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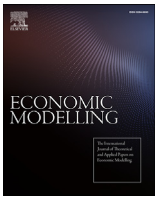

Equity premium and monetary policy in a model with limited asset market participation[☆]

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ABSTRACT

We develop a dynamic stochastic general equilibrium model to examine how monetary policy shocks affect income inequality and the equity premium. The model features Ricardian and non-Ricardian households and shows that a monetary policy tightening causes an endogenous redistribution of income from non-Ricardians to Ricardians. Ricardians' consumption comoves more strongly with asset returns, giving rise to high equity premia. We extend our model with several frictions and estimate it with generalized method of moments using US macroeconomic and financial data from 1960 to 2007. We find that the estimated model jointly matches the bond and equity premia. We complement our theoretical model with vector autoregression estimations and show that a tightening of US monetary policy increases equity premia.

1. Introduction

Following the recent financial crisis, there is a renewed interest in exploring the interactions between monetary policy and income inequality (Coibion et al., 2017; Davtyan, 2017). Traditionally, it has been assumed that the distributional effects of the monetary policy rate net out over the business cycle, and therefore, the interactions between monetary policy and inequality have rarely been examined.

However, some recent papers show that monetary policy affects income inequality (Coibion et al., 2017) through various channels, such as financial segmentation. It has also been shown that income inequality can become a monetary policy transmission channel itself through earnings heterogeneity (Auclert, 2019). This is because low-income households typically have a higher marginal propensity to consume, and therefore, these households may benefit from monetary expansion more than rich households do.

Although the literature examining the effects of monetary policy on income inequality is growing, the implications of income redistribution from a macro-finance perspective have not received sufficient attention in the literature so far. We try to bridge this gap in this paper. Specifically, our paper measures the effect of income redistribution on matching financial and macroeconomic moments jointly in a model with limited asset market participation (LAMP). Importantly, in our paper, income redistribution occurs endogenously, i.e., it is caused by monetary policy shocks. This approach extends the previous literature, which assumes exogenous redistribution shocks (see, e.g., Lansing (2015)). The current literature examining the effects of monetary policy on equity premia has focused on other issues, for example, on the role of market volatility (Mallick et al., 2017).

Our first contribution is to show that monetary policy shocks are the source of the high equity risk premia in a simple model with LAMP. Our model is populated by Ricardian and non-Ricardian households. The former have access to bonds to smooth their consumption ('optimizers'), while the latter do not. This unequal access implies that a limited share of the population participates in financial markets. Non-Ricardians receive only labor income, while Ricardians hold equity

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shares in firms. Ricardians are the sole recipients of dividend income, which we show is a key channel of income redistribution in the case of monetary policy shocks. When the share of non-Ricardians is sufficiently high, redistribution of income from non-Ricardians to Ricardians is significant, and the comovement between Ricardians' consumption and the return on equity is high, giving rise to a large equity risk premium. The equity risk premium is defined as the covariance between Ricardians' consumption and the return on the equity.

To illustrate how redistribution occurs in our baseline model, we consider a contractionary monetary policy shock that elevates nominal and real interest rates through the Taylor rule. Higher rates lead Ricardians to delay their consumption expenditures. Lower consumption demand is associated with a decrease in labor demand and production by firms with rigid prices, as they cannot respond to a decrease in demand by reducing prices.[1] A decline in wages puts downward pressure on non-Ricardians' consumption but creates higher profits (dividends) and yields on the assets held by Ricardians. Hence, there is a redistribution of income from non-Ricardians to Ricardians. The higher the share of non-Ricardians, the stronger is the dividend channel and therefore the comovement between Ricardian consumption and asset returns. As a result, this comovement gives rise to sizable equity premia and a high standard deviation of the return on equity.

Our paper is the first to derive a closed-form solution for equity premia on the basis of monetary policy shocks in a model with LAMP.[2] The closed-form solution helps decompose the equity premium into two main components: the price of risk and the quantity of risk. We show that it is the price of risk (a model-specific component) that is driving the equity premium and not the quantity of risk (the variance of the monetary policy shock). Moreover, our closed-form solution makes it possible to determine how the model's deep parameters affect the price of risk. We also provide empirical evidence for this channel in the form of a simple vector autoregression (VAR) model where monetary policy shocks are identified recursively.

The model we use has two additional desirable properties. First, the equity premium is high, with a risk-aversion coefficient equal to one.[3] Second, the persistence of the monetary policy shock is not counterfactually high, which allows us to arrive at a large equity premium. This is in contrast with de Paoli et al. (2010) and Wei (2009), who use a rigid price model with a representative household and real frictions (habits in consumption and capital adjustment costs). In our paper, the persistence of the monetary policy shock is in line with empirical estimates of approximately 0.8 (see Carrillo et al. (2007) and Rudebusch (2006)). Even with a persistence of zero (which is widely assumed in the earlier monetary business cycle literature), the equity premium in our model is higher than that in the representative agent model.

Our second contribution is the estimation of an extended version of our baseline model by the generalized method of moments (GMM) on US macroeconomic and financial data for the period 1960–2007. In particular, we use the GMM to match the mean, variability and first- and fifth-order autocorrelations of seven time series. Our extended model contains various additional frictions, such as habits in consumption, Epstein-Zin preferences and more realistic fiscal setups. This extension helps capture the bond and equity premium puzzles jointly. Beyond matching the equity premium and a set of macroeconomic moments, this setup allows the model to match the bond premium. Within the extended model, we consider two types of fiscal setups: one where the debt is constant (a simplified fiscal setup) and another with time-varying debt (an empirically more realistic setup). In both fiscal setups, the debt is retired by taxes on labor.

In line with previous literature, we find that in the extended setup, technology shocks are also necessary for the high equity premium. Since Jermann (1998) we know that consumption habits induce excess volatility of the risk-free rate due to the aversion of Ricardian households to short-run fluctuations in the consumption stream (the so-called risk-free rate puzzle). LAMP helps resolve the risk-free rate puzzle, as it generates a higher precautionary savings effect. This effect reduces the level as well as the volatility of the risk-free rate so that the equity premium is easier to match.

The recent literature tries to jointly match the equity and bond premium puzzles (see, e.g., Menna and Tirelli (2014)). To do so in this case, our extended model also features Epstein-Zin preferences that facilitate matching of the bond premium in the yield of long-term nominal government bonds. Epstein-Zin preferences make Ricardian households concerned about not only short- but also long-run risks, and hence, the risk premium in long-maturity bonds can be easily matched. In the model, the bond-risk premium is mainly a compensation for inflation risks due to technology shocks that engineer positive comovement between consumption and real bond yields, making long-term bonds a poor hedge.

The idea that limited participation can help explain equity premia is not new. In a chapter of the Handbook of the Equity Risk Premium, Donaldson and Mehra (2008) provide a complete section on models with market incompleteness. We make two important departures from earlier models in the literature. First, as we explained above, the equity premium in our model is driven by monetary policy shocks and not technology shocks. Second, the earlier models described in Donaldson and Mehra (2008) are endowment economies in which the consumption and dividend streams are exogenously given, and the economies feature a fixed labor supply.[4] In our paper, we depart from the unrealistic assumptions of the endowment economy and fixed labor supply. Instead, we consider a production economy and variable labor supply, which make it more challenging to match the equity premium. With a variable labor supply, agents can easily insure themselves against negative shocks by working more to avoid a decrease in consumption. Our model considers a production economy with a variable labor supply, which acts as insurance against bad shocks. As a result, fluctuations in consumption are less influenced by dividends and asset returns.[5]

We do not claim that monetary policy shocks are the most important for business cycles. To account for business cycles, we need several additional highly persistent shocks (e.g., technology shocks as well as price and wage markup shocks), as is commonly seen in the monetary business cycle literature (see, e.g., Smets and Wouters (2007)). In our baseline model, we only focus on monetary policy shocks to clearly illustrate the mechanism that helps generate a high and volatile equity premium. The autocorrelation of our monetary policy shock is in line with the estimates of Carrillo et al. (2007) and Rudebusch (2006). As we show, the autocorrelation is important for reconciling the high equity premia (in line with the findings of Wei (2009)).

