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## Explaining bond and equity premium puzzles jointly in a DSGE model

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Lorant Kaszab and Ales Marsal

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MNB Working Papers 1

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Explaining Bond and Equity Premium Puzzles Jointly in a DSGE Model\*

(Kötvény és Részvény Kockázati Prémium Együttes Magyarázata egy DSGE modellben)

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# Abstract

We introduce costly firm-entry a la Bilbiie et al. (2012) into a New Keynesian model with Epstein-Zin preferences and show that it can *jointly* account for a high mean value of bond and equity premium without compromising the fit of the model to first and second moments of key macroeconomic variables. In the standard New Keynesian model without entry it is easy to generate inflation risks on long-term nominal bonds when placing high coefficient on the output gap in the Taylor rule. Our model is able to generate inflation risks when the coefficient on the output gap is small. In the entry model real risks are lower and inflation risks are ceteris paribus higher than in the standard New Keynesian model without entry due to the appearance of new varieties that help households smooth their consumption better.

**JEL:** E13, E31, E43, E44, E62.

**Keywords:** firm entry, zero-coupon bond, equity premium, nominal term premium, third-order approximation, New Keynesian, Epstein-Zin preferences.

## Összefoglaló

Egy standard Epstein-Zin preferenciákkal kibővített újkeynesi modellt egészítünk ki oly módon, hogy az iparágba újonnan belépő vállalatoknak egy fix költséget kell fizetniük Bilbiie és szerzőtársai (2012) modelljéhez hasonlóan és megmutatjuk, hogy ez a kiterjesztés képes kötvény és részvény kockázati prémium együttes magyarázatára anélkül hogy romlana a modell fontosabb makrováltozókra való illeszkedése. A standard újkeynesi modell (amiben a vállalatok száma fix) szerint a hosszú lejáratú kötvények hozamában jelentős inflációs kockázati prémium van amikor az output gap koefficiense a Taylor szabályban magas. Az újonnan belépő vállalatok/ termékek miatt a háztartások hatékonyabban képesek simítani a fogyasztásukat és emiatt a reálkockázatok alacsonyabbak míg az inflációs kockázatok ceteris paribus magasabbak lesznek egy olyan modellhez képest amiben a cégek száma fix.

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# 1 Introduction

The empirical literature estimates the mean value of the equity premium to be around 6 per cent and a volatility of equity returns of around 15 per cent based on post-war US data (see the literature review in Donaldson and Mehra (2008)). Kim and Wright (2005) use an arbitrage-free three-factor model and report estimates of the mean and standard deviation of a 10-year bond term-premium of around one and 0.54 per cent, respectively. Rudebusch and Swanson (2012; RS henceforth) produce high and volatile nominal bond term premium using a basic New Keynesian model with Epstein-Zin (1989) preferences. RS point toward further investigation of the model including other types of assets like equities.

We contribute to the macro-finance literature by showing that the RS model extended with costly firm entry *jointly* explains the high mean value of bond and equity risk-premia without compromising the model's fit to macro data. The literature so far has mainly focused on constructing a dynamic-stochastic general equilibrium model (DSGE) that matches either the term premium on long-term bonds (see, e.g. RS or Hördahl et al. (2008)) or the risk-premium on equities (see, e.g. Beaubrun-Driant and Tripier (2005)). We introduce costly firm entry into a basic New Keynesian model (like the one in RS) along the lines of Bilbiie et al. (2007, 2012) where the mass of firms entering the industry in each period are subject to a time-varying sunk entry cost and a time-to-build lag in production. Firm entry has been incorporated into the basic RBC model in order to reproduce the countercyclical markup and procyclical profit found in the data (see, e.g. Rotemberg and Woodford (1999)).

In fact, it is the strong positive correlation between the stock-return and profits that justifies the high-premium on equities which bring low return in bad times i.e. when entry rate is low due to a shrinkage in expected future profits. Therefore, unlike models without entry, equity premium emerges not because of the positive comovement between stock returns and consumption (growth) but due to the positive relationship between equity return (mainly the dividends part of it) and inflation as well as output which depends on the investment into new firms. When using the baseline calibration of RS our model can produce an annualised equity premium of about 10 per cent that is somewhat in excess of the empirical ones that are usually between 3 and 7 per cent depending on the sample period.

Besides the high-equity premium our model exhibits a reasonable bond-premium as well because the negative covariance between consumption and inflation—a pre-requisite for the existence of a positive bond term premium—is also maintained. Investors expect long-term government bonds to pay an excess return (a term premium) in order to be compensated for consumption/inflation risks over the entire life of the bond. Thus, a bond is considered to be risky when low consumption is coupled with high inflation that erodes the real payoff of the bond. When utilising the baseline calibration of RS our model has similar performance to RS without entry in terms of matching the nominal term premium. In particular, the baseline calibration helps to achieve a nominal term premium of about 30 basis points (roughly one-third of the empirical value). While an alternative calibration containing values of the intertemporal elasticity of substitution and Frisch elasticity that are closer to the empirical estimates bring the simulated mean and standard deviation of the nominal term premium in line with its empirical counterpart.

As a second contribution we show that our model produces inflation risks even when the coefficient on the output gap in the Taylor rule is small unlike RS where only a high coefficient on the output gap guarantees the existence of inflation risk premia. Below we review several studies which estimate the size of the inflation risk premium to be between 10 and 115 basis points depending on the country, time period and the type of the dataset that is applied. Standard New Keynesian models like the RS model without entry imply a trade-off between stabilising the standard deviation of inflation and the output gap, that is, a lower volatility of inflation can be achieved at the cost of higher standard deviation of the output gap (see also Clarida et al. (1999) and Woodford (2003)). Further, this trade-off means that the larger is the coefficient on the output gap the higher is the relative weight a central bank places on stabilising fluctuations in the output gap and, therefore, the lower is the unconditional standard deviation of the output gap and the higher is the unconditional standard deviation of inflation.



The case of a high coefficient on the output gap in the standard New Keynesian model—the baseline calibration of RS—is associated with low standard deviation of the output gap and a relatively high standard deviation of inflation (nominal uncertainty) and high inflation risks. When comparing the RS model with and without entry in case of a low coefficient on the output gap one recognises that the latter implies higher real term premium than the former. As a result inflation risks are, *ceteris paribus*, higher in the model with entry relative to the one without it when coefficient on the output gap is low. The intuition for this finding can be explained as follows. In a model with firm entry relative to the one lacking it households can smooth their consumption path better through continuously reoptimising the content of the consumption basket when new varieties appear due to firms that urge to exploit profit opportunities induced by positive productivity shocks. Moreover it is also true that the unconditional standard deviation of inflation is higher in the entry model implying more inflation risks than in the model without entry independently of the size of the output gap coefficient. Our model entails an inflation risk-premium of about 16 basis point which is on the lower end of the empirical estimates.

Our model features Epstein-Zin preferences which are widely employed to increase risk-aversion of the consumer without decreasing intertemporal elasticity of substitution. Vissing-Jorgensen and Attanasio (2003) estimated risk-aversion to be around 5-10 for stockholders using US data over 1982-1996. This paper, however, maintains a high value of risk-aversion similar to RS to obtain a reasonable amount of nominal term premium on long-term default-free bonds. As a third contribution, we demonstrate that the entry model makes some progress by matching the estimated mean of the nominal ten-year bond premium with a risk-aversion (85) smaller than that of RS (110).

RS cite a number of papers in order to support the high risk-aversion coefficient. One of them is based on Barillas et al. (2009) who show that a model with Epstein-Zin preferences and high risk-aversion is “isomorphic to a model in which households have low risk aversion but a moderate degree of uncertainty about the economic environment.” (RS pp. 123). Another interpretation can be derived from Malloy et al. (2009) who find that consumption of stockholders has higher standard deviation than consumption of non-stockholders. Therefore, risk-aversion should be higher in a representative agent model like the RS model with/without entry than in a model which can distinguish between agents with different consumption smoothing behaviour. To put it differently, the DSGE models we use might understate the quantity of risks faced by households so that a higher risk-aversion is needed to match risk premiums in the data.

Our fourth contribution is that the RS model with entry imply an increase in consumption risks in case of distortionary income taxation relative to lump-sum taxation when the coefficient on the output-gap is low. The intuition for this finding is the following. The fiscal setting of the model contains government consumption which is financed with long-term nominal bonds that are paid back through income tax revenue far in the future. From the point of view of highly-risk averse households this type of financing constitutes substantial real/consumption risks originating from the expectation of future periods with depressed income due to low realisations of technology.

Contribution four is connected to Kaszab and Marsal (2013) who employ the RS model with a fiscal sector. Utilising the baseline calibration of RS—implying a high Taylor rule coefficient on the output-gap—they highlight the possibility of fiscal policy with distortionary income taxation in raising inflation risks when households are sufficiently risk-averse. The intuition for their finding is based on the fact that in a New Keynesian model higher future taxes are coupled with higher marginal cost and higher inflation through the New Keynesian Phillips curve and, hence, giving rise to inflation risks.

This paper is also closely related to Swanson (2014) who uses a model quite similar to RS to jointly characterise nominal and real term structure of default-free/defaultable bonds and the return and variability of equities. The main difference between RS and Swanson (2014) is that the former attributes the satisfactory macro and finance fit of the model to temporary while the latter to permanent technology shocks (in particular, he postulates a random walk without drift).

The paper proceeds as follows. The second section describes the model. Further, we characterise market clearing, monetary and fiscal policy in the model. Section three provides an overview of further properties of our model. Then parametrisation of the model is presented. Results follow with particular attention given to equity premium and inflation risks. We also discuss the effects of the different specifications of the entry cost and fiscal policy on the main results. Finally we conclude.

# 2 The Model

## 2.1 FIRM ENTRY AND PROFIT MAXIMISATION

In this paper the canonical New Keynesian model of RS featuring Epstein-Zin preferences is extended with costly firm entry as in Bilbiie et al. (2012). The following short description of the production sector borrows heavily from Bilbiie et al. (2007) who feature a two-sector RBC model with price rigidity. Labour is the only factor of production. In one sector labour is used to produce consumption goods. The other sector requires labour effort to set up new firms. We start with the description of the latter one.

There is a mass of firms. Firm  $\omega$  employs labour ( $l_t(\omega)$ ) in order to produce output ( $y_t(\omega)$ ) using a constant-return-to-scale technology:  $y_t(\omega) = Z_t l_t(\omega)$  where  $Z_t$  is a stationary productivity shock:

$$\log Z_t = \rho_z \log Z_{t-1} + \varepsilon_t^z,$$

where  $\varepsilon_t^z$  is an independently and identically distributed (iid) stochastic technology disturbance with mean zero and variance  $\sigma_z^2$ . The unit cost of production in units of consumption good  $C_t$  is  $w_t/Z_t$  where  $w_t \equiv W_t/P_t$  is the real wage. There is also a mass of prospective entrants. Firms pay an entry cost of  $f_E$  effective labour units, equal to  $w_t f_E/Z_t$ . Each period firms correctly anticipate their future profits and the probability  $\delta$  of the exit-inducing shock. The model features a time-to-build lag in the sense that firms entering at time  $t$  start to produce one period later. Therefore, the number of firms producing at period  $t$ ,  $N_t$ , is described by:

$$N_t = (1 - \delta)(N_{t-1} + N_{E,t-1}) \quad (1)$$

where  $N_E$  stands for new entrants and both new entrants and incumbents survive with probability  $1 - \delta$ .

There is a free-entry condition

$$v_t^{firm} = w_t \frac{f_{E,t}}{Z_t},$$

which says that firm entry happens until the value of the firm ( $v_t^{firm}$ ) is equal to the entry cost expressed in effective labour units ( $w_t f_{E,t}/Z_t$ ). The entry cost is not time-varying and normalised to one,  $f_{E,t} = f_E = 1$ , as in Bilbiie et al. (2007)<sup>1</sup>.

