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Monetary Policy**

Timothy S. Fuerst and Ronald Mau



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**Term Premium Variability and Monetary Policy**

Timothy S. Fuerst and Ronald Mau

Two traditional explanations for the mean and variability of the term premium are: (i) time-varying risk premia on long bonds, and (ii) segmented markets between long- and short-term bonds. This paper integrates these two approaches into a medium-scale DSGE model. We consider two sources of business cycle variability: shocks to total factor productivity (TFP), and shocks to the marginal efficiency of investment (MEI). The ability of the risk approach to match the first moment of the term premium depends upon the relative importance of these two shocks. If MEI shocks are an important driver of the business cycle, then long bonds are a hedge against the business cycle so that the average term premium is negative. The opposite is the case for the TFP shocks. But for either source of shocks, the risk approach to the term premium predicts a trivial amount of variability in the term premium. In contrast, the segmented markets model can easily match both moments. The market segmentation reflects a real distortion, so that smoothing the term premium is typically welfare-improving. There are two difficulties with such a policy. First, the mean level of the term premium will not properly reflect the segmentation distortion because of the risk adjustment. Second, if the term premium is measured with error, the welfare gain of a term premium peg is naturally reduced. The paper demonstrates that both of these effects are quantitatively modest so that the welfare advantage to a term premium peg survives.

**Keywords:** Term premium peg, time-varying risk premia, DSGE, total factor productivity, marginal efficiency of investment, monetary policy.

**JEL Codes:** E52, G12, G17.

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In the aftermath of the 2008 financial crisis many central banks have adopted unconventional policies, including outright purchases of long-term government debt. These bond purchases were an attempt to alter the yield curve for a given path of the federal funds rate. That is, they were meant to alter the term premium. In a monetary policy environment with a large Fed balance sheet, an important policy question going forward is whether the term premium (in addition to the funds rate) should be a regular input into the policy-making process. That is, should the Fed's bond portfolio be used to smooth fluctuations in the term premium?

In this paper we integrate two distinct approaches to modeling the term premium in a medium-scale dynamic stochastic general equilibrium (DSGE) model and characterize the ability of each approach to generate a variable term premium as observed in the data. We then address how a policymaker should respond to term premium variability within the context of each modeling approach. Finally, we highlight two concerns which should be considered with the use of this new policy instrument and comment on the implications of each on the benefits to policy which smooths fluctuations in the term premium.

The first approach we implement to model the term premium alters preferences as in Epstein-Zin (1989), hereafter EZ. EZ preferences separate risk aversion from intertemporal substitution elasticities and are a common feature in the finance literature. Rudebusch and Swanson (2012) is a prominent example of using EZ preferences in a DSGE framework to model the term premium. The second approach deviates from an economy with frictionless asset trade by segmenting the asset market so that short and long bonds are priced by different agents, and the ability of agents to arbitrage the spread between long and short bonds is constrained by the net worth of the financial sector. In this environment a bond purchase policy will alter the term premium and have real effects. Carlstrom, Fuerst and Paustian (2015) is a recent example of this approach.

The two approaches have wildly different implications for monetary policy so that the modeling choice matters for the central bank. If the term premium is simply another asset price in a world with frictionless asset trade, then fluctuations in the term premium reflect changes in real activity but are otherwise irrelevant for central bankers (unless it helps forecast variables of interest to the policymaker).

That is, in a frictionless model with EZ preferences the term premium should not directly concern policy makers. In contrast, if the term premium reflects an economic distortion arising from market segmentation, then there is a first-order role for smoothing fluctuations in the term premium.

Our principal results include the following. First, with a standard calibration of the DSGE model, and assuming that the business cycle is driven by TFP shocks, the EZ approach can produce an average term premium comparable to that found in the data, but a trivial and counterfactually small level of variability in the premium. These results are sensitive to the exogenous shocks. A recurring theme in the estimated DSGE literature is the importance of MEI (marginal efficiency of investment) shocks which perturb the link between investment spending and final capital goods. If the business cycle is instead driven by these shocks, then the average term premium is negative with again trivial variability. We conclude that the EZ approach by itself has difficulty in both hitting the mean and the variability in the term premium.

Our second set of results concerns the segmentation model of Carlstrom, Fuerst, and Paustian (2015). This model features two parameters that define the degree of segmentation in the financial sector: (i) the degree of impatience of financial intermediaries, and (ii) the level of adjustment costs in changes in portfolios. These parameters can be chosen to hit exactly the empirical mean and variability in the term premium. Given such a calibration, there are significant welfare gains to a central bank smoothing variations in the term premium by actively using its portfolio of long bonds.

We consider two practical difficulties with implementing a term premium peg. First, the economic distortion of the peg depends upon the steady-state term premium which is different from the mean term premium if the yield on the long bond includes adjustments for risk. This implies that by implementing a term premium peg the policymaker is suppressing fluctuations in the term premium that come from the risk-adjustment but which are not representative of the segmentation distortion. Second, the term premium is subject to serially correlated measurement error. Thus, under a term premium peg the policymaker is inadvertently introducing exogenous variation into the model economy. This paper explores both of these effects and concludes that their quantitative significance is modest.

The paper proceeds as follows. Section 1 lays out the basic segmented markets model with EZ preferences. Section 2 provides a quantitative analysis of the model with segmentation effects turned off. Section 3 provides the complementary analysis for the model with active segmentation effects. Policy issues are discussed in Section 4. Section 5 concludes.

## 1. The Model

The model economy consists of households, employment agencies, firms, and financial intermediaries (FI). We will discuss each in turn.

### Households

Each household has recursive preferences over consumption and labor given by

$$V_t = U(c_t, h_t) + \beta [E_t(V_{t+1})^{(1-\theta)}]^{1/(1-\theta)} \quad (1)$$

Using the terminology of Rudebusch and Swanson (2012), the Epstein-Zin (EZ) preferences *twist* the value function. Risk aversion is increasing in  $\theta$ . If we set  $\theta = 0$ , we have the standard preferences. The intra-period utility functional is given by:

$$U(c_t, h_t) \equiv \frac{c_t^{1-v}}{1-v} - b \frac{h_t^{1+\eta}}{1+\eta} + k \quad (2)$$

where  $c_t$  and  $h_t$  denote consumption and labor, respectively. We choose the constant  $k > 0$  so that steady state utility is positive which ensures that the value function always takes on positive values.<sup>2</sup>

The household has two means of intertemporal smoothing: short-term deposits ( $D_t$ ) in the financial intermediary (FI) and accumulation of physical capital ( $K_t$ ). Households also have access to the market in short-term government bonds (“T-bills”). But since T-bills are perfect substitutes with deposits, and the supply of T-bills moves endogenously to hit the central bank’s short-term interest rate target, we

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<sup>2</sup> See Rudebusch and Swanson (2012) for a discussion.

treat  $D_t$  as the household's net resource flow into the FI's. To introduce a need for intermediation, we assume that all investment purchases must be financed by issuing new "investment bonds" that are ultimately purchased by the FI. We find it convenient to use perpetual bonds with cash flows of 1,  $\kappa$ ,  $\kappa^2$ , etc. Let  $Q_t$  denote the time- $t$  price of a new issue. Given the time pattern of the perpetuity payment, the new issue price  $Q_t$  summarizes the prices at all maturities, eg.,  $\kappa Q_t$  is the time- $t$  price of the perpetuity issued in period  $t-1$ . The duration and (gross) yield to maturity on these bonds are defined as: duration =  $(1 - \kappa)^{-1}$ , gross yield to maturity =  $Q_t^{-1} + \kappa$ . Let  $CI_t$  denote the number of new perpetuities issued in time- $t$  to finance investment. In time- $t$ , the household's nominal liability on past issues is given by:

$$F_{t-1} = CI_{t-1} + \kappa CI_{t-2} + \kappa^2 CI_{t-3} + \dots \quad (3)$$

We can use this recursion to write the new issue as

$$CI_t = (F_t - \kappa F_{t-1}) \quad (4)$$

The representative's household constraints are thus given by:

$$c_t + \frac{D_t}{P_t} + P_t^k I_t + \frac{F_{t-1}}{P_t} \leq \mathcal{M}_t h_t + R_t^k K_t - T_t + \frac{D_{t-1}}{P_t} R_{t-1} + \frac{Q_t(F_t - \kappa F_{t-1})}{P_t} + div_t \quad (5)$$

$$K_{t+1} \leq (1 - \delta)K_t + I_t \quad (6)$$

$$P_t^k I_t \leq \frac{Q_t(F_t - \kappa F_{t-1})}{P_t} = \frac{Q_t CI_t}{P_t} \quad (7)$$

where  $P_t$  is the price level,  $P_t^k$  is the real price of capital,  $R_{t-1}$  is the gross nominal interest rate on deposits,  $R_t^k$  is the real rental rate,  $\mathcal{M}_t$  is the real wage paid to households,  $T_t$  are lump-sum taxes, and  $div_t$  denotes the dividend flow from the FI's. The household also receives a profit flow from the intermediate goods producers and the new capital producers, but this is entirely standard so we dispense from this added notation for simplicity. The "loan-in-advance" constraint (7) will increase the private cost of purchasing investment goods.<sup>3</sup> The first order conditions to the household problem include:

$$-\frac{U_h(c_t, h_t)}{U_c(c_t, h_t)} = \mathcal{M}_t \quad (8)$$

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<sup>3</sup> Although for simplicity we place capital accumulation within the household problem, this model formulation is isomorphic to an environment in which household-owned firms accumulate capital subject to the loan constraint.

$$1 = E_t S_{t+1} \frac{R_t}{\Pi_{t+1}} \quad (9)$$

$$P_t^k M_t = E_t S_{t+1} [R_{t+1}^k + (1 - \delta) P_{t+1}^k M_{t+1}] \quad (10)$$

$$Q_t M_t = E_t \frac{S_{t+1}}{\Pi_{t+1}} [1 + \kappa Q_{t+1} M_{t+1}] \quad (11)$$

where the real stochastic discount factor (SDF) is given by

$$S_{t+1} = \left[ \left( \frac{V_{t+1}}{[E_t(V_{t+1})^{(1-\theta)}]^{1/(1-\theta)}} \right)^{-\theta} \right] \left[ \frac{\beta U_c(t+1)}{U_c(t)} \right]. \quad (12)$$

and  $\Pi_t \equiv \frac{P_t}{P_{t-1}}$  is gross inflation. Expressions (8) and (9) are the familiar labor supply equation and Fisher equation, respectively. The capital accumulation expression (10) is distorted relative to the familiar by the time-varying distortion  $M_t$ , where  $M_t \equiv 1 + \frac{\vartheta_t}{\Lambda_t}$ ,  $\vartheta_t$  and  $\Lambda_t$  are the multipliers on the loan-in-advance constraint and budget constraint, respectively. The endogenous behavior of this distortion is fundamental to the real effects arising from market segmentation. Other things equal, there is a welfare advantage to stabilizing this distortion.