Lansing (2015) shows that exogenous income redistribution shocks are among the key drivers of high premia on unlevered equity. He uses a model with heterogeneous agents (stockholders and nonstockhold-

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[1] In our model, price rigidity is necessary for monetary policy shocks to drive the equity premium.

[2] We use the loglinear asset-pricing framework of Campbell and Shiller (1988) to provide a closed-form solution for the level of the equity premium.

[3] See Cochrane (2000), who explains that the equity premium can be raised easily with higher risk aversion at the cost of higher volatility of the risk-free rate.

[4] There are some exceptions, however, such as Danthine et al. (2008), who consider a production economy. It may be reasonable to assume that the labor supply is fixed. This is so if we consider the micro evidence on the labor supply elasticity (close to zero) for working-age males, which facilitates high equity premia (Lansing, 2015).

[5] Note that our paper considers a model with a production economy and predicts that the equity premium increases with the degree of limited asset market participation. This is in contrast to papers that consider endowment economies (see Polkovnichenko (2004) and Walentin (2010)) and predict exactly the opposite. In our paper, labor income is endogenous and is influenced by monetary policy. In endowment economies, income is simply the realization of a stochastic shock.

ers) and a fixed labor supply. Our model is different from Lansing's in at least four important dimensions: i) we employ a two-agent New Keynesian (TANK) model and not an RBC-type concentrated ownership model; ii) the redistribution of income in our model happens endogenously due to the TANK structure and not because of redistribution shocks; iii) monetary policy shocks (and not 'redistribution shocks') cause redistribution from non-Ricardian to Ricardian households; and finally, iv) our model features an elastic labor supply, in contrast to Lansing (2015) model, where the labor is fixed.

Our paper is also related to Motta and Tirelli (2014), who examine the redistributive effects of monetary policy shocks in a model with Ricardians and non-Ricardians. However, their paper does not examine the model's asset-pricing implications. Our paper aligns with Menna and Tirelli (2014), who employ a limited asset market participation framework similar to our framework. However, they focus on the different frictions, such as consumption habits, capital adjustment costs and wage rigidities, to explain the equity premium. In their model, the equity premium is driven by permanent technology shocks, whereas in this paper, it is a compensation for monetary policy shocks.

Finally, we note that the model used in this paper is a simplified version of the newly popular HANK (heterogeneous agent New Keynesian) models (see Kaplan et al. (2018)). Indeed, Bilbiie (2020) and Debortoli and Gali (2017) argue that our simplified two-agent New Keynesian (TANK) model captures most features of the computationally intensive HANK models sufficiently well.

The remainder of the paper is organized as follows. Section 2 offers empirical evidence in support of rising equity premiums in response to contractionary monetary policy shocks. Section 3 describes the model and the derivation of the equity premium formula. Section 4 presents the parameterization of our model. Section 5 describes the performance of our model relative to the representative agent model. Section 6 describes the robustness checks. Sections 7 and 8 provide the GMM estimation of our extended model. Finally, we conclude. An online appendix with model derivations and additional results follows.

2. Empirical evidence

In this section, we provide empirical evidence to motivate our theoretical model. In particular, we are interested in how the equity premium responds to a monetary contraction (i.e., an increase in the short-term interest rate) using actual data. We estimate a VAR model with quarterly US data on five variables (unemployment, growth rate of money supply, inflation rate, equity premium, and short-term nominal interest rate) plus a constant for 1960Q1-2007Q1.[6] We use one lag (based on the Hannan-Quinn information criterion) in the estimation.

The monetary policy shock is identified in a standard recursive way. The variables are ordered, as stated above, beginning with the unemployment rate and ending with the interest rate.[7] Intuitively, our recursive identification scheme implies that the error terms in each regression (for each row of the matrix) are uncorrelated with the error term in the preceding equations. For the first row, unemployment is the dependent variable, and the regressors are the lagged values of each variable. For the second row, money is the dependent variable, and the regressors are the contemporaneous values of unemployment plus the lag of each endogenous variable, etc. Stock and Watson (2001) argue that the estimation of each equation by ordinary least squares produces residuals that are uncorrelated across equations.

Fig. 1 presents the impulse response of each variable in the VAR to a contractionary monetary policy shock (an increase in the nominal interest rate). We make the following observations. First, the equity premium increases following a monetary tightening. The maximum effect occurs approximately one to two quarters after the shock. Second, unemployment increases after a monetary contraction, with the strongest effect materializing after approximately two years. This result is in line with the typical findings regarding the speed of monetary policy transmission to economic activity. Third, we find that money growth is negatively associated with interest rates and bottoms out in less than eight quarters. Fourth, we fail to find that inflation responds significantly to monetary shocks. Further, we find that the rise in the equity premium in response to more restrictive monetary policy is robust to the use of a shorter sample (1980Q1-2007Q1) and more lags (two) in the VAR as well as the inclusion of a linear trend in the regression (these results are available upon request).

3. Model

3.1. Households

A share of the households λ have no access to the financial market (see, e.g., Bilbiie (2008)). These households cannot smooth their consumption intertemporally through risk-free bonds and shares in equity. Therefore, their consumption completely depends on their disposable income in each period. These households are called non-Ricardians (r).

The remaining share of households $1 - \lambda$ are Ricardians (optimizers, o) and engage in the intertemporal trade of assets to smooth fluctuations in income.

Each household, either Ricardian or non-Ricardian (denoted $i = o, r$), features a utility function that distinguishes between consumption (C_t^i) and leisure ($1 - N_t^i$):

$$U = \frac{(C_t^i)^{1-\sigma}}{1-\sigma} - \frac{(N_t^i)^{1+\phi}}{1+\phi}. \tag{1}$$

σ is the inverse of the elasticity of intertemporal substitution, and ϕ is the inverse of the Frisch labor supply elasticity.

The consumption of the two types of households can be aggregated through

$$C_t = \lambda C_t^r + (1-\lambda) C_t^o.$$

The consumption index (C_t) is obtained via the standard Dixit-Stiglitz aggregator, which sums a continuum of goods on the unit interval $[0, 1]$, with $\epsilon > 0$ as the elasticity of substitution among goods.

The intertemporal budget constraint of optimizers is given by

$$\begin{aligned} & P_t C_t^o + R_t^{-1}\{B_{t+1}^o\} + V_t^{eq} S_t^o \\ & = (V_t^{eq} + P_t D_t^o) S_{t-1}^o + W_t N_t^o + B_t^o - P_t T_t^o - P_t ST^o, \end{aligned} \tag{2}$$

where P_t is the price level, B^o denotes the amount of nominal riskless government bonds held by Ricardian households, R_t is the gross nominal interest rate on one-period bonds, and W_t is the nominal wage. S_t^o is the number of firm shares owned by optimizers. V_t^{eq} and $P_t D_t^o$ denote the nominal value of shares and dividends received by Ricardians, respectively. T_t^o represents lump-sum taxes paid by optimizers, and ST^o is a steady-state lump-sum tax used to equate the steady-state

