

Nominal Rigidities, Asset Returns and Monetary Policy

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Abstract

We study the asset pricing implications of price and wage rigidities in a quantitative general equilibrium model. Nominal rigidities and recursive preferences improve the model ability to capture high expected excess returns on production claims. The increased premium is mainly a compensation for permanent productivity shocks, since nominal rigidities generate output and profit distortions that are a source of long-run macroeconomic risk. In the cross section, heterogeneity in industry price rigidity generates differences in expected industry asset returns that are determined by product substitutability within and across industries. Monetary policy affects expected excess returns under nominal rigidities through its response to economic conditions and policy shocks. The model calibration captures the observed price and wage rigidities in US data, the volatility of key macroeconomic variables, the low volatility of the risk-free rate, and the high Sharpe ratios on financial assets. Wage rigidities have significantly larger effects than price rigidities on asset returns. Policies that react more aggressively to inflation or less aggressively to output increase expected asset returns. Policy shocks increase asset return volatility but have a small effect on expected excess returns.

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1 Introduction

Explaining both asset return and aggregate business cycle fluctuations in a unified framework remains an important challenge in financial economics. Standard real business cycle models imply a counterfactually low compensation for risk in asset returns since production factors can be freely adjusted to help smooth households' consumption risk.¹ This has motivated the introduction of frictions to these models, such as investment adjustment costs and imperfect factor mobility,² that provide substantial improvements in capturing the joint dynamics of aggregate quantities and asset returns. In this paper, we explore an equilibrium model with a particular friction, rigidities in nominal product prices and wages, to address (i) how these rigidities affect the expected returns of production claims, and (ii) how monetary policy affects the pricing of these claims.

The introduction of nominal rigidities to the analysis of asset returns is motivated first by ample evidence of their existence in the data. For instance, Nakamura and Steinsson (2007) report a median duration of prices between 8 and 11 months, and Taylor (1999) suggests an average wage duration of 12 months.³ Second, nominal rigidities play a critical role in generating consistent business cycle dynamics in equilibrium models such as Christiano, Eichenbaum and Evans (2005) or Smets and Wouters (2007). Third, nominal rigidities generate real effects of monetary policy and allow us to explore the link between monetary policy and asset prices. Understanding this link is of significant importance to policymakers and, up to our knowledge, it has not been studied in the theoretical literature. Nominal rigidities are then a natural candidate to introduce frictions in the production sector to understand the dynamics of asset returns and their link to monetary policy.

¹Campbell and Cochrane (1999) and Bansal and Yaron (2004), among others, have made significant progress in capturing asset pricing dynamics in endowment economies. The success of these models, however, is limited in a production economy framework as shown by Boldrin, Christiano and Fisher (2001) and Kaltenbrunner and Lochstoer (2010), respectively.

²See Boldrin, Christiano and Fisher (2001), for instance.

³Blinder et al. (1998) conducts surveys on firms' pricing policies and summarize different theories for the existence of price rigidities based on the nature of costs, demand, contracts, market interactions, and imperfect information.

We summarize our main findings as follows. First, both price and wage rigidities improve the ability of real business cycle models to generate a large and positive equity premium. The increased premium is mainly a compensation for permanent productivity shocks. As illustrated by Kaltenbrunner and Lochstoer (2010), these shocks endogenously generate long run consumption risk that may lead to a higher or lower price of risk under Epstein and Zin (1989) recursive preferences. We show that the absence or presence of nominal rigidities in the model can determine whether the premium is negative or positive, respectively. Second, the model calibration shows that the quantitative impact of wage rigidities on the premium is much larger than the impact of price rigidities. Third, nominal rigidities generate a positive equity premium for monetary policy shocks. This premium, however, is much smaller than the premium for permanent productivity shocks. Fourth, price rigidities generate interesting markup dynamics that are reflected in differences in the riskiness of output and profit claims. Fifth, the effect of heterogeneous price rigidity across industries on the cross section of industry asset returns depends on the degree of product substitutability within and across industries. Finally, as a result of wage rigidities, economies with monetary policies that react more aggressively to inflation and/or less aggressively to output variation have larger equity premiums.

We model a two-sector production economy with four main ingredients. First, a representative household with Epstein and Zin (1989) recursive preferences over consumption and leisure. Recursive preferences disentangle the elasticity of intertemporal substitution from risk aversion. As in Tallarini (2000), this separation is useful to keep reasonable values for the elasticity of substitution to match macroeconomic dynamics, while having values for risk aversion that match empirical Sharpe ratios of financial assets. The high Sharpe ratios result mainly as a compensation for long run macroeconomic risk. Second, nominal rigidities are modeled following Calvo (1983) staggered price and wage setting. The representative household provides differentiated labor types to the production sectors and has monopolistic power to set its wages. However, at each point of time the household can only adjust the wage optimally for a fraction of labor types. Similarly,

firms provide differentiated products and have monopolistic power to set their prices. However, at each point of time a firm can only adjust the price optimally with some positive probability. We allow for different probabilities for the two sectors to analyze implications of heterogeneous price rigidities on cross-industry asset returns. Third, monetary policy is modeled as a Taylor (1993) policy rule to set the level of a nominal interest rate. This rule responds to economic conditions and is affected by policy shocks. It allows us to quantify the effect on asset returns of changes in the policy response to the state of the economy. Fourth, the model incorporates permanent and transitory shocks. As shown by Campbell (1994), permanent and transitory shocks have different effects on optimal consumption and then different implications on asset returns. By incorporating the two types of shocks, we can determine how nominal rigidities affect individual compensations for these shocks in financial assets.

We calibrate the model to capture the mean and dispersion of price duration and the mean wage duration in U.S. data. The model is able to match the volatility of consumption growth and the Sharpe ratio implied in equity returns, while also matching the variability explained by the model shocks of inflation, de-trended consumption, and the interest rate. The calibration relies on a reasonable elasticity of intertemporal substitution (EIS) of around 0.20 and a relative risk aversion coefficient of 26. Risk aversion is high with respect to empirical and experimental evidence, but significantly lower than in standard business cycle models such as Tallarini (2000). This improvement is the result of introducing permanent productivity shocks and leisure preferences.

We quantify the effect of nominal rigidities as an increase in 85 bps in the equity premium relative to an economy with no rigidities. This increase is mainly a compensation for persistent permanent productivity shocks. To understand why, consider first an economy with flexible prices and wages. Our calibration (shutting down the rigidities) implies a negative equity premium in this economy. A negative persistent permanent productivity shock has a negative persistent effect on consumption and profits, and a persistent increase in the marginal utility of consumption. While lower profits decrease the return on profit claims (substitution effect), the persistent increase in

marginal utility makes claims on future consumption more valuable and have a positive effect on returns (wealth effect). The wealth effect dominates the substitution effect leading to a negative premium in profit claims. In the presence of wage and price rigidities, the substitution effect outweighs the wealth effect. The substitution effect is stronger because the negative response of consumption and profits to a negative shock is amplified relative to an economy with no rigidities. Under wage rigidities, households cannot adjust some wages downwards and producers keep higher prices to obtain an optimal markup over marginal costs. Higher prices reduce the product demand and imply lower output and profits than under flexible wages. Similarly, under price rigidities, firms that cannot adjust prices downwards face a lower demand, and output and profits are lower than under flexible prices. Simultaneously, the wealth effect is weaker under nominal rigidities since the partial adjustment of prices and wages induces less persistent effects of permanent productivity shocks on the marginal utility of consumption. Quantitatively, the effect on returns of wage rigidities is significantly larger than the effect of price rigidities and generates a larger premium.

Price rigidities also generate differences between the expected returns of output and profit claims. The difference is the result of time variation in production markups and depends on whether or not wages are flexible. If wages are flexible (sticky), prices following a negative shock are high (low) relative to marginal costs which increases (reduces) the markup. The countercyclical (procyclical) markup reduces (increases) the riskiness and expected returns of profit claims relative to output claims.

Our two-sector model allows us to analyze the link between industry price rigidity and industry expected asset returns. High prices in an industry with respect to another one lead to two opposite effects on profits: a low industry output demand (low profits) and a high industry markup (high profits) relative to the other industry. The substitutability of goods across industries determines the magnitude of the difference in industry output demands. The substitutability of goods within industries determines the magnitude of the difference in industry markups. If the two elasticities are the same, relative output and markup effects exactly cancel each other and profit claims in

the two industries have the same expected returns. If the elasticities are different, the difference in expected returns is determined by the joint dynamics of the marginal utility of consumption and industry prices.

We consider a nominal interest rate policy rule that reacts to inflation and the output level, and is affected by an interest rate smoothing component and policy shocks. Under nominal rigidities, this rule affects real interest rates, consumption and production decisions, and asset returns. A stronger response to inflation in the rule implies a higher real interest rate and lower output, which increases expected asset returns. A stronger response to output in the rule implies a more stable output and, therefore, lower expected asset returns. A larger weight on interest rate smoothing has a similar effect as a reduction in the response to inflation. Finally, policy shocks require a positive compensation in expected asset returns since contractionary shocks increase the marginal utility of consumption and reduce output and profits. Quantitatively, the premium for policy shocks is significantly smaller than the premium for permanent productivity shocks.

Related literature

Our paper belongs to the literature that links the real economy to financial markets in a unified framework.⁴ It builds on the pioneer work of Kydland and Prescott (1982), and is mostly related to Boldrin, Christiano and Fisher (2001) and Christiano, Eichenbaum and Evans (2005). Boldrin, Christiano and Fisher (2001) show that frictions in the production sector are critical for real business cycle models to capture salient asset pricing dynamics. They find that frictions in intersectoral factor mobility and habit formation in preferences can simultaneously reproduce important business cycle properties, a high price of risk, and the observed equity premium. However, habit formation in their model also leads to a counterfactual high volatility in the risk-free rate. Our model instead relies on Epstein and Zin (1989) recursive preferences and permanent productivity shocks to achieve both a high price of risk and low volatility in the risk-free rate. As in Christiano, Eichenbaum and Evans (2005), frictions in our model result from nominal price and

⁴Cochrane (2005) provides an extensive summary of the main findings and challenges in this literature.

wage rigidities, and allow us to analyze the effects of monetary policy on asset prices. Christiano, Eichenbaum and Evans (2005) focus on the business cycle implications of monetary policy shocks and do not analyze asset pricing dynamics. We find that policy shocks have a small effect on asset returns in comparison to permanent productivity shocks. Li and Palomino (2010) provide a qualitative analysis of the effects of price rigidities and policy shocks on asset returns. They do not calibrate their model and do not quantify these effects. We find that wage rigidities have larger quantitative effects than price rigidities on asset returns.

Our paper is also related to Kaltenbrunner and Lochstoer (2010). They find that permanent and transitory productivity shocks can endogenously generate long run consumption risk as in the endowment economy of Bansal and Yaron (2004) and then high compensations for risk in financial assets. Their model calibration with permanent productivity shocks relies on a high elasticity of intertemporal substitution of consumption and generates a low equity premium. We show that nominal rigidities increase the premium for permanent productivity shocks relying on a low elasticity of intertemporal substitution. Finally, our paper joins recent attempts to understand the effects of labor markets on financial asset returns. Lettau and Uhlig (2000) find that adding labor negatively affects the performance of habit models since labor provides an additional channel to smooth consumption. Uhlig (2007) shows that real wage rigidities can improve the ability of habit models to capture a high equity premium. In the same spirit, Favilukis and Lin (2011) analyze the time series and cross sectional asset return implications of infrequent renegotiation of wages. We focus on nominal wage rigidities rather than real wage rigidities to understand the implications of monetary policy on asset returns.

The paper is organized as follows. Section 2 presents the model and its optimality conditions. Section 3 explains the mechanism that links expected returns and nominal rigidities, and shows the quantitative implications of the calibration. Section 4 concludes.

2 The Model

We model a production economy where households derive utility from the consumption of a basket of two goods and disutility from supplying labor for the production of these goods. The two goods are produced in two different industries characterized by monopolistic competition and nominal price and wage rigidities. We allow for heterogeneous degrees of price rigidity in the two industries to learn about the effects of different rigidities on the cross-section of stock returns.⁵

Nominal rigidities generate real effects of monetary policy. If some producers are not able to adjust prices optimally and/or if households are not able to adjust their wages optimally, inflation generates distortions in relative prices and/or relative real wages that affect production decisions. Since inflation is determined by monetary policy, different policies have different implications for real activity, and affect the returns on financial claims linked to production (e.g., stocks). We model monetary policy as an interest-rate policy rule that reacts to inflation and deviations of output from a target. Risk in the economy is driven by permanent and transitory productivity shocks and monetary policy shocks. In section 3, we analyze how nominal rigidities and monetary policy affect the compensation for these shocks in production claims.

2.1 Households

A representative household maximizes its recursive utility

$$V_t = U_t + \beta Q_t^{\frac{1-\psi}{1-\gamma}}, \quad (1)$$

where

$$U_t = \frac{C_t^{1-\psi}}{1-\psi} - \kappa_t \frac{(N_t^s)^{1+\omega}}{1+\omega}, \quad \text{and} \quad Q_t = \mathbb{E}_t \left[V_{t+1}^{\frac{1-\gamma}{1-\psi}} \right].$$

⁵Aoki (2001) studies a particular case for this economy in which one of the industries has perfectly flexible prices, and wages are perfectly flexible. His analysis focuses on the implications for optimal monetary policy in this economy, and does not explore any asset pricing implications.

The parameters ψ and γ characterize the elasticity of intertemporal substitution of consumption and risk aversion, respectively. The particular case $\psi = \gamma$ corresponds to the standard power utility specification. C_t is the consumption of the final good, and N_t^s is the aggregate supply of labor at time t . The process κ_t is used to obtain balanced growth. Growth is the result of permanent shocks to productivity, as described in the production sector section. The final good is a basket of two intermediate goods produced in two industries. We refer to these industries as $I = \{H, L\}$, to indicate industries with high and low price rigidities, respectively. The consumption of each industry's good is $C_{I,t}$, and the final good is given by

$$C_t = \left[\varphi_H^{1/\eta} C_{H,t}^{\frac{\eta-1}{\eta}} + \varphi_L^{1/\eta} C_{L,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (2)$$

where φ_I is the weight of industry I in the basket ($\varphi_L \equiv 1 - \varphi_H$), and $\eta > 1$ is the elasticity of substitution between industry goods. Each industry good is a Dixit-Stiglitz aggregate of a continuum of differentiated goods, defined as

$$C_{I,t} = \left[\int_0^1 C_{I,t}(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}, \quad (3)$$

where the elasticity of substitution across differentiated goods is $\theta > 1$.

The intertemporal budget constraint faced by the household is

$$\mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} P_{t+\tau} C_{t+\tau} \right] \leq \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} P_{t+\tau} \left(LI_{t+\tau} + \sum_{I \in \{H,L\}} \int_0^1 D_{I,t+\tau}(j) dj \right) \right], \quad (4)$$

where $M_{t,t+\tau}^{\$} > 0$ is the nominal pricing kernel that discounts nominal cash flows at time $t + \tau$ to time t , P_t is the price of the final good, LI_t is the real labor income from supplying labor to the production sector, and $D_{I,t}(j)$ is the real profit from the production of the differentiated good j in industry I .

