Nominal Targeting in an Economy with Government Debt*

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Abstract

Most analyses of monetary policy delegation schemes typically ignore the behavior of the fiscal policy maker. The paper investigates how monetary price level targeting or monetary nominal income targeting may yield social gain in an economy with government debt and where the fiscal policymaker, acting strategically, may take counter actions. We argue that the choice of fiscal policy instrument plays an important role for the performance of monetary policy. The optimal choice of monetary policy delegation scheme depends crucially on the level of government debt and its maturity, with a switch from price level targeting being desirable to nominal income targets being strongly preferred as debt levels rise and maturity shortens.

Key Words: Monetary and Fiscal Policy Interactions, Price Level Targeing, Nominal Income Targeting, Discretionary Policy

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*All errors remain ours.

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1 Introduction

In this paper we explore the optimal delegation of monetary policy to an independent central banker in the context of a policy making environment where that monetary policy maker will inevitably interact with a fiscal policy maker. This is in contrast to the established literature which typically conducts such analyses in the context of models where fiscal policy is absent or implicitly rendered trivial through the application of Ricardian Equivalence. When optimal monetary and fiscal policy are considered then the analysis is usually based on a single benevolent policy maker jointly controlling both monetary and fiscal policy instruments (Benigno and Woodford (2003), Schmitt-Grohe and Uribe (2007), Leith and Wren-Lewis (2000)). Our contribution therefore lies in assessing the appropriateness of common monetary policy delegation schemes in the presence of a non-trivial fiscal policy, while also extending the range of monetary-fiscal interactions by allowing for strategic interactions between monetary and fiscal policy makers.

In the context of the benchmark New Keynesian model, optimal monetary policy imparts a history dependence to policy making which is not necessarily part of the underlying model. For example, in the purely forward looking benchmark New Keynesian model considered by (Woodford, 2003) optimal monetary policy implies a commitment to stabilize the price level following shocks such that any overshooting of the inflation target is undone by a subsequent undershooting even although the original inflationary shock has passed and there is no explicit target for the price level. The policy maker behaves in this way as such commitments have a beneficial effect on expectations allowing the policy maker to stabilize inflation at a lower cost in terms of lost output. An inability to make such commitments leads to welfare losses which have been labelled as being due to a 'stabilization bias' (Svensson, 1997).

However, despite the potential welfare gains from commitment, there is little evidence either from formal econometric estimation of policy making behavior (Chen, Kirsanova, and Leith (2013b), Chen, Kirsanova, and Leith (2013a)) or from policy discussions emanating from central banks that policy making is conducted under commitment particularly when such policies imply a deliberate offsetting deviation from an inflation target following shocks. In light of this there have been calls to adopt alternative monetary policy delegation schemes as an alternative means of offsetting the stabilization bias with particular emphasis on price level targeting (Vestin, 2006) and nominal income growth targeting (Jensen and McCallum, 2002). These calls have been given renewed vigor in the light of the recent financial crisis and the attendant difficulties of implementing monetary policy when interest rates are constrained by the zero lower bound (ZLB).

For example Eggertsson and Woodford (2003), Woodford (2012) advocates a policy of nominal income targeting as a way of influencing inflation expectations such that the economy would be lifted up from the ZLB. Similarly, Chen et al. (2013a) show that in an estimated model for the Euro area the ZLB would not have been met had the ECB been following a policy of flexible price level targeting. Such analyses takes place in models where there is an absence of meaningful monetary and fiscal policy interactions.

In New Keynesian models which do consider monetary and fiscal policy interactions the results are striking. The optimal Ramsey policy implies a random walk in steady-state debt following shocks (see Benigno and Woodford (2003), Schmitt-Grohe and Uribe (2007), Leith and Wren-Lewis (2000)). In an application of Barro (1979)'s tax smoothing result, a shock with negative fiscal consequences results in an adjustment of fiscal variables to sustain the higher level of debt that emerges, but there is no attempt to return debt to its pre-shock level. This is due to the fact that the optimal policy precisely balances the short-run costs of fiscal adjustment in a sticky-price model against the long-run gains of a lower steady state level of debt. However, when the policy maker cannot commit to behave in this way, the resultant time-consistent policy is radically different. Leith and Wren-Lewis (2013) show that the debt stock will be returned to its steady state value following shocks. Moreover, the policy mix employed to achieve this depends crucially on the level of debt. At low debt levels, fiscal instruments are typically employed to stabilize debt and monetary policy behaves as usual in controlling aggregate demand to stabilize inflation, while at higher levels of debt, the implicit policy assignment is reversed and monetary policy acts to stabilize debt (through monetary policy's impact on interest rates and the tax base), while distortionary taxes are adjusted to moderate the higher inflation such monetary accommodation would otherwise imply. Moreover, the speed at which debt is returned to its steady state is much faster at higher debt levels and there may even by an overshooting as the policy maker seeks to reduce expectations of future inflation by reducing debt below steady-state in order to reduce inflation today due to the link between current and future inflation implied by the New Keynesian Phillips curve. However much of this analysis assumes government debt is of one quarter's maturity. Leeper and Leith (2015) show that the interactions between monetary and fiscal policy also depend crucially on the maturity structure of the outstanding stock of government debt. Given that the presence of government debt and its maturity can have such a significant impact on the conduct of monetary policy when the two policy makers are acting cooperatively, but are unable to commit it is important to ask (i) how fiscal policy influences the conduct of an independent central bank when the two policy makers interact strategically rather than cooperatively, and (ii) how such interactions affect the design of monetary policy delegation schemes which hope to achieve outcomes closer to those obtained under commitment.

