Equity Premium and Monetary Policy in a Model with Limited Asset Market Participation*

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Abstract

In a model with Ricardian and non-Ricardian households we show that monetary policy shocks cause endogenous redistribution of income from non-Ricardians to Ricardians whose consumption comoves tighther with asset returns giving rise to large equity premia.

Keywords: Limited Participation, Monetary Policy, DSGE, Equity Premium

JEL Codes: E32, E44, G12

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1 Introduction

In a model with heterogenous agents (stockholders and non-stockholdes) and fixed labour supply Lansing (2015) argues that exogenous income redistribution shocks are among the key drivers of high premia on unlevered equity. In his paper the consumption of asset holders is tightly linked to the dividend income (from equity) which can be quite volatile due to redistribution shocks generating a high equity premium for a given level of risk-aversion. Fixed labour supply facilitate the high equity premia in Lansing (2015). With variable labour supply the agents could easily insure themselves against negative shocks by working more to avoid the decrease in consumption which comoves tightly with asset returns (including dividends).

The redistribution in income can also happen due to exogenous monetary policy shocks as shown by Motta and Tirelli (2014) in a model with Ricardian (optimisers over infinite horizon) and non-Ricardian (static decision makers; hand-to-mouth) households. Indeed, a recent empirical paper Coibion et al. (2012) document using US household level data that monetary policy shocks have statistically significant effects on income inequality. Motta and Tirelli (2014) do not discuss the asset-pricing implications of their model, however.

We contribute to the literature on the modeling of equity premium by showing that a model featuring Ricardiands and non-Ricardians can generate high equity premium driven by monetary policy shocks. In our model with variable labour supply Ricardians use risk-free government bonds and equity to smooth their consumption and thus have an intertemporal perspective, whereas non-Ricardians who are excluded from financial markets (limited participation) have a static horizon and consume their labor income each period as in the Bilbiie (2008) and Gali et al. (2007) model.

The idea that limited participation can help explain equity premia is, however, not new. In a chapter of the Handbook of Equity Premium Donaldson and Mehra (2005) devotes a complete section to models with market incompleteness. We have two important departures from the models in Donaldson and Mehra (2005). First, the equity premium in our model is driven by monetary policy shocks and not technology shocks. Second, those earlier models are endowment economies where the consumption and dividend stream are exogenously given and there is fixed labour supply. Whereas our model is a production economy with variable labour supply which works as an insurance in case of bad shocks and therefore fluctuation of consumption is less influenced by dividends and asset returns.

In our model, price stickiness is necessary for monetary policy shocks to drive the equity premium. Without nominal rigidity, monetary policy shocks lose their importance, as firms adjust prices rather than quantities in response to exogenous shocks. In the case of perfectly flexible prices, firms are neutral toward monetary policy shocks. Similar to Wei (2009) who used a representative agent model, we find that temporary technology shocks contribute little to the equity premium even in a model with limited participation.[1]

To illuminate the workings of our model, we consider a contractionary monetary policy shock that elevates nominal and real interest rates through the Taylor rule and leads Ricardians to delay their consumption expenditures. Lower demand leads to a decrease in labor demand and production by firms with sticky prices, as they cannot accommodate the decrease in demand by reducing prices. The decline in wages puts downward pressure on non-Ricardians' consumption but creates higher profits (dividends) and yields on the assets held by Ricardians who are the owners' of the firms. Hence, redistribution of income occurs from non-Ricardians to Ricardians. The higher is the concentration of Ricardians (the lower is the share of non-Ricardians) the stronger is the comovement between Ricardian consumption and asset returns giving rise to sizable equity premia and high standard deviation of the return on equity.

[1] In a previous working paper we investigate the properties of our model with temporary technology shocks.

We use the log-linear asset-pricing framework of Campbell and Shiller (1988) to provide a closed-form solution for the level of the equity premium. The model used in our paper has two more desirable properties. First, the equity premium in our model is high with a risk-aversion coefficient equal to one (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). Second, the persistence of the monetary policy shock does not need to be counterfactually high to arrive at large equity premium unlike de Paoli et al. (2010) and Wei (2009) who used a sticky price model with a representative household and real frictions (habits in consumption and capital adjustment costs). They conclude that monetary policy shocks are key drivers of equity premia only when the persistence of the shock process is counterfactually high. In our paper the persistence of the monetary policy shock is in line with recent empirical estimates of around 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 the one from the representative agent model.