The maximization of (1) subject to (4) provides us with the intertemporal marginal rate of substitution of consumption for the economy. The marginal rates of substitution of consumption between period t and period $t + 1$ in real and nominal terms are

$$M_{t,t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\psi} \left(\frac{V_{t+1}^{1/(1-\psi)}}{Q_t^{1/(1-\gamma)}} \right)^{\psi-\gamma}, \quad (5)$$

and

$$M_{t,t+1}^{\$} = M_{t,t+1} \left(\frac{P_{t+1}}{P_t} \right)^{-1}, \quad (6)$$

respectively. From these two equations we can compute the real and nominal (gross) one-period risk-free rates as

$$R_{f,t} = \frac{1}{\mathbb{E}_t [M_{t,t+1}]}, \quad \text{and} \quad R_{f,t}^{\$} = \frac{1}{\mathbb{E}_t [M_{t,t+1}^{\$}]}, \quad (7)$$

respectively. These rates are important to compute excess real and nominal returns on stocks. The one-period nominal risk-free rate is the instrument of monetary policy.

Wage Setting

We follow Schmitt-Grohé and Uribe (2007) to model an imperfectly competitive labor market where the representative household monopolistically provides a continuum of labor types indexed by $k \in [0, 1]$ ⁶. Specifically, the supply of labor type k satisfies the demand equation

$$N_t^s(k) = \left(\frac{W_t(k)}{W_t} \right)^{-\theta_w} N_t^d, \quad (8)$$

⁶This approach is different from the standard heterogeneous households approach to model wage rigidities as in Erceg, Henderson and Levin (2000), where each household supplies a differentiated type of labor. In the presence of recursive preferences, this approach introduces heterogeneity in the marginal rate of substitution of consumption across households since it depends on labor. We avoid this difficulty and obtain a unique marginal rate of substitution by modeling a representative agent who provides all different types of labor.

where N_t^d is the aggregate labor demand of the production sector, $W_t(k)$ is the wage for labor type k , and W_t is the aggregate wage index given by

$$W_t = \left[\int_0^1 W_t^{1-\theta_w}(k) dk \right]^{\frac{1}{1-\theta_w}}.$$

The labor demand equation (8) is derived in the production sector section below. The household chooses optimal wages $W_t(k)$ for all labor types k under Calvo (1983) staggered wage setting. Specifically, each period the household is only able to adjust wages optimally for a fraction $1 - \tilde{\alpha}$ of labor types. A fraction $\tilde{\alpha}$ of labor types keeps their previous period wages. The optimal wage maximizes (1) subject to demand functions (8) and the budget constraint (4), where real labor income is given by

$$LI_t = \int_0^1 \frac{W_t(k)}{P_t} N_t^s(k) dk.$$

Because the demand curve and the cost of labor supply are identical across different labor types, the household chooses the same optimal wage W_t^* for all the labor types subject to a wage change at time t . The appendix shows that the optimal wage satisfies

$$\frac{W_t^*}{P_t} = \mu_w \kappa_t (N_t^s)^\omega C_t^\psi \frac{G_{w,t}}{H_{w,t}}, \quad (9)$$

where $N_t^s = \int_0^1 N_t^s(k) dk$ is the aggregate labor supply, $\mu_w \equiv \frac{\theta_w}{\theta_w - 1}$,

$$H_{w,t} = 1 + \tilde{\alpha} \mathbb{E}_t \left[M_{t,t+1}^\$ \left(\frac{N_{t+1}^d}{N_t^d} \right) \left(\frac{W_t}{W_{t+1}} \right)^{-\theta_w} H_{w,t+1} \right],$$

and

$$G_{w,t} = 1 + \tilde{\alpha} \mathbb{E}_t \left[M_{t,t+1}^\$ \left(\frac{P_{t+1}}{P_t} \right) \left(\frac{C_{t+1}}{C_t} \right)^\psi \left(\frac{N_{t+1}^d}{N_t^d} \right) \left(\frac{\kappa_{t+1}}{\kappa_t} \right) \left(\frac{N_{t+1}^s}{N_t^s} \right)^\omega \left(\frac{W_t}{W_{t+1}} \right)^{-\theta_w} G_{w,t+1} \right].$$

In the absence of wage rigidities ($\tilde{\alpha} = 0$), the optimal wage is given by the markup-adjusted marginal rate of substitution between labor and consumption, with optimal markup μ_w .

2.2 Firms

The production of the final consumption good uses two intermediate goods from industry H and L via the aggregator

$$Y_t = \left[\varphi_H^{1/\eta} Y_{H,t}^{\frac{\eta-1}{\eta}} + \varphi_L^{1/\eta} Y_{L,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}.$$

Within each industry, there is a continuum of firms indexed by $j \in [0, 1]$. The final output of industry $I \in \{H, L\}$ is given by the Dixit-Stiglitz aggregator

$$Y_{I,t} = \left[\int_0^1 Y_{I,t}^{\frac{\theta-1}{\theta}}(j) dj \right]^{\frac{\theta}{\theta-1}}.$$

The production technology of firm j in industry I is given by

$$Y_{I,t}(j) = A_t N_{I,t}^d(j),$$

where A_t is labor productivity and $N_{I,t}^d(j)$ is firm j 's labor demand. We assume that labor productivity contains permanent and transitory components. Specifically,

$$A_t = A_t^p Z_t,$$

where the permanent and transitory components follow processes

$$\Delta \log A_{t+1}^p = \phi_a \Delta \log A_t^p + \sigma_a \varepsilon_{a,t+1},$$

and

$$\log Z_{t+1} = \phi_z \log Z_t + \sigma_z \varepsilon_{z,t+1},$$

respectively, with Δ as the difference operator, and innovations $\varepsilon_{a,t}$ and $\varepsilon_{z,t} \sim \text{IID}\mathcal{N}(0, 1)$. The labor input in production is a composite of a continuum of differentiated labor types indexed by

$k \in [0, 1]$ via the aggregator

$$N_{I,t}^d(j) = \left[\int_0^1 N_{I,t}^d(j, k)^{\frac{\theta_w - 1}{\theta_w}} dj \right]^{\frac{\theta_w}{\theta_w - 1}}, \quad (10)$$

where θ_w is the elasticity of substitution across differentiated labor types.

Producers have market power to set the price of their differentiated goods in a Calvo (1983) staggered price setting. That is, with some positive probability a producer is unable to change the product price at any point of time. We allow for different probabilities across the two industries to capture heterogeneous degrees of price rigidities. The probability of not changing the price of a differentiated good at a particular time in industry I is α_I . When the producer is able to set a new price for the good, the price is set to maximize the expected present value of all future profits, taking into account the probability of not changing that price in the future. The maximization problem is

$$\max_{\{P_{I,t}(j)\}} \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} \alpha_I^\tau M_{t,t+\tau}^{\$} (P_{I,t}(j) Y_{I,t+\tau|t}(j) - W_{t+\tau|t}(j) N_{I,t+\tau|t}^d(j)) \right], \quad (11)$$

subject to the demand function (see appendix B for its derivation)

$$P_{I,t}(j) = P_{I,t+\tau} \left(\frac{Y_{I,t+\tau|t}(j)}{Y_{I,t+\tau}} \right)^{-1/\theta}, \quad (12)$$

and the production function

$$Y_{I,t+\tau|t}(j) = A_{t+\tau} N_{I,t+\tau|t}^d(j), \quad (13)$$

where $Y_{I,t+\tau|t}(j)$ is the level of output of firm j in industry I at time $t + \tau$ when the last time the price was reset was at t . A similar definition applies to $N_{I,t+\tau|t}^d(j)$ and $W_{t+\tau|t}(j)$. All firms within an industry adjusting their product price optimally face the same optimization problem

and choose the same optimal price $P_{I,t}^*$. The appendix shows that this price satisfies

$$\left(\frac{P_{I,t}^*}{P_{I,t}}\right) \left(\frac{P_{I,t}}{P_t}\right) H_{I,t} = \frac{\mu}{A_t} \frac{W_t}{P_t} G_{I,t}, \quad (14)$$

where $\mu = \frac{\theta}{\theta-1}$,

$$\begin{aligned} H_{I,t} &= 1 + \alpha_I \mathbb{E}_t \left[M_{t,t+1}^{\$} \left(\frac{Y_{I,t+1}}{Y_{I,t}}\right) \left(\frac{P_{I,t+1}}{P_{I,t}}\right)^{-\theta} H_{I,t+1} \right], \\ \text{and } G_{I,t} &= 1 + \alpha_I \mathbb{E}_t \left[M_{t,t+1}^{\$} \left(\frac{Y_{I,t+1}}{Y_{I,t}}\right) \left(\frac{P_{I,t+1}}{P_{I,t}}\right)^{-\theta} \left(\frac{W_{t+1}}{W_t}\right) \left(\frac{A_t}{A_{t+1}}\right) G_{I,t+1} \right]. \end{aligned}$$

In the absence of price rigidities ($\alpha_I = 0$), the optimal price is the markup adjusted marginal cost, with optimal markup μ .

2.3 Monetary Authority

We model a monetary authority that sets the level of a short-term nominal interest rate. For simplicity, we define the continuously compounded one-period nominal rate, $i_t \equiv \log(R_{f,t}^{\$})$. Monetary policy is described by the policy rule

$$i_t = \rho i_{t-1} + (1 - \rho) (\bar{i} + \nu_{\pi} \pi_t + \nu_x x_t) + u_t, \quad (15)$$

where the interest rate is set responding to the lagged interest rate, aggregate inflation $\pi_t \equiv \log P_t - \log P_{t-1}$, the output gap x_t , and a policy shock u_t . The output gap is defined as the deviation of total output with respect to the output that would be obtained under perfectly flexible prices and wages, Y_t^f . That is,

$$x_t \equiv \log Y_t - \log Y_t^f. \quad (16)$$

It can be shown that real output and real wages in a flexible price and wage economy are

$$Y_t^f = \left(\frac{A_t^{1+\omega}}{\mu \mu_w K_t} \right)^{1/(\omega+\psi)}, \quad \text{and} \quad W_t^{\text{real},f} = \frac{A_t}{\mu}, \quad (17)$$

respectively. The policy shock follows the process

$$u_{t+1} = \phi_u u_t + \sigma_u \varepsilon_{u,t+1}, \quad (18)$$

with $\varepsilon_u \sim \text{IIDN}(0, 1)$.

2.4 Asset Returns

We define stocks as financial claims on all future profits. We are interested in analyzing stock returns at aggregate and industry levels. The real stock price and associated one-period (gross) return for industry I are, respectively,

$$S_{D,I,t} = \mathbb{E}_t \left[\sum_{n=1}^{\infty} M_{t,t+n} D_{I,t+n} \right], \quad \text{and} \quad R_{D,I,t+1} = \frac{D_{I,t+1} + S_{D,I,t+1}}{S_{D,I,t}}. \quad (19)$$

Similarly, the aggregate stock is a claim on aggregate profits $D_t = D_{H,t} + D_{L,t}$. The price and return of this claim are

$$S_{D,t} = \mathbb{E}_t \left[\sum_{n=1}^{\infty} M_{t,t+n} D_{t+n} \right], \quad \text{and} \quad R_{D,t+1} = \frac{D_{t+1} + S_{D,t+1}}{S_{D,t}}, \quad (20)$$

respectively. It is also convenient to compare stock returns with returns of claims on aggregate and industry output. The price and return of a claim on all future real output of industry I are, respectively,

$$S_{Y,I,t} = \mathbb{E}_t \left[\sum_{n=1}^{\infty} M_{t,t+n} Y_{I,t+n}^{\text{real}} \right], \quad \text{and} \quad R_{Y,I,t+1} = \frac{Y_{I,t+1}^{\text{real}} + S_{Y,I,t+1}}{S_{Y,I,t}}, \quad (21)$$

where $Y_{I,t}^{\text{real}} = \left(\frac{P_{I,t}}{P_t}\right) Y_{I,t}$ is the real output of industry I . The price and return of a claim on all aggregate output are, respectively,

$$S_{Y,t} = \mathbb{E}_t \left[\sum_{n=1}^{\infty} M_{t,t+n} Y_{t+n} \right], \quad \text{and} \quad R_{Y,t+1} = \frac{Y_{t+1} + S_{Y,t+1}}{S_{Y,t}}. \quad (22)$$

Asset returns also are useful to provide an alternative specification of the pricing kernel in equation (5). Appendix D shows that it can be written in terms of consumption and a portfolio return as

$$M_{t,t+1} = \left[\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\psi} \right]^{\frac{1-\gamma}{1-\psi}} \left(\frac{1}{R_{YL,t+1}} \right)^{1-\frac{1-\gamma}{1-\psi}}, \quad (23)$$

where

$$\begin{aligned} R_{YL,t+1} &= (1 - \nu_t) R_{Y,t+1} + \nu_t R_{LI^*,t+1}, \\ R_{LI^*,t+1} &= \frac{LI_{t+1}^* + S_{LI^*,t+1}}{S_{LI^*,t}}, \quad LI_t^* \equiv \frac{W_t^*}{P_t} N_t^s \frac{H_w, t}{G_w, t}, \\ \text{and } \nu_t &= \frac{\bar{\nu} S_{LI^*,t}}{\bar{\nu} S_{LI^*,t} - S_{C,t}}. \end{aligned}$$

for $\bar{\nu} \equiv \frac{1-\psi}{1+\omega} \frac{1}{\mu_w}$. Therefore, if $\psi \neq \gamma$, the pricing kernel depends on the portfolio return $R_{YL,t}$. This return is a weighted average of the returns of claims on aggregate output and adjusted labor income LI_t^* . Notice that $LI_t^* = LI_t$ in the absence of wage rigidities. Also, if there is no disutility of labor ($\omega \rightarrow \infty$), the portfolio return converges to $R_{YL,t} = R_{Y,t}$, as in the original specification in Epstein and Zin (1989).

2.5 Equilibrium

The equilibrium of the economy requires product, labor, and financial market clearing.

Product market clearing

The product market clearing conditions are $C_t = Y_t$, and $C_{I,t} = Y_{I,t}$, for $I = \{H, L\}$.

Labor market clearing

In equilibrium, supply and demand of labor type k employed by firm j in industry I are equal. That is, $N_{i,t}^s(j, k) = N_{I,t}^d(j, k)$. From it, Appendix C shows that equilibrium in the aggregate labor market implies $N_t^s = N_t^d F_{w,t}$, where aggregate demand satisfies $N_t^d = \frac{Y_t}{A_t} F_t$. The distortion

$$F_{w,t} = \int_0^1 \left[\left(\frac{W_t(k)}{W_t} \right)^{1-\theta_w} \right]^{\frac{-\theta_w}{1-\theta_w}} dk,$$

is the result of wage dispersion across labor types from wage rigidities. The distortion

$$F_t = \varphi_H \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} F_{H,t} + \varphi_L \left(\frac{P_{L,t}}{P_t} \right)^{-\eta} F_{L,t},$$

where

$$F_{I,t} = \int_0^1 \left(\frac{P_{I,t}(j)}{P_{I,t}} \right)^{-\theta} dj,$$

is the result of price dispersion across firms and industries from price rigidities. The appendix shows that the inefficiencies $F_{w,t}$ and F_t resulting from nominal rigidities translate into $Y_t < A_t N_t^s$.