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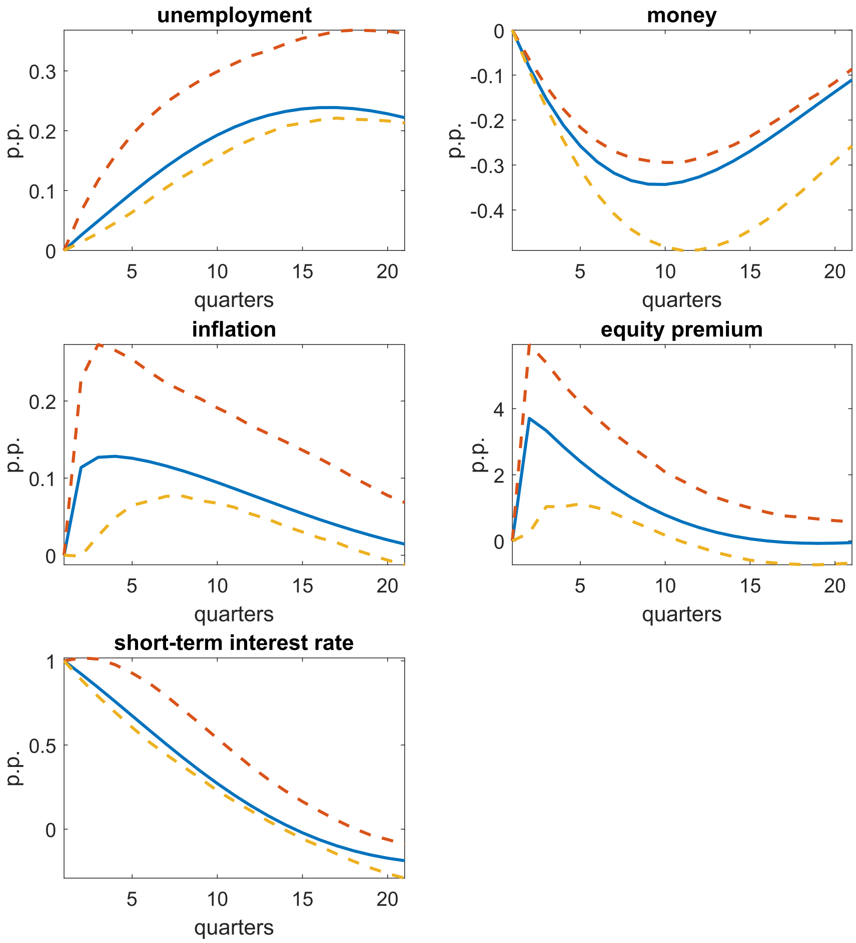
[6] The unemployment rate, inflation rate and short-term nominal interest rate are the variables used by Stock and Watson (2001) to measure the effects of monetary policy shocks. In this paper, two more variables are added to the VAR: the equity premium and the growth rate of the money supply. The inflation rate is the annualized percent change in the CPI, i.e., $\pi = 400\log(P_t/P_{t-1})$. The short-term nominal rate is the annualized value of the US federal funds rate, so it is multiplied by four hundred. The equity premium is based on the S&P 500 and obtained from the online stock price dataset of Shiller (2017). The money supply is the log of the growth rate of the money aggregate M2 multiplied by one hundred. The unemployment rate for individuals aged 15–64 years for all persons in the United States is multiplied by one hundred. For more details on the data, see the data description in the online appendix.

[7] Consider a structural vector autoregression (SVAR) of the form.

$$B_0 x_t = B_1 x_{t-1} + B_2 x_{t-2} + \cdots + B_p x_{t-p} + \epsilon_t,$$



Notes: Recursively identified VAR model (with a constant in the regressions), 1960:Q1-2007:Q1, 68th percentile bootstrapped confidence intervals (1000 replications) following Hall (1992). Time is in quarters. 1 p.p. shock in the interest rate. The interest rate, inflation rate and equity premium are all annualized.

Fig. 1. The effects of a contractionary monetary policy shock in the US Notes: Recursively identified VAR model (with a constant in the regressions), 1960:Q1-2007:Q1, 68th percentile bootstrapped confidence intervals (1000 replications) following Hall (1992). Time is in quarters. 1 p.p. shock in the interest rate. The interest rate, inflation rate and equity premium are all annualized.

consumption of both types of households ($C = C^o = C^r$).[8] All profits are paid out in the form of dividends, which are received by the optimizer and given by

$$P_t D_t^o = \frac{P_t D_t}{1-\lambda} = \frac{P_t Y_t - W_t N_t}{1-\lambda},$$

where D_t is the aggregate level of real dividends and D_t^o represents real dividends received by Ricardian households.

Non-Ricardians also maximize their utility in equation (1) subject to the budget constraint:

$$P_t C_t^r = W_t N_t^r + P_t ST^r,$$

where ST^r is a transfer to rule-of-thumb households that helps to equalise steady-state consumption of the two types of households.

There is a competitive labor market, as in Bilbiie (2008). The Ricardian and non-Ricardian labor supplies are aggregated through the following equation:

$$N_t = \lambda N_t^r + (1-\lambda) N_t^o,$$

where N_t denotes the aggregate labor supply. We do not include government consumption and investment to keep the model simple.

3.2. Firms

Output is produced using a one-to-one production function (abstracting from technology shocks):

$$Y_t(i) = N_t(i).$$

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[8] Note that this approach differs from Bilbiie (2008), who uses a fixed cost of production to eliminate steady-state dividends and equalise the steady-state consumption of the two types of households.

Intermediaries are subject to Calvo-style price-setting frictions.[9] The profit maximization problem of an intermediary firm i at time t, which will not be able to reset its price between time t and time $t + k$, can be formulated as

$$\max_{P_t^*} \sum_{k=0}^{\infty} \theta^k Q_{t,t+k} \left[P_t^*(i) Y_{t+k|t}(i) - W_{t+k} N_{t+k}(i) \right], \tag{3}$$

where P_t^* is the optimal reset price at time $- t$, θ is the probability of not resetting the price, and $Q_{t,t+k}$ is the stochastic discount factor, defined as

$$Q_{t,t+k} \equiv \beta^k \left(\frac{C^o_{t+k+1}}{C^o_{t+k}} \right)^{-\sigma} \frac{P_t}{P_{t+k}}.$$

The profit maximization problem of the intermediary is also subject to the demand schedule for an individual product i:

$$Y_{t+k|t}(i) = \left(\frac{P_t^*(i)}{P_{t+k}} \right)^{-\epsilon} Y_{t+k|t}.$$

3.3. Monetary policy

Monetary policy is described by a simple Taylor rule of the following form:

$$R_t = \beta^{-1} \Pi_t^{\varphi_\pi} exp(\xi_t).$$

$\Pi_t = P_t/P_{t-1}$ represents gross inflation, φ_π measures the strength of the reaction of monetary policy to inflation, β^{-1} is the gross interest rate in the steady state, exp is the exponential function and ξ_t is a monetary policy shock:

$$\xi_t = \rho_\xi \xi_{t-1} + \sigma_\xi \epsilon_t^\xi,$$

where ρ_ξ represents the persistence of the process ξ and σ_ξ denotes the standard deviation of the i.i.d. shock ϵ_t^ξ, which has a zero mean.

3.4. Solution of the model

A summary of the linearized equilibrium conditions is available in online Appendix A. The linear solution for output and inflation, as a function of the monetary policy shock, is provided in Proposition 1. Proposition 2 explains the determinacy of the model. Propositions 3 and 4 describe the linear formulation for the price-dividend ratio and the equity premium, respectively.