Our paper is related to Menna and Tirelli (2014) who used a limited asset market participation framework similar to ours but with several other frictions such as consumption habits, capital adjustment costs and wage rigidities to explain the equity premium by permanent technology shocks. The model used in this paper is also connected to Rossi (2012) who examines the determinacy properties of monetary and fiscal rules in a New Keynesian model with Ricardian and non-Ricardian households.

2 Model

2.1 Households

A share of the households λ has 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, and thus, their consumption completely depends on their disposable income in each period. These households are called non-Ricardians (r).

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

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

$$U = \log(C_t^i) - \frac{(N_t^i)^{1+\varphi}}{1+\varphi} \tag{1}$$

φ is the inverse of the Frisch labor supply elasticity.

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 standard Dixit-Stiglitz aggregator, which sums up 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

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

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 shares in firms owned by optimizers. V_t^{eq} and D_t denote the nominal value and the dividends on the shares, respectively. T_t^o are lump-sum taxes paid by optimizers, and S^o is a steady state lump-sum tax used to equate steady state consumptions of both types of households ($C = C^o = C^r$)[2]. All profits

[2]Note that this approach is different from Bilbiie (2008) who used a fixed cost in

are paid out in the form of dividends, which are received by the optimizer and given by:

$$D_t^o = \frac{D_t}{1-\lambda} = C_t^o - W_t N_t$$

where D_t is the aggregate level of dividends and $W_t N_t$ is the wage bill.

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

$$C_t^r = W_t N_t^r.$$

There is a competitive labor market as in Bilbiie (2008). 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 aggregate labor supply. We abstract from government consumption and investment to keep the model simple.

2.2 Firms

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

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

Intermediaries are subject to Calvo-style price setting frictions[3]. The profit maximization problem of an intermediary firm i at time t, which will not be

production to eliminate steady-state dividends to equalise steady-state consumptions of the two types of households.

[3]As in Woodford (2003 chapter 3) we assume that there is strategic complementarity in price-setting. In his chapter there are various ways (specific labour market, Kimball demand, fixed capital in production) mentioned to introduce strategic complementarity, each of them resulting in a reduction in the slope for the New Keynesian Phillips Curve and thus making shocks to have larger real effects (rather than changes in relative prices). We follow the specific labour market assumption.

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:

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

2.3 Monetary Policy

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

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

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

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

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

2.4 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. Propositions 2 and 3 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 as a function of the monetary policy shock:*

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

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*

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

For the proof and a short description of determinacy, see online appendix A.

In line with conventional wisdom, a restrictive monetary shock ($\xi_t > 0$) leads to decreases in 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 Appendix A) and and the Taylor principle is satisfied ($\phi_\pi > 1$).

2.5 Determinacy Properties of the Model

To study the determinacy properties of the model (the next proposition), we set up 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 combination of previous equation and the connection between Ricardian consumption and aggregate output, $c_t^o = A_c y_t$ (for derivation of this equation see appendix B):

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

dR_t is defined as $R_t - R$.

Note that $\partial \Gamma^{IS} / \partial \lambda > 0$ and thus the IS equation above lends support to the claim (see results section of the paper) that the higher 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 ($\phi_\pi > 1$) leads to determinacy of the model with the 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 ($\phi_\pi < 1$) guarantees determinacy. For the proof, see Bilbiie (2008), who employs a similar model.

For the rest of the paper we abstract from cases wherein $\lambda > 0.39$ which region can be described by the so-called 'inverted aggregate demand logic' (IADL) and where $\phi_\pi < 1$ brings determinacy (for more see Bilbiie (2008)).

2.6 Pricing the Market Portfolio

We use the log-linear 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 followed by Wei (2009), for instance.

Proposition 3 *The return on the market portfolio of equally weighted shares can be written 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 show that* $\kappa_1 \simeq 1$*.* z_t *is a function of the state variable, which is the monetary policy shock* ξ_t*:*

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

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

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

Real dividend growth is given by

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

where $\kappa_{d\xi} \equiv 1 - \frac{W(1+\varphi)}{1-W}$*. For the proof, see appendix B.*

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 equity risk-premium we first decompose the covariance term into the price of risk and the quantity of risk (see e.g. Sangiorgi and Santoro (2005)):

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

■

2.7 Discussion of the equity premium formula

In line with Hördahl et al. (2008) and Sangiorgi and Santoro (2005) we decompose the equity premium into two parts. One part measures the market price of risk and the other part is the quantity of risk which is the covariance between the return on the asset and the innovation of the shock. As Hördahl et al. (2008) argue the market price of risk is of special interest because it is independent of the special characteristics of the asset priced (a premium for a given amount of risk). Whereas the second term measures the non-diversifiable riskiness of an asset.

