Nominal Rigidities, Asset Returns, and Monetary Policy*

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Abstract

We analyze the asset pricing implications of price and wage rigidities and monetary policies in a general equilibrium model with recursive preference, nominal rigidities, and three types of shock: permanent productivity shock, transitory productivity shock, and monetary policy shock. The model is calibrated to match the observed Sharpe ratio, in addition to the volatilities of risk-free rate, inflation, consumption, and consumption growth rate. Among the three types of shocks, permanent productivity shocks contribute 96 percent of the risk premium. Nominal rigidities generate procyclical product markup and employment, through which equity premium is amplified. The monetary policies that show greater tendency of interest rate smoothing, react more aggressively to inflation or less aggressively to output.

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lead to higher equity premium. With a reasonable calibration, the model generates one sixth of the observed equity premium.

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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 because production factors can be freely adjusted to reduce consumption risk.\(^1\) This has motivated the introduction of frictions to these models, such as investment adjustment costs and imperfect factor mobility,\(^2\) to undermine the households’ abilities to smooth consumption. In this paper, we incorporate a particular friction, rigidities in nominal product prices and wages, in a general equilibrium model to address (i) how nominal rigidities and monetary policies affect equity premiums, and (ii) how productivity shocks and policy shocks affect stock returns differently.

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 general equilibrium models such as Christiano, Eichenbaum and Evans (2005) or Smets and Wouters (2007). Third, wage rigidities allow us to explore the impacts of time-varying employment on asset returns, while the focus of the previous literature is capital. Fourth, the existence of nominal rigidities is the most widely studied channel through which monetary policies affect real economies and allow us to explore the link between monetary policy and excess stock returns. Understanding this link is important to policymakers and, to our knowledge, it has not been studied in the theoretical literature.

\(^1\)Campbell 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.

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

\(^3\)Blinder 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.
Our main findings are 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. Without rigidities, the equity premium is negative under our benchmark calibration that matches the business cycle dynamics. Second, procyclical product markup and employment are shown to be the main channels through which nominal rigidities amplify equity premium. Third, the quantitative impact of wage rigidities on the equity premium is much larger than the impact of price rigidities. Fourth, monetary policy shocks contribute less than 1% to the equity premium but more than 60% to the variance of excess stock returns. Fifth, monetary policies with greater tendency of interest rate smoothing, higher responsiveness to inflation or lower responsiveness to output lead to larger equity premiums. Finally, both the product substitutability within each industry and that across industries affect the return difference between the industry with high price rigidities and the industry with low price industry.

We model a production economy with four main ingredients. First, a representative household with Epstein and Zin (1989) recursive preference over consumption and leisure. Recursive preferences disentangle the elasticity of intertemporal substitution from risk aversion. As illustrated by 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. Second, nominal rigidities are modeled in a staggered wage and price setting following Calvo (1983). The representative household provides differentiated labor types to the production sectors and has monopolistic power to set 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. 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, which responds to the last period’s interest rate, inflation, and output and contains unpredictable policy shocks. Fourth, the model incorporates three types of shocks: permanent productivity shocks, transitory productivity shocks, and monetary policy shocks. Campbell (1994) shows that permanent and transitory shocks have different effects on optimal consumption and asset returns. Alvarez and Jermann (2005) find empirically that there is a significant permanent component in the pricing kernel. Bernanke and Kuttner (2005) show that an unexpected 25-basis-point cut in the federal funds rate leads to about one percent increase in broad stock indexes. To our knowledge, this is the first theoretical paper that analyzes the differences of the all three shocks in terms of their effects on asset returns.

We calibrate the model to match the quarterly U.S. data between 1982:1 to 2010:4. Specifically, price and wage rigidities are chosen to match the means of price duration and wage duration, respectively. The dynamics of the three shocks, the parameters of the utility function, and the parameters of the monetary policy are calibrated to match the volatilities of interest rate, inflation, and de-trended consumption explained by the three shocks, respectively. The risk aversion is calibrated to match the Sharpe ratio. In particular, our calibration results in an EIS of around 0.15 and a relative risk aversion coefficient of 17. Risk aversion is high with respect to the empirical and experimental evidence, but significantly lower than the implied value by standard business cycle models such as Tallarini (2000). This improvement is a result of introducing permanent productivity shocks and nominal rigidities.

In our baseline calibration, we find that permanent productivity shocks contribute more than 97% to the equity premium while the other two shocks contribute 3% each. However, almost 70% of the variance in stock returns come from monetary policy shocks while 30% from permanent productivity shocks and a negligible fraction from transitory productivity shocks. The extremely low price of risk for the uncertainties induced by policy shocks is driven by the fact that those shocks contribute less than 1% to the variance of the pricing kernel.

Wage rigidity is the main driver of the positive and large equity premium under our baseline
calibration, even though price rigidity is also found to increase the equity premium. In fact, permanent productivity shocks result in a negative equity premium without rigidities, echoing the results in Bansal and Yaron (2004) and Kaltenbrunner and Lochstoer (2010) for their models with an EIS lower than one. In such a case, the wealth effect dominates the substitution effect, leading to a countercyclical price-dividend ratio and hence a negative equity premium.

In the presence of nominal rigidities, the substitution effect outweighs the wealth effect and the model generates a positive equity premium. There are two critical differences from the frictionless economy. First, employment becomes procyclical, which amplifies the effect of the shock for the current period and hence the substitution effect. As wages and prices are adjusted gradually to the optimal levels, this amplified effect is reverted back partially, reducing the wealth effect. Quantitatively, labor supply is much more procyclical under wage rigidities than under price rigidities. Second, product markup is procyclical in the presence of price rigidities, which enlarges the volatility of dividend claims relative to output claims and results in a larger equity premium.

The existence of nominal rigidities leads to the non-neutrality of monetary policy. We show that monetary policies with higher responsiveness to inflation, lower responsiveness to output, or higher tendency of interest rate smoothing amplifies the effects of permanent productivity shocks and hence lead to higher expected stock returns. However, the differences in stock returns are quantitatively small.

We also explore a two-sector model with heterogeneous price rigidities across sectors, which allows us to analyze the link between industry price rigidity and industry expected asset returns. Because wages are assumed to be universal across industries, difference in returns of the claims on industrial dividends is driven by the difference in product prices due to heterogeneous price rigidities. However, the relation between the relative price and the difference in industrial returns depends on the parameter values. Higher product price of one industry relative to the other one leads to two opposite effects on its profits: a lower output demand (the output effect) and a higher markup (the markup effect) relative to the other industry. The product substitutability across
industries determines the magnitude of the difference in industry output demands. The product substitutability within industries determines the magnitude of the difference in industry markups. Therefore, the industry with higher price rigidity could earn higher or lower expected return than the one with lower price rigidity, depending on the relative magnitude of the two elasticities of substitution.

Even though permanent productivity shocks and nominal rigidities increase equity premium compared to real business cycle models, our model only generates one sixth of the observed magnitude. Other channels need to be added to our simple New Keynesian model in order to fully capture equity premium.

Related literature

Our paper belongs to the literature that links the real economy to financial markets in a unified framework. 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 wage rigidities, and allow us to analyze the effects of monetary policy on asset prices. However, Christiano, Eichenbaum and Evans (2005) focus on the business cycle implications of monetary policy shocks and do not analyze the dynamics of asset returns and the effects of productivity shocks.

Cochrane (2006) provides an extensive summary of the main findings and challenges in this literature.
Our paper is also related to the literature that studies the response of the stock market to monetary policy shocks, e.g., Thorbecke (1997), Bernanke and Kuttner (2005) and Rigobon and Sack (2004), among others. Consistent with what our model predicts, these empirical studies find a positive (negative) reaction in the stock market value to expansionary (contractionary) policy shocks. For instance, Bernanke and Kuttner (2005) find that a surprise cut of 25 basis points in the federal funds rate translates into an increase of 1.25% in the value of the aggregate stock market, which is quantitatively similar to what we find in the impulse response function.

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.

Finally, our paper is related to Bhamra, Fisher and Kuehn (2011) who provide an alternative channel for monetary policies to affect the real economy when firms are levered and coupon payments are in nominal terms, i.e., nominal rigidities in debt obligations. Moreover, the focus of their paper is firms’ default decision while ours is on asset prices.

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 7 concludes.

2 The Model

We model a production economy where households derive utility from the consumption of a basket of differentiated goods and disutility from supplying labor for the production of these goods. The
differentiated goods are produced in an environment characterized by monopolistic competition and nominal price and wage rigidities. 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 real wages that affect production decisions. Since inflation is determined by monetary policy, different policies have different implications for real activity, affecting 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 productivity and monetary policy shocks. In sections 4 and 5, we analyze how nominal rigidities and monetary policy, respectively, affect the compensation for these shocks in production claims.

2.1 Household

The representative household in this economy chooses consumption \( C_t \) and labor supply \( N_s^t \) to maximize the Epstein and Zin (1989) recursive utility function

\[
V_t = (1 - \beta)U(C_t, N_s^t)^{1-\psi} + \beta \mathbb{E}_t \left[ \frac{V_{t+1}^{1-\gamma}}{V_t^{1-\psi}} \right]^{1-\gamma},
\]

where \( \beta > 0 \) is the subjective discount factor, \( \psi^{-1} > 0 \) captures the elasticity of intertemporal substitution of consumption, and \( \gamma > 0 \) determines the coefficient of relative risk aversion. The recursive utility formulation allows us to relax the strong assumption of \( \gamma = \psi \) implied by constant relative risk aversion. The intratemporal utility is

\[
U(C_t, N_s^t) = \left( \frac{C_t^{1-\psi}}{1-\psi} - \kappa_t \frac{(N_s^t)^{1+\omega}}{1+\omega} \right)^{1-\psi},
\]

where \( \omega^{-1} > 0 \) captures the Frisch elasticity of labor supply. The process \( \kappa_t \), defined in section 2.2, is introduced to preserve balanced growth. The consumption good is a basket of differentiated
goods produced by a continuum of firms and defined as the Dixit-Stiglitz aggregator

\[ C_t = \left[ \int_0^1 C_t(j) \frac{\theta_p}{\theta_p - 1} \, dj \right]^\frac{\theta_p}{\theta_p - 1}, \tag{3} \]

where \( \theta_p > 1 \) is the elasticity of substitution across differentiated goods, and \( C_t(j) \) is the consumption of the intermediate good \( j \). As shown in appendix A, household’s utility maximization leads to the demand function for intermediate goods \( j \)

\[ C_t(j) = \left( \frac{P_t(j)}{P_t} \right)^{-\theta_p} C_t, \tag{4} \]

where \( P_t \) is the price of the final consumption good and \( P_t(j) \) is the price of intermediate goods \( j \).

Following Schmitt-Grohe and Uribe (2007), we assume that the representative household provides a continuum of differentiated labor services indexed by \( k \in [0, 1] \). The aggregate supply of labor is

\[ N_t^s = \int_0^1 N_t^s(k) \, dk, \tag{5} \]

where \( N_t^s(k) \) is the supply of labor type \( k \).

