,j,t}, z_{i,j,t}, \Upsilon_{j,t}\right) = V\left(b_{i,j,t}0, \Upsilon_{j,t}\right) - (1-\tau) z_{i,j,t}\bar{k}_{j,t}$.

$$q_{i,j,t}b_{i,j,t+1} = E_t M_{t,t+1} \left\{ \begin{array}{c} \Phi(z^{\star}_{j,t+1})(C+1)b_{i,j,t+1} \\ +(1-\xi_t)\int_{z^{\star}_{j,t+1}}^{\overline{z}} V\left(0, z_{j,t+1}, \Upsilon_{t+1}\right) d\Phi(z_{j,t+1}) \end{array} \right\} \tag{2.21}$$

The first term inside the brackets is the payment when the firm survives multiplied by the probability of survival. It is equal to the coupon payment plus the principal. The second term is the bondholders payoff when the firm defaults, multiplied by the probability of default.

Optimal firm decisions The objective of the manager is to make a series of operating, financing and investment decisions to maximize the value of the firm. The Lagrangian and derivations of the first order necessary conditions are detailed in the appendix.

Let's first examine the optimal capital structure decision. The leverage decision is given by the first order condition with respect to $b_{i,j,t+1}$,

$$q_{i,j,t} + \frac{\partial q_{i,j,t}}{\partial b_{i,j,t+1}} b_{i,j,t+1} = E_t M_{t,t+1} \Phi(z^{\star}_{j,t+1}) \left[(1-\tau)C + 1\right] + \Delta\psi_{b,t} \tag{2.22}$$

where $\Delta\psi_{b,t}$[27] is the net cost associated with issuing an amount $b_{i,j,t+1}$ of debt. This condition means that in equilibrium, the firm equates the marginal benefits (left-hand side) to the marginal costs (right-hand side) of debt. More specifically, issuing an additional unit of debt provides shareholders with an additional payoff equal to $q_{i,j,t}$, adjusted to take account of the decrease in debt value due to the increased probability of default. The cost of issuing an additional unit of debt is the after-tax interest rate, plus the principal due in the next period, plus the change in issuance cost. These costs are multiplied by the probability of survival as shareholders have the option to walk away in the next period. Worth noticing is that equity holders rationally take account of the impact of their choices on the cost of debt, i.e. $\partial q_{i,j,t}/\partial b_{i,j,t+1}$.

The optimal investment decision is obtained by equating the marginal benefits to the marginal costs of an additional unit of capital,

$$\Lambda^K_t = E_t M_{t,t+1} \left(1 + \vartheta_{i,j,t+1}\right) \left\{ D'_{k,i,j,t+1} + \Lambda^K_{t+1} \left[1 - \delta_k + \Gamma_{i,j,t+1} - \Gamma'_{i,j,t+1} \left(\frac{i_{t+1}}{k_{t+1}} \right) \right] \right\} \tag{2.23}$$

where $\vartheta_{i,j,t+1} = \phi(z^{\star}_{i,j,t+1}) \frac{b_{i,j,t+1}}{(1-\tau)k_{j,t}} (\tau C + \xi_{t+1}[(1-\tau)C+1]) - \xi_{t+1}(1 - \Phi(z^{\star}_{i,j,t+1}))$ and Λ^K_t is the Lagrange multiplier on the capital accumulation equation and represents the shadow value of an additional marginal unit of capital (Tobin's Q). The two terms inside the brackets in Eq. 2.23 represents the expected increase in dividend and capital gains from investing a marginal unit of capital today.[28] The multiplicative term $(1 + \vartheta_{i,j,t+1})$ captures the distortion arising from the leverage decision. More specifically, investing today increases future dividends and thereby decreases the probability of default (first term in $\vartheta_{i,j,t+1}$). Besides, because

[27] In particular, $\Delta\psi_{b,t} = \frac{\partial \psi_{b,t}}{\partial b_{i,jt+1}} + E_t M_{t,t+1} \Phi(z^{\star}_{j,t+1}) \frac{\partial \psi_{b,t+1}}{\partial b_{i,jt+1}}$.

[28] Specifically, $D'_{k,i,j,t} = (1-\tau)\tilde{P}_{j,t} \left[1 - \frac{1}{\nu} \frac{y_t}{Y_{j,t}} \right] \alpha \frac{y_t}{k_t} + \tau\delta_k$

bankruptcy is costly, there is a chance that the invested unit is going to be lost partially in the next period (second term). Note that the standard investment Euler equation is a particular case where $\vartheta_{i,j,t+1} = 0$.

2.3.2 Industries dynamics and competition

The final consumption good is produced by a representative firm operating in a perfectly competitive market. The firm uses a continuum of industry goods $Y_{j,t}$ as input in a CES production technology. To keep the number of industries finite, it is assumed that the economy is composed on N different industries equally distributed on the $[0, 1]$ interval,

$$\mathcal{Y}_t = \left(\int_0^1 Y_{j,t}^{\frac{\nu-1}{\nu}} \, dj \right)^{\frac{\nu}{\nu-1}} = \left(\frac{1}{N} \sum_{i=1}^{N} Y_{j,t}^{\frac{\nu-1}{\nu}} \right)^{\frac{\nu}{\nu-1}} \tag{2.24}$$

where ν is the elasticity of substitution between goods of different industries.

Solving the profit maximization problem for the final good firm (see the appendix) yields the following inverse demand function for goods in industry j,

$$Y_{j,t} = \tilde{P}_{j,t}^{-\nu} \, \mathcal{Y}_t \tag{2.25}$$

where $\tilde{P}_{j,t} = P_{j,t}/\mathcal{P}_t$, and $\mathcal{P}_t = \left(\int_0^1 P_{j,t}^{1-\nu} \right)^{\frac{1}{1-\nu}}$ is the aggregate price index. Note that this is the same inverse demand function as the one specified in Eq. 2.9.

2.3.3 Households

The model is closed by specifying the household industry. I assume the existence of a representative household with recursive utility over a bundle of consumption $\mathcal{C}_t$ and leisure $(1 - \mathcal{L}_t)$ as in Croce (2014),

$$U_t = \left\{ \tilde{C}_t^{1-\frac{1}{\psi}} + \beta E_t \left[U_{t+1}^{1-\gamma} \right]^{\frac{1-\frac{1}{\psi}}{1-\gamma}} \right\}^{\frac{1}{1-\frac{1}{\psi}}} \tag{2.26}$$

$$\tilde{C}_t = \mathcal{C}_t{}^{\varphi} (A_{t-1}(1 - \mathcal{L}_t))^{1-\varphi} \tag{2.27}$$

where γ is the coefficient of relative risk aversion, ψ is the elasticity of intertemporal substitution, β is the subjective discount factor, and φ drives the total amount of hours worked. Note that leisure is multiplied by productivity A_{t-1} to ensure balanced growth.

To finance her consumption stream, the representative household collects wages by supplying specialized labor $L_{j,t}$ to industry j. In addition, the household has access to financial markets where she can invest in stocks, and corporate bonds in all industries as well as government bonds. The total position held in equities is denoted by $\mathcal{Q}_t$, while the total amount invested in corporate and government bonds is denoted by $\mathcal{B}_{t+1}^c$ and $\mathcal{B}_{t+1}^g$, respectively. The

real (normalized by $\mathcal{P}_t$) budget constraint of the household is

$$\mathcal{C}_t + \underbrace{\left[\mathcal{B}^c_{t+1} + \mathcal{B}^g_{t+1} + \mathcal{Q}_t\right]}_{\text{Position in securities}} = \mathcal{W}_t\mathcal{L}_t + \underbrace{\left[\mathcal{R}^c_t\mathcal{B}^c_t + \mathcal{R}^f_t B^g_t + \mathcal{R}^d_t\mathcal{Q}_{t-1}\right]}_{\text{Proceeds from securities}} - \mathcal{T}_t \tag{2.28}$$

where $\mathcal{W}_t\mathcal{L}_t = \frac{1}{N}\sum_{j=1}^{N} W_{j,t}L_{j,t}$ is the total labor income, $\mathcal{R}^f_t$ is the risk-free return on government bonds bought in the previous period, and $\mathcal{R}^d_t$ and $\mathcal{R}^c_t$ are the total returns on the equity and corporate debt portfolio. These returns are defined in the next section. $\mathcal{T}_t$ are lump-sum government taxes.[29]

Solving the household problem yields a set of Euler equation to price all the securities in the economy. The equilibrium one-period pricing kernel is

$$M_{t,t+1} = \beta\left(\frac{\mathcal{C}_{t+1}}{\mathcal{C}_t}\right)^{-1}\left(\frac{\tilde{C}_{t+1}}{\tilde{C}_t}\right)^{1-\frac{1}{\psi}}\left(\frac{U_{t+1}}{E_t\left(U^{1-\gamma}_{t+1}\right)^{\frac{1}{1-\gamma}}}\right)^{\frac{1}{\psi}-\gamma} \tag{2.29}$$

The household labor supply for each industry is,

$$W_{j,t} = \left(\frac{1}{\varphi} - 1\right)\frac{\mathcal{C}_t}{(1-\mathcal{L}_t)} \tag{2.30}$$

Because the household works indifferently in all industries, the aggregate wage will be the same across all industries.

2.3.4 Equilibrium and aggregation

As in the simple model, the fixed cost specification for the idiosyncratic risk makes all firms ex-ante identical. Besides, in case of bankruptcy, the firm is transferred to debt-holders who make the same decisions as surviving firms. Therefore, the only cross-sectional difference across firms comes from the realization of the firm-specific shock $z_{i,j,t}$. In the aggregate, the law of large numbers applies to each type of industry $j = 1, ..., N$ and we only need to keep track of the measure of defaulting firms each period, $1 - \Phi(z^\star_{j,t})$.[30] Therefore each industry admits a symmetric Nash equilibrium and the i-subscript can be dropped. In the symmetric equilibrium, the model has $2\times N+2$ state variables; two endogenous state variables for each industry $(\bar{k}_{j,t}, b_{j,t})$, and two exogenous variables (g_t, Δa_t) for the economy.

[29] To close the model, I assume the existence of a government whose objective is to set $\mathcal{T}_t$ to maintain a zero deficit. Therefore the net supply of government debt is zero and household taxes amounts to the total corporate tax subsidy of interests net of corporate tax collection.

[30] A big advantage of this specification is that one can obtain an exact aggregation for the firm distributions without having to rely on the more involved Krusell and Smith (1998) algorithm (e.g. Miao and Wang (2010), Gomes, Jermann, and Schmid (2013)).

Asset returns The return on equity and corporate debt in industry j are defined in a standard way and account for the proportion of firms that defaults,

$$\begin{aligned} \mathcal{R}^d_{j,t} &= \frac{\int_{\underline{z}}^{z^\star_{j,t}} \left[D_{j,t} + Q_{j,t}\right] d\Phi(z)}{Q_{j,t-1}} \\ \mathcal{R}^c_{j,t} &= \frac{\Phi(z^\star_{j,t})(C+1)b_{j,t} + \int_{z^\star_{j,t+1}}^{\overline{z}} (1-\xi_t) V^U_{j,t}\, d\Phi(z)}{B^c_{j,t-1}} \end{aligned} \tag{2.31}$$

where $Q_{j,t} = V_{j,t} - D_{j,t}$ is the ex-dividend value of equity in industry j, and $V^U_{j,t}$ is the equity value cum-dividend of an unlevered firm.

Resource constraint Using the definition for the returns (2.31) earned in financial markets and imposing market clearing on all markets.[31] The aggregate resource constraint (2.28) becomes,

$$\mathcal{Y}_t = \mathcal{C}_t + \mathcal{I}_t + \Psi_{b,t} + \Xi_t \tag{2.32}$$

where $\mathcal{I}_t = \frac{1}{N}\sum_{i=1}^N I_{j,t}$ is aggregate investment, $\Psi_{b,t} = \frac{1}{N}\sum_{i=1}^N \psi_b(b_{i,j,t}, b_{i,j,t+1})$ is the amount of resources spent in debt adjustments, and $\Xi_t = \frac{1}{N}\sum_{i=1}^N \left(\int_{z^\star_{j,t+1}}^{\overline{z}} \xi_t V_{j,t}(0,z)\, d\Phi(z)\right)$ is the aggregate resource lost in bankruptcy.

Industry pricing In the symmetric Nash equilibrium, the industry price is defined as a markup over the industry marginal cost. In particular, denoting the real marginal cost of production by $MC_{j,t} = \frac{W_t}{(1-\alpha)\frac{y_{j,t}}{l_{j,t}}}$,

$$\tilde{P}_{j,t} = MC_{j,t} \underbrace{\left(1 - \frac{h_j}{\nu}\right)^{-1}}_{\text{Price markup}} \tag{2.33}$$

where h_j is the Herfindahl-Hirschman index in industry j. Note that $\tilde{P}_{j,t}$ is increasing in industry concentration. The intuition is that when less players compete in product markets, firms behave more like monopolist and charge a higher markup.

2.4 Model parametrization

This section describes the benchmark model calibration and provides details on the functional forms for the adjustment costs and idiosyncratic shocks distribution. The model is solved using a second order perturbation method about the steady state after normalizing all non-

[31] In particular, I impose that the representative household holds all equity claims, buys all corporate debt issued by corporations: $\mathcal{B}^c_{t+1} = \frac{1}{N}\sum_{j=1}^N q_{j,t} b_{j,t+1}$, that the net supply of government bonds is zero: $\mathcal{B}^g_{t+1}$=0, and that the labor and goods supply equal their respective demands.

stationary variables by A_{t-1}.

2.4.1 Functional forms

The capital adjustment costs function $\Gamma(.)$ is modeled following Jermann (1998),

$$\Gamma(x) = \frac{\alpha_1}{1 - 1/\zeta_k} x^{1-1/\zeta_k} + \alpha_{2,k} \tag{2.34}$$

where $\alpha_{1,k}$ and $\alpha_{2,k}$ are determined such that there is no adjustment costs in the deterministic steady state. The debt adjustment cost is assumed to be quadratic,

$$\psi(\tilde{b}_{t+1}, \tilde{b}_t) = \frac{\chi_b}{2} \left(\tilde{b}_{t+1} - \tilde{b}_t\right)^2 \bar{k}_{j,t} \tag{2.35}$$

where $\tilde{b}_{t+1}$ is corporate debt normalized by the average industry capital $K_{j,t+1}$, and χ_b is a parameter capturing the magnitude of the cost to change leverage. Note that this specification ensures that the debt adjustment cost has no impact on the deterministic steady state.

In a similar spirit as Chen (2010), I model the cost of bankruptcy ξ_t to be a function of the productivity process Δa_t,

$$\xi_t = \xi + \xi_1 \Delta \hat{a}_t \tag{2.36}$$

where $\Delta \hat{a}_t = \Delta a_t - \mu$. Finally, the firm specific shock z is assumed to follow a normal distribution with a mean of zero and a variance σ_z.

2.4.2 Calibration

The model parameters are picked in two ways. First, standard real business cycles parameters as well as preference parameters are set to values from the existing literature. The remaining parameters are estimated by minimizing the distance between moments simulated from the model and empirical targets. All parameters values are summarized in Table 2.1.

The preference parameters are standard in the long-run risk literature (e.g. Croce (2014), Kung (2015)). The elasticity of intertemporal substitution ψ is set to 2 and the coefficient of relative risk aversion γ is set to 10. The subjective discount factor β is equal to 0.99. The relative preference for labor, φ, is set such that the household works 1/3 of her time endowment in the steady state. On the technology side, the capital share α is set to 0.33, and the depreciation rate of capital δ_k is set to 2.0% (e.g. Comin and Gertler (2006)). The productivity process is calibrated following Croce (2014). The persistence of the long run risk is set to imply a annual persistence of 0.85. The conditional annualized volatility of the short- and long-run productivity shocks are $\sigma_a = 4.5\%$ and $\sigma_x = 0.335\%$, respectively. The elasticity of substitution across industries ν does not affect model dynamics much, I set it to 1.[32] Finally, I set the quarterly coupon payment, C to 7%/4 to match the average coupon

[32]Note that when $\nu < 1$, industry goods are complements while when $\nu > 1$, they are substitute. $\nu = 1$ is

payment of my sample (see Table 2.7).

The remaining parameters, namely $\Theta = \left[\sigma_z, \xi, \chi_b, \zeta_k, \tau, \mu, \alpha_1, \{h_j\}_{j=1}^{N}\right]$ are chosen to minimize the distance between a vector of identifying moments from the data and the same moments generated from model simulations.[33] Mathematically, I obtain the parameter estimates by solving,

$$\hat{\Theta} = \arg\min_{\Theta} \left[\hat{m} - m(\Theta)\right]' \tilde{W}^{-1} \left[\hat{m} - m(\Theta)\right] \tag{2.37}$$

where $\tilde{W}$ is a weighing matrix set to the identity matrix, $\hat{m}$ is a vector of empirical moments, and $m(\Theta)$ is the vector of model-implied moments obtained assuming a value of Θ for the structural parameters.

To ensure a successful identification, the empirical targets need to be carefully chosen. Table 2.2 reports the estimated structural parameters along with the eight identifying model and empirical moments. All targets are at the aggregate level except for the profit margin, net of investment that is at the industry level. More specifically, I target a quarterly average default rate of 0.25% in order to match match the Moody's average annual default rate of 1% per year. In the model, default is triggered by the idiosyncratic shock, therefore this moment provides a good identification for σ_z. To identify the parameters governing ξ_t, namely ξ, and α_1, I follow Chen (2010) and target a mean recovery rate in default of 45%, a volatility of recovery rates of 10%, a correlation between recovery rates and default of -0.82, and a correlation between recovery rates and output growth of 0.58. I also target an average annualized credit spreads of 90bps which is the average spread between Baa and Aaa yields used in previous studies (e.g. Gourio (2013)). τ captures the tax-benefits of debt, it is identified using the mean aggregate book-to-asset ratio, set to 0.40 (e.g. Gourio (2013)). Next, I obtain the capital adjustment cost curvature ζ_k by targeting an investment to output volatility of 4.50 (Croce (2014)). The mean growth rate in productivity, μ is chosen to generate an annualized growth rate of output of 1.80%. To obtain χ_b, I aim a standard deviation of book-leverage of 9% (Gourio (2013)).

The last parameters to identify are the degree of concentration in each industry, h_j. To make the model close to the empirical section where I use quintiles sorted on competition, I assume the existence of $N = 5$ representative industries.[34] I further assume that the intensity of competition h_j^{-1} linearly increases between $h_1^{-1} = h_{low}^{-1}$ and $h_5^{-1} = h_{hig}^{-1}$. This leaves me with h_{hig} and h_{low} to estimate. Because h_j is directly linked to measures of market power, I follow a measure similar to Allayannis and Ihrig (2001) that I adjust to take capital expenditures

the Cobb-Douglas case.

[33] Moments from the model are computed on a long sample simulation of 25,000 observations, with a burning period of 1,000 quarters.

[34] Theoretically, the model can accommodate any number of industries N. The cost of having more industries is the increased in computing time. None of the results in this chapter depends on the particular assumption for N.

into account. Specifically, market power is defined as

$$\text{MPI}_{j,t} = \frac{\text{Sales}_{j,t} + \Delta\text{Inventory}_{j,t} - \text{Costs}_{j,t} - \text{Investment}_{j,t}}{\text{Sales}_{j,t} + \Delta\text{Inventory}_{j,t}} \tag{2.38}$$

where $\Delta\text{Inventory}_{j,t}$ is the change in inventory, $\text{Costs}_{j,t}$ is the sum of payroll, cost of material, and energy, and j-t are industry-year subscripts. The data is obtained from the NBER-CES Manufacturing Industry Database. Each year, I sort industries into quintiles based on their lagged measure of concentration. I then compute the average $\text{MPI}_{j,t}$ in the highest and lowest concentration quintile each year and get the average of these series. The resulting two target moments are 0.299 and 0.263.

The SMM estimates are reported in Table 2.2. Overall, the estimation matches the target moments fairly well. The value for σ_z is 0.97 and allows me to exactly match the average quarterly default rate of 0.25%. The estimate value for ξ is estimated at 11.8%, which is in the range of estimates in van Binsbergen, Graham, and Yang (2010). The bankruptcy cost cyclicality parameter α_1 replicates quite well key dynamics of recovery rates reported in Chen (2010). The tax benefits of debt, τ, is about 13.76%. The degree of concentration across industries, h_j's implies a demand elasticity for the firm's product of 3.87 (4.37) for the low- (high-) competition quintile. The value for χ_b generates a relatively stable financial leverage as in the data, i.e. $\sigma(\tilde{b}) = 8.3\%$.

2.5 Quantitative results

This section quantitatively assesses the importance of competition as a determinant of the cross-section of asset prices. First, I examine how the model matches key macroeconomics and asset pricing moments at the aggregate level. This is important as most of the parameters are calibrated at the economy-wide level. Next, I disaggregate moments by industries. The objective is to evaluate whether differences in industry competition are sufficient to explain the cross-sectional differences we observe in the data. Finally, I generate additional empirical predictions on the relationship between credit spreads, competition and idiosyncratic volatility that I test empirically in the next section.

2.5.1 Aggregate moments

Table 2.3 reports key business cycle moments from the calibrated model and the associated data moments. The calibrated model generates an average investment-output ratio of 21%, in line with its 20% empirical counterpart. The output volatility and relative macro volatility are quite close to the data. The model also replicates the correlations across key business cycle variables, namely the procyclicality of consumption, labor, and stock returns. Also, the implied persistence in consumption and output growth is low, as in the data.

Figure 2.2 describes the model dynamics in response to a positive productivity shock by means of impulse response functions. An increase in productivity leads to sustained growth

and persistently increases firms' profits opportunities. Because the elasticity of substitution is greater than one, the substitution effect dominates so that positive productivity leads to an increase in firm valuation proxies, such as the market-to-book ratio (MB). Simultaneously, the excess return on the aggregate stock market rises ($r_e - r_f$). As the continuation value of companies increases, less firms find it optimal to declare bankruptcy leading to a fall in aggregate default and a persistent drop in credit spreads (cs). In the model, agents exhibit preference for early resolution of uncertainty and are therefore averse to the long-run risk generated by low-frequency variations in productivity growth. As a consequence, financial assets that co-move with the business cycle will command a risk premium.

Table 2.3 also reports some key asset pricing moments from simulations. The model generates a large equity risk premium of about 6.80% per annum, and produces substantial variations in excess returns. The annualized standard deviation of excess stock returns is about 9.27%. The strong demand for precautionary savings drives the risk-free rate down to 2.14%, somewhat higher than in the data. The volatility of the risk free rate is also low (1.18%). The model generates a sizable credit spreads of 89bps which exhibits substantial time-series variation. The standard deviation in the model is 24bps and about 42bps in the data. As in the data, credit spreads are counter-cyclical. In particular, the correlation between credit spread and GDP growth is -0.36 in the data and -0.44 in the model. The countercyclicality of credit spreads leads to a bond risk premium. In the model, the credit spread premium is around 20bps, that is 22% of the total credit spread.[35] Although empirical estimates are quite noisy, the credit risk premium in the model is on the lower range of values reported in the literature. Two reasons can explain this. First there exists strong empirical evidence suggesting that other factors contribute to this spread such as taxation (e.g. Elton, Gruber, Agrawal, and Mann (2001)), or liquidity (e.g. Ericsson and Renault (2006), and Chen, Lesmond, and Wei (2007)). Second, the model abstracts from ingredients that have proved useful to generating a large credit risk premia. For instance, Gourio (2013) assume the existence of disaster risk, while Chen (2010) and Bhamra, Kuehn, and Strebulaev (2010) use long-term debt and time-varying uncertainty. In unreported results, I find that allowing for countercyclical idiosyncratic risk helps raise the credit risk premium to 30bps without changing any of the model implications.

Table 2.4 reports several key aggregate corporate financing moments. The model generates an annual market leverage of about 0.11 and a frequency of equity issuance of 0.10 (0.09 in the data). The unconditional probability of default is 0.25% per quarter as in the data. Also, and consistent with recent evidence by Jermann and Quadrini (2012) and Covas and Haan (2011), equity payout are pro-cyclical while debt repayment are countercyclical. For instance, the correlation between equity payout (debt repayment) and GDP is 0.55 (-0.59) in simulated data. Jermann and Quadrini (2012) reports a correlation with GDP of 0.45 and -0.70, respectively.

[35] Formally, the credit spreads premium is defined as the difference between the yield on a risky bond minus the yield of riskless security that pays the expected bond payoff.

Overall, the model does a good job matching unconditional moments and key dynamics of both macro aggregates and asset prices. The next section investigates how competition affects these decisions by disaggregating moments at the industry-level.

2.5.2 Industry moments

In this section, I disaggregate the moments and impulse response functions per industry to study the effects of competition on the cross-section of asset prices. It is important to remember that the only difference across industries is a calibrated proxy for market power. Therefore all cross-sectional differences will be induced by heterogeneity in h_j's.

Table 2.5 reports various model moments for the high- and low-competition quintile. In the model and in the data, more competitive industries are characterized by lower profit margin. The intuition is that competition erodes profits, making a unit of asset less productive in a competitive industry. This result is consistent with previous empirical studies (e.g. MacKay and Phillips (2005)). Because competition erodes firm's growth opportunities by creating a negative externality from rival's actions, competitive firms have lower Book-to-Market ratio. The last two columns compare the difference between the high and low competition quintiles in the model and in the data. The profit margin (as measured by market power) is 3.60% higher in concentrated industries. Moreover, the cross-sectional difference in Book-to-Market ratio is 0.032 closely match its empirical counterpart of 0.040.

The model predicts that concentrated industries use more financial leverage. What happens is that more concentrated industries have higher firm valuation and enjoy a better buffer against idiosyncratic cash-flow shocks. This lowers the probability of default, and increases the expected tax benefits of debt making leverage more attractive. Also, because default is countercyclical, bonds issued by concentrated firms are safer. This further increases the market value of debt and the incentive to use leverage. In the model, market leverage is 2.30% lower in competitive industries.[36] By comparison, summary statistics from my data sample reveal a similar pattern: market leverage is 1.4% lower in the lowest concentration quintile. These results accords with a recent study by Xu (2012) who documents a strong negative relationship between competition and leverage, using import penetration as an instrumental variable. Therefore, the model prediction that competition decreases financial leverage seems supported in the data.[37]

Table 2.5 also reports several asset pricing moments. Equilibrium credit spreads are higher in competitive industries (119bps) than in concentrated industries (62bps). The magnitude of the difference in the model is 57bps, higher than its empirical counterpart of 25bps. There are at least two reasons that explains this larger difference. First, the data sample is biased towards larger firms. Valta (2012) shows that the spread on bank loans is twice as high for smaller firms. This would bring us much closer to the 57bps. Secondly, firms in the sample

[36] Market leverage is obtained as the ratio of the market value of debt divided by sum of the market values of equity and debt.

[37] MacKay and Phillips (2005) also find that competition decreases book leverage by about 3.6%.

varies across many more dimensions that in the model. Therefore a univariate analysis may not capture well the cross-sectional difference in credit spreads. In the data section, I run panel regression to alleviate some of these later concerns.

The model generates substantial differences in equity risk across industries. The average excess return is 7.20% in concentrated vs. 6.43% in competitive industries. This leads to a concentration premium of 0.76%. In the data, this premium is 2.54%, with a standard error of 1.30%. Therefore the difference between model premium and the data estimate is not different at the usual confidence level. The estimated CAPM beta is also higher in less competitive industries by 0.14 (vs. 0.21 in the data). A series of recent empirical studies are supportive of these predictions. For instance Bustamante and Donangelo (2015) document a positive relationship between excess returns, CAPM betas, and measures of industry concentration. To understand why the risk premium on equity is lower in competitive industries, it is useful to look at some impulse response functions. Figure 2.3 compares the response to a positive long-run productivity shock in the high- vs. low-competition industry. Firms in competitive industries face a more elastic demand curve and increase production more when productivity rises. At the industry level, supply gets higher and industry competition increases. This puts a downward pressure on the output price and makes dividends less procyclical in competitive industries. At the same time, firm values rise, and the conditional probability of default drops. Because competitive firms are closer to bankruptcy, the value of their default option falls relatively more. This further dampens the effect of productivity on equity value. Finally, firms in concentrated industries have higher financial leverage which renders cash flows even more procyclical. Taken together, these three forces make equity value in concentrated industries more sensitive to productivity shocks. Since investors are averse to long-run risks, this gives birth to a concentration premium.

In short, the model predicts that competition decreases leverage, increases credit spreads, and decreases the equity premium. These predictions are in line with earlier studies and matches the data quantitatively. This is quite surprising given that the only source of heterogeneity in the model is h_j.

2.5.3 Decomposing the concentration premium

The prior literature has largely focused on linking competition to the *unlevered* equity risk premia. This essay shows that competition also affects optimal capital structure and default. These two decisions in turn affect equity risk. To assess the contribution of leverage and default to the concentration premium, I decompose the premium into two components. The first component measures the effect of competition on equity risk that arises from industry rivals' actions. It relates to how competition affects the firm's assets in place and growth options. This premium is positive because in competitive industries, competitors create a procyclical negative externality that acts as a hedge against aggregate shocks. The second

component measures the contribution of leverage and default.[38]

To obtain this decomposition, I proceed in two steps. First, I compute the equity premium on a security that pays the same cash-flows as the benchmark firm, but has no debt nor options to default. More specifically, the value of that synthetic security is,

$$V_{j,t}^{A} = E_t \sum_{s=t}^{\infty} M_{t,s} \left[(1-\tau)\Pi_{j,s} - I_{j,s} + \tau \delta_k k_{j,s} \right] \tag{2.39}$$

The difference in equity premium between the low- and high-competition quintile measures the rival's externality effect. Next, the remainder of the concentration premium unexplained by cash-flows from real assets is attributed to the default and leverage effects.[39]

Estimating these components for the benchmark calibration reveals that the rivals' externality effect generates a premium of 15bps (see Table 2.5). In other words, about 80% of the concentration premium comes from the "levered" component of returns. This highlights the importance of accounting for leverage and default in explaining the interaction between equity returns and industry competition.

2.5.4 Idiosyncratic risk and corporate spreads

The importance of idiosyncratic volatility for credit spreads dates back to at least Merton (1974). In his paper corporate debt is modeled as a default-free bond minus a put option on the firm assets. A rise in firm volatility increases the value of the put option to default. This lowers the value of debt and leads to an increase in corporate spreads. This section investigates how competition can amplify debtholders' exposure to idiosyncratic volatility shocks. To that end, the model is augmented to allow for time-varying volatility in the firm-specific shock $z_{j,t}$

$$\sigma_{z_{j,t}} = \rho_{\sigma_z} \sigma_{z_{j,t-1}} + \sigma_{\sigma_z} \epsilon_{\sigma,j,t} \tag{2.40}$$

where $e_{\sigma,j,t}$ are standard normal i.i.d. shocks.

As we saw earlier, firms in competitive industries operate on a lower profit margin. As such, an increase in idiosyncratic volatility is more likely to drive competitive firms to default. In Merton (1974) context, competitive firms are more likely to exercise their default put option. Therefore we expect that the effects of a persistent increases in $\sigma_{z_{j,t}}$ on debt value to be stronger for more competitive firms. Figure 2.4 presents the impulse response fuctions to an increase in idiosyncratic volatility.[40] In response to the higher idiosyncratic risk, default rates and credit spreads increase. To alleviate the increase in risk, firms try to cut on debt but adjusting leverage is costly. This leads to a small, persistent decrease in debt-to-assets that

[38] I consider these two effects jointly because the probability of bankruptcy drives both the value of the default option and the cost of leverage and are therefore hard to disentangle.

[39] The premium are obtained by building synthetic securities that are priced using the benchmark calibration pricing kernel to avoid that the pricing of risk changes across specifications.

[40] The idiosyncratic risk process is calibrated as follows; $\rho_{\sigma_z} = 0.6$, and $\sigma_{\sigma_z} = 4\%$ which implies an annualized standard deviation of idiosyncratic industry volatility of 10% (e.g. Campbell, Lettau, Malkiel, and Xu (2001)).

is not sufficient to avoid the sharp increase in default probability. Importantly, while credit spreads in both industries rise, the reaction in competitive industries is larger by around 33%.

Testing this prediction empirically is challenging because idiosyncratic volatility shocks are not as easily identified as in the model. In the empirical section of the chapter, I go around this problem by using proxies based on stock market prices.

2.6 Panel regression

In this section, I test two empirical implications of the model using a data set of publicly traded bonds: (i) credit spreads in competitive industries are higher, and (ii) shocks to idiosyncratic volatility are amplified in competitive industries.

2.6.1 Bond sample construction

Bond sample construction I obtain corporate bond prices from the National Association of Insurance Commissioners (NAIC) bond transaction file. The NAIC file records all public corporate bond transactions by life insurance companies, property and casualty insurance companies, and Health Maintenance Organizations (HMOs). The database starts in 1994 but the coverage of disposal transactions (e.g. sales) only begins in 1995, leaving a sample period of 1995 to 2012. While not exhaustive, the NAIC database represents a substantial portion of the corporate bond market. Schultz (2001) and Campbell and Taksler (2003) for instance note that insurance companies hold between one-third and 40% of issued corporate bonds. Bessembinder, Maxwell, and Venkataraman (2006) estimate that they represent a substantial proportion (≈12.5%) of total bond trading volume.

The NAIC bond transactions table is linked to the Mergent Fixed Income Securities Database (FISD) to obtain bond specific information such as the maturity, coupon rate, etc. To be part of the sample, bonds must be issued by a U.S. firm and pay a fixed coupon. Following Campbell and Taksler (2003), I also eliminate bonds with special bond features such as put, call, exchangeable, asset backed, and convertible. I only keep bonds with an investment-grade rating because insurance companies are often forbidden to invest in speculative-grade bonds. The transaction data for these bonds are thus likely to be unrepresentative of the market.[41] I follow a common practice in the finance literature and remove from the sample firms that belongs to the regulated utilities industry (SIC codes 49) and financial institutions (SIC codes in the 60-69 range).