In the equity premium formula above $A_y < 0$ due to the monetary policy shock and thus, the price of risk is also negative. The quantity of risk is also negative: $cov_t(\xi_{t+1}, rr_{t+1}) < 0$[4]. As a result the equity premium is positive. Both the price and the quantity of risk rise (in absolute value) with more restricted asset market participation (higher λ). $\kappa_1 A_{z1}$ 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 quantity 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 and therefore we have $(\kappa_1 A_{z1} + k_{d\xi} A_y) < 0$ consistent with Sangiorgi and Santoro (2005) who used a representative agent

[4]Note that $cov_t(\xi_t, rr_{t+1}) > 0$ (a monetary restriction of today causes a drop in the price-dividend ratio today and a rise in future return). The significance of $cov_t(\xi_t, rr_{t+1}) > 0$ is more explained in the results section below.

Table 1: Parametrization

—	$\beta = 0.99$	$\phi_\pi = 1.1$
$\epsilon = 11$	$\varphi = 1.5$	$\rho_\xi = 0.75$
$\theta = 0.80$	$\lambda = 0.39$	$\sigma_\xi = 0.005$

model. When participation is restricted enough the absolute value of the price of risk and the quantity of risk can be much larger in the limited participation model relative to the representative agent model.

3 Parametrization

We present the parameter values in Table 1. The parameter φ is set to 1.5, which implies that the Frisch elasticity of 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.

The elasticity of substitution among intermediary goods (ϵ) is set to 11, implying a net markup ($1/(\epsilon - 1)$) of 10 percent that is standard in the literature. The Calvo parameter of price adjustment is 0.80, which implies that the average duration of a price spell of 5 quarters which is 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 0.38 which is in the lower end of the estimates (see e.g. Gali et al. (2007) and De Graeve et al. (2005) who set 0.5 and 0.6 for λ, respectively). 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).