The representative household is subject to the intertemporal (nominal) budget constraint

\[ \mathbb{E}_t \left[ \sum_{s=0}^{\infty} M^s_{t,t+s} P_{t+s} C_{t+s} \right] \leq \mathbb{E}_t \left[ \sum_{s=0}^{\infty} M^s_{t,t+s} P_{t+s} (LI_{t+s} + D_{t+s} + \varphi_{t+s}) \right], \tag{6} \]

where \( M^s_{t,t+s} \) is the nominal discount factor for cash flows at time \( t + s \). The real labor income

\[ 5 \text{This approach is different from the standard heterogeneous households approach to model wage rigidities in Erceg, Henderson and Levin (2000), where each household supplies a differentiated type of labor. In the presence of recursive preferences, this approach introduces heterogeneity in the marginal rate of substitution of consumption across households since it depends on the labor types supplied by households. We avoid this difficulty and obtain a unique marginal rate of substitution by modeling a representative agent who provides all different types of labor.} \]
from supplying labor to the production sector is

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

where $W_t(k)$ is the wage of labor type $k$. The household is the owner of the production sector and receives aggregate dividends (profits) $D_t$. The last term in the budget constraint is the aggregate operation cost incurred during production, $\varphi_t$. Its detailed discussion will be given in section 2.2.

Appendix A shows from the household’s optimality conditions that the one-period real and nominal discount factors are the marginal rates of substitution

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

and

$$M_{t,t+1}^s = \frac{P_{t+1}}{P_t},$$

respectively. The nominal discount factor gives us the one-period (continuously compounded) nominal interest rate $i_t$, characterized as

$$i_t = - \log \mathbb{E}_t \left[ M_{t,t+1}^s \right].$$

Wage Setting

The labor market is imperfectly competitive. The representative household monopolistically provides the continuum of differentiate labor services described by equation (5). These labor services produce the homogeneous labor service used by the production sector, $N_t^d$, given by

$$N_t^d = \left[ \int_0^1 N_t^s(k) \theta_w^{\theta_w - 1} \theta_w^{\theta_w - 1} dk \right]^{\theta_w - 1},$$

where $\theta_w > 1$ is the elasticity of substitution across differentiated labor types. Appendix A shows

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6It is assumed that the household does not participate in managing the production activity. In reality, individuals own firms through diffused ownership and collectively hire professional managers to run firms for them.
that the optimal demand for labor type \( k \) is
\[
N_t^*(k) = \left( \frac{W_t(k)}{W_t} \right)^{\theta_w} N_t^d,
\]
and the aggregate wage is
\[
W_t = \left[ \int_0^1 W_t^{1-\theta_w}(k) \, dk \right]^\frac{1}{1-\theta_w}.
\]

Note that \( N_t^s \) refers to the aggregate supply of all labor types, while \( N_t^d \) refers to the homogeneous labor service demanded by the production sector. The household chooses wages \( W_t(k) \) for all labor types \( k \) under Calvo (1983) staggered wage setting. Specifically, at each time \( t \) the household adjust wages optimally only for a fraction \( 1 - \alpha_w \) of random labor types. For the remaining fraction \( \alpha_w \), the household keeps the previous period wages \( W_{t-1}(k) \). Since the demand curve and the cost of labor supply are identical across different labor types, the optimal nominal wage of labor type \( k \), \( W_t^* \), is the same for all labor type \( k \in [0, 1] \), denoted as \( W_t^* \). The appendix shows that the optimal wage satisfies
\[
\frac{W_t^*}{P_t} = \mu_{w,t} \kappa_t (N_t^s)^\omega C_t^\psi,
\]
where \( \mu_{w,t} \) is the time-varying wage markup (described in the appendix). Equation (13) can be interpreted as follows: in the absence of wage rigidities \( (\alpha_w = 0) \), the marginal rate of substitution between labor and consumption is \( \kappa_t (N_t^s)^\omega C_t^\psi \), and the optimal wage is this rate adjusted by the optimal constant markup \( \mu_w = \theta_w/ (\theta_w - 1) \). Wage rigidities generate a time-varying wage markup \( \mu_{w,t} \), since the wage of some labor types is not adjusted optimally.
2.2 Production Sector

The production of differentiated goods is characterized by monopolistic competition and price rigidities in a continuum of firms. Firms, indexed by $j$, take wages as given and set prices for their differentiated goods in a Calvo (1983) staggered price setting: at each time $t$, a fraction $\alpha_p$ of random firms keep their previous period prices $P_{t-1}(j)$, while the remaining fraction $1 - \alpha_p$ set prices to maximize the present value of their profits. A firm maximizing profits takes into account the probability $\alpha_p$ of not being able to adjust the price optimally in the future. Specifically, firm $j$ solves the maximization problem

$$\max_{\{P_t(j)\}} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \alpha_p^s M^S_{t,t+s} \left[ P_t(j) Y_{t+s|t}(j) - W_{t+s|t} N^d_{t+s|t}(j) - \varphi_{t+s} \right] \right\},$$

subject to the demand function

$$Y_{t+s|t}(j) = \left( \frac{P_t(j)}{P_{t+s}} \right)^{-\theta_p} Y_{t+s},$$

and the production function

$$Y_{t+s|t}(j) = A_{t+s} N^d_{t+s|t}(j).$$

Output $Y_{t+s|t}(j)$ is the production of firm $j$ at time $t + s$ given that its last optimal price change was at time $t$. The wage $W_{t+s|t}$ and the firm’s demand $N^d_{t+s|t}(j)$ of homogeneous labor service have a similar interpretation. The functional form of the demand function is identical to the demand function for consumption in equation (4).

The production function depends on labor productivity $A_t$ and labor. We assume that labor productivity contains permanent and transitory components. Specifically, $A_t = A^p_t Z_t$, where the
permanent and transitory components follow processes

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

(17)

and

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

(18)

respectively, with \( \Delta \) as the difference operator, and innovations \( \varepsilon_{a,t} \) and \( \varepsilon_{z,t} \sim \text{IIDN}(0, 1) \). Given the permanent component in productivity, the operation cost is defined as \( \varphi_t \equiv A_t^p \bar{\varphi} \). Under this definition, the operation cost is fixed (\( \bar{\varphi} \)) relative to the balanced growth path. The cost is paid by producers to the household as presented in the budget constraint (6). An example of this cost is rental of office space owned by households. Similarly, the scaling process \( \kappa_t \) in the utility function (2) is defined as \( \kappa_t \equiv (A_t^p)^{1-\psi} \) to preserve balanced growth.

All firms that set prices optimally face and identical maximization problem and then choose the same optimal price \( P_t^* \) when allowed. Appendix B shows that the optimal price satisfies

\[ \left( \frac{P_t^*}{P_t} \right) = \frac{\mu_{p,t} W_t}{A_t P_t}, \]  

(19)

where \( \mu_{p,t} \) is the time-varying product markup. Its recursive formulation is presented in the appendix. Equation (19) can be interpreted as follows: In the absence of price rigidities, the product price is the markup-adjusted marginal cost of production, with optimal markup \( \mu_p = \theta_p / (\theta_p - 1) \). Price rigidities generate the time-varying markup \( \mu_{p,t} \), since some firms do not adjust their prices optimally.
2.3 Monetary Policy

A monetary authority sets the level of the one-period nominal interest rate $i_t$. Monetary policy is described by the policy rule

$$i_t = \rho i_{t-1} + (1 - \rho) (\bar{i} + \tau \pi_t + \tau x_t) + u_t,$$

(20)

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

$$x_t \equiv \log Y_t - \log Y^f_t,$$

(21)

where $Y^f_t$ is the output under perfectly flexible prices and wages, defined in appendix E. The policy shock follows the process

$$u_{t+1} = \phi u_t + \sigma_u \varepsilon_{u,t+1},$$

(22)

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

2.4 Asset Returns

The real price of a claim on all future cash flows $\{B_{t+s}\}_{s=0}^\infty$ is

$$S_{B,t} = \mathbb{E}_t \left[ \sum_{s=1}^{\infty} M_{t,t+s} B_{t+s} \right].$$

(23)

The one-period real return of this claim is

$$R_{B,t+1} = \frac{B_{t+1} + S_{B,t+1}}{S_{B,t}} = \frac{B_{t+1}}{B_t} \left( 1 + \frac{P_{B,t+1}}{P_{B,t}} \right),$$

(24)
where $P_{B,t}$ is the cash flow-price ratio, defined as $P_{B,t} \equiv \frac{S_{B,t}}{B_t}$.

We analyze expected returns for claims on aggregate output ($B = Y$) and dividends ($B = D$). Appendix F derives the approximation for the expected excess return

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

(25)

where $R_{f,t}$ is the real (simple) risk-free rate satisfying $(1+R_{f,t})^{-1} = \mathbb{E}_t [M_{t,t+1}]$, $m_{t,t+1} = \log M_{t,t+1}$, and $b_t = \log B_t$.

### 2.5 Equilibrium

The equilibrium of the economy requires product, labor, and financial market clearing. Product market clearing requires that consumption equals production, i.e., $C_t = Y_t$. Labor market clearing requires that the supply and demand of labor type $k$ to produce good $j$ are equal for all $k$ and $j$. Financial market clearing requires that the nominal interest rate from the household’s problem in equation (9) to match the interest rate set by the monetary authority, i.e.,

$$
- \log \mathbb{E} [M_{t,t+1}^\$] = \rho i_{t-1} + (1 - \rho) (i + \pi_t + \pi_t x_t) + u_t.
$$

Appendix E provides a summary of the system of recursive equations describing the equilibrium of the model. We find the equilibrium numerically, using a second-order approximation of the optimality conditions.\(^7\) A second-order approximation is required to capture expected excess returns on financial claims.

\(^7\)We use the Dynare package available from www.dynare.org to solve the model.
3 Calibration and Model Implications

We analyze the implications of nominal rigidities and monetary policy on expected asset returns of production claims. We focus on claims on all future output and profits. The effects of nominal rigidities on expected excess returns can be understood by the impact of these rigidities on the pricing kernel, output, labor, 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 Calibration

We use quarterly U.S. data from 1982:1 to 2008:3 for consumption, inflation, the short-term nominal interest rate, and stock returns to calibrate the model. 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 nondurables and services from the Bureau of Economic Analysis. The series is de-trended using the 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). The model is calibrated at the quarterly frequency.

Table 1 presents the parameter values for the baseline calibration. The constant growth rate of the permanent productivity shock $g_a$ is chosen to match the growth rate of consumption for our sample period. The value of $\theta_p$ is chosen to obtain an average production markup of 20%.

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8We do not include data after 2008:3 since the financial crisis drove short-term interest rates to the zero bound. For the most recent period after 2008, monetary policy is better described by unconventional tools such as quantitative easing rather than by an interest-rate rule.
This is the value for the “high markup” specification in Altig et al. (2011) (hereafter ACEL). The price rigidity parameter value $\alpha_p$ is chosen such that the average price duration is 2.2 quarters, consistent with the empirical evidence in Bils and Klenow (2004). The value of $\theta_w$ is such that the average wage markup is 5%. The wage rigidity parameter $\alpha_w$ implies a duration of wages of four quarters, as estimated in ACEL. The parameter $\beta$ (and $\bar{i} = -\log(\beta) + \psi g_a$) is chosen to match the average level of the nominal risk-free rate. This value implies a subjective discount factor adjusted by growth of $\beta e^{-\psi g_a} = 0.975$. The interest rate rule parameters $\rho$, $\tau_\pi$, and $\tau_x$ 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 $\psi$, $\omega$, and the autocorrelations and conditional volatilities of productivity and policy shocks are chosen to match the variance decompositions of (detrended) consumption, inflation and the short-term nominal interest rate 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. Productivity and policy shocks explain 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 components in productivity, we require additional restrictions to identify how much of the variability is explained by each of these components. We choose a mix of shocks that matches the volatility of consumption growth. Specifically, a calibration in which productivity has only a permanent component implies a volatility of consumption growth significantly higher than in the data. On the other hand, a calibration where productivity has only a transitory component implies a very low volatility in consumption growth. The combination of permanent and productivity shocks with policy shocks

\footnote{ACEL refers to these productivity shocks as “neutral technology” shocks. The variance decomposition in 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, consistent with our sample period.}
matches the volatility of consumption growth in the data.\textsuperscript{10} A significant fraction of this volatility is attributed to permanent shocks.