Following Bessembinder, Kahle, Maxwell, and Xu (2009), I eliminate transactions smaller than $100,000 or those that involve the bond issuer, i.e. transactions labelled as *cancelled*, *corrected*, *cancelled*, *corrected*, *issuer*, *direct*, *called*, *conversion*, *exchanged*, *matured*, *put*, *redeemed*, *sinking fund*, *tax-free*, *exchange*, or *tendered*. To eliminate potential data-entry errors,

[41] When an issue is rated by more than one agency at a given date, the average rating is computed, otherwise the last rating in date is used.

I also remove return reversals. A return reversal is defined as a return of more than 15% in magnitude immediately followed by a more than 15% return in the opposite direction. Besides I exclude observations with obvious data errors such as negative price or transaction dates occurring after maturity. In case there are several bond transactions in a day, the daily bond price is obtained by weighting each transaction price by its volume (in face value).

Reported price in the NAIC file are *clean* bond price and accrued interests are added to get the full settlement price (i.e. the bond *dirty* price). Yields are computed by equating the dirty price to the present value of cash-flows and yield spreads are defined in excess of the benchmark treasury at the date of transaction. To get the benchmark treasury, I match the bond duration to the zero-coupon Treasury yields curve from Gürkaynak, Sack, and Wright (2007), linearly interpolating if necessary. Treasury yields with a maturity lower than 1 year are obtained from the CRSP risk-free series. Matching duration instead of maturity provides a more robust benchmark as coupon payment can vary greatly across issuers. As a final check and following Gilchrist and Zakrajšek (2011), I truncate the yield spreads in the sample to be between 5bps and 3,500bps and restrict the bond remaining maturity to be below 30 years.

Issuers' accounting information are from Compustat and are matched using the 6 digits issuer CUSIP. Stock prices information are obtained in a similar way from the CRSP file. To ensure that all information is included in asset prices, stock returns and bond yield spreads from July of year t to June of year $t+1$ are matched with accounting information for fiscal year ending in year $t-1$, following Fama and French (1992). Monthly yield spread observations are constructed using the last transaction of the month. The sample consists of an unbalanced monthly panel of 12,198 different bond-month transactions. The final number of observations depends on the definition of competition.

Industry competition measures In the model, the degree of competition is captured by industry concentration. A direct empirical proxy is the sales-based Herfindahl-Hirschman index (HHI) published by the U.S. Census of Manufactures. I use this measure as my benchmark. More formally, the sales-based HHI is defined as follows,

$$\text{HHI}_j = \sum_{i=1}^{N_j} s_{i,j}^2 \tag{2.41}$$

where $s_{i,j}$ is the sales market share of firm i in industry j. The U.S. Census data is updated every five years and covers only manufacturing industries. Following Ali, Klasa, and Yeung (2009), I use the HHI for a given year, and assume this is also a good proxy for concentration for the one or two years immediately before and after it. An advantage of the U.S. Census data is that it covers both public and private firms and it has been shown in a prior literature that it is a good proxy for actual industry concentration (e.g. Ali, Klasa, and Yeung (2009)). Throughout the rest of the chapter, I define an industry by using the 4-digit SIC industry classification.

To check the robustness of my results, I use several other well-used measures of competition. The first is a measure based on markup power used in Allayannis and Ihrig (2001):

$$\text{Market power}_{j,t} = \frac{\text{Sales}_{j,t} + \Delta\text{Inventory}_{j,t} - \text{Payroll}_{j,t} - \text{Cost of Material}_{j,t}}{\text{Sales}_{j,t} + \Delta\text{Inventory}_{j,t}} \tag{2.42}$$

The data are obtained at the industry level from the NBER-CES Manufacturing Industry Database. The second measure is the *Fitted SIC-based Industry concentration* data used in Hoberg and Phillips (2010). This fitted measure has the advantage of capturing the influence of both public and private firms, and to be available for all industries.[42]

2.6.2 Descriptive statistics

In Table 2.6, I report the average yield and yield spread from my NAIC benchmark bond transactions sample, sorted on credit rating. To facilitate notation, I report credit rating using the Moody's rating scale only. In the sample, the majority of bond transactions ($\approx$ 79%) lies in the A-Baa categories, a pattern consistent with earlier studies (e.g. Campbell and Taksler (2003)). The average monthly spread between Baa and Aaa bonds is about 113 bps, close to the average spread reported by Moody's over the same period (101 bps). In Figure 2.5, I plot the time series of the average Baa yield spread obtained from my NAIC sample along with the spreads reported by Moody's over the same period. The two series follow a similar pattern with pikes occurring during the 2000's and the financial crisis. The time series correlation between the two series is high ($\approx$ 0.91). In Panel A of Table 2.7, I report summary statistic for my bond sample. The size of issue is positively skewed, with an average (median) debt issue of 541 (350) millions. The time-to-maturity of the bonds is long, about 10 years. The summary statistics are similar to those of previous studies using public debt (e.g. Gilchrist and Zakrajšek (2011)). Panel B reports individual firm summary statistics. The average firm size in the sample is fairly large. This is consistent with previous empirical work that finds that firms issuing public debt are larger than firms using bank loans (e.g. Denis and Mihov (2003)). Finally, I report the average 4-digit SIC HHI by 2-digit SIC industries inTable 2.8. The resulting sort of industries is similar to that in Table 5 of Ali, Klasa, and Yeung (2009).

Overall these results suggest that my bond transaction sample is quite representative of the investment-grade bond market. My firm sample is biased towards the largest, safest firms. As a consequence, my empirical results should be a lower bound of the true effects of competition on credit spreads.

2.6.3 Concentration and the cross section of corporate yield spreads

This section investigates the first empirical prediction of the model, namely credit spreads in competitive industries are higher. Following the litterature I define competition as a dummy

[42] Many thanks to the authors for making the data available on their website.

equal to one if HHI is in the lowest quintile of the yearly sample distribution and zero otherwise. This specification will facilitate the economic interpretation of the coefficient and also mitigate measurement errors.

Univariate analysis I start my investigation by looking at univariate sorts on industry concentration. Table 2.9 reports the mean, and median bond yield spread for the highest and lowest competition quintile. Consistent with the model predictions, credit spreads in more competitive industries are higher by 25bps. The difference in mean and median are both statistically significant. Also and perhaps surprisingly, the estimate is quite close to the bank loan spread difference between low and high competition industry reported in Valta (2012) (22bps for large firms). Table 2.9 also reports the mean and median stock excess return across competition quintiles. Excess stock returns are lower in competitive industries (-2.54% for the mean and -3.29% for the median). These results are statistically significant and consistent with the model prediction that equity is safer in more competitive industries.

Multivariate analysis Using my monthly panel data, I investigate whether measures of concentration have any predictive power on corporate yield spreads for public debt. In particular, I run the following regression model,

$$\mathrm{cs}_{i,t} = \delta \times \mathrm{Comp}_{i,t-1} + \beta\, \mathrm{X}_{i,t-1} + \epsilon_{i,t} \tag{2.43}$$

where (i, t) denotes a specific firm-month observation, $\mathrm{Comp}_{i,t-1}$ is equal to one if the firm is in the highest competition quintile and zero otherwise, and $\mathrm{X}_{i,t-1}$ is a vector of controls, potentially including time, or industry fixed effects. The parameter of interest is δ. It captures the difference in credit spreads for firms operating in competitive industries.

I group my set of controls into three categories: equity characteristics, bond characteristics, and macroeconomic variables. It is important to control for all these characteristics because, in contrast to the model, the bond data set exhibits vast heterogeneity in both bond and firm characteristics. In the equity controls category, I include the mean of the firm abnormal equity returns (net of the market return), for the 180 days prior to the month when the transaction occurs. I also control for leverage (total debt to capitalization), the firm size (log-asset) and asset tangibility (e.g. Ortiz-Molina and Phillips (2014)). I also add the log-book-to-market ratio and the log-market value of equity, two well-known determinants of the cross-section of equity returns.[43]

I also control for a series of bond specific characteristics. I include bond ratings to take into account the overall risk of the firm. Moody's ratings are converted to numerical values by

[43]Total debt to capitalization is [total long-term debt (DLTT) + debt in current liabilities (DLC) - cash holdings (CHE)] to [total liabilities (LT) + market value of equity (CRSP)]. The book-to-market ratio is defined as [book value of stockholders' equity (CEQ), plus balance sheet deferred taxes (TXDITC) - book value of preferred stock (PST)] to [market equity (CRSP) at the end of June of the year following the fiscal year.

creating an index starting at 12 (Baa3) and linearly increasing by one for each credit rating notch. I control for the bond years-to-maturity because longer maturity bonds are likely to be risker (e.g. Leland and Toft (1996)). I also include the coupon rate since bonds that pay higher coupon suffers from higher taxation (e.g. Elton, Gruber, Agrawal, and Mann (2001)). Corporate bonds exhibit various degree of trading frequency which can lead to the presence of an illiquidity premium (e.g. Ericsson and Renault (2006), and Dick-Nielsen, Feldhütter, and Lando (2012)). To control for bond-specific illiquidity I include a measure of trading turnover defined as the average, over the past twelve months, of trading volume as a proportion of total amount outstanding. I also add the log amount outstanding because smaller issue are likely to be less liquid.

Finally, I include a series of macroeconomic variables to capture the level (3-month Treasury Bill), and the slope (10-year minus 1-year Treasury Bond yields) of the yield curve. I also use the 1-month Euro-Dollar spread as a proxy for aggregate demand for liquidity (e.g. Longstaff (2004)). I also include the 180-day moving average and standard deviation of the aggregate market return. Finally, I control for the aggregate labor share obtained from Bureau of Labor Statistics (Favilukis, Lin, and Zhao (2013)). In the regressions, bond yield spreads from July of year t to June of year $t+1$ are matched with accounting information for fiscal year ending in year $t-1$. Equity and macroeconomic data are lagged one month. This ensures that all information is included in asset prices at the time the transaction takes place. Also all reported t-statistics are calculated using standard errors clustered at the industry level.

Table 2.10 reports the main regression results (see for Table 2.12 for the detailed regression output) estimated both from the NAIC bond transaction panel and from simulated model data.[44] Columns (1) presents coefficient estimates without any controls. The coefficient of interest, δ, is estimated to be around 23bps and is statistically significant. In other words, a firm operating in the highest competition quantile is expected to have its corporate debt discounted by about 23bps on financial markets. Columns (2) presents the same regression using simulated data from the calibrated model. As expected, the model overestimates the effects of competition on credit spreads. This is due to the fact that the empirical data set is biased towards the largest, safest firms. The coefficient of interest is estimated at 37bps and is statistically significant. The last three columns present robustness checks. Column (3) checks whether these results are robust to the inclusion of the battery of controls defined earlier. I also add industry fixed effects. While δ slightly drops from 23bps to 18bps, it is strongly significant at the usual confidence level. Columns (4)-(5) present results from the same regression as column (3) but using alternative measures for competition and show that the model predictions are also robust across those dimensions. Note that the estimates are in line with findings in Valta (2012) who find that competitive firms pay about 15bps more on bank loans.

In short, this section shows that firms operating in more competitive industries have less

[44]Simulated panel are such that the total number of observations is equal to the data. For more details see the table description.

valuable corporate debt. The value discount is estimated to be between 15bps and 24bps. In terms of cash flow, it means that firms facing tougher competition pay on average between USD811,500 and USD1,298,000 of additional interest payments on their debt, per year.[45] The magnitude is also comparable to the effect of a one- to three-notch downgrade in credit rating.

2.6.4 Competition, firm volatility and yield spreads

In the model, competitive firms are more sensitive to changes in idiosyncratic risk (e.g. see Figure 2.4). In this section, I test this prediction in the data. While shocks to firm-level volatility are well-identified in the model, they are quite challenging to identify in the data. To go around this problem, I use the 180-day moving standard deviation of abnormal excess returns as a proxy for $\sigma_{z,t}$. In particular, I run the following regression model,

$$\mathrm{cs}_{i,t} = \delta_0 \times \sigma^{rx}_{i,t-1} + \delta_1 \times \mathrm{Comp}_{i,t-1} \times \sigma^{rx}_{i,t-1} + \beta\, \mathrm{X}_{i,t-1} + \epsilon_{i,t} \tag{2.44}$$

where (i,t) denotes a specific firm-month observation, $\mathrm{Comp}_{i,t-1}$ is equal to one if the firm is in the highest competition quintile and zero otherwise, $\sigma^{rx}_{i,t-1}$ is a 180-day backward moving average of the market-adjusted stock return volatility, and $\mathrm{X}_{i,t-1}$ is a vector of controls, potentially including time, industry or firm fixed effects.[46] The parameter of interest is the interaction coefficient δ_1. It captures the extent to which competition increases the sensitivity of credit spreads to change in idiosyncratic risk.

Table 2.11 presents the main regression output. The full detailed panel is reported in Table 2.13. Column (1) reports the coefficient estimates without controls, except for industry fixed effects. The interaction term coefficient has the expected sign, companies in more competitive industries are more sensitive to change in firm-specific volatility. The coefficient falls short of statistical significance, which is not surprising given the degree of heterogeneity in bond and firm characteristics. Column (2) reports the coefficient estimates from model simulations. δ_1 is estimated at around 13bps which is slightly lower than in the data (19bps). In column (3) I control for firm and bond characteristics and δ_1 becomes significant while keeping the same magnitude of around 21bps. In economic terms, a 1% increase in idiosyncratic volatility increases corporate yield spreads by an additional 21bps in a more competitive industry. In terms of portfolio performance, a bond portfolio of debt issued by competitive firms lose an *additional* 1.49% return for each 1% increase in idiosyncratic volatility.[47] These results stays economically and statistically significant, even after controlling for firm fixed effects in column (4), or using the alternative measures of competition in columns (5)-(6).

[45] These values are obtained assuming a debt face value of \$541M (the average face value in the sample).

[46] I also include in the controls the $Comp_{i,t-1}$ dummy.

[47] These calculations are obtained by computing the realized return on a bond whose characteristics are set to the sample average and assuming a 1% increase in idiosyncratic volatility.

2.7 Conclusion

This chapter develops a production-based asset pricing model to explore the effects of industry competition on the cross-section of credit spreads and levered equity returns. The model features two main sources of risks: aggregate and idiosyncratic. In equilibrium, competition affects asset prices by affecting the firm exposure to these risks. First, the *competitive externality* channel creates an externality from peers' actions that makes the firm cash flows less procyclical. This effect reduces firm risk. Second, competition increases the firm exposure to idiosyncratic risk and leads to a *default option* effect. This further reduces the risk of equity and leads corporate debt to be both less valuable and riskier. As a result of their competitive disadvantage in issuing debt, firms in competitive industries substitute equity for debt. Ultimately, competitive firms issue less, but more expensive debt.

The model is calibrated to match a set of aggregate moments and to replicate cross-sectional differences in market power across concentration quintiles. Because the only difference across industries is the intensity of competition, the model offers a compelling laboratory to quantify the importance of product market structure. I find that competition has large effects on corporate decisions and asset prices. The magnitudes across competition quintiles for equity returns and financial leverage accords with the existing empirical literature. I verify additional predictions using a panel of publicly traded corporate bond transactions and find that product market competition increases average credit spreads by 15bps. Also, credit spreads in more competitive industries are 40% more sensitive to idiosyncratic risk. These results are robust to the inclusions of various controls and alternative measures of competition.

Table 2.1: Quarterly calibration

Parameter	Description	Model
A. Preferences		
β	Subjective discount factor	0.99
ψ	Elasticity of intertemporal substitution	2.00
γ	Risk aversion	10.00
B. Production		
α	Capital share	0.33
δ_k	Depreciation rate of capital stock	2.00%
ζ_k	Capital adjustment cost parameter	$10.54^{\dagger}$
C. Productivity		
4μ	Mean of Δa_t	$1.72\%^{\dagger}$
ρ^4	Persistence of Δa_t	0.85
$\sqrt{4}\sigma_a$	Conditional volatility of a_t	4.50%
$\sqrt{4}\sigma_g$	Conditional volatility of g_t	0.34%
D. Finance		
C	Coupon payment	7%/4
ξ_0	Bankruptcy costs	$11.81\%^{\dagger}$
ξ_1	Bankruptcy costs cyclicality	$-10.89^{\dagger}$
σ_z	Volatility idiosyncratic shock	$0.97^{\dagger}$
τ	Corporate tax rate	$13.76\%^{\dagger}$
χ_b	Debt adjustment cost parameter	$0.28^{\dagger}$
E. Industry parameters		
ν	Elasticity of substitution across industries	1
h_{low}	Elast. of subst. in low concentr. industry	$0.2287^{\dagger}$
h_{hig}	Elast. of subst. in high concentr. industry	$0.2583^{\dagger}$

This table reports the parameter values used in the benchmark quarterly calibration of the model. † denotes a parameter estimated by SMM.

Table 2.2: Simulated methods of moments estimates

Target moment	Data	Model	Estimates
Quarterly default rate	0.25%	0.25%	$\sigma_z = 0.9685$
Baa-Aaa yields spread	90bps	89bps	$\xi = 11.812\%$
Average bond recovery	0.40	0.41	ξ_1 = -10.89
Volatility bond recovery	0.10	0.21	
Corr(Bond recovery,Default)	-0.82	-0.52	
Corr(Bond recovery,Profit growth)	0.58	0.96	
Book leverage	0.40	0.35	$\tau = 13.76\%$
Standard deviation book leverage	0.09	0.08	$\chi_b = 0.2816$
Investment-to-output vol.	4.50	5.99	ζ_k= 10.544
Mean growth rate of output	1.80%	1.85%	$\mu = 0.430\%$
Profit margin high concentration	0.299	0.299	$h_{hig} = 0.2583$
Profit margin low concentration	0.263	0.263	$h_{low} = 0.2287$

This table reports the empirical targets, model moments, and corresponding parameters estimates obtained from the simulated method of moments procedure.

Table 2.3: Aggregate business cycle and asset pricing moments

Moment	Data	Model	Moment	Data	Model
A. Business cycle					
$E(\Delta y)$	1.80	1.85†	$corr(\Delta c, \Delta y)$	0.39	0.82
$E(I/Y)$	0.20	0.21	$corr(\Delta l, \Delta y)$	0.75	0.53
$\sigma(\Delta y)$	3.56	3.44	$corr(\Delta c, r_e - r_f)$	0.25	0.82
$\sigma_{\Delta c}/\sigma_{\Delta y}$	0.71	0.85	$ACF_1(\Delta y)$	0.35	0.10
$\sigma_{\Delta i}/\sigma_{\Delta y}$	4.50	5.99†	$ACF_1(\Delta c)$	0.32	0.13
$\sigma_{\Delta l}$	1.70%	1.31%	$ACF_1(i-k)$	0.86	0.89
B. Asset prices					
$E(r_e - r_f)$	7.23	6.80	$\sigma(r_e - r_f)$	16.54	9.27
$E(r_f)$	1.51	2.14	$\sigma(r_f)$	2.25	1.18
$E(cs_t)$	90bps	89bps†	$\sigma(cs_t)$	42bps	24bps

This table reports aggregate macroeconomics and asset pricing moments from the model and the data. Δy, Δc, Δl, Δi denotes output growth, consumption growth, labor growth, and investment growth respectively. I/Y is investment over GDP, $i-k$ is the log investment-to-capital ratio, $r_e - r_f$ is the aggregate stock market excess return, r_f is the one-period real risk-free rate, and cs_t is the aggregate credit spread. Model moments are calculated by simulating the model for 25,000 quarters, with a 1,000 quarters burning period. Aggregate quantities are obtained by summing up industry-level data, aggregate returns and credit spreads are equally-weighted. Growth rates, and returns moments are annualized percentage, credit spreads are in annualized basis point units. † denotes a SMM target moment.

Table 2.4: Aggregate financing moments

	Data	Model
Market leverage	0.18	0.11
Frequency of equity issuance	0.09	0.10
Default rate	0.25%	0.25%†
corr(Equitypay,GDP)	0.45	0.55
corr(DebtRep,GDP)	-0.70	-0.59
corr(cs,Δy)	-0.36	-0.44

This table reports aggregate financing moments from the model and from the data. Debt repayment (DebtRep) and Equity payout (Equitypay) are normalized by output. Data moments are obtained from Jermann and Quadrini (2012) and Chen, Collin-Dufresne, and Goldstein (2009). Model moments are calculated by simulating the model for 25,000 quarters, with a 1,000 quarters burning period. The data are aggregated by summing up industry-level data. Growth rates, and returns moments are annualized percentage, credit spreads are in annualized basis point units. † denotes a SMM target moment.

Table 2.5: Industry variables

	Simulated moments		High minus Low	
	High comp.	Low comp.	Model	Data
Market power	0.263†	0.299†	-0.036†	-0.036
Book-to-Market	0.377	0.345	0.032	0.040
Market Leverage	0.100	0.124	-0.023	-0.014
Default rate	0.35%	0.15%	0.20%	-
$E(cs)$	119bps	62bps	57bps	25bps
$E(r_i - r_f)$	6.43%	7.20%	-0.76%	-2.54%
β_{CAPM}	0.93	1.07	-0.14	-0.21
$E(r_i^A - r_f)$	3.73%	3.88%	-0.15%	-

This table reports several key moments sorted by competition quintiles. Model moments are calculated by simulating the model for 25,000 quarters, with a 1,000 quarters burning period. The data are then aggregated by competition quintiles. Data moments are obtained as follows: market power is calculated following Eq. 2.38; excess returns, market leverage, and credit spreads moments are obtained from my panel data set where competition is defined as the U.S. Census 4-digit SIC HHI; CAPM beta, and Book-to-Market are from Bustamante and Donangelo (2015). Market leverage is obtained as the ratio of the market value of debt divided by sum of the market values of equity and debt. The market value of debt is defined as total debt times the market value of 1$ of debt obtained from my data sample. $r_i - r_f$ is the return on equity in excess of the risk-free rate, $r_i^A - r_f$ is the excess return on a security that receives the same operating cash flows as the benchmark firm with no idiosyncratic risk nor debt (see Eq. 2.39). † denotes a SMM target moment.

Table 2.6: Yield data per rating category

Rating	Yield	Yield Spread	N
Aaa	5.31	64.72	304
Aa	5.17	74.61	716
A	5.87	123.63	1958
Baa	6.44	198.05	1842

This table presents the sample average of corporate yields and yield spreads by credit rating for the benchmark data set (Manufacturing Census HHI measure). The yield spread is obtained by subtracting from the corporate spread, a Treasury yield with equal duration. The sample period of the NAIC data is from 1995 and 2012. Yields are in percent and yield spreads are in basis points. All bonds are in U.S. dollars and have no special features (call, put, convertibility, etc.).

Table 2.7: Summary statistics

Variable	Mean	Median	SD	Min	Max
A. Bond characteristics					
Yield (%)	5.95	6.20	1.70	0.38	15.72
Yield spread (bps)	141	110	113	6	1,276
Coupon (%)	7.00	6.99	1.23	2.13	12.63
Time to maturity (years)	9.78	7.30	7.62	0.01	29.98
Issue size (Millions)	541	350	604	25	4,800
Credit rating	A	A	-	Baa	Aaa
B. Firm characteristics					
Census HHI (log)	5.13	5.16	1.05	1.24	7.07
Asset size (log Millions)	9.21	9.19	1.12	6.33	12.27
Long-term debt to asset	0.22	0.21	0.11	0.02	0.91
Book-to-Market	0.40	0.34	0.32	-0.04	2.35

This table reports summary statistics for the benchmark sample. Panel A reports bond characteristics. Yield spreads are defined as the bond yield in excess a government bond with equal duration, coupon is the annualized coupon rate, Time to maturity is the difference between the maturity of the bond and the transaction date, the issue size is the total principal issued for a bond. Panel B reports firm characteristics, Census HHI is the U.S. Census Herfindhal Index computed at the 4-digit SIC industry level using the same methodology as Ali, Klasa, and Yeung (2009), Asset size is defined as total assets in Compustat, Long-term debt to asset is obtained from Compustat, the Book-to-Market ratio is defined as the ratio of book equity to the market value of equity. The variable units are detailed in the first column.

Table 2.8: List of industries by concentration

SIC	HHI	Description
24	13.23	Lumber and wood products
34	46.20	Fabricated metal products
35	139.11	Industrial and commercial machinery and computer equipment
25	172.17	Furniture and fixtures
26	182.94	Paper and allied products
28	224.81	Chemicals and allied products
36	234.47	Electronic, electrical equipment
38	235.04	Measuring instruments
29	335.99	Petroleum refining
20	344.65	Food and kindred products
30	540.61	Rubber and plastic products
37	607.97	Transportation equipment
33	790.06	Primary metal industries
21	806.12	Tobacco products
32	891.21	Stone, clay, glass, and concrete products

This table reports the average values of HHI-Census for 4-digit SIC industries within a 2-digit SIC industry. 4-digit SIC industries HHI are calculated by weighting the HHI-Census values of component 6-digit NAICS industries by the square of their share of the broader 4-digit SIC industry as in Ali, Klasa, and Yeung (2009).

Table 2.9: Univariate analysis

	High Competition		Low Competition		Test of differences	
	Mean	Median	Mean	Median	t-test	Wilcoxon test
Yield spread	163 bps	123 bps	138 bps	108 bps	4.41***	4.48***
$E[r_i - r_f]$	8.59%	10.09%	11.14%	13.38%	-1.96**	-1.78*

This table reports the means and medians aggregated across all firms/months for subsamples of the data sorted on the U.S. Census 4-digit HHI concentration measure. The *High Competition* corresponds to the lowest concentration quintile and *Low Competition* to the highest concentration quintile. The yield spread is defined as the bond yield in excess of a government bond with equal duration and $r_i - r_f$ is the annualized realized stock return over the following year in excess of the daily bill. The last two columns of the table present test statistics of the t-test and the Wilcoxon test of the differences in mean and median across the two samples. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 2.10: Competition and the cross-section of yield spreads

	HHI	Model	HHI	Fit HHI	Markup
	(1)	(2)	(3)	(4)	(5)
Competition	22.75**	37.39***	18.18**	31.67***	31.34***
	(1.86)	(9.39)	(1.92)	(2.89)	(3.12)
Controls	No	No	Yes	Yes	Yes
Observations	4814	5000	4814	10000	4529
R^2	0.01	0.13	0.49	0.36	0.50
Industry FE	No	No	Yes	Yes	Yes

This table presents point estimates from the panel regressions examining the effects of competition on industry credit spreads. Columns 1 and 3 are estimated using the U.S. Census HHI index at the 4-digit SIC level. Column 2 is estimated from simulated model data across 5 industries, with a time series length such that the total number of observations in the panel is 5,000. Columns 4 and 5 present robustness checks using *Fit HHI* from Hoberg and Phillips (2010) and the empirical measure of markup in Eq. 2.42, respectively. Product market competition is measured as a dummy equal to 1 if the firm is in the lowest quintile of concentration or market power measures in the year previous to the transaction date. All control variables are lagged by one month for monthly variables and 12 months for yearly variables. Definitions of the variables included in the controls category is detailed in the sample description. Twelve month dummies are included in the regressions to control for any unobserved monthly time effects, and were omitted from the table. The detailed coefficient estimates are reported in Table 2.12. I report t-statistics calculated over standard errors clustered at the 48 Fama-French industries level in parentheses below the coefficient estimates. Significance at the 10%, 5%, and 1% level is indicated by *, **, and ***, respectively.

Table 2.11: Firm-risk, competition and the cross-section of yield spreads

	HHI	Model	HHI		Fit HHI	Markup
	(1)	(2)	(3)	(4)	(5)	(6)
Competition × Ex. ret. volatility	18.90	12.81*	22.04***	21.25***	44.96*	15.77*
	(1.21)	(1.83)	(3.28)	(2.74)	(1.79)	(1.86)
Volatility excess return	50.32***	29.15***	48.74***	39.89***	42.81***	47.73***
	(6.28)	(5.65)	(4.69)	(5.93)	(5.68)	(3.77)
Controls	No	No	Yes	Yes	Yes	Yes
Observations	4814	5000	4814	4814	10000	4529
R^2	0.24	0.87	0.54	0.64	0.44	0.56
Industry FE	Yes	Yes	Yes	No	Yes	Yes
Firm FE	No	No	No	Yes	No	No

This table presents point estimates from the panel regressions examining how competition amplifies the effects of firm-specific risk on credit spreads. Columns 1 and 3-4 are estimated using the U.S. Census HHI index at the 4-digit SIC level. Column 2 is estimated from simulated model data across 5 industries, with a time series length such that the total number of observations in the panel is 5,000. Columns 5-6 presents robustness checks using *Fit HHI* from Hoberg and Phillips (2010) and the empirical measure of markup in Eq. 2.42. Product market competition is measured as a dummy equal to 1 if the firm is in the lowest quintile of concentration or market power measures in the year previous to the transaction date. All control variables are lagged by one month for monthly variables and 12 months for yearly variables. The volatility of excess return is calculated as the moving standard deviation of the individual stock return in excess of the market return over the past 180 days. Idiosyncratic volatility in the model is measured by $\sigma_{z,t}$ (see Eq. 2.40). Definitions of the variables included in the different control categories is detailed in the sample description. Comp. × Ex. ret. volatility is the interaction term between the competition dummy and excess return volatility. A dummy for competition is also included in the regression but omitted from the table. Definitions of the variables included in the controls category is detailed in the sample description. Twelve month dummies are included in the regressions and omitted from the table. The detailed coefficient estimates are reported in Table 2.13. I report t-statistics calculated over standard errors clustered at the 48 Fama-French industries level in parentheses below the coefficient estimates. Significance at the 10%, 5%, and 1% level is indicated by *, **, and ***, respectively.

Table 2.12: Competition and the cross-section of yield spreads

	Census HHI		Fit HHI	Markup
	(1)	(2)	(3)	(4)
Competition	22.75**	18.18**	31.67***	31.34***
	(1.86)	(1.92)	(2.89)	(3.12)
Mean excess return		-67.40***	-119.84***	-82.46***
		(-2.60)	(-4.36)	(-3.72)
Total debt to capitalization		-40.26	113.60	-64.31
		(-0.72)	(1.25)	(-1.20)
Tangibility		1.49	-52.27***	-4.87
		(0.06)	(-2.60)	(-0.31)
Book-to-market (log)		70.57***	51.23**	72.20***
		(5.18)	(1.94)	(3.56)
Size (log)		-4.10	-6.11***	-2.37
		(-1.15)	(-2.00)	(-0.48)
Bond characteristics				
Credit rating		-13.03***	-8.43***	-10.98***
		(-5.30)	(-5.43)	(-4.46)
Years to maturity		1.82***	1.94***	1.91***
		(4.82)	(7.62)	(4.70)
Coupon rate (in %)		14.69***	6.68***	12.24***
		(5.35)	(2.30)	(5.68)
Issue size (log)		-6.37	-3.70	-8.46
		(-1.00)	(-0.90)	(-1.14)
Trading turnover		-77.72***	-54.61***	-43.50***
		(-2.95)	(-2.97)	(-2.44)
Macroeconomic variables				
3m T-Bill (in %)		-11.96***	-12.15***	-9.49**
		(-3.60)	(-4.15)	(-2.07)
Term spread (in %)		-3.59	-8.53	0.37
		(-0.52)	(-1.42)	(0.05)
1m Eurodollar spread (in %)		25.85***	10.57	22.00***
		(7.05)	(1.59)	(5.89)
Labor share		-1.39	7.80***	-0.79
		(-0.72)	(5.93)	(-0.49)
Vol. of daily index ret. (in %)		60.72***	21.56***	56.02***
		(3.87)	(2.30)	(4.11)
Mean daily index ret. (in %)		-238.52***	-346.55***	-216.95***
		(-4.08)	(-6.72)	(-4.26)
Constant	129.96***	526.17***	-423.93***	443.58***
	(9.80)	(2.72)	(-2.91)	(2.99)
Observations	4814	4814	10000	4529
R^2	0.01	0.49	0.36	0.50
Industry FE	No	Yes	Yes	Yes

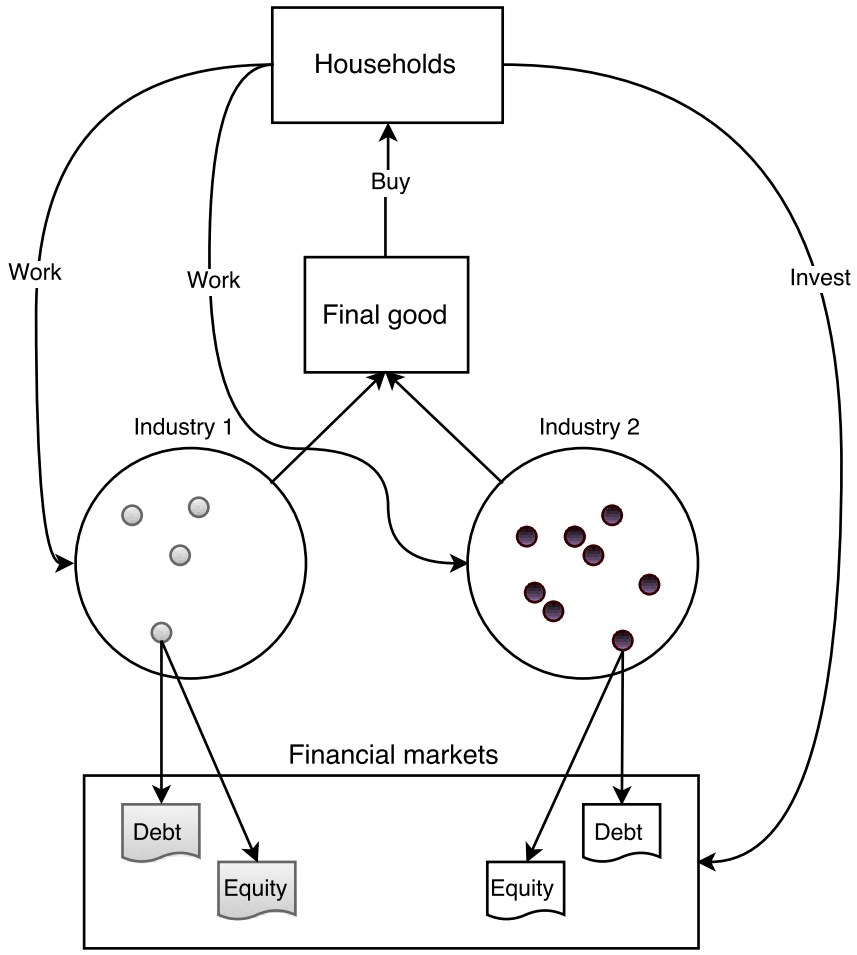
For a detailed description, refer to Table 2.10.