4 Results

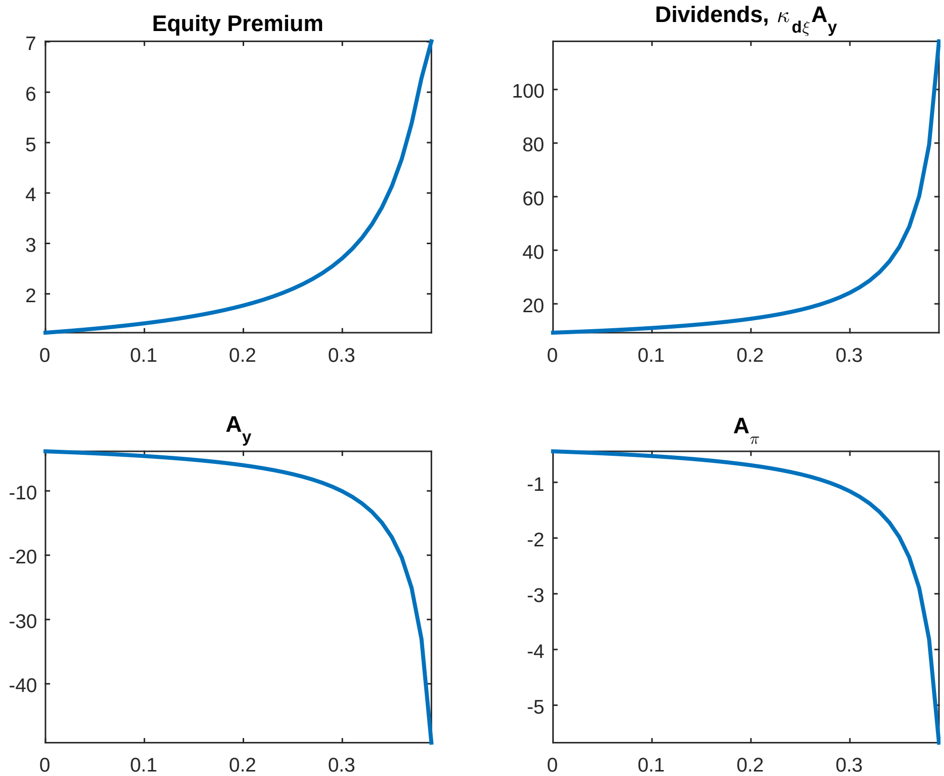
4.1 Representative agent model

To better understand the workings of the limited participation model we first explain the effects of an unanticipated rise in the nominal interest 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 higher real interest rate which make Ricardian households to delay their consumption from present to the future. The negative wealth effect of the monetary policy shock also engineers a decline in leisure time (normal good) and induce Ricardians to work more with a fixed time frame. Hence, labour supply shifts out depressing the real wage. As many of the firms face sticky price not all of them can reduce prices when demand falls. As a result those firms which cannot reset their price will decrease production and demand less labour shifting labour demand leftwards and depressing real wages even more. 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 around 0.8 %. This finding is consistent with the literature (see de Paoli et al. (2010) and Wei (2009)). Unless the model is enriched with capital and Jermann (1998)-type capital adjustment costs and the persistence of the monetary policy shock is counterfactually high the equity premium remains small. It is because of the mildly persistent monetary policy shock (our baseline calibration) that the equity premium is closer to one rather than to zero.

4.2 Limited participation model

Now we split the population into Ricardian and non-Ricardian households ($\lambda > 0$). Figure 1 displays the sensitivity of output, inflation, dividends and the equity premium to share of non-Ricardian households. On each

Figure 1: Sensitivity of A_y, A_π, $\kappa_{d\xi}A_y$ and the Equity Premium (ep) 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.

graph, $\lambda = 0$ delivers the standard representative agent model (only Ricardian households), where the equity premium is around 1 % (see the right bottom panel, *ep*). The sensitivity of output, inflation and the growth rate of dividends to a monetary policy shock (see the subplots denoted A_y, A_π and $\kappa_{d\xi} A_y$, respectively) increases with the share of non-Ricardian households in the population. This can be explained as follows. Consider a contractionary monetary policy shock increasing real interest rates and curbing Ricardian expenditures. The higher the share of non-Ricardians the more successful monetary policy is in curtailing aggregate demand through rises in the real interest rate. The latter channel exists due to the nominal price rigidity which establishes the link between non-Ricardians' demand (based on their wage income) and real interest rates. With sticky prices, the monetary tightening also leads to decreases in labor demand, marginal costs (real wages) and, thus the wage income of non-Ricardians but increases in profits, endogenously redistributing income from non-Ricardians to Ricardians. The stronger the redistribution, the more concentrated the ownership of capital, that is, the lower is the share of Ricardians whose consumption is susceptible to changes in dividend income[5] and to asset returns that positively co-move with the growth rate of dividends. As a result, a positive connection emerges between the share of non-Ricardians and the equity premium.

This intuitive explanation can be linked to equations above. Specifically, a restrictive monetary shock today ($\xi_t > 0$) leads to a decline in the price-dividend ratio (z_t) (in equation 5) which raises next period returns (r_{t+1}) (see equation 4) as long as $A_{z1} < 0$ which is satisfied in our baseline calibration. With sufficiently high share of non-Ricardians ($\lambda = 0.39$) we achieve large equity premium ($ep = 7.0089$ percent) and a high standard deviation of equity returns (25.71 percent) which are close to the 6.33 (in annualised terms) by Bansal and Yaron (2004) for the market portfolio using post-war

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

US data.

5 Sensitivity Analysis

We present the result of our sensitivity analysis in Figure 2.