Table 2 shows that the model is able to match the contributions of productivity and policy shocks to the total variability of de-trended consumption, inflation, and the nominal interest rate. The calibration implies a low elasticity of intertemporal substitution of consumption of 1/6.5 \approx 0.15, and a Frisch elasticity of labor supply of 1/0.35 \approx 2.86.\textsuperscript{11}

Finally, we choose the fixed operation cost $\bar{\varphi}$ to match the volatility of dividend growth of the aggregate stock market, and $\gamma$ to match the stock market quarterly Sharpe ratio, as in Tallarini (2000) and Kaltenbrunner and Lochstoer (2010). Consistent with the empirical practice, we use the nominal expected asset returns and risk-free rate of the model to calculate the model implied Sharpe ratio.

The recursive utility specification is critical for the model to match the Sharpe ratio. It allows us to increase the degree of risk aversion without affecting the elasticity of intertemporal substitution of consumption. As in Tallarini (2000), the macroeconomic properties of the model depend on the elasticity of substitution but are not significantly affected by risk aversion. The parameter $\gamma$ is set at 84.5. In the presence of leisure preferences, the household’s attitude toward risk is not only determined by this parameter but also by the willingness to supply labor in different states of the world. As shown by Swanson (2012), the (average) coefficient of relative risk aversion for the recursive preferences in equation (1) is

$$\frac{\psi}{1 + \frac{\psi}{\omega \mu} + \frac{\gamma - \psi}{1 - \frac{1 - \psi}{1 + \sigma}} \approx 16 \text{.}$$

\textsuperscript{10}Ideally, we should match the volatility of consumption growth explained by productivity and policy shocks. However, we match the total volatility of consumption growth to make a more meaningful comparison with other asset pricing models.

\textsuperscript{11}Macroeconomic 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.
This value is still high according to empirical and experimental evidence, but significantly lower than the values required by standard real business cycle models to match Sharpe ratios. For instance, Tallarini (2000) requires a risk aversion coefficient around 1,000.

3.2 Quantitative results

We explain in this section the three main implications for asset returns of the model calibration. First, expected excess returns on production claims are mainly a compensation for shocks to the permanent component of productivity. Table 3 presents summary statistics for our baseline calibration along with those from alternative model specifications. Column (1) shows that expected excess returns on output and profit claims are 12 and 24 bps., respectively, in the baseline calibration. Claims on profits are riskier than claims on output as a result of a procyclical production markup, \( \rho(\Delta c, \log \mu) > 0 \), and the fixed production cost, \( \overline{\phi} > 0 \). Fixed operation costs add a leverage effect that amplify the magnitude and risk of returns on profit claims. In an economy with no fixed production costs (\( \overline{\phi} = 0 \)), the expected excess return on the profit claim is 13 bps. The procyclical markup is the result of price rigidities in combination with wage rigidities. Profits are riskier than output because profits decline by more than output when marginal utility is high, as a result of lower markups (product prices are low relative to marginal costs).

Columns (2) to (4) in the table allow us to quantify the individual contributions of the three model shocks to the results. Each column corresponds to the baseline calibration with only one shock in the economy (the volatility of the two other shocks is set to zero). It is clear from the table that expected excess returns are mostly a compensation for permanent productivity shocks. These shocks contribute around 12 and 23 bps. to the premium in output and profit claims, respectively. The total contribution of transitory productivity and policy shocks is less than one basis point. The difference is also reflected in the implied Sharpe ratios. The Sharpe ratio for permanent shocks is significantly higher than the Sharpe ratios for the other two shocks: 0.28 for

\[^{12}\text{See, for instance, Barsky et al. (1997).}\]
permanent shocks in profit claims compared to 0.01 for transitory productivity and policy shocks. The significant contribution of permanent shocks and the low contribution of the other two shocks is explained in section 4.

Second, both price and wage rigidities increase expected excess returns on output and profit claims, but wage rigidities have a significantly larger impact than price rigidities. Table 3 allows us to make comparisons of the baseline model with model specifications with no rigidities, or only wage or price rigidities. The economy with no rigidities in column (2) can be seen as a frictionless real business cycle economy. In the absence of nominal rigidities, our model implies negative expected excess returns on both output and profit claims. Once wage rigidities or price rigidities are introduced, columns (3) and (4), respectively, show that expected excess returns on these claims become positive. It can be seen that wage rigidities generate larger expected excess returns than price rigidities. This can be explained by the significant response of employment to permanent productivity shocks under wage rigidities, as shown in section 4. It is worth noting in column (3) that claims on output and profits have the same expected returns since markups are constant when prices are flexible. On the other hand, column (4) shows that profit claims are less risky than output claims in a model with only price rigidities. This is the result of a countercyclical markup that generates high (sticky) prices when marginal utility is high, offsetting the negative effect of the output reduction on profits.

Third, the magnitude of the equity premium implied by the model is very small in comparison to its empirical counterpart. Table 3 shows that the expected excess return on profit claims is 24 bps. per quarter in our baseline calibration. This represents a small fraction of the equity premium of 1.78% per quarter in the data. Since our calibration matches the empirical Sharpe ratio, the result implies that the volatility of profit claim returns in the model is too low. It occurs despite the

\[^{13}\]For this comparison, notice that we set the fixed operation cost \( \bar{\varphi} \) to zero. This simplification allows a clean comparison across models for returns on profit claims, and does not alter the qualitative properties of the model. Specifically, the fixed operation cost value was chosen in the baseline model to match the volatility of aggregate dividends. This value implies implausible high dividend growth volatility in the specification with only price rigidities that obscures the interpretation of the results.
fact that we match the volatility of dividend growth in the data. It leads us to conclude that the
traditional model with nominal rigidities has a significant limitation to translate macroeconomic
volatility into asset return volatility. We address this shortcoming, provide an interpretation, and
suggest potential improvements for the model in section 7.

4 Understanding the Mechanism

Expected excess returns on production claims are amplified by nominal rigidities, mainly as a com-
pensation for permanent productivity shocks. We provide an explanation for these observations
in this section.

4.1 Role of permanent productivity shocks

Permanent productivity shocks have the largest contribution to the volatility of the pricing ker-
nel in equation (8). To understand why, appendix D shows that the log-pricing kernel can be
decomposed as

$$m_{t,t+1} = \vartheta \log \beta + m_{t,t+1}^{SR} + m_{t,t+1}^{LR},$$

where

$$m_{t,t+1}^{SR} = -\psi \vartheta \Delta c_{t+1} - (1 - \vartheta) \Delta q_{t+1}, \quad \text{and} \quad m_{t,t+1}^{LR} = -(1 - \vartheta) \log \left( \frac{1 + P_{Q,t+1}}{P_{Q,t}} \right),$$

are the short- and long-run components, respectively, for $\vartheta \equiv (1 - \gamma)/(1 - \psi)$. $P_{Q,t}$ is the price-cash
flow ratio for the claim on all future cash flows $\{Q_{t+s}\}_{s=0}^{\infty}$, and $q_t \equiv \log Q_t$. For simplicity, we refer
to this claim as the adjusted-wealth portfolio. The short-run component $m^{SR}$ contains shocks
to current period consumption and labor income growth, while the long-run component $m^{LR}$

\[14\] The cash flow $Q_t$ is a combination of consumption and labor income, defined in the appendix. The dependence
on labor income results from the preferences on labor. In the absence of these preferences, $Q_t = C_t$, and the
adjusted-wealth portfolio is the consumption claim $S_{C,t}$. 

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contains shocks to the return on adjusted-wealth. In Bansal and Yaron (2004) and Croce (2012), the short- and long-run components are uncorrelated by design. In our production economy, similar to Kaltenbrunner and Lochstoer (2010), innovations to the short- and long-run components come from the same shocks and, hence, are correlated. Productivity and monetary policy shocks contribute to both components. Therefore, not only the volatility of these components but also their correlation are important to determine the volatility of the pricing kernel and the prices of risk.

Table 5 shows that the volatility of the pricing kernel from permanent shocks is twenty times larger than that from transitory shocks, and fifty times larger than that from monetary policy shocks. However, the contributions of these shocks to the volatilities of short-run and long-run components of the pricing kernel are of similar magnitude. The large difference in the volatility of the pricing kernel is mainly driven by the correlation between \( m^{SR} \) and \( m^{LR} \). This is positive under permanent productivity shocks, but negative under transitory productivity and monetary policy shocks. After a permanent productivity shock, both current and future consumption (and labor income) go down, and then generate a positive correlation between \( m^{SR} \) and \( m^{LR} \) and a large volatility of the pricing kernel. On the other hand, since both transitory productivity and monetary policy shocks are mean-reverting, bad news for current consumption (labor income) means good news to future consumption (labor income). Consequently, the correlation between \( m^{SR} \) and \( m^{LR} \) generated by these shocks is negative and their contribution to the volatility of the pricing kernel is small.

### 4.2 Role of nominal rigidities

Nominal rigidities affect returns on production claims through their effects on employment and product markup dynamics. To highlight the main mechanisms, we analyze an economy affected only by permanent productivity shocks and no fixed operation costs (\( \bar{\varphi} = 0 \)). Permanent productivity shocks are the quantitatively important source of risk premia, as shown above. Fixed costs
in the model always amplify the volatility of dividends relative to output and, hence, the absolute value of the risk premium in dividend claims relative to output claims. For comparison purposes, we describe first the properties of expected excess returns in an economy with no rigidities.

Asset returns under flexible prices and wages

Table 3 shows that expected asset returns are negative in an economy with no rigidities.\textsuperscript{15} Employment and production markups are constant in this economy. Profits are then a constant fraction of output, and expected returns on output and profit claims are the same. Consider the expected excess return for the output claim described by equation (25). The first term in the equation generates a positive premium because a negative shock leads to a higher marginal rate of substitution of consumption and lower output. However, the second term generates a negative premium that is larger than the first term. The second term is negative since the negative shock leads to a higher price-output ratio, $P_{Y,t+1}$. To understand why, appendix G shows that $P_{Y,t}$ is approximately given by

$$\log P_{Y,t} = \text{const} + \frac{\phi_a (1 - \psi)}{1 - \kappa_Y \phi_a} \Delta a_t,$$

where the positive constant $\kappa_Y < 1$ is defined in the appendix. We use “const” throughout the paper to refer to any constant unimportant for the analysis. It is clear that the sensitivity of $P_{Y,t}$ to the shock is negative when the inverse of the elasticity of substitution (EIS) $\psi$ is larger than one. Two opposite effects drive this result. First, a substitution effect: after a persistent negative shock, the household reduces the demand for the output claim to smooth consumption over time (lowers $P_{Y,t+1}$); and second, a wealth effect: the persistent shock signals lower future output which increases its relative price (raises $P_{Y,t+1}$). When the EIS is lower than one, the wealth effect dominates the substitution effect, making output claims a hedging instrument.