Financial market clearing

In equilibrium, the nominal interest rate from household maximization in equation (7) matches the interest rate set by the monetary authority. That is,

$$-\log [M_{t,t+1}^s] = \rho i_{t-1} + (1 - \rho) (\bar{i} + \iota_\pi \pi_t + \iota_x x_t) + u_t.$$

Appendix E provides a summary of the system of equations describing the equilibrium of the model. In order to obtain balanced growth, we make $\kappa_t = (A_t^p)^{1-\psi}$. This condition ensures that Y_t , $Y_{I,t}$, W_t , and W_t^* are growing at the same rate. We solve the model numerically, applying

a second-order approximation of the optimality conditions.⁷ A second-order approximation is required to capture expected excess returns on financial claims.

3 Analysis

We analyze the implications of nominal rigidities and monetary policy on expected asset returns at aggregate and industry level. We focus on expected excess returns of claims on all future output (consumption) and profits. The effects of nominal rigidities on expected excess returns can be understood by their impact on the pricing kernel, output, and production markups. We calibrate the model to capture important dynamics of U.S. macroeconomic variables and stock returns. We compare different model specifications to highlight the most important channels driving the results.

3.1 Understanding the Mechanism: Output and Markup Effects

Expected excess asset returns over the risk-free rate reflect a compensation for macroeconomic risk. The compensation is determined by the joint dynamics of the marginal rate of substitution of consumption and asset returns, which is affected by nominal rigidities and monetary policy. We are interested in analyzing the returns on the output and profit claims in equations (19) to (22).

To illustrate the mechanism, we assume that the log-pricing kernel, output growth, profit growth and asset log-returns follow normal distributions. Consider first a claim on aggregate output. Appendix F shows that the expected excess return of this claim over the risk-free rate is

$$\begin{aligned} \log \mathbb{E}_t [R_{Y,t+1}] - \log R_{f,t} &= -\text{cov}_t(m_{t,t+1}, \log R_{Y,t+1}) \\ &= -\text{cov}_t(m_{t,t+1}, \Delta y_{t+1}) - \text{cov}_t(m_{t,t+1}, \log(1 + P_{Y,t+1})) , \end{aligned} \quad (24)$$

⁷We use the Dynare code available in www.dynare.org.

where $m_{t,t+1} \equiv \log M_{t,t+1}$, $y_t \equiv \log Y_t$, and $P_{Y,t} \equiv \frac{S_{Y,t}}{Y_t}$ is the wealth-consumption ratio. The covariance of the pricing kernel with output growth and the wealth-consumption ratio captures the expected excess return of the claim on production over the risk-free rate. Similarly, the expected excess return of the claim on aggregate profits over the risk-free rate is

$$\log \mathbb{E}_t [R_{D,t+1}] - \log R_{f,t} = -\text{cov}_t(m_{t,t+1}, \Delta d_{t+1}) - \text{cov}_t(m_{t,t+1}, \log(1 + P_{D,t+1})), \quad (25)$$

where $d_t \equiv \log D_t$, and $P_{D,t} \equiv \frac{S_{D,t}}{D_t}$ is the price-dividend ratio. Nominal rigidities affect the dynamics of consumption and profits, and therefore, the responses to shocks of the marginal rate of substitution of consumption, output and profit growth, and the wealth-consumption and price-dividend ratios. We use the model calibration to analyze and compare these responses in the presence and absence of nominal rigidities.

We also explore the difference in expected returns between output and profit claims implied by the rigidities. Consider a potentially time-varying markup μ_t such that profits are $D_t = \left(1 - \frac{1}{\mu_t}\right) Y_t$. From equations (24) and (25), it follows that

$$\log \left(\frac{\mathbb{E}_t [R_{D,t+1}]}{\mathbb{E}_t [R_{Y,t+1}]} \right) = -\text{cov}_t \left(m_{t,t+1}, \log \left(1 - \frac{1}{\mu_{t+1}} \right) \right) - \text{cov}_t \left(m_{t,t+1}, \log \left(\frac{1 + P_{D,t+1}}{1 + P_{Y,t+1}} \right) \right). \quad (26)$$

Two terms capture the difference in expected excess returns between output and profit claims. The first term is the difference in the covariance of output and profit growth with the pricing kernel. This difference is driven by the markup dynamics. The expected return of a claim on profits is lower (higher) than the expected return of a claim on output if the markup and the discount factor are positively (negatively) correlated. That is, claims on profits are less (more) risky than claims on output if profits represent a larger (smaller) fraction of production when the marginal rate of substitution of consumption is high. The second component captures the difference in the dynamics of wealth-consumption and price-dividend ratios with the pricing kernel. This difference

is also driven by markup dynamics.

Nominal rigidities generate interesting markup dynamics. In the absence of nominal rigidities, producers choose a level of production to charge a constant optimal markup $\mu_t = \mu$ over marginal costs. Since the markup is constant, claims on output and profits have the same expected returns. On the other hand, if the economy is affected by price and wage rigidities, the markup is

$$\mu_t = \frac{\mu}{F_t} \left(\frac{W_t^{\text{real}}}{W_t^{\text{real},f}} \right)^{-1},$$

where $W_t^{\text{real}} = \frac{W_t}{P_t}$ is the real wage. The markup is driven by the aggregate price dispersion across firms, F_t , and the “wage gap,” or the value of the real wage index relative to its value in a reference economy with flexible prices and wages. Since $F_t > 1$, a direct effect of price dispersion is a reduction in the markup relative to μ . In addition, the wage gap has an intuitive effect on the markup. If real wages are higher than those under flexible prices and wages, the markup is lower than μ . Therefore, analyzing the effects of the time variation in markups induced by the nominal rigidities amounts to analyzing the covariance between the marginal rate of substitution and the wage gap.

Equations (24), (25), and (26) also apply to industry claims. Differences in expected stock returns across industries result from differences in the covariance of their respective outputs and markups with the discount factor. We analyze the responses to shocks of industry outputs and markups to understand the effects of nominal rigidities on the cross section of asset returns.

3.2 Calibration

We use quarterly U.S. data from 1987:1 to 2010:4 for consumption, inflation, the short-term nominal interest rate, and stock returns. We focus on the Greenspan-Bernanke period to avoid changes in the monetary policy regime, as suggested by Clarida, Galí and Gertler (2000). The consumption series was constructed using data on real consumption of nondurable and services

Table 1: **Baseline Parameter Values**

Parameter	Description	Value
β	Subjective discount factor	0.9778
ψ	Inverse of elasticity of intertemporal substitution	5.3
γ	Risk aversion parameter	111.5
ω	Inverse of Frisch labor elasticity	0.35
φ_H	Weight of industry H good in the basket	0.5
θ	Elasticity of substitution of differentiated goods	6
η	Elasticity of substitution of industry goods	6
θ_w	Elasticity of substitution of labor types	21
α_H	Price rigidity parameter for industry H	0.8
α_L	Price rigidity parameter for industry L	0
$\tilde{\alpha}$	Wage rigidity parameter	0.78
ρ	Interest-rate smoothing coefficient in policy rule	0.76
\bar{i}	Constant in the policy rule	0.0224
ι_π	Response to inflation in the policy rule	1.5
ι_x	Response to output gap in the policy rule	0.125
ϕ_u	Autocorrelation of policy shock	0.15
$\sigma_u \times 10^2$	Conditional volatility of policy shock	0.175
ϕ_a	Autocorrelation of permanent productivity shock	0.275
$\sigma_a \times 10^2$	Conditional volatility of permanent productivity shock	0.246
ϕ_z	Autocorrelation of transitory productivity shock	0.957
$\sigma_z \times 10^2$	Conditional volatility of permanent productivity shock	0.19625

from the Bureau of Economic Analysis. The series is de-trended using a Hodrick-Prescott filter. The inflation series was constructed to capture inflation related only to consumption of non-durables and services, following the methodology in Piazzesi and Schneider (2007). The short-term nominal rate is the 3-month T-bill rate from the Fama risk-free rates database. The stock market data are the quarterly returns of the market portfolio obtained from the Center for Research in Security Prices (CRSP).

Our calibration strategy has two steps. First, we choose values for all parameters but γ to match second moments of de-trended consumption, consumption growth, inflation, and the nominal interest rate. Second, we choose γ to match the Sharpe ratio of the aggregate stock market. Table 1 presents the parameter values for the baseline calibration.

For the first step, we mostly rely on Altig et al. (2011) (hereafter ACEL). All parameters values are standard in the macroeconomic literature. The value of θ is chosen to provide a markup of 20%, which is the value for the “high markup” specification in ACEL. We set the elasticity of substitution across industry goods, η , equal to θ . In the analysis of the cross section of stock returns, we present results for specifications for η different than θ , since this difference has important cross sectional implications. The price rigidity parameter values for α_H and α_L are chosen such that the average price duration \overline{dur} and dispersion of price duration across industries $\sigma(dur)$ are, respectively,

$$\overline{dur} = -\varphi_H \frac{1}{\log \alpha_H} - \varphi_L \frac{1}{\log \alpha_L} = 2.2 \text{ quarters},$$

and

$$\sigma(dur) = \left[\varphi_H \left(-\frac{1}{\log \alpha_H} - \overline{dur} \right)^2 + \varphi_L \left(-\frac{1}{\log \alpha_L} - \overline{dur} \right)^2 \right]^{1/2} = 2.13 \text{ quarters}.$$

These values are consistent with the empirical evidence in Bils and Klenow (2004). For simplicity, we assume same weights for industries H and L , $\varphi_H = \varphi_L = 0.5$. The value of θ_w is chosen to have an average markup of wages over the marginal rate of substitution of leisure and consumption of 5%. The parameter $\tilde{\alpha}$ implies a duration of wages of four quarters, as estimated in ACEL. The parameter β (and $\bar{i} = -\log(\beta)$) is chosen to match the average level of the nominal risk-free rate. The interest rate rule parameters ρ , ι_π , and ι_x are chosen to be consistent with the evidence for the Greenspan era according to Clarida, Galí and Gertler (2000).

The parameter values for the elasticities ψ , ω , and the autocorrelations and conditional volatilities of productivity and policy shocks are chosen to match some empirical results presented in ACEL. ACEL use a VAR to identify productivity and policy shocks and obtain a variance decomposition for different macroeconomic variables. Table 2 presents their variance decomposition for inflation, consumption and the short-term interest rate.⁸ Productivity and policy shocks ex-

⁸ACEL refers to these productivity shocks as “neutral technology” shocks. The variance decomposition in

Table 2: **Data and Model Volatility.**

The table contains the total volatility of macroeconomic variables and the volatility explained by the model shocks in the data and the model. The variance decomposition is obtained from Altig et al. (2011). Columns labeled “All” refer to the volatility explained by policy and productivity shocks. Columns labeled “Prod.” refer to productivity shocks (permanent and transitory). The column labeled “Perm.” refers to permanent productivity shocks. The column labeled “Trans.” refers to transitory productivity shocks. The row labeled \hat{c}_t refers to de-trended log consumption. The volatility figures are presented in annualized percentage terms.

	Total volatility Data (1987-2010)	Variance decomp. (%)		Volatility explained by the shocks							
		Policy	Prod.	Data			Model				
				All	Policy	Prod.	All	Policy	Prod.	Perm.	Trans.
i_t	2.29	14	2	0.92	0.86	0.32	0.95	0.86	0.41	0.20	0.36
π_t	1.70	5	12	0.70	0.38	0.59	0.71	0.39	0.59	0.36	0.46
\hat{c}_t	2.90	5	8	1.05	0.65	0.82	1.04	0.65	0.81	0.50	0.63
Δc_t	1.55	-	-	-	-	-	1.55	0.52	1.46	1.44	0.23

plain a small fraction of the total volatility of the three macroeconomic variables. Based on this decomposition, we choose parameter values to match the contribution of these shocks to the total variability of the macroeconomic series. Since our model has both permanent and transitory productivity shocks, we require additional restrictions to identify how much of the variability explained by productivity shocks is the result of permanent and transitory shocks. We choose a mix of shocks that matches the volatility of consumption growth. Specifically, a calibration in which all productivity shocks are permanent implies a volatility of consumption growth significantly higher than in the data. On the other hand, a calibration where all productivity shocks are transitory implies a very low volatility in consumption growth. The combination of permanent and productivity shocks with policy shocks matches the volatility of consumption growth in the data.⁹ A significant fraction of this volatility is attributed to permanent shocks. The table shows

ACEL for the short-term rate refers to the Federal Funds rate. We assume that the same variance decomposition applies to the three-month T-bill rate. ACEL estimate their VAR using data for 1982-2008. We assume that their variance decomposition also applies to our sample period.

⁹Ideally, we would like to match only the volatility of consumption growth explained by productivity and policy shocks. However, this information is not available. Also, matching the total volatility of consumption growth is helpful to make more direct comparisons with other asset pricing models.

that the model is able to match the contributions of productivity and policy shocks to the total variability of consumption, inflation, and the nominal interest rate. The calibration implies a low elasticity of intertemporal substitution of consumption of $1/5.3 \approx 0.19$, and a Frisch elasticity of labor supply of $1/0.35 \approx 2.86$.¹⁰

In the second calibration step, we choose γ to match the stock market quarterly (annualized) Sharpe ratio of 0.40 for the period. Since the empirical Sharpe ratio is computed using nominal stock returns and the nominal risk-free rate, we use the nominal expected asset returns and risk-free rate of the model to match the data.¹¹ Alternatively, we could have chosen γ to match the equity premium. However, profit claims in the model are not directly comparable to dividend claims of the aggregate U.S. stock market for several reasons: The model abstracts from capital accumulation and firm leverage, and profits are only the result of monopolistic competition, among others. Instead, we match the Sharpe ratio and quantify the contribution of nominal rigidities to the equity premium. The recursive utility specification allows us to increase risk aversion without affecting the elasticity of intertemporal substitution. By doing so, the macroeconomic properties of the model are not significantly affected by the degree of risk aversion, as shown by Tallarini (2000). In the presence of leisure preferences, the coefficient of constant relative risk aversion is not only determined by γ . The household's attitude toward risk is also affected by their willingness to supply labor in different states of the world. As shown by Swanson (2011), the (average) coefficient

¹⁰Macroeconomic models usually rely on elasticities of substitution between 0 and 1. The Bansal and Yaron (2004) model requires an elasticity of substitution greater than 1 in order to capture the observed equity premium. Empirical estimates range between 0 and 1. For instance, Hall (1988) provides an estimate very close to zero, and Vissing-Jorgensen (2002) finds an elasticity for stockholders around 0.3 to 0.4., and very close to zero for non-stockholders.