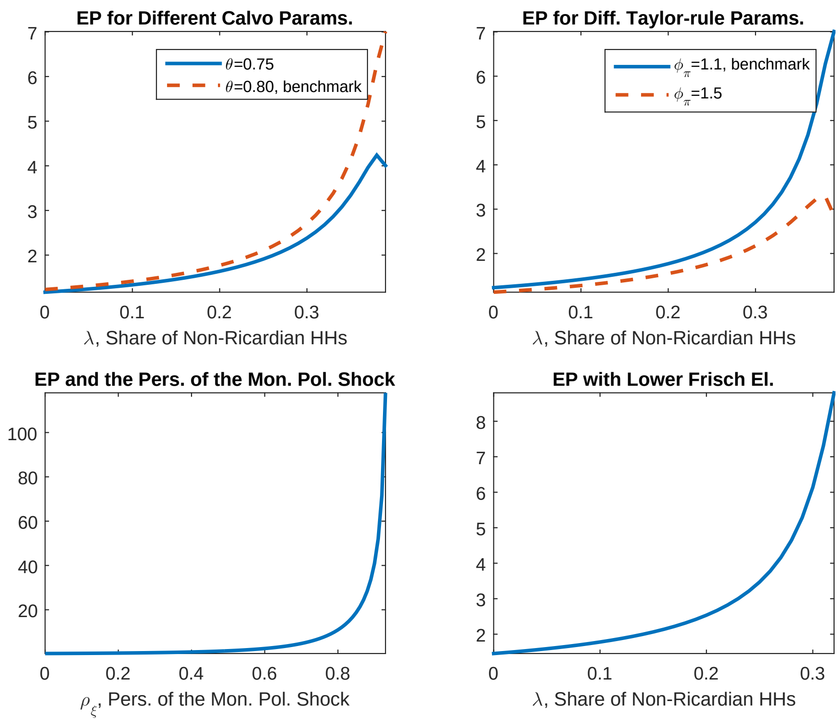
The inverse of the Frisch elasticity (φ). When labour supply is less elastic (i.e. Frisch elasticity is lower, φ is raised from 1.5 to 2), we expect that labour can be adjusted less flexibly in case of negative shocks and the equity premium is larger. When setting $\varphi = 2$ the equity premium is higher by more than 1 percentage points but the determinacy region shrinks. In this case equity premium is the highest at $\lambda = 0.32$ and the highest value of λ for which the equilibrium is determinate occurs at 0.33.

Calvo parameter of price rigidity (θ). The higher is the price rigidity we expect monetary policy shocks to be stronger. In this scenario we consider lower average duration of price-rigidity than in the baseline calibration (4 quarters instead of the 5 quarters assumed in the baseline calibration). Now the equity premium reduces to 3.30 percent that is still more than three times larger than the one in the representative agent model.

Coefficient of inflation in the Taylor rule (ϕ_π). With 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 is substantially reduced. The figure shows the effects of increasing ϕ_π from 1.1 to 1.5. The equity premium halves with the rise in ϕ_π. When $\phi_\pi \to \infty$ the monetary policy shock is completely neutralised (no relative price distortions) and we are back to the case of fully flexible prices where the monetary policy has no effect and therefore 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 is confirmed by the figure which shows that the equity premium can be counterfactually high

Figure 2: Sensitivity Checks



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.

6 Concluding Remarks

Monetary policy shocks are important drivers of the equity premium when they cause redistribution of income and risky assets are concentrated in the hands of relatively few investors whose consumption strongly covaries with asset returns. Unlike technology shocks in other papers, our result does not require real friction such as capital with adjustment costs.

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7 Online Appendix A

7.1 Summary of loglinear equilibrium conditions

This section provides a loglinear solution to the model.

The loglinear equilibrium conditions are detailed below and are, in fact, similar to those in Bilbiie (2008) and Gali et al. (2007). We differ from Gali et al. (2007) to the extent that we exclude capital with adjustment costs and government sector. Our exclusion of capital facilitates analytical solution and the identification of the channels that contribute to the high equity premium.

Please note that in all derivations below the inverse of the intertemporal elasticity of substitution is chosen to be one (log utility in consumption): $\sigma = 1$.

The intratemporal conditions for type $i = r, o$:

$$w_t = \sigma c_t^i + \varphi n_t^i$$

which can be aggregated to

$$w_t = \sigma c_t + \varphi n_t$$

using the consumption and labor aggregators, respectively:

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

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

The budget constraint of the non-Ricardian household is:

$$c_t^r = w_t + n_t^r$$

The intertemporal Euler equation of Ricardians is given by:

$$\sigma(c_t^o - E_t c_{t+1}^o) = -(dR_t - E_t \pi_{t+1}) \tag{6}$$

The production function reads as:

$$y_t = a_t + n_t$$

The aggregate resource constraint (market clearing) is:

$$y_t = c_t$$

The New Keynesian Phillips curve (NKPC) is given by

$$\pi_t = \beta E_t \pi_{t+1} + \kappa mc_t$$

where mc_t stands for the real marginal cost and κ is the slope of NKPC. The system is closed by adding a linear Taylor rule of the form:

$$dR_t = \phi_\pi \pi_t + \xi_t$$

The model can be solved using the method of undetermined coefficients. Let us postulate that output and inflation is given as a linear function of the monetary policy shock:

$$y_t = A_y \xi_t = y_\xi \xi_t$$
$$\pi_t = A_\pi \xi_t = \pi_\xi \xi_t$$

where $A_y = y_\xi$ and $A_\pi = \pi_\xi$ are coefficients to be determined.

7.2 Proof of Proposition 1. Derivation of $A_\pi = \pi_\xi$

The NKPC is given by

$$\begin{aligned}
\pi_t &= \beta E_t \pi_{t+1} + \kappa mc_t \\
&= \beta E_t \pi_{t+1} + \kappa(\sigma c_t + \varphi n_t - a_t) \\
&= \beta E_t \pi_{t+1} + \kappa(\sigma y_t + \varphi n_t + \varphi a_t - \varphi a_t - a_t) \\
&= \beta E_t \pi_{t+1} + \kappa[(\sigma + \varphi) y_t - (1 + \varphi) a_t].
\end{aligned}$$

The second line makes use of the fact that the marginal cost equals to the real wage minus the technology shocks (in linear terms). The third line uses the market clearing and adds and substacts φa_t. The fourth line makes use of the production function $y_t = a_t + n_t$. For the rest of the derivation we can ignore the technology shock (a_t) as our focus is the monetary policy shock.

Let us first rewrite the New Keynesian Phillips curve as function of the monetary policy shock:

$$\begin{aligned}
\pi_t &= \beta \pi_\xi \rho_\xi \xi_t + \kappa(\sigma + \varphi) A_y \xi_t \\
&= \{\beta \pi_\xi \rho_\xi + \kappa(\sigma + \varphi) A_y\} \xi_t
\end{aligned}$$

where A_y is calculated below.

Matching coefficients:

$$\pi_\xi = \beta \pi_\xi \rho_\xi + \kappa(\sigma + \varphi) y_\xi$$

$$\pi_\xi = \frac{\kappa(\sigma + \varphi) y_\xi}{1 - \beta \rho_\xi} \tag{7}$$

or in the empirically relevant case of $\rho_\xi = 0$:

$$\pi_\xi = \kappa(\sigma + \varphi) y_\xi$$

7.3 Proof of Proposition 1. Derivation of $A_y = y_\xi$

The separate labor supply decision of non-Ricardian households is given by the following linear intratemporal condition:

$$c_t^r + \varphi n_t^r = w_t$$

which we express for n_t^r as:

$$n_t^r = \varphi^{-1}(w_t - c_t^r)$$

which we substitute in for n_t^r in the loglinear budget constraint of non-Ricardians and also making use of the aggregate intratemporal condition:

$$c_t^r = w_t + n_t^r$$

and

$$\sigma c_t^r + \varphi n_t^r = w_t.$$

The previous one can be expressed for c_t^r as:

$$c_t^r = [w_t] + \varphi^{-1}([w_t] - \sigma c_t^r)$$

and we can substitute the aggregate intratemporal condition for the real wage in squared brackets:

$$c_t^r = [\sigma c_t + \varphi n_t] + \varphi^{-1}([\sigma c_t + \varphi n_t] - \sigma c_t^r).$$

The c_t^r terms can be collected on the left-hand side as follows:

$$c_t^r \left(1 + \frac{\sigma}{\varphi}\right) = \sigma c_t + \varphi n_t + \varphi^{-1}\left(\sigma c_t + \varphi n_t\right)$$

Then it follows that the consumption of non-Ricardians is a function of the aggreagate variables of the model:

$$c_t^r = \frac{\sigma\,(1+\varphi)}{\varphi+\sigma} c_t + \frac{(1+\varphi)\varphi}{\varphi+\sigma} n_t. \tag{8}$$

Let us define the forward operator as L^{-1} and apply $1 - L^{-1}$ to both sides of the previous equation:

$$c_t^r - E_t c_{t+1}^r = \frac{\sigma\,(1+\varphi)}{\varphi+\sigma}(c_t - E_t c_{t+1}) + \frac{(1+\varphi)\varphi}{\varphi+\sigma}(n_t - E_t n_{t+1}) \tag{9}$$