Nominal rigidities and employment dynamics

\textsuperscript{15}This is a standard result in models with permanent productivity shocks and a lower than one EIS. See Bansal and Yaron (2004) for an endowment economy and Croce (2012) and Kaltenbrunner and Lochstoer (2010) for production economies with fixed employment.
Employment becomes procyclical and mean reverting in the presence of nominal rigidities. This feature is critical in the model to generate positive expected excess returns. Appendix G shows that employment and the price-output ratio are approximated by

\[ \log N^d_t = \text{const} + n_a \Delta a_t, \quad \text{and} \quad \log P_{Y,t} = \text{const} + \frac{[\phi_a - (1 - \phi_a)n_a](1 - \psi)}{1 - \kappa_Y \phi_a} \Delta a_t, \]

respectively. Procyclical labor demand, \( n_a > 0 \), leads to a procyclical \( P_{Y,t} \) and, hence, a positive expected excess return in output claims if \( n_a \) is large enough. The economic intuition for a positive \( n_a \) is as follows. Wage rigidities prevent nominal wages from adjusting downward after a negative productivity shock. Product prices remain high to preserve production markups, real production costs stay high, and labor demand declines. Similarly, price rigidities keep prices high after a negative productivity shock. Nominal wages stay high to preserve labor markups, and labor demand declines. Therefore, nominal rigidities lead to a procyclical labor demand that amplifies the effect of permanent productivity shocks on output. This effect, however, is mean reverting since prices and wages gradually adjust over time, increasing future labor demand after a negative shock. Strong mean reversion in labor demand, \( n_a > \phi_a/(1 - \phi_a) \), leads to a higher expected consumption growth after a negative shock, the substitution effect increases the demand for future output claims (raises \( P_{Y,t} \)), and the wealth effect reduces the price of future consumption (lowers \( P_{Y,t} \)). The wealth effect dominates if \( \psi > 1 \), making output claims risky.

**Price rigidities and time-varying markups**

Table 3 shows that output and profit claims have the same expected returns in models with no rigidities or with only wage rigidities. This is the result of a constant production markup. Producers freely adjust prices to keep their optimal markups. This is no longer true in the presence of price rigidities. In our baseline model with price and wage rigidities, markups are procyclical and expected returns on profit claims are higher than expected returns on output claims. Markups
vary over time since some producers are unable to adjust prices to restore the optimal markup.\footnote{In a model with only price rigidities, production markups are countercyclical and expected returns on profit claims are lower than expected returns on output claims. In both models, however, profits remain procyclical as observed in the data.} They are procyclical since nominal wages react by less than prices in our calibration given the rigidities: after a negative shock, marginal costs remain high relative to product prices, decreasing production markups and amplifying the risk of profit claims relative to output claims.

5 Interest Rate Policy Rule and Asset Returns

We analyze how monetary policy shocks and the response to economic conditions in the interest rate rule (20) affect asset returns. In our economy with flexible prices and wages, the policy rule does not have any real effects: policy changes in the nominal interest rate are solely reflected in changes in inflation and do not affect real interest rates and asset returns. That is, the interest rate rule does not affect (real) risk premia and return volatility.

Policy shocks, asset volatility and expected returns

In the model economy with nominal rigidities, Table 3 shows that policy shocks generate volatility in real asset returns and command a small positive compensation for risk. Figure ?? shows that a negative (expansionary) shock to the policy rule leads to lower nominal and real interest rates. The real rate declines since prices and nominal wages cannot fully adjust to neutralize the change in the nominal rate.\footnote{There is also a feedback effect on nominal interest rate from contemporaneous changes in inflation and output caused by the monetary policy shock.} Consequently, both output and dividends increase, the marginal utility of consumption declines, and the compensation for policy shocks in expected returns on output and dividend claims is positive. The compensation is small, however, as the volatility in the pricing kernel induced by policy shocks is small. This occurs despite the fact that the volatility in asset returns induced by these shocks is comparable to the one induced by productivity shocks.

Bernanke and Kuttner (2005) show that an unanticipated 25-basis-point cut in the federal
funds rate is associated with about a 100-basis-point increase in a broad stock market index. In our baseline model calibration, the policy shock impulse response in Figure ?? indicates that a 40-basis-point decrease in the annualized nominal interest rate leads to a 48-basis-point increase in the return on the dividend claim. This result is qualitatively consistent with the Bernanke and Kuttner (2005) empirical evidence but significantly smaller. This difference raises the question of what mechanism could amplify this effect.

Response to economic conditions and asset returns

Table 6 allows us to compare summary statistics for the baseline model calibration and three “policy experiments”. The experiments are individual changes in the responses to inflation ($\pi$) and the output gap ($x$), and the interest rate smoothing coefficient ($\rho$) in the policy rule. Column (2) in the table shows that an increase of $\pi$ from 1.5 to 1.89 leads to a 10% drop in inflation volatility, and 9.82% (1.22 bps) and 3.47% (0.82 bps) increases in expected excess returns on output and dividend claims, respectively. After a negative permanent productivity shock, wage rigidities keep wages high and prices increase to compensate for the high labor costs. A stronger response to inflation in the rule leads to a higher real interest rate, which further lowers output and increases risk premia.

Similarly, a reduced response to the output gap, $x$, reduces the response to productivity shocks of the real interest rate. It then amplifies the negative effects on output of a negative productivity shock. Therefore, risk premia are higher with a lower $x$. Quantitatively, column (3) in the table shows that a change in $x$ from 0.125 to $-0.16$ leads to a 10% increase in output gap volatility, and 16.48% (2.05 bps) and 3.94% (0.95 bps) increases in expected excess returns on output and dividend claims, respectively.\footnote{We use a negative $x$ only to obtain an increase of 10% in output gap volatility. A negative response to the output, however, is not empirically supported.}

Finally, stronger interest rate smoothing reduces the relative weight of the response to inflation and the output gap in the rule. Column (4) in the table shows that an increase in $\rho$ from 0.63
to 0.712 simultaneously increases inflation and output volatility. The 10% increase in output gap volatility translates into 6.38% (0.79 bps) and 0.83% (0.20 bps) increments in expected excess returns on output and dividend claims, respectively. It is worth noting that the model calibration implies a very small sensitivity of expected excess returns to variations in the monetary policy rule. We interpret this result in section 7.

### 6 Price Rigidities and Cross-Industry Returns

Bils and Klenow (2004) present evidence of significant dispersion of price stickiness across industries. Differences in the degree of price rigidity across industries may translate into differences in the expected returns of their production claims. To explore this channel, we extend our model to incorporate two sectors, \( H \) and \( L \), characterized by high and low price rigidities, \( \alpha_{pH} \) and \( \alpha_{pL} \), respectively. The two sectors are identical except for the degree of price rigidity. The consumption products of the two sectors, \( C_{H,t} \) and \( C_{L,t} \), respectively, conform the basket of consumption goods

\[
C_t = \left[ \nu^{1/\eta} C_{H,t}^{\frac{\eta-1}{\eta}} + (1 - \nu)^{1/\eta} C_{L,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad \text{where} \quad C_{I,t} = \left[ \int_{0}^{1} C_{I,t}(j) \frac{\theta_p^{-1}}{\theta_p - 1} dj \right]^{\frac{\theta_p}{\theta_p - 1}},
\]

for \( I = \{H, L\} \), \( \nu \) is the weight of sector \( H \) in the basket, and \( \eta > 1 \) is the elasticity of substitution between industry goods. Each production sector maximizes profits as in section 2 subject to the price rigidity \( \alpha_{pi} \).\(^{19}\) We compare the returns of the industry output and profit claims, \( R_{Y_{I,t}} \) and \( R_{D_{I,t}} \), respectively, for both industries. If \( \alpha_{pH} \) and \( \alpha_{pL} \) 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 elasticity parameters. To illustrate the main mechanism, consider the valuation of claims on industry profits that pay off only one-period in the future. Appendix F shows that the difference in expected returns on these claims can be

\[^{19}\text{Additional details of the model extension can be provided by the authors under request.}\]
approximated as

$$\log \mathbb{E}_t \left[ R_{H,t+1}^{(1)} \right] - \log \mathbb{E}_t \left[ R_{L,t+1}^{(1)} \right] = -(\theta_p - \eta) \text{cov}_t(m_{t,t+1}, p_{H,t+1} - p_{L,t+1}),$$

where $p_{I,t}$ is the product (log) price for industry $I$. Differences in expected returns on industry profit claims are driven by the dynamics of the relative price $p_{H,t} - p_{L,t}$, and the elasticities of substitution $\eta$ for goods across industries and $\theta_p$ for goods within each industry.

The difference in returns on profit claims is the result of the difference in output (output effect) and the difference in markups (markup effect) across the two industries. In our baseline model, a negative productivity shock increases product prices to compensate for high marginal costs given the wage rigidity. The price of good $H$ is lower than the price of good $L$ due to higher price rigidities in industry $H$. Then, the output effect is a higher demand for industry $H$ output in states of high marginal utility. It makes a claim on output $L$ riskier than a claim on output $L$, and increases the expected return of the industry $L$ claim relative to the industry $H$ claim. The output effect depends on the elasticity of substitution between the two goods, $\eta$. On the other hand, the negative relative price ($p_{H,t} < p_{L,t}$) implies that the markup of industry $H$ is smaller than that of industry $L$. This markup effect makes a claim on profits $H$ riskier than a claim on profits $L$, and increase the expected return of the industry $L$ claim relative to industry $H$. The markup effect depends on the elasticity of substitution among the differentiated goods within each industry $\theta_p$. As a result, the net effect on expected returns on industry profit claims depend on the difference in elasticities within and across industries.\(^{20}\)

To explore the difference in expected returns quantitatively, we set $\alpha_{pH} = 0.8$ and $\alpha_{pL} = 0$. This implies a mean and a standard deviation of price durations of 2.2 quarters and 2.13 quarters, respectively, which are consistent with Bils and Klenow (2004) evidence. Table 7 presents the

\(^{20}\)It is worth mentioning that in a model with perfectly flexible wages, differences in price rigidities have the opposite effect on the relative price, and then an opposite effect on expected returns. After a negative productivity shock, the price of the industry $H$ good is high relative to the price of the industry $L$ good.
expected returns of industry output and profit claims for model specifications with different values of \( \eta \). The table shows that the output effect dominates \((\mathbb{E}[R_{Y_H} - R_{Y_L}] < 0 \text{ and } \mathbb{E}[R_{D_H} - R_{D_L}] < 0)\) if \( \eta > \theta_p \), while the markup effect dominates \((\mathbb{E}[R_{D_H} - R_{D_L}] > 0)\) if \( \eta < \theta_p \). The two effects exactly offset each other if \( \theta_p = \eta \). The table also shows that the differences in expected returns are only quantitatively important for significant differences between \( \theta_p \) and \( \eta \).

7 Discussion

The nominal rigidities explored in this paper have interesting qualitative and quantitative implications for asset returns. Qualitatively, nominal price and wage rigidities generate procyclical mean-reverting variation in labor demand that increases the riskiness of output and profit claims. In addition, price rigidities generate time variation in production markups that translate into differences between the riskiness of output and profit claims. In the presence of rigidities, real asset returns become sensitive to the response to economic conditions in an interest rate policy rule, and policy shocks become a priced risk factor that affect asset return volatility. Differences in price rigidities translate into differences in expected returns across production sectors. Quantitatively, wage rigidities have larger effects on expected asset returns than price rigidities, mainly as a compensation for permanent productivity shocks. However, the equity premium is only a small fraction of its empirical counterpart and has a minor sensitivity to the specification of the interest rate policy rule. This occurs in a framework with recursive preferences and substantial risk aversion, since the implied macroeconomic dynamics fail to generate significant short- and long-run risk in production claims.