Table 2.13: Firm volatility, competition and the cross-section of yield spreads

	Census HHI			Fit HHI	Markup
	(1)	(2)	(3)	(4)	(5)
Competition × Ex. ret. volatility	18.90	22.04***	21.25***	44.96*	15.77*
	(1.21)	(2.88)	(2.72)	(1.71)	(1.86)
Mean excess return		-50.69***	-46.16***	-97.51***	-66.97***
		(-3.77)	(-4.13)	(-5.20)	(-5.53)
Equity characteristics					
Volatility excess return	50.32***	48.74***	39.89***	42.81***	47.73***
	(6.28)	(4.69)	(5.93)	(5.68)	(3.77)
Total debt to capitalization		-53.06	11.50	102.27	-50.37
		(-1.34)	(0.20)	(1.57)	(-1.17)
Tangibility		-22.25	22.74	-45.73***	-40.14
		(-0.87)	(0.35)	(-2.80)	(-1.45)
Book-to-market (log)		56.51***	46.51***	45.62*	54.24***
		(4.01)	(2.96)	(1.91)	(3.44)
Size (log)		-7.25*	-37.29***	-8.44***	-8.39
		(-1.78)	(-3.09)	(-3.42)	(-1.43)
Bond characteristics					
Credit rating		-10.31***	-2.76	-5.34***	-6.69***
		(-3.97)	(-0.59)	(-3.09)	(-2.32)
Years to maturity		1.86***	1.47***	2.00***	1.96***
		(5.07)	(6.36)	(8.91)	(4.66)
Coupon rate (in %)		14.84***	15.79***	7.96***	13.69***
		(5.83)	(3.76)	(3.96)	(5.56)
Issue size (log)		-5.80	-11.62***	-1.41	-5.45
		(-1.45)	(-2.94)	(-0.52)	(-1.02)
Trading turnover		-70.58***	-63.50***	-50.80***	-47.43***
		(-3.22)	(-2.80)	(-3.31)	(-2.45)
Macroeconomic variables					
3m T-Bill (in %)		-17.68***	-29.36***	-20.80***	-16.70***
		(-6.43)	(-5.92)	(-6.18)	(-3.49)
Term spread (in %)		-6.95	-25.47***	-15.08***	-6.85
		(-1.50)	(-3.76)	(-2.76)	(-1.10)
1m Eurodollar spread (in %)		29.73***	24.79***	11.75***	25.36***
		(8.51)	(7.22)	(1.99)	(8.80)
Labor share		-6.41***	-4.96***	2.65*	-6.18***
		(-2.94)	(-2.83)	(1.69)	(-3.16)
Vol. of daily index ret. (in %)		11.84	17.93	-27.67*	10.07
		(1.05)	(1.58)	(-1.83)	(0.79)
Mean daily index ret. (in %)		-259.50***	-247.97***	-321.26***	-233.59***
		(-5.03)	(-4.78)	(-8.09)	(-5.75)
Competition	-29.76	-29.12***	-41.74***	-74.91	0.35
	(-0.95)	(-2.37)	(-2.41)	(-1.46)	(0.02)
Constant	42.03***	1050.70***	1436.00***	67.45	982.92***
	(3.06)	(4.16)	(3.71)	(0.40)	(4.42)
Observations	4814	4814	4814	10000	4529
R^2	0.24	0.54	0.64	0.44	0.56
Industry FE	Yes	Yes	No	Yes	Yes
Firm FE	No	No	Yes	No	No

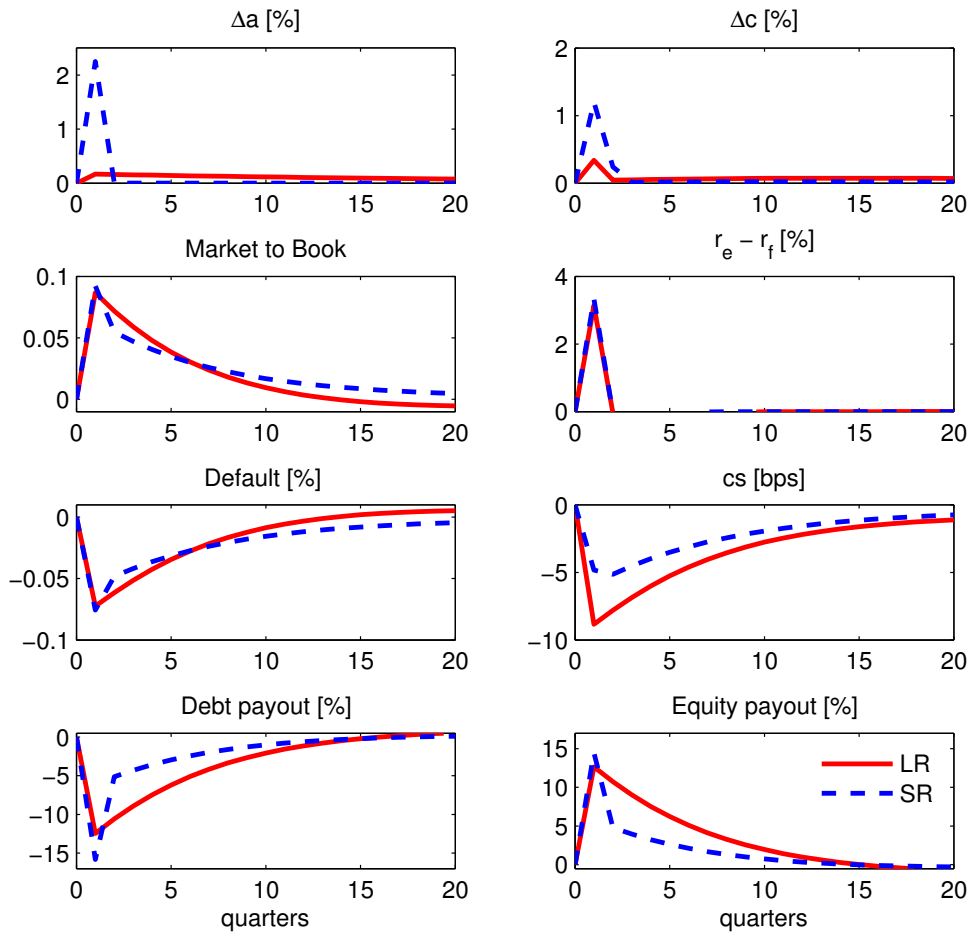
For a detailed description, refer to Table 2.11.

Figure 2.1: Economic environment



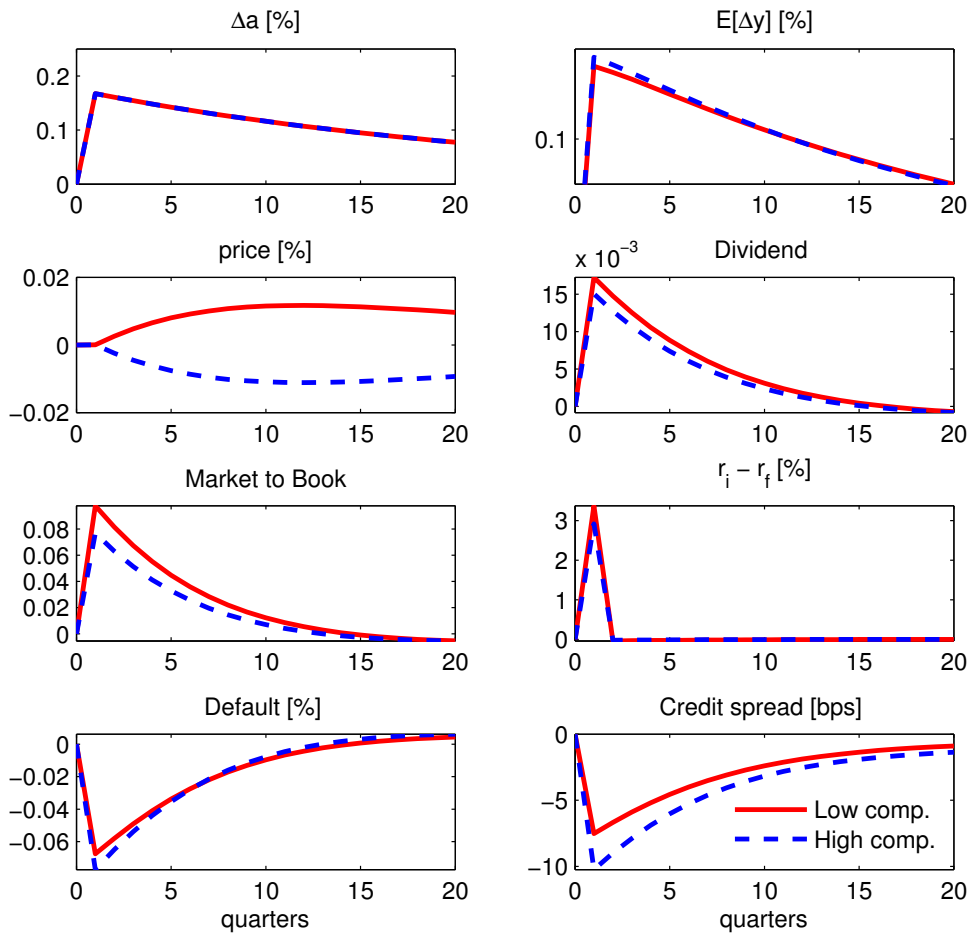
This figure depicts the economic environment of the benchmark model assuming two industries in the economy.

Figure 2.2: Aggregate impulse-response functions



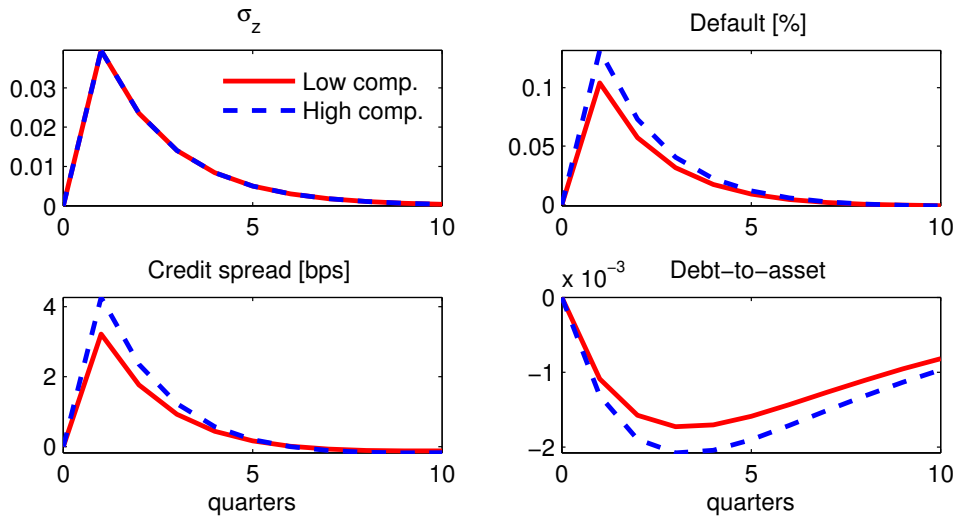
This figure plots the impulse-response function to a positive long-run (red solid) and short-run (blue dashed) productivity shock for productivity growth (Δa), consumption growth (Δc), the aggregate Market to Book ratio, the aggregate stock market excess return ($r_e - r_f$), the aggregate default probability (Default), the aggregate credit spread (cs), and the aggregate debt and equity payout. The plots are calculated as deviation from the steady state. Units, when applicable, are specified next to the plot title.

Figure 2.3: Industries impulse-response functions



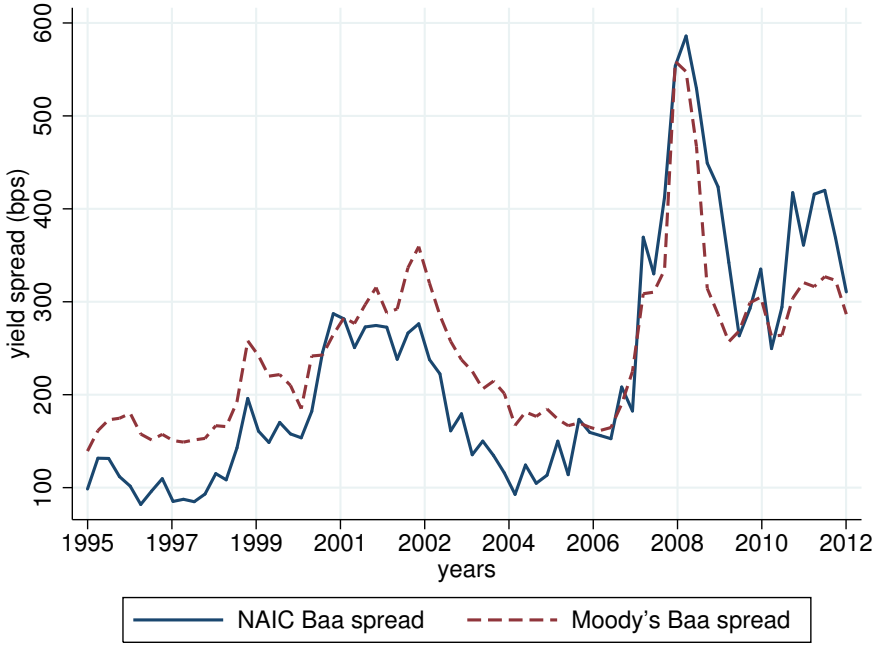
This figure plots the impulse-response functions to a positive long-run productivity shock for industries that differ in their degree of product market competition. The responses in the low-competition industry are plotted in red solid while those in the high-competition industry are plotted in dashed blue. Δa denotes productivity growth, $E[\Delta y]$ is the expected production growth in the industry, price is the industry output price relative to the aggregate price index, and $r_i - r_f$ is the industry stock excess return. The plots are calculated as deviation from the steady state. Units, when applicable, are specified next to the plot title.

Figure 2.4: Idiosyncratic risk shock and industry credit spreads



This figure plots the impulse-response functions to a positive idiosyncratic volatility shock for industries that differ in their degree of product market competition. The responses in the low-competition industry are plotted in red solid while those in the high-competition industry are plotted in dashed blue. σ_z denotes the volatility of the idiosyncratic shock. The plots are calculated as deviation from the steady state. Units, when applicable, are specified next to the plot title.

Figure 2.5: Time-series of Baa spread from NAIC sample and Moody's



This figure compares the quarterly time series of average Baa bond spreads reported by Moody's and the same series obtained from the NAIC bond transaction file between 1995 and 2012. Yield spreads are in basis points. Bonds from NAIC are in U.S. dollars and have no special features (call, put, convertibility, etc.).

Chapter 3

Competition, Markups, and Predictable Returns

3.1 Introduction

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

In this essay, we quantitatively link variation in industry concentration to the predictable component in equity risk premia. We show theoretically and empirically that measures of net business formation and markups forecast the equity premium. To this end, we build a general equilibrium asset pricing model with monopolistic competition and endogenous firm entry and exit. There are two endogenous components of measured productivity in the model, *product innovation* and *process innovation*. Product innovation refers to resources expended for the creation of new products and firms (e.g., Atkeson and Burstein (2011)). Process innovation refers to incumbent firms investing to upgrade their technology in response to the entry threat.

[1] See, e.g., Chatterjee and Cooper (2014), Devereux, Head, and Lapham (1996), Jaimovich and Floetotto (2008), Bilbiie, Ghironi, and Melitz (2012)

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

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

Due to spillover effects from process innovation, process innovation provides a powerful low-frequency growth propagation mechanism that leads to sizable endogenous long-run risks as in Kung (2015) and Kung and Schmid (2015).

Product innovation, on the other hand, implies a novel amplification mechanism for shocks at business cycle frequencies. A positive technology shock raises profits and increases firm creation, and vice versa (e.g., firm creation is procyclical). Also, the price elasticity of demand is positively related to the number of competitors in a particular industry. Thus, markups are countercyclical, which magnifies short-run risks. In booms (downturns), markups fall which expands (contracts) production more. Consequently, short-run dividends are very risky and the model produces a U-shaped term structure of equity returns, consistent with the empirical evidence from van Binsbergen, Brandt, and Koijen (2012).

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

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

3.1.1 Literature

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

Our starting point is an innovation-driven model of stochastic endogenous growth follow-

ing Kung (2015) and Kung and Schmid (2015). Also, Ward (2015) uses a similar framework as Kung and Schmid (2015) to estimate the transition dynamics of the IT revolution. Methodologically, this work builds on the literature on medium-term cycles pioneered by Comin and Gertler (2006) and Comin, Gertler, and Santacreu (2009). More generally, these papers are a stochastic extension of the endogenous growth models developed by Romer (1990), Aghion and Howitt (1990), and Peretto (1999). We extend the framework from Kung (2015) and Kung and Schmid (2015) to account for entry and exit along the lines of Bilbiie, Ghironi, and Melitz (2012) and Jaimovich and Floetotto (2008), and examine the asset pricing implications. We follow the multisector approach from Jaimovich and Floetotto (2008), which yields endogenous countercyclical markups. Opp, Parlour, and Walden (2014) obtain time-varying markups in a model of strategic interactions at the industry level.

This essay is related to a growing literature studying the link between product market competition and stock returns. Hou and Robinson (2006), Bustamante and Donangelo (2015), van Binsbergen (2015), and Loualiche (2014) examine the impact of competition on the cross section of stock returns. This essay is closely related to Loualiche (2014) who also considers a general equilibrium asset pricing model with recursive preferences and entry and exit. He finds that aggregate shocks to entry rates are an important factor priced in the cross-section of returns. Our work differs from these papers by focusing on the time-series implications and especially on how changes in competition endogenously generate time-varying risk premia. Our approach therefore provides distinct and novel empirical predictions.

This essay shares its focus with the growing literature on asset pricing in general equilibrium models with production. Papers that use habit preferences include Jermann (1998) and Boldrin, Christiano, and Fisher (2001). More recently, Tallarini (2000), Campanale, Castro, and Clementi (2010), Kuehn (2008), Ai (2010) and Kaltenbrunner and Lochstoer (2010) explore endogenous long-run consumption risks in real business cycle models with recursive preferences. Gourio (2012) and Gourio (2013) examine disaster risks. Particularly closely related are recent papers by Croce (2014), Backus, Routledge, and Zin (2007), Backus, Routledge, and Zin (2008), Gomes, Kogan, and Yogo (2009), Kogan and Papanikolaou (2010), Garleanu, Kogan, and Panageas (2009), Papanikolaou (2011), and Ai, Croce, and Li (2013) who examine the implications of long-run productivity risk and technological innovation for equity market returns. Our approach differs from their work as technological progress and productivity growth is endogenous in our model through process and product innovation. Furthermore, these papers focus on unconditional asset pricing moments, while we consider return predictability.

Our work is related to papers examining mechanisms that generate return predictability. Dew-Becker (2014) and Kung (2015) generate return predictability by assuming exogenous time-varying processes in risk aversion and the volatility of productivity, respectively. A number of papers show how predictability can be generated endogenously. Favilukis and Lin (2016) and Favilukis and Lin (2015), Kuehn, Petrosky-Nadeau, and Zhang (2012), Santos and

Veronesi (2006) work through frictions in the labor markets. In these papers, wages effectively generate operating leverage and they identify variables related to labor market conditions that can forecast stock returns. Gomes and Schmid (2010) explicitly model financial leverage in general equilibrium and find that credit spreads forecast stock returns through countercyclical leverage. Our channel, which operates through endogenous time-varying markups, is novel and allows us to empirically identify a new set of predictive variables for stock returns linked to time-varying competitive pressure.

Finally, this essay relates to models that try to explain the declining term structure of equity returns documented in van Binsbergen, Brandt, and Koijen (2012) and van Binsbergen, Hueskes, Koijen, and Vrugt (2013). Belo, Collin-Dufresne, and Goldstein (2015) show, in an endowment economy, that imposing a stationary and procyclical leverage ratio amplifies short-run risks and increases the procyclicality of short-term dividends, which leads to a downward sloping term structure. Croce, Lettau, and Ludvigson (2014) also generate this result using an endowment economy with limited information. Ai, Croce, Diercks, and Li (2012) and Favilukis and Lin (2016) show how vintage capital and wage rigidities, respectively, are alternative channels in a production-based framework. In contrast to these papers, endogenous countercyclical markups in our model provide a distinct but complimentary amplification mechanism for short-run risks that helps to explain the equity term structure.

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

3.2 Model

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

Overall the model is a real version of the endogenous growth framework of Kung (2015), extended to allow for entry and exit with multiple industries and time-varying markups. We start by briefly describing the household sector, which is quite standard. Then we explain in detail the production sector and the innovation process in our economy, and define the general equilibrium. Also, note that we use calligraphic letters to denote aggregate variables.

3.2.1 Household

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

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

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

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

where χ captures the Frisch elasticity of labor[5], and χ_0 is a scaling parameter. Note that we multiply the second term by an aggregate productivity trend $\mathcal{Z}_t^{1-1/\psi}$ to ensure that utility for leisure does not become trivially small along the balanced growth path.

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

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

$$\mathcal{C}_t + \mathcal{Q}_t\Omega_{t+1} + \mathcal{B}_{t+1} = \mathcal{W}_t\mathcal{L}_t + (\mathcal{Q}_t + \mathcal{D}_t)\Omega_t + \mathcal{R}_{f,t}\mathcal{B}_t, \tag{3.1}$$

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

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

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

Additionally, the labor supply condition states that at the optimum the household trades

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

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

off the wage rate against the marginal disutility of providing labor, so that

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

3.2.2 Production sector

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

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

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

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

where ν_1 is the elasticity of substitution between sectorial goods. The profit maximization problem of the firm yields the isoelastic demand for sector j goods,

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

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

In turn, each industry j produces sectoral goods using a finite number $N_{j,t}$ of differentiated goods $X_{i,j,t}$. Importantly, the number of differentiated goods in each industry is allowed to vary over time. Because each industry is atomistic, sectorial firms face an isoelastic demand curve with constant price elasticity ν_1. The sectoral goods are aggregated using a CES

production technology

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

where $N_{j,t}$ is the number of firms and ν_2 is the elasticity of substitution between intermediate goods. The multiplicative term $N_{j,t}^{1-\frac{\nu_2}{\nu_2-1}}$ is added to eliminate the variety effect in aggregation.

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

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

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

Intermediate Goods Intermediate goods production in each industry is characterized by monopolistic competition. In each period, a proportion δ_n of existing firms becomes obsolete and leaves the economy. The specification of the production technology is similar to Kung (2015). Intermediate goods firms produce $X_{i,j,t}$ using a Cobb-Douglas technology defined over physical capital $K_{i,j,t}$, labor $L_{i,j,t}$, and technology $Z_{i,j,t}$. We think of technology as intangible capital, such as patents. Firms rent their physical and technology from capital producers at a period rental rate of $r_{j,t}^k$ and $r_{j,t}^z$, respectively. Labor input is supplied by the household. We assume that technology is only partially appropriable and that there are spillovers across firms. The production technology is

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

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

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

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

Dividends for an intermediate goods firm is then given by

$$D_{i,j,t} = \frac{P_{i,j,t}}{P_{Y,t}} X_{i,j,t} - W_{j,t} L_{i,j,t} - r^k_{j,t} K_{i,j,t} - r^z_{j,t} Z_{i,j,t}.$$

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

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

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

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

$$\begin{aligned} V_{i,j,t} = & \max_{\left\{L_{i,j,t}, K_{i,j,t}, Z_{i,j,t}, \tilde{P}_{i,j,t}\right\}_{t\geq 0}} E_0 \left[\sum_{s=0}^{\infty} \mathcal{M}_{t,t+s} (1-\delta_n)^s D_{i,j,s}\right] \\ \text{s.t.} \quad & X_{i,j,t} = \frac{\mathcal{Y}_t}{N_{j,t}} \left(\tilde{P}_{i,j,t}\right)^{-\nu_2} \left(\tilde{P}_{j,t}\right)^{\nu_2-\nu_1} \end{aligned}$$

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

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

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

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

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

Physical capital producers lease capital $K^c_{j,t}$ to sector j for production in period t at a

rental rate of $r^k_{j,t}$. At the end of the period, they retrieve $(1-\delta_k)K^c_{j,t}$ of depreciated capital. They produce new capital by transforming $I_{j,t}$ units of output bought from the final goods producers into new capital via the technology[6]:

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

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

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

and the dividend is defined as $r^k_{j,t}K^c_{j,t} - I_{j,t}$.

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

$$\begin{aligned} V^k_{j,t} &= \max_{\{I_{j,t},K^c_{j,t+1}\}_{t\geq 0}} E_0\left[\sum_{s=0}^{\infty}\mathcal{M}_{t,t+s}(r^k_{j,s}K^c_{j,s} - I_{j,s})\right] \\ \text{s.t.} \quad & K^c_{j,t+1} = (1-\delta_k)K^c_{j,t} + \Phi_{k,j,t}K^c_{j,t} \end{aligned}$$

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

$$\begin{aligned} Q^k_{j,t} &= \Phi'^{-1}_{k,j,t} \\ Q^k_{j,t} &= E_t\left[\mathcal{M}_{t,t+1}\left(r^k_{j,t+1} + Q^k_{j,t+1}\left(1-\delta_k - \Phi'_{k,j,t+1}\left(\frac{I_{j,t}}{K^c_{j,t}}\right) + \Phi_{k,j,t+1}\right)\right)\right] \end{aligned}$$

where Q^k_t is the Lagrange multiplier on the capital accumulation constraint.

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

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

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

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

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

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

$$\begin{aligned}
Q^z_{j,t} &= \Phi'^{-1}_{z,j,t} \\
Q^z_{j,t} &= E_t\left[\mathcal{M}_{t,t+1}\left(r^z_{j,t+1} + Q^z_{j,t+1}\left(1-\delta_z - \left(\frac{S_{j,t+1}}{Z^c_{j,t+1}}\right)\Phi'_{z,j,t+1} + \Phi_{z,j,t+1}\right)\right)\right] \\
Z^c_{j,t+1} &= (1-\delta_z)Z^c_{j,t} + \Phi_{z,j,t}Z^c_{j,t}.
\end{aligned}$$

3.2.3 Entry & exit

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

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

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

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

$$E_t[\mathcal{M}_{t+1}V_{j,t+1}] = F_{E,j,t} \tag{3.2}$$

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

3.2.4 Equilibrium

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

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

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

coming from the production sector is defined as

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

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

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

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

The market clearing condition for the labor market is:

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

Imposing symmetry, the equation above implies

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

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

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

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

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

3.3 Economic mechanisms

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

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

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

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

3.3.1 Product innovation

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

Entry & Exit We start by examining the business creation process through the free entry condition, equation (3.2). Suppose there is a positive technology shock. As firms become more productive, the value of intermediate goods firms increases. Attracted by higher profit opportunities, new firms enter the market. Firms will enter the market up until the entry condition is satisfied, implying procyclical entry. On the other hand, as the number of firms in the economy grows, product market competition intensifies. Thus, the model is consistent with the empirical evidence that the degree of competitiveness in industries is procyclical, as documented, for example, in Bresnahan and Reiss (1991) and Campbell and Hopenhayn (2005).

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

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

In contrast, in our model the measure of firms within each sector is finite. Consequently, the intermediate producer takes into account its effect on the sectoral price index. This implies that the price elasticity of demand in a sector depends on the number of firms. As we show in the appendix, intermediate firms' cost minimization problem implies that the price markup

is[8]

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

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

$$\frac{\partial \phi_t}{\partial \mathcal{N}_t} = \frac{\nu_1 - \nu_2}{\left[-(\nu_2 - 1)\mathcal{N}_t + (\nu_2 - \nu_1)\right]^2} < 0. \tag{3.3}$$

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

The expression for the derivative of the markup with respect to the number of firms $\mathcal{N}_t$ implies that the sensitivity of markups to a marginal entrant depends on the number of firms in the industry. The nonlinear relation between markups and $\mathcal{N}_t$ is illustrated in figure 3.1. Adding a new firm to an already highly competitive industry (high $\mathcal{N}_t$) will have little impact on product market competition. In contrast, a marginal entrant will have a large impact on markups when the number of firms are low. Consequently, markups will rise more recessions than it falls in booms, which leads to countercyclical macroeconomic volatility.

3.3.2 Process innovation

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

Endogenous Productivity The aggregate production technology can be expressed as

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

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

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

through product innovation. Due to the spillover effect from process innovation, $\mathcal{Z}_t$ grows and is the endogenous trend component.

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

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

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

3.4 Quantitative implications

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

In order to quantitatively isolate the contributions of process innovation, product innovation and time-varying markups on aggregate risk and risk premia, we find it instructive to compare our benchmark model to another nested model. In the following, we refer to the benchmark model as model A. Model B features a CES aggregator, and abstracts away from entry and exit, so that the mass of firms and hence markups are constant.

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

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

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

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

and adjusting for potential nonlinearities in the empirical counterparts. Here, $\mathcal{S}_{L,t}$ is the labor

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

share in the model. We discuss further details about the construction of the markup measure in the appendix.

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

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

Table 3.1 presents the quarterly calibration. Panel A reports the values for the preference parameters. The elasticity of intertemporal substitution ψ is set to 1.8 and the coefficient of relative risk aversion γ is set to 10.0, both of which are standard values in the long-run risks literature (e.g. Bansal, Kiku, and Yaron (2008)). The labor elasticity parameter χ, is set to 3. This implies a Frisch elasticity of labor supply of 2/3, which is consistent with estimates from the microeconomics literature (e.g. Pistaferri (2003)). χ_0 is set so that the representative household works 1/3 of her time endownment in the steady state. The subjective discount factor β is calibrated to 0.995 to be consistent with the level of the real risk-free rate.

Panel B reports the calibration of the technological parameters. The capital share α is set to 0.33, and the depreciation rate of capital δ_k is set to 2.0%. These two parameters are calibrated to standard values in the macroeconomics literature (e.g. Comin and Gertler (2006)). The parameters related to R&D are calibrated following Kung (2015). The depreciation rate of the R&D capital stock δ_z is set to 3.75%, implying an annualized depreciation rate of 15%. The physical and R&D capital adjustment cost parameters ζ_k and ζ_z are both set at 0.738 to be consistent with the relative volatility of R&D investment growth to physical investment growth. The degree of technological appropriability η is calibrated to 0.065, in line with Kung (2015). The exogenous firm exit shock δ_n is set to 1%, slightly lower than in Bilbiie, Ghironi, and Melitz (2012). The price elasticity across (ν_1) and within (ν_2) industries are calibrated to 1.05 and 75, respectively to be consistent with estimates from Jaimovich and Floetotto (2008). κ is set to ensure an aggregate price markup of 20% in the deterministic steady state.

Panel C reports the parameter values for the exogenous technology process. The volatility parameter σ is set at 1.24% to match the unconditional volatility of measured productivity

growth. The persistence parameter ρ is calibrated to 0.985 to match the first autocorrelation of expected productivity growth. $a^\star$ is chosen to generate an average output growth of 2.0%.

3.4.1 Quantitative results

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

Implications for growth and cycles

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

Industry Cycles Table 3.2 reports basic industry moments from the benchmark model. The average markup and the mean profit share are broadly consistent with the data. Similarly, the model quantitatively captures industry cycles well by closely matching the volatilities and first autocorrelations of markups, intangible capital growth, profit shares and net entry rates. The last panel confirms the negative relation between the mass of firms and entry rates.

Figure 3.2 illustrates the underlying dynamics by plotting the responses of key variables to a positive one standard deviation exogenous technology shock. We focus on two model specifications, namely the benchmark model and model B (constant mass of firms and a constant markup). In the benchmark model, a positive technology shock raises valuations and thus triggers entry, as shown in the top left panel, and the mass of firms increases, as documented in the top right panel. In our benchmark model, firms take their effect on competitor firms into account when setting prices, so that increasing competitive pressure leads to falling markups, as shown in the lower left panel. Importantly, as the lower right panel illustrates, the entry margin significantly amplifies investment in technology. This is because in response to falling markups, demand for intermediate goods increase. To satisfy the higher demand, firms produce more and increase demand for both physical and technology capital.

In table 4.4, we report results from predictive regressions of aggregate growth rates on entry rates. Qualitatively, the model predicts that a rise in entry rates forecasts higher growth. Indeed, we empirically find that entry positively forecasts higher growth rates of output, consumption, and investment. While the signs are consistent with the model prediction throughout, statistical significance obtains only for shorter horizons, consistent with the notion that entry rates are highly cyclical. This suggests that variations in entry rates are an important determinant of business cycles fluctuations, which we examine next.