Proposition 1. *In the absence of state variables, the model has a closed-form solution for output and inflation, which is a function of the monetary policy shock:*

$$y_t = A_y \xi_t, \quad \pi_t = A_\pi \xi_t,$$

where $y_t \equiv (Y_t - Y)/Y$ and $\pi_t \equiv (\Pi_t - \Pi)/\Pi$ denote linearized output and inflation, respectively; the absence of the time index indicates the steady state. The coefficients A_y and A_π are defined as

$$A_y \equiv -\frac{(1-\lambda)(1-\beta\rho_\xi)}{\Gamma(1-\beta\rho_\xi)\sigma - \Gamma\rho_\xi(1-\beta\rho_\xi)\sigma + (1-\lambda)(\varphi_\pi - \rho_\xi)\kappa(\sigma+\phi)},$$

$$A_\pi \equiv \frac{\kappa(\sigma+\phi)A_y}{1-\beta\rho_\xi}, \Gamma \equiv 1 - \lambda(1+\phi), \kappa \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta(1+\epsilon\phi)}.$$

For the Proof, *see online* .Appendix A.

In line with conventional wisdom, a restrictive monetary shock ($\xi_t > 0$) decreases output and inflation, i.e., $A_y < 0$ and $A_\pi < 0$, provided that the share of non-Ricardians does not exceed a threshold value (see online Appendix A), and the Taylor principle is satisfied ($\varphi_\pi > 1$).

3.5. Determinacy properties of the model

To study the determinacy properties of the model (the next proposition), we generate the IS curve. To do so, we first recall the linear bond Euler equation of the Ricardians

$$c_t^o - E_t c_{t+1}^o = -(dR_t - E_t \pi_{t+1}).$$

The previous equation and the connection between Ricardian consumption and aggregate output are combined as $c_t^o = A_c y_t$ (for the derivation of this equation, see online Appendix B):

$$y_t = E_t y_{t+1} - \Gamma^{IS}(dR_t - \pi_{t+1}), \text{where} \Gamma^{IS} \equiv \frac{1}{A_c} = \frac{1-\lambda}{1-\lambda(1+\phi)}.$$

dR_t is defined as $R_t - R$, and we restrict the analysis to the case of $\phi > 0$.[10]

Note that $\partial\Gamma^{IS}/\partial\lambda > 0$ as long as $(1-\lambda)/\lambda > \phi$. Therefore, the IS equation above lends support to the claim (see the results section of this paper) that a larger share of non-Ricardians leads to more effective monetary policy due to the higher sensitivity of aggregate demand to the real interest rate, i.e., Γ^{IS} increases in λ.

Proposition 2. *When $\lambda \leq 0.39$ and/or the labor supply is sufficiently elastic (ϕ is low), the Taylor principle ($\varphi_\pi > 1$) leads to determinacy of the model with baseline parametrization, and the slope of the IS curve Γ^{IS} is negative.*

When $\lambda > 0.39$, the slope of the IS curve is positive and passive monetary policy ($\varphi_\pi < 1$) guarantees determinacy. For the Proof, *see* Bilbiie (2008), *who employs a similar model.*

For the remainder of the paper, we abstract from cases wherein $\lambda > 0.39$, and this region can be described by the 'inverted aggregate demand logic' (IADL), where $\varphi_\pi < 1$ yields determinacy (for further information, see Bilbiie (2008)).

3.6. Pricing the market portfolio

We use the loglinear asset pricing framework of Campbell and Shiller (1988) to price the market portfolio of equally weighted shares and to derive a closed-form solution for the equity premium. A similar strategy is also followed by Wei (2009).

Proposition 3. *The return on the market portfolio of equally weighted shares can be written as as*

$$rr_{t+1} = \kappa_0 + \kappa_1 z_{t+1} - z_t + \Delta d_{i,t+1}, \tag{4}$$

where z_t denotes the price-dividend ratio, Δd_{t+1} is the growth rate of real dividends, and κ_0 and κ_1 are constants. Campbell and Shiller (1988) *show that $\kappa_1 \simeq 1$. z_t is a function of the state variable, which is the monetary policy shock ξ_t:*

$$z_t = A_{z0} + A_{z1}\xi_t, \tag{5}$$

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[9] As in Woodford (2003, chapter 3), we assume that there is strategic complementarity in price setting in the form of a specific labor market, which leads to a reduction in the slope of the New Keynesian Phillips Curve and thus causes shocks to have larger real effects (rather than changes in relative prices).

[10] At this point, we make two observations. First, the slope of the IS curve is almost the same as that of Bilbiie (2008). The only difference comes from the fact that Bilbiie eliminates steady-state dividends through a fixed cost in production, which adds another multiplicative term to the slope in his paper. Second, we must abstract from the case of infinitely elastic labor supply ('indivisible labor'), $\phi = 0$, because this makes the wealth heterogeneity across households irrelevant and the slope of the IS curve becomes independent of the share of the non-Ricardian households.

where A_{z0} is a constant that can be ignored and

$$A_{z1} \equiv \frac{A_c A_y (1-\rho_\xi)}{1-\beta\rho_\xi} - \frac{(1-\rho_\xi) A_y \kappa_{d\xi}}{1-\beta\rho_\xi},$$

where

$$A_c \equiv \frac{1-\lambda(1+\phi)}{1-\lambda}.$$

Real dividend growth is given by

$$\Delta d_{t+1} = \kappa_{d\xi} A_y \Delta\xi_{t+1}, \tag{6}$$

where $\kappa_{d\xi} \equiv 1 - \frac{W(1+\phi)}{1-W}$ *and* $W = \frac{\epsilon-1}{\epsilon}$. *For the* Proof, *see online* Appendix B.

Proposition 3 states that there is a linear relationship between the expected dividend growth and the difference between the expected and current monetary policy shocks.

Proposition 4. *The equity premium is calculated as* $-\,cov_t(sdf_{t,t+1}, rr_{i,t+1})$, *where* $sdf_{t,t+1} \equiv -A_c A_y(\xi_{t+1} - \xi_t)$ *is the linearized stochastic discount factor. The equity premium is given by* $ep_t = A_c A_y\{\kappa_1 A_{z1} + k_{d\xi} A_y\}\sigma_\xi^2$.

Proof. To derive a closed-form solution for the equity risk premium, we first decompose the covariance term into the price of risk and the amount of risk:

$$\begin{aligned} ep_t &= A_c A_y cov_t(\xi_{t+1}, rr_{t+1}) \\ &= \underbrace{A_c A_y\{\kappa_1 A_{z1} + k_{d\xi} A_y\}}_{\text{priceofrisk}} \times \underbrace{\sigma_\xi^2}_{\text{quantityofrisk}}. \end{aligned}$$

For the Proof, see online Appendix B.

■

3.7. Discussion of the equity premium formula

In line with Hordahl et al. (2008) and Sangiorgi and Santoro (2005), we decompose the equity premium into two parts. The first part measures the market price of risk. The second part represents the amount of risk, which is the covariance between the return on the asset and the innovation of the shock. As Hordahl et al. (2008) argue, the market price of risk is of particular interest because it is independent of the special characteristics of the asset being priced (a premium for a given amount of risk). The second term measures the nondiversifiable riskiness of an asset.

Both the price and the amount of risk increase (in absolute value) with more limited asset market participation (higher λ). It is useful to observe the individual determinants of the price of risk. $\kappa_1 A_{z1}$ captures the negative effect ($A_{z1} < 0$) of the monetary policy shock on the price-dividend ratio (z_t). Dividends alone have a direct positive effect on the amount of risk ($k_{d\xi} A_y > 0$).

For our calibration, the negative sign on the price-dividend ratio dominates the positive sign on dividends; therefore, we have $(\kappa_1 A_{z1} + k_{d\xi} A_y) < 0$, which is consistent with Sangiorgi and Santoro (2005), who use a representative agent model. When participation is sufficiently restricted, the absolute value of the price of risk and the amount of risk can be much higher in the limited participation model than in the representative agent model.