¹¹The difference between nominal and real expected excess returns depends on the joint dynamics of inflation, returns, and the pricing kernel. To see this, consider the real and nominal asset returns R_t and $R_t^{\$}$, respectively. Under log-normality assumptions, it can be shown that nominal and real expected excess returns are linked by

$$\log \left(\frac{\mathbb{E}_t[R_{t+1}^{\$}]}{R_{f,t}^{\$}} \right) = \log \left(\frac{\mathbb{E}_t[R_{t+1}]}{R_{f,t}} \right) - \text{cov}_t(\pi_{t+1}, m_{t,t+1} - \log R_{t+1}) + \text{var}_t(\pi_{t+1}).$$

for the recursive preferences in equation (1) is

$$\frac{\psi}{1 + \frac{\psi}{\omega\mu}} + \frac{\gamma - \psi}{1 - \frac{1-\psi}{1+\omega}} \approx 26.$$

This value is still high according to empirical and experimental evidence,¹² but significantly lower than the values required by standard real business cycle models to match Sharpe ratios. This reduction is the result of permanent productivity shocks and leisure preferences in the model.

Table 3 presents summary statistics for our benchmark calibration along with those from alternative model specifications. The alternative specifications help us understand the main channels driving the results. In the benchmark calibration, the volatility of consumption growth is equal to the volatility in the data by construction. The volatility of profit growth is more than twice as large as the volatility of consumption growth. This is a direct result of nominal rigidities inducing variability in production markups. Matching a nominal Sharpe ratio for profit claims of 0.40 implies a real Sharpe Ratio of 0.48 and a real expected excess return of 0.76%. The expected excess return of a claim on output is slightly lower at 0.71%, indicating that the markup volatility increases the riskiness of profits with respect to output. Columns (2) to (4) allow us to quantify the contribution of the three different shocks to the results. Each column corresponds to the baseline calibration with only one shock affecting the economy (the volatility of the two other shocks is set to zero). It is clear from this table that most of the premium is a compensation for permanent productivity shocks. These shocks contribute with almost 73 bps to the premium, while the individual contribution of transitory productivity and policy shocks is less than 2 bps each. The differences are also reflected in the implied Sharpe ratios. The Sharpe ratio for permanent shocks is significantly higher than the Sharpe ratios for the two other shocks.

Columns (5) to (7) present model specifications with flexible prices, or flexible wages, or both. The economy related to column (5) can be seen as a frictionless only-labor real business cycle

¹²See, for instance, Barsky et al. (1997).

Table 3: **Model Summary Statistics for Different Specifications.**

The baseline parameter values are presented in Table 1. “Benchmark” indicates an economy with both price and wage rigidities. “Only A^p ” indicates only permanent productivity shocks ($\sigma_z = \sigma_u = 0$). “Only Z ” indicates only transitory productivity shocks ($\sigma_a = \sigma_u = 0$). “Only u ” indicates only policy shocks ($\sigma_a = \sigma_z = 0$). “No Rig.” indicates no price and wage rigidities ($\alpha_H = \alpha_L = \tilde{\alpha} = 0$). “Only WR” indicates no price rigidities ($\alpha_H = \alpha_L = 0$). “Only PR” indicates no wage rigidities ($\tilde{\alpha}=0$). The expected excess returns and the Sharpe ratio for asset b are $XR_{b,t} = R_{b,t+1} - R_{f,t}$, and $SR_b = \frac{\mathbb{E}[XR_{b,t}]}{\sigma(XR_{b,t})}$, respectively. Volatilities and expected excess returns are presented in annualized percentage terms. Sharpe ratios are annualized.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Benchmark	Only A^p	Only Z	Only u	No Rig.	Only WR	Only PR
$\sigma(\pi)$	0.706	0.363	0.464	0.389	2.961	1.125	1.913
$\sigma(x)$	0.821	0.503	0.061	0.646	0.000	0.821	0.333
$\sigma(i)$	0.949	0.196	0.359	0.856	0.722	0.934	0.578
$\sigma(r)$	1.156	0.169	0.228	1.120	1.499	1.202	1.006
$\sigma(\log \mu)$	0.770	0.422	0.451	0.460	0.000	0.000	1.884
$\sigma(\Delta c)$	1.550	1.442	0.227	0.522	1.041	1.608	1.179
$\sigma(\Delta d)$	3.304	2.702	1.819	0.555	1.041	1.608	7.191
$\sigma(\Delta w)$	1.008	1.000	0.095	0.083	1.030	1.030	1.684
$\rho(\pi, \Delta c)$	-0.478	-0.975	-0.884	0.394	0.449	-0.566	0.576
$\rho(\Delta c, \Delta d)$	0.826	0.987	0.984	-0.069	1.000	1.000	-0.474
$\mathbb{E}[R_{f,t}^s] - 1$	4.009	4.067	9.050	9.054	4.440	3.888	4.320
$\mathbb{E}[XR_{Y,t+1}]$	0.718	0.683	0.019	0.017	-0.202	0.845	0.094
$\mathbb{E}[XR_{D,t+1}]$	0.764	0.726	0.016	0.016	-0.202	0.845	0.037
$\sigma(R_Y)$	3.404	1.820	0.964	2.710	1.797	3.576	1.564
$\sigma(R_D)$	3.402	1.935	1.110	2.569	1.797	3.576	1.362
SR_Y	0.450	0.753	0.044	0.014	-0.432	0.503	0.160
SR_D	0.479	0.753	0.044	0.014	-0.432	0.503	0.083

economy. In the absence of nominal rigidities, the calibration parameters imply negative expected excess returns and Sharpe ratios. This is the result of permanent productivity shocks as explained in the next section. Column (6) presents results for the benchmark calibration assuming that prices are perfectly flexible ($\alpha_H = \alpha_L = 0$). It becomes clear that introducing wage rigidities significantly increases the premium in output and profit claims from -20 bps to 85 bps. Since wage rigidities do not generate markup volatility, claims on aggregate output and profits have the same expected returns. Column (7) shows implications for a model with price rigidities only ($\tilde{\alpha} = 0$).

Price rigidities induce positive expected excess returns. Profit claims have lower expected returns than output claims, since the time variation in markups induced by price rigidities decreases the riskiness of profits relative to output. Quantitatively, the effect of wage rigidities on the premium is significantly larger than the effect of price rigidities.

3.3 Risk Compensations in Expected Asset Returns under Nominal Rigidities

Our model calibration shows that nominal rigidities contribute to increase expected excess returns on output and profit claims. The increased premium is mainly a compensation for exposure to permanent productivity shocks and wage rigidities. To understand these results, we compare the contribution of each shock to expected asset returns in economies with and without nominal rigidities.

Compensation for Permanent Productivity Shocks

Panel A of Table 4 shows that nominal rigidities increase the premium for permanent productivity shocks in output and profit claims. To see why, consider first an economy with perfectly flexible prices and wages. Output and profit claims have the same expected returns in this economy since the markup is constant. Figure 1 shows that a negative permanent shock increases the marginal utility of consumption and the return on the output claim. This claim then act as hedging instrument and has a negative expected excess return. Two opposite effects drive this result. The first term in equation (24) generates a positive premium since the negative shock leads to lower consumption growth. The second term generates a negative premium since the negative shock leads to a higher wealth-consumption ratio, $P_{Y,t+1}$. The ratio increases because the permanent increase in the pricing kernel raises the price of the claim.¹³ The negative contribution of this

¹³There are two channels affecting $P_{Y,t+1}$: the effect of the shock on all future pricing kernels and the effect of the shock on all future output. After a negative shock, the higher pricing kernel increases $P_{Y,t+1}$, and the lower output decreases $P_{Y,t+1}$. Bansal and Yaron (2004) refer to these effects as wealth and substitution effects, respectively.

term to the premium offsets the positive contribution of the first term, and results in a negative expected excess return.

Consider now an economy with wage rigidities and flexible prices. The expected excess returns on output and profit claims increase to 80 bps in this economy. After a negative shock, Figure 1 shows that output declines by more than under flexible wages. Since some nominal wages are not adjusted downwards, producers increase their product prices to restore the optimal markup μ . Higher prices imply a lower output demand, lower profits, and a higher marginal utility than under flexible wages. The permanent decline in output and profits also decreases the wealth-consumption and price-dividend ratios. As a result, wage rigidities induce a positive compensation for permanent shocks in expected returns on output and profit claims.

Table 4 also shows results for an economy with price rigidities and flexible wages. In this case, Figure 1 shows that a negative permanent shock decreases output by more than under flexible prices and wages. Producers that cannot adjust their product prices downwards face a reduction in product demand. Real wages decrease and production markups increase. As a result, profits initially increase reducing the riskiness of profit claims relative to output claims. However, there is a permanent decline in output and profits that induces negative returns on both output and profit claims. That is, price rigidities generate a positive premium in these returns for exposure to permanent shocks. Quantitatively, the premium generated by price rigidities is lower than the premium generated by wage rigidities. While the premium in profit claims for wage rigidities is 80 bps, it is only 2 bps for price rigidities.

Finally, in an economy characterized by both price and wage rigidities, the premium for permanent shocks in profit claims is around 73 bps. The premium is lower than in an economy with only wage rigidities because the price rigidity partially offsets the negative effect of wage rigidities on output. Since prices are sticky, some producers cannot increase their prices to offset the high nominal wages given the negative shock. Therefore, real wages do not decline as much as in the

For a low elasticity of intertemporal substitution ($\psi > 1$), and positively autocorrelated consumption growth, the effect of a higher pricing kernel dominates the effect of a lower output stream.

Table 4: **Contribution of Individual Shocks to Expected Excess Returns.**

The baseline parameter values are presented in Table 1. “Benchmark” indicates an economy with both price and wage rigidities. “No Rig.” indicates no price and wage rigidities ($\alpha_H = \alpha_L = \tilde{\alpha} = 0$). “Only WR” indicates no price rigidities ($\alpha_H = \alpha_L = 0$). “Only PR” indicates no wage rigidities ($\tilde{\alpha}=0$). Expected excess returns and Sharpe ratios for asset b are $XR_{b,t} = R_{b,t+1} - R_{f,t}$, and $SR_b = \frac{\mathbb{E}[XR_{b,t}]}{\sigma(XR_{b,t})}$, respectively. Volatilities and expected excess returns are presented in annualized percentage terms. Sharpe ratios are annualized.

	Benchmark	No Rig.	Only WR	Only PR
Panel A: Only A^p				
$\mathbb{E}[XR_{Y,t+1}]$	0.683	-0.217	0.803	0.079
$\mathbb{E}[XR_{D,t+1}]$	0.726	-0.217	0.803	0.022
$\sigma(R_Y)$	1.820	1.634	2.152	0.967
$\sigma(R_D)$	1.935	1.634	2.152	0.945
SR_Y	0.753	-0.741	0.755	0.745
SR_D	0.753	-0.741	0.755	0.745
Panel B: Only Z				
$\mathbb{E}[XR_{Y,t+1}]$	0.019	0.014	0.028	0.012
$\mathbb{E}[XR_{D,t+1}]$	0.022	0.014	0.028	0.014
$\sigma(R_Y)$	0.964	0.747	1.376	0.650
$\sigma(R_D)$	1.110	0.747	1.376	0.736
SR_Y	0.040	0.039	0.042	0.039
SR_D	0.040	0.039	0.042	0.039
Panel C: Only u				
$\mathbb{E}[XR_{Y,t+1}]$	0.017	0.000	0.014	0.003
$\mathbb{E}[XR_{D,t+1}]$	0.016	0.000	0.014	0.001
$\sigma(R_Y)$	2.710	0.000	2.502	1.043
$\sigma(R_D)$	2.569	0.000	2.502	0.648
SR_Y	0.014	-	0.012	0.006
SR_D	0.014	-	0.012	0.006

economy with only wage rigidities, inflation is lower, and output demand is less negatively affected by the shock. The relative increase in real wages reduces the markup, which translates into higher expected returns on profit claims than on output claims.

Compensation for Transitory Productivity Shocks

Panel B of Table 4 shows positive expected excess returns in both output and profit claims as a compensation for transitory shocks. This compensation is significantly lower than the compen-

sation for permanent shocks. The difference can be explained by comparing the impulse responses of the pricing kernel to the two shocks in figures 1 and 2. The response to permanent shocks of the marginal rate of substitution of consumption is an order of magnitude more significant than the response to transitory shocks. Therefore, the covariance induced by transitory shocks between the pricing kernel and asset returns is much smaller than the covariance induced by permanent shocks. The premium for transitory shocks is positive even in the absence of rigidities. The reason is that both terms in the premium decompositions in equations (24) and (25) are positive. Wealth-consumption and price-dividend ratios decrease after a negative transitory shock because the effect of the shock on the marginal utility of consumption is small and mean reverting. Wage rigidities increase the premium and price rigidities decrease the premium with respect to the economy with flexible prices and wages. The explanation for the increased premium under wage rigidities is similar to that one for the premium for permanent shocks: high nominal wages increase prices and reduce output demand as displayed in Figure 2. Price rigidities decrease the premium because prices do not increase as much as under flexible prices, and then output is less negatively affected by the shock. The combination of the two rigidities reduce production markups and make claims on profits more risky than claims on output.

Compensation for Policy Shocks

Panel C of Table 4 shows compensations for policy shocks in economies with and without rigidities. This compensation is minimal relative to the compensation for permanent productivity shocks, since policy shocks have a small effect on the pricing kernel. A positive shock to the policy rule in equation (15) increases the nominal interest rate.¹⁴ If prices and wages are flexible, the increase in the nominal rate reduces inflation but has no effects on real variables. Producers and workers adjust nominal prices and wages, respectively, such that real wages, the optimal markup, output, and the real rate remain unchanged. Claims on output and profits do not have any

¹⁴This initial increase does not take into account the feedback effects resulting from potential changes in inflation and output caused by the shock.

compensation for policy shocks. In the presence of wage rigidities, the wage stickiness implies that producers obtain their optimal markup reducing their product prices by less than under flexible wages. As shown in Figure 3, output and profits decline, the marginal utility of consumption increases, and expected excess returns on output and profit claims are positive. Price rigidities also generate a positive premium for policy shocks. Since some product prices do not adjust downwards after an expansionary shock, output demand declines. Real wages also decline and increase the markup, reducing the riskiness of profit claims relative to output claims. Quantitatively, all these effects are very small. Interestingly, as a result of wage rigidities, a significant component of the volatility of returns on output and profit claims is the result of policy shocks.

3.4 Heterogeneity in Price Rigidities and the Cross-Section of Returns

Differences in the degree of price rigidity across industries may be reflected in differences in the expected returns of their production claims. We compare the returns of the industry output and profit claims in equations (19) and (21) for industries H and L . If the degrees of price rigidity, α_H and α_L , are the same, the two industries are identical and share the same expected asset returns. If the price rigidities are different, the implications on the cross section of asset returns depend on whether the economy is also affected by wage rigidities, and the elasticities of substitution across industry goods, η , and within industry differentiated goods, θ .