The real profits of firm  $\omega$  at time  $t$  (transferred back to households in the form of dividends,  $d_t(\omega)$ ) can be expressed as:

$$d_t(\omega) = p_t(\omega) y_t^D(\omega) - w_t l_t(\omega) - pac_t(\omega) p_t(\omega) y_t^D(\omega)$$

where  $p_t(\omega) \equiv p_t(\omega)/P_t$  is the real price of firm  $\omega$ ,  $y_t^D(\omega)$  is the demand schedule coming from the cost-minimisation problem of the firm ( $y_t^D(\omega) = (p_t(\omega)/P_t)^{-\varepsilon} [C_t + G_t + PAC_t]$ ). Lower-case letters denote firm-specific variables while upper-case ones stand for the aggregate. The consumption and price indices are given, respectively, by:

$$C_t \equiv \left[ \int_0^1 C_t(\omega)^{\frac{\varepsilon-1}{\varepsilon}} d\omega \right]^{\frac{\varepsilon}{\varepsilon-1}},$$

$$P_t \equiv \left[ \int_0^1 P_t(\omega)^{1-\varepsilon} d\omega \right]^{\frac{1}{1-\varepsilon}}.$$

<sup>1</sup> In this paper we do not study deregulation shocks by making  $f_{E,t}$  an AR(1) process as Bilbiie et al. (2007) did in one of their experiment.

Adjusting prices is costly. Hence, nominal rigidity is introduced in the form of price adjustment costs that can be described with a quadratic function as in Rotemberg (1982):

$$PAC_t(\omega) = \frac{\phi_p}{2} \left[ \frac{p_t(\omega)}{p_{t-1}(\omega)} - 1 \right]^2$$

where  $\phi_p$  measures how strong price adjustment costs are.

The real value of firm  $\omega$  in units of consumption at time  $t$ , denoted as  $v_t^{firm}(\omega)$  can be expressed as the sum of present and discounted future dividends:

$$v_t^{firm}(\omega) = E_t \sum_{j=0}^{\infty} \lambda_{t+j} d_{t+j}(\omega)$$

where  $\lambda_t$  is the marginal utility of consumption used to discount future profits. Firms face a death shock occurring with probability  $\delta \in (0, 1)$  in each period.

Thus, at time  $t$ , firm  $\omega$  chooses  $p_t(\omega)$  to maximise  $d_t(\omega)$  subject to  $y_t(\omega) = y_t^D(\omega)$  taking  $w_t$ ,  $P_t$ ,  $C_t$ ,  $PAC_t$ , and  $Z_t$  as given. Equivalently, firm  $\omega$  maximises the present and future discounted value of its profits:

$$\max_{p_t(\omega)} E_t \sum_{j=0}^{\infty} [\beta(1 - \delta)]^j \lambda_{t+j} \left[ \begin{array}{l} \rho_{t+j}(\omega) y_{t+j}^D(\omega) - w_t l_{t+j}(\omega) \\ - \frac{\phi_p}{2} \left( \frac{p_{t+j}(\omega)}{p_{t-1+j}(\omega)} - 1 \right)^2 \rho_{t+j}(\omega) y_{t+j} \end{array} \right]$$

where  $\lambda_t$  is the marginal utility of consumption (defined below at the household's utility maximisation problem),  $\rho_t(\omega) y_t^D(\omega)$  is the revenue,  $w_t l_t(\omega)$  is the cost of labour and the last term appears because of Rotemberg price adjustment costs<sup>2</sup>. The price ratio is given by  $\rho_t(\omega) = \frac{p_t(\omega)}{p_t}$ . The maximisation problem of the firm is subject to the demand curve for the product of an individual firm  $\omega$  ( $y_t^D(\omega) = \left( \frac{p_t(\omega)}{p_t} \right)^{-\varepsilon} y_t$ ), the production function ( $y_t^D(\omega) = Z_t l_t(\omega)$ ).

After taking the first-order condition<sup>3</sup> with respect to the price of an individual firm ( $p_t(\omega)$ ), imposing symmetric equilibrium, introducing the definition of producer-price inflation (PPI)  $\frac{p_t(\omega)}{p_{t-1}(\omega)} = \frac{p_t}{p_{t-1}} \equiv 1 + \pi_t$  and defining the economy-wide real marginal cost as  $\psi_t = w_t/Z_t$  one obtains

$$(\varepsilon - 1) \left( 1 - \frac{\phi_p}{2} (\pi_t)^2 \right) + \phi_p (\pi_t) (1 + \pi_t) - \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \phi_p (\pi_{t+1}) \frac{y_{t+1}^D}{y_t^D} (1 + \pi_{t+1}) \frac{p_{t+1}}{p_t} \right\} = \varepsilon \psi_t \frac{1}{\rho_t}$$

which is the same as equation two in Bilbiie et al. (2007):

$$\rho_t = \mu_t \psi_t = \mu_t \frac{w_t}{Z_t} \tag{2}$$

where

$$\mu_t \equiv \frac{\varepsilon}{(\varepsilon - 1) \left( 1 - \frac{\phi_p}{2} (\pi_t)^2 \right) + \phi_p (\pi_t) (1 + \pi_t) - \beta E_t \left\{ \frac{\lambda_{t+1}}{\lambda_t} \phi_p (\pi_{t+1}) \frac{y_{t+1}^D}{y_t^D} (1 + \pi_{t+1}) \frac{p_{t+1}}{p_t} \right\}} \tag{3}$$

which is the definition of the time-varying price markup. Intuitively, equation (2) can be interpreted as follows: the firm sets the relative price of its product ( $\rho_t$ ) as a markup ( $\mu_t$ ) above the marginal cost ( $w_t/Z_t$ ). The markup is time-varying because of the presence of Rotemberg price-setting frictions.

Next we can also make use of the aggregate production function

$$Y_t^C = \rho_t N_t y_t^D = \rho_t N_t Z_t l_t$$

<sup>2</sup> This price-setting problem has the implausible implication that even new firms have to pay price adjustment cost. Bilbiie et al. (2007) also examines the more plausible case that new firms have to pay this cost from time  $t + 1$ . However, they note that the latter modification has no major impact on their main results.

<sup>3</sup> Further details on the price-setting problem (especially derivations) and also the calculation of the steady-state number of firms can be found in Kaszab (2014).

to substitute for  $y_t^D$  in equation (3):

$$\mu_t \equiv \frac{\varepsilon}{(\varepsilon - 1) \left( 1 - \frac{\phi_p}{2} (\pi_t)^2 \right) + \phi_p (\pi_t) (1 + \pi_t) - \beta E_t \left\{ \mathcal{K}_{t,t+1} \phi_p (\pi_{t+1}) \frac{\frac{y_{t+1}^C}{y_t^C}}{\rho_t N_t} (1 + \pi_{t+1}) \frac{\rho_{t+1}}{\rho_t} \right\}}$$

where we applied the notation of Table (1) for the ratio of marginal utilities ( $\mathcal{K}_{t,t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t}$ ).

## 2.2 THE HOUSEHOLD'S PROBLEM

The representative household maximises the continuation value of its utility ( $V$ ):

$$V_t = \begin{cases} U(C_t, L_t) + \beta [E_t V_{t+1}^{1-\alpha}]^{\frac{1}{1-\alpha}} & \text{if } U(C_t, L_t) \geq 0 \\ U(C_t, L_t) - \beta [E_t (-V_{t+1})^{1-\alpha}]^{\frac{1}{1-\alpha}} & \text{if } U(C_t, L_t) < 0 \end{cases} \quad (4)$$

with respect to its flow budget constraint.  $\beta \in (0, 1)$  is the subjective discount factor. Utility ( $U$ ) at period  $t$  is derived from consumption ( $C_t$ ) and leisure ( $1 - L_t$ ). As the time frame is normalised to one leisure time ( $1 - L_t$ ) is what we are left with after spending some time working ( $L_t$ ). The recursive functional form in equation (4) is called Epstein-Zin preferences and is the same as the one used by RS. The period utility  $U$  which is additively separable in consumption and labour is given by<sup>4</sup>:

$$U(C_t, L_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \chi_0 \frac{L_t^{1+\varphi}}{1+\varphi} \quad (5)$$

where  $\sigma$  is the inverse of the intertemporal elasticity of substitution (IES),  $\varphi$  is the inverse of the Frisch elasticity of labour supply to wages and  $\chi_0 > 0$ . Note that in this paper we consider an IES < 1 so that  $U < 0$  and, thus, the second line of equation (4) is employed.

Swanson (2012) shows that the connection between coefficient of relative risk-aversion (CRRA) and parameter  $\alpha$  of the recursive utility in equation (4) is<sup>5</sup>:

$$CRRA \approx \frac{\sigma}{1 + \frac{\sigma}{\varphi}} + \frac{\alpha(1 - \sigma)}{1 + \frac{\sigma - 1}{1 + \varphi}}$$

Households possess two types of assets: shares in a mutual fund of firms and government bonds. Let  $x_t$  denote the share in the mutual fund of firms entering period  $t$ . In each period the mutual fund pays the representative household a total profit (in units of currency) of all firms that produce in that period,  $P_t N_t d_t$ . In period  $t$  the representative household purchases  $x_{t+1}$  shares in a mutual fund of  $N_{H,t} \equiv N_t + N_{E,t}$  firms where the first term refer to firms already operating at time  $t$  while the second term stands for the new entrants. Only  $N_{t+1} = (1 - \delta)N_{H,t}$  firms will produce and pay dividends at time  $t + 1$ . As the household does not know the share of firms induced to leave the market due to the exogenous exit shock  $\delta$  at the end of period  $t$ , it finances the continuing operation of all preexisting firms and all new entrants during period  $t$ . The nominal price of a claim to the future profit stream of the mutual fund of  $N_{H,t}$  firms at time  $t$  equals to  $V_t^{firm} \equiv P_t v_t^{firm}$ .

At time  $t$  the representative household holds nominal bonds and a share  $x_t$  in the mutual fund. It receives labour income ( $W_t L_t$ ) interest income  $i_{t-1}$  on nominal bonds and dividend income (in nominal terms) on mutual fund share holdings ( $D_t \equiv P_t d_t$ ) in nominal terms and the value of selling its initial share position ( $V_t^{firm}$ ).

Therefore, the period budget constraint of the representative household (in real terms) can be written as:

$$B_{t+1} + v_t^{firm} N_{H,t} x_{t+1} + C_t = (1 + r_t) B_t + (d_t + v_t^{firm}) N_t x_t + w_t L_t + t_t^l$$

where  $B_{t+1} \equiv B_{N,t+1}/P_t$  and  $1 + r_t \equiv (1 + i_{t-1})/(1 + \pi_t^C)$  is the consumption-based gross real interest rate on bond holdings between time  $t - 1$  and  $t$  with consumer-price inflation (CPI) defined as  $\pi_{t+1}^C \equiv P_{t+1}/P_t - 1$ , and lump-sum transfers/taxes  $t_t^l \equiv T_t^l/P_t$ .

<sup>4</sup> Note that this felicity function is slightly different from the one of RS mainly because we abstract from deterministic growth in line with Bilbiie et al. (2007, 2012).

<sup>5</sup> Note that this formula applies only when the utility function in equation (5) is used.

The first-order conditions derived from the households' optimisation problem yield the Euler equations for bond and share-holdings:

$$1 = \beta E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{1 + i_t}{1 + \pi_{t+1}^c} \right\}$$

$$v_t^{firm} = \beta(1 - \delta) E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} (v_{t+1}^{firm} + d_{t+1}) \right\}$$

The intratemporal condition says that labour effort is chosen optimally when the marginal disutility of labour equals to the marginal utility from consuming real wage received for one more hour worked:

$$\chi \frac{L_t^{\frac{1}{\varphi}}}{C_t^{-\sigma}} = \frac{W_t}{P_t}$$

where  $\chi$  is set such that hours worked makes up for one-third of the total time endowment.