How should we interpret the limited quantitative performance of the model? On one hand, it highlights a significant shortcoming of the traditional New Keynesian framework to capture asset pricing dynamics. It raises doubts on whether nominal rigidities can be an important channel of transmission of monetary policy through asset prices. Certainly, the model cannot be used
to support policy recommendations based on asset price conditions. On the other hand, the model results can be taken as a reference point for both future model developments and empirical analysis.

The model can be extended in at least four dimensions. First, our model abstracts from capital accumulation and therefore ignores any potential effects of nominal rigidities on investment behavior. The joint study of investment dynamics, nominal rigidities, and asset prices merits further exploration. Second, our model does not incorporate shocks that are becoming standard in New Keynesian models such as price and wage markup shocks or investment specific shocks. These shocks are important in these models to reproduce some observed macroeconomic dynamics, and can become significant risk factors in asset returns. Third, we 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. Fourth, we assume 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).

The model delivers empirical predictions for the link between nominal rigidities and expected asset returns that can be used to test its validity and quantitative importance. All else equal, economies with higher wage or price rigidities should have higher expected excess returns on production claims than economies with lower wage or price rigidities. Different labor laws or monopoly regulations around the world translate into differences in wage and price frictions that can be a source of variation across international equity returns. Different pricing policies across firms and production sectors can be reflected in heterogeneity in their expected stock returns. This study is already been undertaken by Gorodnichenko and Weber (2013) with positive results. Finally, interest rate monetary policy rules with more weight on inflation relative to output stabilization should be associated to higher expected stock returns.
References


A Household’s Utility Maximization under Wage Rigidities

The household’s problem is

$$\max \{ C_t, N^*_t, W_t \} \quad V_t = U_t + \beta Q_t^{1-\psi}$$

where

$$U_t = \frac{C_t^{1-\psi}}{1-\psi} - \kappa_t \frac{(N^*_t)^{1+\omega}}{1+\omega}, \quad \text{and} \quad Q_t = E_t \left[ V_{t+1}^{1-\psi} \right],$$

subject to the budget constraint

$$E_t \left[ \sum_{\tau=0}^{\infty} M^g_{t, t+\tau} P_{t+\tau} C_{t+\tau} \right] \leq E_t \left[ \sum_{\tau=0}^{\infty} M^g_{t, t+\tau} P_{t+\tau} \left( LI_{t+\tau} + D_{t+\tau} \right) \right],$$

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

$$\mathcal{L} = \frac{C_t^{1-\psi}}{1-\psi} - \kappa_t \frac{(N^*_t)^{1+\omega}}{1+\omega} + \beta Q_t^{1-\psi} + \lambda E_t \left[ \sum_{\tau=0}^{\infty} M^g_{t, t+\tau} P_{t+\tau} \left( LI_{t+\tau} + D_{t+\tau} - C_{t+\tau} \right) \right].$$

It can be shown that utility maximization implies $\lambda = \frac{C_t^{1-\psi}}{P_t}$, and

$$M^g_{t, t+1} = \frac{\partial V_t}{\partial C_{t+1}} P_t = \frac{\partial V_t}{\partial C_t} \frac{\partial C_t}{\partial C_{t+1}} \frac{P_t}{P_{t+1}}$$

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

The $\tau$-period nominal pricing kernel is

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

Households minimize the expenditure of consumption

$$P_t C_t = \int_0^j P_t(j) C_t(j) \, dj$$

subject to the aggregator (??) where $P_t$ is the price of the final consumption goods and $P_t(j)$ is the price of goods $j$. The demand function for intermediate goods $j$ is then given by

$$C_t(j) = \left( \frac{P_t(j)}{P_t} \right)^{-\theta_j} C_t.$$
The wages of $1 - \alpha_w$ labor types are chosen to maximize households’ utility $V_t$. We assume that the wage choice for one labor type has negligible effects on the aggregate wage index and the aggregate labor demand. Denote the optimal wage choice for labor type $k$ as $W_t^*(k)$. To see the impact of $W_t^*(k)$ on the household’s utility, we rewrite the labor supply at $t + \tau$ as

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

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

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

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

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

We obtain derivatives

$$\frac{\partial N_{t+\tau}^s}{W_t^*(k)} = N_t^d (1 - \alpha_w) \alpha_w^\tau \left( -\theta_w \right) \left( \frac{W_t^*(k)}{W_{t+\tau}} \right)^{-\theta_w},$$

$$\frac{\partial LI_{t+\tau}}{W_t^*(k)} = \frac{N_t^d W_{t+\tau}}{P_{t+\tau}} (1 - \alpha_w) \alpha_w^\tau (1 - \theta_w) \left( \frac{W_t^*(k)}{W_{t+\tau}} \right)^{-\theta_w}.$$

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

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

where

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

Rearranging terms, we get

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

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

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

where

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

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

The optimal real wage and the optimal wage markup \( \mu_{w,t} \) are then given by

\[ \frac{W_t^*}{P_t} = \mu_{w,t} C_t^\psi \kappa_t (N_t^s)^\omega \quad \text{and} \quad \mu_{w,t} = \frac{\mu_w G_{w,t}}{H_{w,t}} . \]
B Profit Maximization under Price Rigidities

Firm $j$ chooses the optimal price $P_t^*(j)$ to solve the following maximization problem:

$$\max_{\{P_t^*(j)\}} \mathbb{E}_t \sum_{\tau=0}^{\infty} M_{t,t+\tau}^8 \left[ P_t^*(j) Y_{t+\tau|t}(j) - W_{t+\tau|t}(j) N_{t+\tau|t}(j) \right]$$

subject to

$$Y_{t+\tau|t}(j) = Y_{t+\tau} \left( \frac{P_t^*(j)}{P_{t+\tau}} \right)^{-\theta_p}, \text{ and } Y_{t+\tau|t}(j) = A_t N_{t+\tau|t}(j).$$

The first-order condition of this problem with respect to $P_t^*(j)$ is

$$\mathbb{E}_t \left[ \sum_{\tau=0}^{\infty} M_{t,t+\tau}^8 \alpha_p Y_{t+\tau|t}(j) P_t^*(j) \right] = \mathbb{E}_t \left[ \sum_{\tau=0}^{\infty} M_{t,t+\tau}^8 \alpha_p Y_{t+\tau|t}(j) \mu_p \frac{W_{t+\tau|t}(j)}{A_{t+\tau}} \right].$$

Because all firms changing prices face the same optimization problem, $P_t^*(j) = P_t^*$. We omit the index $j$ to simplify our notation in the rest derivation. The left-hand side (LHS) of the equation can be written recursively as

$$LHS = P_t^* \left( \frac{P_t^*}{P_t} \right)^{-\theta_p} Y_t H_t,$$

where

$$H_t = 1 + \alpha_p \mathbb{E}_t \left[ M_{t,t+1}^8 \left( \frac{Y_{t+1}}{Y_t} \right) \left( \frac{P_t}{P_{t+1}} \right)^{-\theta_p} H_{t+1} \right].$$

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

$$RHS = \mu_p Y_t \left( \frac{P_t^*}{P_t} \right)^{-\theta_p} \frac{W_t}{P_t} P_t G_t$$

where

$$G_t = 1 + \alpha_p \mathbb{E}_t \left[ M_{t,t+1}^8 \left( \frac{Y_{t+1}}{Y_t} \right) \left( \frac{P_t}{P_{t+1}} \right)^{-\theta_p} \left( \frac{W_{t+1}}{W_t} \right) \left( \frac{A_t}{A_{t+1}} \right) G_{t+1} \right].$$

The optimal price is hence given by

$$\left( \frac{P_t^*}{P_t} \right) \left( \frac{P_t}{P_t} \right) H_t = \frac{\mu_p}{A_t} \frac{W_t}{P_t} G_t.$$

Based on the definition of markup, the optimal time-varying product markup is given by

$$\mu_{p,t} = \mu_p \frac{G_t}{H_t} \text{ and } P_t^* = \mu_{p,t} \frac{W_t}{A_t}.$$
Labor Market Clearing Conditions

Labor market clearing requires that the aggregate supply of homogenous labor service by households equals the aggregate demand of homogenous labor service by firms, i.e.,

\[
\left[ \int_0^1 N^s_t(k)^{\theta_w-1} dk \right]^{\frac{\theta_w}{\theta_w-1}} = N^d_t = \int_0^1 N^d_t(j) dj .
\]

Define a measure of wage dispersion, \( F_{w,t} \), as

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

The aggregate supply of differentiated labor service can be written as

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

Next we show that based on the labor market clearing condition, the aggregate output is related to the aggregate labor supply through the relation

\[
Y_t = A_t N^s_t F_{w,t} F_t ,
\]

where \( F_t \) is a measure of price dispersion, defined as

\[
F_t = \int_0^1 \left( \frac{P_t(j)}{P_t} \right)^{-\theta_p} dj .
\]

Rewrite the supply of labor type \( k \) as follows:

\[
N^s_t(k) = N^d_t \left( \frac{W_t(k)}{W_t} \right)^{-\theta_w} = \left( \frac{W_t(k)}{W_t} \right)^{-\theta_w} \int_0^1 N^d_t(j) dj
\]

\[
= \left( \frac{W_t(k)}{W_t} \right)^{-\theta_w} \frac{Y_t}{A_t} \int_0^1 \left( \frac{P_t(j)}{P_t} \right)^{-\theta_p} dj = \left( \frac{W_t(k)}{W_t} \right)^{-\theta_w} \frac{Y_t}{A_t} F_t .
\]

Hence, the aggregate labor supply can be written as

\[
N^s_t = \int_0^1 N^s_t(k) dk = \frac{Y_t}{A_t} \int_0^1 \left( \frac{W_t(k)}{W_t} \right)^{-\theta_w} dk = \frac{Y_t}{A_t} F_{w,t} F_t .
\]

Note that both the wage dispersion \( F_{w,t} \) and the price dispersion \( F_t \) are bounded below by one. Rewrite \( F_{w,t} \) as follows:

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

where the second equality is due to Jensen’s inequality for \( \frac{-\theta_w}{1-\theta_w} \). 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 The Pricing Kernel

D.1 A Return Representation of the Pricing Kernel

The pricing kernel in terms of consumption and continuation utility is

\[ M_{t,t+1} = \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\psi} \left( \frac{V_{t+1}^{1/(1-\psi)}}{\tilde{V}_{t+1}^{1/(1-\gamma)}} \right)^{\psi-\gamma}, \]

where

\[ V_t = \frac{C_t^{1-\psi}}{1-\psi} - \kappa_t \left( N_t \right)^{1+\omega} + \beta \tilde{V}_t^{1-\psi}, \quad \text{and} \quad \tilde{V}_t = E_t \left[ \frac{1}{\psi} \right]. \]