### Labor Unions and Employment Agencies

There is a continuum of labor unions that purchase raw labor from households at price  $\mathcal{M}_t$  and transform it into a unique labor skill that is then sold to competitive employment agencies.<sup>4</sup> Union  $i$  faces a labor demand curve given by:

$$H_t^i = H_t \left( \frac{W_t^*}{W_t} \right)^{-\epsilon_w} \quad (13)$$

where  $W_t$  is the aggregate real wage and  $W_t^*$  is the real wage set by union  $i$ . With probability  $(1 - \theta)$ , the union can re-set its nominal wage in the current period, while with probability  $\theta$  its nominal wage simply

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<sup>4</sup> It is convenient to separate nominal wage rigidity from the household. If each household set a nominal wage then labor input would vary across households. This would imply differences in lifetime utility across households. This would needlessly complicate asset pricing that depends upon innovations in lifetime utility because of the EZ preferences.



grows by  $\Pi_t^{\iota_w}$ , where  $\iota_w$  is the degree of nominal wage indexation to the inflation rate. If union  $i$  can re-set its wage in time- $t$ , its maximization problem is given by:

$$\begin{aligned} \max_{W_t^*} \{ & W_t^* H_t^i - H_t^i M_t + \theta S_{t+1} \{ W_t^* \Psi_{t+1}^{1-\epsilon_w} H_{t+1}^i - H_{t+1}^i \Psi_{t+1}^{-\epsilon_w} \mathcal{M}_{t+1} \} + \\ & \theta^2 S_{t+1} S_{t+2} \{ W_t^* \Psi_{t+1}^{1-\epsilon_w} \Psi_{t+2}^{1-\epsilon_w} H_{t+2}^i - H_{t+2}^i \Psi_{t+1}^{-\epsilon_w} \Psi_{t+2}^{-\epsilon_w} \mathcal{M}_{t+2} \} + \dots \} \end{aligned} \quad (14)$$

where  $\Psi_{t+1} \equiv \frac{\Pi_t^{\iota_w}}{\Pi_{t+1}}$  denotes the automatic adjustment of the real wage to inflation. The optimal real wage

choice for a typical union that can re-set its wage is given by the following:

$$W_t^* = \frac{G_{1t}}{G_{2t}} \quad (15)$$

$$G_{1t} = W_t^{\epsilon_w} H_t M_t + S_{t+1} \theta_w \left( \frac{\Pi_{t+1}}{\Pi_t^{\iota_w}} \right)^{\epsilon_w} G_{1t+1} \quad (16)$$

$$G_{2t} = \frac{\epsilon_w - 1}{\epsilon_w} W_t^{\epsilon_w} H_t + S_{t+1} \theta_w \left( \frac{\Pi_{t+1}}{\Pi_t^{\iota_w}} \right)^{(\epsilon_w - 1)} G_{2t+1} \quad (17)$$

The aggregate real wage then evolves as follows:

$$W_t^{1-\epsilon_w} = (1 - \theta_w) (W_t^*)^{1-\epsilon_w} + \theta_w \left( \frac{\Pi_t^{\iota_w}}{\Pi_t} \right)^{1-\epsilon_w} W_{t-1}^{1-\epsilon_w} \quad (18)$$

The nominal wage rigidity implies a time-varying dispersion ( $d_t^w$ ) of real wages that is given by:

$$d_t^w = (1 - \theta_w) \left( \frac{W_t^*}{W_t} \right)^{-\epsilon_w} + \theta_w \left( \frac{W_{t-1}}{W_t} \right)^{-\epsilon_w} \left( \frac{\Pi_t}{\Pi_{t-1}^{\iota_w}} \right)^{\epsilon_w} d_{t-1}^w \quad (19)$$

Each union sells its specific employment variety to a competitive employment agency. These agencies aggregate up these varieties into a labor service that is sold to firms at real wage  $W_t$ . These agencies solve the following maximization problem:

$$W_t \left[ \int_0^1 (H_t^i)^{1-1/\epsilon_w} di \right]^{1/(1-1/\epsilon_w)} - \int_0^1 W_t^i H_t^i di \quad (20)$$

The optimization conditions are given by:

$$H_t^i = \left( \frac{W_t^i}{W_t} \right)^{-\epsilon_w} H_t \quad (21)$$

$$H_t \equiv \left[ \int_0^1 (H_t^i)^{1-1/\epsilon_w} di \right]^{1/(1-1/\epsilon_w)} \quad (22)$$

## Firms and Production

The production side of the model is standard and symmetric with the provision of labor input. There is a continuum of intermediate good producers, each with monopoly power over the input variety they produce. A monopolist produces intermediate good  $i$  according to the production function

$$Y_t(i) = A_t K_t(i)^\alpha H_t(i)^{1-\alpha} \quad (23)$$

where  $K_t(i)$  and  $H_t(i)$  denote the amounts of capital and labor employed by firm  $i$ . The variable  $\ln A_t$  is the exogenous level of TFP and evolves according to:

$$\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_{a,t}, \quad (24)$$

Every period a fraction  $\theta_p$  of intermediate firms cannot choose its price optimally, but resets it according to the indexation rule

$$P_t(i) = P_{t-1}(i) \Pi_{t-1}^{\iota_p}, \quad (25)$$

where  $\Pi_t = \frac{P_t}{P_{t-1}}$  is gross inflation. The firms who can re-set their prices, choose their relative price

$x_t \equiv \frac{P_t(i)}{P_t}$ , optimally to maximize the present discounted value of profits:

$$\max_{x_t} \left\{ x_t Y_t^i - Y_t^i MC_t + \theta_p S_{t+1} \left\{ x_t Y_{t+1}^i \Psi_{t+1}^{1-\epsilon_p} - Y_{t+1}^i \Psi_{t+1}^{-\epsilon_p} MC_{t+1} \right\} + \right. \\ \left. \theta_p^2 S_{t+1} S_{t+2} \left\{ x_t \Psi_{t+1}^{1-\epsilon_p} \Psi_{t+2}^{1-\epsilon_p} Y_{t+2}^i - Y_{t+2}^i \Psi_{t+1}^{-\epsilon_p} \Psi_{t+2}^{-\epsilon_p} MC_{t+2} \right\} + \dots \right\} \quad (26)$$

where  $MC_t$  denotes real marginal cost,  $\Psi_{t+1} \equiv \frac{\Pi_t^{\iota_p}}{\Pi_{t+1}}$  is the automatic movement in the relative price, and

the firm faces a demand curve given by

$$Y_t^i = Y_t x_t^{-\epsilon_p} \quad (27)$$

The firm's optimization conditions include:

$$R_t^k = MC_t MPK_t \quad (28)$$

$$W_t = MC_t MPL_t \quad (29)$$

$$\Pi_t^* = \frac{\epsilon_p}{\epsilon_p - 1} \frac{X_{1t}}{X_{2t}} \Pi_t \quad (30)$$

$$X_{1t} = MC_t Y_t + S_{t+1} \theta_p \Pi_t^{-\iota_p \epsilon_p} \Pi_{t+1}^{\epsilon_p} X_{1t+1} \quad (31)$$

$$X_{2t} = Y_t + S_{t+1} \theta_p \Pi_t^{t_p(1-\epsilon_p)} \Pi_{t+1}^{\epsilon_p-1} X_{2t+1} \quad (32)$$

The aggregate inflation rate and price dispersion, respectively, then evolve as:

$$\Pi_t^{1-\epsilon_p} = (1 - \theta_p)(\Pi_t^*)^{1-\epsilon_p} + \theta_p \Pi_{t-1}^{t_p(1-\epsilon_p)} \quad (33)$$

$$d_t = \Pi_t^{\epsilon_p} [(1 - \theta_p)(\Pi_t^*)^{-\epsilon_p} + \theta_p \Pi_{t-1}^{-t_p \epsilon_p} d_{t-1}] \quad (34)$$

These monopolists sell their intermediate goods to perfectly competitive firms that produce the final consumption good  $Y_t$  combining a continuum of intermediate goods according to the CES technology:

$$Y_t = \left[ \int_0^1 Y_t(i)^{1-\epsilon_p} di \right]^{1/(1-\epsilon_p)} \quad (35)$$

Profit maximization and the zero profit condition imply that the price of the final good,  $P_t$ , is the familiar CES aggregate of the prices of the intermediate goods.

### New Capital Producers

New capital is produced according to the production technology that takes  $I_t$  investment goods and transforms them into  $\mu_t \left[ 1 - S\left(\frac{I_t}{I_{t-1}}\right) \right] I_t$  new capital goods. The time- $t$  profit flow is thus given by

$$P_t^k \mu_t \left[ 1 - S\left(\frac{I_t}{I_{t-1}}\right) \right] I_t - I_t \quad (36)$$

where the function  $S$  captures the presence of adjustment costs in investment, and is given by  $S\left(\frac{I_t}{I_{t-1}}\right) \equiv \frac{\psi_i}{2} \left( \frac{I_t}{I_{t-1}} - 1 \right)^2$ . These firms are owned by households and discount future cash flows using the household's SDF. The investment shock follows the stochastic process

$$\log \mu_t = \rho_\mu \log \mu_{t-1} + \varepsilon_{\mu,t}, \quad (37)$$

where  $\varepsilon_{\mu,t}$  is *i.i.d.*  $N(0, \sigma_\mu^2)$ . Using the terminology of Justiniano, Primiceri, and Tambalotti (2011), we will refer to these shocks as “marginal efficiency of investment” (MEI) shocks.