Business Cycles Table 3.4 reports the main business cycle statistics for models A, and B. While all of them are calibrated to match the mean and volatility of consumption growth, the cyclical behavior across models differs considerably.

The benchmark model quantitatively captures basic features of macroeconomic fluctuations in the data well. It produces consumption volatility, investment volatility and R&D volatility that are similar to their empirical counterparts. While investment volatility falls a bit short of the empirical analogue, Kung (2015) shows that incorporating sticky nominal prices and interest rate shocks in such a framework can help to explain the remaining volatility. The model generates volatile movements in labor markets, even overshooting the volatility of hours worked slightly. This is noteworthy, as standard macroeconomic models typically find it challenging to generate labor market fluctuations of the orders of magnitude observed in the data.

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

The amplification mechanism is illustrated in figure 3.3, which plots the impulse response functions of aggregate quantities. Upon impact of a positive exogenous productivity shock, output, investment and consumption all rise, and significantly more so than in a specification without the entry margin. The lower two panels show that both the responses of realized and and expected consumption growth are amplified in the benchmark model. Accordingly, the amplification mechanism increases the quantity of priced risk in the economy, since the stochastic discount factor in the model reflects both realized and predictable movements in consumption growth, given the assumption of Epstein-Zin preferences.

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

Table 3.5 provides empirical support for the model predictions regarding the cyclical behavior of entry rates, number of firms, and markups. The correlation of aggregate quantities and our empirical markup series is negative while the number of firms and entry rates are procyclical.

Asymmetric Cycles Fig. 3.4 plots the *difference* between the response of quantities to a positive shock and to a negative shock of the same magnitude. Any deviation from a zero difference reflects an asymmetry in responses at some horizon. Observe that model B, with constant firm mass and markups, generates no differential response at any horizon. That specification thus predicts symmetric cycles. This is quite different in our benchmark model.

It features differential responses at all horizons. The number of firms increases relatively more in expansions than it falls in recessions. Similarly, markups fall relatively more in upswings than they rise in downturns. On the other hand, investment, consumption and output rise by relatively less in good times than they fall in bad times, so that recessions are deeper in our benchmark economy.

The source of asymmetry in the model comes from the nonlinear relation between markups and the number of firms, which is highlighted in figure 3.5. This figure plots responses of quantities in the benchmark conditional on high and low number of firms. Note that the figure shows that both realized and expected consumption growth fall by relatively more in a scenario with a low mass of incumbent firms (i.e., during a recession). Consequently, this asymmetry implies conditional heteroscedasticity in fundamentals, including consumption growth. If we fit our simulated data to the consumption process of Bansal and Yaron (2004), we obtain:

$$\begin{aligned} z_{t+1} &= 0.961\ z_t + 0.433\ \sigma_t e_{t+1} \\ g_{t+1} &= z_t + \sigma_t \eta_{t+1} \\ \sigma^2_{t+1} &= 0.0046^2 + 0.975\ (\sigma^2_t - 0.0046^2) + 0.184 \times 10^{-6}\ w_{t+1} \end{aligned}$$

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

$$\begin{aligned} z_{t+1} &= 0.939\ z_t + 0.151\ \sigma_t e_{t+1} \\ g_{t+1} &= z_t + \sigma_t \eta_{t+1} \\ \sigma^2_{t+1} &= 0.0022^2 + 0.962\ (\sigma^2_t - 0.0022^2) + 8.282 \times 10^{-6}\ w_{t+1} \end{aligned}$$

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

Table 3.6 highlights that our time-varying macroeconomic volatility is also countercyclical. Using our markup series, we split the data sample into high and low markup episodes. This procedure allows us to compute moments conditional on markups. Given the countercyclicality of our markup measure, it is perhaps not surprising that average output, consumption and investment is lower in high markup episodes. More interestingly, however, we find that the volatilities conditional on high markups are also higher. In line with the discussion above, the model is consistent with these findings.

Asset pricing implications

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

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

Equity Premium Table 3.7 reports the basic asset pricing implications of the benchmark model and the alternative specification. Absent entry and exit, the risk free rate is about double its empirical counterpart (model B), while the benchmark model (model A) replicates a low and stable risk free rate. While we calibrate the endogenous average growth rate to coincide across all models, the amplification mechanism working through the entry margin coupled with countercyclical markups creates higher persistent uncertainty. Higher uncertainty increases the precautionary savings motive, driving down interest rates to realistic levels in our benchmark economy.

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

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

Competition and asset prices Imperfect competition and variations in competitive pressure is a key mechanism driving risk premia in our setup. We now provide some comparative statics of risk and risk premia with respect to average competitive pressure. We do this by reporting some sensitivity analysis of simulated data with respect to the sectoral elasticity of substitution between goods, ν_2. Fig. 3.6 reports the results by plotting key industry, macro and asset pricing moments for different values of ν_2.

Raising the sectoral elasticity of substitution between goods, ν_2, has two main effects on markups. First, by facilitating substitution between intermediate goods, it increases compe-

tition and therefore, holding all else constant, lowers markups. Second, by the virtue of our expression for the markup, equation (3.3), it raises the sensitivity of markups with respect to the number of incumbent firms, and thus, all else equal, makes markups more volatile. The first effect is an important determinant of the average growth rate of the economy, while the latter affects the volatility of growth.

With respect to the first effect, increasing ν_2 has two opposing implications. First, decreasing the average markup, holding all else equal, lowers monopoly profits in the intermediate sector. Second, a lower average markup increases the demand for intermediate goods inputs, which raises monopoly profits. In our benchmark calibration, the second effect dominates, and therefore more intense competition, and a higher average markup raises steady-state growth. On the other hand, a more volatile demand for intermediate goods inputs triggered by increasingly volatile markups leads to a more volatile growth path. This effect is exacerbated by increasingly cyclical entry as profit opportunities become more sensitive to aggregate conditions. The net effect is a riskier economy, which translates into a higher risk premium.

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

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

The left panel of figure 3.7 shows that the term structures of (unlevered) equity returns for the benchmark model and the model without entry and exit. Consistent with the standard long-run risks model, the model absent entry and exit produces an upward sloping term structure. In the benchmark model, countercyclical markups substantially amplify short-run risks and increase the procyclicality of short-term cash flows, which leads to a downward-sloping equity term structure for roughly the first five years. Note also that the risk premia on the very short-term strips are significantly higher than those at medium to long horizons, consistent with the data.

These cash flow dynamics are illustrated in the right panel of figure 3.7, which plots the impulse response function of the aggregate dividend growth rate to a positive exogenous technology shock in the benchmark model and the model without entry and exit. Both models generate a persistent increase in dividend growth at longer maturities through the process innovation channel. Thus, long-run cash flows are risky as reflected by the high long-horizon risk premia. On the other hand, industry and markup dynamics render short-run dividends significantly more risky in the benchmark model. Intuitively, dividends spike upwards on

impact as new firms enter more slowly in response to attractive profit opportunities. When competitive pressure rises, markups and dividends start falling until the aggregate demand for capital and R&D increases, triggering low-frequency movements in productivity that drive up dividends again.

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

Table 3.8 presents our main predictability results. Panel A first verifies standard long-horizon predictability regressions projecting future aggregate returns on current log price-dividend ratios in our data sample, and shows statistically significant and negative slope coefficients, and R^2's increasing with horizons up to five years. Perhaps more interestingly, we run the same regressions with simulated data from our benchmark model using a sample of equal length as the empirical counterpart. The top right panel reports the results. Consistent with the data, we find statistically significant and negative slope coefficients, with R^2's increasing with horizons up to five years and of similar magnitude as the data. Notably, the R^2's in our model simulations match their empirical counterparts remarkably well.

These predictability results in the model imply that the model generates endogenous conditional heteroscedasticity, as shocks to the forcing process, A_t, are assumed to be homoscedastic. Figure 3.8 confirms this. It shows the impulse response functions of the conditional risk premium and the conditional variance of excess returns to a positive exogenous technology shock, both in the benchmark model and in model absent entry and exit. While in model B neither the risk premium nor the conditional variance respond, they both persistently fall on impact in the benchmark model. With the entry margin and countercyclical markups, the risk premium and its variance are countercyclical, mirroring the endogenous countercyclical consumption volatility.

Our predictability results are related to the degree of competition, which we confirm in the remaining panels in table 3.8. Moreover, we present novel empirical evidence supporting this prediction. We use two measures of entry, our markup series, and the profit share as predictive variables. Panels B to E report the results from projecting future aggregate returns on these variables for horizons up to 5 years, in the model and in the data. In the model, the proxies for entry forecast aggregate returns with a statistically significant negative sign, while markups and profit shares forecast them with a statistically significant positive sign. We verify this empirical prediction in the data. The empirically estimated slope coefficients all have the predicted sign, and except for the profit share regressions, are statistically significant. We thus provide novel evidence on return predictability related to time-varying competitive

pressure.

It is well-known that statistical inference in predictive regressions is complicated through small sample biases. To illustrate that the sources of predictability in our model is robust to these concerns, we repeat the predictability regressions in a long sample of 200,000 quarters. For simplicity, we only report evidence from projecting returns on log price-dividend ratios. Table 3.9 shows the results from these regressions across model specifications. In case of the model without entry and exit, the explanatory power of the regressions are identically equal to zero. In contrast, the benchmark model produces R^2 that are still sizeable and increasing with horizon.

3.4.2 Extensions

Given the importance of markup dynamics for our asset pricing results, we next consider two extensions of the model that address properties of markups recently emphasized in the literature. Countercyclical movements in both price and wage markups are often recognized as the main source of fluctuations at higher frequency (e.g. Christiano, Eichenbaum, and Evans (2005)). The objective of this section is to investigate which features of markups appear relevant through the lens of asset pricing. In a first extension, we consider price markup shocks, in a way often considered in the DSGE literature (e.g. Smets and Wouters (2003), Justiniano, Primiceri, and Tambalotti (2010)). Second, in addition to price markups, we consider wage markups, whose relevance has recently been pointed out in the context of New Keynesian macroeconomic models (e.g. Gali, Gertler, and Lopez-Salido (2007)). The two extensions also allow us to gain further intuition about the mechanisms underlying the risk premia and predictability results in the benchmark model.

Markup shocks

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

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

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

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

Panels A, B, and C in table 3.10 report the main quantitative implications for asset returns and price-dividend ratios. The results are instructive. Panel B shows that introducing

uncorrelated stochastic markups has a 40 bps impact on the risk premia and increases significantly the volatility of the price dividend ratio. Consistent with the intuition developed earlier, the additional risk raises the precautionary savings motive and lowers the risk-free rate. When markups are exogenously countercyclical, panel C shows that the risk premium goes up by close to one percent. In line with the intuition explained in the benchmark case, countercyclical markups amplifiy uncertainty.

While countercyclical markups increase uncertainty, it does not generate predictability if the dynamics are symmetric. Table 3.11 illustrates this point by reporting the results from projecting future returns on log price-dividend ratios in models with exogenous markups. The results in panels A, B, and C show that none of these specifications generate any predictability. The missing ingredient is the asymmetry or conditional heteroscedasticity in markups that is generated endogenously in our benchmark model.

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

$$\begin{aligned} a_t &= (1-\rho_a)a^\star + \rho_a a_{t-1} + \sigma_t \epsilon_t \\ \sigma_t &= \sigma(1+\kappa_\emptyset \hat{\emptyset}_t) \end{aligned}$$

where $\kappa_\emptyset > 0$ captures the effects of markups on the conditional volatility of productivity shocks. We choose $\kappa_\emptyset$ to approximately replicate the asymmetry generated by the benchmark model. Results from the simulation are reported in Tables 3.10 and 3.11, panel D. While the average risk premium is barely affected, markup induced heteroskedasticity generates excess stock return predictability.

Wage markups

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

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

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

reflecting imperfect competition in the labor supply market. We specify the wage markup

process exogenously as an AR(1) process in logs

$$\log(\varnothing_t^w) \quad = \quad (1-\rho_{\varnothing}^w)\log(\varnothing^w) + \rho_{\varnothing}^w \log(\varnothing_{t-1}^w) + \sigma_{\varnothing}^w u_t^w$$

where u_t^w is a standard normal i.i.d. shock that has a contemporaneous correlation of ϱ^w with ϵ_t.

We augment the benchmark model with wage markups and compare asset pricing moments and predictability results for two additional specifications: (i) uncorrelated time-varying markups, and (ii) countercyclical wage markup. We calibrate the markup process to match the standard deviation and first autocorrelation of the wage markup reported in Gali, Gertler, and Lopez-Salido (2007): $\rho_{\varnothing}^w = 0.96$, and $\sigma_{\varnothing}^w = 2.88\%$. Whenever applicable, we set $\varrho^w = -0.45$ in order to replicate the -0.79 correlation between wage markups and output documented in Gali, Gertler, and Lopez-Salido (2007). The steady state markup is set to 1.2 (see e.g., Comin and Gertler (2006)).

The main asset pricing implications are collected in table 3.12 and predictability results are reported in table 3.13. Accounting for wage markups in addition to endogenous countercyclical price markups amplifies priced risk and raises risk premia. On the other hand, introducing wage markups only sharpens predictability when the dynamics are countercyclical.

3.5 Conclusion

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

Table 3.1: Quarterly calibration

Parameter	Description	Model
A. Preferences		
β	Subjective discount factor	0.995
ψ	Elasticity of intertemporal substitution	1.8
γ	Risk aversion	10
χ	Labor elasticity	3
B. Production		
α	Capital share	0.33
η	Degree of technological appropriability	0.065
δ_k	Depreciation rate of capital stock	2.0%
δ_k	Depreciation rate of R&D stock	3.75%
δ_n	Firm obsolescence rate	1.0%
ζ_k	Capital adjustment cost parameter	0.738
ζ_z	R&D capital adjustment cost parameter	0.738
ν_1	Price elasticity accross industries	1.05
ν_2	Price elasticity within industries	75
C. Productivity		
ρ	Persistence of a_t	0.985
σ	Conditional volatility of a_t	1.24%

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

Table 3.2: Industry moments

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

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

Table 3.3: Forecasts with growth of new incorporations

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

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

Table 3.4: Business cycle moments

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

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

Table 3.5: Industry cycles

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

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

Table 3.6: Summary statistics sorted on markups

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

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

Table 3.7: Asset pricing moments

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

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

Table 3.8: Stock return predictability

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

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

Table 3.9: Stock return predictability in the long sample

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

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

Table 3.10: Asset pricing moments: exogenous markups

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

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

Table 3.11: Stock return predictability: exogenous markups

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

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

Table 3.12: Asset pricing moments: wage markup

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

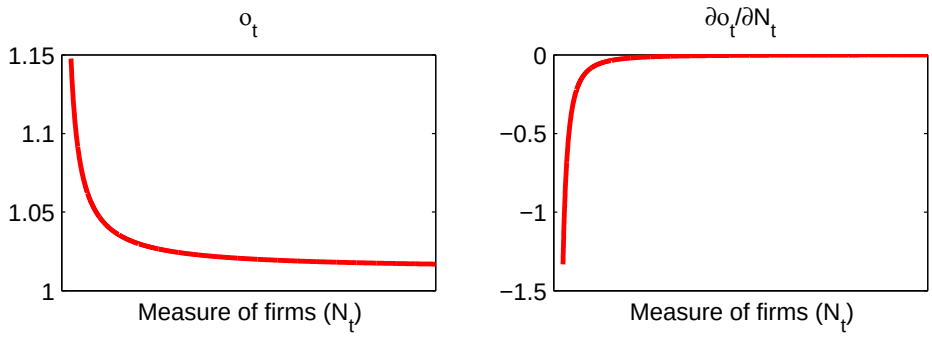
This table reports asset pricing moments for four specifications of the model with wage markups as well as the benchmark model. Column A reports moments for the benchmark model. Column B reports model moments for the benchmark model with time-varying, uncorrelated wage markup ($\sigma_{\varnothing}^{w}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

Table 3.13: Stock return predictability: wage markup

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

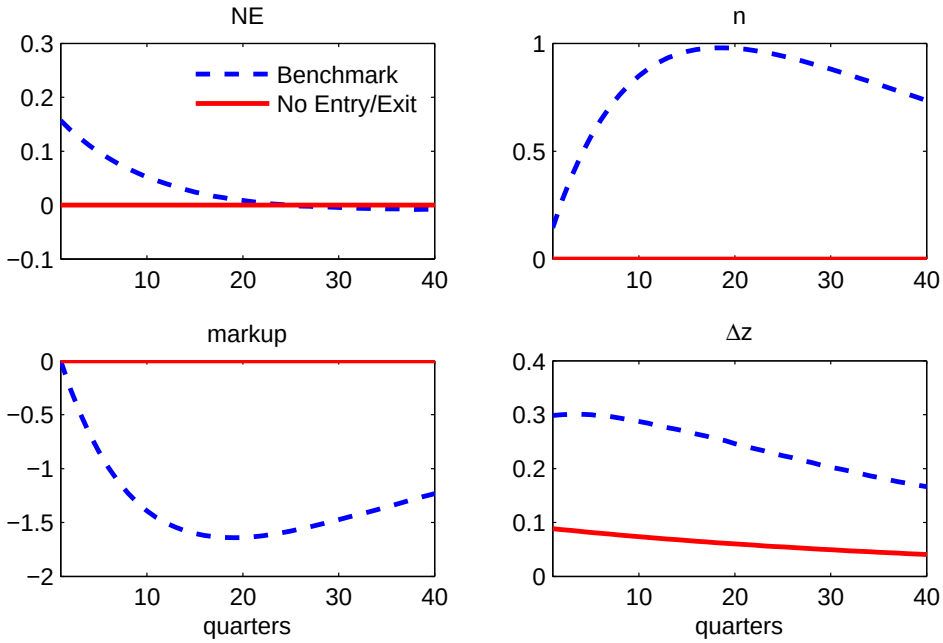
This table reports long sample excess stock return forecasts in the model with exogenous wage markup for horizons of one to five years using the log-price-dividend ratio: $r_{t,t+n}^{ex} - y_t^{(n)} = \alpha_n + \beta \log(P_t/D_t) + \epsilon_{t+1}$. Panel A reports the forecasting regressions for the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

Figure 3.1: Markup and number of firms



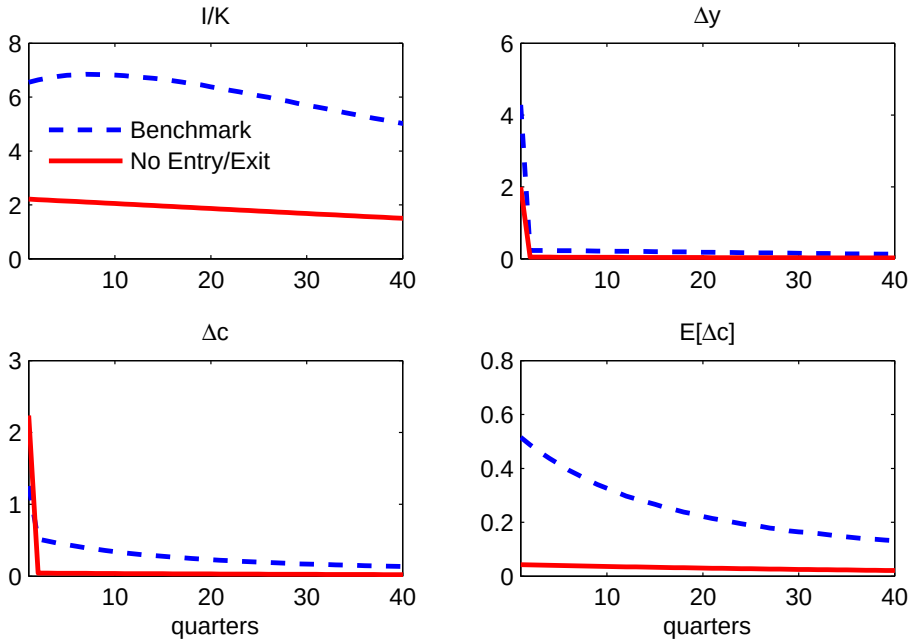
This figure plots the markup (left) and the first derivative of the markup with respect to $\mathcal{N}_t$ (left) as a function of the number of firms ($\mathcal{N}_t$) for the benchmark calibration of the model.

Figure 3.2: Impulse-response functions - productivity shock



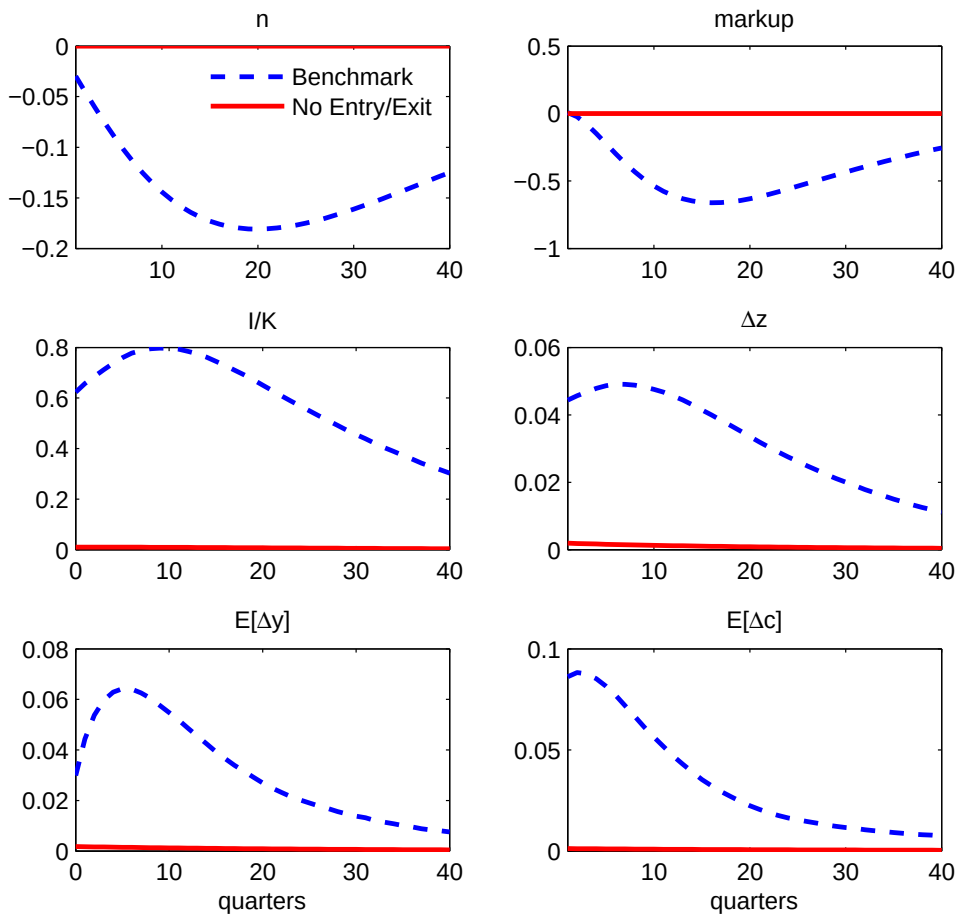
This figure plots the impulse response functions for entry (NE), the number of firms (n), the price markup, and the growth of technology (Δz) to a positive one standard deviation productivity shock for the benchmark model (dashed line), and the model without entry and exit (solid line). The parameters used to solve the no entry/exit model are the same as the benchmark model except for $a^\star$ that is modified to ensure an average growth rate of 2%, and σ that is modified to get a consumption growth volatility of 1.10%. All values on the y-axis are in annualized percentage log-deviation from the steady state.

Figure 3.3: Impulse-response functions - productivity shock (cont.)



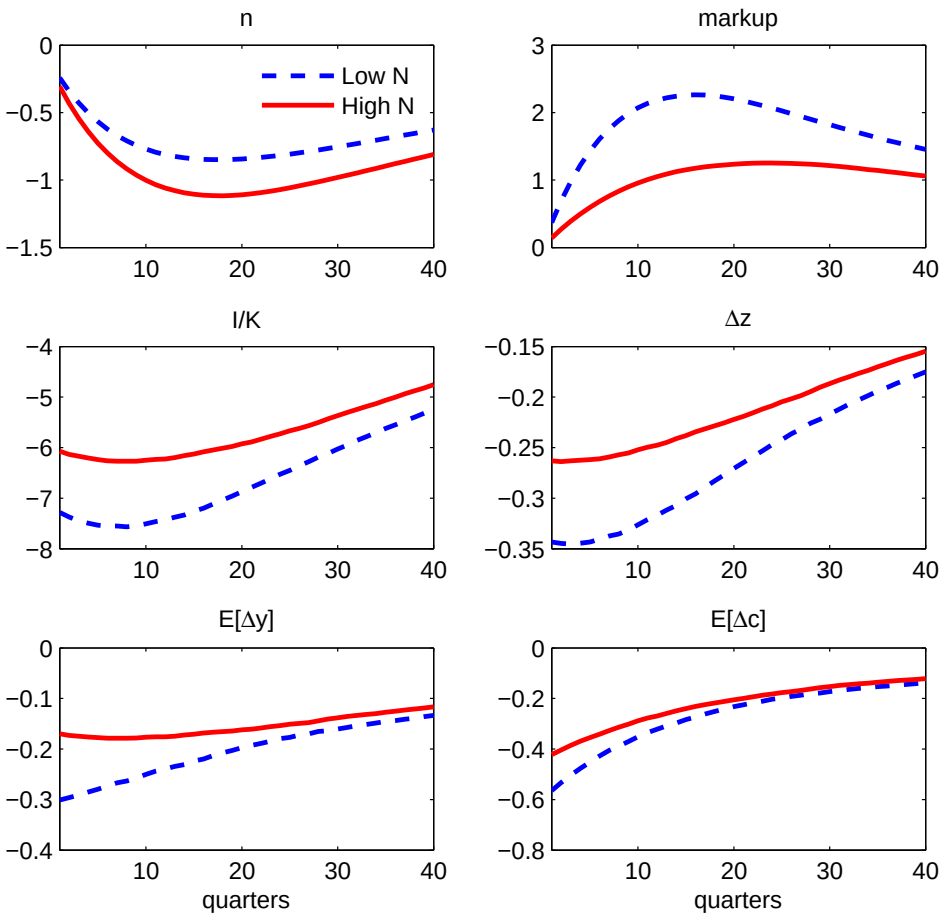
This figure plots the impulse response functions for the investment-to-capital ratio (I/K), output growth (Δy), consumption growth (Δc), and expected consumption growth ($E[\Delta c]$) to a positive one standard deviation productivity shock for the benchmark model (dashed line), and the model without entry and exit (solid line). The parameters used to solve the no entry/exit model are the same as the benchmark model except for $a^\star$ that is modified to ensure an average growth rate of 2%, and σ that is modified to get a consumption growth volatility of 1.10%. All values on the y-axis are in annualized percentage log-deviation from the steady state.

Figure 3.4: Business cycles asymmetry



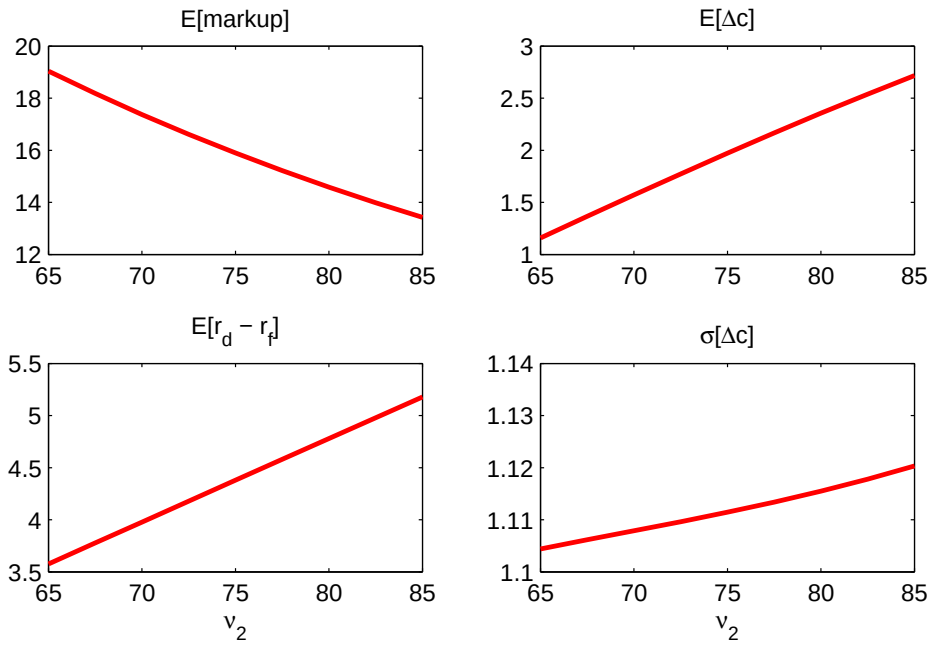
This figure plots the asymmetry in impulse response functions for the number of firms (n_t), the price markup, the investment-to-capital ratio (I/K), the growth in technology (Δz), and the expected growth rate of output ($E[\Delta y]$) and consumption ($E[\Delta c]$) in the benchmark model (dashed line),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

Figure 3.5: Business cycles and number of firms



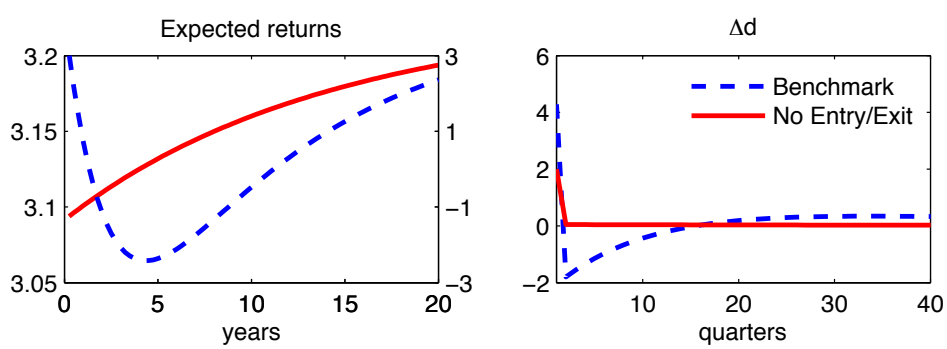
This figure plots the impulse response functions for the number of firms (n_t), the price markup, the investment-to-capital ratio (I/K), the growth in technology (Δz), and the expected growth rate of output ($E[\Delta y]$) and consumption ($E[\Delta c]$) in the benchmark model to a negative one standard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

Figure 3.6: Comparative statics: industry competition



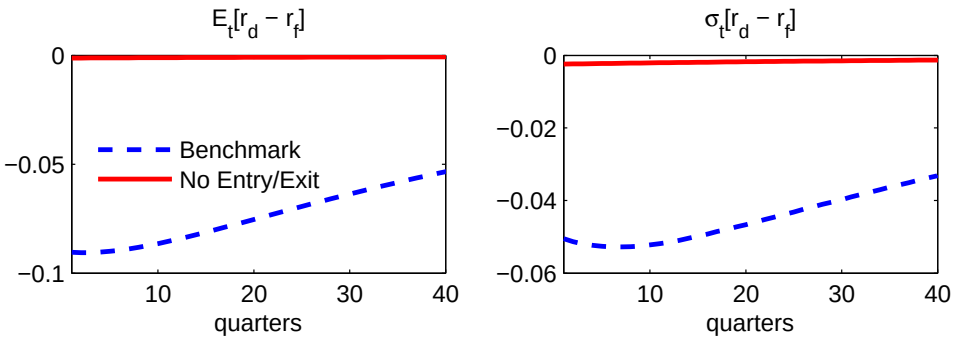
This figure plots the impact of varying the degree of competition within industry ν_2 on the average markup, the average output growth, the average equity premium, and the volatility of output growth. Values on y-axis are in annualized percentage units for expected consumption growth and the equity premium and in percentage units for the price markup.

Figure 3.7: Term structure of dividend strips



This figure plots the term structure of equity returns (left) and the response of dividend growth to a positive technology shock (right) in the benchmark model and in the model without entry and exit (constant markups). The parameters used to solve the no entry/exit model are the same as the benchmark model except for $a^\star$ that is modified to ensure an average growth rate of 2%, and σ that is modified to get a consumption growth volatility of 1.10%. All values on the y-axis are in annualized percentage.

Figure 3.8: Business cycles and volatility



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

Chapter 4

Government Maturity Structure Twists

4.1 Introduction

During the global financial crisis, central banks, constrained by the zero lower bound (ZLB) on nominal interest rates, conducted open market operations on an unprecedented scale. The series of quantitative easing (QE) operations between 2008 and 2014 reduced the average duration of U.S. government liabilities (including reserve balances) held by the public by over 20%. Fig. 4.1 illustrates the impact of the QE operations on average maturity.[1] Given that the risk profiles of bonds vary by maturity, rebalancing the maturity structure also changes the expected return on the government bond portfolio. In the fiscal theory of the price level, variation in government discount rates affect the price level through the intertemporal government budget equation. In this essay, we explore the role of this *fiscal discount rate channel* for open market maturity restructuring operations. We also highlight the importance of the term structure of interest rates, in the fiscal theory, as a transmission channel for open market maturity operations.

To quantitatively examine these issues we build a small-scale New Keynesian model that has several distinguishing features. First, households have recursive preferences (e.g., Epstein and Zin (1989)) which allows the model to generate realistic term premia. Second, the supply of nominal government bonds over various maturities is time-varying (e.g., Greenwood and Vayanos (2014)). Third, the monetary/fiscal policy mix is subject to regime shifts between monetary- and fiscally-led regimes (e.g., Davig and Leeper (2007a), Bianchi and Ilut (2014), and Bianchi and Melosi (2014)). In the monetary-led regime, the Taylor principle is satisfied and the monetary authority controls inflation while the fiscal authority stabilizes the real value of debt. In the fiscally-led regime, the fiscal authority determines the price level through

[1] When calculating the average maturity of privately-held public debt we include reserve balances with Federal Reserve Banks. Reserve balances are included since the Federal Reserve started to pay interests on reserves in October 2008 making them, effectively, government debt.

the government budget equation while the monetary authority stabilizes debt and anchors expected inflation.