To gain intuition, consider the valuation of claims on industry output and profits that pay off only one-period in the future. Appendix B shows that real output in industry I is

$$Y_{I,t}^{\text{real}} = \varphi_I \left(\frac{P_{I,t}}{P_t} \right)^{1-\eta} Y_t.$$

It follows that differences in real output across industries are captured by the relative price $P_{R,t} \equiv \frac{P_{H,t}}{P_{L,t}}$, such that

$$\frac{Y_{H,t}^{\text{real}}}{Y_{L,t}^{\text{real}}} = \left(\frac{\varphi_H}{\varphi_L} \right) P_{R,t}^{1-\eta}.$$

Under log-normality assumptions, the difference in expected returns of claims on industry output are

$$-\text{cov}_t(m_{t,t+1}, \Delta y_{H,t+1}^{\text{real}} - \Delta y_{L,t+1}^{\text{real}}) = -(1 - \eta)\text{cov}_t(m_{t,t+1}, p_{R,t+1}),$$

where $y_{I,t}^{\text{real}} \equiv \log Y_{I,t}^{\text{real}}$, and $p_{R,t+1} \equiv \log P_{R,t+1}$. The difference depends on the elasticity η and the covariance of the marginal utility of consumption with the relative price. The industry with higher prices in periods of high marginal utility faces a lower product demand and then has higher expected returns on the output claim. Consider now the valuation of claims on industry profits. Profits in industry I are $D_{I,t} = Y_{I,t}^{\text{real}}(1 - \frac{1}{\mu_{I,t}})$, where the industry markup is

$$\mu_{I,t} = \frac{Y_{I,t}^{\text{real}}}{L I_{I,t}} = \frac{A_t}{F_{I,t}} \left(\frac{W_t}{P_t} \right)^{-1} \left(\frac{P_{I,t}}{P_t} \right).$$

It follows that the difference in markups is

$$\frac{\mu_{H,t}}{\mu_{L,t}} = \left(\frac{F_{H,t}}{F_{L,t}} \right)^{-1} P_{R,t}.$$

This difference is captured by differences in the price distortions $F_{I,t}$, and the relative price. It can be shown that the difference in expected returns on profit claims across industries can be approximated as

$$\begin{aligned} -\text{cov}_t(m_{t,t+1}, \Delta d_{H,t+1} - \Delta d_{L,t+1}) &\approx -\text{cov}_t(m_{t,t+1}, \Delta y_{H,t+1}^{\text{real}} - \Delta y_{L,t+1}^{\text{real}}) + (1 - \theta)\text{cov}_t(m_{t,t+1}, p_{R,t+1}) \\ &= -(\theta - \eta)\text{cov}_t(m_{t,t+1}, p_{R,t+1}). \end{aligned}$$

Therefore, the dynamics of the relative price implied by the two industry goods and the elasticities η and θ capture differences in expected returns on output and profit claims. These differences are the result of differences in the covariance of output and markups with the pricing kernel across industries.

Table 5 presents summary statistics for expected returns of industry claims under different model specifications. The models vary the elasticity η with respect to the elasticity θ . We present results for economies with and without wage rigidities, since it has implications on the cross-section of returns. In the baseline calibration, the rigidity in industry H is $\alpha_H = 0.8$, while we assume perfectly flexible prices in industry L .

Consider first economies with perfectly flexible wages. The table shows that expected returns on output claims are higher in industry H than in industry L . A shock that increases the marginal utility of consumption also increases the relative price $p_{R,t}$. Therefore, the demand of the industry H good decreases relative to the demand of the industry L good. However, the same shock expands the markup in industry H relative to the markup in industry L , which reduces the riskiness of claims on profits for industry H relative to industry L . If $\theta = \eta$, the relative markup effect exactly cancels out the relative output effect and claims on profits for the two industries have the same expected returns. If $\theta < \eta$, the relative output effect outweighs the relative markup effect, and the stock in industry H is more risky than the stock in industry L . The opposite occurs if $\theta > \eta$. As the substitutability across industry goods η decreases with respect to the substitutability within industry products θ , the markup effect becomes stronger and profit claims of industry L have higher expected returns than profit claims of industry H .

Consider now the benchmark case with wage rigidities. Wage rigidities make claims on industry L output riskier than for industry H . A shock that increases the marginal utility of consumption makes the price of the industry L good increase relative to the industry H price. Since wages do not fully adjust downwards, the industry with more flexible prices sets a higher price to compensate the higher marginal costs. The higher price reduces the output demand for this industry, and expected returns on output L claims reflect the additional risk exposure. On the other hand, the same shock reduces markups in industry H relative to markups in industry L , increasing the riskiness of industry H profits relative to industry L . The output effect dominates if $\eta > \theta$, the markup effect dominates if $\eta < \theta$, and the two effects exactly cancel out if $\theta = \eta$.

Table 5: **Summary Statistics for Industry Returns.**

“Benchmark” indicates an economy with both price and wage rigidities. “Only PR” indicates no wage rigidities ($\tilde{\alpha}=0$). Expected excess returns and Sharpe ratios for asset b are $XR_{b,t} = R_{b,t+1} - R_{f,t}$, and $SR_b = \frac{\mathbb{E}[XR_{b,t}]}{\sigma(XR_{b,t})}$, respectively. Expected excess returns are presented in annualized percentage terms. Sharpe ratios are annualized.

	Benchmark			Only PR		
	$\theta > \eta = 2$	$\theta = \eta = 6$	$\theta < \eta = 20$	$\theta > \eta = 2$	$\theta = \eta = 6$	$\theta < \eta = 20$
$\mathbb{E}[XR_{Y,t+1}]$	0.718	0.718	0.718	0.094	0.094	0.094
$\mathbb{E}[XR_{Y,H,t+1}]$	0.709	0.673	0.545	0.105	0.151	0.311
$\mathbb{E}[XR_{Y,L,t+1}]$	0.727	0.764	0.891	0.083	0.037	-0.123
$\mathbb{E}[XR_{D,t+1}]$	0.764	0.764	0.764	0.037	0.037	0.037
$\mathbb{E}[XR_{D,H,t+1}]$	0.800	0.764	0.636	-0.009	0.037	0.197
$\mathbb{E}[XR_{D,L,t+1}]$	0.727	0.764	0.891	0.083	0.037	-0.123
SR_Y	0.225	0.225	0.225	0.08	0.080	0.08
$SR_{Y,H}$	0.222	0.209	0.162	0.084	0.097	0.111
$SR_{Y,L}$	0.228	0.239	0.271	0.075	0.042	-0.096
SR_D	0.239	0.239	0.239	0.042	0.042	0.042
$SR_{D,H}$	0.250	0.239	0.196	-0.011	0.042	0.103
$SR_{D,L}$	0.228	0.239	0.271	0.075	0.042	-0.096

In summary, the implications on the cross section of returns of heterogeneity in price rigidities depends considerably on product and labor market characteristics. Wage rigidities and the substitutability of goods within and across industries affect the riskiness of output and profit claims at industry level. Quantitatively, the differences in expected returns can be minor or significant depending on the degree of price and wage rigidities, and the difference between θ and η .

3.5 Monetary Policy Rule and Asset Returns

The interest rate policy rule (15) allows us to analyze the effects on asset returns of the systematic reaction of the monetary authority to economic conditions. In the absence of nominal rigidities, the dynamics of real variables and, therefore, real asset returns are not affected by the policy rule. Nominal rigidities are then a potential channel to understand the effects of monetary policy on asset returns, and asset returns may contain important information to identify changes in

monetary policy.

For the analysis, consider the extended Fisher equation

$$i_t = r_t + \mathbb{E}_t[\pi_{t+1}] - \frac{1}{2}\text{var}_t(\pi_{t+1}) + \text{cov}_t(m_{t,t+1}, \pi_{t+1}), \quad (27)$$

which can be derived under some log-normality assumptions. This equation tells us that movements in the nominal rate are related to movements in the real rate, expected inflation, the volatility of inflation, and/or an inflation risk premium. Changes in the policy rule then have to be reflected in the dynamics of the real rate, inflation, and the marginal rate of substitution of consumption.

Changes in the response to inflation

Panel A of Table 6 presents summary statics for economies where the response to inflation, ι_π , is lower or higher than in the baseline calibration. A stronger response to inflation in the policy reduces the volatility of inflation and the output gap. The effects of these changes on expected asset returns depend on the particular type of rigidity affecting the economy. In an economy with only wage rigidities, an increase in ι_π increases expected excess returns. In an economy with only price rigidities, an increase in ι_π reduces expected excess returns. To understand why, consider equation (27). Under wage rigidities, a stronger response to inflation is reflected in a higher real rate because nominal wages, inflation, and expected inflation do not decline as much as in an economy with flexible wages. The higher real interest rate has a negative effect on output, and implies higher expected returns on output and profit claims. Under price rigidities, a stronger response to inflation is reflected in lower inflation, lower expected inflation, and a lower real interest rate. The lower real rate reduces the negative effects of shocks on output. Output and profit claims then reflect lower expected excess returns. Quantitatively, the effect of wage rigidities in the calibration is stronger than the price rigidity effect. An increase in the reaction coefficient from 1.25 to 1.75 increases expected returns in 5 bps.

Table 6: **Summary Statistics for Models with Different Reaction Coefficients in the Policy Rule.**

“Benchmark” indicates an economy with both price and wage rigidities. “Only WR” indicates no price rigidities ($\alpha_H = \alpha_L = 0$). “Only PR” indicates no wage rigidities ($\tilde{\alpha}=0$). Expected excess returns and Sharpe ratios for asset b are $XR_{b,t} = R_{b,t+1} - R_{f,t}$, and $SR_b = \frac{\mathbb{E}[XR_{b,t}]}{\sigma(XR_{b,t})}$, respectively. Volatilities and expected excess returns are presented in annualized percentage terms. Sharpe ratios are annualized.

	Benchmark		Only WR		Only PR	
Panel A: v_π	1.25	1.75	1.25	1.75	1.25	1.75
$\sigma(\pi)$	0.772	0.665	1.210	1.070	2.124	1.754
$\sigma(x)$	0.847	0.805	0.834	0.816	0.372	0.303
$\sigma(\Delta c)$	1.542	1.558	1.593	1.622	1.188	1.171
$\sigma(\Delta d)$	3.321	3.293	1.593	1.622	7.938	6.600
$\mathbb{E}[XR_{Y,t+1}]$	0.687	0.746	0.802	0.884	0.106	0.083
$\mathbb{E}[XR_{D,t+1}]$	0.734	0.790	0.802	0.884	0.047	0.027
SR_Y	0.213	0.235	0.239	0.261	0.083	0.075
SR_D	0.229	0.248	0.239	0.261	0.051	0.032
Panel B: v_x	0	0.25	0	0.25	0	0.25
$\sigma(\pi)$	0.718	0.695	1.129	1.122	1.950	1.879
$\sigma(x)$	0.862	0.786	0.853	0.792	0.341	0.326
$\sigma(\Delta c)$	1.572	1.531	1.628	1.589	1.181	1.177
$\sigma(\Delta d)$	3.304	3.305	1.628	1.589	7.302	7.085
$\mathbb{E}[XR_{Y,t+1}]$	0.748	0.691	0.876	0.816	0.097	0.091
$\mathbb{E}[XR_{D,t+1}]$	0.791	0.739	0.876	0.816	0.038	0.036
SR_Y	0.225	0.225	0.252	0.251	0.081	0.078
SR_D	0.239	0.239	0.252	0.251	0.043	0.040
Panel C: ρ	0.6	0.9	0.6	0.9	0.6	0.9
$\sigma(\pi)$	0.635	1.380	1.047	1.871	1.439	3.716
$\sigma(x)$	0.642	1.596	0.703	1.414	0.241	0.695
$\sigma(\Delta c)$	1.517	1.782	1.596	1.789	1.164	1.250
$\sigma(\Delta d)$	3.287	3.559	1.596	1.789	5.383	13.315
$\mathbb{E}[XR_{Y,t+1}]$	0.737	0.733	0.884	0.831	0.075	0.123
$\mathbb{E}[XR_{D,t+1}]$	0.787	0.767	0.884	0.831	0.010	0.069
SR_Y	0.272	0.138	0.288	0.162	0.081	0.055
SR_D	0.279	0.156	0.288	0.162	0.012	0.056

Changes in the response to the output gap

Panel B of Table 6 shows that an increase in the response to the output gap, ι_x , decreases the expected excess returns on output and profit claims in the presence of rigidities. Both price and wage rigidities decrease the volatility of the output gap and the negative response of output to shocks that increase marginal utility. The mechanism is similar to the one presented for the response to inflation: the increased response in output in the interest rate rule decreases the real interest rate and reduces the variability of output. An increase in the reaction to the output gap from 0 to 0.5 reduces in 5 bps the expected excess returns on output and profit claims.

Changes in interest rate smoothing

Panel C of Table 6 shows that nominal rigidities affect the response of expected excess returns to changes in the interest rate smoothing coefficient ρ . An increased weight of the policy rule on the lagged interest rate decreases the stabilization effects of the rule on inflation and output. The higher volatility in inflation has the opposite effect of increasing the response to inflation in the rule: If there are only wage rigidities, expected excess returns decrease. If there are only price rigidities, expected returns increase. In the presence of both rigidities, the calibration implies that the two effects offset each other and expected excess returns are not significantly affected. However, the increase in ρ increases the return volatility, and reduces the Sharpe ratios.

3.6 Additional Asset Pricing Implications

Variance Decomposition of Asset Returns

Table 7 presents the contribution of policy shocks and permanent and transitory productivity shocks to the variance of the pricing kernel and returns on aggregate output and profit claims. It is clear from the table that most of the volatility of the pricing kernel is the result of permanent productivity shocks. However, the volatility of asset returns is considerably affected by policy shocks in our benchmark calibration. In the absence of rigidities, policy shocks do not have any

Table 7: **Variance Decomposition of Asset Returns.**

“Benchmark” indicates an economy with both price and wage rigidities. “Only WR” indicates no price rigidities ($\alpha_H = \alpha_L = 0$). “Only PR” indicates no wage rigidities ($\tilde{\alpha}=0$).

		ε_u	ε_a	ε_z
Benchmark	m	0.04	99.68	0.28
	R_Y	63.39	28.59	8.02
	R_D	57.01	32.36	10.64
No rigidities	m	0.00	99.72	0.28
	R_Y	0.00	82.71	17.29
	R_D	0.00	82.71	17.29
Only WR	m	0.03	99.65	0.31
	R_Y	48.96	36.22	14.81
	R_D	48.96	36.22	14.81
Only PR	m	0.01	99.72	0.27
	R_Y	44.47	38.23	17.30
	R_D	22.62	48.17	29.22

real effects and does affect real asset returns. Under nominal rigidities, policy shocks can be a significant source of variability in the real interest rate which generate volatility in asset returns. This additional volatility, however, has a small effect on expected asset returns since policy shocks have a small impact on the pricing kernel. This finding suggests that in order to understand the large volatility of asset returns is important to understand uncertainty in monetary policy.

Predictability of Asset Returns and Production Markups

Santos and Veronesi (2006) find that the labor income - consumption ratio has predictive power for stock returns. A high ratio decreases conditional expected stock returns since profits represent a lower fraction of consumption and have a lower covariance with consumption. In our model, this ratio is given by the inverse of the aggregate markup μ_t . Price rigidities generate time variation in this markup. We analyze univariate predictive regressions where we regress profit claim returns

Table 8: **Predictive Regressions.**

“Benchmark” indicates an economy with both price and wage rigidities. “Only PR” indicates no wage rigidities ($\tilde{\alpha}=0$). The predictive regressions are $XR_{D,t+1,t+\tau} = a + b \log \mu_t + \epsilon_{t+hor}$, where $XR_{D,t+1,t+\tau}$ are cumulative excess returns for a horizon τ . The t-statistics are computed based on Newey-West corrected standard errors with $2 * (\tau - 1)$ lags.