## Financial Intermediaries

The FI's in the model are a stand-in for the entire financial nexus that uses accumulated net worth ( $N_t$ ) and short-term liabilities ( $D_t$ ) to finance investment bonds ( $F_t$ ) and the long-term government bonds ( $B_t$ ). The FIs are the sole buyers of the investment bonds and long-term government bonds. We again assume that government debt takes the form of perpetuities that provide payments of 1,  $\kappa$ ,  $\kappa^2$ , etc. Let  $Q_t$  denote the price of a new-debt issue at time- $t$ . The time- $t$  asset value of the current and past issues of investment bonds is:

$$Q_t CI_t + \kappa Q_t [CI_{t-1} + \kappa CI_{t-2} + \kappa^2 CI_{t-3} + \dots] = Q_t F_t \quad (38)$$

The FIs balance sheet is thus given by:

$$\frac{B_t}{P_t} Q_t + \frac{F_t}{P_t} Q_t = \frac{D_t}{P_t} + N_t = L_t N_t \quad (39)$$

where  $L_t$  denotes leverage. Note that on the asset side, investment lending and long-term bond purchases are perfect substitutes to the FI. Let  $R_{t+1}^L \equiv \left( \frac{1 + \kappa Q_{t+1}}{Q_t} \right)$ , denote the realized nominal holding period return on the long bond. The FI's time- $t$  profits are then given by:

$$prof_t \equiv \frac{P_{t-1}}{P_t} [(R_t^L - R_{t-1}^d) L_{t-1} + R_{t-1}] N_{t-1} \quad (40)$$

The FI will pay out some of these profits as dividends ( $div_t$ ) to the household, and retain the rest as net worth for subsequent activity. In making this choice the FI discounts dividend flows using the household's pricing kernel augmented with additional impatience.<sup>5</sup> The FI accumulates net worth because it is subject to a financial constraint: the FI's ability to attract deposits will be limited by its net worth. We will use a simple hold-up problem to generate this leverage constraint, but a wide variety of informational restrictions will generate the same constraint. We assume that leverage is taken as given by the FI. We will return to this below. The FI chooses dividends and net worth to solve:

$$V_t \equiv \max_{N_t, div_t} E_t \sum_{j=0}^{\infty} (\beta \zeta)^j \Lambda_{t+j} div_{t+j} \quad (41)$$

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<sup>5</sup> In contrast, Gertler and Karadi (2011, 2013) assume that FI's only pay out dividends upon their exogenous death.

subject to the financing constraint developed below and the following budget constraint:

$$div_t + N_t[1 + f(N_t)] \leq \frac{P_{t-1}}{P_t} [(R_t^L - R_{t-1}^d)L_{t-1} + R_{t-1}]N_{t-1} \quad (42)$$

The function  $f(N_t) \equiv \frac{\psi_n}{2} \left( \frac{N_t - N_{ss}}{N_{ss}} \right)^2$ , denotes an adjustment cost function that dampens the ability of the FI to adjust the size of its portfolio in response to shocks. The FI's optimal accumulation decision is then given by:

$$\Lambda_t[1 + N_t f'(N_t) + f(N_t)] = E_t \beta \zeta \Lambda_{t+1} \frac{P_t}{P_{t+1}} [(R_{t+1}^L - R_t^d)L_t + R_t^d] \quad (43)$$

The hold-up problem works as follows. At the beginning of period  $t+1$ , but before aggregate shocks are realized, the FI can choose to default on its planned repayment to depositors. In this event, depositors can seize at most fraction  $(1 - \Phi)$  of the FI's assets. If the FI defaults, the FI is left with  $\Phi R_{t+1}^L L_t N_t$ , which it carries into the subsequent period. To ensure that the FI will always re-pay the depositor, the time- $t$  incentive compatibility constraint is thus given by:

$$E_t S_{t+1} \frac{P_t}{P_{t+1}} \{R_{t+1}^L L_t N_t - R_t^d (L_t - 1)N_t\} \geq \Phi L_t N_t E_t S_{t+1} \frac{P_t}{P_{t+1}} R_{t+1}^L \quad (44)$$

It is useful to think of (44) as determining leverage. Since net worth scales both sides of the inequality, leverage is a function of aggregate variables but is independent of each FI's net worth. We will calibrate the model so that this constraint is binding in the steady state (and thus binding for small shocks around the steady state).

Equations (43) and (44) are fundamental to the model as they summarize the limits to arbitrage between the return on long-term bonds and the rate paid on short-term deposits. The leverage constraint (44) limits the FI's ability to attract deposits and eliminate the arbitrage opportunity between the deposit and lending rate. Increases in net worth allow for greater arbitrage and thus can eliminate this market segmentation. Equation (43) limits this arbitrage in the steady-state by additional impatience ( $\zeta < 1$ ) and dynamically by portfolio adjustment costs ( $\psi_n > 0$ ). Since the FI is the sole means of investment finance, this market segmentation means that central bank purchases that alter the supply of long-term debt will

have repercussions for investment loans because net worth and deposits cannot quickly sterilize the purchases.

### **Central Bank Policy**

We assume that the central bank follows a familiar Taylor rule over the short rate (T-bills and deposits):

$$\ln(R_t) = (1 - \rho) \ln(R_{ss}) + \rho \ln(R_{t-1}) + (1 - \rho)(\tau_\pi \pi_t + \tau_y y_t^{gap}) \quad (45)$$

where  $y_t^{gap} \equiv \ln(Y_t/Y_t^f)$  denotes the deviation of output from its flexible price counterpart. We will think of this as the Federal Funds Rate (FFR). The supply of short-term bonds (T-bills) is endogenous, varying as needed to support the FFR target. As for the long-term bond policy, the central bank will choose between: (i) an exogenous path for the quantity of long-term debt available to FIs, or (ii) a policy rule that pegs the term premium and thus makes the level of debt endogenous. We will return to this below.

Fiscal policy is entirely passive. Government expenditures are set to zero. Lump sum taxes move endogenously to support the interest payments on the short and long debt.

### **Debt Market Policies**

To close the model, we need one more restriction that will pin down the behavior in the long debt market. We will consider two different policy regimes for this market: (i) exogenous debt, and (ii) endogenous debt. We will discuss each in turn.

#### ***Exogenous Debt***

The variable  $b_t \equiv Q_t \frac{B_t}{P_t}$  denotes the real value of long-term government debt on the balance sheet of FI's.

There are two distinct reasons why this variable could fluctuate. First, the central bank could engage in long bond purchases (“quantitative easing,” or QE). Second, the fiscal authority could alter the mix of short debt to long debt in its maturity structure. Further research could model both of these scenarios as

exogenous movements in long debt and the quantitative effect of each. Our benchmark experiments will hold long debt fixed at steady state. Under this exogenous debt scenario, the long yield and term premium will be endogenous.

### ***Endogenous Debt***

The polar opposite scenario is a policy under which the central bank pegs the term-premium at its steady state value. Under this policy regime the level of long debt will be endogenous. Under a term premium peg the asset value of the intermediary will remain fixed, while composition of assets will vary. That is, any increase of FI holdings of investment debt is achieved via the central bank purchasing an equal magnitude of government bonds. The proceeds from this sale effectively finances loans for investment.

### **Yields and Term Premia**

The (gross) yield on the long-term bond is defined by  $R_t^{long}$ :

$$R_t^{long} = Q_t^{-1} + \kappa \quad (46)$$

The term premium is defined to be the difference between this yield and the corresponding yield implied by the expectations hypothesis (EH) of the term structure. This hypothetical bond price and corresponding yield are defined as

$$Q_t^{EH} = \frac{1 + \kappa E_t Q_{t+1}^{EH}}{R_t} \quad (47)$$

$$R_t^{EH, long} = \frac{1}{Q_t^{EH}} + \kappa \quad (48)$$

The term premium is then given by:

$$TP_t \equiv \frac{1}{Q_t} - \frac{1}{Q_t^{EH}} = R_t^{long} - R_t^{EH, long} \quad (49)$$

## **2. The Term Premium with Frictionless Financial Markets**

We begin our quantitative analysis by abstracting from market segmentation effects. Segmentation is toggled off by setting  $\zeta = 1$ , and  $\psi_n = 0$ . This implies  $M_t \equiv 1$ . Expanding the definition of the bond price we have:

$$Q_t = E_t \frac{S_{t+1}}{\Pi_{t+1}} + \kappa E_t \frac{S_{t+1}}{\Pi_{t+1}} \frac{S_{t+2}}{\Pi_{t+2}} + \kappa^2 E_t \frac{S_{t+1}}{\Pi_{t+1}} \frac{S_{t+2}}{\Pi_{t+2}} \frac{S_{t+3}}{\Pi_{t+3}} + \dots \quad (50)$$

Similarly we have:

$$Q_t^{EH} = E_t \frac{S_{t+1}}{\Pi_{t+1}} + \kappa E_t \frac{S_{t+1}}{\Pi_{t+1}} E_t \frac{S_{t+2}}{\Pi_{t+2}} + \kappa^2 E_t \frac{S_{t+1}}{\Pi_{t+1}} E_t \frac{S_{t+2}}{\Pi_{t+2}} E_t \frac{S_{t+3}}{\Pi_{t+3}} + \dots \quad (51)$$

This implies that the bond price can be expressed as

$$Q_t = Q_t^{EH} + \kappa cov_t \left( \frac{S_{t+1}}{\Pi_{t+1}}, \frac{S_{t+2}}{\Pi_{t+2}} \right) + \dots \quad (52)$$

Since  $\kappa < 1$ , the early covariances are quantitatively the most important. Hence, there is a positive term premium if and only if the nominal SDF  $\left( \frac{S_{t+1}}{\Pi_{t+1}} \right)$  is negatively autocorrelated at short horizons.

As emphasized by Fuerst (2015), it is impossible to generate a significantly positive term premium with standard preferences ( $\theta = 0$ ). There are two reasons for this result. First, with  $\theta = 0$ , and for plausible values of  $\nu$  in (2), the real SDF has trivial variability (this is just a manifestation of the equity premium puzzle). Second, inflation is positively autocorrelated at short horizons, an autocorrelation that is inherited by the nominal SDF. This positive autocorrelation in the nominal SDF kills any chance of generating a positive term premium.