We show that in the presence of a fiscally-led regime, a nonzero slope of the nominal yield curve implies that debt maturity restructuring affects inflation. To isolate the effects of debt maturity, we consider *self-financing* shocks to the maturity structure that keep the market value of total government bonds the same immediately after the operation (e.g., Maturity Extension Program), but is allowed to adjust freely afterwards. When the financing costs of bonds vary by maturity, changing the financing mix also alters the government cost of capital. In the fiscally-led regime, the price level is determined by the ratio of nominal debt to the present value of surpluses. Thus, variation in the government discount rate changes the fiscal backing, and the price level adjusts to revalue debt to satisfy the present value condition. Sticky prices are required for this channel to have real effects. Interpreted more generally, these results illustrate how accounting for heterogeneity in expected returns across different assets in the fiscal theory breaks Wallace (1981) neutrality.

The slope of the nominal yield curve dictates the effects of maturity restructuring for the fiscal discount rate channel. When the yield curve is upward-sloping (downward-sloping), shortening the maturity structure in a self-financing operation is contractionary (expansionary). Taking interest rates as given, increasing the proportion of short-term debt in the maturity structure when the yield curve is upward-sloping implies that the government is refinancing at a lower rate. Lowering the government discount rate puts upward pressure on the real value of debt. In anticipation of this, households increase demand for bonds and decrease demand for consumption goods, which drives down the price level. With sticky prices, the fall in the price level is sluggish, so that prices are temporarily too high, which leads to a contraction in production and output. The opposite results are obtained when the yield curve is downward-sloping. Furthermore, the endogenous yield curve reactions reinforce our fiscal discount rate channel.

Under persistent deficits, the discount rate effects from maturity restructuring are attenuated, and can potentially be reversed if the deficit is particularly severe. Consider the case where the yield curve is upward-sloping, then shortening the maturity lowers the discount rate persistently. With a budget deficit today, discounting temporarily negative surpluses at a lower rate has a negative effect on the present value of the fiscal backing. One the other hand, since the deficit is temporary, discounting positive future surpluses at a lower rate has a positive effect on the present value. Hence, if the deficit today is particularly severe or persistent, the discount rate effects from the deficit component can potentially dominate.

When the yield curve is flat, debt maturity operations are neutral even in the presence of a fiscally-led regime since the cost of financing is the same across maturities. In a monetary-led regime without the possibility of regime shifts, the economy is insulated from fiscal disturbances as surplus policy will completely offset changes to the debt burden. Thus, maturity restructuring is also neutral in this case regardless of the slope of the yield curve. However,

with regime shifts and rational expectations, the possibility of entering the fiscally-led regime and a nonzero slope is also sufficient for debt maturity non-neutrality in the monetary-led regime.

Since the nominal yield curve provides the key transmission channel for the maturity structure shocks, we also calibrate our model to explain key term structure facts. Supply shocks in the model drive countercyclical real marginal costs which generate negative co-movement between consumption growth and inflation similar to Kung (2015). With recursive preferences, these dynamics produce sizable bond risk premia (e.g., Piazzesi and Schneider (2007) and Bansal and Shaliastovich (2013)) and the model matches the average five-year term spread. The model also replicates the persistence in yields and the forecasting ability of the term spread for macroeconomic aggregates in the data.

We consider an extended version of the model to assess the quantitative importance of the fiscal discount rate channel for QE operations involving maturity twists. In the extended model, we incorporate market segmentation, short-term liquidity demand shocks, and a zero lower bound (ZLB) constraint to capture other relevant features for these maturity operations. Also, we start the economy off in the monetary-led regime (with a possibility of entering the fiscally-led regime) and a budget deficit. During the Great Recession, the yield curve was significantly upward-sloping, and we find that the fiscal discount rate channel implies contractionary effects from shortening debt maturity. Indeed, using an estimated process for the maturity structure of debt and assuming that the economy starts off in the monetary-led regime, we find that the fiscal channel significantly dampened expansionary effects from increasing short-term liquidity. In particular, the fiscal channel dampened inflation responses by 53% and output by 60% during QE2. Thus, we highlight a potential "cost" of QE operations.

4.1.1 Related literature

The literature examining how the interactions between monetary and fiscal policy determine the price level begins with Sargent and Wallace (1981) who show that permanent fiscal deficits have to eventually be financed by seignorage when the government only issues real debt. Further, the money creation leads to inflation. Building on this paper, the fiscal theory of the price level (FTPL) shows that when the government issues nominal debt and does not provide the necessary fiscal backing, deficits are linked to current and expected inflation through the intertemporal government budget equation, without necessarily relying on seignorage revenues (e.g., Leeper (1991), Sims (1994), Woodford (1994), Woodford (1995), Woodford (2001), Schmitt-Grohé and Uribe (2000), Cochrane (1999), Bassetto (2002), Bassetto (2008), Cochrane (2005), and Cochrane (2011)).

Our essay relates to the literature examining the role of the government maturity structure for policy. Angeletos (2002) and Buera and Nicolini (2004) demonstrate how a portfolio of non-state-contingent real debt of different maturities can replicate the complete markets allocation with state-contingent securities. Lustig, Sleet, and Yeltekin (2008), Leeper and Zhou

(2013), and Faraglia, Marcet, Oikonomou, and Scott (2013) analyze optimal maturity structure of nominal debt in DSGE models with distortionary taxes and market incompleteness. Greenwood and Vayanos (2014), Chen, Curdia, and Ferrero (2012), and Guibaud, Nosbusch, and Vayanos (2013) analyze nominal maturity restructuring polices in models with preferred habitats. Reis (2015) studies maturity operations in a framework that features an exogenous fiscal limit and endogenous default. We differ from these papers by highlighting a distinct but complementary mechanism for maturity structure non-neutralities. Notably, we demonstrate how accounting for heterogeneity in risk across nominal bonds in the context of the fiscal theory provides a channel for the maturity structure to affect inflation without market segmentation or distortionary taxation.

Our essay is most closely related to Cochrane (2001) who also considers the maturity structure in the fiscal theory. In a partial equilibrium setting with a constant interest rate, Cochrane illustrates how restructuring the face value of nominal government debt alters the timing of inflation. In contrast, we focus on *market value* restructuring operations (i.e., holding the market value of debt constant initially), and highlight how a nonzero yield curve slope is essential for such open market procedures to affect inflation through the fiscal discount rate channel. Furthermore, we also evaluate our mechanism in a Dynamic Stochastic General Equilibrium (DSGE) framework with an estimated process for the average duration of public debt to quantitatively examine effects of maturity restructuring policies.

The Markov-switching Dynamic Stochastic General Equilibrium (DSGE) framework builds on Davig and Leeper (2007a), Davig and Leeper (2007b), Farmer, Waggoner, and Zha (2009), Bianchi and Ilut (2014), and Bianchi and Melosi (2014). In particular, Bianchi and Ilut (2014) and Bianchi and Melosi (2014) also consider stochastic shifts between monetary- and fiscally-led policy regimes. However, our focus is on how the interaction between risk composition and the fiscally-led policy regime (or expectations of entering the regime) propagates maturity restructuring shocks.

Our essay connects to the theoretical literature studying the effects of unconventional monetary policy and transmission channels. Cúrdia and Woodford (2010), Gertler and Karadi (2011), and Araújo, Schommer, and Woodford (2015) analyze the role of financial frictions for central bank purchases of risky assets. Correia, Farhi, Nicolini, and Teles (2013) demonstrate how distortionary tax policy can deliver an economic stimulus when monetary policy is constrained at the zero lower bound. Reis (2015) explores QE operations in an environment with an exogenous fiscal limit, default risk, and a fiscal regime. Gomes, Jermann, and Schmid (2013) illustrate how incorporating nominal corporate debt in a DSGE framework provides an important source of monetary non-neutrality. We offer an alternative transmission channel for thinking about unconventional monetary policy that relies on the interaction between the fiscal theory and bond risk premia to break Wallace neutrality.

More broadly, this essay relates to general equilibrium models that link policy to risk premia. For example, Rudebusch and Swanson (2012), Palomino (2012), Dew-Becker (2014)

Campbell, Pflueger, and Viceira (2014), and Kung (2015) link asset prices to monetary policy. Croce, Kung, Nguyen, and Schmid (2012), Pastor and Veronesi (2012), Gomes, Michaelides, and Polkovnichenko (2013), and Belo, Gala, and Li (2013) look at fiscal policy and asset prices.

The chapter is organized as follows. Section 2 provides a simple partial equilibrium model to qualitatively illustrate the basic mechanisms. Section 3 presents the benchmark model. Section 4 examines the quantitative implications of the model and considers a policy experiment relating to the QE operations. Section 5 concludes.

4.2 Simple model

In this section we propose a simple partial equilibrium model to illustrate how the risk composition of the government portfolio affects inflation. Using approximate analytical solutions, we explicitly show how the impact of changing debt maturity on inflation depends on the slope of the yield curve. These concepts are then formalized and quantified in the benchmark general equilibrium model.

4.2.1 Government budget equation

We assume that the government finances nominal surpluses by issuing one- and two-period nominal debt. The flow government budget constraint at time t is therefore given by:

$$B_{f,t}^{(1)} + Q_t^{(1)} B_{f,t}^{(2)} = Q_t^{(1)} B_{f,t+1}^{(1)} + Q_t^{(2)} B_{f,t+1}^{(2)} + S_t, \tag{4.1}$$

where $B_{f,t}^{(n)}$ is the nominal face value of debt issued by the treasury with a maturity of n periods, Q_t^n is the corresponding nominal bond price, and $S_t \equiv T_t - G_t$ is the nominal primary surplus. The relative supply of government bonds (portfolio weights) is assumed to be exogenous and constant. In particular, we define the relative supply of the one-period bond (in terms of market values) as:

$$\frac{Q_t^{(1)} B_{f,t+1}^{(1)}}{Q_t^{(1)} B_{f,t+1}^{(1)} + Q_t^{(2)} B_{f,t+1}^{(2)}} \equiv w_t = w, \tag{4.2}$$

which we assume to be constant.

4.2.2 Monetary/fiscal policy

We assume that the monetary/fiscal policy mix is permanently characterized by a fiscally-led policy regime (without regime shifts). We consider a particular policy mix that allows for analytical tractability.

Fiscal policy

Fiscal policy sets the real surplus independently of debt. We assume that $s_t \equiv S_t/P_t$, follows an exogenous stochastic process:

$$s_t = (1-\rho_s)\bar{s} + \rho_s s_{t-1} + \sigma_s \epsilon_{s,t}, \tag{4.3}$$

where $\epsilon_{s,t} \sim iid\ N(0,1)$.

Monetary policy

Monetary policy sets the short-term nominal interest rate independently of inflation. Specifically, the nominal short rate is determined by an exogenously specified nominal stochastic factor M_t via the Euler equation:

$$r_t \equiv \log(R_t) = -\log\left(E_t[M_{t+1}]\right).$$

4.2.3 Stochastic discount factor

The log nominal stochastic discount factor, $m_t \equiv log(M_t)$, is assumed to follow an ARMA(1,1) as in Backus and Zin (1994b):

$$-m_t = (1-\rho)\delta - \rho m_{t-1} + \epsilon_t + \theta\epsilon_{t-1}, \tag{4.4}$$

where $\epsilon_t \sim iid\ N(0,\sigma^2)$. This specification of the pricing kernel allows for various average slopes of the yield curve.

Bond pricing

The nominal price of a n-period nominal zero-coupon bond can be written recursively using the Euler equation:

$$Q_t^{(n)} = E_t\left[M_{t+1}Q_{t+1}^{(n-1)}\right], \tag{4.5}$$

where $Q^{(0)} \equiv 1$ and $Q_t^{(1)} \equiv 1/R_{t+1}^{(1)}$. The corresponding yield-to-maturity for the n-period bond is defined as:

$$y_t^{(n)} \equiv -\frac{1}{n}\log Q_t^{(n)}. \tag{4.6}$$

When yields are persistent, there is tight relation between the yield spread and the corresponding return spread:

$$E[\log(R_t^{(2)}) - \log(R_t^{(1)})] \approx 2 \cdot E[y_t^{(2)} - y_t^{(1)}], \tag{4.7}$$

where $R_t^{(2)} \equiv Q_t^{(1)}/Q_{t-1}^{(2)}$ and $R_t^{(1)} \equiv 1/Q_{t-1}^{(1)}$.[2]

4.2.4 Fiscal discount rate channel

We can rewrite the flow government budget constraint in terms of market values of debt and returns:

$$R_t^{(1)} B_t^{(1)} + R_t^{(2)} B_t^{(2)} = B_{t+1}^{(1)} + B_{t+1}^{(2)} + S_t, \tag{4.8}$$

where $B_t^{(i)} \equiv Q_{t-1}^{(i)} B_{f,t}^{(i)}$, $R_t^{(2)} \equiv Q_t^{(1)}/Q_{t-1}^{(2)}$, $R_t^{(1)} \equiv 1/Q_{t-1}^{(1)}$, $B_t \equiv B_t^{(1)} + B_t^{(2)}$, $R_t^g \equiv wR_t^{(1)} + (1-w)R_t^{(2)}$. Iterating Eq. (4.8) forward and imposing the transversality condition, we obtain the present value formula relating the real value of government liabilities to the present value of future surpluses (see C.3 for derivation):

$$b_t \equiv \frac{B_t}{P_t} = E_t \sum_{i=0}^{\infty} \left[\frac{s_{t+i}}{\prod_{j=0}^{i} \left\{ R_{t+j}^g / \Pi_{t+j} \right\}} \right]. \tag{4.9}$$

In the fiscally-led regime, the price level, P_t, is determined by the intertemporal government budget equation (Eq. (4.9)). Any current or expected fiscal disturbances directly affect the price level.

The slope of the nominal yield curve determines the relative cost of debt financing across maturities. When the yield curve is not flat, rebalancing the maturity structure changes the government cost of capital, R_g, which directly affects the price level through Eq. (4.9). Importantly, the sign of effect on the price level depends on the sign of the slope of the nominal yield curve. Suppose the yield curve is downward-sloping, then shortening the maturity structure increases R^g. To satisfy the intertemporal government budget equation, the increase in discount rates is compensated by a devaluation of the debt portfolio through inflation (increases in P_t). The effects are reversed when the yield curve is upward-sloping and neutral when the yield curve is flat. If we add *sticky prices* (and the slope is nonzero), rebalancing the maturity structure will also have real effects, so that the fiscal discount rate channel violates *Wallace neutrality.*

Fig. 4.2 illustrates comparative statics from shortening the maturity structure (i.e., increasing w) on the government discount rate (top figure) and inflation (bottom figure). We show these comparative statics for parameterizations of the SDF where the nominal yield curve is upward-sloping (solid line), flat (line with circles), downward-sloping (dashed line). Consistent with the intuition above, the sign of the slope determines the sign of the responses to changes in maturity restructuring.

[2] Note that $\log(R_t^{(2)}) = 2y_{t-1}^{(2)} - y_t^{(1)}$ and $\log(R_t^{(1)}) = y_{t-1}^{(1)}$. Thus, if yields are persistent, then $E[R_t^{(2)} - R_t^{(1)}] \approx E[2y_t^{(2)} - 2y_t^{(1)}] = 2 \cdot E[y_t^{(2)} - y_t^{(1)}]$.

Approximate analytical solution

We can directly link the impact of debt maturity changes on inflation to the slope by means of an approximate analytical solution. Define $B_t \equiv B_t^{(1)} + B_t^{(2)}$ as the total nominal market value of the debt portfolio. Substituting this definition in the government budget equation (Eq. (4.8)), we can write the return on the government bond portfolio as:

$$R_t^g = \frac{B_{t+1} + S_t}{B_t}. \tag{4.10}$$

Rewriting this return in terms of real surpluses and debt:

$$\frac{R_t^g}{\Pi_t} = \frac{b_{t+1} + s_t}{b_t},$$

where lowercase variables denote real variables. Define $\log(x) \equiv \widetilde{x}$, and take logs of Eq. (4.11):

$$\widetilde{R}_t^g - \widetilde{\Pi}_t = \widetilde{b}_{t+1} + \log\left(1 + \frac{s_t}{b_{t+1}}\right) - \widetilde{b}_t. \tag{4.11}$$

Since surpluses can be negative, substitute $s_t = \tau_t - g_t$ (τ_t and g_t are real taxes and government expenditures, respectively) into Eq. (4.11) and rearrange:

$$\widetilde{R}_t^g - \widetilde{\Pi}_t = \widetilde{b}_{t+1} - \widetilde{b}_t + \log\left(1 + \exp\left(\widetilde{\tau}_t - \widetilde{b}_{t+1}\right) - \exp\left(\widetilde{g}_t - \widetilde{b}_{t+1}\right)\right). \tag{4.12}$$

Following Berndt, Lustig, and Yeltekin (2012), log-linearize Eq. (4.12) with respect to the log tax-to-debt and the log government expenditure-to-debt ratios around the steady-state:

$$\widetilde{R}_t^g - \widetilde{\Pi}_t = \theta_1 \widetilde{b}_{t+1} - \widetilde{b}_t + \theta_0 + (1 - \theta_1)(\mu_\tau \widetilde{\tau}_t - \mu_g \widetilde{g}_t), \tag{4.13}$$

where $\theta_1, \theta_0, \mu_\tau$, and μ_g are parameters of linearization that are defined in C.4. Iterating Eq. (4.13) forward and imposing the transversality condition:

$$\widetilde{b}_t = \frac{\theta_0}{1 - \theta_1} + \sum_{j=0}^{\infty} \theta_1^j \left((1 - \theta_1)(\mu_\tau \widetilde{\tau}_{t+j} - \mu_g \widetilde{g}_{t+j}) - \widetilde{R}_{t+j}^g + \widetilde{\Pi}_{t+j}\right). \tag{4.14}$$

Take expectations of Eq. (4.14), solve for expected inflation, and substitute $\widetilde{R}_t^g = \omega \widetilde{R}_t^{(1)} + (1 - \omega)\widetilde{R}_t^{(2)}$:

$$\frac{E\left[\widetilde{\Pi}_t\right]}{1 - \theta_1} = E\left[\widetilde{b}_t\right] - \frac{\theta_0}{1 - \theta_1} - E\left[\mu_\tau \widetilde{\tau}_t - \mu_g \widetilde{g}_t\right] + \frac{E\left[\widetilde{R}_t^{(2)} - \omega(\widetilde{R}_t^{(2)} - \widetilde{R}_t^{(1)})\right]}{1 - \theta_1}. \tag{4.15}$$

Taking derivative of expected inflation with respect to ω we see that the sign and magnitude from shortening maturity on inflation depends negatively on the average slope of the nominal

yield curve:

$$\frac{dE\left[\widetilde{\Pi}_t\right]}{d\omega} = -E\left[\widetilde{R}_t^{(2)} - \widetilde{R}_t^{(1)}\right] \approx -2 \cdot E[y_t^{(2)} - y_t^{(1)}]. \tag{4.16}$$

where the last approximate equality uses Eq. (4.7). Thus, the impact of shortening maturity on expected inflation is negatively related to the slope of the nominal yield curve.

Other asset classes

The fiscal discount rate channel also extends beyond maturity restructuring operations to other asset classes with different risk profiles. Accounting for differences in expected returns across financing instruments, regardless of maturity, in the fiscal theory provides a direct channel for changes in the government portfolio to affect inflation. Assume now that the government issues one-period riskless nominal debt $B_t^{(1)}$ and one-period defaultable nominal debt D_t:

$$R_t^{(1)} B_t^{(1)} + R_t^{(d)} D_t \quad = \quad B_{t+1}^{(1)} + D_{t+1} + S_t. \tag{4.17}$$

The return of the defaultable bond is:

$$R_t^{(d)} \quad \equiv \quad 1/Q_{t-1}^{(d)}, \tag{4.18}$$

where the price, $Q_t^{(d)}$, is given by the Euler equation:

$$Q_t^{(d)} \quad = \quad E_t\left[\frac{M_{t+1}}{\Pi_{t+1}} e^{-\kappa_{t+1}}\right], \tag{4.19}$$

and κ_{t+1} is the fraction of debt that is defaulted at time t, which follows an exogenous process:

$$\kappa_t \quad = \quad (1-\rho_\kappa)\kappa + \rho_\kappa \kappa_{t-1} + \sigma_\kappa \varepsilon_{\kappa,t}. \tag{4.20}$$

The discount rate of the government is given by:

$$R_t^{(g)} \quad = \quad (1-w_d) R_t^{(1)} + w_d R_t^{(d)}. \tag{4.21}$$

Given default risk, we can show that $E[R_t^{(d)}] > E[R^{(1)}]$. Therefore, increasing the financing weight on risky debt will increase the government discount rate and generate inflation. These comparative statics are illustrated in Fig. 4.3.

4.3 Benchmark model

This section presents the benchmark model which builds on and quantifies the insights from the simple model.

4.3.1 Households

The representative household is assumed to have Epstein-Zin preferences over streams of consumption C_t and labor L_t:

$$U_t = \left\{ (1-\beta)\left(C_t^\star\right)^{1-1/\psi} + \beta \left(E_t \left[U_{t+1}^{1-\gamma} \right] \right)^{\frac{1}{\theta}} \right\}^{\frac{\theta}{1-\gamma}}, \tag{4.22}$$

$$C_t^\star = C_t \left(\frac{\bar{L}}{L_t} \right)^{\varphi}, \tag{4.23}$$

where γ is the coefficient of risk aversion, ψ is the elasticity of intertemporal substitution, $\theta \equiv \frac{1-\gamma}{1-1/\psi}$ is a parameter defined for convenience, β is the subjective discount rate, and $\bar{L}$ is the agent's time endowment. The time t budget constraint of the household is

$$P_t C_t + B_{t+1} = P_t D_t + W_t L_t + R_t B_t - T_t, \tag{4.24}$$

where P_t is the aggregate price level, B_t is the nominal market value of a portfolio of government bonds, D_t represents real dividends received from the intermediate firms, R_t is the gross nominal interest rate on the bond portfolio, W_t is the nominal competitive wage, and T_t are lump sum taxes from the government. The household chooses sequences of C_t, L_t, and B_t to maximize lifetime utility subject to the budget constraints.

4.3.2 Firms

Production in our economy is comprised of two sectors: the final goods sector and the intermediate goods sector.

Final goods

A representative firm produces the final consumption goods Y_t in a perfectly competitive market. The firm uses a continuum of differentiated intermediate goods X_{it} as input in a constant elasticity of substitution (CES) production technology:

$$Y_t = \left(\int_0^1 X_{i,t}^{\frac{\nu-1}{\nu}} \right)^{\frac{\nu}{\nu-1}}, \tag{4.25}$$

where ν is the elasticity of substitution between intermediate goods. The profit maximization problem of the final goods firm yields the following isoelastic demand schedule with price elasticity ν:

$$X_{i,t} = Y_t \left(\frac{P_{i,t}}{P_t} \right)^{-\nu}, \tag{4.26}$$

where P_t is the nominal price of the final goods and $P_{i,t}$ is the nominal price of the intermediate goods i. The inverse demand schedule is

$$P_{i,t} = P_t Y_t^{\frac{1}{\nu}} X_{i,t}^{\frac{-1}{\nu}}. \tag{4.27}$$

Intermediate goods

The intermediate goods sector is characterized by a continuum of monopolistic firms. Each intermediate goods firm produces $X_{i,t}$ using labor $L_{i,t}$:

$$X_{i,t} = Z_t L_{i,t} - \Phi Z_t, \tag{4.28}$$

where Z_t represents an aggregate productivity shock common across firms, and is composed of both transitory and permanent components (e.g., Croce (2014) and Kung and Schmid (2015)):

$$Z_t = e^{z^\star + a_t + n_t}, \tag{4.29}$$

$$a_t = \rho_a a_{t-1} + \sigma_a \epsilon_{at}, \tag{4.30}$$

$$\Delta n_t = \rho_n \Delta n_{t-1} + \sigma_n \epsilon_{nt}, \tag{4.31}$$

where $z^\star$ is the unconditional mean of $\log(Z_t)$, $\Delta n_t = n_t - n_{t-1}$, ϵ_{at} and ϵ_{nt} are standard normal shocks with a contemporaneous correlation equal to ρ_{an}. The low-frequency component in productivity, Δn_t, generates long-run risks and sizeable risk premia (i.e., Bansal and Yaron (2004)). The fixed cost of production Φ is multiplied by Z_t to ensure that it does not become trivially small along the balanced growth path.

Using the inverse demand function from the final goods sector, nominal revenues for intermediate firm i can be expressed as

$$P_{i,t} X_{i,t} = P_t Y_t^{\frac{1}{\nu}} \left[Z_t L_{i,t} - \Phi Z_t \right]^{1-\frac{1}{\nu}}. \tag{4.32}$$

The intermediate firms face a cost of adjusting the nominal price à la Rotemberg (1982), measured in terms of the final good as

$$G(P_{i,t}, P_{i,t-1}) = \frac{\phi_R}{2} \left(\frac{P_{i,t}}{\Pi_{ss} P_{i,t-1}} - 1 \right)^2 Y_t, \tag{4.33}$$

where $\Pi_{ss} \geq 1$ is the steady-state inflation rate and ϕ_R is the magnitude of the costs.

The source of funds constraint is

$$P_t D_{i,t} = P_{i,t} X_{i,t} - W_t L_{i,t} - P_t G(P_{i,t}, P_{i,t-1}; P_t, Y_t), \tag{4.34}$$

where $D_{i,t}$ is the real dividend paid by the firm. The objective of the firm is to maximize shareholder's value $V_t^{(i)} = V^{(i)}(\cdot)$ taking the pricing kernel M_t, the competitive nominal wage W_t, and the vector of aggregate state variables $\Upsilon_t = (P_t, Z_t, Y_t)$ as given:

$$V_t^{(i)}\left(P_{i,t-1}; \Upsilon_t\right) = \max_{P_{i,t}, L_{i,t}} \left\{ D_{i,t} + E_t \left[M_{t+1}\ V^{(i)}\left(P_{i,t}; \Upsilon_{t+1}\right) \right] \right\}, \tag{4.35}$$

subject to

$$D_{i,t} = \frac{P_{i,t}}{P_t} X_{i,t} - W_t L_t - G(P_{i,t}, P_{i,t-1}; P_t, Y_t), \tag{4.36}$$

$$\frac{P_{i,t}}{P_t} = \left(\frac{X_{i,t}}{Y_t} \right)^{-\frac{1}{\nu}}. \tag{4.37}$$

The corresponding first-order conditions are listed in C.1.

Government

The flow budget constraint of the government is given by:

$$\sum_{i=1}^{N} B_{t+1}^{(i)} = \sum_{i=1}^{N} R_t^{(i)} B_t^{(i)} - S_t, \tag{4.38}$$

where $B_{t+1}^{(i)}$ is the nominal debt of maturity i issued at the end of period t, $R_t^{(i)}$ is the nominal interest paid on debt of maturity i, S_t denotes the nominal value of primary surpluses. For parsimony, we assume that the government only levies lump-sum taxes and government expenditures are excluded. Thus, the primary surplus equals lump-sum taxes. Denoting the total market value of public debt by B_t and scaling the budget constraint by nominal output $P_t Y_t$,

$$b_{t+1} = \frac{R_t^g}{\Pi_t \Delta Y_t} b_t - s_t, \tag{4.39}$$

where $b_{t+1} \equiv B_{t+1}/(P_t Y_t)$, $s_t \equiv S_t/(P_t Y_t)$ and $R_t^g = \sum_{i=1}^{N} w_t^{(i)} R_t^{(i)}$ is the nominal gross interest paid on the portfolio of government debt. The government issues nominal debt at N different maturities and we assume that each period the government retires outstanding debt and issues new debt over the N maturities. The proportion of the debt financed with bonds of maturity i is given by:

$$w_t^{(i)} = \bar{w}^{(i)} + \beta^{(i)} x_{mt}, \tag{4.40}$$

where the constants $\bar{w}^{(i)}$'s determine the steady state maturity structure of debt and the $\beta^{(i)}$'s determine the sensitivity to x_{mt}, a stochastic process drives the dynamics of the maturity

structure. The evolution of x_{mt} is given by:

$$x_{mt} = \rho_m x_{mt-1} + \sigma_m \epsilon_{mt}, \tag{4.41}$$

subject to $\sum_{i=1}^{N} \bar{w}_t^{(i)} = 1$. Note that these shocks are self-financing so that the total market value of debt B_{t+1} is unaffected initially, but is allowed to adjust freely afterwards.

Monetary and fiscal rules

The central bank follows an interest rate feedback rule:

$$\ln\left(\frac{R_t^{(1)}}{R^{(1)}}\right) = \rho_r \ln\left(\frac{R_{t-1}^{(1)}}{R^{(1)}}\right) + (1-\rho_r)\left(\rho_{\pi,\zeta_t} \ln\left(\frac{\Pi_t}{\Pi}\right) + \rho_y \ln\left(\frac{\widehat{Y}_t}{\widehat{Y}}\right)\right) + \sigma_r \epsilon_{rt}, \tag{4.42}$$

where $R_{t+1}^{(1)}$ is the gross one-period nominal interest rate, Π_t is inflation, $\widehat{Y}_t$ is detrended output, and ϵ_{rt} is a normal i.i.d. shock. Note that the coefficient ρ_{π,ζ_t} is indexed by ζ_t, which determines the policy mix at time t.

The fiscal authority adjusts the primary surplus-to-GDP ratio, $s_t \equiv S_t/(P_t Y_t)$, according to the following rule:

$$s_t - s = \rho_s(s_{t-1} - s) + (1-\rho_s)\,\delta_{b,\zeta_t}(b_t - b) + \sigma_s \epsilon_{s_t}. \tag{4.43}$$

The coefficient δ_{b,ζ_t} is also indexed ζ_t and is therefore depends on the policy mix at time t.

Monetary/Fiscal Policy Mix

Leeper (1991) distinguishes four policy regions in a model with fixed policy parameters. Two of the parameter regions admit a unique bounded solution for inflation. One of the determinacy regions is what Leeper refers to as the Active Monetary/Passive Fiscal (AM/PF) regime, which is the familiar textbook case (e.g., Woodford (2003) and Galí (2015)). The Taylor principle is satisfied ($\rho_\pi > 1$) and the fiscal authority adjusts taxes to stabilize debt ($\delta_b > \left(\beta \Delta Y^{1-\frac{1}{\psi}}\right)^{-1} - 1$). In this policy mix, monetary policy determines inflation while fiscal policy passively provides the fiscal-backing to accommodate the inflation targeting objectives of the monetary authority. We refer to this regime as the *monetary-led* regime.

The other determinacy region is the Passive Monetary/Active Fiscal (PM/AF) regime. The fiscal authority is not committed to stabilizing debt ($\delta_b < \left(\beta \Delta Y^{1-\frac{1}{\psi}}\right)^{-1} - 1$), but instead the monetary authority passively accommodates fiscal policy ($\rho_\pi < 1$) by allowing the price level to adjust (to satisfy the government budget constraint). In this setting, fiscal policy determines inflation while monetary policy stabilizes debt and anchors expected inflation. Importantly, in this regime, fiscal disturbances, including non-distortionary taxation, have a direct impact on the price level via the government budget constraint because households

know that changes in taxes will not be offset by future tax changes.[3] We refer to this regime as the *fiscally-led* regime.

When both the fiscal and monetary authorities are active (AM/AF), no stationary equilibrium exists. When both authorities are passive, there exist multiple equilibria. In our regime-switching specification, we follow Bianchi and Melosi (2014) and assume that the policy mix alternates between monetary- and fiscally-led regimes according to a two-state Markov chain with the following transition matrix:

$$\mathcal{M} = \begin{pmatrix} p_{MM} & 1 - p_{FF} \\ 1 - p_{MM} & p_{FF} \end{pmatrix},$$

where $p_{ij} \equiv Pr(\zeta_{t+1} = i | \zeta_t = j)$ and M denotes the monetary-led regime and F denotes the fiscally-led regime.

4.4 Results

This section presents the key results of the model. We begin with a description of the calibration of the model followed by a quantitative analysis. The model is solved using a global projection method that is outlined in C.2.

4.4.1 Calibration

Table 4.1 presents the quarterly calibration. Panel A reports the values for the preference parameters. The elasticity of intertemporal substitution ψ is set to 1.5 and the coefficient of relative risk aversion γ is set to 10.0, which are standard values in the long-run risks literature (e.g., Bansal and Yaron (2004)). The subjective discount factor β is calibrated to 0.9935 to be consistent with the average return on the government bond portfolio (see Panel A of Table 4.2). The relative preference for leisure φ is set so that the household works one-third of the time in the steady-state.

Panel B reports the calibration of the technological parameters. The price elasticity of demand ν is set to 2. The fixed cost of production Φ is set such that the dividend is zero in the deterministic steady state. The price adjustment cost parameter ϕ_R is set to 10.[4] The mean growth rate of productivity $z^\star$ is set to obtain a mean growth rate of output of 2%. The parameters ρ_a and σ_a are set to be consistent with the standard deviation and persistence of output growth, respectively (see Panel B of Table 4.2). The parameters ρ_n and σ_n are set to match the standard deviation and persistence of expected productivity growth.

For parsimony, we assume that shocks to the short-run and long-run components of pro-

[3] In this regime, the government budget constraint is an equilibrium condition rather than a constraint that has to hold for any price path, which Cochrane (2005) refers to as the government debt valuation equation.