## 2.3 MONETARY POLICY

The New-Keynesian model is closed by a monetary policy rule (so called Taylor rule):

$$R_t = \rho R_{t-1} + (1 - \rho)[R + \log \bar{\Pi}_t + \phi_\pi (\log \bar{\Pi}_t - \log \Pi_t^*) + \phi_y (Y_t - Y)/Y] + \varepsilon_t^i \quad (6)$$

where  $R_t \equiv 1 + i_t$  is the policy rate,  $\bar{\Pi}_t$  is a four-quarter moving average of inflation and  $Y$  denotes the steady-state level of  $Y_t$ . As in RS we annualise  $\log \bar{\Pi}$  and  $R$  so that the choice of  $\phi_\pi = 0.53$  corresponds to roughly one-fourth of the empirical estimates using quarterly data (see, e.g., Clarida et al. (2000)).

$\Pi_t^*$  is the target rate of inflation,  $\varepsilon_t^i$  is an iid shock with mean zero and variance  $\sigma_i^2$ . In the baseline version of the Rudebusch and Swanson (2012) model without long-run inflation risks the inflation target is constant ( $\Pi_t^* = \Pi^*$  for all  $t$ ).

The four-quarter moving average of inflation ( $\bar{\Pi}_t$ ) can be approximated by a geometric moving average of inflation:

$$\log \bar{\Pi}_t = \theta_\pi \log \bar{\Pi}_t + (1 - \theta_\pi) \log \Pi_t, \quad (7)$$

where the choice of  $\theta_\pi = 0.7$  ensures that the geometric average in equation (7) has an effective duration of about four quarters. In this paper we do not consider long-run inflation risks as in one of the version of RS.

## 2.4 FISCAL POLICY

The description of the fiscal block is based on Kaszab and Marsal (2013). The government spending follows the process:

$$\log(G_t/G) = \rho_G \log(G_{t-1}/G) + \varepsilon_t^G, \quad 0 < \rho_G < 1,$$

where  $G$  is the steady-state level of  $G_t$  and  $\varepsilon_t^G$  is an iid shock with mean zero and variance  $\sigma_G^2$ .

Rudebusch and Swanson (2012) assume that government spending is financed through lump-sum taxes in each period i.e. government budget is balanced. Instead, we can allow for deficit that is retired through lump-sum taxes:

$$B_t + T_t = \frac{R_{t-1}B_{t-1}}{\Pi_t} + G_t \quad (8)$$

where  $B_t$ ,  $T_t$ ,  $R_t$  and  $\Pi_t$  stand for government debt, lump-sum taxes, short-term nominal interest rate and inflation, respectively. All quantities are expressed as real except for the nominal interest rate ( $R_t$ ).  $R_{t-1}B_{t-1}$  are interest-payments on the previous period debt. If one imposes the restriction of  $B_t = B_{t-1} = 0$  for all  $t$  expression (8) boils down to the case of balanced budget  $G_t = T_t$  for all  $t$ .

The tax rule in case of lump-sum taxes is given by:

$$T_t = \psi B_{t-1} \quad (9)$$

where  $\psi \in (0, 2)$  ensures that fiscal policy is passive in the sense of Leeper (1991). When  $\psi$  is set to be close to zero debt is paid back in the very long-run. By contrast a coefficient of  $\psi$  close to two roughly mimics the case of balanced budget.

An alternative way to retire government debt is through income tax revenue ( $\tau_t Y_t$ ):

$$B_t + \tau_t^i Y_t = \frac{R_{t-1} B_{t-1}}{\Pi_t} + G_t. \quad (10)$$

where  $\tau_t^i$  is the income tax rate. The level of output ( $Y_t$ ) equals to the sum of profit and labour income which are taxed at the same rate.

The tax revenue rule for the latter case is given by:

$$\tau_t^i Y_t = \psi B_{t-1}. \quad (11)$$

Kaszab and Marsal (2013) have shown that the way government spending is financed affects first and second moments calculated from the model to non-negligible extent. Therefore, as an alternative of lump-sum taxes we present results for the case when spending is financed by distortionary taxes levied on labour and profit income.

## 2.5 EQUILIBRIUM

In the symmetric equilibrium all firms make identical choices so that  $p_t(\omega) = p_t$ ,  $d_t(\omega) = d_t$ ,  $y_t(\omega) = y_t$ ,  $v_t^{firm}(\omega) = v_t^{firm}$ ,  $l_t(\omega) = l_t$ ,  $\mu_t(\omega) = \mu$  and  $pac_t(\omega) = pac_t$ .

The labour market clearing is given by:

$$L_t = N_t l_t + N_{E,t} \frac{f_{E,t}}{Z_t} \quad (12)$$

where the firm term on the RHS denotes the amount of labour used in production while the second term stands for the amount of labour employed to set up new firms. One can use equation (12) to back out  $N_{E,t}$  in equation (1).

The aggregate output of the consumption basket ( $Y_t^C$ ) is used for private ( $C_t$ ) and public consumption ( $G_t$ ) and to pay price adjustment costs:

$$\begin{aligned} Y_t^C &\equiv C_t + G_t + PAC_t \\ &= N_t \rho_t y_t \\ &= N_t \rho_t Z_t l_t \end{aligned}$$

The previous accounting identity says that total absorption (the first line) equals to total production (second line). The last line made use of the production function.

# 3 Further properties of our model

We summarised the equations of the model in Table (1) below. This is slightly different from the Table 5.1 of Bilbiie et al. (2007) because our extension contains Epstein-Zin preferences and government spending as well (as in Rudebusch and Swanson (2012)). Note that the Calvo-type of price stickiness used by RS is equivalent to the Rotemberg style price rigidity applied in Bilbiie et al. (2007) and in this paper. In fact, the Rotemberg price adjustment cost parameter can be set such that it implies that the same average duration of price stickiness as the Calvo model.

The model used in this paper departs from Rudebusch and Swanson (2012) to the extent of i) the inclusion of firm entry, ii) the omission of fixed capital (and hence fixed investment)<sup>6</sup> and iii) using a lower estimate on the coefficient of output gap in the Taylor rule ( $\phi_y = 0.125$  which is close to one of the estimate by Clarida et al. (1998) instead of  $\phi_y = 0.93$  in Rudebusch and Swanson (2012)).

We shortly elaborate on points ii) and iii). First, we describe consequences of the omission of fixed capital (see point ii) above). In Woodford (2003) fixed/firm-specific capital is a way of introducing strategic complementarity into price-setting. A higher level of strategic complementarity manifest in a smaller coefficient on the marginal cost (or output gap) in the New Keynesian Phillips curve. Thus, the elimination of fixed capital results in higher coefficient on marginal cost in the Phillips curve and is equivalent to lower level of price-rigidity in the model. In our model we induced a lower level of price stickiness by a smaller  $\phi_p$  which is the parameter of price adjustment costs in the Phillips curve (see equation called markup in Table 1 below).

Regarding iii) we motivate low coefficient on the output gap in the Taylor rule for four reasons. First, in our model a coefficient of  $\phi_y = 0.93$  leads to indeterminacy<sup>7</sup> when entry cost is specified in consumption units (discussed below). The highest output gap coefficient with which the model can be solved is around 0.6. Second, most estimated New Keynesian models place small coefficient on the output gap (see e.g. Smets and Wouters (2007)). Bilbiie et al. (2007) go even further asserting that a small coefficient on the output gap is consistent with the behaviour of the Federal Reserve since that 1980s and places a coefficient of zero on the output gap in many of their experiments. Third, a small positive output gap coefficient is also in line with the empirical evidence (see Clarida et al. (1998) and more in the calibration section). Fourth, it is argued below that the higher is the output gap coefficient the stronger is the negative covariance between consumption and inflation, which is a pre-requisite for achieving a high term premium on long-term bonds (see Kaszab and Marsal (2013) for more on this).

The behaviour of our model with a zero coefficient on the output gap is contrasted with the case of a small, positive coefficient ( $\phi_y = 0.125$ ) by looking at the impulses responses of a positive technology shock (see Figure 1). In both versions the markup responds positively on impact although it turns to negative (below zero) sooner when the output gap coefficient is zero.

Most importantly inflation falls more when  $\phi_y$  is higher than zero strengthening the negative comovement between consumption and inflation and contributing more to the nominal term premium. The reason why inflation plummets to higher extent in case of a positive  $\phi_y$  is due to the reaction of the real interest rate. As Figure 1 indicates real interest rate rises more with ( $\phi_y > 0$ ) and depressing aggregate demand so much that it leads to huge deflation.

Here we provide a brief description of some equations of interest in Table 1. The first equation is the pricing kernel used to value payoffs across time and states of nature. The second and third equations say that the optimal price ratio (or a value of a variety) equals to the marginal cost with a markup which is time-varying due to endogenous entry and price rigidity. Equation four is the variety effect in case of translog preferences (see more below). Alternatively, the variety effect could operate through

<sup>6</sup> We plan to explore the role of physical capital with adjustment costs in the entry model in another paper.

<sup>7</sup> We do not face this challenge when entry costs are defined in effective labour units.

**Table 1**  
**Summary of the Model**

Pricing kernel	$\mathcal{K}_{t,t+1} \equiv \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \left[ \frac{V_{t+1}}{(E_t V_{t+1}^{1-\alpha})^{1/(1-\alpha)}} \right]^{-\alpha}$
Pricing	$\rho_t = \mu_t \frac{w_t}{z_t}$
Markup	$\mu_t = \frac{\theta(N_t)}{(\theta(N_t)-1) \left[ 1 - \frac{\phi_p}{2} \Pi_t^2 \right] + \phi_p \left[ (1+\Pi_t)\Pi_t - \beta(1-\delta)E_t \left[ \mathcal{K}_{t,t+1} \frac{N_t}{N_{t+1}} \frac{Y_{t+1}^c}{Y_t^c} (1+\Pi_{t+1})\Pi_{t+1} \right] \right]}$
Variety effect	$\rho_t = \exp \left( -\frac{1}{2} \frac{\bar{N}-N_t}{\zeta \bar{N} N_t} \right)$
Connection between $\theta$ and $N_t$	$\mu_t(N_t) = \frac{\theta(N_t)}{\theta(N_t)-1} = 1 + \frac{1}{\zeta N_t}$
Profits	$d_t = \left[ 1 - \frac{1}{\mu_t} - \frac{\phi_p}{2} \Pi_t^2 \right] \frac{Y_t^c}{N_t}$
Free Entry	$v_t^{firm} = w_t \frac{f_{E,t}}{z_t}$
Number of firms	$N_t = (1-\delta)(N_{t-1} + N_{E,t-1})$
Intratemporal Condition	$\chi C_t^\sigma N_t^{\frac{1}{\theta}} = (1-\tau_t^i)W_t$
Euler equation (shares)	$v_t^{firm} = \beta(1-\delta)E_t \left\{ \mathcal{K}_{t,t+1} (v_{t+1}^{firm} + d_{t+1}) \right\}$
Euler equation (bonds)	$1 = \beta \mathcal{K}_{t,t+1} \frac{R_t}{1+\Pi_{t+1}^c}$
Output of the consumption sector	$Y_t^c = \left[ 1 - \frac{\phi_p}{2} \Pi_t^2 \right]^{-1} (C_t + G_t)$
Aggregate accounting	$Y_t^c + N_{E,t} v_t^{firm} = W_t L_t + N_t D_t$
CPI inflation	$\frac{1+\Pi_t}{1+\Pi_t^c} = \frac{\rho_t}{\rho_{t-1}}$
Taylor Rule and the definition of $\bar{\Pi}$	We adapted the non-linear version of equations (6) and (7). Plus three more equations describing $U(C_t, L_t) - \beta [E_t (-V_{t+1})^{1-\alpha}]^{\frac{1}{1-\alpha}}$ .
	For details see Kaszab and Marsal (2013) and the appendix of Rudebusch and Swanson (2012).

a CES aggregator ( $\rho(N_t) = N_t^{1/(\theta-1)}$  and  $\theta$  is the constant elasticity of substitution among goods). Moreover, the variety effect can be supplemented with a competition effect such that elasticity of substitution rises in the number of available products as in equation five<sup>8</sup>. Therefore, the markup which is an inverse function of  $\theta$  declines in the number of varieties. As in Bilbiie et al. (2007)  $\zeta$  is chosen such that the steady-state number of firms in the CES and the translog case is the same. Kaszab (2014) provides further evidence that the markup in our model is countercyclical.