But the EZ effect ( $\theta > 0$ ) can easily deliver a positive term premium. Recall that the real SDF is given by:

$$S_{t+1} = \left[ \left( \frac{V_{t+1}}{[E_t(V_{t+1})^{(1-\theta)}]^{1/(1-\theta)}} \right)^{-\theta} \right] \left[ \frac{\beta U_c(t+1)}{U_c(t)} \right]. \quad (53)$$

The SDF is a product of an EZ term and the traditional inter-temporal marginal rate of substitution. The EZ term is, essentially, a forecast error, an innovation in lifetime utility. If  $\theta$  is large enough, then a positive innovation in lifetime utility will lead to a sharp one-time decline in the real SDF. To generate a term premium we need a persistent movement inflation that is of the opposite sign as this innovation in



lifetime utility. The model has two exogenous shocks: TFP shocks and MEI shocks. Positive innovations in either of these shocks will lead to positive innovations in lifetime utility. The implications for the term premium then depend upon the response of inflation to these shocks. We will look at each shock in turn.

To capture the mean and variability of the term premium, we use a third-order approximation to the model. The baseline parameter values are displayed in Table 1. The financial parameters are chosen to imply a bond duration of 40 quarters, a steady state term premium of 100 bp, and FI leverage of 6. In this section we abstract from segmentation issues and set  $\zeta = 1$  (implying no steady state term premium), and  $\psi_n = 0$ . The remaining parameter values are broadly consistent with the literature that estimates medium-scale DSGE models, with two important caveats. The estimation literature typically includes habit in consumption (from which we abstract), but excludes EZ effects (which we include). Consistent with the evidence in Justiniano, Primiceri, and Tambalotti (2011), output and investment variability are largely driven by MEI shocks. At the 8-quarter horizon, MEI shocks account for 62% of the variability of output, and 87% of the variability of investment.

Measurement of the term premium is easy in theory, but difficult in practice. For the period 1961-2007, Rudebusch and Swanson (2012) report a mean term premium of 106 bp, and a standard deviation of 54 bp. For the period 1962:1-2008:4, Adrian, Crump, and Moench (2013) report a mean of 169 bp, and a standard deviation of 154 bp. For our benchmark data target we will use a mean of 130 bp, and a standard deviation of 100 bp.

Figures 1 and 4 examine the model's implications for TFP shocks. With no EZ effects ( $\theta = 0$ ), the model generates a trivial average term premium. But with sufficient EZ risk aversion, it is quite easy to hit a fairly large mean premium: with  $\theta = 200$ , the mean term premium is nearly 100 bp. The reason for this is quite evident in the impulse response function in Figure 4 (which assumes  $\theta = 200$ ). A positive TFP shock leads to a sharp increase in lifetime utility which implies a large negative innovation in the real SDF. The persistent TFP shock implies a persistent decline in inflation. Hence, the nominal SDF is significantly negatively correlated at short horizons thus implying a positive term premium. Without the EZ effect, the movement in the real SDF is trivial so that there is only a tiny term premium.

But there is a problem with TFP shocks. The variability of the term premium is counterfactually small. Even with  $\theta = 200$ , the standard deviation is less than 5 bp(!). This result is distinct from the results reported by Rudebusch and Swanson (2012) who report much larger variability in the premium. For example, their “best fit” in their Table 2 reports a term premium standard deviation of 47 bp. The reason for this different result is the form of the Taylor rule used. Rudebusch and Swanson (2012) assume that the central bank responds to the level of output relative to steady state (or trend in a model with exogenous growth). Let us call this an “output” rule in contrast to the “gap” rule in (45). It is useful to rewrite the gap as,

$$y_t^{gap} = \ln\left(\frac{Y_t/Y_{ss}}{Y_t^f/Y_{ss}}\right) = \ln(Y_t/Y_{ss}) - \ln(Y_t^f/Y_{ss}) = y_t - y_t^{flex}$$

Since output is the sum of flexible price output and the gap, we can write an output rule as:

$$\ln(R_t) = (1 - \rho) \ln(R_{ss}) + \rho \ln(R_{t-1}) + (1 - \rho)(\tau_\pi \pi_t + \tau_y y_t^{gap} + \tau_y y_t^{flex}) \quad (54)$$

For the case of TFP shocks, an output rule is akin to adding serially correlated exogenous policy shocks to a gap-based Taylor rule. Consider a positive TFP shock. An output based rule implies that the central bank commits to a persistent series of contractionary policy shocks. This then implies that the decline of inflation is much more substantial, and thus generates more term premium variability. Under a gap rule, the initial decline in inflation is 45 bp and the (negative) innovation in the real SDF is under 10%. Under an output rule, the initial inflation decline is 275 bp and the SDF innovation is over 15%. Further, under an output rule the persistent sequence of contractionary policy shocks keeps inflation persistently below steady state. Even after 20 quarters, inflation is over 200 bp below steady state (compared to 10 bp for the gap rule). We thus conclude that the model is able to generate substantial term premium variability only if the central bank uses a non-typical policy rule.

Figures 2 and 5 provide the corresponding analysis for MEI shocks. In this case, the EZ preferences actually hurt the model’s ability to generate a positive term premium: the mean term premium is monotonically decreasing in  $\theta$ . The reason for this is clear in the impulse response function in Figure 5 (which assumes  $\theta = 200$ ). A positive MEI shock increases lifetime utility and thus generates a negative

innovation in the real SDF. But by increasing the demand for final output which can now more easily be transformed into capital, the MEI shock increases total demand and thus persistently increases the inflation rate. Hence, the nominal SDF has positive serial correlation and thus delivers a negative term premium. For demand shocks long-term bonds are a hedge, and thus have a negative term premium. As with TFP shocks, the variability of the term premium is again trivial.

Figure 3 reports the mean and standard deviation of the term premium when both shocks are active. The results are as anticipated. The mean term premium is increasing in the EZ parameter, but the effect is much more modest than in Figure 1. The variability of the term premium is again trivial.

As emphasized by Bansal and Yaron (2004), long run risk is helpful in matching the equity premium with EZ preferences. The basic logic is that more persistence in the shock process implies larger variability in the real SDF. For the case of the term premium, greater persistence in either the TFP or MEI shocks is not helpful. As TFP shocks become more persistent, the wealth effect on labor supply tends to increase marginal cost and inflation, an effect that mitigates the EZ effects. For example, if we set  $\rho_A = 0.999$ , and  $\theta = 200$ , the mean term premium is 34 bp, with a standard deviation of 8 bp. For MEI shocks, greater persistence simply amplifies the hedging properties of the long bond. With  $\rho_\mu = 0.95$ , and  $\theta = 200$ , the mean term premium is -416 bp, with a standard deviation of 78 bp.

We thus conclude that the EZ approach to the term premium has difficulty in matching either the mean or standard deviation of the term premium. One significant caveat to this is if the cycle is driven by TFP shocks and the central bank follows an output Taylor rule. Since the gap represents departure from the flexible price benchmark, optimal Taylor rules will typically include responses to the measured gap. In contrast, there is never a welfare-based argument for responding to measured output. One could thus suggest that to match the mean and variability of the term premium requires EZ effects and a suboptimal policy rule of a particular form.

### 3. Adding Segmented Markets

Given the difficulty of generating significant variability in the term premium solely from EZ effects, here we investigate the model with the segmentation effects turned on. As noted in Table 1, we use  $\psi_n = 1$ , and  $\zeta = 0.9852$ . The portfolio adjustment elasticity is comparable to the estimate of Carlstrom, Fuerst and Paustian (2015). The extra-level of discounting generates a steady-state term premium of 100 bp, and a steady state segmentation distortion of  $M_{ss} = 1.072$ . The mean term premium will be the sum of the steady-state premium and the EZ risk adjustment that comes from the higher order approximation of the model.

Figure 6 reports the mean and standard deviation of the model's term premium for the case in which both shocks are active. The results with the segmentation effects turned off are also reported for comparison. Several comments are in order. First, the model with segmentation effects make long bonds much riskier. Compared to the model without segmentation effects, the mean term premium is more sharply increasing in  $\theta$ . These effects are quantitatively important. With  $\theta = 200$ , the segmentation effects increase the mean risk adjustment for long bonds by over 200 bp. It is thus quite easy to match the empirical mean of the term premium by choosing some combination of EZ effects ( $\theta$ ) and extra discounting ( $\zeta$ ). Second, and more importantly, the segmentation effects can easily generate significant term premium variability. Again, the segmentation effects are quantitatively important: the SD of the term premium is an order of magnitude larger in the model with active segmentation effects. A EZ term of, say,  $\theta = 50$ , allows the model to closely mirror both the mean and SD of the term premium in the data. We will use this value going forward.

Figures 7-8 report the impulse response functions to the two exogenous shocks (for  $\theta = 50$ ). The TFP shock causes a significant decline in the inflation rate. Since long bonds are nominal, this leads to a surge in the FI's real holdings of long bonds. The portfolio adjustment costs imply that the FI is willing to hold this abundance of long bonds only if term premia rise in compensation. This premia movement is

substantial (roughly 20 bp on impact), and because of the loan-in-advance constraint on investment, leads to a decline in investment and a corresponding surge in consumption.

For the MEI shock there are contrasting effects on the term premium. The surge in inflation lowers the FI's holding of long bonds implying a decline in term premia. But the MEI shock increases the demand for investment and a consequent rise in term premia. The net effect is quite small: the term premium falls by 7 bp on impact. This is an important observation. Although the MEI shocks are an important driver of the business cycle, they contribute only a modest portion of variability in the term premium.

These endogenous movements in the term premium reflect changes in the risk adjustment on long bonds and changes in the segmentation distortion. From our earlier results, we know that there are trivial movements in the premium arising from risk effects. Instead, almost all of the variability in the term premium reflects changes in the segmentation distortion. The central bank could use purchases (sales) of long debt to mitigate these increases (decreases) in the term premium and their consequent effect on real activity. We will investigate these issues below.

## 4. Segmented Markets and Monetary Policy

Carlstrom, Fuerst and Paustian (2015) demonstrate that up to a first-order approximation the term premium moves one-for-one with the market segmentation distortion ( $M_t$ ). This segmentation distortion has real effects by altering the efficient allocation of output between consumption and investment. Hence, a policy that stabilizes the term premium is likely to be welfare increasing. But things are more complicated with EZ effects and higher order approximations. Now the term premium will reflect both the segmentation distortion (as in Carlstrom, Fuerst, and Paustian (2015)), and the time-varying risk effects arising from the EZ preferences.