[4] For example, in a log-linear approximation, the parameter ϕ_R can be mapped directly to a parameter that governs the average price duration in a Calvo pricing framework. In this calibration, $\phi_R = 10$ corresponds to an average price duration of 3.7 quarters, a standard value in the macroeconomics literature (e.g. Fernández-Villaverde, Gordon, Guerrón-Quintana, and Rubio-Ramírez (2012)).

ductivity are perfectly correlated ($\epsilon_{a,t} = \epsilon_{n,t}$). Indeed, Kung and Schmid (2015) and Kung (2015) show that a stochastic endogenous growth framework produces a very strong positive correlation between these components (i.e., around 0.98). Kung (2015) illustrates that these productivity dynamics help to generate countercyclical real marginal costs, which implies a negative relation between inflation and expected growth. Further, these inflation and growth dynamics imply an upward sloping nominal yield curve (see Table 4.3).

Panel C reports the calibration of the policy rule parameters. We set the steady state debt-to-GDP ratio to match the empirical average. The persistence and volatility parameters, ρ_s and σ_s, are chosen to match primary surplus dynamics. The surplus rule parameter, δ_b, is set to 0.05 and 0.00 in the AM/PF and PM/AF regimes, respectively. The interest rate rule parameter, ρ_π, is set to 1.5 and 0.4 in the AM/PF and PF/AM regimes, respectively. The calibration of these policy parameters, conditional on regime, are consistent with structural estimation evidence from Bianchi and Ilut (2014). The persistence of the interest rate rule ρ_R is calibrated to 0.5. For parsimony, we abstract from monetary policy shock and output smoothing. Steady-state inflation Π_{ss} is calibrated to match the average level of inflation. Following Bianchi and Melosi (2014), we assume that the transition matrix governing the dynamics of the policy/mix is symmetric: $p_{MM} = p_{FF} \equiv p$ is set to 0.9875, implying that the economy stays on average 20 years in a given regime.

Panel D reports the calibration of the government bond supply dynamics. Fig. 4.1 plots the average maturity of net government liabilities, including reserves, from Q1:2005 to Q3:2013. Note that the three QE operations and the Maturity Extension Program (MEP), show up quite visibly as each of these operations significantly shortened the maturity structure of debt.[5] We calibrate the bond supply process to capture salient features of the maturity structure dynamics. We set $N = 40$, so that we include bonds up to a maturity of 10 years, as in our data sample. The steady state maturity structure $\{\bar{w}^{(i)}\}$ is set to match the sample average. To calibrate the dynamics of the process driving the duration of government liabilities, x_{mt}, we proceed as follows. First, we run a principal component analysis on the panel data of maturity structure. Next, we extract the first principal component (PC_1) and fit the time series to an AR(1) process.[6] The estimates for ρ_m and σ_m are 0.9513 and 1.28%, respectively. The loadings $\{\beta^{(i)}\}$ for bonds of each maturity are also obtained from the first principal component.

4.4.2 Yield curve

The dynamics of the nominal yield curve provide the key transmission channel for maturity restructuring operations in the fiscal theory. In this section, we show that the model endogenously generates realistic term structure implications. Table 4.3 reports the mean, standard deviation, and first autocorrelation of nominal yields for maturities of one quarter to five

[5] Details on the data construction are described in C.5.

[6] The first principal component explains about 62% of the cross-sectional dynamics of the debt maturity structure

years. The model does a fairly good job in explaining the level and persistence of yields. In particular, the negative link between inflation and expected consumption growth implies that long nominal bonds are riskier than short nominal bonds, which helps the model explain the upward-sloping average yield curve (five-year minus one-quarter yield spread is 0.55%). The volatility of yields falls short of the empirical moments, however Kung (2015) shows that incorporating volatility shocks to productivity and interest rate rule shocks in a similar DSGE framework helps to fit the second moments better.

The model can explain the joint dynamics between bond yields and macroeconomic variables. Table 4.4 shows that the slope of the nominal yield curve can positively forecast consumption and output growth while negatively forecast inflation as in the data. The interest rate rule plays an important role in these forecasting regressions. Suppose that inflation falls persistently today, then the monetary authority responds by lowering the short rate. A temporary fall in the short rate steepens the slope of the yield curve. Further, due to the negative inflation-growth link, a fall in inflation is also associated with higher expected growth rates.

4.4.3 Maturity structure shocks

As described in the simple model, the combination of a fiscally-led regime and a non-zero slope implies that rebalancing the maturity structure affects inflation. We again can derive a similar present value relation by iterating forward the government budget equation (Eq. (4.38)) from our benchmark model (see C.3 for the derivation):

$$b_t \equiv \frac{B_t}{P_t} = E_t \left[\sum_{i=0}^{\infty} \frac{s_{t+i}}{\prod_{j=0}^{i} R_{t+j}^{g} / (\Pi_{t+j} \Delta Y_{t+j})} \right]. \tag{4.44}$$

In the fiscally-led regime, Eq. (4.44) is an equilibrium condition that determines the price level. This equation is similar to the present value relation derived in the simple model except that there is now debt issued up to N-periods and the equation accounts for growth. When the yield curve is not flat, changing the financing mix alters the government cost of capital, R_g, which leads to an adjustment in inflation (and expected inflation) to satisfy Eq. (4.44). The addition of sticky prices in the benchmark model implies that the fiscal discount rate channel has real effects and therefore violates Wallace neutrality. We show that the direction of these effects is determined by the slope of the nominal yield curve.

Fig. (4.4) plots impulse response functions, conditional on staying in the fiscally-led regime, to a shock that reduces average maturity by 0.18 years (similar magnitude as in QE2). We illustrate the effects of the maturity shock for when the yield curve is upward-sloping (solid line), flat (line with circles), and downward-sloping (dashed line). Since the average slope in the model is positive, for the downward-sloping case we look at maturity structure shocks conditional on periods when the slope is negative. For the upward-sloping case, we consider the average effects from maturity restructuring (without conditioning on the realized slope).

For the flat yield curve scenario, we assume that the monetary authority implements an interest rate peg.

In the positive slope case, shortening the maturity structure implies that the government is refinancing at a lower rate. In the fiscally-led regime, a persistent decline in the government discount rate leads requires that inflation fall persistently to revalue nominal debt obligations to satisfy the intertemporal government equation. A heuristic interpretation of the discount rate-inflation link is as follows (e.g., Cochrane (2011)). A fall in the government discount rate puts upward pressure on the real value of debt. Households, in anticipation of the appreciation in their debt portfolio, increase demand for debt and decrease demand for consumption goods. The fall in aggregate demand leads to a decline in the price level. Without sticky prices, the fall in prices will be sufficient to leave households content with their original consumption allocation. However, with sticky prices, the fall in prices is sluggish, so that prices are temporarily too high relative to the flexible price case, which depresses production (output) and increases the real rate. Thus, when the yield curve is upward-sloping, the fiscal channel implies a potential "cost" of QE operations.

The endogenous yield curve responses to the maturity structure shocks provide a feedback channel that amplifies the fiscal channel. For example, the fall in inflation (in the upward-sloping case) leads to a decline in the short rate due to the interest rate rule. A temporary fall in the short rate steepens the slope of the nominal yield curve, which deepens the fall in the government discount rate from shortening maturity. Furthermore, the fall in the overall level of the yields from falling inflation further depresses the nominal bond portfolio return.

In the negative slope case, shortening the maturity structure gives the *opposite effects* compared to when the slope is positive, which is illustrated in Fig. (4.4). In particular, reducing maturity in this case means that the government is refinancing at a higher rate. In the fiscal regime, an increase in the discount rate requires a devaluation in the real value of the bond portfolio via higher inflation to satisfy the intertemporal government budget constraint. With sticky prices, the increase in inflation stimulates an expansion in output. Also, flattening of the yield curve due to the increase in the short rate amplifies the maturity restructuring effects, following a similar logic as above. Finally, when the yield curve is flat, our fiscal channel is neutral even in the fiscally-led regime, as the financing costs are the same across maturities. These results illustrate how monetary policy is important for open market operations even when it is "passive". Overall, we highlight the importance of the yield curve for maturity restructuring in the fiscal theory.

Due to the recurrent regime shifts and rational expectations, maturity restructuring also has non-neutral effects in the monetary-led regime when the yield curve is nonzero. Fig. (4.5) displays impulse response functions, conditional on *staying* in the fiscally-led (dashed line) and the monetary-led (solid line) regimes for the relevant period, to a shock to maturity structure that reduces average maturity by 0.18 years. We show these plots for the upward-sloping case. Without regime shifts, changes in fiscal discount rates are neutral in the monetary-led

regime due to offsetting surplus policy. However, the possibility of entering the fiscally-led regime propagates the restructuring effects, through agent's expectations, to the monetary-led regime.

Indeed, the responses in the monetary-led regime are qualitatively similar to the reactions in the fiscally-led regime. However, since the probability of changing regimes is small, the responses of macroeconomic quantities in the monetary-led regime are significantly smaller. For example, output drops by 33 basis points in the fiscal regime compared to 5 basis points in the monetary-led regime. Note that the responses of the short rate and yield spread are of similar magnitude despite the much smaller response of inflation in the monetary-led regime. This is because the short rate responds more aggressively to inflation deviations in the monetary-led regime than in the fiscally-led regime.

4.4.4 Macroeconomic fluctuations

Table 4.2 reports basic macroeconomic summary statistics from the data and the model counterparts. The 'model' column reports the unconditional moments while 'fiscal' and 'monetary' columns report the moments conditional on the regime. Macroeconomic volatility is significantly higher in the fiscally-led regime because the economy is less insulated from fiscal disturbances than in the monetary-led regime (e.g., Bianchi and Ilut (2014)). This was highlighted in the previous section when we compared responses from changes in government discount rates due to maturity restructuring operations in the two regimes.

Fig. 4.6 plots impulse response functions to a positive one standard deviation shock to real surpluses, conditional on staying in the monetary-led (solid line) and fiscally-led (dashed line) regimes for the relevant period. In the fiscally-led regime, an increase in real surpluses raises the fiscal-backing for debt. To satisfy the intertemporal government budget constraint, the price level needs to fall to increase the real value of debt. In the monetary-led regime without regime shifts, surplus shocks are offset by stabilizing future surplus policy which implies that surplus shocks are neutral. However, the possibility of entering the fiscally-led regime propagates the effects to the monetary regime. Qualitatively, the responses are similar in the two regimes, but quantitatively, the responses are significantly larger in the fiscally-led regime since the regimes are persistent.

4.4.5 Market timing policies

Fig. 4.7 plots impulse response functions from a shock that lengthens average maturity, conditional on staying in the fiscally-led regime, for various slopes as in Fig. 4.4. The effects of lengthening maturity are the opposite to shortening maturity. When the yield curve is upward-sloping (downward-sloping), lengthening maturity is expansionary (contractionary). These results suggest that there might be a role for market timing maturity operations based on the slope of the nominal yield curve.

Consider a maturity restructuring policy that depends directly on the slope of the nominal

yield curve:

$$x_{m,t} = \rho_m x_{m,t-1} + \phi \left(y_t^{5Y} - y_t^{1Q} \right) + \sigma_m \epsilon_{m,t}. \tag{4.45}$$

A positive coefficient ($\phi > 0$) implies that the government shortens the maturity structure when yield curve is upward-sloping and lengthens the maturity structure when the yield curve is downward-sloping. A negative coefficient implies the opposite policy. Fig. 4.8 plots comparative statics for varying ϕ from -1 to 1. Note that more negative values of ϕ smooth macroeconomic fluctuations, reduce risk premia, and improve welfare through the fiscal discount rate channel. In contrast, more positive values of ϕ increase consumption and inflation volatility, and, in turn, increase welfare costs. Negative values of ϕ shorten the maturity structure when the yield curve is downward sloping, which stimulates the economy and generates fiscal inflation exactly during low expected growth states. Using similar logic, positive values for ϕ deepen recessions and increase deflationary pressure.

4.4.6 Policy experiment

In this section we explore the quantitative significance of the fiscal discount rate channel for quantitative easing operations during the Great Recession. To enrich this analysis, we augment the benchmark model with a zero lower bound (ZLB) constraint on nominal interest rates and include market segmentation through transaction costs. We also assume that the economy starts in the monetary-led regime (with the possibility of entering the fiscally-led regime) along with a government budget deficit calibrated to match the data during the Great Recession.

At the onset and during the aftermath of the Great Recession, interest rates were near zero, and therefore the monetary authority was unable to prevent deflationary/contractionary pressure by lowering interest rates using conventional measures. Consequently, policymakers resorted to unconventional monetary policy, such as maturity twist operations (e.g., the Maturity Extension Program and QE2). One motivation for implementing the maturity twist operations is because of market segmentation, so that government purchases of long-term debt would lower long-term borrowing costs. Indeed, there is empirical evidence suggesting that the QE operations were effective in flattening the yield curve in the short-run.[7] We analyze each new feature before we combine these elements in our policy experiment.

[7]See, for example, Gagnon, Raskin, Remache, and Sack (2011), Krishnamurthy and Vissing-Jorgensen (2011), Swanson (2011), d'Amico, English, López-Salido, and Nelson (2012), Hamilton and Wu (2012), Greenwood and Vayanos (2014).

ZLB

To capture periods where the ZLB constraint is binding for multiple periods, we also incorporate time preference shocks (e.g., Eggertsson and Woodford (2003)):

$$\ln(\beta_t) = (1-\rho_\beta)\ln(\beta) + \rho_\beta \ln(\beta_{t-1}) + \sigma_\beta \epsilon_\beta. \tag{4.46}$$

The ZLB constraint is given by:

$$\ln\left(\frac{R_t^{(1)}}{R^{(1)}}\right) = \max\left\{0, \rho_r \ln\left(\frac{R_{t-1}^{(1)}}{R^{(1)}}\right) + (1-\rho_r)\left(\rho_{\pi,\zeta_t}\ln\left(\frac{\Pi_t}{\Pi}\right) + \rho_y \ln\left(\frac{\widehat{Y}_t}{\widehat{Y}}\right)\right) + \sigma_r \epsilon_{rt}\right\} \tag{4.47}$$

As in Aruoba, Cuba-Borda, and Schorfheide (2013), Fernández-Villaverde, Gordon, Guerrón-Quintana, and Rubio-Ramírez (2012), and Gust, López-Salido, and Smith (2012), we use global projection methods and rational expectations (as in our bechmark model) to approximate the policy functions with the ZLB constraint.

Fig. 4.9 plots impulse response functions for a shock that reduces average maturity by 0.18 years (e.g., QE2), conditional on starting in the monetary-led regime, for when the ZLB binds (dashed line) and when the ZLB is not binding (solid line). For the binding case, we use a time preference shock to send the economy to the ZLB for an average of four quarters as in Fernández-Villaverde, Gordon, Guerrón-Quintana, and Rubio-Ramírez (2012). Also, we consider the benchmark case where the yield curve is, on average, upward-sloping.

The effects of maturity restructuring are amplified at the ZLB. This is because the demand shock that temporarily sends the economy to the ZLB steepens the slope of the nominal yield curve. Indeed, during the aftermath of the Great Recession when interest rates were close to zero (2008 - 2015), the average slope was about 50% larger than the longer sample (1953 - 2015). With a steeper slope, shortening debt maturity decreases the government discount rate more than being away from the ZLB. Consequently, a binding ZLB enhances the contractionary effects of the fiscal discount rate channel when the yield curve is upward-sloping. More broadly, this example with the ZLB illustrates how the magnitude of the slope dictates the magnitude of the effects from the fiscal channel.

Market segmentation

While this essay highlights a potential cost of QE through the fiscal discount rate channel, for our policy experiment, we also account for a key proposed benefit of maturity operations - lowering long-term borrowing costs. To this end, we incorporate market segmentation via transaction costs for bonds of different maturities (e.g., Bansal and Coleman (1996)).

The transaction costs captures, in a reduced-form, a preferred habitat motive (e.g., Vayanos and Vila (2009)). These costs imply that operations shortening debt maturity flattens the yield curve by reducing the risk premium of bonds at a specific maturity. More specifically, the household pays an additional fee $\chi_t^{(i)}$ for each unit of bond of maturity i purchased. We

modify the budget constraint of the representative household in the following way:

$$P_t C_t + \sum_{i=1}^{n} B_{t+1}^{(i)}(1+\chi_t^{(i)}) = P_t D_t + W_t L_t + \sum_{i=1}^{n} \frac{Q_t^{(i-1)}}{Q_{t-1}^{(i)}} B_t^{(i)} - S_t. \tag{4.48}$$

Solving the household problem, the nominal price of a i-maturity bond is

$$Q_t^{(i)} = E_t \left[\frac{M_{t+1}}{\Pi_{t+1}} \frac{Q_{t+1}^{(i-1)}}{1+\chi_t^{(i)}} \right]. \tag{4.49}$$

Note that the existence of transaction costs gives rise to a liquidity premium that depends on $\chi_t^{(i)}$. Following the literature on preferred habitats, it is assumed that the liquidity premium depends on the aggregate supply of bonds:

$$\begin{aligned} \chi_t^{(i)} &= \bar{\chi}^{(i)} e^{\left(\frac{B_{t+1}^{(i)}}{B_{t+1}} - \frac{B^{(i)}}{B} \right)}, & (4.50) \\ &= \bar{\chi}^{(i)} e^{(\beta^{(i)} x_{m,t})}, & (4.51) \end{aligned}$$

where $\bar{\chi}^{(i)} > 0$ is the steady state transaction cost, and $\bar{\chi}^{(i)} \geq \bar{\chi}^{(i-1)}$ that is, longer-term bond are relatively more costly to trade than shorter-term bonds.

Fig. 4.10 shows impulse response functions from shortening maturity with (solid line) and without (dashed line) market segmentation. To isolate the effects of the new ingredients, we shut down the fiscal discount rate channel by assuming the economy can only be in the monetary-led regime without the possibility of entering the fiscally-led regime. The market segmentation parameters are calibrated such that a QE2-type operation reduces the five-year nominal yield spread, on average, by around 15 basis points on impact to be consistent with empirical estimates from Krishnamurthy and Vissing-Jorgensen (2011), while still matching the average yields implied by the benchmark model (Table 4.3).

Without the fiscal discount rate channel or market segmentation, maturity restructuring policies are neutral. However, with market segmentation, shortening maturity drives down long-term interest rates while stimulating economic activity (e.g., increasing inflation and output).

Persistent deficits

Fig. 4.11 explores the impact of persistent budget deficits on maturity restructuring policies at the zero lower bound. This figure displays impulse response functions, conditional on starting in the monetary-led regime and an upward-sloping nominal yield curve, to a shock that reduces average maturity by 0.18 years under positive surpluses around the steady-state level as in the benchmark (solid line), a budget deficit shock calibrated to the data during the Great Recession (line with circles), and a severe deficit shock that is eight times the magnitude of the

deficit during the Great Recession (dashed line).[8] Restructuring under a deficit attenuates the fiscal discount rate effects on inflation. In the case where the yield curve is upward-sloping, shortening the maturity lowers the discount rate persistently. For the negative surpluses today and in the immediate future, lowering the discount rate has a negative effect on the present value of the fiscal backing. Since the surplus process is mean-reverting, surpluses will be positive at some point in the future, and a lower discount rate applied to these cash flows has a positive effect on the present value.[9] Hence, if the deficit today is particularly severe or persistent, the discount rate effects from the deficit component can potentially dominate. Quantitatively, when the magnitude of the deficit is calibrated to the recent U.S. data, we have similar responses as the positive surplus case (benchmark), albeit somewhat weakened. For the responses to be reversed (i.e., negative component dominates), it requires a deficit that is almost an order of magnitude larger than the current deficit.

Full analysis

We analyze these responses with (solid line) and without (dashed line) the fiscal discount rate channel. In the latter case, we shut down the fiscal channel by eliminating regime changes and assuming policy is always characterized by the monetary-led regime. Given that the yield curve is upward-sloping, we find that the fiscal discount rate channel significantly dampens the expansionary effects, due to market segmentation, from maturity restructuring. Comparing the impulse response functions, we find that the fiscal discount rate channel dampens inflation responses by 21% after 5 quarters, and 53% after 10 quarters. Similarly, the fiscal channel dampens output responses by 17% after 5 quarters, and 60% after 10 quarters. The increasing effects by horizon reflect that the cumulative probability of switching to the fiscally-led regime increases over time. In addition, the fiscal channel also partially undoes the flattening of the yield curve from market segmentation. Interpreting these results, accounting for the fiscal discount rate channel provides a potential explanation for why there was not a strong response in inflation after the QE operations.

4.5 Conclusion

This essay explores the interactions between yield curve dynamics and nominal government debt maturity operations through the fiscal discount rate channel. Self-financing debt maturity operations are non-neutral when the slope of the nominal yield curve is nonzero in the fiscal theory. When the risk profile of bonds varies by maturity, rebalancing the maturity structure affects the cost of government financing. Changes in government discount rates then directly affect inflation through the intertemporal government budget equation. With sticky prices, the fiscal discount rate channel has real effects and therefore breaks Wallace neutrality.

[8] During the onset of crisis, the surplus dropped sharply, which corresponds to a negative 3.5-sigma shock to the surplus process. In the severe deficit case, the shock is set to be eight times the magnitude of the deficit shock at the onset of the crisis.

[9] This is implicitly assuming that the maturity structure shock is more persistent than the deficit.

When the yield curve is upward-sloping (downward-sloping) the effects of maturity restructuring implied by the fiscal channel are contractionary (expansionary). In contrast, the effects are neutral when the slope is zero. Thus, when the yield curve is upward-sloping, we illustrate a potential cost for QE operations.

We quantitatively assess the fiscal discount rate channel in a DSGE framework with a stochastic maturity structure and policy regime changes between monetary-led and fiscally-led regimes. Without regime shifts, the effects of maturity restructuring are neutral in the monetary-led regime. However, with regime shifts, the possibility of entering in the fiscally-led regime along with a nonzero slope also implies violations of nominal debt maturity neutrality in the monetary-led regime. Using an estimated process for the maturity structure of public debt, we show that the fiscal discount rate channel had substantial dampening effects on inflation and output responses to QE2, given an upward-sloping yield curve. Overall, this essay highlights the importance of the term structure of interest rates as a transmission channel for quantitative easing policies in the fiscal theory.

Table 4.1: Quarterly calibration

Parameter	Description	Model
A. Preferences		
β	Subjective discount factor	0.9935
ψ	Elasticity of intertemporal substitution	1.5
γ	Risk aversion	10
B. Production		
ν	Price elasticity for intermediate goods	2
ϕ_R	Magnitude of price adjustment costs	10
$z^\star$	Unconditional mean growth rate	0.5%
ρ_a	Persistence of a_t	0.95
σ_a	Volatility of transitory shock e_{at}	0.7%
ρ_n	Persistence of Δn_t	0.99
σ_n	Volatility of permanent shock e_{nt}	0.015%
C. Policy		
ρ_s	Persistence of government surpluses	0.92
σ_s	Volatility of government surpluses e_{st}	0.05%
$\delta_b(M/F)$	Sensitivity of taxes to debt	0.05 / 0.0
ρ_r	Degree of monetary policy inertia	0.5 / 0.5
$\rho_\pi(M/F)$	Sensitivity of interest rate to inflation	1.5 / 0.4
p	Switching probability	0.9875
D. Bond Supply		
$\bar{b}$	Steady state Debt-to-GDP ratio	0.5
ρ_m	Persistence of x_{mt}	0.958
σ_m	Volatility of e_{mt}	1.28%

This table reports the parameter values used in the quarterly calibration of the model. The table is divided into four categories: Preferences, Production, Policy, and Bond Supply parameters.

Table 4.2: Summary statistics

	Data	Model	Monetary	Fiscal
A. Means				
$\mathrm{E}\left(y^{(20)} - y^{(1)}\right)$ (in %)	1.02	0.55	0.89	0.18
$\mathrm{E}\left(r_g\right)$ (in %)	5.47	6.06	5.95	6.21
B. Standard Deviations				
$\sigma(\Delta y)$ (in %)	2.22	2.90	1.47	4.07
$\sigma(\Delta c)$ (in %)	1.42	2.85	1.44	4.02
$\sigma(\pi)$	1.64	1.20	0.32	1.62
$\sigma(\Delta l)/\sigma(\Delta y)$	0.92	0.51	0.21	0.57
$\sigma\left(r_g\right)$ (in %)	4.53	1.22	0.81	1.52
C. Correlations				
$\mathrm{corr}(\pi, \Delta c)$ (low-frequency)	-0.85	-0.91	-0.91	-0.92

This table presents the means, and standard deviations for key macroeconomic variables from the data and the model. The model is calibrated at a quarterly frequency and the reported statistics are annualized.

Table 4.3: Term structure

	Maturity						
	1Q	1Y	2Y	3Y	4Y	5Y	5Y - 1Q
Mean (Model) (in %)	5.68	5.91	6.03	6.11	6.17	6.23	0.55
Mean (Data) (in %)	5.03	5.29	5.48	5.66	5.80	5.89	1.02
Std (Model) (in %)	1.20	1.00	0.90	0.80	0.70	0.60	0.70
Std (Data) (in %)	2.97	2.96	2.91	2.83	2.78	2.72	1.05
AC1 (Model)	0.95	0.90	0.90	0.90	0.90	0.92	0.95
AC1 (Data)	0.93	0.94	0.95	0.95	0.96	0.96	0.74

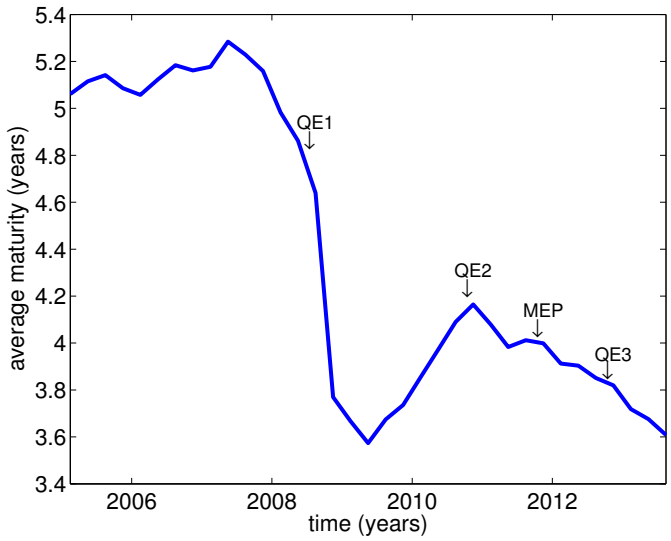
This table presents the mean, standard deviation, and first autocorrelation of the one-quarter, one-year, two-year, three-year, four-year, and five-year nominal yields and the 5-year and one-quarter spread from the model and the data. The model is calibrated at a quarterly frequency and the moments are annualized.

Table 4.4: Forecasts with the yield spread

	Data			Model		
	Horizon (in quarters)					
	1	4	8	1	4	8
A. Output						
β	1.023	0.987	0.750	1.694	1.211	0.820
S.E.	0.306	0.249	0.189	0.413	0.217	0.169
R^2	0.067	0.148	0.147	0.045	0.147	0.176
B. Consumption						
β	0.731	0.567	0.373	1.650	1.179	0.800
S.E.	0.187	0.163	0.153	0.398	0.211	0.165
R^2	0.092	0.136	0.088	0.045	0.145	0.173
C. Inflation						
β	-1.328	-1.030	-0.649	-2.370	-1.784	-1.266
S.E.	0.227	0.315	0.330	0.154	0.215	0.237
R^2	0.180	0.157	0.071	0.484	0.355	0.235

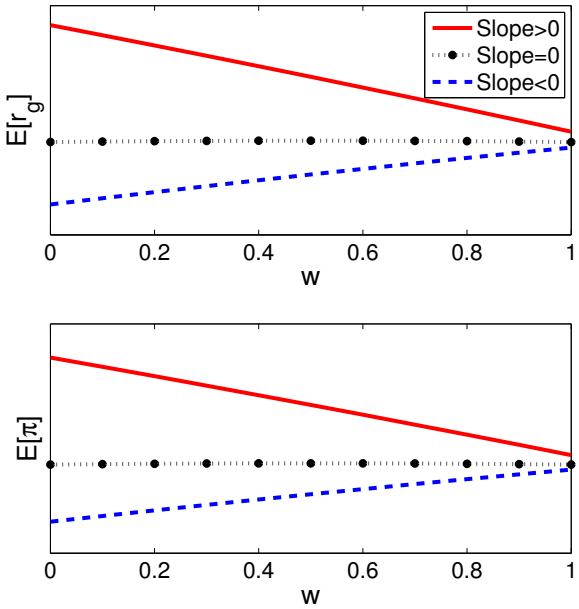
This table presents output growth, consumption growth, and inflation forecasts for horizons of one, four, and eight quarters using the five-year nominal yield spread from the data and the model. The n-quarter regressions, $\frac{1}{n}(x_{t,t+1} + \cdots + x_{t+n-1,t+n}) = \alpha + \beta(y_t^{(5)} - y^{(1Q)}) + \epsilon_{t+1}$, are estimated using overlapping quarterly data and Newey-West standard errors are used to correct for heteroscedasticity.

Figure 4.1: Average maturity of public debt



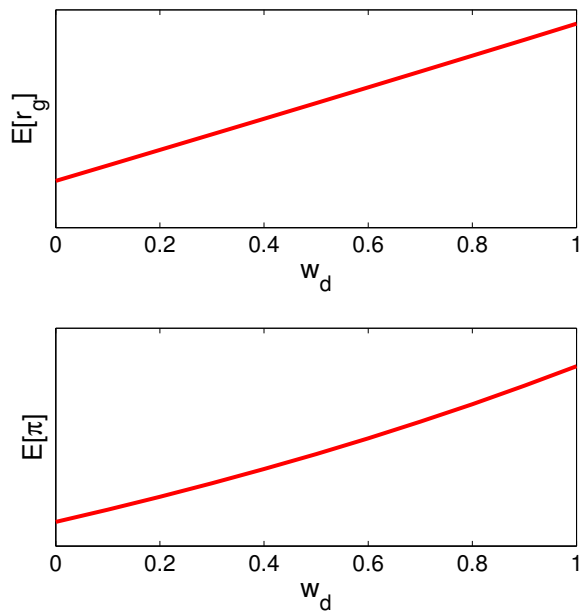
This figure plots the average maturity structure of government debt held by the public from Q1-2005 to Q3-2013.

Figure 4.2: Comparative statics: shortening maturity



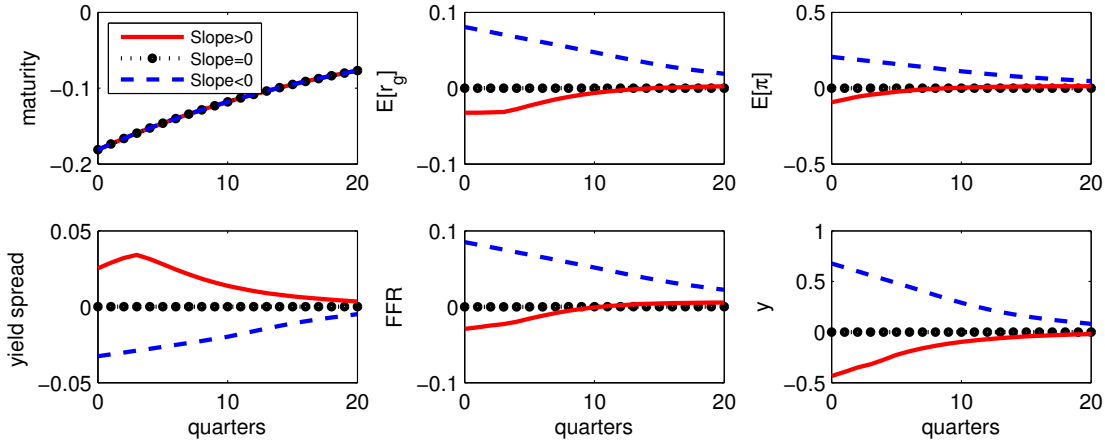
This figure plots the average effect from increasing the portfolio weight on short-term debt, w, on the government discount rate R^g (top figure) and log inflation π (bottom figure) for when the average yield curve is upward-sloping (solid line), downward-sloping (dashed line), and flat (line with circles).

Figure 4.3: Comparative statics: defaultable debt



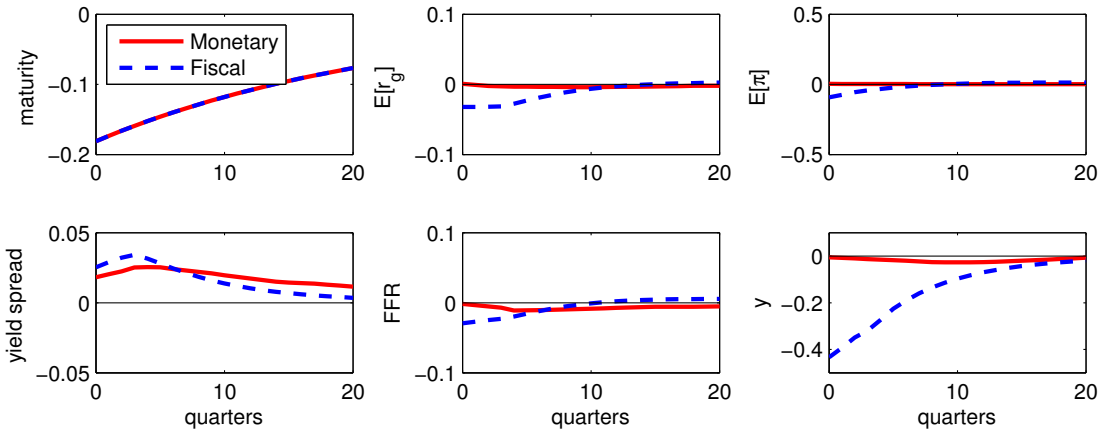
This figure plots the average effect from increasing the portfolio weight on risky debt, w_d, on the government discount rate R^g (top figure) and log inflation π (bottom figure).