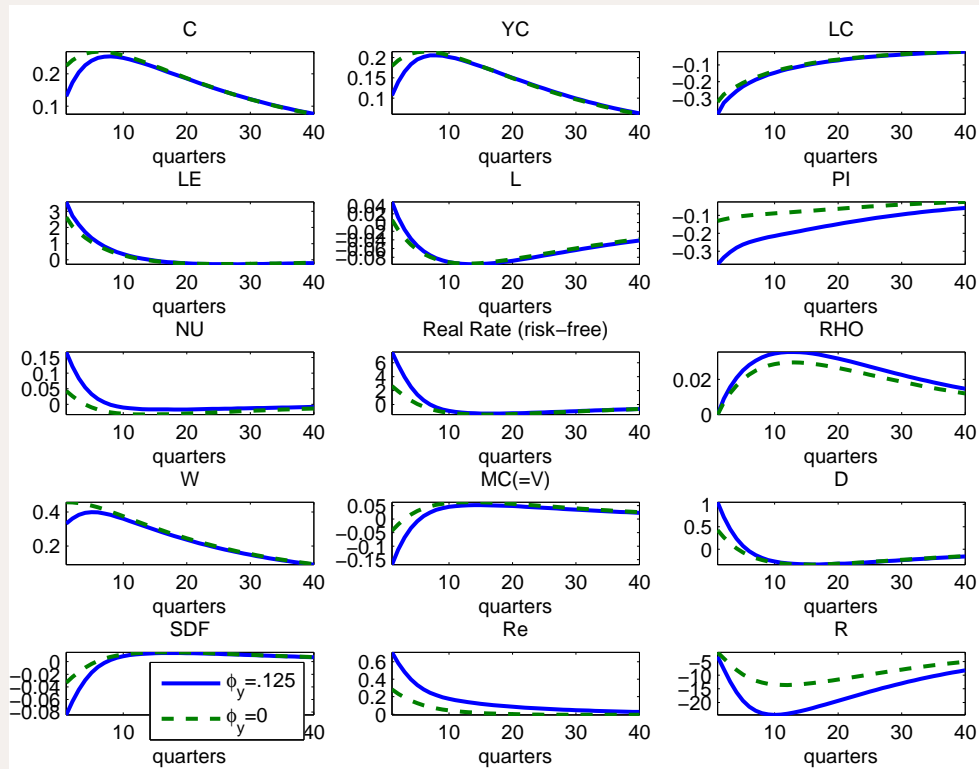
Equation six is the definition of profits. Equation seven is the free-entry condition stating that the value of the firm (the present value of profit) equals to a sunk cost. The entry cost could fluctuate for exogenous reasons (Bilbiie et al. (2012) study deregulation as an exogenous fall in  $f_{E,t}$ ) but we keep it fixed i.e.  $f_{E,t} = f_E$ . Equation eight describes the evolution of the number of firms at time  $t$  ( $N_t$ ) as a function of firms in the previous period ( $N_{t-1}$ ) and new entrants ( $N_{E,t-1}$ ) allowing for the fact that some of existing firms exit with probability  $\delta$ . The interpretation of the rest of the equations is quite standard.

<sup>8</sup> In the literature there are several ways to induce competition effect. In particular, Colciago and Etro (2010a) induce strategic interactions among firms through quantity competition a la Cournot while Colciago and Etro (2010b) consider competition in prices a la Bertrand. Furthermore, Colciago and Etro (2010b) compare the response of the markup to a temporary technology shock under Cournot, Bertrand and translog preferences and conclude that competition effect is the strongest under translog preferences as in Bilbiie et al. (2012).



**Figure 1**

**Impulse responses of selected variables to a positive (temporary) technology shock. All of them are expressed in percentage deviation from steady-state. Inflation, real and nominal interest rates and the return on equity are annualised.**



# 4 Parameterisation and solution method

Parameter values are collected in Table 3 which closely follows Rudebusch and Swanson (2012). The model is approximated to the third-order using Dynare (see Adjemian et al. (2011)). We follow Bilbiie et al. (2007) and assume that the entry cost is unity ( $f_E = 1$ ). We have not found proper guidance<sup>9</sup> on how to calibrate  $\tilde{N}$  so we picked a high value of 10,000 varieties. In fact we do not experience a major change in results when we use either  $\tilde{N} = 1000$  or  $\tilde{N} = 10,000$ . Parameter  $\chi_0$  is chosen such that steady-state hours worked is normalised to one-third of the total time endowment ( $\bar{L} = 1/3$ ). Data on equity premium and the standard deviation of equity is taken from Beaubrun-Driant and Tripier (2005). In this paper the implications of two different estimates of the output gap coefficient (either 0.07 or 0.93) are explored in line with the estimates of Clarida et al. (1998, 2000) and Rudebusch (2002) (for more information see Table 2). The price-adjustment cost ( $\phi_p = 77$ ) coincides with the one in Bilbiie et al. (2007) and is in line with most of the literature.

The steady-state tax rate is pinned down by  $\tau = ((1/\beta)(B/Y) + G/Y)/(1 + 1/\psi)$  where the quarterly steady-state debt-to-GDP ratio ( $B/4Y$ ) is sixty per cent and  $G/Y$  is chosen to be 17 per cent that is in line post-war US evidence. As a baseline we set  $\psi = 0.12$  so that the steady-state tax rate is 0.2767 which is slightly higher than that of Linnemann (2006).

**Table 2**  
**Calibration**

Taylor-rule estimates of Clarida et al. (1998, 2000) for the US

	$\rho$	$\phi_\pi$	$\phi_y$
Rule 1 (Clarida et al. 1998) for 1979-1994	0.92	1.79	0.07
Rule 2 (Clarida et al. 2000) for 1983-1996*	0.79	2.16	0.93

Clarida et al. (1998, 2000) estimated the following forward-looking Taylor rule:  $i_t = \rho i_{t-1} + (1 - \rho)[\phi_\pi \bar{\pi}_{t+1} + \phi_y y_t]$ . In RS  $\bar{\pi}_t$  is used instead of  $\bar{\pi}_{t+1}$ , although we found similar results for the case of  $\bar{\pi}_{t+1}$ . \*Quite close to the values of RS who utilised the estimate by Rudebusch (2002):  $\rho = 0.73$ ,  $\phi_\pi = 2.1$  and  $\phi_y = 0.93$  [Remark: in RS inflation is annualised in their Taylor rule and, therefore,  $\phi_\pi = 0.53$  is set].

<sup>9</sup> Bilbiie et al. (2007, 2012) use the first-order loglinear form of the entry model and they can rewrite the model in such a way that  $\tilde{N}$  drops. However, when the non-linear model is maintained as in this paper  $\tilde{N}$  cannot be eliminated.

**Table 3**  
**Calibration**

$\sigma$	2	$\varphi$	3/2	$\rho_i$	0.73	$\rho_Z$	0.95
$\beta$	0.99	CRRRA	75	$\phi_\pi$	0.53	$\rho_G$	0.95
$\bar{L}$	1/3	$\theta$	0.2	$\phi_y$	0.125	$\rho_M$	0
$G/Y$	0.17	$\phi_p$	77	$\Pi^*$	1	$\sigma_Z^2$	0.005 <sup>2</sup>
$\varepsilon$	6					$\sigma_M^2$	0.003 <sup>2</sup>
$B/(4Y)$	0.6					$\sigma_G^2$	0.004 <sup>2</sup>

where  $G/Y$  is the government spending-to-GDP ratio. This table follows the calibration of RS except for the value of  $\phi_y$  and  $\phi_p$  which they have chosen to be 0.93 and 233, respectively.

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# 5 Results

## 5.1 ENTRY COST IN EFFECTIVE LABOUR UNITS

### 5.1.1 EQUITY PREMIUM

The mean excess return on equities (i.e. equity risk-premium) is 3-7 per cent depending on the sample considered and the annualised standard deviation of equities is at least 15 per cent (see, e.g., Donaldson and Mehra (2008)). Equity premium is defined as the return on the profit (dividend) claim minus the return on the risk-free asset. All profits are paid out as dividends. Our New Keynesian model with costly firm entry model produces a high equity premium relative to the baseline New Keynesian model without entry. Table 4 reports macro and finance statistics of the models with/without entry for different values of the output gap coefficient in the Taylor rule. The success of the entry model at explaining the equity premium is due to the strong positive correlation between dividends and equity return that is absent in the model without entry. In particular, this correlation is 0.87 in CES while 0.95 in the translog case. It is important to emphasize that the entry model generates a high mean of the equity premium independently of the recursive preferences in the model. There is no need for Epstein-Zin preferences and/or high risk-aversion to arrive at a high equity premium from the entry model.

Equities are considered to be risky when their real returns comoves strongly with the business cycle (output) in general. The return on equity is procyclical in the model when the variety effect is in CES form (this correlation of the equity with output is 0.35). Intuitively, it is risky to hold equity because it brings low real returns in bad times when consumption is valued the most (the marginal utility of consumption is high or, equivalently, consumption is low). Another essential contributor to risk premia is the strong positive correlation between profits and inflation.

The average annual volatility of equities is found to be at least 15 per cent in the data (see, e.g., Donaldson and Mehra (2008)). Currently our entry model with fiscal policy can capture roughly one-fourth of this volatility (see the last row and the last column of Table 6). Further research should be done to explore the ways of improving the fit of the model to the volatility of equity.

### 5.1.2 INFLATION RISKS

In this section we argue that our model exhibits inflation risks when coefficient on the output gap in the Taylor-rule is small. Before that we shortly summarise the empirical evidence on the inflation risk content of long-term nominal bonds. Early studies which do not include information from indexed bonds usually predict substantial inflation risk-premia based on no-arbitrage models. One such paper is by Buraschi and Jiltsov (2005) who find an average inflation risk premium of 70 basis points from 1960. Ang et al. (2008) estimate a term-structure model in which US inflation display regime-switching and report an inflation risk premium of around 115 basis points on average for bonds of five-year maturity over the period 1952-2004. Studies that incorporate information from indexed bonds reveal smaller estimates. For instance, Durham (2006) estimates a no-arbitrage model using US TIPS data and find a slightly positive inflation risk-premia for the sample starting at 2003. Before 2003 risk premia on 10-year inflation indexed bonds reflected liquidity risks rather than inflation risks. D'Amico et al. (2008) employ a model similar to Durham (2006) utilising data from 1990 onwards and report a positive and relatively stable 10-year inflation risk premium of about 50 basis points.