Our focus is on policy across the business cycle, so we introduce steady-state subsidies on factor prices (to counter the monopoly mark-ups) and the cost of capital goods (to counter the loan-in-advance

constraint) so that the steady-state of the model is efficient. Using a third-order approximation, we compute the welfare gain of a policy that varies the central bank's holdings of long bonds to stabilize the term premium at its steady state level of 100 bp. The baseline comparison policy is one in which the central bank holds its nominal bond portfolio fixed. Welfare is measured by expected lifetime utility of the household evaluated at the non-stochastic steady state.<sup>6</sup>

Figure 9 reports the welfare gain of a term premium peg as a function of  $\theta$ . The welfare gain is normalized to consumption units so that for example, 0.05, means a perpetual increase in steady state consumption of 0.05%. Figure 9 also reports the welfare gain of a long debt policy in which the central bank pegs the market segmentation distortion at steady-state ( $M_t = M_{ss}$ ). Absent any interactions with the mark-up distortions, a segmentation peg will be optimal as it eliminates a time-varying distortion from the model. We do not view a segmentation peg as a reasonable policy alternative, but it helps demonstrate the advantages and disadvantages of a term premium peg. Recall that up to a first-order approximation, these two pegs are identical. But there are differences with higher order effects.

For the case of both shocks and  $\theta = 0$ , there is a welfare gain of the term premium peg of nearly 0.2%. This is close to the gain of a segmentation peg. But as we increase the EZ coefficient  $\theta$ , these two welfare gains diverge. The gain of a segmentation peg is modestly increasing in  $\theta$ , an implication of the household's preference for distortion-stabilization as risk aversion increases. But the gain of a term premium peg diminishes in  $\theta$ . This decline arises because of the growing gap between the steady-state and mean term premium. The steady state premium comes from the additional FI discounting and thus reflects the segmentation distortion. The mean term premium is the steady-state premium plus the risk adjustment (either positive or negative) that comes from the EZ effect. As we increase the EZ coefficient, the mean term premium under the baseline policy becomes further separated from the steady-state term premium. A central bank that pegs the mean term premium at 100 bp. will therefore exacerbate the

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<sup>6</sup> We use Dynare to carry out these calculations. It is important to note that our welfare criterion will have the same value for both a second order and third order approximation.

average segmentation distortion by pegging the premium at the wrong level. This mismeasurement problem is increasing in  $\theta$ , so that the welfare gain of the premium peg is decreasing in  $\theta$ .

This mismeasurement problem is similar but distinct for the two shocks. Consider first the case of TFP shocks in Figure 9. As we increase  $\theta$ , the mean term premium under an exogenous debt policy increases because of risk aversion effects (see Figure 1). If the central bank pegs the mean term premium at 100 bp, it is then using its portfolio to overcompensate for segmentation effects, thus driving the average segmentation distortion below steady state. These effects are illustrated in Figure 10 which graphs the average segmentation wedge (relative to steady-state) as a function of  $\theta$ . Under a term premium peg this mean distortion is decreasing in  $\theta$  as the “overcompensation” effect increases. This then implies that the gain to a term premium peg is diminishing in  $\theta$ . The story is symmetric for the case of MEI shocks. The risk effect on the average term premium is now decreasing in  $\theta$  (see Figure 2). If the central bank pegs the mean term premium at 100 bp, it will drive the average segmentation distortion above steady state (see Figure 10). The average segmentation distortion is thus increasing in  $\theta$ , so that the welfare gain of a term premium peg is again decreasing in  $\theta$ .

In summary, in a world with EZ risk effects on bond prices, the mean term premium is not the same as the mean segmentation distortion. By pegging the mean term premium, the central bank will typically exacerbate the mean segmentation distortion, pushing it above or below its non-stochastic steady state. There is thus a trade-off between minimizing variability in the segmentation distortion and achieving a desired mean. But these mismeasurement effects are modest. Even with  $\theta = 200$ , the welfare gain of the peg is still substantial at 0.14%.

All of these effects are magnified if we abstract from subsidies that make the non-stochastic steady state efficient. With TFP shocks, the mean segmentation distortion is decreasing in  $\theta$ , so that the welfare gain of the term premium peg is increasing in  $\theta$ . Just the converse is true for MEI shocks. With  $\theta = 200$ , the welfare gain of the term premium peg is nearly 1.2% for TFP shocks, -0.5% for MEI shocks, and 0.68% for both shocks.

Another pitfall to responding to the term premium is that it is likely measured with significant error. We thus introduce serially correlated measurement error to the model's observed term premium. By pegging the measured term premium at a mean of 100 bp, measurement error implies that the central bank is inadvertently introducing exogenous fluctuations in the term premium into the model economy. We set the serial correlation of measurement error to 0.50. Figure 11 sets  $\theta = 50$ , and plots the welfare gain of the term premium peg as a function of the SD of measurement error. Since the SD of the term premium in the data is no more than 130 bp, a reasonable upper bound on the measurement error is 100 bp. But even with this large degree of noise, the gain to a term premium peg remains substantial.

Table 2 provides some sensitivity analysis by combining these two forms of measurement error. As discussed, the gain to a segmentation peg is modestly increasing in risk aversion  $\theta$ . The gain of the term premium peg is decreasing in both  $\theta$ , and the level of measurement error in the central bank's observation of the term premium. But even with very high risk aversion, and a large level of measurement error, the welfare gain of the term premium peg is still significant: 0.07%.

## 5. Conclusion

The last decade has demonstrated the creativity of central banks in creating new policy tools to deal with an evolving financial crisis and tepid recovery. A natural question going forward is which of these tools should become part of the regular toolbox of policymakers. One justification for the large scale asset purchases was to alter the term structure for a given path of the short-term policy rate. That is, the policies were (in part) designed to alter the term premium.<sup>7</sup> In analyzing such policies in a DSGE environment, one needs an economic rationale for both the mean and variability in the term premium. This paper has investigated two natural choices: (i) a time-varying risk premium for long bonds, and (ii) a time-varying market segmentation effect.

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<sup>7</sup> Meltzer (2003, 2009) recounts other time periods in which the Fed attempted to alter the term structure.



The paper suggests that the risk approach has difficulty in explaining the observed variability in the premium, whereas the segmentation approach can easily match the variability in the data. Further, according to the segmentation approach this variability is welfare-reducing so that there is a natural argument for a central bank to use its balance sheet to smooth fluctuations in the term premium. There are at least two concerns to consider when smoothing these fluctuations. The first is that a term premium peg prohibits fluctuations due to real economic activity, i.e. time varying risk effects. The second is that the term premium could be mismeasured and pegging the observed term premium introduces the measurement error into the economy. This paper shows that the effect of both of these concerns is modest and there are considerable welfare gains to smoothing term premium fluctuations.

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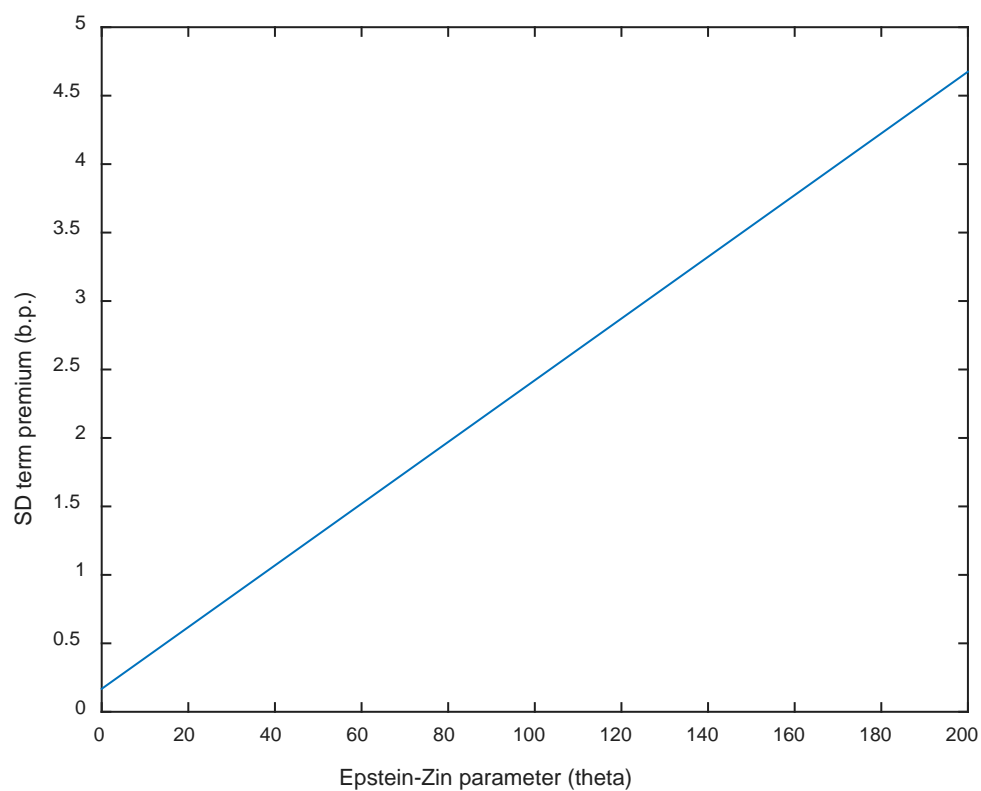
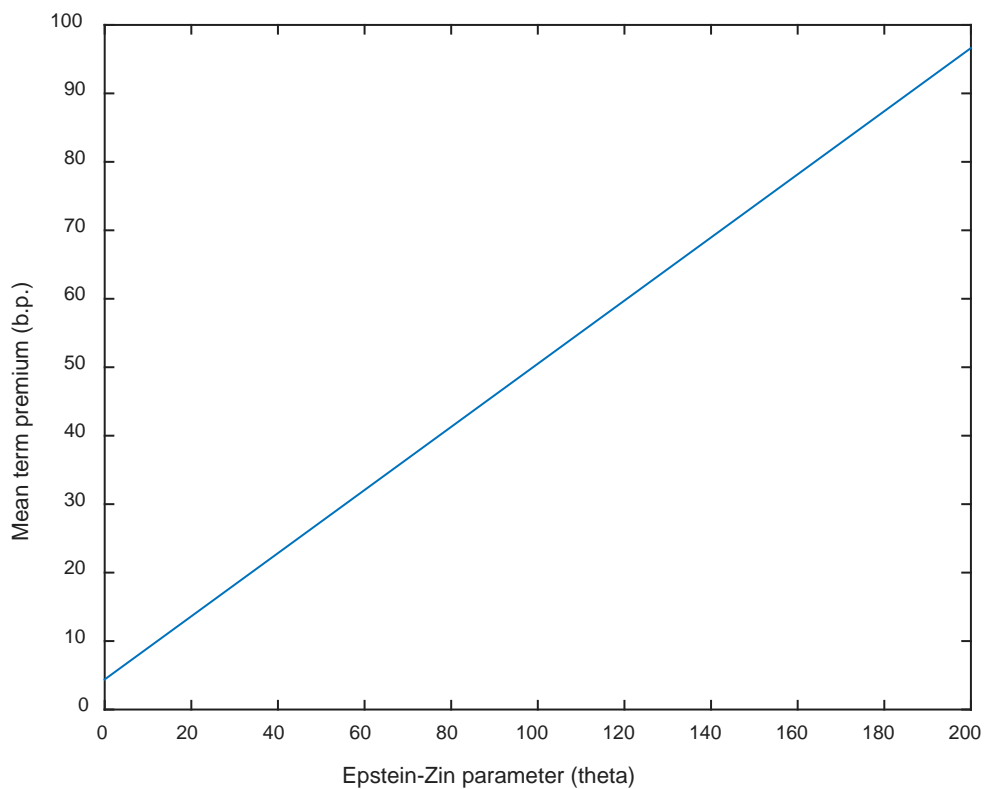
**Table 1: Parameter values for baseline calibration.**