4. Parametrization

We present the parameter values in Table 1. The inverse of the intertemporal elasticity of substitution (σ) implies that the utility in consumption has a logarithmic form. The parameter ϕ is set to 1.5, which implies that the Frisch elasticity of the labor supply is 2/3. When technology is set to unity in the steady state ($A = 1$), the steady-state equality of consumption for each type implies that the same hours are worked by both types ($N^o = N^r = N$) in this state.

Table 1
Parametrization.

$\sigma = 1$	$\beta = 0.99$	$\varphi_\pi = 1.1$
$\epsilon = 11$	$\phi = 1.5$	$\rho_\xi = 0.75$
$\theta = 0.80$	$\lambda = 0.39$	$\sigma_\xi = 0.005$

The elasticity of substitution among intermediary goods (ϵ) is set to 11, implying a net markup ($1/(\epsilon - 1)$) of 10 percent, which is standard in the literature. The Calvo parameter of price adjustment is 0.80, which implies an average duration of a price spell of 5 quarters. This is a value similar to the value chosen by Christiano et al. (2011). For simplicity, we consider a Taylor rule that focuses only on inflation with a coefficient of 1.1, which satisfies the Taylor principle. The share of non-Ricardian households is set to 0.39, which is at the lower end of the estimates.[11] The persistence and standard deviation of the monetary policy shock are set to 0.75 and 0.005, respectively, in line with Carrillo et al. (2007) and Rudebusch (2006).

5. Results

5.1. Representative agent model

To better clarify the functioning of the limited participation model, we first explain the effects of an unanticipated increase in the nominal interest rate due to a monetary policy shock in the representative agent model ($\lambda = 0$). According to the Taylor principle, a contractionary monetary policy shock leads to a higher real interest rate, which causes Ricardian households to delay their consumption from the present to the future. The negative wealth effect of the monetary policy shock also causes a decline in leisure time (normal good) and induces Ricardians to work more within a fixed time frame. Hence, the labor supply shifts out, depressing the real wage.

As many of the firms face price rigidity, not all of them can reduce prices when demand falls. As a result, those firms that cannot reset their prices will decrease production and demand less labor, shifting labor demand leftward and further depressing real wages. Price rigidity is therefore necessary for monetary policy shocks to have real effects.

With our baseline calibration, the standard representative agent model delivers an equity premium of approximately 0.3 percent. This finding is consistent with the literature (see de Paoli et al. (2010) and Wei (2009)). Unless the model is enriched with capital, Jermann (1998)-type capital adjustment costs and a counterfactually high persistence of the monetary policy shock, the equity premium remains small. Because of the mildly persistent monetary policy shock (our baseline calibration), the equity premium is closer to one than zero.

5.2. Limited participation model

We now divide the population into Ricardian and non-Ricardian households ($\lambda > 0$). Fig. 2 displays the sensitivity of output, inflation, dividends and the equity premium to the share of non-Ricardian households. In each graph, $\lambda = 0$ delivers the standard representative agent model (only Ricardian households), where the equity premium is approximately 1 percent (see the bottom-right panel, *ep*). The sensitivity of output, inflation and the growth rate of dividends to a monetary policy shock (see the subplots denoted as A_y, A_π and $\kappa_{d\xi} A_y$, respectively)

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[11] Gali et al. (2007) and De Graeve et al. (2010) employ 0.5 and 0.6 for λ, respectively. Campbell and Mankiw (1991) use 35 percent, while Fuhrer (2000) employs the estimate in the range of 26–29 percent depending on the econometric method used.

increases with the share of non-Ricardian households in the population. This can be explained as follows. Consider a contractionary monetary policy shock that leads to a rise in real interest rates and curbs Ricardian expenditures. With rigid prices, the monetary tightening also leads to decreases in labor demand, marginal costs (real wages) and thus the wage income of non-Ricardians. However, at the same time, it leads to increases in profits, endogenously redistributing income from non-Ricardians to Ricardians.[12] The latter channel exists due to the price rigidity effect establishing the link between non-Ricardians' demand (based on their wage income) and real interest rates.

With a higher share of non-Ricardians, monetary policy is more successful at curtailing aggregate demand through increases in the real interest rate. With a stronger redistribution of income from non-Ricardians to Ricardians, the ownership of firms is more concentrated. This concentration decreases the consumption of Ricardians, whose consumption is susceptible to changes in dividend income.[13] In addition, asset returns positively comove with the growth rate of dividends. As a result, a positive connection emerges between the share of non-Ricardians and the equity premium.

Specifically, a restrictive monetary shock today ($\xi_t > 0$) leads to a decline in the price-dividend ratio (z_t) (in equation (5)), which increases the next-period returns (r_{t+1}) (see equation (4)) as long as $A_{z1} < 0$, which is satisfied in our baseline calibration. With a sufficiently high share of non-Ricardians ($\lambda = 0.39$), we obtain a large equity premium ($ep = 7.0089$ percent) and a high standard deviation of equity returns (30.81 percent). These values are reasonably close to the 6.33 and 19.42 (in annualized terms), respectively, reported by Bansal and Yaron (2004) for the market portfolio using postwar US data. Our model is also successful in reproducing the empirical value of the Sharpe ratio (the ratio of the mean of the equity premium and the standard deviation of the equity return), which is approximately 0.2–0.3 in the postwar US data and 0.32 in our model.

A shortcoming of our model is that it produces the risk-free rate puzzle. When the share of non-Ricardians is sufficiently high, the volatility of both the consumption of Ricardians and the stochastic discount factor exhibits three times more volatility in the risk-free rate in our model than its empirical equivalent. An extension of our model with further frictions, such as wage rigidity, capital accumulation with adjustment costs and technology shocks, could also solve the risk-free rate puzzle. In this paper, however, we include the smallest number of frictions to clearly illustrate the mechanisms leading to the redistribution of income between the two types of households and to the high equity premium.

6. Sensitivity analysis

We present the results of our sensitivity analysis in Fig. 3. In particular, we investigate the sensitivity of our main result to the lower Frisch elasticity, the lower average duration of price rigidity and a larger coefficient on inflation in the Taylor rule.

The inverse of the Frisch elasticity (ϕ). When the labor supply is less elastic (i.e., when Frisch elasticity is lower, ϕ increases from 1.5 to 2), we expect lower flexibility of labor in the case of negative shocks. We also expect that the equity premium is larger. When setting $\phi = 2$, the equity premium is higher by more than 1 percentage point, but the determinacy region shrinks. In this case, the equity premium is the highest at $\lambda = 0.32$, and the highest value of λ for which the equilibrium is determinate is 0.33.

Calvo parameter of price rigidity (θ). With greater price rigidity, we expect stronger monetary policy shocks. In this scenario, we consider a lower average duration of price rigidity than in the baseline calibration (4 quarters instead of the 5 quarters assumed in the baseline). With lower price rigidity, the equity premium declines to 3.30 percent, which is nevertheless more than three times larger than that in the representative agent model.

Coefficient of inflation in the Taylor rule (φ_π). With a higher coefficient on inflation in the Taylor rule, we expect the effects of the monetary policy shock to be more contained and thus equity premium to be substantially reduced. The figure shows the effects of increasing φ_π from 1.1 to 1.5. The equity premium is halved with an increase in φ_π. When $\varphi_\pi \rightarrow \infty$, the monetary policy shock is completely neutralized (no relative price distortions), and we return to the case of fully flexible prices in which monetary policy has no effect. Therefore, the equity premium is zero in such an economy.

Persistence of the monetary policy shock (ρ_ξ). When the persistence of the monetary policy shock is higher, we expect the real effects of the shock to be stronger and the equity premium to be larger. This expectation is confirmed by Fig. 3, which shows that the equity premium can be counterfactually high when the monetary policy shock is very persistent. The figure also tells us that some moderate level of persistence is necessary for the equity premium to be in the empirically relevant range.