Inflation risks can be approximated to high precision in case of a third-order Taylor approximation that we make use of as the difference between nominal and real term premia (see Andreasen (2012)). The case when entry cost is defined in terms of effective labour units is treated as the baseline in Bilbiie et al. (2012) and in our paper as well. We present a detailed decomposition of the nominal and real term premium in Table 4. In particular, nominal term premium is calculated as the

difference between the yield on a 10-year nominal bond held by a risk-averse investor ( $\text{yield}_{10\text{-year}}^{\text{nom}}$ ) and the yield on a nominal bond that is rolled over—in each quarter—for 10 years ( $\text{yield}_{10\text{-year}}^{\text{nom, eh}}$ ). The latter can be interpreted as the yield expected by a risk-neutral investor and is consistent with the expectations hypothesis (*eh*) of the term structure. Similarly, real term premium is the difference between the same measures but for inflation-indexed (real) bonds i.e.  $\text{RTP} = \text{yield}_{10\text{-year}}^{\text{real}} - \text{yield}_{10\text{-year}}^{\text{real, eh}}$ .

We make the following observations. First, the correlation between inflation and consumption growth is negative in our model unlike the RS without entry where it is slightly negative only when coefficient on output gap is high in the Taylor-rule. Second, nominal uncertainty ( $\sigma(\hat{\pi})$ ) is much higher in the model with entry (5.43) than in the model without entry (1.63). Third, real uncertainty ( $\sigma(\Delta\hat{c})$ ) is higher in the model with entry. Fourth, nominal term premium is higher in the model without entry irrespectively of the size of the coefficient on the Taylor rule. Fifth, RTP is low in the model without entry when output gap coefficient is high and there are substantial inflation risks with the opposite being true in case of a high coefficient on the output gap. Sixth, exactly the inverse of observation five is true in our model i.e. RTP is high in the model with entry.

Before we provide intuition regarding the previous observations, it is worth having a look at nominal and real yield curves as well as the inflation risk premium obtained from the entry model (see Figure 2). On the left-hand side of the graph we can see that the nominal yield curve is above the real yield curve mainly for bonds with maturities of at least 10 or 15 quarters depending on whether lump-sum or distortionary taxation is assumed. The difference between nominal and real term structure captures inflation risks. On the right hand side we observe that the nominal term premium is higher than real term premium and, thus, inflation risks emerge. The previous plot is generated based on the assumption that the coefficient on the output gap is low ( $\phi_y = 0.125$ ).

However, the RS model without entry implies positive inflation risks only when the coefficient on the output gap is high ( $\phi_y = 0.93$ ). To show this we plot yield curves of the RS model without entry on Figure 3. On the left panel of the preceding figure inflations risks are positive for  $\phi_y = 0.93$  while, on the right panel, they are negative for  $\phi_y = 0.125$ . Hördahl et al. (2008) employ a model similar to RS with low coefficient on the output gap and also find that inflation risks are zero. It is well-known about the New Keynesian model that the higher is the coefficient on the output gap in the Taylor rule (*ceteris paribus*) the higher is the standard deviation of inflation (or other nominal variables in general) and the amount of inflation risks (see e.g. Clarida et al. (1999)). Hence, the size of the coefficient on the output gap appears to be a key determinant of inflation risks.

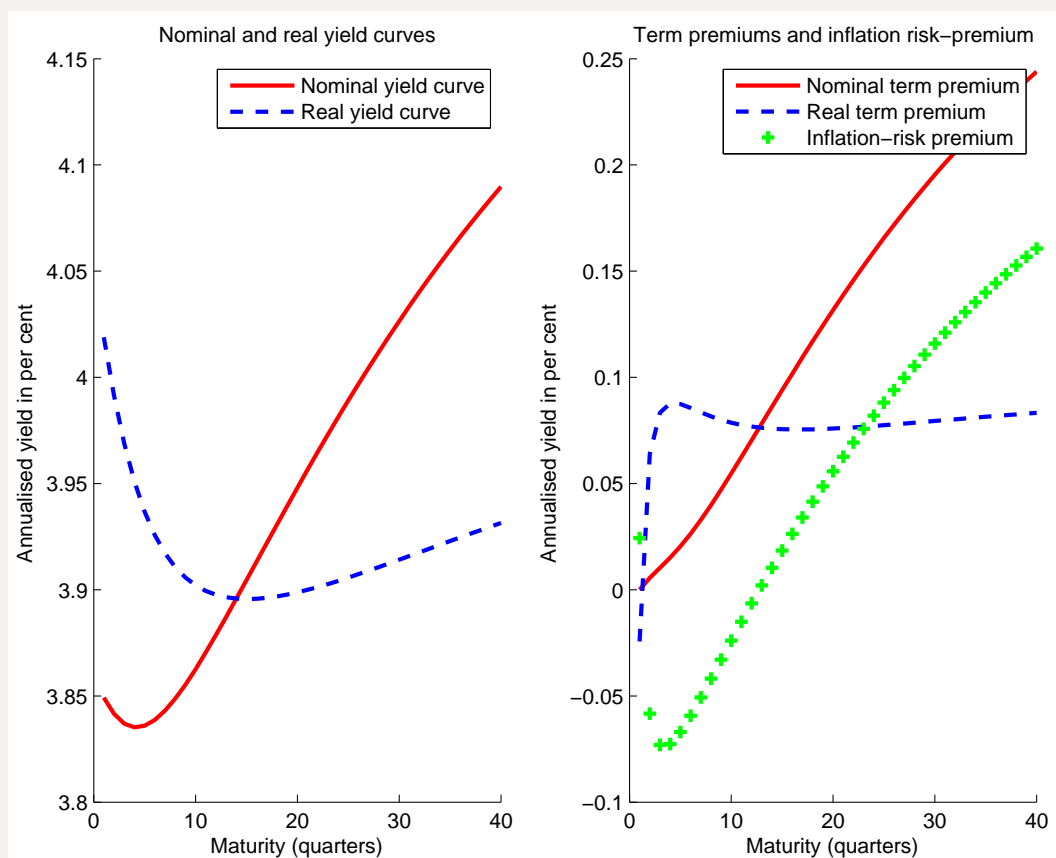
One can gain insight into the workings of the models with/without entry by inspecting the inflation and output gap volatility trade-off. In the RS model without entry the inflation-output gap volatility trade-off is the standard one: a higher coefficient on the output gap reduces real uncertainty (the standard deviation of the output gap) and raises nominal uncertainty (the standard deviation of inflation) (see, e.g., Clarida et al. (1999)). Rather surprisingly this trade-off becomes non-linear after adding entry to the New Keynesian model. For an output gap coefficient of lower than 0.5 the trade-off is maintained similar to the standard New Keynesian model. However, for output gap coefficients of 0.5 or above the trade-off between inflation and output gap volatility disappears. Figure (4) and (5) show that these findings are independent of the specification of the entry costs that can be either in effective labour units or in consumption units (see more on this below), respectively. The figures also indicate that the standard deviations for both inflation and output gap are higher for the entry model in general.

After comparing Figure 6 and 7 we recognise that the response of the short-term real interest rate on impact is much stronger in the model with entry compared to the one without entry implying that real interest rate increases to a large extent in order to counteract the sizeable real and nominal uncertainty when coefficient on the output gap is high ( $\phi_y = 0.93$ ). Also it is not surprising that the short-term real rate jumps more in the entry model where there is an additional surge in GDP due to higher investment into new firms which the central bank aims to counteract. Figure 6 and 7 also reveal that differences in the short-term real rates are reflected by long-term real rates as well. Indeed, the 10-year real rate ( $\text{yield}_{10\text{-year}}^{\text{real}}$ ) falls in the model without entry after a positive innovation to technology while 10-year real rate in the entry model jumps to the same shock. These differences are more pronounced the higher is the coefficient on the output gap.

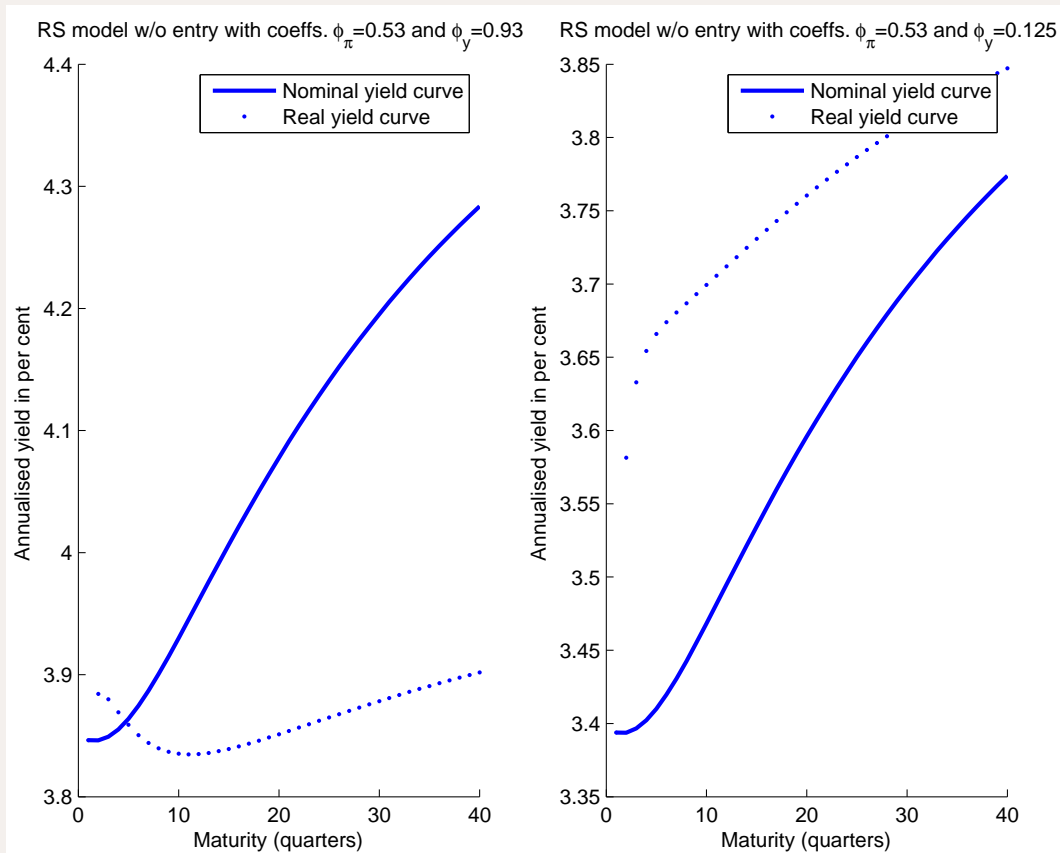
Therefore, it follows that our model implies low real term premium when the output gap coefficient is large. When the coefficient on the output gap is high real risks emerge which are reflected by the higher real term premium. In the latter case the inflation risk premium turns to negative. On the contrary the entry model exhibits substantial real term premium (real/consumption risks) and a reduced nominal term premium for a high output gap coefficient and, thus, there are no inflation risk which is, in fact, negative.

Finally we compare models without and with entry in case of a low output gap coefficient. As shown before the volatility of inflation is higher in the entry model than in the one without entry. Hence the entry model is more successful in producing

**Figure 2**  
Yield curves, nominal and real term and inflation-risk premium



**Figure 3**  
**Yield curves from the Rudebusch and Swanson (2012) model without entry and with different coefficients on the output gap.**



a high nominal term premium. Importantly we find that the 10-year real rate consistent with the expectations hypothesis ( $\text{yield}_{10\text{-year}}^{\text{real}, eh}$ ) is smaller in the model without entry. This happens because of the precautionary savings effect which is stronger in the entry-less model leading to lower real interest rates but higher real term premium. In the opposite case, firm-entry can be interpreted as a mechanism for households to insulate themselves from negative outcomes of technology and to rely less on precautionary savings to smooth consumption.