Horizon	Benchmark			Only PR		
	4	8	12	4	8	12
Coefficient	1.25	2.03	2.48	-0.05	0.11	0.15
t-stat	0.83	1.40	1.25	-0.17	0.61	0.92
R^2	0.02	0.05	0.06	0.01	0.04	0.03

on the aggregate markup. Table 8 presents the results of these regressions for cumulative excess returns of 4, 8, and 12 quarters. The reported coefficients and statistics are the mean values of 200 simulations of the model, using the same sample size as the period under study (96 quarters). We use a third-order approximation of the model since expected excess returns are constant up to second order. The benchmark model with both price and wage rigidities captures the positive loading of excess returns on lagged markups. The coefficients and R^2 's increase with the horizon. The model with only price rigidities is not able to capture this relation. However, the coefficients are not statistically significant suggesting that wage rigidities have only limited power to explain the predictability observed in the data.

4 Conclusion

We explore the asset pricing implications of nominal rigidities and monetary policy in a dynamic equilibrium model with recursive preferences. Price and, especially, wage rigidities improve the ability of the model to capture a large and positive equity premium. Nominal rigidities generate distortions in output and labor that amplify the response of the marginal utility of consumption and firm cashflows to permanent productivity shocks. These distortions become a source of long

run macroeconomic risk, and returns on production claims reflect an additional compensation for this risk under recursive preferences. Differences in price rigidities across industries lead to differences in industry asset returns which depend on the product substitutability within and across industries. Monetary policy determines the real effects of nominal rigidities and affect asset returns. Our calibration implies that a more aggressive response to inflation or a less aggressive response to output fluctuations increase the equity premium. Uncertainty in the policy is reflected in more volatile asset returns and a small positive compensation for this risk in expected asset returns.

We now discuss some limitations of the analysis and potential directions for future research. First, our model abstracts from capital accumulation and therefore ignores any potential effects of nominal rigidities on investment behavior. Jermann (1998), Boldrin, Christiano and Fisher (2001), and Jermann (2010) point out that investment adjustment costs have important asset pricing implications. The joint study of investment dynamics and nominal rigidities merits further exploration. Second, we allow for heterogeneity in price rigidities to understand its cross sectional asset return implications but assume homogeneous wage rigidities across industries. Heterogeneity in wage rigidities and imperfect labor mobility across industries can be an additional source of differences in the cross section of asset returns. Third, nominal rigidities generate interesting dynamics for returns on financial and human wealth. Our model can be used to understand the implications of nominal rigidities on human capital returns, and shed light into the empirical findings of Lustig and Nieuwerburgh (2008). Finally, we study the effects of monetary policy on asset returns assuming that financial markets are complete and frictionless. The effects of monetary policy and nominal rigidities on asset returns can be amplified by financial frictions such as the financial accelerator in Bernanke, Gertler and Gilchrist (1999) or under limited financial market participation as in Galí, López-Salido and Vallés Liberal (2004).

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A Household's Utility Maximization under Wage Rigidities

The household's problem is

$$\max_{\{C_t, N_t^s, W_t^*\}} V_t = U_t + \beta Q_t^{\frac{1-\psi}{1-\gamma}}$$

where

$$U_t = \frac{C_t^{1-\psi}}{1-\psi} - \kappa_t \frac{(N_t^s)^{1+\omega}}{1+\omega}, \quad \text{and} \quad Q_t = \mathbb{E}_t \left[V_{t+1}^{\frac{1-\gamma}{1-\psi}} \right],$$

subject to the budget constraint

$$\mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} P_{t+\tau} C_{t+\tau} \right] \leq \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} P_{t+\tau} (LI_{t+\tau} + D_{t+\tau}) \right],$$

where LI_t and D_t are aggregate labor income and firm profits, respectively. The Lagrangian associated with this problem is

$$\mathcal{L} = \frac{C_t^{1-\psi}}{1-\psi} - \kappa_t \frac{(N_t^s)^{1+\omega}}{1+\omega} + \beta Q_t^{\frac{1-\psi}{1-\gamma}} + \lambda \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} P_{t+\tau} (LI_{t+\tau} + D_{t+\tau} - C_{t+\tau}) \right].$$

It can be shown that utility maximization implies $\lambda = \frac{C_t^{-\psi}}{P_t}$, and

$$\begin{aligned} M_{t,t+1}^{\$} &= \frac{\partial V_t / \partial C_{t+1}}{\partial V_t / \partial C_t} \frac{P_t}{P_{t+1}} = \beta \frac{\frac{\partial Q_t}{\partial C_{t+1}} \frac{\partial V_t}{\partial Q_t}}{C_t^{-\psi}} \frac{P_t}{P_{t+1}} \\ &= \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\psi} \left(\frac{V_{t+1}^{1/(1-\psi)}}{Q_t^{1/(1-\gamma)}} \right)^{\psi-\gamma} \frac{P_t}{P_{t+1}}. \end{aligned}$$

The τ -period nominal pricing kernel is

$$M_{t,t+\tau}^{\$} = \prod_{s=1}^{\tau} M_{t,t+s}^{\$}.$$

The household cannot change wages for $\tilde{\alpha}$ fraction of labor types. For the remaining $1 - \tilde{\alpha}$ fraction of labor types k , the household chooses wages $W_t^*(k)$ to maximize V_t . We assume that the wage choice for one labor type has negligible effects on the aggregate wage index and the aggregate labor demand. To see the impact of $W_t^*(k)$ on the household's utility, we rewrite the labor supply at $t + \tau$ as

$$N_{t+\tau}^s = \int_0^1 N_{t+\tau}^s(k) dk = N_{t+\tau}^d \int_0^1 \left(\frac{W_{t+\tau}(k)}{W_{t+\tau}} \right)^{-\theta_w} dk,$$

and the aggregate labor income at $t + \tau$ as

$$LI_{t+\tau} = \int_0^1 \frac{W_{t+\tau}(k)}{P_{t+\tau}} N_{t+\tau}^s(k) dk = N_{t+\tau}^d \frac{W_{t+\tau}}{P_{t+\tau}} \int_0^1 \left(\frac{W_{t+\tau}(k)}{W_{t+\tau}} \right)^{1-\theta_w} dk.$$

For the wage of type k labor at $t + \tau$, there are $\tau + 2$ possible values:

$$W_{t+\tau}(k) = \begin{cases} W_{t+\tau-s}^*(k), & \text{with prob} = (1 - \tilde{\alpha})\tilde{\alpha}^s \text{ for } s = 0, 1, \dots, \tau \\ W_{t-1}, & \text{with prob} = \tilde{\alpha}^{\tau+1}. \end{cases}$$

We obtain derivatives

$$\begin{aligned} \frac{\partial N_{t+\tau}^s}{W_t^*(k)} &= N_{t+\tau}^d (1 - \tilde{\alpha})\tilde{\alpha}^\tau \left(\frac{-\theta_w}{W_t^*(k)} \right) \left(\frac{W_t^*(k)}{W_{t+\tau}} \right)^{-\theta_w}, \\ \frac{\partial LI_{t+\tau}}{\partial W_t^*(k)} &= \frac{N_{t+\tau}^d}{P_{t+\tau}} (1 - \tilde{\alpha})\tilde{\alpha}^\tau (1 - \theta_w) \left(\frac{W_t^*(k)}{W_{t+\tau}} \right)^{-\theta_w}. \end{aligned}$$

The first-order condition of the Lagrangian with respect to $W_t^*(k)$ is given by

$$\frac{\partial \mathcal{L}}{\partial W_t^*(k)} = \frac{\partial V_t}{\partial W_t^*(k)} + \lambda \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} P_{t+\tau} \frac{\partial LI_{t+\tau}}{\partial W_t^*(k)} \right] = 0,$$

where

$$\frac{\partial V_t}{\partial W_t^*(k)} = -\mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} \frac{P_{t+\tau}}{P_t} \left(\frac{C_{t+\tau}}{C_t} \right)^\psi \kappa_{t+\tau} (N_{t+\tau}^s)^\omega \frac{\partial N_{t+\tau}^s}{\partial W_t^*(k)} \right].$$

Rearranging terms, we get

$$\mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} \tilde{\alpha}^\tau W_{t+\tau}^{\theta_w} N_{t+\tau}^d \frac{W_t^*(k)}{P_t} C_t^{-\psi} \right] = \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} \tilde{\alpha}^\tau \left(\frac{P_{t+\tau}}{P_t} \right) W_{t+\tau}^{\theta_w} N_{t+\tau}^d \mu_w \kappa_{t+\tau} (N_{t+\tau}^s)^\omega \left(\frac{C_{t+\tau}}{C_t} \right)^\psi \right].$$

Since all labor types face the same demand curve, we have $W_t^*(k) = W_t^*$ for all k . We can write the left-hand side of the equation as

$$LHS = C_t^{-\psi} W_t^{\theta_w} N_t^d H_{w,t} \frac{W_t^*}{P_t},$$

where

$$H_{w,t} = 1 + \tilde{\alpha} \mathbb{E}_t \left[M_{t,t+1}^{\$} \left(\frac{N_{t+1}^d}{N_t^d} \right) \left(\frac{W_t}{W_{t+1}} \right)^{-\theta_w} H_{w,t+1} \right].$$

Similarly, the right-hand side of the first-order condition can be written as

$$RHS = \mu_w W_t^{\theta_w} N_t^d (N_t^s)^\omega G_{w,t} = \mu_w W_t^{\theta_w} N_t^d \kappa_t (N_t^s)^\omega G_{w,t}$$

where

$$G_{w,t} = 1 + \tilde{\alpha} \mathbb{E}_t \left[M_{t,t+1}^{\$} \left(\frac{P_{t+1}}{P_t} \right) \left(\frac{C_{t+1}}{C_t} \right)^\psi \left(\frac{N_{t+1}^d}{N_t^d} \right) \left(\frac{\kappa_{t+1}}{\kappa_t} \right) \left(\frac{N_{t+1}^s}{N_t^s} \right)^\omega \left(\frac{W_t}{W_{t+1}} \right)^{-\theta_w} G_{w,t+1} \right].$$

The optimal real wage is then given by

$$\frac{W_t^*}{P_t} = \mu_w C_t^\psi \kappa_t (N_t^s)^\omega \frac{G_{w,t}}{H_{w,t}}.$$

B Profit Maximization under Price Rigidities

Consider the Dixit-Stiglitz aggregate (3) as a production function, and a competitive “producer” of the industry good facing the problem

$$\max_{\{C_{I,t}(j)\}} P_{I,t} C_{I,t} - \int_0^1 P_{I,t}(j) C_{I,t}(j) dj$$

subject to (3). Solving the problem, we find the demand function

$$P_{I,t}(j) = P_{I,t} \left(\frac{C_{I,t}(j)}{C_{I,t}} \right)^{-1/\theta} \quad (28)$$

The zero-profit condition implies

$$P_{I,t} C_{I,t} = \int_0^1 P_{I,t}(j) C_{I,t}(j) dj = \int_0^1 P_{I,t} C_{I,t} \left(\frac{P_{I,t}(j)}{P_{I,t}} \right)^{-\theta} dj.$$

Solving for $P_{I,t}$, it follows that

$$P_{I,t} = \left[\int_0^1 P_{I,t}(j)^{1-\theta} dj \right]^{\frac{1}{1-\theta}}, \quad (29)$$

which can be written as the demand function for each differentiated good in sector I

$$C_{I,t}(j) = \left(\frac{P_{I,t}(j)}{P_{I,t}} \right)^{-\theta} C_{I,t}. \quad (30)$$

Similarly, we can solve the profit maximization problem of the final good industry, which use goods from industry H and L as inputs. The demand function for industry I good is

$$C_{I,t} = \varphi_I \left(\frac{P_{I,t}}{P_t} \right)^{-\eta} C_t \quad (31)$$

where P_t is the final good price, defined as the aggregate price index. The zero profit condition of the final goods production implies

$$P_t = \left[\varphi P_{H,t}^{1-\eta} + (1-\varphi) P_{L,t}^{1-\eta} \right]^{1/(1-\eta)}.$$

Notice that these relations imply that consumption in both sectors is related by

$$C_{H,t} = \frac{\varphi}{1-\varphi} \left(\frac{P_{H,t}}{P_{L,t}} \right)^{-\eta} C_{L,t}.$$

Therefore, when prices are flexible, prices of the sector goods are the same and consumptions in the two sectors are proportional.

The profit maximization problem is

$$\max_{\{P_{I,t}(j)\}} \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} \alpha_I^{\tau} \left[P_{I,t}(j) Y_{I,t+\tau|t}(j) - W_{t+\tau|t}(j) N_{I,t+\tau|t}^d(j) \right] \right]$$

subject to

$$Y_{I,t+\tau|t}(j) = Y_{I,t+\tau} \left(\frac{P_{I,t}(j)}{P_{I,t+\tau}} \right)^{-\theta}, \quad \text{and} \quad Y_{I,t+\tau|t}(j) = A_t N_{I,t+\tau|t}^d(j).$$

The first-order condition of this problem with respect to $P_{I,t}(j)$ is

$$\mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} \alpha_I^{\tau} Y_{I,t+\tau|t}(j) P_{I,t}^*(j) \right] = \mathbb{E}_t \left[\sum_{\tau=0}^{\infty} M_{t,t+\tau}^{\$} \alpha_I^{\tau} Y_{I,t+\tau|t}(j) \mu \frac{W_{I,t+\tau|t}(j)}{A_t} \right].$$

The left-hand side (LHS) of the equation can be written recursively as

$$LHS = P_{I,t}^* \left(\frac{P_{I,t}^*}{P_{I,t}} \right)^{-\theta} Y_{I,t} H_{I,t},$$

where

$$H_{I,t} = 1 + \alpha_I \mathbb{E}_t \left[M_{t,t+1}^{\$} \left(\frac{Y_{I,t+1}}{Y_{I,t}} \right) \left(\frac{P_{I,t}}{P_{I,t+1}} \right)^{-\theta} H_{I,t+1} \right].$$

Similarly, the right-hand side (RHS) of the equation can be written as

$$RHS = \frac{\mu}{A_t} Y_{I,t} \left(\frac{P_{I,t}^*}{P_{I,t}} \right)^{-\theta} \frac{W_t}{P_t} P_t G_{I,t}$$

where

$$G_{I,t} = 1 + \alpha_I \mathbb{E}_t \left[M_{t,t+1}^{\$} \left(\frac{Y_{I,t+1}}{Y_{I,t}} \right) \left(\frac{P_{I,t+1}}{P_{I,t}} \right)^{-\theta} \left(\frac{W_{t+1}}{W_t} \right) \left(\frac{A_t}{A_{t+1}} \right) G_{I,t+1} \right].$$

The optimal price is hence given by

$$\left(\frac{P_{I,t}^*}{P_{I,t}} \right) \left(\frac{P_{I,t}}{P_t} \right) H_{I,t} = \frac{\mu}{A_t} \frac{W_t}{P_t} G_{I,t}.$$

Here, $P_{I,t}^*(j) = P_{I,t}^*$ because all firms changing prices face the same demand curve and hence the same optimization problem.