7. GMM estimation of the extended model

We extend our baseline model with the physical capital of Jermann (1998)-type capital adjustment costs, habits in consumption, Epstein-Zin preferences, and a more realistic fiscal setup[14] and estimate our extended model with the GMM toolbox of Andreasen et al. (2018) using the following quarterly US macroeconomic and financial time series in 1960Q1-2007Q1: i) per capita consumption growth, dC_t; (d denotes the temporal difference operator); ii) one-quarter nominal interest rate, i_t; iii) per capita hours growth, dL_t; iv) growth rate of real wage $d(W_t/P_t)$; v) inflation, Π_t; vi) slope of the term structure proxied by the difference between the 10-year nominal interest rate, $i_t^{(40)}$, and the one-quarter nominal interest rate, i_t; vii) 10-year nominal term premium from Adrian et al. (2013); viii) growth rate of labor tax revenue per GDP ($d(\tau_t W_t L_t / Y_t)$); and ix) leveraged excess return on US stocks. The online appendix provides more information about the data used in the estimation and describes the extended model, including its derivation.

As in Andreasen et al. (2018) and Bretscher et al. (2020), we focus on three types of unconditional moments for the GMM estimation: i) the sample means $m_1(y_t) = y_t$, the contemporaneous covariances $m_2(y_t) = vech(y_t y_t')$, and the own autocovariances, $m_3(y_t) = \{y_{i,t} y_{i,t-k}\}_{i=1}^{n_y}$ for $k = 1$ and $k = 5$. As a result, the set of moments we use in the estimation is given by $m(y_t) = [m_1(y_t) m_2(y_t) m_3(y_t)]'$.

Letting θ denote the structural parameters, the GMM estimator is given by:

$$\arg\min_{\theta \in \Theta} \left(\frac{1}{T} \sum_{t=1}^{T} q_t - E(q_t(\theta)) \right)' W \left(\frac{1}{T} \sum_{t=1}^{T} q_t - E(q_t(\theta)) \right). \tag{7}$$

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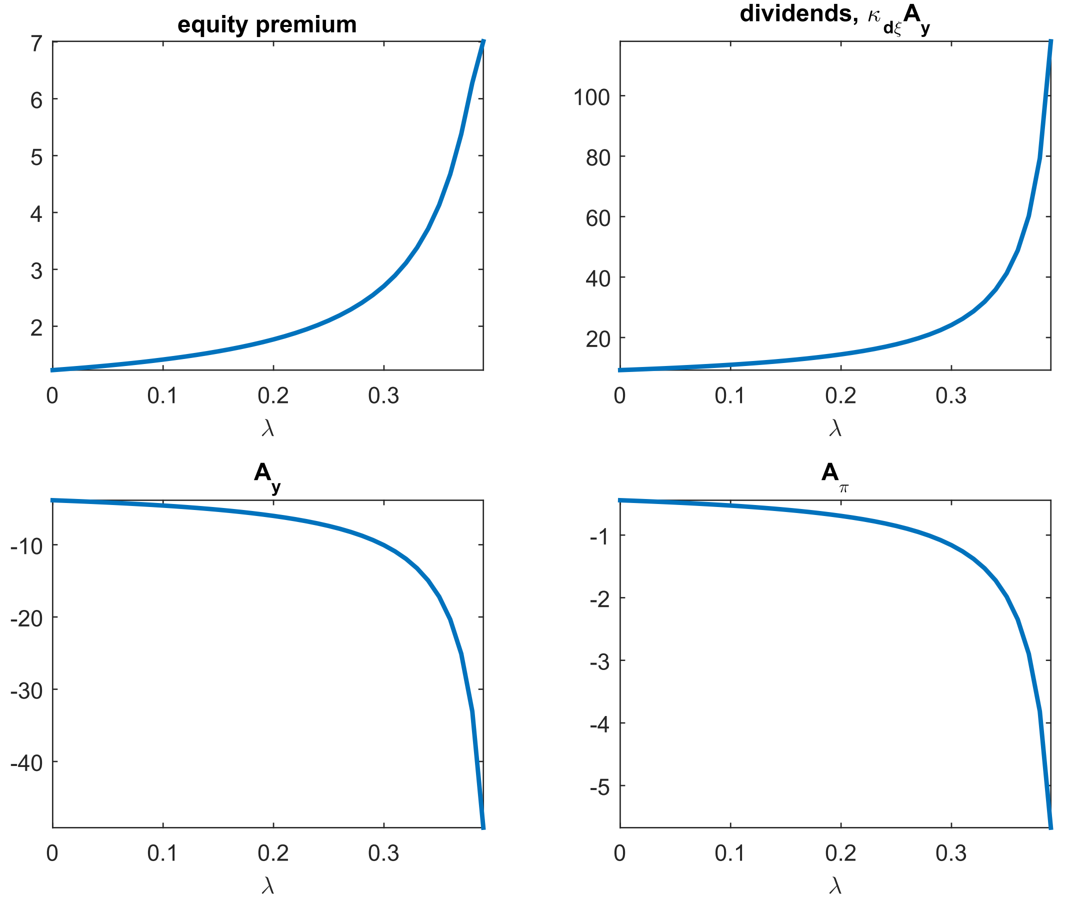
[12] Real dividends are calculated as the difference between output minus the wage bill in real terms: $D_t = Y_t - \frac{W_t}{P_t} N_t = Y_t (1 - \frac{W_t}{P_t})$, where the second equality assumes a one-to-one production function with technology normalized to one. The equation that describes the connection between the real wage ($w_t = (\sigma + \phi) y_t$ in loglinear terms) and output shows that a unit change in output will induce more than a one-unit change in the real wage as long as the inverse of the Frisch elasticity is not zero ($\phi > 0$). Even when $\phi > 0$, an intertemporal elasticity of substitution lower than one (equivalent to $\sigma > 1$) will lead to a response in the real wage that is in excess of unity. Hence, returning to the dividend equation, we can claim that the fall in wages has a larger effect on dividends than the corresponding fall in output. Overall, the total effect will be a rise in dividends following a contractionary monetary policy shock.

[13] The dividend income of Ricardians is increasing in the share of non-Ricardian households for a given level of aggregate dividends ($D_t^o = D_t/(1-\lambda)$).

[14] We assume either constant or time-varying debt.



Notes: A_π is annualized. The *ep* is measured as an annualized percentage. Values of λ higher than 0.39 are excluded, as the equilibrium is indeterminate for that region.

Fig. 2. Sensitivity of A_y, A_π, $\kappa_{d\xi}A_y$ and the equity premium (*ep*) relative to the share of non-Ricardian households (λ) Notes: A_π is annualized. The *ep* is measured as an annualized percentage. Values of λ higher than 0.39 are excluded, as the equilibrium is indeterminate for that region.

In equation (7), W is a positive definite weighting matrix, $\frac{1}{T}\sum_{t=1}^{T} q_t$ represents data moments, and $E(q_t(\theta))$ are moments computed from the model. We employ a standard two-step procedure to implement the GMM. We set $W_T = diag(\widehat{S}^{-1})$ in the first step in order to obtain $\widehat{\theta}^{(1)}$ where $\widehat{S}$ denotes the long-run variance-covariance matrix of $\frac{1}{T}\sum_{t=1}^{T} q_t$ when centered around its sample mean. In the second step, we obtain $\widehat{\theta}^{(2)}$ using the optimal weighting matrix $W_T = \widehat{S}^{-1}_{\widehat{\theta}^{(1)}}$ where the diagonal of $\widehat{S}^{-1}_{\widehat{\theta}^{(1)}}$ includes the long-run variance of our moments recentered around $E\left(q_t(\widehat{\theta}^{(1)})\right)$. The long-run variances in both steps are estimated with the Newey-West approach with five lags; our results are robust to the inclusion of, e.g., ten lags.