Preference parameters	
$\beta$	0.99
$\nu$	2
$\eta$	1
$U_{ss}$	1
$h_{ss}$	1
Production parameters	
$\alpha$	0.33
$\delta$	0.025
$\epsilon_p = \epsilon_w$	5
$\psi_i$	2
Nominal stickiness.	
$\theta_p = \theta_w$	0.75
$i_p = i_w$	0.5
Financial parameters	
$\kappa$	1-1/40
$\psi_n$	1
$\zeta$	0.9852
$\Phi$	0.1687
Exogenous shocks	
$\rho_A, \sigma_A$	0.95, 0.01
$\rho_\mu, \sigma_\mu$	0.80, 0.06

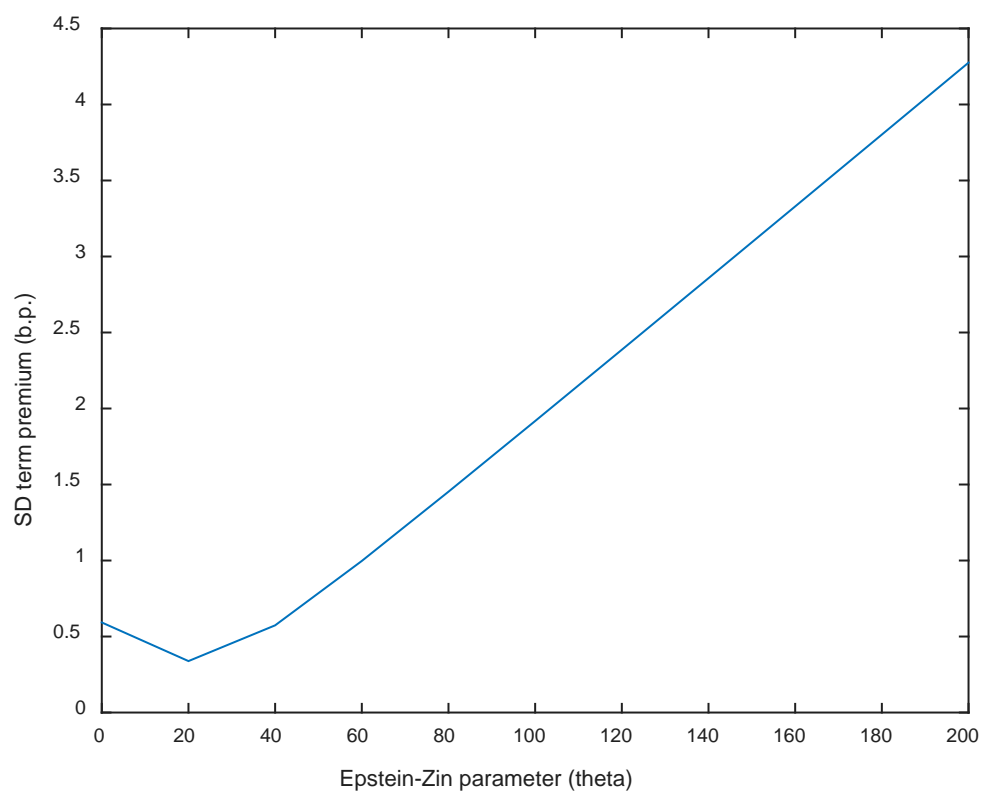
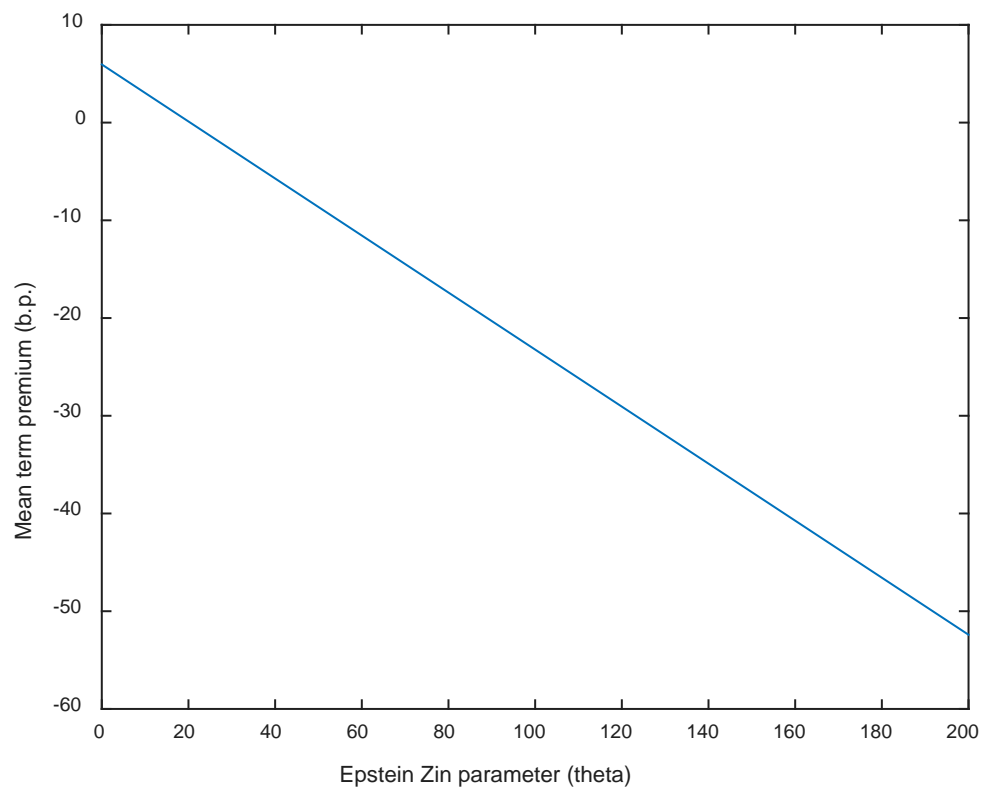
**Table 2: Welfare gain of Term Premium Peg  
and Segmentation Peg (both shocks).**

	Term Peg	Segmentation Peg
<b><math>\theta = 0</math></b>		
$\sigma_{me} = 0$	0.1869	0.1974
$\sigma_{me} = 100$	0.1185	0.1974
<b><math>\theta = 50</math></b>		
$\sigma_{me} = 0$	0.1759	0.2000
$\sigma_{me} = 100$	0.1076	0.2000
<b><math>\theta = 200</math></b>		
$\sigma_{me} = 0$	0.1431	0.2079
$\sigma_{me} = 100$	0.0748	0.2079