The inflation in price for industry I is given by

$$1 = (1 - \alpha_I) \left(\frac{P_{I,t}^*}{P_{I,t}} \right)^{1-\theta} + \alpha_I \left(\frac{P_{I,t+1}}{P_{I,t}} \right)^{-(1-\theta)},$$

and the relation between the price index and industry prices is

$$1 = \varphi_H \left(\frac{P_{H,t}^*}{P_t} \right)^{1-\eta} + \varphi_L \left(\frac{P_{L,t}^*}{P_t} \right)^{1-\eta}.$$

C Labor Market Clearing Conditions

The total supply of type k labor to industry I is given by

$$N_{I,t}^s(k) = \int_0^1 N_{I,t}^s(j, k) dj = \int_0^1 N_{I,t}^d(j, k) dj = \left(\frac{W_t(k)}{W_t} \right)^{-\theta_w} \int_0^1 N_{I,t}^d(j) dj,$$

From the production function $Y_{I,t}(j) = A_t N_{I,t}^d(j)$, we obtain

$$N_{I,t}^s(k) = \left(\frac{W_t(k)}{W_t} \right)^{-\theta_w} \int_0^1 \frac{Y_{I,t}(j)}{A_t} dj = \left(\frac{W_t(k)}{W_t} \right)^{-\theta_w} \frac{Y_{I,t}}{A_t} \int_0^1 \left(\frac{P_{I,t}(j)}{P_{I,t}} \right)^{-\theta} dj.$$

where the second equality follows from the product demand function (12). Defining the price dispersion aggregator within industry I , and the wage dispersion aggregator by

$$F_{I,t} \equiv \int_0^1 \left(\frac{P_{I,t}(j)}{P_{I,t}} \right)^{-\theta} dj, \quad \text{and} \quad F_{w,t} \equiv \int_0^1 \left(\frac{W_t(k)}{W_t} \right)^{-\theta_w} dk,$$

respectively, it follows that

$$N_{I,t}^s = \frac{Y_{I,t} F_{I,t} F_{w,t}}{A_t}.$$

Aggregate labor supply is then

$$\begin{aligned} N_t^s &= N_{H,t}^s + N_{L,t}^s = \left(\frac{Y_{H,t} F_{H,t}}{A_t} + \frac{Y_{L,t} F_{L,t}}{A_t} \right) F_{w,t} \\ &= \frac{Y_t}{A_t} \left[\varphi_H \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} F_{H,t} + \varphi_L \left(\frac{P_{L,t}}{P_t} \right)^{-\eta} F_{L,t} \right] F_{w,t} = \frac{Y_t F_t F_{w,t}}{A_t}, \end{aligned}$$

where the third equality comes from the relation between final goods output and intermediate goods output

$$Y_{I,t} = \varphi_I Y_t \left(\frac{P_{I,t}}{P_t} \right)^{-\eta}.$$

F_t is the price dispersion aggregator

$$F_t \equiv \varphi_H \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} F_{H,t} + \varphi_L \left(\frac{P_{L,t}}{P_t} \right)^{-\eta} F_{L,t}.$$

From the resource constraint

$$N_t^d = \sum_{I \in \{H,L\}} \int_0^1 N_{I,t}^d(j) dj,$$

it can be shown that $N_t^d = N_t^s / F_{w,t} = \frac{Y_t F_t}{A_t}$.

Note that the wage dispersion $F_{w,t}$ is bounded below by one.

$$F_{w,t} = \int_0^1 \left[\left(\frac{W_t(k)}{W_t} \right)^{1-\theta_w} \right]^{\frac{-\theta_w}{1-\theta_w}} dk \geq \left[\int_0^1 \left(\frac{W_t(k)}{W_t} \right)^{1-\theta_w} dk \right]^{\frac{-\theta_w}{1-\theta_w}} = 1^{-\theta_w} = 1,$$

where the second equality is due to Jensen's inequality for $\frac{-\theta_w}{1-\theta_w} > 1$. Similarly, we can show that $F_{H,t}$ and $F_{L,t}$ are both bounded below by one, which leads to the same conclusion for F_t .

D A Return Representation of the Pricing Kernel

The pricing kernel in terms of consumption and continuation utility is

$$M_{t,t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\psi} \left(\frac{V_{t+1}^{1/(1-\psi)}}{Q_t^{1/(1-\gamma)}} \right)^{\psi-\gamma},$$

where

$$V_t = \frac{C_t^{1-\psi}}{1-\psi} - \kappa_t \frac{(N_t^s)^{1+\omega}}{1+\omega} + \beta Q_t^{\frac{1-\psi}{1-\gamma}}, \quad \text{and} \quad Q_t = \mathbb{E}_t \left[V_{t+1}^{\frac{1-\gamma}{1-\psi}} \right].$$

Using the definitions of Q_t and $M_{t,t+1}$, we have

$$\beta Q_t^{\frac{1-\psi}{1-\gamma}} = \beta Q_t Q_t^{-\frac{\psi-\gamma}{1-\gamma}} = \beta \mathbb{E}_t \left[V_{t+1}^{-\frac{\psi-\gamma}{1-\psi}} Q_t^{-\frac{\psi-\gamma}{1-\gamma}} \right] = C_t^{-\psi} \mathbb{E}_t \left[M_{t,t+1} C_{t+1}^\psi V_{t+1} \right].$$

Equation (9) shows that the optimal wage is set as

$$\frac{W_t^*}{P_t} = \mu_w C_t^\psi \kappa_t (N_t^s)^\omega \frac{G_{w,t}}{H_{w,t}}.$$

Therefore, the household's utility can be written as

$$V_t = \frac{C_t^{1-\psi}}{1-\psi} - \frac{1}{1+\omega} \frac{1}{\mu_w} LI_t^* C_t^{-\psi} + \beta Q_t^{\frac{1-\psi}{1-\gamma}},$$

where we define

$$LI_t^* \equiv \frac{W_t^*}{P_t} N_t^s \frac{H_{w,t}}{G_{w,t}}.$$

Notice the LI_t^* can be interpreted as the labor income if all labor supply is paid at the nominal wage W_t^* adjusted by $\frac{H_{w,t}}{G_{w,t}}$. If wages are perfectly flexible, $LI_t^* = LI_t$. Substituting the expression for $\beta Q_t^{\frac{1-\psi}{1-\gamma}}$ and solving V_t recursively, we get

$$(1-\psi)C_t^\psi V_t = C_t + S_{C,t} - \bar{\nu} (LI_t^* + S_{LI^*,t})$$

where $\bar{\nu} \equiv \frac{1-\psi}{1+\omega} \frac{1}{\mu_w}$,

$$S_{C,t} = \mathbb{E}_t \left[\sum_{s=1}^{\infty} M_{t,t+1} C_{t+s} \right], \quad \text{and} \quad S_{LI^*,t} = \mathbb{E}_t \left[\sum_{s=1}^{\infty} M_{t,t+1} LI_{t+s}^* \right].$$

$S_{C,t}$ is the present value of all future consumption and $S_{LI^*,t}$ is the present value of all future adjusted labor income LI^* . It follows that the continuation utility term $\beta Q_t^{\frac{1-\psi}{1-\gamma}}$ can be written as

$$\beta Q_t^{\frac{1-\psi}{1-\gamma}} = \frac{C_t^{-\psi}}{1-\psi} [S_{C,t} - \bar{\nu} S_{LI^*,t}].$$

Therefore, we get

$$\begin{aligned} \left(\frac{V_{t+1}^{1/(1-\psi)}}{Q_t^{1/(1-\gamma)}} \right)^{\psi-\gamma} &= \left(\frac{V_{t+1}}{Q_t^{\frac{1-\psi}{1-\gamma}}} \right)^{\frac{\psi-\gamma}{1-\psi}} = \left[\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\psi} \right]^{\frac{\psi-\gamma}{1-\psi}} \left[\frac{C_{t+1} + S_{C,t+1} - \bar{\nu} (LI_{t+s}^* + S_{LI^*,t+1})}{S_{C,t} - \bar{\nu} S_{LI^*,t}} \right]^{\frac{\psi-\gamma}{1-\psi}} \\ &= \left[\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\psi} R_{CL,t+1} \right]^{\frac{\psi-\gamma}{1-\psi}} \end{aligned}$$

where

$$\begin{aligned} R_{CL,t+1} &= (1 - \nu_t) R_{C,t+1} + \nu_t R_{LI^*,t+1}, \\ R_{C,t+1} &= \frac{C_{t+1} + S_{C,t+1}}{S_{C,t}}, \\ R_{LI^*,t+1} &= \frac{LI_{t+1}^* + S_{LI^*,t+1}}{S_{LI^*,t}}, \\ \text{and } \nu_t &= \frac{\bar{\nu} S_{LI^*,t}}{\bar{\nu} S_{LI^*,t} - S_{C,t}}. \end{aligned}$$

The pricing kernel is then given by

$$M_{t,t+1} = \left[\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\psi} \right]^{\frac{1-\gamma}{1-\psi}} \left(\frac{1}{R_{CL,t+1}} \right)^{1-\frac{1-\gamma}{1-\psi}}.$$

E Equilibrium Conditions

This appendix provides a summary of the equilibrium equations for the model. These conditions need to be expressed in terms of de-trended variables. In order to obtain balanced growth, we make $\kappa_t = (A_t^p)^{1-\psi}$. This condition ensures that Y_t , $Y_{I,t}$, W_t , and W_t^* are growing at the same rate. Therefore, the equations can be written in terms of $\hat{Y}_t = \frac{Y_t}{A_t^p}$, $\hat{Y}_{I,t} = \frac{Y_{I,t}}{A_t^p}$, $\hat{W}_t = \frac{W_t}{A_t^p}$, and $\hat{W}_t^* = \frac{W_t^*}{A_t^p}$.

Wage Setting

$$\begin{aligned} \frac{W_t^*}{P_t} &= \mu_w \kappa_t (N_t^s)^\omega C_t^\psi \frac{G_{w,t}}{H_{w,t}}. \\ H_{w,t} &= 1 + \tilde{\alpha} \mathbb{E}_t \left[M_{t,t+1}^s \left(\frac{N_{t+1}^d}{N_t^d} \right) \left(\frac{W_t}{W_{t+1}} \right)^{-\theta_w} H_{w,t+1} \right], \\ \text{and } G_{w,t} &= 1 + \tilde{\alpha} \mathbb{E}_t \left[M_{t,t+1}^s \left(\frac{P_{t+1}}{P_t} \right) \left(\frac{C_{t+1}}{C_t} \right)^\psi \left(\frac{N_{t+1}^d}{N_t^d} \right) \left(\frac{\kappa_{t+1}}{\kappa_t} \right) \left(\frac{N_{t+1}^s}{N_t^s} \right)^\omega \left(\frac{W_t}{W_{t+1}} \right)^{-\theta_w} G_{w,t+1} \right]. \end{aligned}$$

Price Dispersion

$$\begin{aligned} F_t &= \varphi_H \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} F_{H,t} + \varphi_L \left(\frac{P_{L,t}}{P_t} \right)^{-\eta} F_{L,t}, \\ F_{I,t} &= \int_0^1 \left(\frac{P_{I,t}(j)}{P_{I,t}} \right)^{-\theta} dj = (1 - \alpha_I) \left(\frac{P_{I,t}^*}{P_{I,t}} \right)^{-\theta} + \alpha_I \left(\frac{P_{I,t-1}}{P_{I,t}} \right)^{-\theta} F_{I,t-1}. \end{aligned}$$

Wage Dispersion

$$F_{w,t} = \int_0^1 \left(\frac{W_t(k)}{W_t} \right)^{-\theta_w} dk = (1 - \tilde{\alpha}) \left(\frac{W_t^*}{W_t} \right)^{-\theta_w} + \tilde{\alpha} \left(\frac{W_{t-1}}{W_t} \right)^{-\theta_w} F_{w,t-1}.$$

Wage Aggregator

$$\left(\frac{W_t}{P_t} \right)^{1-\theta_w} = \int_0^1 \left(\frac{W_t(k)}{P_t} \right)^{1-\theta_w} dk = (1 - \tilde{\alpha}) \left(\frac{W_t^*}{P_t} \right)^{1-\theta_w} + \tilde{\alpha} \left(\frac{P_{t-1}}{P_t} \right)^{1-\theta_w} \left(\frac{W_{t-1}}{P_{t-1}} \right)^{1-\theta_w},$$

Price Setting

$$\begin{aligned} \left(\frac{P_{I,t}^*}{P_{I,t}} \right) \left(\frac{P_{I,t}}{P_t} \right) H_{I,t} &= \frac{\mu}{A_t} \frac{W_t}{P_t} G_{I,t}, \\ H_{I,t} &= 1 + \alpha_I \mathbb{E}_t \left[M_{t,t+1}^s \left(\frac{Y_{I,t+1}}{Y_{I,t}} \right) \left(\frac{P_{I,t+1}}{P_{I,t}} \right)^{-\theta} H_{I,t+1} \right], \\ \text{and } G_{I,t} &= 1 + \alpha_I \mathbb{E}_t \left[M_{t,t+1}^s \left(\frac{Y_{I,t+1}}{Y_{I,t}} \right) \left(\frac{P_{I,t}}{P_{I,t+1}} \right)^{-\theta} \left(\frac{W_{t+1}}{W_t} \right) \left(\frac{A_t}{A_{t+1}} \right) G_{I,t+1} \right]. \end{aligned}$$

Industry Output

$$Y_{I,t} = \varphi_I Y_t \left(\frac{P_{I,t}}{P_t} \right)^{-\eta}, \quad Y_{I,t}^{\text{real}} = \varphi_I Y_t \left(\frac{P_{I,t}}{P_t} \right)^{1-\eta}.$$

Industry Inflation

$$\frac{P_{I,t+1}}{P_{I,t}} = \frac{P_{I,t+1}}{P_{t+1}} \frac{P_{t+1}}{P_t} \frac{P_t}{P_{I,t}}.$$

Price Aggregators

$$\begin{aligned} 1 &= (1 - \alpha_I) \left(\frac{P_{I,t}^*}{P_{I,t}} \right)^{1-\theta} + \alpha_I \left(\frac{P_{I,t-1}}{P_{I,t}} \right)^{1-\theta} \\ 1 &= \varphi_H \left(\frac{P_{H,t}}{P_t} \right)^{1-\eta} + \varphi_L \left(\frac{P_{L,t}}{P_t} \right)^{1-\eta}. \end{aligned}$$

Aggregate Labor Supply and Demand

$$N_t^s = F_{w,t} N_t^d, \quad N_t^d = \frac{Y_t}{A_t} F_t.$$

Markups

$$\mu_t = \frac{Y_t}{L I_t} = \frac{A_t}{F_t} \left(\frac{W_t}{P_t} \right)^{-1}, \quad \mu_{I,t} = \frac{P_{I,t}}{P_t} \frac{Y_{I,t}}{L I_{I,t}} = \frac{A_t}{F_{I,t}} \left(\frac{W_t}{P_t} \right)^{-1} \left(\frac{P_{I,t}}{P_t} \right).$$