Using the definitions of \( \tilde{V}_t \) and \( M_{t,t+1} \), we have

\[ \beta \tilde{V}_t^{1-\psi} = \beta \tilde{V}_t \tilde{V}_t^{1/\psi} = \beta E_t \left[ V_{t+1} V_{t+1}^{1-\psi} \right] = C_t^{1-\psi} E_t \left[ M_{t,t+1} C_{t+1}^{1-\psi} V_t \right]. \]  

Equation (13) shows that the optimal wage is set as

\[ W_t^* = \frac{\mu w}{P_t} C_t^{1-\psi} \frac{1}{1 + \omega} \frac{P_t}{\mu w} \frac{H_{w,t}}{G_{w,t}}. \]

Therefore, the household’s utility can be written as

\[ V_t = \frac{C_t^{1-\psi}}{1-\psi} - \frac{1}{1+\omega} \frac{1}{\mu w} LI_t C_t^{1-\psi} + \beta \tilde{V}_t^{1-\psi}, \]

where we define

\[ LI_t^* = \frac{W_t^*}{P_t} N_t \frac{H_{w,t}}{G_{w,t}}. \]

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 \( \beta \tilde{V}_t^{1-\psi} \) and solving \( V_t \) recursively, we get

\[ (1-\psi)C_t^{\psi} V_t = q_t + S_{q,t} \]

where

\[ Q_t = C_t - \frac{1}{1+\omega} \frac{1}{\mu w} LI_t^* \]

\[ S_{q,t} = E_t \left[ \sum_{s=1}^{\infty} M_{t,t+1} Q_{t+s} \right]. \]

Multiply equation (27) by \( (1-\psi)C_t^{\psi} \) and get

\[ \beta (1-\psi)C_t^{\psi} \tilde{V}_t^{1-\psi} = E_t \left[ M_{t,t+1} (1-\psi)C_t^{\psi} V_{t+1} \right] = E_t \left[ M_{t,t+1} (q_{t+1} + S_{q,t+1}) \right]. \]
Therefore, the return on claims \( \{Q_{t+s}\}_{s=1}^{\infty} \) is given by

\[
R_{q,t+1} = \frac{Q_{t+1} + S_{q,t}}{S_{q,t}} = \frac{C_{t+1}V_{t+1}}{\beta C_t V_t^{1-\psi}}
\]

Simple algebra leads to an alternative expression for the pricing kernel as

\[
M_{t,t+1} = \left[ \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\psi} \right]^{\frac{1-\psi}{1-\psi}} \frac{\psi}{R_{q,t+1}}.
\] (29)

\( S_{q,t} \) can be interpreted as the present value of wealth, whose dividend includes consumption and labor income. Define the price-cash flow ratio for claims on \( q \) as

\[
P_{q,t} = \frac{S_{q,t}}{Q_t}
\]

and we rewrite the pricing kernel as

\[
m_{t,t+1} = \theta \log \beta - \psi \theta \Delta a_{t+1} - (1 - \theta) r_{q,t+1}
\] = \[ \theta \log \beta - \psi \theta \Delta a_{t+1} - (1 - \theta) \Delta q_{t+1} - (1 - \theta) \log \left( \frac{1 + P_{q,t+1}}{P_{q,t}} \right),
\]

where \( \theta = \frac{1}{1-\psi} \).

### D.2 Short-run and long-run components of the pricing kernel

For illustrative purpose, we compute the conditional covariance of \( m^S R_{t+1} \) and \( m^L R_{t+1} \) using long-linear approximation. In the case with only permanent productivity shock, the economy can be approximately described as

\[
\Delta a_t = \Delta a_t + n_a^d
\]
\[
n_a^d = n_a \Delta a_t
\]
\[
p_{q,t} = p_a \Delta a_t
\]
\[
\Delta q_t = (1 + \eta_{qn} n_a) \Delta a_t - \eta_{qn} n_a \Delta a_t
\]
\[
\eta_{qn} = 1 - \frac{(1 - \psi)(\omega + \psi)}{1 + \omega} \tilde{\kappa}
\]
\[
r_{q,t+1} = \Delta q_{t+1} + \kappa_0 + \kappa_1 p_{q,t+1} - p_{q,t}
\]

where \( 0 < \tilde{\kappa} < 1 \) and \( \kappa_1 > 1 \). Therefore, the short-run and long-run components of the pricing kernel can be rewritten as

\[
m_{t+1}^{SR} - \mathbb{E}_t [m_{t+1}^{SR}] = -[\theta \psi (1 + n_a) + (1 - \theta) (1 + \eta_{qn} n_a)] c_{t+1}^a
\]
\[
m_{t+1}^{LR} - \mathbb{E}_t [m_{t+1}^{LR}] = -(1 - \theta) \kappa_1 p_a c_{t+1}^a
\]
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 $\kappa_t = (A^*_t)^{-\psi}$. This condition ensures that $Y_t$, $Y_t^*$, $W_t$, and $W_t^*$ are growing at the same rate. Therefore, the equations can be written in terms of $Y_t = \frac{Y_t}{A^*_t}$, $Y_t^* = \frac{Y_t^*}{A_t}$, $W_t = \frac{W_t}{A_t}$, and $W_t^* = \frac{W_t^*}{A_t}$.

Wage Setting

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

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

and

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

Price Dispersion

$$F_t = \int_0^1 \left( \frac{P_t(j)}{P_t} \right)^{-\theta_p} dj = (1 - \alpha_p) \left( \frac{P_t^*}{P_t} \right)^{-\theta_p} + \alpha_p \left( \frac{P_{t-1}}{P_t} \right)^{-\theta_p} F_{t-1}.$$  

Wage Dispersion

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

Wage Aggregator

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

Price Setting

$$\left( \frac{P_t^*}{P_t} \right) \left( \frac{P_t}{P_t} \right) H_t = \mu \frac{W_t}{A_t} G_t,$$

$$H_t = 1 + \alpha_p \mathbb{E}_t \left[ M_{t,t+1}^\delta \left( \frac{Y_{t+1}}{Y_t} \right) \left( \frac{P_{t+1}}{P_t} \right)^{-\theta_p} H_{t+1} \right],$$

and

$$G_t = 1 + \alpha_p \mathbb{E}_t \left[ M_{t,t+1}^\delta \left( \frac{Y_{t+1}}{Y_t} \right) \left( \frac{P_t}{P_{t+1}} \right)^{-\theta_p} \left( \frac{W_{t+1}}{W_t} \right) \left( \frac{A_t}{A_{t+1}} \right) G_{t+1} \right].$$

Price Aggregators

$$1 = (1 - \alpha_p) \left( \frac{P_t^*}{P_t} \right)^{1-\theta_p} + \alpha_p \left( \frac{P_{t+1}}{P_t} \right)^{-\theta_p}.$$
Aggregate Labor Supply and Demand

\[ N_s^t = F_{w,t} N_d^t, \quad N_d^t = \frac{Y_t}{A_t} F_t. \]

Markups

\[ \mu_t = \frac{Y_t}{L_t} = \frac{A_t}{F_t} \left( \frac{W_t}{P_t} \right)^{-1}. \]

Pricing Kernel

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

Output and Wage under Perfectly Flexible Wages and Prices

\[ Y_t^f = (\mu_p \mu_w)^{-\frac{1}{\gamma+1}} A_t, \quad \text{and} \quad \frac{W_t^f}{P_t} = \frac{A_t}{\mu_p}, \quad (30) \]

respectively.
Understanding the Mechanism

F.1 Excess expected stock returns

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

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

The price of claim X can be written as

\[ 1 = E_t [M_{t,t+1} R_{X,t+1}] = \exp \left[ E_t [m_{t,t+1} + \log R_{X,t+1}] + \frac{1}{2} \text{var}_t (m_{t,t+1} + \log R_{X,t+1}) \right]. \]

Therefore, the expected excess return is given by

\[ \log E_t [R_{X,t+1}] - \log R_{f,t} = -\text{cov}_t (m_{t+1}, \log R_{X,t+1}) \]

\[ = -\text{cov}_t (m_{t,t+1}, \Delta y_{t+1}) - \text{cov}_t (m_{t,t+1}, \log (1 + P_{X,t+1})). \]

F.2 Cross-sectional stock returns

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 \( \Delta y_{I,t}^{\text{real}} \equiv \log Y_{I,t}^{\text{real}} \), and \( P_{R,t+1} \equiv \log P_{R,t+1} \). The difference depends on the elasticity \( \eta \) 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

\[ \mu_{I,t} = \frac{Y_{I,t}^{\text{real}}}{L_{I,t}} = A_t \left( \frac{W_t}{P_t} \right)^{-1} \left( \frac{P_{I,t}}{P_t} \right). \]
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.

The markup term can be approximated around \( \log \mu_{I,t} = \log \mu, \) where \( \mu = \frac{\theta_w}{\theta_w - 1} \). That is,

\[ \log \left( 1 - \frac{1}{\mu_{I,t}} \right) \approx \log \left( 1 - \frac{1}{\mu} \right) + \frac{1}{\mu - 1} (\log \mu_{I,t} - \log \mu). \]

It follows that

\[ \log \left( 1 - \frac{1}{\mu_{H,t}} \right) - \log \left( 1 - \frac{1}{\mu_{L,t}} \right) \approx (\theta_w - 1) \log \left( \frac{\mu_{H,t}}{\mu_{L,t}} \right) = (\theta_w - 1) \left[ -(f_{H,t} - f_{L,t}) + p_{R,t} \right]. \]

Therefore, the difference in expected returns on profit claims across industries can be approximated as

\[ -\text{cov}_t(m_{t,t+1}, \Delta d_{H,t+1} - \Delta d_{L,t+1}) \approx -\text{cov}_t(m_{t,t+1}, \Delta y_{H,t+1}^{\text{real}} - \Delta y_{L,t+1}^{\text{real}}) + (1 - \theta_w)\text{cov}_t(m_{t,t+1}, p_{R,t+1}) - (1 - \theta_w)\text{cov}_t(m_{t,t+1}, f_{H,t} - f_{L,t}) \]

where the term \( \text{cov}_t(m_{t,t+1}, f_{H,t} - f_{L,t}) \approx 0 \). Therefore, the dynamics of the relative price implied by the two industry goods and the elasticities \( \eta \) and \( \theta_w \) 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.
G Log-linear solution of Equity Premium

In this section, we provide the analytical solution for the price-dividend ratio using the loglinear approximation. We show that without rigidity, our model with an EIS < 1 leads to a negative equity premium; with rigidities, the model generates a positive equity premium with the same EIS.

The model without rigidities

Without rigidities, markup is constant and the returns on the consumption claim, the dividend claim, and the labor income claim are the same. As shown in Campbell and Shiller (1988), the return on the consumption claim is given by

\[ r_{c,t+1} = \Delta c_{t+1} + \kappa_0 + \kappa_1 p_{c,t+1} - p_{c,t} \]

where \( \kappa_1 \) is a constant less than one, and \( p_{c,t} \) is the log of price-consumption ratio.

As shown in Appendix D, the pricing kernel can be written as

\[ m_{t,t+1} = \left( \frac{1 - \gamma}{1 - \psi} \right) \log(\beta) - \psi \left( \frac{1 - \gamma}{1 - \psi} \right) \Delta c_{t+1} + \left( \psi - \frac{\gamma}{1 - \psi} \right) r_{q,t+1}, \]

where \( \Delta c_{t+1} = \Delta y_{t+1} = \Delta a_{t+1} + \frac{1 + \omega}{\omega + \psi} \Delta z_t \), and because markup is constant

\[ r_{q,t+1} = r_{c,t}. \]

Note that the last term in \( m_{t,t+1} \) should be the weighted average of returns to the consumption claim and the labor income claim, which is the same as the return on the consumption claim in an economy without rigidities.