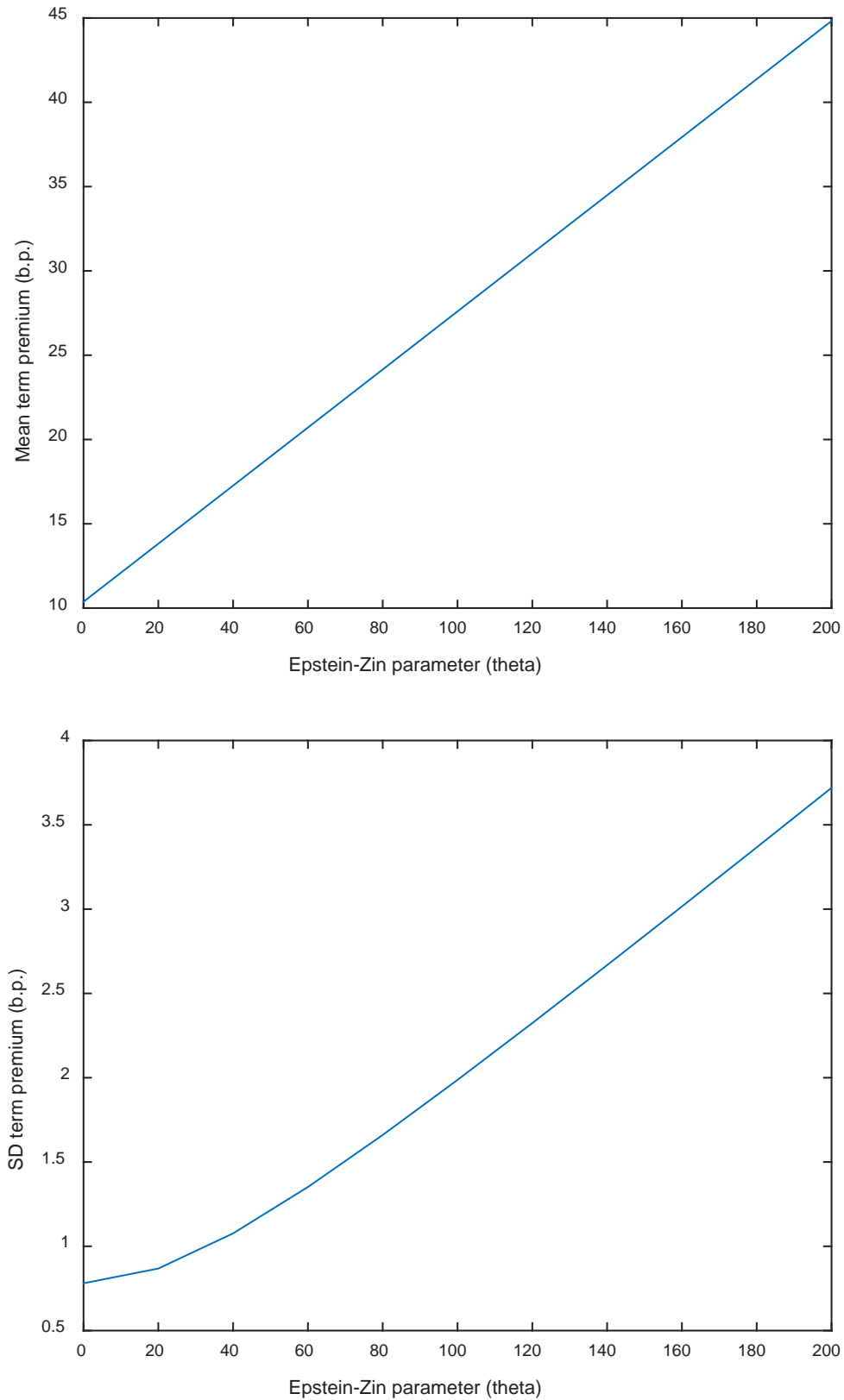
**Figure 1: Term premium with TFP shocks.**



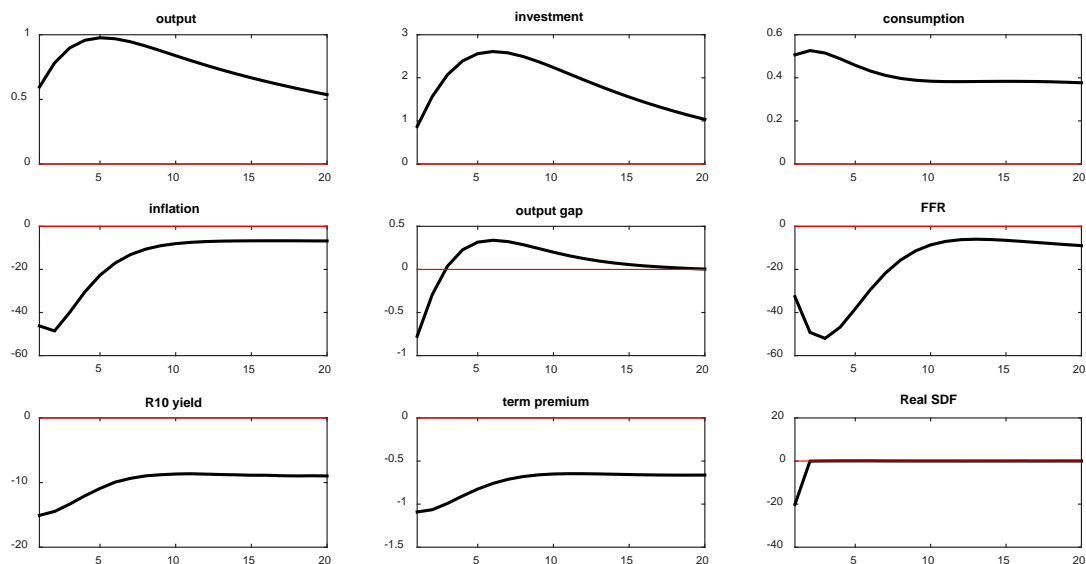
**Figure 2: Term premium with MEI shocks.**



**Figure 3: Term premium with TFP and MEI shocks.**



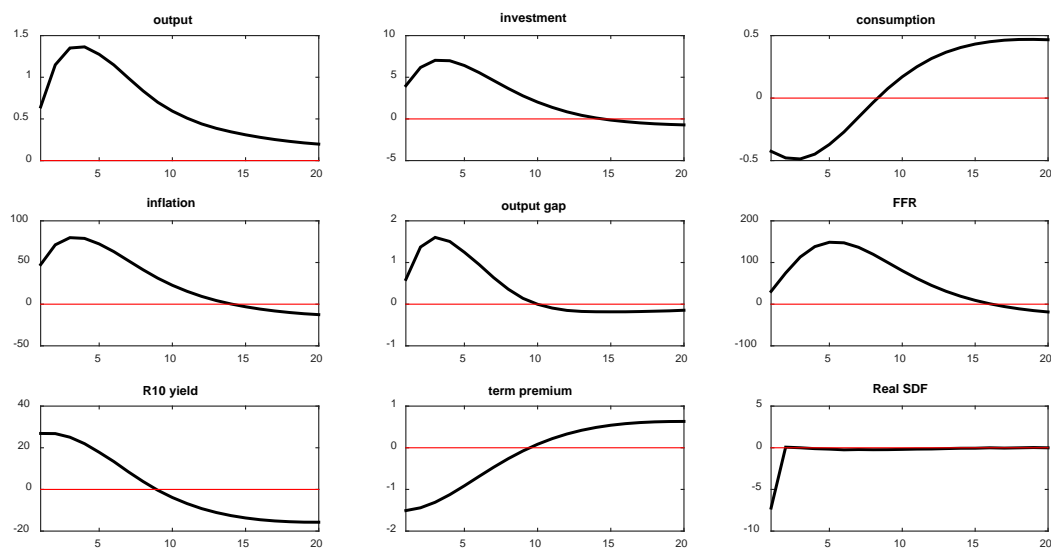
**Figure 4: IRF to a TFP shock.**  
**(no segmentation effects)**



Legend: Output, investment, consumption, output gap, and real SDF, are percent deviations from steady state. Inflation, the funds rate, the 10-year yield, and the term premium (prem) are deviations from steady state in annualized bp. The IRFs are computed with a third-order approximation.

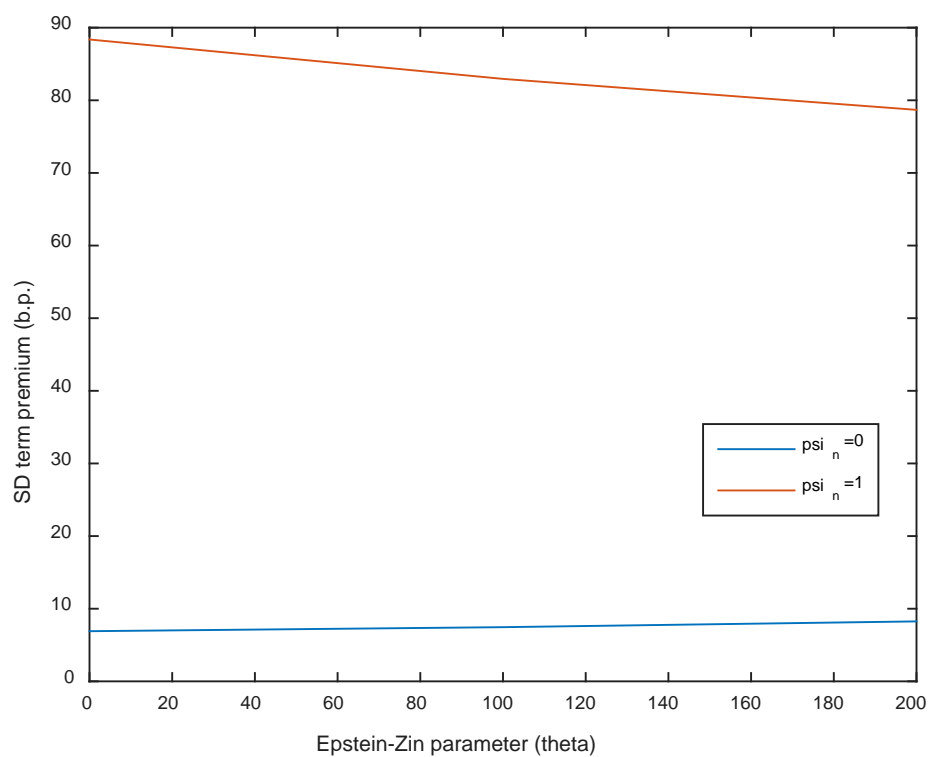
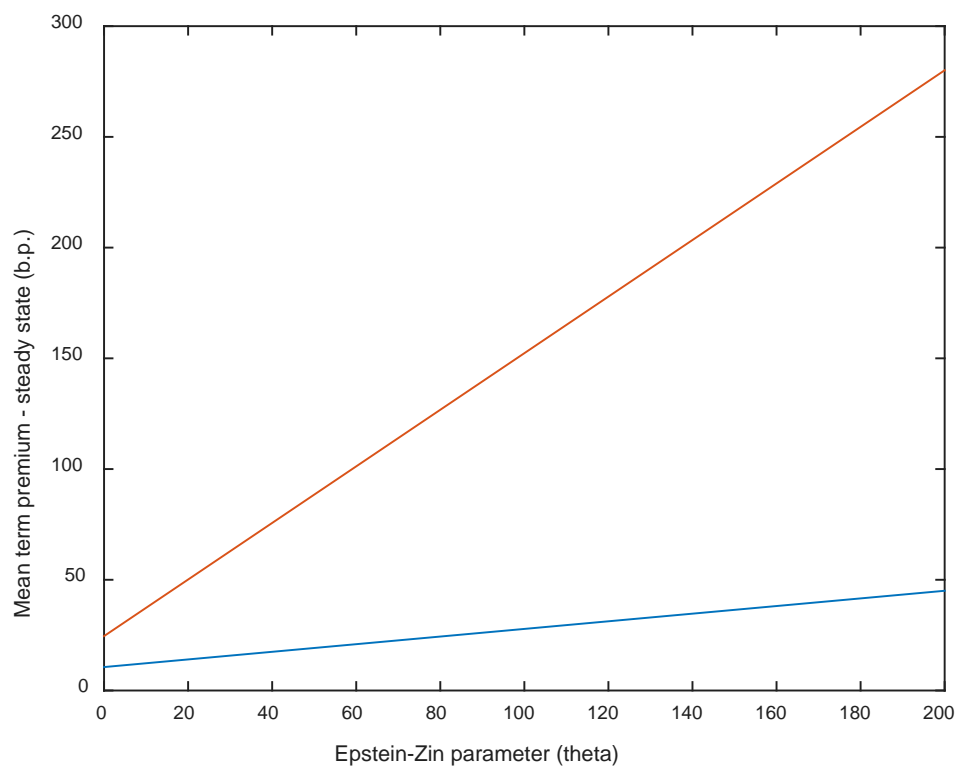