Figure 4.4: Maturity restructuring with different slopes



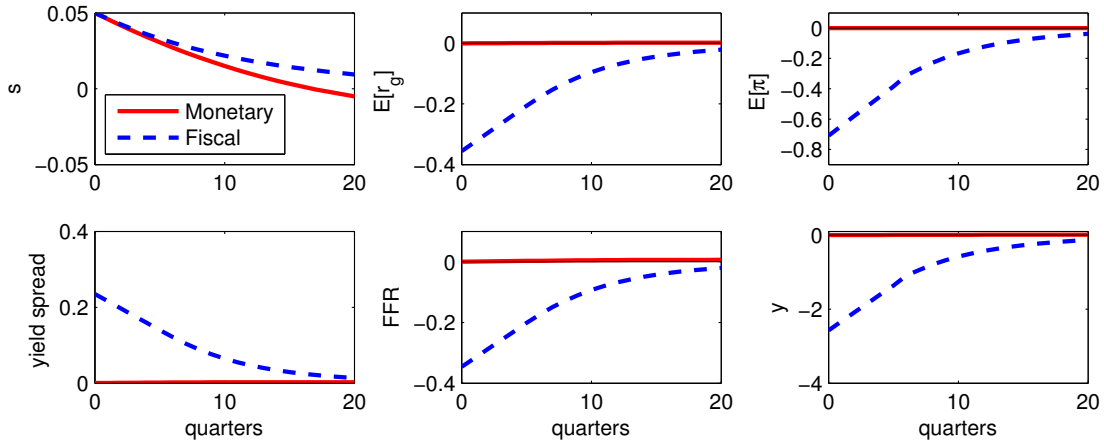
This figure plots conditional impulse response functions for the government discount rate, expected inflation, the 5-year minus 1-quarter nominal yield spread, the fed funds rate, and output to a decrease in the average maturity of government debt (similar in magnitude as QE2) in the fiscal regime. Results are reported for when the yield curve is upward-sloping (solid line), flat (line with circles), and downward-sloping (dashed line). The units of the y-axis are annualized percentage deviations from the steady-state, except for the average duration that is in years.

Figure 4.5: Maturity restructuring in different regimes



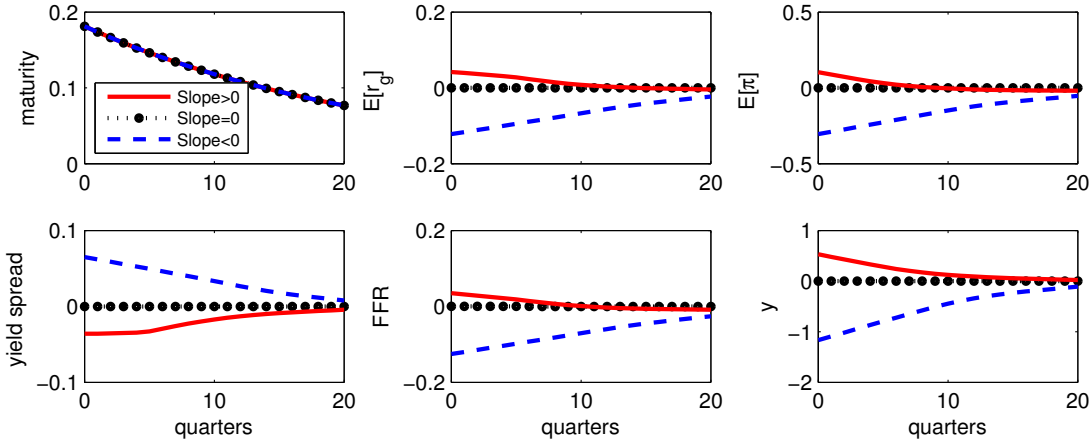
This figure plots the conditional impulse response functions for the government discount rate, expected inflation, the 5-year minus 1-quarter nominal yield spread, the fed funds rate, and output to a decrease in the average maturity of government debt (similar magnitude as QE2) in the monetary regime (solid line) and fiscal regime (dashed line). The units of the y-axis are annualized percentage deviations from the steady-state, except for the average duration that is in years.

Figure 4.6: Surplus shocks in different regimes



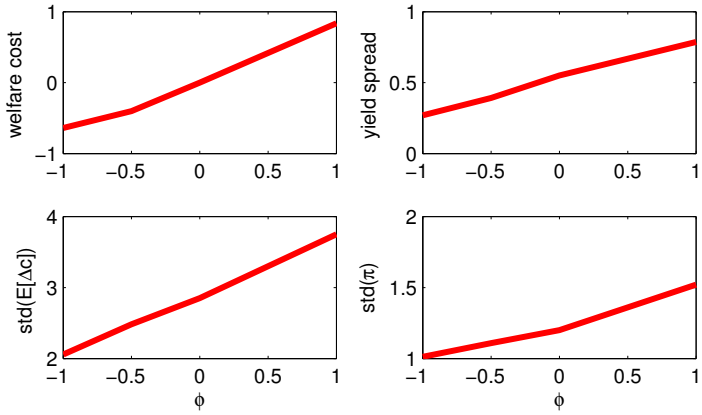
This figure plots conditional impulse response functions of the government discount rate, expected inflation, the 5-year minus 1-quarter nominal yield spread, the fed funds rate, and output to a positive one standard deviation surplus shock in the monetary (solid line) and fiscal (dashed line) regime. The units of the y-axis are annualized percentage deviations from the steady-state, except for the surplus that is in levels.

Figure 4.7: Lengthening maturity



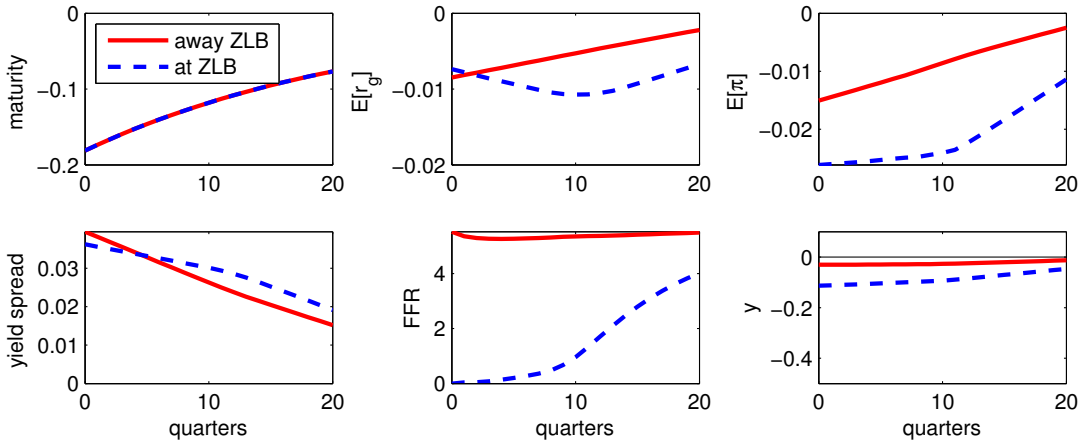
This figure plots conditional impulse response functions of the government discount rate, expected inflation, the 5-year minus 1-quarter nominal yield spread, the fed funds rate, and output to an increase in the average maturity of government debt in the fiscal regime. Results are reported for when the yield curve is upward sloping (solid line), flat (line with circles), and downward sloping (dashed line). The units of the y-axis are annualized percentage deviations from the steady-state, except for the average duration that is in years.

Figure 4.8: Market timing policies



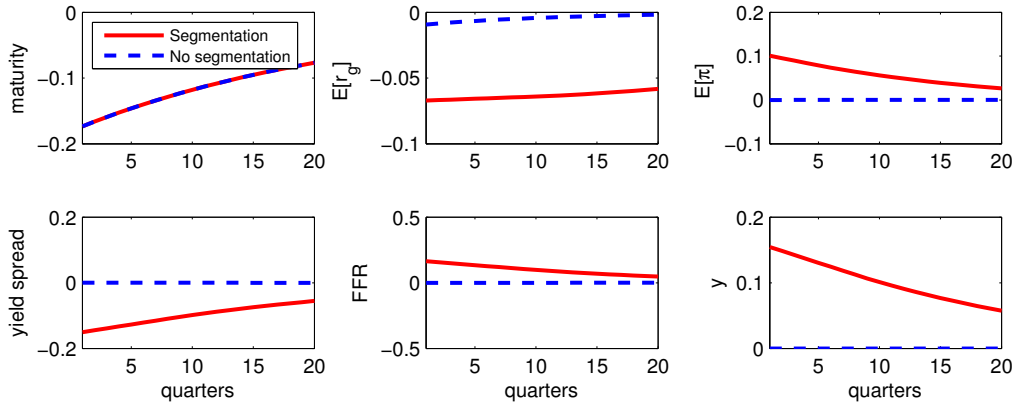
This figure plots comparative statics for the welfare cost, average yield spread, standard deviation of consumption growth, and the standard deviation of inflation when the market timing sensitivity to the yield spread varies.

Figure 4.9: Maturity restructuring at the ZLB



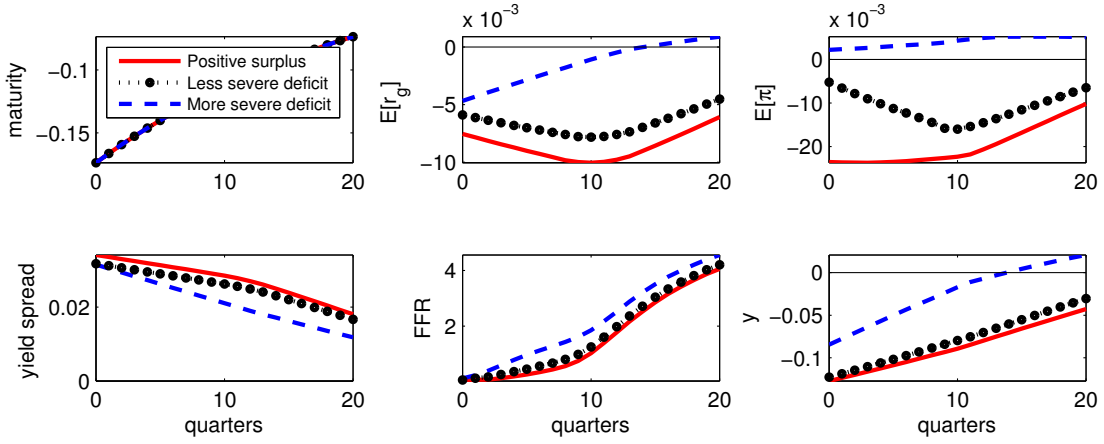
This figure plots the conditional impulse response functions of the government discount rate, expected inflation, the 5-year minus 1-quarter nominal yield spread, the fed funds rate, and output to a decrease in the average maturity of government debt (similar magnitude as QE2) when in the monetary regime. The dashed line represents the response at the zero lower bound and the solid line represents the response away from the zero lower bound. The units of the y-axis are annualized percentage deviations from the steady-state, except for the average duration that is in years and the fed funds rate that is in levels.

Figure 4.10: Maturity restructuring with market segmentation



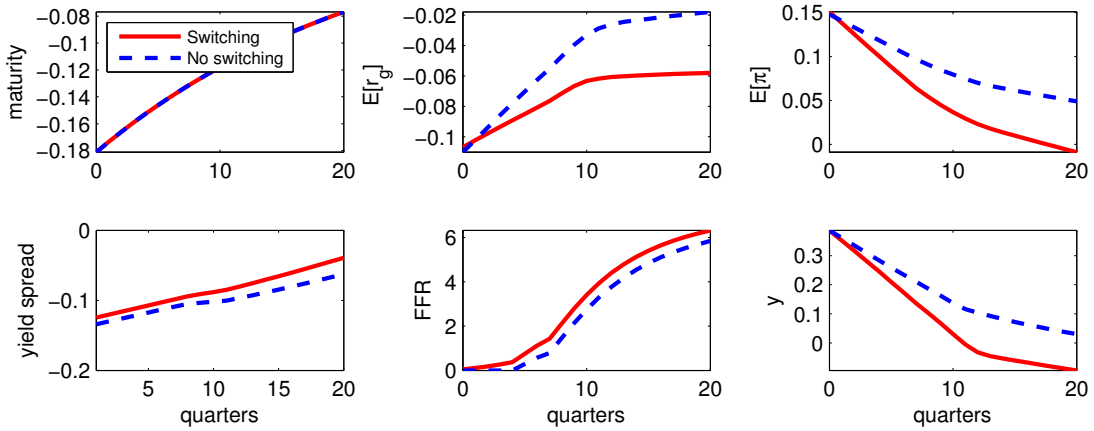
This figure plots the impulse response functions of the government discount rate, expected inflation, the 5-year minus 1-quarter nominal yield spread, the fed funds rate, and output to a decrease in the average maturity of government debt (similar magnitude as QE2) in the monetary regime (without regime shifts). The dashed line represents the response without market segmentation and the solid line, the response with market segmentation. The units of the y-axis are annualized percentage deviations from the steady-state, except for the average duration that is in years.

Figure 4.11: Maturity restructuring with persistent deficits



This figure plots the conditional impulse response functions of the government discount rate, expected inflation, the 5-year minus 1-quarter nominal yield spread, the fed funds rate, and output to a decrease in the average maturity of government debt (similar magnitude as QE2) when the economy starts initially in the monetary regime at the zero lower bound. The solid line represents the response under positive surpluses. The line with circles represents the response under a deficit shock (-3.5 sigma) calibrated to the data during the Great Recession (2008-2010). The dashed line represents a severe deficit shock that is eight times the magnitude of the deficit during the Great Recession. The units of the y-axis are annualized percentage deviations from the steady-state, except for the average duration that is in years and the fed funds rate that is in levels.

Figure 4.12: Policy experiment



This figure plots the conditional impulse response functions of the government discount rate, expected inflation, the 5-year minus 1-quarter nominal yield spread, the fed funds rate, and output to a decrease in the average maturity of government debt (similar magnitude as QE2) when the economy starts initially in the monetary regime at the zero lower bound. These plots come from the augmented model that also incorporates market segmentation and a short-term liquidity demand. The solid line represents the response with switching to the fiscal regime and the dashed line represents the response without the possibility of switching to the fiscal regime. The units of the y-axis are annualized percentage deviations from the steady-state, except for the average duration that is in years and the fed funds rate that is in levels.

Chapter 5

Conclusion

This thesis is a collection of three essays on Macro Finance. The first essay, chapter 2, examines how industry competition affects the cross-section of asset prices. Empirically, more competitive industries are characterized by higher credit spreads, but lower expected returns. I reconcile these two facts within a structural model that captures the rich interaction between a firm's competitive environment, optimal capital structure, and asset prices. In the model, tougher competition erodes profit margins and reduces the firm value. Consequently, competitive firms are more exposed to idiosyncratic cash-flow shocks which increases credit risk and leads to higher credit spreads. In contrast, equityholders in competitive industries own a more valuable option to default. Effectively, the limited liability feature acts as an insurance for bad states of the world. This makes equity safer and decreases expected returns. In equilibrium, competitive industries issue less, but more expensive debt, and have a lower cost of equity. I find substantial empirical evidence for these predictions. Besides, the calibrated model generates cross-sectional variation in leverage and valuation ratios close to the data. More generally, this essay provides new evidence that competition is a key determinant of the cross-section of asset prices, both equity returns and credit spreads. It also shows the importance to account for leverage and default in explaining the interaction between equity returns and industry competition.

In chapter 3, I explore the implications of firm entry dynamics for asset prices and macroeconomic fluctuations. The model features two sources of innovation. First, process innovation refers to incumbent firms investing to upgrade their current technology in response to the threat of entry. In equilibrium, R&D investment by incumbents drives a small, but persistent component in productivity growth that leads to sizable endogenous long-run risks. With recursive preferences, households are very averse to such persistent movements and command high risk premia in asset markets that help the model match key asset price data, such as a high equity premium and a low riskfree rate. The second type of innovation is product innovation and refers to resources spent on the creation of new products and firms. In the model, entry is procyclical and leads to countercyclical markups. Novelly, these entry dynamics make short-term dividends very risky and the model produces a U-shaped term structure of equity

returns, consistent with the data. Firm entry is also endogenously asymmetric which produces countercyclical macroeconomic volatility. With recursive preferences, these volatility dynamics generate a countercyclical equity premium that can be forecasted by measures of industry concentration. These predictions are tested and confirmed in the data. Overall, this chapter presents new theoretical and empirical evidence that fluctuations in competition is an important determinant of time-varying risk premia.

The last essay, chapter 4, studies the impact of government policy on asset prices and the economy. In this chapter, I document a novel transmission channel for open market operations targeting the average maturity of government debt. I emphasize two key ingredients for this channel to work. First, the risk profiles of bonds vary by maturity, i.e. the slope of the nominal yield curve is nonzero. In this case, varying the maturity structure changes the expected return on the government bond portfolio and affects its market value through a discount rate channel. When the monetary policy is passive and fiscal authorities are not committed to stabilize government liabilities, changes in government debt value impact the price level through a fiscal inflation channel. This is the second key ingredient. In short, I show that in the presence of a fiscally-led regime and a nonzero slope of the nominal yield curve, government debt maturity restructurings affect inflation. More specifically, when the nominal yield curve is upward-sloping, this channel implies that shortening the maturity structure has contractionary effects. The quantitative importance of these effects are assessed in a model calibrated to replicate the second round of Quantitative Easing (QE) and I find that this new fiscal channel significantly dampened the inflation and output responses to QE2. Therefore, this essay shows the importance of the term structure of interest rates as a transmission channel for quantitative easing policies in the fiscal theory and highlights a new potential cost of QE operations.

5.1 Future work

The three essays presented in this thesis could be extended along several dimensions. In the first essay, for instance, all industries are assumed to be similar except for the number of firms, which is exogenously specified. While this assumption allows the model to stay relatively tractable, it would be interesting to allow for endogenous, and potentially time-varying industry competition. In addition, the model provides new predictions on the cross-sectional relationship between competition and expected bond returns that could be tested empirically. In the second essay, I assume the existence of a perfectly liquid capital market from which firms rent their technology. It would be interesting to see how allowing firms to innovate "in-house" and to sell their patents in imperfect markets would impact the quantitative results. Finally, in the third essay, firms produce output using labor and finance themselves only through equity markets. Thus the model abstracts from key corporate decisions such as capital expenditures and capital structure. An important question that remains to be answered is the extent to which debt maturity restructurings also affect corporate investment

and financial leverage decisions of firms.

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Appendix A

Appendix to Chapter 2

A.1 A simple model: derivation details

A.1.1 Firm's problem

First note that shareholders declare default as soon as the value of the firm turns negative. In period 1, the value of the firm is simply d_1. Therefore the default threshold is the value $z^\star$ that solves $d_1(z^\star) = 0$, that is

$$z^\star = (P_1 y_1 - W_1 l_1 - (1 + (1-\tau)C)b)\,\bar{l}^{-1} \tag{A.1}$$

Substituting the price using the inverse demand schedule (Eq. 2.1), and using the valuation of corporate debt (Eq. 2.3), and the default threshold (Eq. A.1) into the firm's problem, the objective of the firm becomes

$$V_j = \max_{l_0, l_1, b_1} \mathcal{Y}_0^{\frac{1}{\nu}} \left(\sum_{i=1}^{n} y_{i,0} \right)^{-\frac{1}{\nu}} y_{i,0} - W_0 l_0 - (1 + (1-\tau)C)b_0 + \beta\Phi(z^\star)(1+C)b_1 \tag{A.2}$$

$$+ \beta \int_{\underline{z}}^{z^\star} (z^\star - z)\, d\Phi(z)\, \bar{l} \tag{A.3}$$

Applying Leibniz' rule, the first order necessary conditions with respect to l_t, and b_1 are

$$\begin{aligned} W_t &= \mathcal{Y}_0^{\frac{1}{\nu}} \left(\sum_{i=1}^{n} y_{i,0} \right)^{-\frac{1}{\nu}} \frac{y_{i,0}}{l_{i,0}} \left(1 - \frac{1}{\nu} \frac{y_{i,0}}{\sum_{i=1}^{n} y_{i,0}} \right) \\ \Phi(z^\star)\tau C &= \phi(z^\star)(1 + (1-\tau)C)(1+C)\frac{b}{\bar{l}} \end{aligned} \tag{A.4}$$

Each firm in the industry faces the same problem and differs only by the realization of the idiosyncratic shock z. Because this cost enters as a fixed cost, it doesn't affect individual firm decisions so that the industry admits a unique symmetric Nash equilibrium in which

all firms make identical decisions. The i-subscript can be dropped and $\bar{l} = l$. Imposing the market clearing on the goods market that demand must equal supply in equilibrium, we have $ny_t = Y_t = \mathcal{Y}_t$. Imposing market clearing on the labor market, i.e. $nl_t = 1$, the set of FOCs becomes

$$\begin{aligned} W &= \left(1 - \frac{h}{\nu}\right) A \\ \Phi(z^\star)\tau C &= \phi(z^\star)(1 + (1-\tau)C)(1+C)\tilde{b} \end{aligned} \tag{A.5}$$

where $h = \sum_{i=1}^{n} (y_{i,t}/Y_t)^2 = 1/n$ is the Herfindahl-Hirschman index of the industry, and $\tilde{b} = b/\bar{l}$ is a measure of leverage (debt over the firm size).
The price-elasticity of demand $\eta_{y,P}$ in the symmetric equilibrium is obtained using Eq. 2.1,

$$\eta_{y,P} = -\frac{\frac{\partial y_{i,t}}{y_{i,t}}}{\frac{\partial P_t}{P_t}} = \frac{\nu}{h} \tag{A.6}$$

A.1.2 Proof of proposition 1

Proof. First, note that I assume that $z^\star$ is an interior solution on the interval $[-a/2, a/2]$.[1] In addition, under the assumption that z is uniformly distributed on $[-a/2, a/2]$, the cumulative distribution function is

$$\Phi(x) = \begin{cases} 0 & x < -a/2 \\ \frac{1}{a}\left(x + \frac{a}{2}\right) & -a/2 \leq x \leq a/2 \\ 1 & x < a/2 \end{cases} \tag{A.7}$$

and the associated probability density function is $\phi(x) = \frac{1}{a}$. Using the set of equilibrium conditions (A.5), and the default threshold (A.1), the equilibrium default threshold is given by

$$z^\star = \left(\frac{hA}{\nu} - \frac{a}{2}\frac{\tau C}{(1+C)}\right)\left(1 + \frac{\tau C}{(1+C)}\right)^{-1} \tag{A.8}$$

To prove the effects of competition on the expected default probability, I take the partial derivative of $z^\star$ with respect to h,

$$\frac{\partial z^\star}{\partial h} = \frac{A}{\nu}\left(1 + \frac{\tau C}{1+C}\right)^{-1} \tag{A.9}$$

which is positive. Therefore an increase in competition (decrease in h) decreases the optimal default threshold and the survival probability of the firm, $\Phi(z^\star)$.

[1] This is without loss of generality as one can always find a value for a such that it holds.

To see the effect on debt, note that equilibrium leverage is given by

$$\tilde{b} = \left(z^\star + \frac{a}{2}\right) \frac{\tau C}{(1+(1-\tau)C)(1+C)} \tag{A.10}$$

The result follows from the fact that $z^\star$ is increasing in h.
Next, the equilibrium firm value over labor is

$$\tilde{V}(A) = \frac{hA}{\nu} - (1+(1-\tau)C)\tilde{b}_0 + \beta\left[\Phi(z^\star)(1+C)\right]\tilde{b}_1(z^\star) + \beta\int_{\underline{z}}^{z^\star}\left[z^\star - z\right]\, d\Phi(z) \tag{A.11}$$

where $\tilde{b}_1(z^\star)$ is the optimal leverage. Plugging the optimal policy for $\tilde{b}(z^\star)$ and taking the partial derivative with respect to h,

$$\begin{aligned}\frac{\partial \tilde{V}(A)}{\partial h} =& \frac{A}{\nu} + \beta\left\{\frac{\tau C\Phi(z^\star)}{(1+(1-\tau)C)}\left[2 - \frac{\Phi(z^\star)\phi'(z^\star)}{\phi^2(z^\star)}\right] + \Phi(z^\star)\right\}\frac{\partial z^\star}{\partial h} \\ =& \frac{A}{\nu}\left(1 + \beta\Phi(z^\star)\frac{1+C}{1+(1-\tau)C}\right)\end{aligned} \tag{A.12}$$

where the second line is obtained using the expression for $\frac{\partial z^\star}{\partial h}$ in Eq. A.9. The term inside the parentheses is strictly positive, implying that the firm value is a increasing function of concentration and therefore a decreasing function of competition.
Finally, the credit spread is defined as $cs = (1+C)/q - \beta^{-1}$, therefore

$$\frac{\partial cs}{\partial h} = -\frac{(1+C)}{q^2}\frac{\partial q}{\partial h} = -\beta\phi(z^\star)\frac{(1+C)^2}{q^2}\frac{\partial z^\star}{\partial h} < 0 \tag{A.13}$$

where the inequality sign follows from Eq. A.9.

□

A.1.3 Conditional equity beta

Proof. Formally, the conditional equity beta is measured as the elasticity of V_j with respect to A,

$$\begin{aligned}\beta_i = \frac{d\log\tilde{V}_j(A)}{d\log A} &= \frac{Ah}{\nu}\left(1 + \beta\Phi(z^\star)\frac{1+C}{1+(1-\tau)C}\right)\frac{1}{\tilde{V}(A)} \\ &= \frac{1 + \beta\Phi(z^\star)\frac{1+C}{1+(1-\tau)C}}{1 + \frac{\nu}{hA}\frac{a\beta}{2}\Phi^2(z^\star)\left(\frac{\tau C+1+C}{1+(1-\tau)C}\right)}\end{aligned} \tag{A.14}$$

Taking the partial derivative of β_i with respect to h is somewhat more involved, however, it can be shown that a sufficient condition for $\frac{\partial\beta_i}{\partial h} > 0$ is $\tau < 1$, which is always the case. Therefore an increase in competition decreases the firm conditional beta. □

To obtain the expression for the conditional equity beta in Eq. 2.8, note that the normalized

value of the firm can be rewritten as

$$\tilde{V}_j(A) = \frac{Ah}{\nu}(1+\beta) - (1+(1-\tau))\tilde{b}_0 + \beta\left[\Phi(z^\star)\tilde{b}_1\tau C - (1-\Phi(z^\star))\frac{Ah}{\nu}\right] - \beta\int_{\underline{z}}^{z^\star} z\, d\Phi(z) \tag{A.15}$$

Rewriting the expression for the conditional equity beta (Eq. A.14), I get

$$\beta_i = 1 + \frac{(1+(1-\tau)C)b_0}{V_j(A)} + \frac{\beta\tau C}{1+(1-\tau)C}\frac{\Phi(z^\star)z^\star}{V_j(A)} - \frac{\beta\int_{z^\star}^{\overline{z}} z\, d\Phi(z)}{V_j(A)} \tag{A.16}$$

A.2 Shareholders' optimization problem

To keep notation readable, the (i,j)-subscript is omitted, unless necessary but all lower case variables should be understood as firm-specific variables.

Optimization problem Assuming that the firm doesn't default in the current period, and replacing for $\tilde{P}_{j,t}$ using the inverse demand schedule, the recursive representation of the Lagrangian for the shareholders' problem is

$$\begin{aligned}\mathcal{L}\left(b_t, k_t, z_t, \Upsilon_t\right) = {} & (1-\tau)(\mathcal{Y}_t^{\frac{1}{\nu}}\left(Y_{j,t}^- + y_t\right)^{\frac{-1}{\nu}} y_t - W_t l_t - z_{i,j,t}\bar{k}_{j,t}) - i_t + \tau\delta_k k_t \\ & - ((1-\tau)C+1)\, b_t + q_t b_{t+1} - \psi_b(b_t, b_{t+1}) \\ & + \Lambda_t^K\left((1-\delta_k)k_t + \Gamma\left(\frac{i_t}{k_t}\right)k_t - k_{t+1}\right) \\ & + E_t M_{t,t+1}\int_{\underline{z}}^{\overline{z}} \mathcal{L}\left(b_{t+1}, k_{t+1}, z', \Upsilon_{t+1}\right) d\Phi(z')\end{aligned} \tag{A.17}$$

where $Y_{j,t}^- = \sum_{k=1,k\neq i}^{n_j} y_{k,j,t}$ is the total industry output produced by the firm's rivals, and Λ_t^K is the Lagrange multiplier on the capital accumulation equation. The set of first order necessary conditions are:

$$\begin{aligned}[i_t] &: \Lambda_t^K\Gamma_t' = 1 \\ [l_t] &: \tilde{P}_{j,t}\left[1 - \frac{1}{\nu}\frac{y_t}{Y_{j,t}}\right](1-\alpha)\frac{y_t}{l_t} - W_t = 0 \\ [k_{t+1}] &: q_{k,t}' b_{t+1} - \Lambda_t^K + E_t M_{t,t+1}\int_{\underline{z}}^{z_{t+1}^\star} \mathcal{L}_{k,t+1}' d\Phi(z') = 0 \\ [b_{t+1}] &: q_{b,t}' b_{t+1} + q_t - \psi_{b,2,t}' + E_t M_{t,t+1}\int_{\underline{z}}^{z_{t+1}^\star} \mathcal{L}_{b,t+1}' d\Phi(z') = 0\end{aligned} \tag{A.18}$$

where I use the following notation: $\Gamma_t' = \partial\Gamma_t/\partial(i_t/k_t)$, $q_{k,t}' = \partial q_t/\partial k_{t+1}$, $q_{b,t}' = \partial q_t/\partial b_{t+1}$, $\mathcal{L}_{k,t}' = \partial\mathcal{L}_t/\partial k_t$, $\mathcal{L}_{b,t}' = \partial\mathcal{L}_t/\partial b_t$, $\psi_{b,1,t}' = \partial\psi_{b,t}/\partial b_t$, and $\psi_{b,2,t}' = \partial\psi_{b,t}/\partial b_{t+1}$. $\mathcal{L}_{k,t}'$ and $\mathcal{L}_{b,t}'$ are

obtained by applying the enveloppe theorem,

$$\begin{aligned}
\mathcal{L}'_{k,t} &= (1-\tau)\tilde{P}_{j,t}\left[1-\frac{1}{\nu}\frac{y_t}{Y_{j,t}}\right]\alpha\frac{y_t}{k_t}+\tau\delta_k+\Lambda_t^K\left(1-\delta_k+\Gamma_t-\Gamma'_t\frac{i_t}{k_t}\right)\\
\mathcal{L}'_{b,t} &= -\left((1-\tau)C+1\right)-\psi'_{b,1,t}
\end{aligned} \tag{A.19}$$

Finally, $q'_{k,t}$ and $q'_{b,t}$ are obtained by taking partial derivatives of total debt value $q_t b_{t+1}$ with respect to b_t+1 and k_{t+1},[2]

$$\begin{aligned}
q'_{b,t}b_{t+1}+q_t &= E_t M_{t,t+1}\left[(C+1)\Phi(z^\star_{t+1})+z^{\star'}_{b,t+1}\phi(z^\star_{t+1})b_{t+1}(\tau C+\xi_{t+1}[(1-\tau)C+1])\right]\\
q'_{k,t}b_{t+1} &= E_t M_{t,t+1}\left[z^{\star'}_{k,t+1}\phi(z^\star_{t+1})b_{t+1}(\tau C+\xi_{t+1}[(1-\tau)C+1])+(1-\xi_{t+1})\int_{z^\star_{t+1}}^{\bar{z}}\mathcal{L}'_{k,t+1}\,d\Phi(z')\right]
\end{aligned} \tag{A.20}$$

where

$$\begin{aligned}
z^{\star'}_{k,t} &= \frac{\mathcal{L}'_{k,t}}{(1-\tau)\bar{k}_{j,t}}\\
z^{\star'}_{b,t} &= \frac{\mathcal{L}'_{b,t}}{(1-\tau)\bar{k}_{j,t}}
\end{aligned} \tag{A.21}$$

Note that Eq. 2.23 is obtained by replacing for $z^{\star'}_{k,t}$ and $q'_{k,t}$ in the capital FOC.

Symmetric equilibrium Because each firm is ex-ante identical and the i.i.d. shock enters as a fixed costs, all firms make the same decisions and the model admits a symmetric Nash equilibrium in each industry. In particular, we have $y_{i,j,t}=y_{j,t}$, $Y_{j,t}=n_j y_{j,t}$, $l_{i,j,t}=l_{j,t}$, $k_{i,j,t}=k_{j,t}=\bar{k}_{j,t}$, and $b_{i,j,t}=b_{j,t}$.