**Table 4**  
**Unconditional moments of the term-structure**

Unconditional moments	Data	$\phi_Y = 0.93$	$\phi_Y = 0.125$
		RS model without entry	
$\text{corr}(\Delta\hat{c}, \hat{\pi})$	-0.35*	-0.20	0.11
$\sigma(\hat{\pi})$	2.52	1.63	0.92
$\sigma(\Delta\hat{c})$	1.96*	0.86	0.74
(a) $\text{yield}_{10\text{-year}}^{\text{nom}}$	6.94^	4.3792	3.7524
(b) $\text{yield}_{10\text{-year}}^{\text{nom}, eh}$	na	3.8443	3.3306
(c) $\text{yield}_{10\text{-year}}^{\text{real}}$	1.96^	3.8665	3.8263
(d) $\text{yield}_{10\text{-year}}^{\text{real}, eh}$	na	3.8443	3.3306
(e) NTP(=a-b)	1.06	0.53	0.42
(f) RTP(=c-d)	$\approx 1.00^\circ$	0.01	0.49
IRP(=e-f)	$0.5^\circ$	0.51	-0.07
EQPR	6.2	1.08	0.81
		Our model	
$\text{corr}(\Delta\hat{c}, \hat{\pi})$	-0.35*	-0.45	-0.55
$\sigma(\hat{\pi})$	2.52	5.43	1.38
$\sigma(\Delta\hat{c})$	1.96*	2.16	1.83
(g) $\text{yield}_{10\text{-year}}^{\text{nom}}$	6.94^	3.6551	4.0898
(h) $\text{yield}_{10\text{-year}}^{\text{nom}, eh}$	na	3.5221	3.8234
(j) $\text{yield}_{10\text{-year}}^{\text{real}}$	1.96^	3.9872	3.9314
(k) $\text{yield}_{10\text{-year}}^{\text{real}, eh}$	na	3.5254	3.8482
(l) NTP(=g-h)	1.06	0.13	0.24
(m) RTP(=j-k)	$\approx 1.00^\circ$	0.46	0.08
IRP(=l-m)	$0.5^\circ$	-0.33	0.16
EQPR	6.2	11.43	10.51

where  $\text{yield}_{10\text{-year}}^{\text{nom}}$  ( $\text{yield}_{10\text{-year}}^{\text{real}}$ ) stands for the unconditional mean on a 10-year nominal (real) bond while  $\text{yield}_{10\text{-year}}^{\text{nom}, eh}$  ( $\text{yield}_{10\text{-year}}^{\text{real}, eh}$ ) denote yields for a 10-year nominal (real) bond which is consistent with the expectations hypothesis of the term structure. Corr,  $\sigma$ , NTP, RTP, IRP and EQPR are abbreviations of the unconditional correlation, standard deviation, nominal term premium, real term premium, inflation risk premium and equity premium. Data on  $\sigma(\pi)$  and NTP is from Rudebusch and Swanson (2012). All simulated results in this table are generated by a 2nd order approximation of the non-linear models using our baseline calibration in Table 3.

\*the source is Binsbergen et al. (2012) who used US NIPA data over 1953-2008.

^the source are the databases of Gürkaynak et al. (2007, 2008).

°inflation risk premium and RTP is the estimate by D'Amico et al. (2008). They note that most of the RTP is liquidity premium (especially in the early years of TIPS). None of the models in this paper can capture liquidity risks.

na=not identified from the data.

### 5.1.3 UNCONDITIONAL MOMENTS

Table 5 collects several simulated macro and finance moments. The first column is taken from RS and contain moments calculated from US data for the period 1961-2007. The second column shows simulated moments based on our reproduction of the RS model (our results and theirs are quite similar). The third column (denoted with A) provides simulated moments of the RS



**Figure 4**  
 Trade-off between inflation and output-gap volatility in the Rudebusch and Swanson (2012) model with and w/o entry (entry costs are specified in effective labour units). The coefficient on the output-gap increases as we move from left to the right.

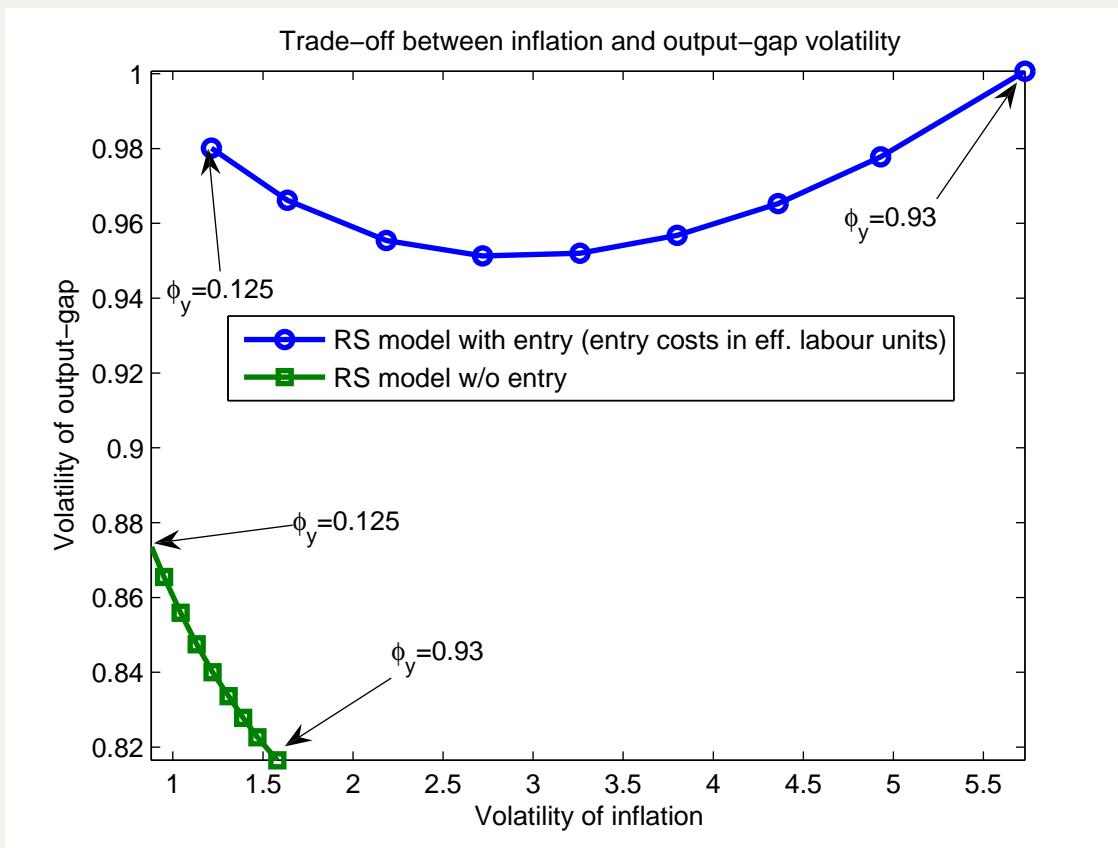


Figure 5

Trade-off between inflation and output-gap volatility in the Rudebusch and Swanson (2012) model with and w/o entry (entry costs are specified in consumption units). In this case we faced difficulties with simulations when the output-gap coefficient was higher than  $\phi_y > 0.5$  so that we graph inflation-output-gap volatility pairs for  $\phi_y \in [0.125, 0.5]$ . The coefficient on the output-gap increases as we move from left to the right.

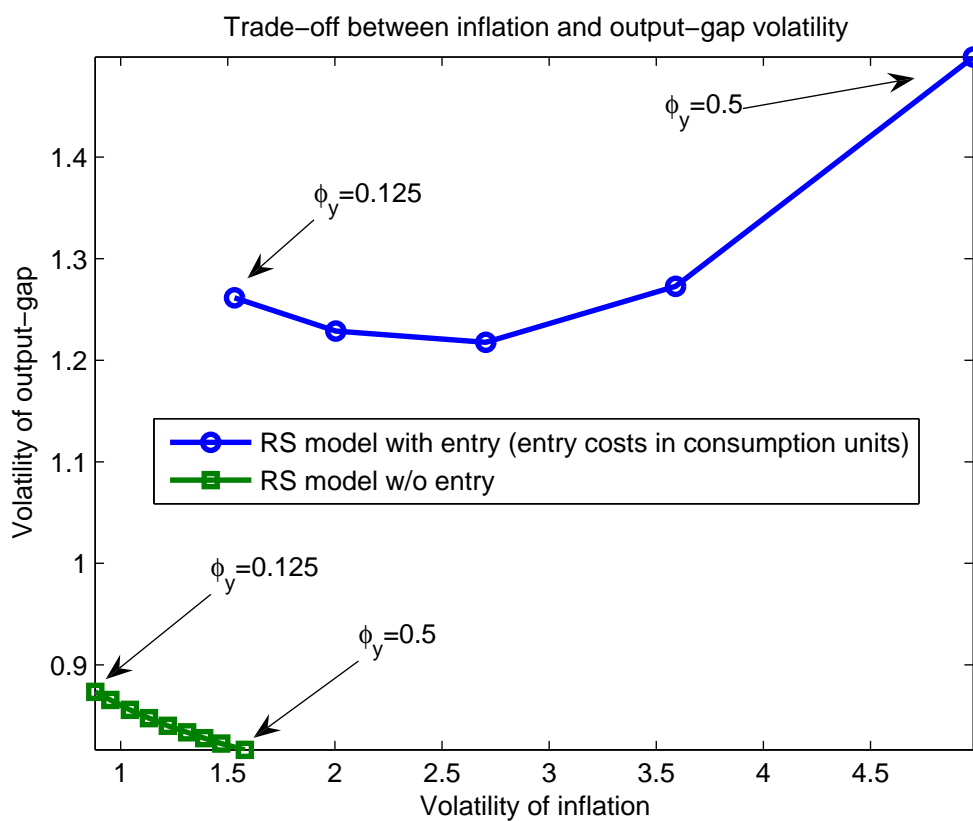


Figure 6

Impulse responses of selected variables to a positive (temporary) technology shock using the Rudebusch and Swanson (2012) model with entry. All of them are expressed in percentage deviation from steady-state. Inflation, real and nominal interest rates and the return on equity are annualised.