Recall the consumption aggregator and apply the $1 - L^{-1}$ operator to obtain:

$$c_t - E_t c_{t+1} = \lambda(c_t^r - E_t c_{t+1}^r) + (1-\lambda)(c_t^o - E_t c_{t+1}^o)$$

Then using equation (9) leads to:

$$\begin{aligned} c_t - E_t c_{t+1} = {} & \frac{\lambda\sigma\,(1+\varphi)}{\varphi+\sigma}(c_t - E_t c_{t+1}) + \frac{\lambda(1+\varphi)\varphi}{\varphi+\sigma}(n_t - E_t n_{t+1}) \\ & + (1-\lambda)(c_t^o - E_t c_{t+1}^o) \end{aligned}$$

Recall Ricardian Euler equation:

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

where $dR_t = R_t - R$ is deviation of the nominal interest from its steady-state. The Ricardian Euler equation can be inserted into the previous equation to obtain:

$$\begin{aligned} c_t - E_t c_{t+1} = {} & \frac{\lambda\sigma\,(1+\varphi)}{\varphi+\sigma}(c_t - E_t c_{t+1}) + \frac{\lambda(1+\varphi)\varphi}{\varphi+\sigma}(n_t - E_t n_{t+1}) \\ & - \frac{(1-\lambda)}{\sigma}(dR_t - E_t \pi_{t+1}) \end{aligned}$$

Using the market clearing and the production function we obtain:

$$y_t - E_t y_{t+1} = \frac{\lambda\sigma\,(1+\varphi)}{\varphi+\sigma}(y_t - E_t y_{t+1}) + \frac{\lambda(1+\varphi)\varphi}{\varphi+\sigma}(y_t - E_t y_{t+1})$$
$$- \frac{\lambda(1+\varphi)\varphi}{\varphi+\sigma}(a_t - E_t a_{t+1}) - \frac{(1-\lambda)}{\sigma}(dR_t - E_t \pi_{t+1})$$

The previous one can be rewritten as (after inserting the Taylor rule for dR_t). After simplifications we obtain

$$[1-\lambda\,(1+\varphi)]y_t = [1-\lambda\,(1+\varphi)]E_t y_{t+1}$$
$$- \frac{\lambda(1+\varphi)\varphi}{\varphi+\sigma}(a_t - E_t a_{t+1}) - \frac{(1-\lambda)}{\sigma}(\phi_\pi \pi_t + \xi_t - E_t \pi_{t+1})$$

Let us define

$$\Gamma \equiv 1-\lambda\,(1+\varphi)$$

and use the guesses and the AR(1) property of the shock for y_{t+1} and π_{t+1} to rewrite the previous equation as:

$$y_t = \frac{[1-\lambda\,(1+\varphi)]}{\Gamma} y_\xi \rho_\xi \xi_t$$
$$- \frac{\lambda(1+\varphi)\varphi}{\Gamma(\varphi+\sigma)}(a_t - E_t a_{t+1}) - \frac{(1-\lambda)}{\Gamma\sigma}(\phi_\pi \pi_t + \xi_t - \pi_\xi \rho_\xi \xi_t).$$

Here Γ is the same as the one in proposition 1.

From now, we can ignore the technology part as our focus is the monetary policy shock. We can also substitute in for π_t the undetermined coefficient solution from equation (7) to obtain:

$$y_t = \left[\frac{[1-\lambda\,(1+\varphi)]}{\Gamma} y_\xi \rho_\xi - \frac{(1-\lambda)}{\sigma\Gamma}(\phi_\pi - \rho_\xi)\frac{\kappa(\sigma+\varphi)y_\xi}{1-\beta\rho_\xi} - \frac{(1-\lambda)}{\sigma\Gamma}\right]\xi_t$$