We conjecture that the log price-consumption ratio follows

\[ p_{c,t} = p_0 + p_a \Delta a_t + p_z z_t. \]

The return on consumption claim must satisfy the following Euler equation

\[ \mathbb{E}_t [e^{m_{t,t+1} + r_{c,t+1}}] = 1 \]

for any values of the state variables \( \Delta a_t \) and \( z_t \). Therefore, in the above Euler equation, all terms that involves \( \Delta a_t \)

\[ \phi_a (1 - \psi) + (\kappa_1 \phi_a - 1) p_a = 0 \]

and all terms that involves \( z_t \)

\[ (\phi_z - 1)(1 - \psi)(1 + \omega) - [\phi_z \kappa_1 - 1] p_z = 0. \]

It is straightforward to show that

\[ p_a = \frac{\phi_a (1 - \psi)}{1 - \kappa_1 \phi_a} \]

and

\[ p_z = \frac{(\phi_z - 1)(1 - \psi)(1 + \omega)/(\omega + \psi)}{1 - \kappa_1 \phi_z}. \]
With EIS less than one, \( \psi \) is larger than one, leading to a negative \( p_a \) and a positive \( p_z \). This result shows that when there is a positive permanent productivity shock, price-consumption ratio decreases while with a positive transitory shock, price-consumption ratio increases. Therefore, the risk premium of consumption claim to the permanent shock is negative but positive to the transitory shock.

The model with rigidities

With rigidities, the markup is not constant anymore and the labor supply becomes time-varying. Consequently, the consumption growth also depends on the changes in labor supply:

\[
\Delta c_{t+1} = \Delta a_{t+1} + \Delta z_t + \Delta n_{t+1},
\]

where we assume that

\[ n_t = n_a \Delta a_t + n_z z_t. \]

To simplify the analysis, we assume that\(^{21}\)

\[ r_{q,t+1} \approx r_{c,t+1} \]

so that we can still write the pricing kernel as

\[
m_{t,t+1} = \left( \frac{1 - \gamma}{1 - \psi} \right) \log(\beta) - \psi \left( \frac{1 - \gamma}{1 - \psi} \right) \Delta c_{t+1} + \left( \frac{\psi - \gamma}{1 - \psi} \right) r_{c,t+1}.
\]

Following the same approach, we can get

\[
p_a = \frac{[\phi_a - (1 - \phi_a)n_a](1 - \psi)}{1 - \kappa_1 \phi_a},
\]

\[
p_z = \frac{(\phi_z - 1)(1 - \psi)(1 + n_z)}{1 - \kappa_1 \phi_z}.
\]

When \( n_a \) is positive and large enough, \( p_a \) becomes positive, which is what happens with the existence of wage rigidities. With price rigidities, even though \( n_a \) is positive, but its magnitude is not large enough, hence we still have a negative \( p_a \). But combined with the negative effect on consumption, the return on consumption claims \( r_{c,t+1} \) is positive. Finally, it is straightforward to show that \( p_z \) is positive.

It is easy to show that the persistence of consumption growth is lower than the persistence without rigidities, i.e., \( \phi_a \).

\[
cov(\Delta y_{t+1}, \Delta y_t) = cov_t((n_a + 1)\Delta a_{t+1} - n_a \Delta a_t, (n_a + 1)\Delta a_t - n_a \Delta a_{t-1})
\]

\[= [(n_a + 1)^2 + n_a^2] \phi_a - n_a(n_a + 1) \phi_a^2 - n_a(n_a + 1) \]

\[
var(\Delta y_t) = (n_a + 1)^2 + n_a - 2n_a(n_a + 1) \phi_a
\]

\[
\rho_y = \phi_a + \frac{n_a(n_a + 1)[\phi_a^2 - 1]}{(n_a + 1)^2 + n_a - 2n_a(n_a + 1) \phi_a} < \phi_a
\]

\(^{21}\)Our numerical analysis shows that this approximation does not lead to qualitative changes to returns.
Table 1: **Baseline Parameter Values**

This table contains the parameter values for the benchmark calibration. The model is calibrated at quarterly frequency. The average productivity growth and volatilities are presented in per cent per quarter.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preferences</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>Subjective discount factor</td>
<td>1.0054</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Inverse of elasticity of intertemporal substitution</td>
<td>6.5</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Risk aversion parameter</td>
<td>84.5</td>
</tr>
<tr>
<td>$\omega$</td>
<td>Inverse of Frisch labor elasticity</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Rigidities and Monopolistic Competition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\theta_p$</td>
<td>Elasticity of substitution of differentiated goods</td>
<td>6</td>
</tr>
<tr>
<td>$\theta_w$</td>
<td>Elasticity of substitution of labor types</td>
<td>21</td>
</tr>
<tr>
<td>$\alpha_p$</td>
<td>Price rigidity parameter</td>
<td>0.63</td>
</tr>
<tr>
<td>$\alpha_w$</td>
<td>Wage rigidity parameter</td>
<td>0.78</td>
</tr>
<tr>
<td><strong>Interest Rate Policy Rule</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho$</td>
<td>Interest-rate smoothing coefficient in policy rule</td>
<td>0.63</td>
</tr>
<tr>
<td>$\bar{i}$</td>
<td>Constant in the policy rule</td>
<td>0.029</td>
</tr>
<tr>
<td>$i_\pi$</td>
<td>Response to inflation in the policy rule</td>
<td>1.5</td>
</tr>
<tr>
<td>$i_x$</td>
<td>Response to output gap in the policy rule</td>
<td>0.125</td>
</tr>
<tr>
<td>$\phi_u$</td>
<td>Autocorrelation of policy shock</td>
<td>0.564</td>
</tr>
<tr>
<td>$\sigma_u$</td>
<td>Conditional volatility of policy shock</td>
<td>0.151</td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\bar{\varphi}$</td>
<td>Fixed production cost</td>
<td>0.1472</td>
</tr>
<tr>
<td>$g_a$</td>
<td>Average productivity growth</td>
<td>0.4695</td>
</tr>
<tr>
<td>$\phi_a$</td>
<td>Autocorrelation of permanent productivity shock</td>
<td>0.391</td>
</tr>
<tr>
<td>$\sigma_a$</td>
<td>Conditional volatility of permanent productivity shock</td>
<td>0.202</td>
</tr>
<tr>
<td>$\phi_z$</td>
<td>Autocorrelation of transitory productivity shock</td>
<td>0.985</td>
</tr>
<tr>
<td>$\sigma_z$</td>
<td>Conditional volatility of permanent productivity shock</td>
<td>0.102</td>
</tr>
</tbody>
</table>
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. Volatilities are measured in per cent per quarter. The sign “-” in the data columns indicates that the statistic is not available.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$i_t$</td>
<td>0.65</td>
<td>0.24</td>
<td>0.09</td>
<td></td>
<td>0.24</td>
<td>0.09</td>
<td>0.07</td>
<td>0.06</td>
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<tr>
<td>$\pi_t$</td>
<td>0.34</td>
<td>0.08</td>
<td>0.12</td>
<td></td>
<td>0.08</td>
<td>0.09</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>$\hat{c}_t$</td>
<td>0.76</td>
<td>0.17</td>
<td>0.22</td>
<td></td>
<td>0.17</td>
<td>0.22</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>$\Delta c_t$</td>
<td>0.37</td>
<td>-</td>
<td>-</td>
<td></td>
<td>0.12</td>
<td>0.35</td>
<td>0.35</td>
<td>0.03</td>
</tr>
</tbody>
</table>

**Panel B: Asset pricing moments**

<table>
<thead>
<tr>
<th>Sharpe ratio ($SR_D$)</th>
<th>Data (1982-2008)</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.215</td>
<td>0.215</td>
</tr>
</tbody>
</table>
Table 3: Model Summary Statistics. The Effect of Different Shocks.
The baseline parameter values are presented in Table 1. “Baseline” 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 ($\sigma_a = \sigma_z = 0$). De-trended log consumption is denoted by $\hat{c}_t$. Excess returns and the Sharpe ratio for asset $b$ are $XR_{b,t} = R_{b,t+1} - R_{f,t}$, and $SR_b = \frac{E[XR_{b,t}]}{\sigma(XR_{b,t})}$, respectively. Volatilities and returns are measured in per cent per quarter. The sign “-” in the data column indicates that the statistic is not available.

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>(1) Baseline</th>
<th>(2) Only $A^p$</th>
<th>(3) Only $Z$</th>
<th>(4) Only $u$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Macroeconomic variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma(\pi)$</td>
<td>0.34</td>
<td>0.12</td>
<td>0.08</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>$\sigma(\hat{c})$</td>
<td>0.76</td>
<td>0.27</td>
<td>0.17</td>
<td>0.14</td>
<td>0.17</td>
</tr>
<tr>
<td>$\sigma(i)$</td>
<td>0.65</td>
<td>0.26</td>
<td>0.07</td>
<td>0.06</td>
<td>0.24</td>
</tr>
<tr>
<td>$\sigma(\log \mu)$</td>
<td>-</td>
<td>0.17</td>
<td>0.13</td>
<td>0.08</td>
<td>0.07</td>
</tr>
<tr>
<td>$\sigma(\Delta c)$</td>
<td>0.37</td>
<td>0.37</td>
<td>0.35</td>
<td>0.03</td>
<td>0.12</td>
</tr>
<tr>
<td>$\sigma(\Delta d)$</td>
<td>8.10</td>
<td>8.10</td>
<td>6.74</td>
<td>4.39</td>
<td>0.97</td>
</tr>
<tr>
<td>$\rho(\Delta c, \log \mu)$</td>
<td>-</td>
<td>0.47</td>
<td>0.60</td>
<td>0.77</td>
<td>0.03</td>
</tr>
<tr>
<td>$\rho(\Delta c, n^d)$</td>
<td>-</td>
<td>0.30</td>
<td>0.87</td>
<td>-0.06</td>
<td>0.37</td>
</tr>
<tr>
<td>$ar(\Delta c)$</td>
<td>0.40</td>
<td>0.00</td>
<td>0.01</td>
<td>0.03</td>
<td>-0.07</td>
</tr>
<tr>
<td><strong>Panel B: Asset returns</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E[i]$</td>
<td>1.30</td>
<td>1.30</td>
<td>1.31</td>
<td>2.53</td>
<td>2.54</td>
</tr>
<tr>
<td>$E[XR_{Y,t+1}]$</td>
<td>-</td>
<td>0.12</td>
<td>0.12</td>
<td>0.002</td>
<td>0.004</td>
</tr>
<tr>
<td>$E[XR_{D,t+1}]$</td>
<td>1.78</td>
<td>0.24</td>
<td>0.23</td>
<td>0.006</td>
<td>0.003</td>
</tr>
<tr>
<td>$\sigma(R_Y)$</td>
<td>-</td>
<td>0.85</td>
<td>0.43</td>
<td>0.12</td>
<td>0.72</td>
</tr>
<tr>
<td>$\sigma(R_D)$</td>
<td>8.30</td>
<td>1.10</td>
<td>0.82</td>
<td>0.47</td>
<td>0.56</td>
</tr>
<tr>
<td>$SR_Y$</td>
<td>-</td>
<td>0.15</td>
<td>0.28</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>$SR_D$</td>
<td>0.22</td>
<td>0.22</td>
<td>0.28</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Table 4: Model Summary Statistics. The Effect of Different Rigidities.
The baseline parameter values are presented in Table 1, except the fixed cost parameter $\bar{\phi}$. All model specifications assume $\bar{\phi} = 0$. “Baseline No $\bar{\phi}$” indicates the baseline economy with both price and wage rigidities but no fixed production costs. “No Rig.” indicates no price and wage rigidities ($\alpha_p = \alpha_w = 0$). “Only WR” indicates no price rigidities ($\alpha_p = 0$). “Only PR” indicates no wage rigidities ($\alpha_w=0$). Detrended log consumption is denoted by $\hat{c}_t$. Excess returns and the Sharpe ratio for asset $b$ are $XR_{b,t} = R_{b,t+1} - R_{f,t}$, and $SR_b = \frac{E[XR_{b,t}]}{\sigma(XR_{b,t})}$, respectively. Volatilities and returns are measured in per cent per quarter.