We present the parameters estimated by the GMM in Tables 2 and 3. The column titles with a star indicate the model version without capital adjustment costs. To summarize, we note that the majority of our parameter estimates are in line with those presented in Andreasen et al. (2018) and Bretscher et al. (2020). Similar to the findings of Andreasen et al. (2018) and Bretscher et al. (2020), the curvature parameter of recursive preferences, α^{EZ}, is estimated rather imprecisely.

Regarding the estimates of the curvature parameter, we make the two following observations. First, the models are estimated with lower relative risk-aversion coefficients, similar to the findings of Horvath et al. (2019) (see the implied CRRA in the range of 31–37 for the time-varying and constant debt models) rather than earlier papers (see Rudebusch and Swanson (2012) with a value of CRRA at 110 in their best fit calibration and Andreasen (2012) with the value of 168). Nevertheless, the estimated level of risk aversion is high, which is needed to match the bond premium and is a feature of many recent macro-finance papers (see, e.g., Andreasen (2012), Andreasen et al. (2018), Rudebusch and Swanson (2012) and Li and Palomino (2014)).[15] Second, the constant debt setup induces higher risk premia, and therefore, constant debt models are estimated with relatively lower curvature as well as CRRA parameters. This result confirms the findings of Horvath et al. (2019).

The estimated share of non-Ricardians (λ) is higher for the model versions without capital adjustment costs. The capital adjustment cost parameter (χ_K) is estimated to be somewhat higher than the value used by de Paoli et al. (2010). The share of capital in production (or, alternatively, in income), α, is close to one-third, which is a standard value in the real business cycle literature. The estimated share of hours worked in the total time allocation, N, is in the range of 0.33–0.38. The latter is consistent with the conventional value of 0.33 used in the real business cycle literature.

The habit formation parameter for Ricardians and non-Ricardians is also estimated (denoted as h_o and h_r, respectively). We find that habit formation is typically higher in model versions without capital adjust-

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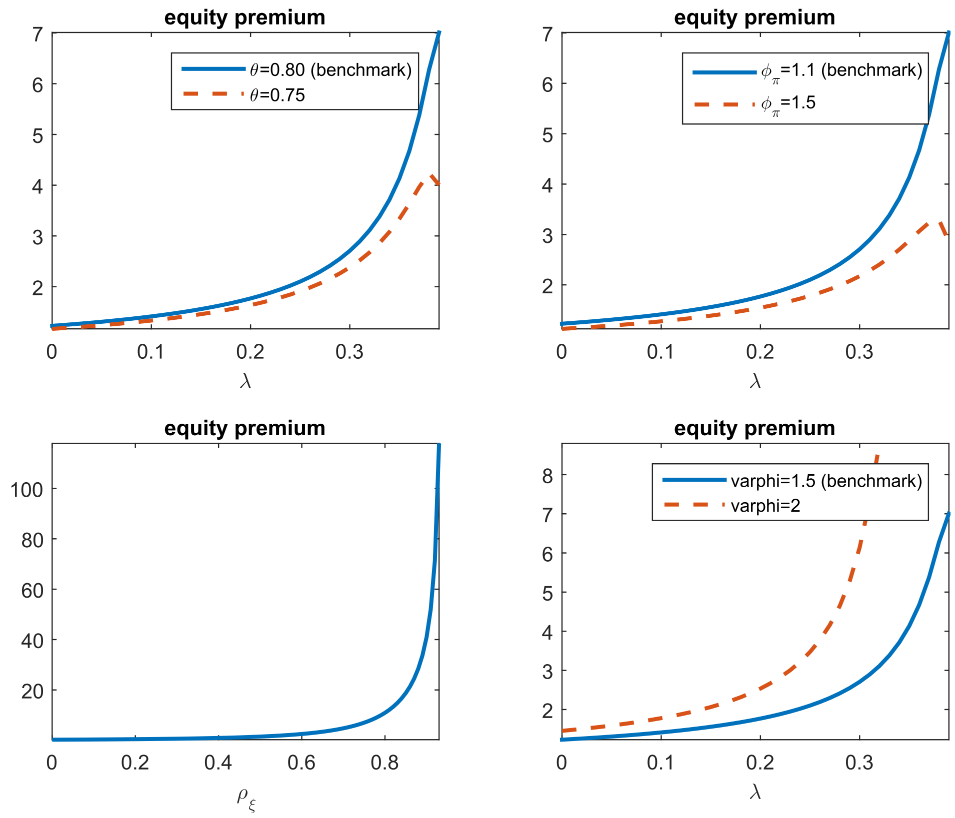
[15] There are several possible explanations to justify the high risk aversion, see the discussion in Rudebusch and Swanson (2012).



Notes: A_π is annualized. The equity premium is measured as an annualized percentage. Values of λ higher than 0.6 are excluded, as they deliver implausibly high equity premia and are not in line with empirical evidence.

Fig. 3. Sensitivity checks Notes: A_π is annualized. The equity premium is measured as an annualized percentage. Values of λ higher than 0.6 are excluded, as they deliver implausibly high equity premia and are not in line with empirical evidence.

ment costs. The omission of capital adjustment costs implies that the model tries to capture the persistence in the data by somewhat higher values of the habit formation parameter.

The estimated high value of the Rotemberg adjustment cost parameter (χ_P) does not necessarily indicate a high price rigidity but points to the fact that some real frictions are missing from the model. The introduction of further real rigidities (such as a specific labor market) could help reduce the reliance on a high value of price rigidity in the matching persistence in the data.

The estimated value of the standard deviation of the dividend payout shock, σ_d, is reasonably close to the value reported by Croce (2014) for both fiscal setups. The estimates of the parameters in the Taylor rules as well as the monetary policy shock are in line with those of Rudebusch (2002) and Andreasen (2012). The estimate of the persistence and the size of the technology shock is close to the GMM estimates of Andreasen (2012).

Examining the estimates of the fiscal processes in Table 3, we find that the AR(1) term and the standard deviation for the government spending process are reasonably close to the single-equation estimates in the literature (see, e.g., King and Rebelo (1999)). The estimated coefficients in the tax rule are close to Leeper et al. (2010) and Zubairy (2014), who estimate middle-size DSGE models using Bayesian methods.

Some parameters and steady-state quantities are not estimated but calibrated as follows. ε is the elasticity of substitution among intermediary goods and is calibrated to six. The steady-state markup is given by $\varepsilon/(\varepsilon - 1)$. The steady-state marginal cost ($\overline{mc}$) is the inverse of the markup. The $\gamma_b = 2.4$ is consistent with a yearly debt-to-GDP ratio of 60 percent. The steady-state inflation rate is zero ($\Pi^* = 1$).

The government spending-to-GDP ratio is calibrated to 20 percent, which is in line with postwar US data. The steady-state tax rate implied by the government budget constraint is 36 percent. The leverage parameter, φ_{lev}, is calibrated to two, as in Croce (2014), and is on the lower side of the empirical estimates. Model versions that do not include capital adjustment costs are invoked by setting $\chi_K = 300000$.

8. Results from the extended model

8.1. Macro and finance moments from the extended model

The extended model matches a selection of macroeconomic and finance moments calculated using US data from 1960 to 2007 (see Table A1 in online Appendix D).[16] Beyond macro and finance variables, the models' fit is assessed on the basis of fiscal moments such as the unconditional correlation of the labor tax revenue and first-order autocorrelation of labor tax revenue. The models with either constant or time-varying government debt exhibit modest fit to a series of macroeconomic and financial moments.

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[16] We focus on data from before the great recession to avoid complications posed by the fact that the US monetary policy rate reached the zero lower bound at the end of 2008.

Table 2
GMM estimates of the models I.