Price markups Using the first order condition with respect to labor, and the symmetric property of the equilibrium,

$$\tilde{P}_{j,t}\left(1-\frac{h_j}{\nu}\right)=\frac{W_t}{(1-\alpha)\frac{y_{j,t}}{l_{j,t}}} \tag{A.22}$$

where $h_j=1/n_j$ is the Herfindahl-Hirschman index. The right-hand-side is the firm real marginal cost of production. Defining the price markup to be the price set by the firm over

[2] It is implicitly assumed that although creditors inherit an unlevered firm in bankruptcy, the debt adjustment cost is paid on the leverage level at the time of bankruptcy.

marginal cost, the price markup is,

$$\mu_{j,t} = \left(1 - \frac{h_j}{\nu}\right)^{-1} \tag{A.23}$$

A.3 Derivation of inverse demand schedule

The final goods firm solves the following profit maximization problem

$$\max_{Y_{j,t}\in[0,1]} \mathcal{P}_t \left(\int_0^1 Y_{j,t}^{\frac{\nu-1}{\nu}}\, dj\right)^{\frac{\nu}{\nu-1}} - \int_0^1 P_{j,t} Y_{j,t}\, dj \tag{A.24}$$

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

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

$$\mathcal{P}_t \left(\int_0^1 Y_{j,t}^{\frac{\nu-1}{\nu}} dj\right)^{\frac{\nu}{\nu-1}-1} Y_{j,t}^{-\frac{1}{\nu}} - P_{j,t} = 0 \tag{A.25}$$

which can be rewritten as

$$Y_{j,t} = \mathcal{Y}_t \left(\frac{P_{j,t}}{\mathcal{P}_t}\right)^{-\nu} \tag{A.26}$$

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

$$Y_{j,t} = Y_{k,t} \left(\frac{P_{j,t}}{P_{k,t}}\right)^{-\nu} \tag{A.27}$$

Raising the expression above to the power of $\frac{\nu-1}{\nu}$, integrating over j and raising the expression to the power of $\frac{\nu}{\nu-1}$,

$$Y_{j,t} = \mathcal{Y}_t \left(\frac{P_{j,t}}{\left(\int_0^1 P_{j,t}^{1-\nu}\right)^{\frac{1}{1-\nu}}}\right)^{-\nu} \tag{A.28}$$

Using (A.26), I obtain the expression for the price index

$$\mathcal{P}_t = \left(\int_0^1 P_{j,t}^{1-\nu}\right)^{\frac{1}{1-\nu}} \tag{A.29}$$

Appendix B

Appendix to Chapter 3

B.1 Data sources

Quarterly data for consumption, capital investment, and GDP are from the Bureau of Economic Analysis (BEA). Annual data on private business R&D investment are from the survey conducted by the National Science Foundation. Annual data on the stock of private business R&D are from the Bureau of Labor Statistics. Real annual capital stock data is obtained from the Penn World Table. Quarterly productivity data are from Fernald (2012) (Federal Reserve Bank of San Francisco) and is measured as Business sector total factor productivity. The labor share and average weekly hours are obtained from the Bureau of Labor Statistics (BLS). The monthly index of net business formation (NBF) and number of new business incorporations (INC) are from the U.S. Basic Economics Database. Consumption is measured as expenditures on nondurable goods and services. Capital investment is measured as private fixed investment. Output is measured as GDP. The labor share is defined as the business sector labor share. Average weekly hours is measured for production and nonsupervisory employees of the total private sector. The variables are converted to real using the Consumer Price Index (CPI), which is obtained from the Center for Research in Security Prices (CRSP). Annual data are converted into quarterly data by linear interpolation. The inflation rate is computed by taking the log return on the CPI index. The sample period is for 1948-2013, except for the average weekly hours series which starts in 1964 and the NBF and INC series that were discontinued in 1993.

Monthly nominal return and yield data are from CRSP. The real market return is constructed by taking the nominal value-weighted return on the New York Stock Exchange (NYSE) and American Stock Exchange (AMEX) and deflating it using the CPI. The real risk-free rate is constructed by using the nominal average one-month yields on treasury bills and taking out expected inflation[1]. Aggregate market and dividend values are from CRSP. The price dividend ratio is constructed by dividing the current aggregate stock market value

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

by the sum of the dividends paid over the preceding 12 months.

B.1.1 Markup measure

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

$$\emptyset_t = \frac{1}{MC_t}$$

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

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

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

The inverse of the labor share should thus be a good proxy for the price markup. However, there are many reasons why standard assumptions may lead to biased estimates of the markup (see Rotemberg and Woodford (1999)). In this paper, we follow Campello (2003) by focusing on non-linearities in the cost of labor[2]. More specifically, when deriving the cost function, we assumed that the firm was able to hire all workers at the marginal wage. In practice however, the total wage paid $W(L_t)$, is likely to be convex in hours (e.g. Bils (1987)). This creates a wedge between the average and marginal wage that makes the labor share a biased estimate of the real marginal cost. Denoting this wedge by $\omega_t = W'(L_t)/(W(L_t)/L_t)$, the markup becomes,

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

Log-linearizing this expression around the steady state,

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

where ω_L is the steady state elacticity of ω_t with respect to average hours. Bils (1987) proposes a simple model of overtime. Assuming a 50% overtime premium[3] he estimates the elasticity ω_L to be 1.4. We use this value to build our overtime measure of the price markups. We set the steady state values for L_t and $S_{L,t}$ to 40 hours and 100[4], respectively and linearly detrend

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

[3]This is the statutory premium in the United States.

[4]The Bureau of labor statistics use 100 as the index for the labor share in 2009. Our results stay robust to

the series.

B.2 Derivation of demand schedule

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

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

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

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

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

which can be rewritten as

$$Y_{j,t} = \mathcal{Y}_t\left(\frac{P_{j,t}}{P_{Y,t}}\right)^{-\nu_1} \tag{B.1}$$

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

$$Y_{j,t} = Y_{k,t}\left(\frac{P_{j,t}}{P_{k,t}}\right)^{-\nu_1} \tag{B.2}$$

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

$$P_{Y,t}Y_t = \int_0^1 P_{j,t}Y_{j,t}\,dj \tag{B.3}$$

Substituting (B.6) into (B.3) gives

$$Y_{j,t} = P_{Y,t}\mathcal{Y}_t\frac{P_{j,t}^{-\nu_1}}{\int_0^1 P_{j,t}^{1-\nu_1}\,dj} \tag{B.4}$$

Substitute (B.5) into (B.4) to obtain the price index

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

Since each sector is atomistic, their actions will not affect $\mathcal{Y}_t$ nor $P_{Y,t}$. Thus, each of these

change in this value.

sectors will face an isoelastic demand curve with price elasticity ν_1.

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

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

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

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

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

which can be rewritten as

$$X_{i,j,t} = \frac{Y_{j,t}}{N_{j,t}} \left(\frac{P_{i,j,t}}{P_{j,t}} \right)^{-\nu_2} \tag{B.5}$$

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

$$X_{i,j,t} = X_{k,j,t} \left(\frac{P_{i,j,t}}{P_{k,j,t}} \right)^{-\nu_2} \tag{B.6}$$

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

$$\left(\sum_{i=1}^{N_{j,t}} X_{i,j,t}^{\frac{\nu_2-1}{\nu_2}} \right)^{\frac{\nu_2}{\nu_2-1}} = X_{k,j,t} \frac{\left(\sum_{i=1}^{N_{j,t}} P_{i,j,t}^{1-\nu_2} \right)^{\frac{\nu_2}{\nu_2-1}}}{P_{k,j,t}^{-\nu_2}} \tag{B.7}$$

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

$$\frac{Y_{j,t}}{\mathcal{N}_t} \frac{P_{k,j,t}^{-\nu_2}}{X_{k,j,t}} = \mathcal{N}_t^{-\frac{\nu_2}{\nu_2-1}} \left(\sum_{i=1}^{N_{j,t}} P_{i,j,t}^{1-\nu_2} \right)^{\frac{-\nu_2}{\nu_2-1}} \tag{B.8}$$

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

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

B.2.1 Individual firm problem

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

$$\begin{aligned} X_{i,j,t} &= \frac{\mathcal{Y}_t}{N_{j,t}} \left(\frac{P_{i,j,t}}{P_{j,t}} \right)^{-\nu_2} \left(\frac{P_{j,t}}{P_{Y,t}} \right)^{-\nu_1} && \text{(B.9)} \\ &= \frac{\mathcal{Y}_t}{N_{j,t}} \left(\tilde{P}_{i,j,t} \right)^{-\nu_2} \left(\tilde{P}_{j,t} \right)^{\nu_2-\nu_1} && \text{(B.10)} \end{aligned}$$

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

The (real) source of funds constraint is

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

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

$$\begin{aligned} V_{i,j,t} &= \max_{\{L_{i,j,t}, K_{i,j,t}, Z_{i,j,t}, \tilde{P}_{i,j,t}\}_{t\geq 0}} E_0 \left[\sum_{s=0}^{\infty} M_{t,t+s} (1-\delta_n)^s D_{i,j,s} \right] \\ \text{s.t.} \quad & X_{i,j,t} = \frac{\mathcal{Y}_t}{N_{j,t}} \left(\tilde{P}_{i,j,t} \right)^{-\nu_2} \left(\tilde{P}_{j,t} \right)^{\nu_2-\nu_1} \end{aligned}$$

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

The Lagrangian of the problem is

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

The corresponding first order necessary conditions are

$$
\begin{aligned}
r^k_{j,t} &= \alpha \frac{X_{i,j,t}}{K_{i,t}} (\tilde{P}_{i,j,t} + \Lambda^d_t) \\
r^z_{j,t} &= \eta(1-\alpha) \frac{X_{i,j,t}}{Z_{i,j,t}} (\tilde{P}_{i,j,t} + \Lambda^d_t) \\
W_{j,t} &= (1-\alpha) \frac{X_{i,j,t}}{L_{i,j,t}} (\tilde{P}_{i,j,t} + \Lambda^d_t) \\
X_{i,j,t} &= \Lambda^d_{j,t} \frac{\mathcal{Y}_t}{N_{j,t}} \left[-\nu_2 \tilde{P}^{-\nu_2-1}_{i,j,t} \tilde{P}^{\nu_2-\nu_1}_{j,t} + (\nu_2-\nu_1) \tilde{P}^{-\nu_2}_{i,j,t} \tilde{P}^{\nu_2-\nu_1-1}_{j,t} \frac{\partial \tilde{P}_{j,t}}{\partial P_{i,j,t}} \right]
\end{aligned}
$$

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

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

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

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

$$
\begin{aligned}
r^k_{j,t} &= \alpha \frac{X_{j,t}}{K_{j,t}} (1 + \Lambda^d_{j,t}) \\
r^z_{j,t} &= \eta(1-\alpha) \frac{X_{j,t}}{Z_{j,t}} (1 + \Lambda^d_{j,t}) \\
W_{j,t} &= (1-\alpha) \frac{X_{j,t}}{L_{j,t}} (1 + \Lambda^d_{j,t}) \\
\Lambda^d_{j,t} &= \left[-\nu_2 + (\nu_2 - \nu_1) \frac{1}{N_{j,t}} \right]^{-1}
\end{aligned}
$$

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

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

In Lagrangian form,

$$\mathcal{V}_{i,j,t} = r^k_{j,t} K_{i,j,t} + r^z_t Z_{i,j,t} + W_t L_{i,j,t} + \lambda_{i,j,t} \left(X^\star - K^\alpha_{i,j,t} (A_t Z^\eta_{i,j,t} \mathcal{Z}_t^{1-\eta} L_{i,j,t})^{1-\alpha} \right)$$

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

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

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

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

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

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

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

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

B.2.2 Capital producer problem

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

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

The Lagrangian in recursive form is,

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

The first order conditions are:

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

Using the enveloppe theorem,

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

The set of equilibrium conditions for the representative capital producer is

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

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

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

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

Appendix C

Appendix to Chapter 4

C.1 Equilibrium

The equilibrium is given by the sequence $\{Y_t, C_t, U_t, L_t, w_t, \Lambda_t, b_t, M_t, Z_t, a_t, \Delta n_t, s_t, x_t, w_t^{(i)}, R_t^{(1)}, \Pi_t\}_{t=0}^{\infty}$ determined by:

1. Household's first-order conditions:

$$1 = E_t\left[\frac{M_{t+1}}{\Pi_{t+1}} R_{t+1}^{(i)}\right], \tag{C.1}$$

$$M_{t+1} = \beta\left(\frac{C_{t+1}\left(\frac{\bar{L}}{L_{t+1}}\right)^{\varphi}}{C_t\left(\frac{\bar{L}}{L_t}\right)^{\varphi}}\right)^{1-\frac{1}{\psi}}\left(\frac{C_{t+1}}{C_t}\right)^{-1}\left(\frac{U_{t+1}^{1-\gamma}}{E_t\left[U_{t+1}^{1-\gamma}\right]}\right)^{1-\frac{1}{\theta}}, \tag{C.2}$$

$$w_t = \frac{\varphi C_t}{L_t}. \tag{C.3}$$

2. Household's utility:

$$U_t = \left\{(1-\beta)\left(C_t\left(\frac{\bar{L}}{L_t}\right)^{\varphi}\right)^{1-1/\psi} + \beta\left(E_t\left[U_{t+1}^{1-\gamma}\right]\right)^{\frac{1}{\theta}}\right\}^{\frac{\theta}{1-\gamma}}. \tag{C.4}$$

3. Intermediate firm's first-order conditions:

$$w_t = \left(1-\frac{1}{\nu}\right)Z_t + \Lambda_t\left(\frac{1}{\nu}\right)\frac{Z_t}{Y_t}, \tag{C.5}$$

$$\Lambda_t = \phi_R\left(\frac{\Pi_t}{\Pi_{ss}}-1\right)\frac{\Pi_t Y_t}{\Pi_{ss}} - E_t\left[M_{t+1}\ \phi_R\left(\frac{\Pi_{t+1}}{\Pi_{ss}}-1\right)\frac{Y_{t+1}\Pi_{t+1}}{\Pi_{ss}}\right]. \tag{C.6}$$

4. Government policy:

$$\ln\left(\frac{R_t^{(1)}}{R^{(1)}}\right) = \rho_r \ln\left(\frac{R_{t-1}^{(1)}}{R^{(1)}}\right) + (1-\rho_r)\left(\rho_{\pi,\varrho_t}\ln\left(\frac{\Pi_t}{\Pi}\right) + \rho_y \ln\left(\frac{\widehat{Y}_t}{\widehat{Y}}\right)\right) + \sigma_r \epsilon_{rt}, \tag{C.7}$$

$$s_t - s = \rho_s(s_{t-1} - s) + (1-\rho_s)\,\delta_{b,\varrho_t}(b_t - b) + \sigma_s \epsilon_{s_t}, \tag{C.8}$$

$$b_{t+1} = \frac{R_t^g}{\Pi_t \Delta Y_t} b_t - s_t, \tag{C.9}$$

$$R_t^g = \sum_{i=1}^{N}\left(\bar{w}^{(i)} + \beta^{(i)} x_{mt}\right) R_t^{(i)}. \tag{C.10}$$

5. Output:

$$Y_t = Z_t L_t - \Phi Z_t. \tag{C.11}$$

6. Market clearing:

$$Y_t = C_t + \frac{\phi_R}{2}\left(\frac{\Pi_t}{\Pi_{ss}} - 1\right)^2 Y_t. \tag{C.12}$$

7. Stochastic processes:

$$\ln(Z_t) = z^\star + a_t + n_t, \tag{C.13}$$

$$a_t = \rho_a a_{t-1} + \sigma_a \epsilon_{at}, \tag{C.14}$$

$$\Delta n_t = \rho_n \Delta n_{t-1} + \sigma_n \epsilon_{nt}, \tag{C.15}$$

$$x_{mt} = \rho_m x_{mt-1} + \sigma_m \epsilon_{mt}. \tag{C.16}$$

C.2 Numerical procedure

The model is solved using a global method following Judd, Maliar, and Maliar (2012) and Judd, Maliar, Maliar, and Valero (2014). A subset of the policy functions are approximated by piece-wise ordinary polynomials of the state variables. The state variables are:

$$\mathbb{S}_t = (r_{t-1}, a_{t-1}, s_{t-1}, b_{t-1}, x_{mt}, Y_{t-1}, \Delta n_{t-1}, \beta_t, +\epsilon_{at}, \epsilon_{nt}, \epsilon_{st}, \{Q_{t-1}^{(n)}\}_{i=2}^{N}), \tag{C.17}$$

where r_{t-1} is the nominal one-period risk-free rate, a_{t-1} is the transitory productivity shock, s_{t-1} is the governments' surplus, b_{t-1} is the total debt of the government, x_{mt} is the stochastic process driving the maturity structure, Y_{t-1} is the final consumption goods, Δn_{t-1} is the permanent productivity shock, β_t is the subjective discount rate, e_{at} is the innovation to the transitory productivity shock, e_{nt} is the innovation to the permanent productivity shock, e_{st} is the innovation to the government's surplus, and $\{Q_{t-1}^{(i)}\}_{i=2}^{N}$ are the nominal bond prices.

The approximated policy functions are:

$$\mathbb{G} = (F_t, C_t, \mathrm{U}_t, \{Q_t^{(i)}\}_{i=2}^N, E\Delta C_t, E\pi_t), \tag{C.18}$$

where

$$F_t = \left(\frac{\Pi_t}{\Pi_{ss}} - 1\right)\frac{\Pi_t}{\Pi_{ss}}, \tag{C.19}$$

C_t is consumption, U_t is household utility, $\{Q_t^{(i)}\}_{i=2}^N$ are nominal bond prices, $E\Delta C_t$ is expected consumption growth, and $E\pi_t$ is expected inflation.

Let $\mathcal{L}$ be a policy function, the policy function is approximated as:

$$\widehat{\mathcal{L}} = \mathbb{1}_F p_F + \mathbb{1}_M p_M, \tag{C.20}$$

where $\mathbb{1}_j$ is an indicator function equals to one in regime j and zero otherwise, and p_j is a polynomial. Note that a different polynomial is used in each regime as indicated by the F, and M subscript.

The model is solved by finding the set of polynomial coefficients Θ that minimizes the mean squared residuals for the approximated decision rules over a fixed grid. For each point j on the grid the residuals $\{\mathfrak{R}_k^j\}_{k=1}^{N+4}$ are calculated as:

$$\begin{aligned}
\mathfrak{R}_1^j &= \phi_R F_t^j Y_t^j - E_t^j\left[M_{t+1}\ \phi_R F_{t+1} Y_{t+1}\right] - \Lambda_t, && \text{(C.21)}\\
\mathfrak{R}_2^j &= E_t^j\left[M_{t+1} R_{t+1}^W\right] - 1, && \text{(C.22)}\\
\mathfrak{R}_3^j &= U_t^j - \left\{(1-\beta)\left(C_t^{j\star}\right)^{1-1/\psi} + \beta\left(E_t^j\left[U_{t+1}^{1-\gamma}\right]\right)^{\frac{1}{\theta}}\right\}^{\frac{1}{1-1/\psi}}, && \text{(C.23)}\\
\mathfrak{R}_4^j &= E_t^j\left[Cg_{t+1}\right] - ECg_t^j, && \text{(C.24)}\\
\mathfrak{R}_5^j &= E_t^j\left[\pi_{t+1}\right] - E\pi_t^j, && \text{(C.25)}\\
\mathfrak{R}_{i+4}^j &= E_t^j\left[\frac{M_{t+1}}{\Pi_{t+1}} Q_{t+1}^{(i-1)}\right] - Q_t^{j,(i)}\ \forall i = 2..N. && \text{(C.26)}
\end{aligned}$$

$\mathfrak{R}_1^j$ is calculated using the first order condition (in equilibrium) of the firms in the intermediate goods sector, $\mathfrak{R}_2^j$ is calculated using the Euler equation for the return on the wealth portfolio, $\mathfrak{R}_3^j$ is computed using the value function equation. $\mathfrak{R}_4^j$ and $\mathfrak{R}_5^j$ are calculated directly from their definition. Finally, $\{\mathfrak{R}_i^j\}_{i=6}^{N+4}$ are computed using the Euler equations for the nominal bonds.

The grid on the state variables space is calculated in 5 steps. First, for each of the regimes the model is solved using a second-order perturbation approximation to obtain an initial guess for the set of coefficients Θ. Second, the regime-specific model is simulated and the principal components of the state variables are calculated. Third, an auxiliary grid on the principal components space is calculated using the Smolyak algorithm. Fourth, the regime-specific

grid on the state variables space is calculated by performing a linear transformation of the auxiliary grid calculated in the previous step. Finally, the grid is calculated as the union of the two single regime grids (fiscally-led regime and monetary-led regime).

The Smolyak algorithm is used for the auxiliary grid because it is a highly efficient method to calculate a sparse grid in a hypercube. The drawback of the Smolyak algorithm is that the points are not chosen to maximize the number of points on the region of the state space where the ergodic distribution of the model is located. The Smolyak algorithm is improved by adapting it to the characteristics of the model using the principal components transformation.

Second-order standard ordinary polynomials are used for each of the regime-specific polynomials. The nominal bond prices are approximated as linear combinations of variables that are known to be important to understand the dynamics of the yield curve (see Bansal and Shaliastovich (2013) and Kung (2015)), namely, expected consumption growth and expected inflation. These approximations can be thought of as being second-order approximations on the state variables where the coefficients are restricted to be linear combinations of the coefficients for expected consumption growth and expected inflation. The minimization is done using a numerical optimizer. To improve the speed of the code, an analytical gradient and monomial integration are used. The mean square error is of the order of 10^{-6}.

C.3 Present value relations

The flow budget constraint of the government for the simple model Eq. (4.8) can be written as

$$\frac{B_t}{P_{t-1}} = \frac{\Pi_t}{R_t^g}\left(\frac{B_{t+1}}{P_t} + s_t\right), \tag{C.27}$$

where $B_t = B_t^{(1)} + B_t^{(2)}$ is the total nominal value of government debt, s_t is the real surplus, and $R_t^g = R_t^{(1)}\frac{B_t^{(1)}}{B_t} + R_t^{(2)}\frac{B_t^{(2)}}{B_t}$ is the nominal gross interest rate paid on the portfolio of government debt. In real terms we have:

$$b_t = \frac{\Pi_t}{R_t^g}(b_{t+1} + s_t). \tag{C.28}$$

Leading Eq. (C.28) for one period and taking the conditional expectation at time t,

$$E_t[b_{t+1}] = E_t\left[\frac{\Pi_{t+1}}{R_{t+1}^g} b_{t+2}\right] + E_t\left[\frac{\Pi_{t+1}}{R_{t+1}^g} s_{t+1}\right]. \tag{C.29}$$

Iterating forward on $E_t[b_{t+1}]$ using the law of iterated expectations and assuming a transversality condition on real debt, we have

$$E_t[b_{t+1}] = E_t\left[\sum_{i=1}^{\infty} \frac{P_{t+i}}{P_{t-1}} \frac{1}{\prod_{j=1}^{i} R_{t+j}^g} s_{t+i}\right]. \tag{C.30}$$

Using Eq. (C.28) and Eq. (C.30) together, the present value of government surpluses is

$$b_t = E_t \left[\sum_{i=0}^{\infty} \frac{s_{t+i}}{\prod_{j=0}^{i} \left\{ R_{t+j}^g / \Pi_{t+j} \right\}} \right]. \tag{C.31}$$

The present value relation for the benchmark model can be calculated in a similar way. Leading Eq. (4.39) for one period and taking the conditional expectation at time t we get:

$$E_t[b_{t+1}] = E_t \left[\frac{\Pi_{t+1} \Delta Y_{t+1}}{R_{t+1}^g} b_{t+2} \right] + E_t \left[\frac{\Pi_{t+1} \Delta Y_{t+1}}{R_{t+1}^g} s_{t+1} \right]. \tag{C.32}$$

Iterating forward on $E_t[b_{t+1}]$ using the law of iterated expectations and assuming a transversality condition on real debt,

$$E_t[b_{t+1}] = E_t \left[\sum_{i=1}^{\infty} \frac{P_{t+i}\, Y_{t+i}}{P_{t-1}\, Y_{t-1}} \frac{1}{\prod_{j=1}^{i} R_{t+j}^g} s_{t+i} \right]. \tag{C.33}$$

Simplifying, we get that the present value of government surpluses is

$$b_t = E_t \left[\sum_{i=0}^{\infty} \frac{s_{t+i}}{\prod_{j=0}^{i} \Pi_{t+j}^{-1} \Delta Y_{t+j}^{-1} R_{t+j}^g} \right]. \tag{C.34}$$

C.4 Simple model: approximate analytical solution

The real return of the government portfolio is:

$$\frac{R_t^g}{\Pi_t} = \frac{b_{t+1} + s_t}{b_t}, \tag{C.35}$$

where lowercase variables denote real variables. Define $\log x \equiv \widetilde{x}$, and take logs of Eq. (C.35):

$$\widetilde{R}_t^g - \widetilde{\Pi}_t = \log\left(b_{t+1} + s_t\right) - \log\left(b_t\right), \tag{C.36}$$

$$= \widetilde{b}_{t+1} + \log\left(1 + \frac{s_t}{b_{t+1}}\right) - \widetilde{b}_t. \tag{C.37}$$

Since surpluses can be negative, substitute $s_t = \tau_t - g_t$ (τ_t and g_t are real taxes and government expenditures, respectively) into Eq. (C.36) and rearrange:

$$\widetilde{R}_t^g - \widetilde{\Pi}_t = \widetilde{b}_{t+1} + \log\left(1 + \frac{\tau_t - g_t}{b_{t+1}}\right) - \widetilde{b}_t, \tag{C.38}$$

$$= \widetilde{b}_{t+1} - \widetilde{b}_t + \log\left(1 + \exp\left(\widetilde{\tau}_t - \widetilde{b}_{t+1}\right) - \exp\left(\widetilde{g}_t - \widetilde{b}_{t+1}\right)\right). \tag{C.39}$$

Following Berndt, Lustig, and Yeltekin (2012), we log-linearize the last term in Eq. (C.39) with respect to the log tax-to-debt and the log government expenditures-to-debt ratios around

the steady-state:

$$\begin{aligned}
& \log\left(1+\exp\left(\widetilde{\tau}_t-\widetilde{b}_{t+1}\right)-\exp\left(\widetilde{g}_t-\widetilde{b}_{t+1}\right)\right) \simeq \log\left(1+\exp\left(\widetilde{\tau}-\widetilde{b}\right)-\exp\left(\widetilde{g}-\widetilde{b}\right)\right) \\
+ \quad & \frac{\exp\left(\widetilde{\tau}-\widetilde{b}\right)}{1+\exp\left(\widetilde{\tau}-\widetilde{b}\right)-\exp\left(\widetilde{g}-\widetilde{b}\right)}\left(\widetilde{\tau}_t-\widetilde{b}_{t+1}-\left(\widetilde{\tau}-\widetilde{b}\right)\right) \\
- \quad & \frac{\exp\left(\widetilde{g}-\widetilde{b}\right)}{1+\exp\left(\widetilde{\tau}-\widetilde{b}\right)-\exp\left(\widetilde{g}-\widetilde{b}\right)}\left(\widetilde{g}_t-\widetilde{b}_{t+1}-\left(\widetilde{g}-\widetilde{b}\right)\right). \qquad \text{(C.40)}
\end{aligned}$$

Collecting constant terms and rearranging:

$$\log\left(1+\exp\left(\widetilde{\tau}_t-\widetilde{b}_{t+1}\right)-\exp\left(\widetilde{g}_t-\widetilde{b}_{t+1}\right)\right) \simeq \theta_0+(1-\theta_1)\left(\mu_\tau\widetilde{\tau}_t-\mu_g\widetilde{g}_t-\widetilde{b}_{t+1}\right), \quad \text{(C.41)}$$

where

$$\begin{aligned}
\mu_\tau &= \frac{\exp\left(\widetilde{\tau}-\widetilde{b}\right)}{\exp\left(\widetilde{\tau}-\widetilde{b}\right)-\exp\left(\widetilde{g}-\widetilde{b}\right)}, \ \mu_g = \frac{\exp\left(\widetilde{g}-\widetilde{b}\right)}{\exp\left(\widetilde{\tau}-\widetilde{b}\right)-\exp\left(\widetilde{g}-\widetilde{b}\right)}, \\
\theta_1 &= \frac{1}{1+\exp\left(\widetilde{\tau}-\widetilde{b}\right)-\exp\left(\widetilde{g}-\widetilde{b}\right)}, \\
\text{and } \theta_0 &= \log\left(1+\exp\left(\widetilde{\tau}-\widetilde{b}\right)-\exp\left(\widetilde{g}-\widetilde{b}\right)\right)-\frac{\exp\left(\widetilde{\tau}-\widetilde{b}\right)}{1+\exp\left(\widetilde{\tau}-\widetilde{b}\right)-\exp\left(\widetilde{g}-\widetilde{b}\right)}\left(\widetilde{\tau}-\widetilde{b}\right) \\
&+ \frac{\exp\left(\widetilde{g}-\widetilde{b}\right)}{1+\exp\left(\widetilde{\tau}-\widetilde{b}\right)-\exp\left(\widetilde{g}-\widetilde{b}\right)}\left(\widetilde{g}-\widetilde{b}\right).
\end{aligned}$$

Eq. (C.39) can be written as:

$$\widetilde{R}_t^g-\widetilde{\Pi}_t=\theta_1\widetilde{b}_{t+1}-\widetilde{b}_t+\theta_0+(1-\theta_1)(\mu_\tau\widetilde{\tau}_t-\mu_g\widetilde{g}_t). \qquad \text{(C.42)}$$

Iterating Eq. (C.42) forward and imposing the transversality condition:

$$\widetilde{b}_t=\frac{\theta_0}{1-\theta_1}+\sum_{j=0}^{\infty}\theta_1^j\left((1-\theta_1)(\mu_\tau\widetilde{\tau}_{t+j}-\mu_g\widetilde{g}_{t+j})-\widetilde{R}_{t+j}^g+\widetilde{\Pi}_{t+j}\right), \qquad \text{(C.43)}$$

taking unconditional expectations:

$$E\left[\widetilde{b}_t\right]=\frac{\theta_0}{1-\theta_1}+\sum_{j=0}^{\infty}\theta_1^j\left((1-\theta_1)E\left[\mu_\tau\widetilde{\tau}_{t+j}-\mu_g\widetilde{g}_{t+j}\right]-E\left[\widetilde{R}_{t+j}^g\right]+E\left[\widetilde{\Pi}_{t+j}\right]\right). \qquad \text{(C.44)}$$

Since the unconditional expectation is the same for all t, we can simplify the expression:

$$E\left[\widetilde{b}_t\right] = \frac{\theta_0}{1-\theta_1} + (1-\theta_1)\frac{E\left[\mu_\tau \widetilde{\tau}_{t+j} - \mu_g \widetilde{g}_t\right]}{1-\theta_1} - \frac{E\left[\widetilde{R}_t^g\right]}{1-\theta_1} + \frac{E\left[\widetilde{\Pi}_t\right]}{1-\theta_1}, \tag{C.45}$$

$$= \frac{\theta_0}{1-\theta_1} + E\left[\mu_\tau \widetilde{\tau}_t - \mu_g \widetilde{g}_t\right] - \frac{E\left[\widetilde{R}_t^g\right]}{1-\theta_1} + \frac{E\left[\widetilde{\Pi}_t\right]}{1-\theta_1}. \tag{C.46}$$

Solving for $E\left[\widetilde{\Pi}_t\right]$:

$$\frac{E\left[\widetilde{\Pi}_t\right]}{1-\theta_1} = E\left[\widetilde{b}_t\right] - \frac{\theta_0}{1-\theta_1} - E\left[\mu_\tau \widetilde{\tau}_t - \mu_g \widetilde{g}_t\right] + \frac{E\left[\widetilde{R}_t^g\right]}{1-\theta_1}, \tag{C.47}$$

$$= E\left[\widetilde{b}_t\right] - \frac{\theta_0}{1-\theta_1} - E\left[\mu_\tau \widetilde{\tau}_t - \mu_g \widetilde{g}_t\right] + \frac{E\left[\omega \widetilde{R}_t^{(1)} + (1-\omega)\widetilde{R}_t^{(2)}\right]}{1-\theta_1}. \tag{C.48}$$

In Eq. (C.48) we substituted $\widetilde{R}_t^g$ for $\omega \widetilde{R}_t^{(1)} + (1-\omega)\widetilde{R}_t^{(2)}$. Reordering the last term we have:

$$\frac{E\left[\widetilde{\Pi}_t\right]}{1-\theta_1} = E\left[\widetilde{b}_t\right] - \frac{\theta_0}{1-\theta_1} - E\left[\mu_\tau \widetilde{\tau}_t - \mu_g \widetilde{g}_t\right] + \frac{E\left[\widetilde{R}_t^{(2)} - \omega(\widetilde{R}_t^{(2)} - \widetilde{R}_t^{(1)})\right]}{1-\theta_1}. \tag{C.49}$$

Finally, we can calculate the derivative of expected inflation with respect to the weight of the 1-period bond ω:

$$\frac{dE\left[\widetilde{\Pi}_t\right]}{d\omega} = -E\left[\widetilde{R}_t^{(2)} - \widetilde{R}_t^{(1)}\right]. \tag{C.50}$$

C.5 Data

We obtain quarterly data for consumption and output from the Bureau of Economic Analysis (BEA). Consumption is measured as real personal consumption expenditures (DPCERX1A020NBEA). Output is measured as real gross domestic product (GDPC1). Inflation is computed by taking the log return on the Consumer Price Index for All Urban Consumers (CPIAUCSL), obtained from the Bureau of Labor Statistics (BLS). Monthly yield data are from CRSP. Nominal yield data for maturities of 4, 8, 12, 16, and 20 quarters are from the CRSP Fama-Bliss discount bond file. The one-quarter nominal yield is from the the CRSP Fama risk-free rate file. Finally we build our bond supply maturity structure data using the same methodology as Doepke and Schneider (2006) and Greenwood and Vayanos (2014). In particular, in each month we collect the complete history of U.S. government bonds issued from the CRSP historical bond database. We then break the stream of each bonds cash flows into principal and coupon payments. Summing the streams from each outstanding bond vintage over their respective maturity give us the monthly maturity structure of government

debt. The sample period runs from Q1-1964 to Q3-2013. We obtain the maturity distribution of privately-held Treasury marketable securities from Table FD-5 of the Treasury Bulletin. We supplement the information on the Treasury Bulletin by including reserve balances with Federal Reserve Banks from the Federal Reserve H.4.1.