Pricing Kernel

$$\begin{aligned} M_{t,t+1} &= \left[\beta \left(\frac{Y_{t+1}}{Y_t} \right)^{-\psi} \right]^{\frac{1-\gamma}{1-\psi}} \left(\frac{1}{R_{Y L,t+1}} \right)^{1-\frac{1-\gamma}{1-\psi}}, \\ R_{Y L,t+1} &= (1 - \nu_t) R_{C,t+1} + \nu_t R_{L I^*,t+1}, \\ R_{Y,t+1} &= \frac{C_{t+1} + S_{Y,t+1}}{S_{Y,t}}, \quad R_{L I^*,t+1} = \frac{L I_{t+1}^* + S_{L I^*,t+1}}{S_{L I^*,t}}, \\ \nu_t &= \frac{\bar{\nu} S_{L I^*,t}}{\bar{\nu} S_{L I^*,t} - S_{Y,t}}. \end{aligned}$$

Returns and Price-Payoff Ratios

$$\begin{aligned} 1 &= \mathbb{E}_t[M_{t,t+1} R_{K,t+1}], \quad \text{for } K = \{Y, D\}, \quad \text{at aggregate and industry level,} \\ R_{Y,t+1} &= (1 + P_{Y,t+1}) \frac{Y_{t+1}}{Y_t} \frac{1}{P_{Y,t}}, \quad R_{Y,I,t+1} = (1 + P_{Y,I,t+1}) \frac{Y_{I,t+1}^{\text{real}}}{Y_{I,t}^{\text{real}}} \frac{1}{P_{Y,I,t}}, \\ R_{D,t+1} &= (1 + P_{D,t+1}) \frac{Y_{t+1}}{Y_t} \frac{1 - \frac{1}{\mu_{t+1}}}{1 - \frac{1}{\mu_t}} \frac{1}{P_{D,t}}, \quad R_{D,I,t+1} = (1 + P_{D,I,t+1}) \frac{Y_{I,t+1}^{\text{real}}}{Y_{I,t}^{\text{real}}} \frac{1 - \frac{1}{\mu_{I,t+1}}}{1 - \frac{1}{\mu_{I,t}}} \frac{1}{P_{D,I,t}}. \end{aligned}$$

F Understanding the Mechanism

Under the assumption of log-normality, the risk-free rate in equation (7) satisfies

$$R_{f,t} = \exp \left[-\mathbb{E}_t [m_{t,t+1}] - \frac{1}{2} \text{var}_t(m_{t,t+1}) \right].$$

The price of the output claim in equation (22) can be written as

$$\begin{aligned} 1 &= \mathbb{E}_t [M_{t,t+1} R_{Y,t+1}] \\ &= \exp \left[\mathbb{E}_t [m_{t,t+1} + \log R_{Y,t+1}] + \frac{1}{2} \text{var}_t(m_{t,t+1} + \log R_{Y,t+1}) \right] \\ &= R_{f,t}^{-1} \exp [\text{cov}_t(m_{t,t+1}, \log R_{Y,t+1})] \mathbb{E}_t [R_{Y,t+1}]. \end{aligned}$$

Equation (24) follows from expressing $R_{Y,t+1}$ in terms of the wealth-consumption ratio as

$$R_{Y,t+1} = \frac{(1 + P_{Y,t+1}) Y_{t+1}}{P_{Y,t} Y_t}.$$

A similar analysis can be applied to obtain equation (25).

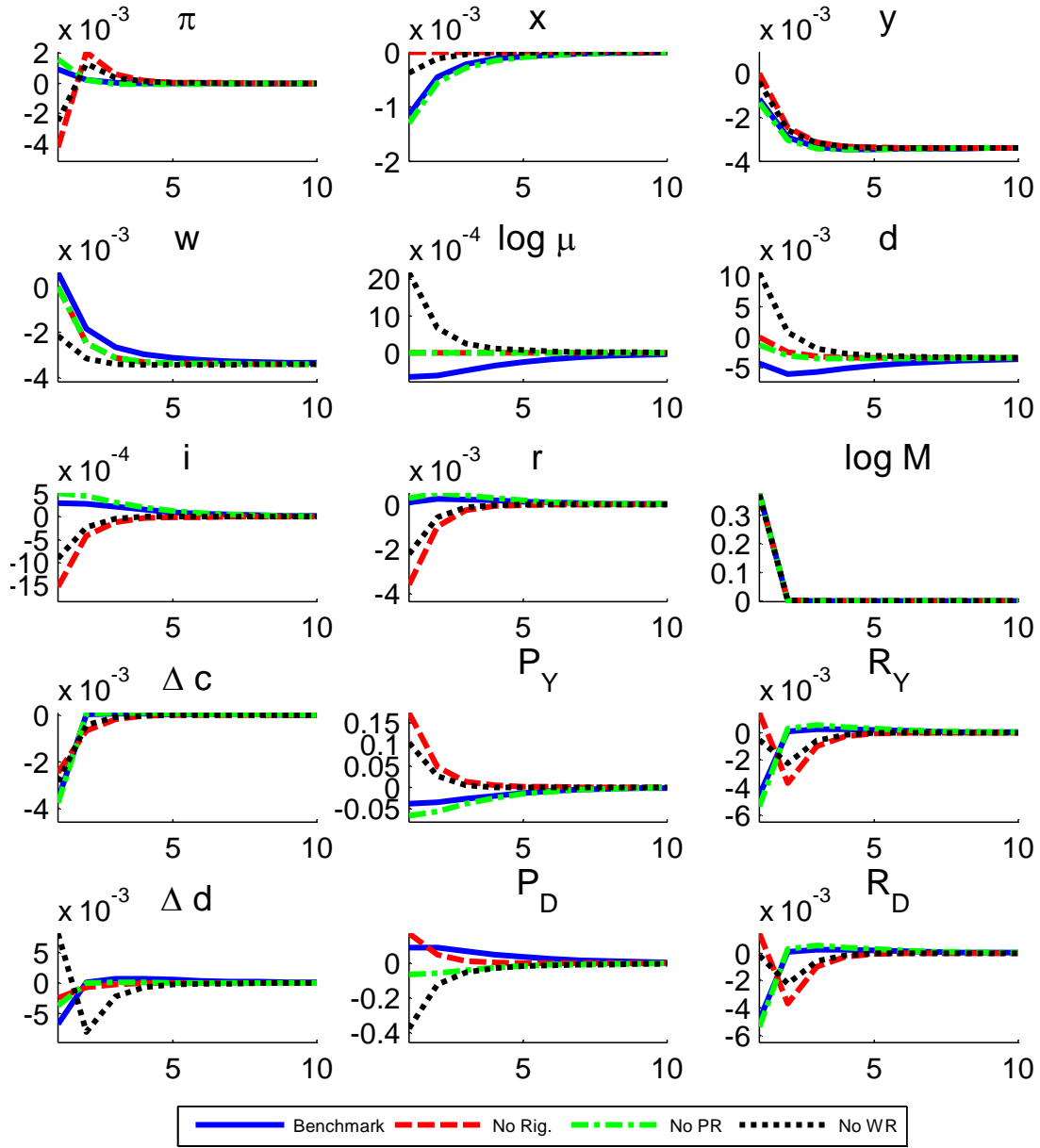


Figure 1: Impulse responses to a one-standard deviation negative permanent productivity shock for different macroeconomic variables and asset returns. The parameter values are presented in Table 1.

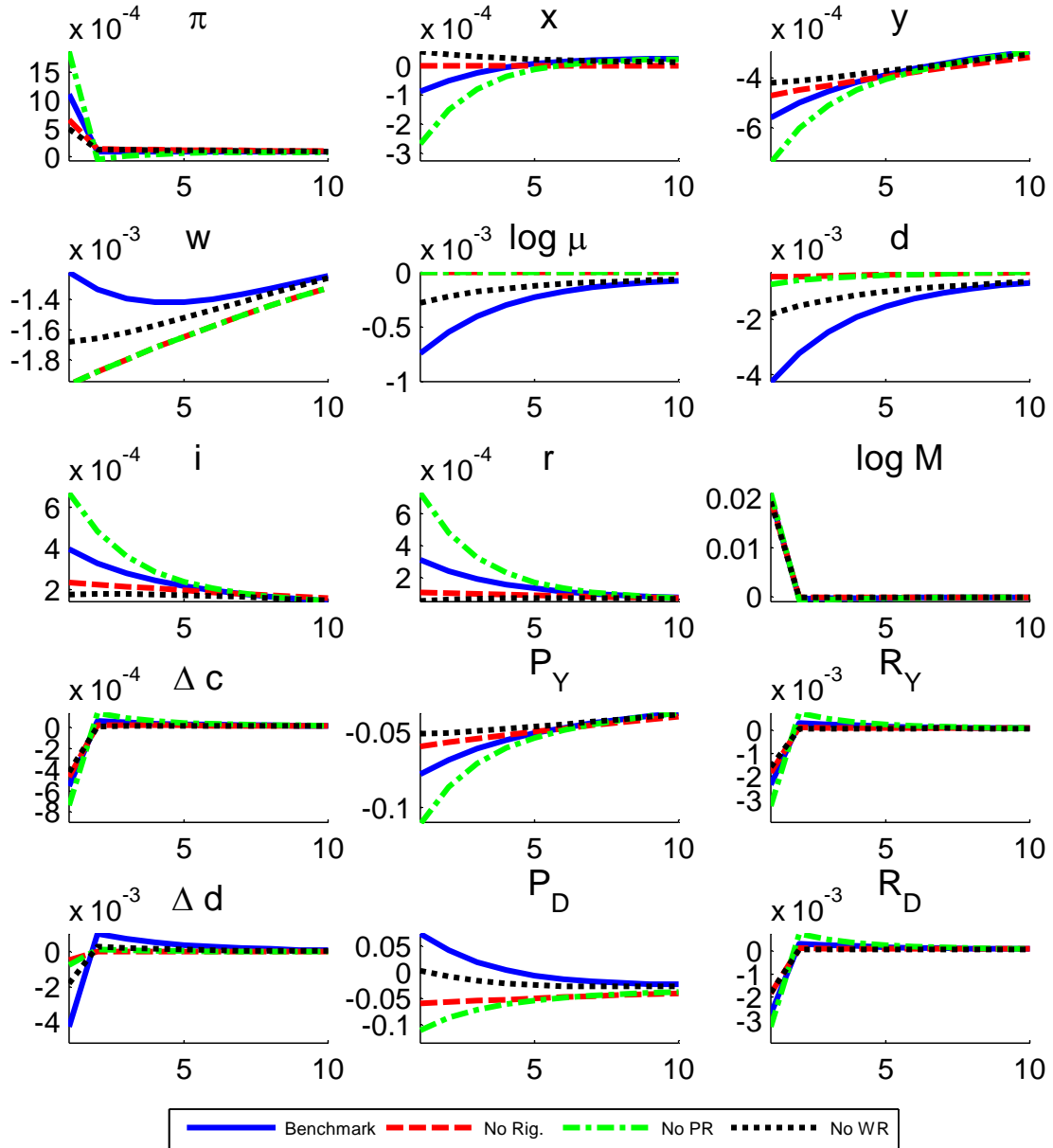


Figure 2: Impulse responses to a one-standard deviation negative transitory productivity shock for different macroeconomic variables and asset returns. The parameter values are presented in Table 1.

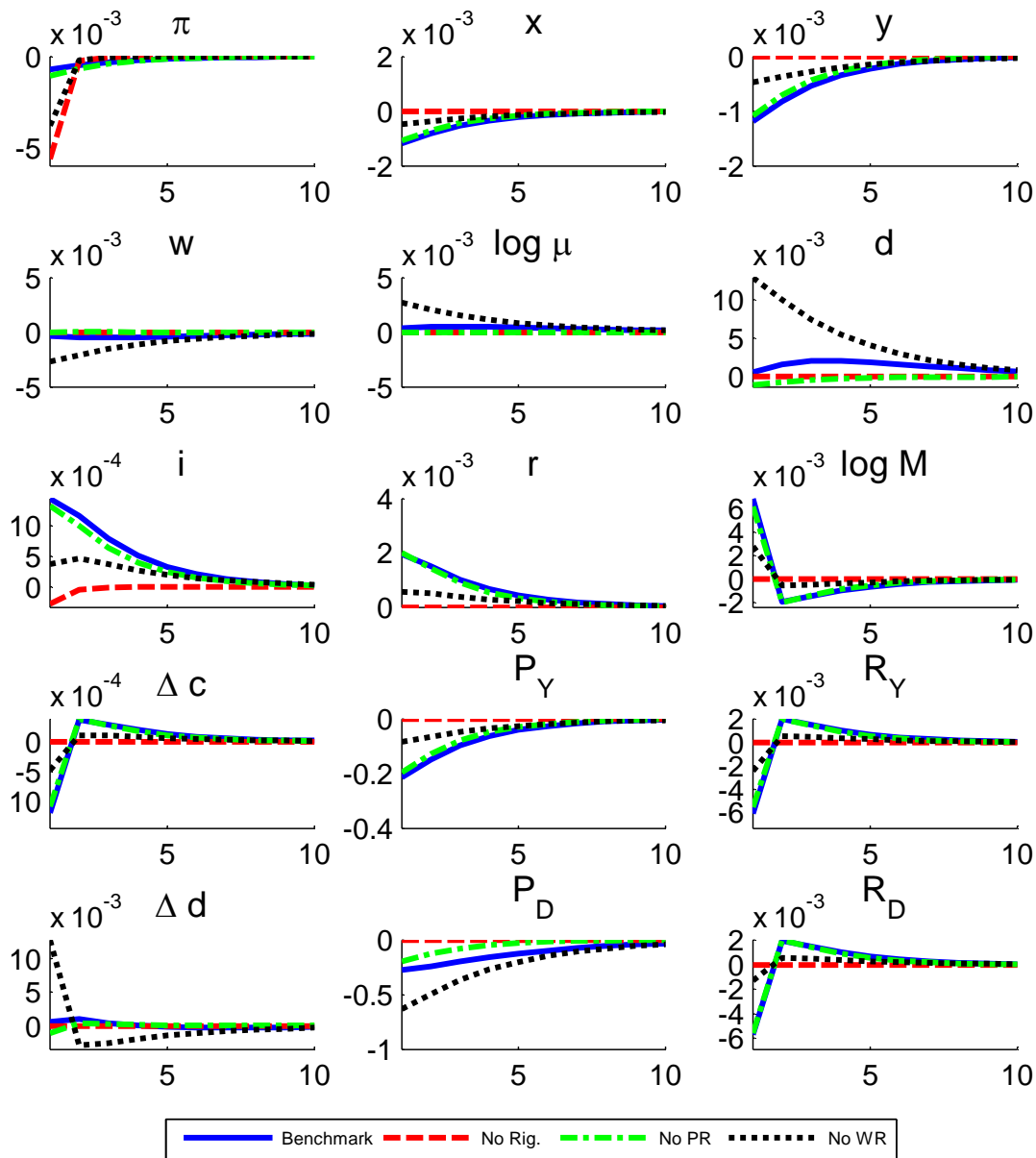


Figure 3: Impulse responses to a one-standard deviation positive policy shock for different macroeconomic variables and asset returns. The parameter values are presented in Table 1.