**Figure 5: IRF to a MEI shock.**  
**(no segmentation effects)**

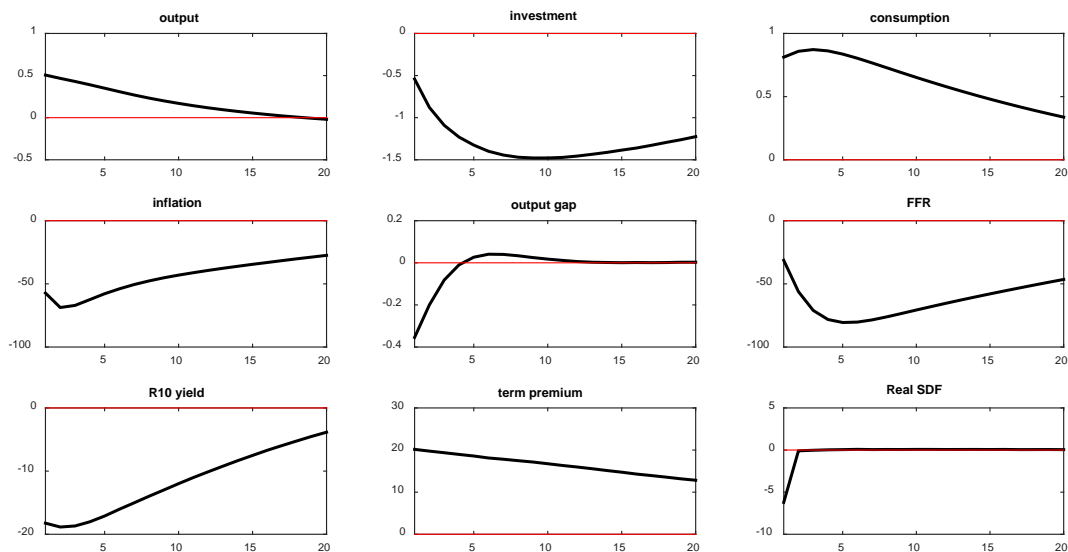


Legend: Output, investment, consumption, output gap, and real SDF, are percent deviations from steady state. Inflation, the funds rate, the 10-year yield, and the term premium (prem) are deviations from steady state in annualized bp. The IRFs are computed with a third-order approximation.

**Figure 6: Term premium with segmentation.**  
**(TFP and MEI shocks)**

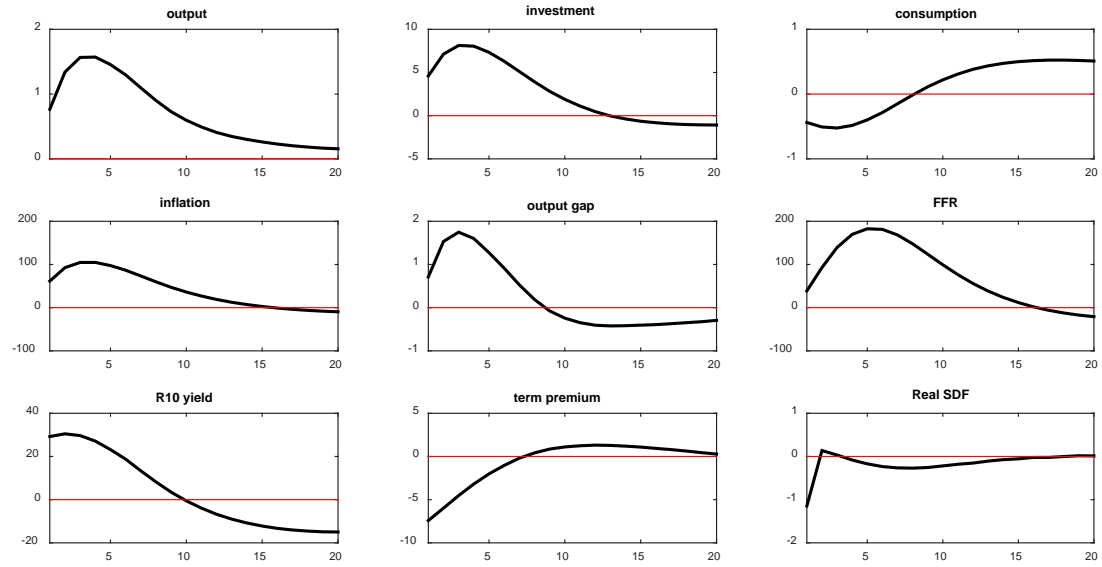


**Figure 7: IRF to a TFP shock.**  
**(with segmentation effects)**



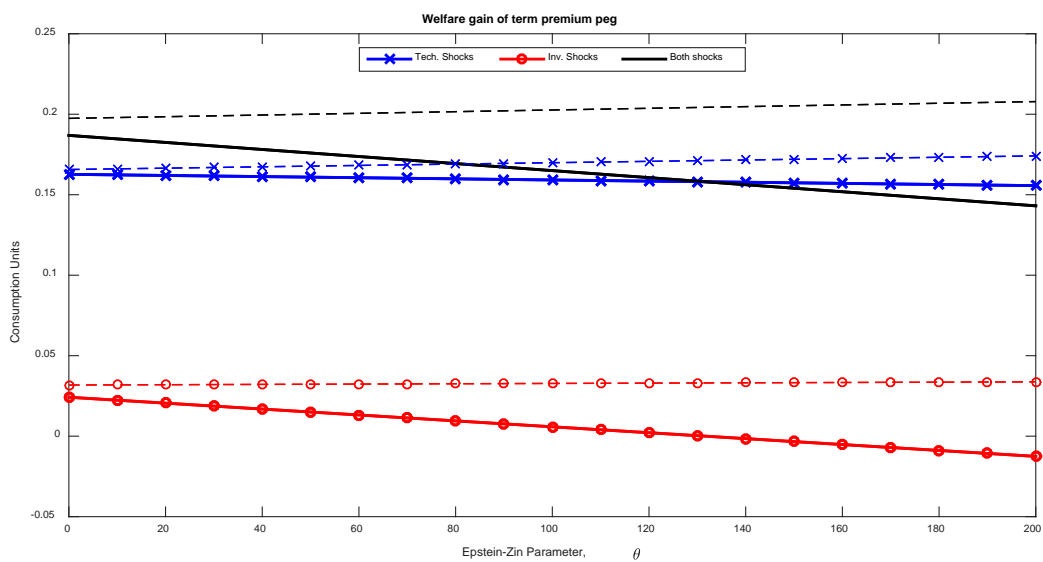
Legend: Output, investment, consumption, output gap, and real SDF, are percent deviations from steady state. Inflation, the funds rate, the 10-year yield, and the term premium (prem) are deviations from steady state in annualized b.p. The IRFs are computed with a third-order approximation.

**Figure 8: IRF to a MEI shock.**  
**(with segmentation effects)**



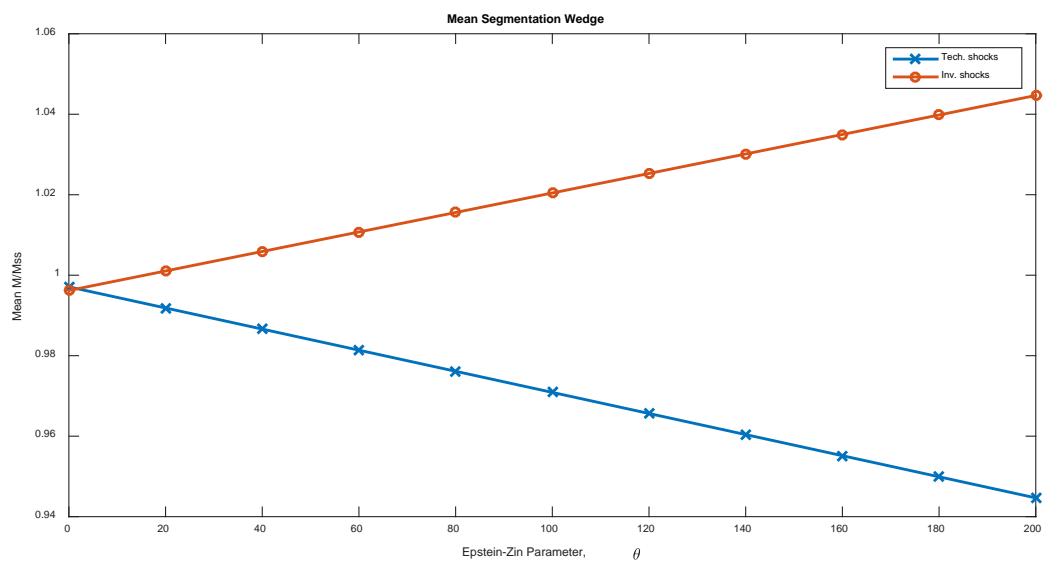
Legend: Output, investment, consumption, output gap, and real SDF, are percent deviations from steady state. Inflation, the funds rate, the 10-year yield, and the term premium (prem) are deviations from steady state in annualized bp. The IRFs are computed with a third-order approximation.

# **Figure 9: Welfare gain of a Term Premium Peg**



Solid lines denote term premium peg; dashed lines denote segmentation peg.

**Figure 10: Mean Segmentation Wedge**



Mean segmentation wedge under a term premium peg of 100 bp.

**Figure 11: Welfare gain of a Term Premium Peg**  
**(measurement error)**