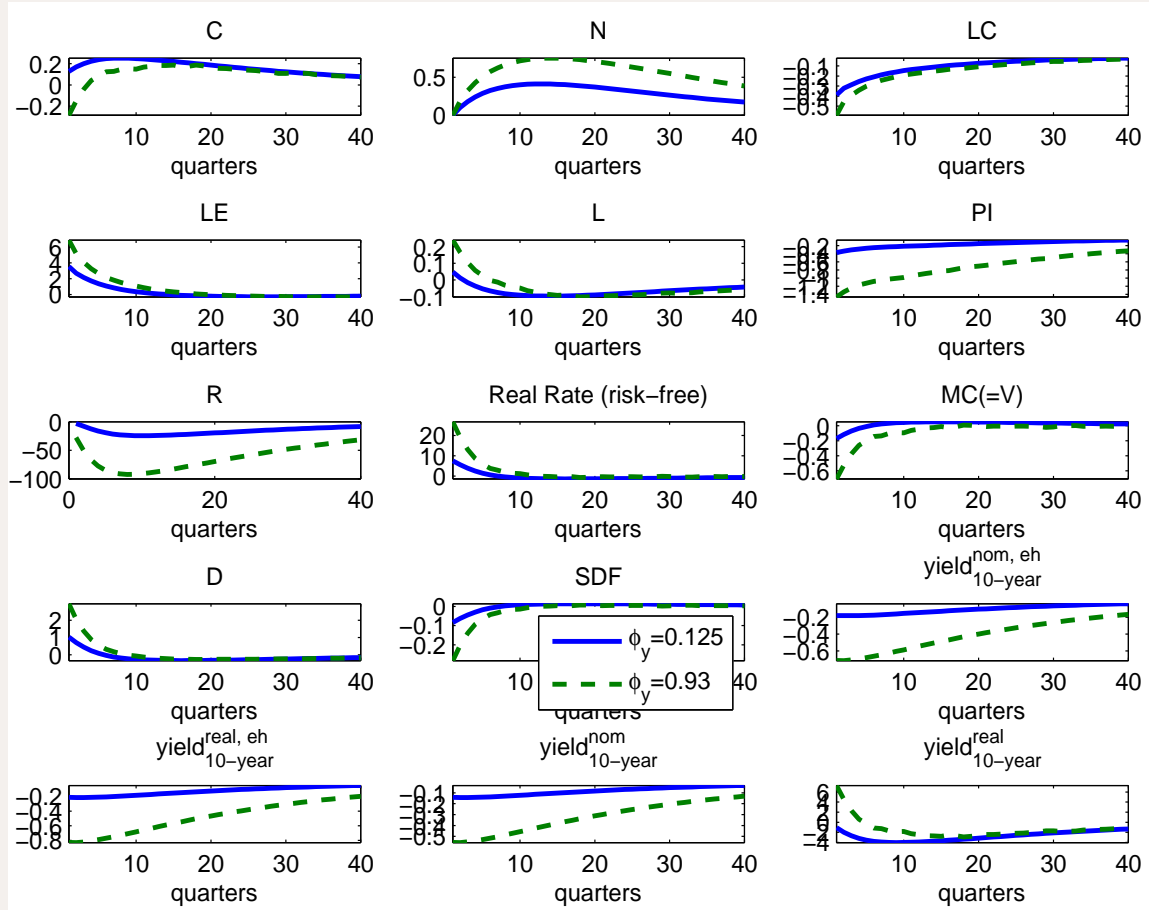
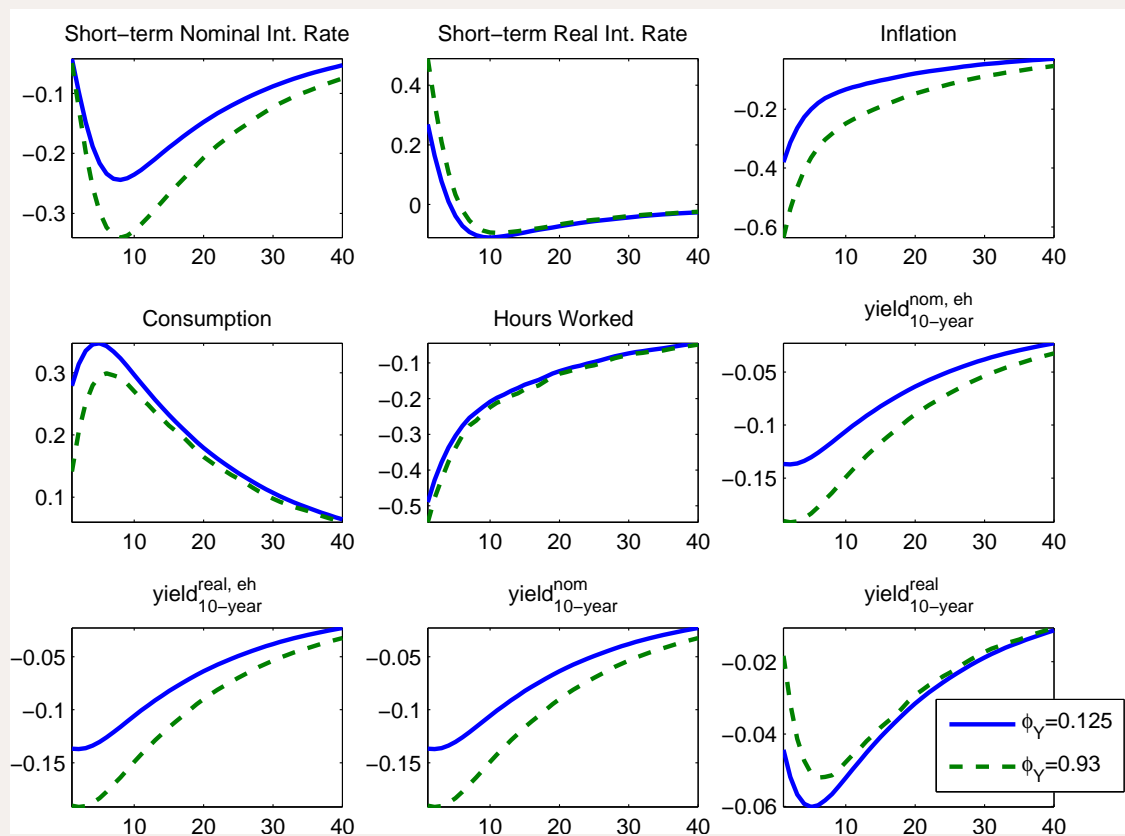


Figure 7

Impulse responses of selected variables to a positive (temporary) technology shock using the Rudebusch and Swanson (2012) model without entry. All of them are expressed in percentage deviation from steady-state. Inflation, real and nominal interest rates and the return on equity are annualised.



model with firm entry using temporary technology and fiscal shocks. All the columns except for E and F are based on the model in which government spending is financed by lump-sum taxes. However, column E and F present an alternative when spending is covered through income taxation as in the previous chapter.

Nominal term premium on a long-term bond, say a 10 year-bond, is computed as the return on the risky 10-year bond minus the return on a bond that is rolled over for 10 years. The yield on the latter strategy is often called as risk-neutral yield which is consistent with the expectations hypothesis of the term structure. Besides the mean and standard deviation of the nominal term premium we report its alternative measures like the slope of the term structure and the excess holding period return. The slope of the term structure is the difference between the yield on a long-term bond (say a 40-quarter bond) and the short-term bond ( $R^{(40)} - R$ ). The excess holding period return ( $x^{(40)}$ ) is defined e.g. for a 40-quarter bond as:  $p_t^{(39)}/p_{t-1}^{(40)} - R_{t-1}$  where the first term is the gross return to holding the 40-quarter bond for one period ( $p$  is the price of the bond) and the second term is the gross one-period risk-free rate.

Consistent with Bilbiie et al. we also provide moments of real variables that are consistent with the change in the composition of goods of the consumption basket after the arrival of new varieties. In particular, a data-consistent variable  $\bar{X}$  is calculated as  $X/\rho$  where  $\rho$  is the price ratio that changes with the appearance of new varieties. Data-consistent variables can be found in column B, D and F. Generally, data-consistent standard deviations are higher than the baseline ones except for consumption.

The inclusion of the monetary policy shock (see columns C and D) facilitates the match of data for nominal and real interest rates. Also, we establish after comparing column A with columns C and D that our model containing all three shocks outperforms the RS model without entry in achieving higher standard deviations for short-term nominal and real interest rates and a lower standard deviation for consumption. A shortcoming of our model is the small standard deviation of labour compared to data. However, the introduction of fiscal policy with income taxation mitigates this problem to some extent (see columns E and F). On the negative side fiscal policy with income taxation further magnifies the standard deviation of real wage departing more from its empirical counterpart. It deserves some explanation why fiscal policy with income taxation is able to raise the standard deviation of labour and real wage.

Fiscal policy has substitution and wealth effects. The higher variability of hours worked is associated with a rise in government spending that is covered (partly) by higher labour taxes making people reduce (increase) their labour supply due to the substitution (wealth) effect. At the same time income taxation leads to higher standard deviation of the pre-tax real wage compared to the lump-sum taxes case and we depart more from its empirical counterpart. Thus, fiscal policy with income taxation improves (worsens) the fit in terms of labour (real wage).

## 5.2 ENTRY COST IN CONSUMPTION UNITS

### 5.2.1 UNCONDITIONAL MOMENTS

In the previous section entry cost is defined in units of effective labour that is equal to the firm's value ( $v_t = w_t \frac{f_{E,t}}{A_t}$ ). Following Bilbiie et al. (2012) we can instead assume that all labour is utilised in the goods-producing sector and entry cost is defined in units of the consumption basket (entry cost has a different notation now:  $f_{E,t}^C$ ). Still we maintain the assumption that entry cost is constant ( $f_{E,t}^C = f_E^C$  for all  $t$ ). This modification imply some changes in the equations listed in Table 1 above. In particular, there is no need to differentiate output of the consumption sector from the whole GDP so that the accounting identity becomes  $Y_t = N_t \rho_t y_t = w_t L_t + N_t d_t$  and there is no longer sectoral reallocation of labour between product creation and production of consumption goods. This also means that  $Y_t$  replaces  $Y_t^C$  in the definition of profits and there is no need for a separate equation defining  $Y_t^C$ . Remember that in the model of Bilbiie et al. the real price of investment ( $v_t$ ) is time-varying and is equal to the entry cost in effective labour units ( $w_t \frac{f_{E,t}}{A_t}$ ). However, in this case the consumption-based price of investment is constant and equal to one unit of consumption (after imposing the normalisation of  $f_E^C = 1$  as in Bilbiie et al.)

Results from applying a second-order approximation<sup>10</sup> to the model are collected in Table 6. The structure of the columns is similar to that of the previous table. This version of the model definitely improves upon the baseline one not just in terms

<sup>10</sup> Unfortunately, we obtain a non-trivial error in Dynare when taking a third-order approximation so we have to rely on second-order approximation in this case.

of higher nominal term premium but also producing higher standard deviations for both macro and finance moments. The standard deviation of the nominal term premium is zero because of the second-order approximation. However, it would turn to positive with an approximation to the third-order<sup>11</sup>.

It also needs to be added that distortionary fiscal policy elevates real/consumption risks and not inflation risks in this version of the model. An analogous way of stating this is that the additional increase nominal term premium occurs due to a rise in the real term premium and not inflation risk premium. This is in stark contrast to RS where the high nominal term premium is due to substantial inflation risks. It seems to be reasonable that the model with entry costs in effective labour units predicts higher inflation risks than the model where entry costs are in consumption units as the former one implies higher wage costs to finance new entrants following a positive productivity shock and also higher marginal cost and inflation through the New Keynesian Phillips curve.

## 5.2.2 ROBUSTNESS CHECKS

In Table (7) we perform robustness checks using the model in which entry costs are expressed in terms of consumption units and government spending is covered by income taxes. All three shocks are employed. In column A and B we gauge how much our results change in the absence of price-rigidity i.e. setting  $\phi_p = 0$  which is the case of fully flexible prices. In line with findings of previous literature (see, e.g., de Paoli et al. (2010)), nominal term premium has increased. However, the standard deviation of real interest rate became counterfactually low.

Some papers like Binsbergen et al. (2012) argue that it is relatively easier to generate high equity premium with lower EIS as in our paper rather than a higher one. In Column C and D we cut EIS to 0.3, *ceteris paribus*. Even if there is some improvement in terms of matching standard deviation of the equity return, the model undershoots in terms of the volatilities of finance variables relative to data. Most importantly, we find that the size of the equity premium is not affected by the higher EIS.

In column E and F we investigate into the case of a lower Frisch elasticity ( $1/\varphi = 0.28$ ). On the negative side, the model overshoots the standard deviation of consumption, real wage and hours worked relative to data. On the positive side the finance moments are closer to the data. For instance, nominal term premium has risen to 75 basis points from 55 basis points.

In the last two columns (G and H) EIS and Frisch elasticity are simultaneously reduced while risk-aversion is increased—as a further attempt to match data (for a similar experiment see RS and also Kaszab and Marsal (2013))—to values which can help match the empirical level of the nominal term premium. In particular, the EIS, the Frisch elasticity and risk-aversion are set to 0.3, 0.28 and 85 respectively. In RS without entry risk-aversion needs to be raised to 110 in order to arrive at a high mean value of the nominal term premium consistent with data. However, the RS model with entry allows us to produce the empirical mean of the nominal term premium with smaller upward movement in risk-aversion (to 85) relative to the baseline value (75).

<sup>11</sup> This confirms Rudebusch and Swanson (2012) who argue that the nominal term-premium is time-varying only when the model (or, at least, the asset-pricing equations) is approximated to the third-order.