In the next step we match coefficients, such that the expression in the squared bracket is made equal to y_ξ. After the expression in [] is matched, we collect all the terms containing y_ξ:

$$y_\xi \left\{ 1 - \frac{[1-\lambda\,(1+\varphi)]\rho_\xi}{\Gamma} + \frac{(1-\lambda)(\phi_\pi - \rho_\xi)}{\sigma\Gamma} \frac{\kappa(\sigma+\varphi)}{1-\beta\rho_\xi} \right\} = -\frac{(1-\lambda)}{\sigma\Gamma}$$

which can be written as (with a common denominator):

$$y_\xi \left\{ \frac{\Gamma(1-\beta\rho_\xi)\sigma - [1-\lambda\,(1+\varphi)]\rho_\xi(1-\beta\rho_\xi)\sigma + (1-\lambda)(\phi_\pi-\rho_\xi)\kappa(\sigma+\varphi)}{\sigma\Gamma(1-\beta\rho_\xi)} \right\} = -\frac{(1-\lambda)}{\sigma\Gamma}$$

The coefficient we are looking for is, thus, the following:

$$y_\xi = -\frac{(1-\lambda)(1-\beta\rho_\xi)}{\Gamma(1-\beta\rho_\xi)\sigma - [1-\lambda\,(1+\varphi)]\rho_\xi(1-\beta\rho_\xi)\sigma + (1-\lambda)(\phi_\pi-\rho_\xi)\kappa(\sigma+\varphi),}$$

which is the same as in proposition 1 ($\sigma = 1$ because of the logarithm of consumption in the utility)

8 Online Appendix B

This appendix provides a loglinear solution to the price-dividend ratio and the equity premium.

8.1 Proof of Proposition 2

We provide details on the derivation of A_{z1}, A_c and $\kappa_{d\xi}$ in Proposition 2.

The loglinear version of the stochastic discount factor is given by:

$$sdf_{t,t+1} = -\sigma\Delta c^o_{t+1}$$

In order to establish connection between Ricardian consumption and aggregate variables we use consumption aggregator of the two types and equation (8) to derive:

$$c^o_t = \frac{1}{1-\lambda}c_t - \frac{\lambda(1+\varphi)}{1-\lambda}n_t \tag{10}$$

Then it follows that

$$\Delta c^o_{t+1} = \frac{1-\lambda(1+\varphi)}{1-\lambda}\Delta y_{t+1}$$

Thus, the sdf can be expressed as:

$$\begin{aligned}
sdf_{t,t+1} &= -\sigma \Delta c^o_{t+1} = -\sigma \left\{ \frac{1-\lambda(1+\varphi)}{1-\lambda} \right\} \Delta y_{t+1} \\
&= -\sigma A_c A_y (\xi_{t+1} - \xi_t) \\
\text{where } A_c &\equiv \frac{1-\lambda(1+\varphi)}{1-\lambda} \\
E_t sdf_{t,t+1} &= \sigma A_c A_y (1-\rho_\xi)\xi_t
\end{aligned}$$

where $A_y = y_\xi$ is derived in appendix A.

$$d_t = \kappa_{d\xi} n_t,$$

where

$$\kappa_{d\xi} = 1 - \frac{W}{1-W}(\sigma+\varphi).$$

Recall from the main text that the return on asset i is given by:

$$rr_{i,t+1} = \beta A_{z1}\xi_{t+1} - A_{z1}\xi_t + \Delta d_{i,t+1} \tag{11}$$

where real dividends can be expressed as:

$$d_t = \kappa_{d\xi} A_y \xi_t$$

After linearising the asset Euler equation and taking expectations we obtain (using $E_t\xi_{t+1} = \rho_\xi \xi_t$):

$$\begin{aligned}
0 &= E_t rr_{i,t+1} + E_t sdf_{t,t+1} \\
&= (\beta\rho_\xi - 1)A_{z1}\xi_t - (1-\rho_\xi)\kappa_{d\xi}A_y\xi_t + A_c A_y (1-\rho_\xi)\xi_t
\end{aligned}$$

Therefore, in order for the previous expression to be equal to zero the sum of the coefficients multiplying ξ_t has to satisfy:

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

Hence the return on equity can be written, using equation (11), as:

$$\begin{aligned} rr_{i,t+1} = & -\frac{\beta(1-\rho_\xi)\kappa_{d\xi} A_y}{(1-\beta\rho_\xi)}\xi_{t+1} + \frac{\beta\sigma A_c A_y (1-\rho_\xi)}{(1-\beta\rho_\xi)}\xi_{t+1} \\ & - A_{z1}\xi_t + \kappa_{d\xi} A_y \Delta\xi_{t+1} \end{aligned}$$