<table>
<thead>
<tr>
<th></th>
<th>(1) Baseline No $\bar{\phi}$</th>
<th>(2) No Rig.</th>
<th>(3) Only WR</th>
<th>(4) Only PR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A: Macroeconomic variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\sigma(\pi)$</td>
<td>0.12</td>
<td>0.86</td>
<td>0.21</td>
<td>0.33</td>
</tr>
<tr>
<td>$\sigma(\hat{c})$</td>
<td>0.27</td>
<td>0.12</td>
<td>0.28</td>
<td>0.17</td>
</tr>
<tr>
<td>$\sigma(i)$</td>
<td>0.26</td>
<td>0.42</td>
<td>0.26</td>
<td>0.14</td>
</tr>
<tr>
<td>$\sigma(\log \mu)$</td>
<td>0.17</td>
<td>0.00</td>
<td>0.00</td>
<td>0.84</td>
</tr>
<tr>
<td>$\sigma(\Delta c)$</td>
<td>0.37</td>
<td>0.22</td>
<td>0.38</td>
<td>0.30</td>
</tr>
<tr>
<td>$\sigma(\Delta d)$</td>
<td>0.69</td>
<td>0.02</td>
<td>0.22</td>
<td>4.48</td>
</tr>
<tr>
<td>$\rho(\Delta c, \log \mu)$</td>
<td>0.47</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.79</td>
</tr>
<tr>
<td>$\rho(\Delta c, n^d)$</td>
<td>0.30</td>
<td>-0.01</td>
<td>0.33</td>
<td>0.19</td>
</tr>
<tr>
<td>$ar(\Delta c)$</td>
<td>0.00</td>
<td>0.39</td>
<td>-0.02</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Panel B: Asset returns</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E[\bar{\gamma}]$</td>
<td>1.30</td>
<td>1.64</td>
<td>1.28</td>
<td>1.55</td>
</tr>
<tr>
<td>$E[XR_{Y,t+1}]$</td>
<td>0.12</td>
<td>-0.13</td>
<td>0.15</td>
<td>0.03</td>
</tr>
<tr>
<td>$E[XR_{D,t+1}]$</td>
<td>0.13</td>
<td>-0.13</td>
<td>0.15</td>
<td>0.00</td>
</tr>
<tr>
<td>$\sigma(R_Y)$</td>
<td>0.85</td>
<td>0.51</td>
<td>0.89</td>
<td>0.42</td>
</tr>
<tr>
<td>$\sigma(R_D)$</td>
<td>0.85</td>
<td>0.51</td>
<td>0.89</td>
<td>0.30</td>
</tr>
<tr>
<td>$SR_Y$</td>
<td>0.15</td>
<td>-0.26</td>
<td>0.17</td>
<td>0.06</td>
</tr>
<tr>
<td>$SR_D$</td>
<td>0.16</td>
<td>-0.26</td>
<td>0.17</td>
<td>0.02</td>
</tr>
</tbody>
</table>
Table 5: Pricing Kernel Decomposition: Short-Run and Long-Run Components

The baseline parameter values are presented in Table 1. All model specifications except the benchmark, assume $\bar{\varphi} = 0$.”Baseline” 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 ($\sigma_a = \sigma_z = 0$).

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Only $A^p$</th>
<th>Only Z</th>
<th>Only $u$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unconditional Moments</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m$</td>
<td>0.272</td>
<td>0.267</td>
<td>0.056</td>
<td>0.006</td>
</tr>
<tr>
<td>$m^{SR}$</td>
<td>0.182</td>
<td>0.161</td>
<td>0.078</td>
<td>0.035</td>
</tr>
<tr>
<td>$m^{LR}$</td>
<td>0.130</td>
<td>0.125</td>
<td>0.022</td>
<td>0.031</td>
</tr>
<tr>
<td>$\text{corr}(m^{SR}, m^{LR})$</td>
<td>0.512</td>
<td>0.738</td>
<td>-0.974</td>
<td>-0.992</td>
</tr>
<tr>
<td>$\text{corr}(m, m^{LR})$</td>
<td>0.914</td>
<td>0.913</td>
<td>-0.950</td>
<td>-0.690</td>
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<tr>
<td><strong>Conditional Moments</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>$m$</td>
<td>0.303</td>
<td>0.298</td>
<td>0.056</td>
<td>0.004</td>
</tr>
<tr>
<td>$m^{SR}$</td>
<td>0.206</td>
<td>0.190</td>
<td>0.077</td>
<td>0.022</td>
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<tr>
<td>$m^{LR}$</td>
<td>0.117</td>
<td>0.114</td>
<td>0.021</td>
<td>0.017</td>
</tr>
<tr>
<td>$\text{corr}(m^{SR}, m^{LR})$</td>
<td>0.641</td>
<td>0.804</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td>$\text{corr}(m, m^{LR})$</td>
<td>0.823</td>
<td>0.943</td>
<td>-1.000</td>
<td>-0.985</td>
</tr>
</tbody>
</table>
Table 6: Summary Statistics for Models with Different Reaction Coefficients in the Interest Rate Policy Rule.

The baseline parameter values are presented in Table 1. The interest rate rule is

\[ i_t = \rho i_{t-1} + (1 - \rho) (\bar{\pi} + \pi_t + x_t) + u_t. \]

"Baseline" indicates an economy with both price and wage rigidities. Columns (2), (3) and (4) report model statistics for individual changes in parameter values for \( \pi_t \), \( x_t \), and \( \rho \), respectively. The calibration in column (4) also adjusts the \( \pi_t \) and \( x_t \) coefficients such that \( (1 - \rho) \pi_t \) and \( (1 - \rho) x_t \) stay at their baseline levels. Expected excess returns and Sharpe ratios for asset \( b \) are

\[ \mathbb{E}[X_{R_{b,t+1}}] = \frac{R_{b,t+1} - R_{f,t}}{\sigma(X_{R_{b,t+1}})}, \]

and \( SR_b = \frac{\mathbb{E}[X_{R_{b,t+1}}]}{\sigma(X_{R_{b,t+1}})} \), respectively. “No \( \bar{\varphi} \)” indicates a statistic for a model with \( \bar{\varphi} = 0 \). Figures in parenthesis are percentage changes with respect to the baseline calibration. Volatilities and returns are reported in basis points per quarter.

<table>
<thead>
<tr>
<th></th>
<th>(1) Baseline</th>
<th>(2) ( \pi_t = 1.89 )</th>
<th>(3) ( x_t = -0.16 )</th>
<th>(4) ( \rho = 0.712 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma(\pi) )</td>
<td>12.12</td>
<td>10.91 (-9.96)</td>
<td>12.21 (0.78)</td>
<td>12.65 (4.44)</td>
</tr>
<tr>
<td>( \sigma(x) )</td>
<td>23.71</td>
<td>23.54 (-0.72)</td>
<td>26.09 (10.03)</td>
<td>26.10 (10.05)</td>
</tr>
<tr>
<td>( \sigma(\Delta c) )</td>
<td>36.92</td>
<td>37.34 (1.15)</td>
<td>38.41 (4.05)</td>
<td>37.83 (2.46)</td>
</tr>
<tr>
<td>( \sigma(\Delta d) ) no ( \bar{\varphi} )</td>
<td>809.92</td>
<td>803.09 (-0.84)</td>
<td>787.97 (-2.71)</td>
<td>806.15 (-0.47)</td>
</tr>
<tr>
<td>( \mathbb{E}[X_{R_{Y,t+1}}] )</td>
<td>12.41</td>
<td>13.63 (9.82)</td>
<td>14.46 (16.48)</td>
<td>13.20 (6.38)</td>
</tr>
<tr>
<td>( \mathbb{E}[X_{R_{D,t+1}}] )</td>
<td>23.65</td>
<td>24.47 (3.47)</td>
<td>24.58 (3.94)</td>
<td>23.85 (0.83)</td>
</tr>
<tr>
<td>( \mathbb{E}[X_{R_{D,t+1}}] ) no ( \bar{\varphi} )</td>
<td>13.21</td>
<td>14.38 (8.91)</td>
<td>15.14 (14.68)</td>
<td>13.94 (5.52)</td>
</tr>
<tr>
<td>( SR_Y )</td>
<td>0.15</td>
<td>0.16 (11.46)</td>
<td>0.15 (3.71)</td>
<td>0.14 (-3.57)</td>
</tr>
<tr>
<td>( SR_D )</td>
<td>0.22</td>
<td>0.22 (2.93)</td>
<td>0.22 (0.47)</td>
<td>0.21 (-1.05)</td>
</tr>
<tr>
<td>( SR_D ) no ( \bar{\varphi} )</td>
<td>0.16</td>
<td>0.17 (10.09)</td>
<td>0.16 (2.66)</td>
<td>0.15 (-3.67)</td>
</tr>
</tbody>
</table>
Table 7: Summary Statistics for Industry Expected Returns.
The baseline parameter values are presented in Table 1, except for $\beta = 1.0063$ and $\gamma = 0.79$. The industry price rigidity parameters are $\alpha_{p,H} = 0.8$ and $\alpha_{p,L} = 0$. “Baseline” indicates an economy with both price and wage rigidities. Excess returns are $XR_{b,t} = R_{b,t+1} - R_{f,t}$. Returns are measured in per cent per quarter.

<table>
<thead>
<tr>
<th></th>
<th>$\theta_p &gt; \eta = 2$</th>
<th>$\theta_p = \eta = 6$</th>
<th>$\theta_p &lt; \eta = 20$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E[XR_{Y,t+1}]$</td>
<td>0.123</td>
<td>0.123</td>
<td>0.123</td>
</tr>
<tr>
<td>$E[XR_{Y,H,t+1}]$</td>
<td>0.122</td>
<td>0.115</td>
<td>0.093</td>
</tr>
<tr>
<td>$E[XR_{Y,L,t+1}]$</td>
<td>0.125</td>
<td>0.131</td>
<td>0.153</td>
</tr>
<tr>
<td>$E[XR_{D,t+1}]$</td>
<td>0.271</td>
<td>0.271</td>
<td>0.271</td>
</tr>
<tr>
<td>$E[XR_{D,H,t+1}]$</td>
<td>0.371</td>
<td>0.272</td>
<td>-0.072</td>
</tr>
<tr>
<td>$E[XR_{D,L,t+1}]$</td>
<td>0.171</td>
<td>0.270</td>
<td>0.622</td>
</tr>
</tbody>
</table>