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## 6 Conclusion

This paper has shown that the Rudebusch and Swanson (2012, RS) model extended with firm entry can *jointly* explain the high empirical means of bond and equity premium reasonably well without worsening the fit of the model to key macroeconomic variables. In our model the procyclical firm entry is the major contributor to the equity premium. Both bond and equity premium are driven by supply shocks in the model. For example, positive temporary technology shocks ignite firm entry due to higher expected profits. All profits are paid back to households in the form of dividends. Bad times are associated with a series of negative supply shocks, less investment into new firms, lower profit income and smaller return on equities. Hence, investors command a premium on equities due to their procyclical nature.

The nominal term premium (a type of risk premium) on long-term default-free bonds (like US Treasuries) emerges due to the negative covariance between consumption growth and inflation induced by temporary productivity shocks. For instance, a low realisation of productivity causes low consumption and high inflation eroding the real return of nominal bonds. Therefore, nominal bonds which bring low real return in bad times are considered to be risky.

We have argued that the RS model without entry generates inflation risks only when the output gap coefficient in the Taylor rule is high. This happens because a high output gap parameter enlarges the standard deviation of inflation and, thus, inflation risks. However, the entry model gives rise to inflation risks even when the coefficient on the output gap is low for two reasons. On one hand the entry model exhibits higher variability of inflation (and also inflation risks) than the model without entry independently of the value of the output gap parameter. On the other hand households can smooth their consumption better through the wider range of varieties due to entry. As a consequence real term premium (and also real risk) is lower in the entry model.

A shortcoming of our model is that it cannot capture the enormous volatility of the stock return (15 per cent). Therefore, future research should address the ways our model can increase the standard deviation of the return on equity without magnifying the volatility of macro variables extremely. This is quite a challenging exercise if we insist on small-size shocks as done in this paper. However, an extension of our model with capital definitely deserves further exploration.

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Table 5

Simulated Moments from Variants of Our Model Compared to US Data (in this variant of the model entry costs are in effective labour units)

Unconditional Moment	US data, 1961-2007	$\mathcal{RS}$	$\mathcal{RS}'$	A	B	C	D	E	F
SD(C)	0.83	1.42	1.58	0.93	0.87	1.01	0.97	1.15	1.09
SD(L)	1.71	1.5	1.12	0.40	0.63	0.43	0.66	0.59	0.83
SD(W)	0.82	1.32	1.64	1.33	1.33	1.47	1.49	1.54	1.52
SD( $\pi$ )	2.52	1.64	1.04	1.44	-	1.62	-	1.59	-
SD( $R$ )	2.71	1.6	1.18	1.43	-	2.01	-	2.09	-
SD( $R^{real}$ )	2.30	0.93	0.77	0.57	0.63	1.87	2.06	1.9	2.07
SD( $R^{(40)}$ )	2.41	0.85	0.58	1.01	-	1.03	-	0.96	-
Mean( $NTP^{(40)}$ )	1.06	0.39	0.42	0.28	-	0.29	-	0.30	-
SD( $NTP^{(40)}$ )	0.54	0.04	0.01	0.02	-	0.02	-	0.02	-
Mean( $R^{(40)} - R$ )	1.43	0.43	0.49	0.27	-	0.30	-	0.37	-
SD( $R^{(40)} - R$ )	1.33	0.9	0.68	0.56	-	1.47	-	1.58	-
Mean( $x^{(40)}$ )	1.76	0.69	0.87	0.48	-	0.51	-	0.57	-
SD( $x^{(40)}$ )	23.43	7.81	6.07	8.94	-	9.14	-	8.85	-
Equity Premium	6.2	0.85	0.81	7.46	-	7.49	-	10.61	-
SD( $Re$ )	15.98	1.20	1.20	1.46	1.29	2.63	2.68	2.75	2.79

where  $SD$ =standard deviation,  $NTP^{(40)}$ =nominal term premium on a 40-quarter bond, Mean=Unconditional Mean,  $R^{(40)} - R$  is the slope and  $x^{(40)}$  is the excess holding period return for a 40-quarter bond.  $Re$  is the return on equity. Each version of the models listed above utilises the *baseline calibration* of Rudebusch and Swanson (2012) that does not fit finance moments of US data (neither here nor in their paper).

$\mathcal{RS}$ =reproduction of the results of Rudebusch and Swanson (2012) without entry (Note that their results are very close to ours.) using *their calibration*.  $\mathcal{RS}'$  shows results from the RS model using *our baseline calibration*. Both  $\mathcal{RS}$  and  $\mathcal{RS}'$  contain technology, fiscal (lump-sum taxation) and monetary policy shocks.

Columns A-F make use of our model with the *baseline calibration* in Table 3 and employing the following shocks:

A=Technology and fiscal shock (lump-sum taxation).

B=Technology and fiscal shock (lump-sum taxation), data-consistent real variables.

C=Technology, fiscal (lump-sum taxation) and monetary policy shocks.

D=Technology, fiscal (lump-sum taxation) and monetary policy shocks, data-consistent real variables.

E=Technology, fiscal (income taxation) and monetary policy shocks.

F=Technology, fiscal (income taxation) and monetary policy shocks, data-consistent real variables.

Note that column  $\mathcal{RS}'$  is comparable only with columns C (and D) as they are based on the same types of shocks and the same calibration.

Table 6

Simulated Moments from Variants of Our Model Compared to US Data (in this variant of the model entry costs are in consumption units)

Unconditional	US data,	$\mathcal{RS}'$	A	B	C	D	E	F
Moment	1961-2007							
SD(C)	0.83	1.60	1.12	0.98	1.33	1.08	1.58	1.41
SD(L)	1.71	1.17	0.83	1.28	0.92	1.50	0.92	1.31
SD(W)	0.82	1.63	1.18	1.09	1.87	1.75	1.89	1.72
SD( $\pi$ )	2.52	1.06	1.58	-	1.90	-	2.03	-
SD(R)	2.71	1.22	1.53	-	2.21	-	2.61	-
SD( $R^{real}$ )	2.30	0.80	0.54	0.64	0.97	1.16	1.25	1.36
SD( $R^{(40)}$ )	2.41	0.59	0.88	-	1.59	-	1.10	-
Mean( $NTP^{(40)}$ )	1.06	0.42	0.30	-	0.38	-	0.55	-
SD( $NTP^{(40)}$ )	0.54	0.00	0.00	-	0.00	-	0.00	-
Mean( $R^{(40)} - R$ )	1.43	0.46	0.47	-	0.57	-	0.70	-
SD( $R^{(40)} - R$ )	1.33	0.71	0.75	-	1.59	-	1.83	-
Mean( $x^{(40)}$ )	1.76	0.73	0.80	-	0.94	-	1.18	-
SD( $x^{(40)}$ )	23.43	6.17	7.95	-	9.20	-	11.78	-
Equity Premium	6.2	0.81	10.77	-	11.00	-	11.17	-
SD(Re)	15.98	1.22	1.63	1.94	1.88	3.66	2.44	4.10

where  $SD$  = standard deviation,  $NTP^{(40)}$  = nominal term premium on a 40-quarter bond, Mean = Unconditional Mean,  $R^{(40)} - R$  is the slope and  $x^{(40)}$  is the excess holding period return for a 40-quarter bond. Each version of the models listed above utilises our *baseline calibration* similar to the one of Rudebusch and Swanson (2012) that does not fit finance moments of US data (neither here nor in their paper). Note that we are unable to carry out a third-order approximation when entry cost is specified in consumption units as Dynare stops with a non-trivial error. Thus we have to resort to a second-order approximation when calculating moments in this table (column  $\mathcal{RS}'$  is also true to the second-order).

$\mathcal{RS}'$  = reproduction of the results of Rudebusch and Swanson (2012) without entry (Note that their results are close to ours.) using our *baseline calibration*. The  $\mathcal{RS}'$  model contains technology, fiscal (lump-sum taxation) and monetary policy shocks.

Columns A-F make use of our model with the *baseline calibration* in Table 3 and employing the following shocks:

A=Technology and fiscal shock (lump-sum taxation).

B=Technology and fiscal shock (lump-sum taxation), data-consistent real variables.

C=Technology, fiscal (lump-sum taxation) and monetary policy shocks.

D=Technology, fiscal (lump-sum taxation) and monetary policy shocks, data-consistent real variables.

E=Technology, fiscal (income taxation) and monetary policy shocks.

F=Technology, fiscal (income taxation) and monetary policy shocks, data-consistent real variables.

Note that column  $\mathcal{RS}'$  and columns C and D are comparable as based on the same calibration and same shocks.

**Table 7**  
**Simulated Moments of Our Model Compared to US Data**

Unconditional Moment	US data, 1961-2007	A	B	C	D	E	F	G	H
SD(C)	0.83	1.75	1.64	1.16	0.98	1.72	1.61	1.42	1.32
SD(L)	1.71	0.42	0.85	1.25	1.79	0.73	1.06	0.89	1.35
SD(W)	0.82	2.03	1.93	1.95	1.80	2.73	2.77	2.73	2.75
SD( $\pi$ )	2.52	5.02	-	1.78	-	2.40	-	2.33	2.48
SD( $R$ )	2.71	2.65	-	2.51	-	2.77	-	2.89	-
SD( $R^{real}$ )	2.30	0.71	0.81	1.18	1.32	1.21	1.37	1.23	1.37
SD( $R^{(40)}$ )	2.41	1.19	-	1.08	-	1.30	-	1.51	-
Mean( $NTP^{(40)}$ )	1.06	0.67	-	0.51	-	0.75	-	1.06	-
SD( $NTP^{(40)}$ )	0.54	0.00	-	0.00	-	0.00	-	0.00	-
Mean( $R^{(40)} - R$ )	1.43	0.78	-	0.52	-	0.84	-	1.09	-
SD( $R^{(40)} - R$ )	1.33	1.61	-	1.73	-	1.81	-	1.78	-
Mean( $x^{(40)}$ )	1.76	1.23	-	0.91	-	1.44	-	1.93	-
SD( $x^{(40)}$ )	23.43	13.10	-	11.13	-	13.25	-	14.69	-
Equity Premium	6.2	10.57	-	11.11	-	11.47	-	11.87	-
SD( $Re$ )	15.98	1.69	1.78	2.03	3.73	2.79	4.16	2.66	3.97

where  $SD$  = standard deviation,  $NTP^{(40)}$  = nominal term premium on a 40-quarter bond, Mean = Unconditional Mean,  $R^{(40)} - R$  is the slope and  $x^{(40)}$  is the excess holding period return for a 40-quarter bond.  $Re$  is the return on equity.

Here we used the second version of the entry model where entry costs are defined in consumption units. All three types of shocks are employed and spending is financed by income taxation. Note that we are unable to carry out a third-order approximation when entry cost is specified in consumption as Dynare stops with a non-trivial error. Thus we have to resort to a second-order approximation when calculating moments in this table.

Columns A-H make use of our model with *our calibration* in Table 3 except for the following modifications:

A=removing price rigidity ( $\phi_p = 0$ ).

B=removing price rigidity ( $\phi_p = 0$ ), data-consistent real variables.

C=Lower elasticity of intertemporal substitution ( $EIS = 1/\sigma = 0.3$  instead of the baseline 0.5).

D=Lower elasticity of intertemporal substitution ( $EIS = 1/\sigma = 0.3$  instead of the baseline 0.5), data-consistent real variables.

E=Lower Frisch elasticity of labour supply ( $1/\varphi = 0.28$  instead of the baseline 2/3).

F=Lower Frisch elasticity of labour supply ( $1/\varphi = 0.28$  instead of the baseline 2/3), data-consistent real variables.

G=Lowering  $EIS$  to 0.3 and Frisch elasticity to  $1/\varphi = 0.28$ .

H=Lowering  $EIS$  to 0.3 and Frisch elasticity to  $1/\varphi = 0.28$ , data-consistent real variables.



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