Parameters and steady-states	Time-varying debt	Time-varying debt∗	Constant debt	Constant debt∗
Household				
$\widetilde{\beta}$	$\underset{0.0024}{0.9989}$	$\underset{0.0027}{0.9981}$	$\underset{0.0039}{0.9912}$	$\underset{0.0086}{0.9948}$
σ	$\underset{0.48}{1.9996}$	$\underset{0.37}{1.9982}$	$\underset{0.46}{2.0046}$	$\underset{0.48}{2.065}$
ϕ	$\underset{0.99}{2.8499}$	$\underset{0.96}{2.8547}$	$\underset{0.13}{2.7125}$	$\underset{0.29}{2.6571}$
α^{EZ}	$\underset{53.27}{-79.3370}$	$\underset{55.81}{-89.6291}$	$\underset{33.34}{-62.1382}$	$\underset{36.12}{-69.4397}$
N	$\underset{0.0048}{0.3490}$	$\underset{0.0085}{0.3152}$	$\underset{0.00062}{0.3882}$	$\underset{0.0027}{0.3611}$
CRRA (implied)	39.95	47.38	30.73	34.51
λ	$\underset{0.0398}{0.3321}$	$\underset{0.0463}{0.3719}$	$\underset{0.0351}{0.3182}$	$\underset{0.0571}{0.3641}$
h_o	$\underset{0.019}{0.73}$	$\underset{0.023}{0.85}$	$\underset{0.038}{0.72}$	$\underset{0.014}{0.86}$
h_r	$\underset{0.024}{0.71}$	$\underset{0.026}{0.79}$	$\underset{0.015}{0.74}$	$\underset{0.028}{0.81}$
Firm				
α	$\underset{0.0051}{0.3454}$	$\underset{0.0055}{0.3475}$	$\underset{0.0039}{0.3541}$	$\underset{0.0047}{0.3523}$
χ^P	$\underset{0.0027}{321.05}$	$\underset{0.0033}{358.53}$	$\underset{0.0065}{342.31}$	$\underset{0.0074}{352.16}$
χ^K	$\underset{0.0027}{0.041}$	–	$\underset{0.0015}{0.053}$	–
Monetary policy				
ρ_I	$\underset{0.33}{0.7305}$	$\underset{0.41}{0.7513}$	$\underset{0.26}{0.7334}$	$\underset{0.28}{0.8712}$
g_π	$\underset{3.98}{0.5298}$	$\underset{3.36}{0.5532}$	$\underset{1.51}{0.5197}$	$\underset{1.53}{0.5216}$
g_y	$\underset{0.05}{0.9299}$	$\underset{0.04}{0.9132}$	$\underset{0.03}{0.9224}$	$\underset{0.03}{0.9305}$
Persistence and standard deviations of shocks				
ρ_i	$\underset{0.0053}{0.7665}$	$\underset{0.0065}{0.8352}$	$\underset{0.0037}{0.8174}$	$\underset{0.0051}{0.8218}$
σ_a	$\underset{0.0028}{0.0534}$	$\underset{0.0013}{0.0521}$	$\underset{0.0014}{0.0558}$	$\underset{0.0012}{0.0561}$
σ_i	$\underset{0.0202}{0.0231}$	$\underset{0.0519}{0.0336}$	$\underset{0.0285}{0.0371}$	$\underset{0.0325}{0.0358}$
σ_d	$\underset{0.0046}{0.0063}$	$\underset{0.0035}{0.0068}$	$\underset{0.0143}{0.0051}$	$\underset{0.0312}{0.0065}$

Notes: Numbers below the parameter estimates denote the standard error of the estimate in percent. – means that χ_K is not estimated in the absence of capital adjustment costs. * indicates a model version without capital adjustment costs.

Table 3
GMM estimates of the models II.

Parameters and steady-states	Time-varying debt	Time-varying debt∗	Constant debt	Constant debt∗
Fiscal policy rule and persistence of fiscal shocks				
ρ_g	$\underset{1.9}{0.9401}$	$\underset{2.4}{0.9401}$	$\underset{2.11}{0.9829}$	$\underset{3.25}{0.9601}$
ρ_τ	$\underset{0.0055}{0.9602}$	$\underset{0.0145}{0.9802}$	– –	– –
$\rho_{\tau b}$	$\underset{0.0021}{0.0599}$	$\underset{0.0151}{0.0631}$	– –	– –
$\rho_{\tau y}$	$\underset{0.33}{0.9602}$	$\underset{0.26}{0.9902}$	– –	– –
Standard deviation of fiscal shocks				
σ_g	$\underset{0.0031}{0.011}$	$\underset{0.0162}{0.018}$	$\underset{0.0029}{0.0094}$	$\underset{0.0062}{0.0099}$
σ_τ	$\underset{0.0064}{0.0033}$	$\underset{0.0171}{0.0037}$	– –	– –

Notes: Numbers below the parameter estimates denote the standard error of the estimate in per cent. — indicates those parameters which do not appear in the constant debt model. * denotes the models without capital adjustment cost.

8.2. The interaction of consumption habits and limited asset market participation in the extended model

It is well known that consumption habits raise the variability of short-term interest rates due to the aversion of Ricardians against sudden changes in the consumption stream (see, e.g., Jermann (1998)). It is important to emphasize that non-Ricardian behavior raises not only the strength of the comovement between Ricardian consumption and dividends (generating a high equity premium) but also increases variability in dividends, which makes Ricardian consumption even more volatile, inducing higher precautionary savings. Specifically, the introduction of LAMP nearly doubles the standard deviation of the dividends (not reported in the moments table), raises precautionary savings and thus reduces the variability of the short-term interest rate. This property of LAMP is also valid in the model of Menna and Tirelli (2014).

9. Concluding remarks

We examine the interactions among monetary policy, financial markets and income inequality in this paper. To motivate our theoretical model, we start with an empirical exercise. First, we estimate a VAR model on US data in 1960q1-2007q1 and find that a recursively identified monetary restriction leads to an increase in the equity premium. This prediction is in line with the prediction of our theoretical model.

Second, we develop a simple labor-only New Keynesian model with heterogeneous agents (Ricardian vs. non-Ricardian households) and show that monetary policy shocks are important drivers of equity premia. This is so when they cause a redistribution of income from non-

Ricardian to Ricardian households and when risky assets are concentrated in the hands of relatively few investors whose consumption strongly covaries with asset returns. In our model, a contractionary monetary policy shock causes the redistribution of income from non-Ricardians to Ricardians in the form of higher dividends.

Third, we augment our simple New Keynesian model with a more realistic fiscal setup, capital adjustment costs, and Epstein-Zin preferences to jointly explain the equity premium and the term premium in the yields of long-term nominal bonds. The model's parameters are estimated on US data from 1960 to 2007 by the GMM using a third-order accurate solution of the model. In line with other studies, we find that these frictions help produce high equity and bond premia as long as risk aversion is sufficiently high and temporary technology shocks are also included in the model.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2020.03.010.where x is a vector of variables, $B_0, B_1, \ldots, B_p$ are matrices and the structural shocks are $\epsilon\%i.i.dN(0, I)$. However, we can estimate the VAR in reduced form (multiplying both sides of the previous equation by B_0^{-1})

$$x_t = B_0^{-1}B_1x_{t-1} + B_0^{-1}B_2x_{t-2} + \cdots + B_0^{-1}B_px_{t-p} + B_0^{-1}\epsilon_t,$$

$$= A_1x_{t-1} + A_2x_{t-2} + \cdots + A_px_{t-p} + v_t,$$

where $A_i = B_0^{-1}B_i$ and the variance-covariance matrix is given by $E_t(v_tv_t') = B_0^{-1}B_0^{-1'} = \Omega$.

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