To answer these questions we present a formal analysis of key features of nominal targeting in an economy which has accumulated government debt. Specifically, we study price-level and nominal income targeting schemes in a direct comparison with the benchmark case of benevolent (and thus cooperative) monetary and fiscal policy. The main focus of the paper is to assess how the presence of a time consistent fiscal policy maker affects the design of monetary nominal targeting schemes. We investigate which scheme is most effective in facilitating a welfare improving slowdown in the speed of fiscal correction, and how that depends on debt levels and its average maturity. We also look at the extent to which an independent monetary policy maker, who is not given explicit fiscal objectives, is affected by the conduct of fiscal policy. We investigate which delegation scheme allows monetary policy to remain active for longer before higher debt or shorter maturity tips the monetary authority into being effectively passive in Leeper (1991) sense.

We explicitly model two optimizing non-cooperative policy makers, the monetary and fiscal authorities, respectively. We use a version of the familiar sticky price New Keynesian model modified to incorporate debt accumulation (Benigno and Woodford, 2003). Fiscal policy is assumed to be strategic, so that it has a chance to decide on the level of fiscal instruments every period, rather than precommit to particular rules for infinitely long period of time. We assume that fiscal policy maker's objective is to minimize the micro-founded social welfare loss function, and the fiscal policymaker is able to conduct itself as an intra-period leader, so that any potential conflict between the two authorities due to the difference in objectives is minimized.[1] In this setup the fiscal policymaker understands the both the objective and the policy design of the monetary policymaker and effectively allows the intra-period follower to conduct most of the stabilization under price- or nominal income- targeting mandate.[2]

Our results are striking. First, the choice of fiscal instrument plays an important role in the ability of macroeconomic policy to achieve gains from delegation.[3] In two discretionary regimes with either cooperative monetary-fiscal policy making (the benchmark regime) or under strategic interactions with the central bank implementing a price level target and the fiscal authority max-

[1] The empirical evidence suggests that this regime is more likely to realise in countries without fiscal decentralization, like the UK, see Fragetta and Kirsanova (2010) and Le Roux and Kirsanova (2013).

[2] See Blake and Kirsanova (2011) for the discussion.

[3] Much of the theoretical literature treats government consumption as a stream which needs to be financed (see for example Schmitt-Grohe and Uribe (2007) and Benigno and Woodford (2003)). However, recent fiscal consolidation programmes have tended to be driven by adjustments to government spending rather than tax adjustments (see IMF, 2012). It is therefore interesting to compare and contrast both fiscal instruments.

imizing social welfare, once the debt to output ratio is above some threshold and debt maturity is relatively short then monetary policy becomes passive. Monetary policy accommodates inflation to facilitate the rapid reduction in debt levels following negative shocks and the resultant stabilization process results in large welfare losses. We demonstrate that for these two regimes the debt-to-output threshold is higher and maturity threshold is shorter if fiscal policy operates with taxes rather than spending.

Second, the optimal choice of monetary policy delegation scheme depends crucially on the level of government debt and its maturity, with a switch from price level targeting to nominal income targets being strongly preferred as debt levels rise and maturity shortens. Delegating price level targeting to the monetary policymaker can bring a substantial reduction in social loss – the loss can be very close to the one under benevolent commitment – but only for low levels of debt and long maturity, precisely in those cases when fiscal policy does not interfere with monetary policy. However, we demonstrate that the choice of fiscal instrument is nevertheless important for the performance of monetary policy. If fiscal policy operates with spending then the social gain is only possible for relatively small debt to output ratios: even for the average maturity of 8 years we need to keep the annual value of debt to output ratio below 80% to achieve some gain. If fiscal policy operates with taxes, however, then as soon as the average maturity is longer than 1 year, then there is a large social gain from delegation even for debt to output ratio of 100%. Nominal income targeting results in much smaller social gain from delegation, in most cases the stabilization bias is hardly halved. Moreover, if fiscal policy operates with spending then there is no gain from the delegation if maturity is in excess of 4 years. However, there is a welfare gain with relatively short-term debt with a maturity of between one and four years, and the gain is particularly large if fiscal policy operates with taxes. If fiscal policy operates with taxes then we do not discover passive monetary policy regime for combinations of debt and maturity which we studied, so fiscal policy effectively does not interfere with monetary policy.

The paper is organized as follows. In the next section we outline the model. Section 3 defines all policy scenarios of interest and Section 4 describes the calibration. Section 5 presents the analysis of all cases we consider, for each of the fiscal instruments. Section 6 concludes.

2 The Model

We consider the now-mainstream New Keynesian policy model modified to take account of the effects of fiscal policy, see e.g. Woodford (2003) and Benigno and Woodford (2003). It is a closed economy model with two policymakers, the fiscal and monetary authorities. Fiscal policy is assumed to support monetary policy in stabilization of the economy around the non-stochastic steady state.

The economy consists of a representative infinitely-lived household, a representative firm that produces the final good, a continuum of intermediate goods-producing firms and a monetary and fiscal authority. The intermediate goods-producing firms act under monopolistic competition and produce according to a production function that depends only on labor. Goods are combined via a Dixit and Stiglitz (1977) technology to produce aggregate output. Firms set their prices subject to a Calvo (1983) price rigidity. Households choose their consumption and leisure and can transfer income through time through their holdings of government bonds. We assume that the fiscal authority faces a stream of exogenous public consumption. These expenditures are financed by levying income taxes[4] and by issuing one-period risk-free nominal bonds.

2.1 Consumers

The representative consumer maximizes the following utility function

$$\max_{\{C_v,h_v\}_{v=t}^{\infty}} \mathbb{E}_t \sum_{v=t}^{\infty} \beta^{v-t} \left[u(C_v) + f(G_v) - v(h_v(z)) \right]. \tag{1}$$

The price of a differentiated good z is denoted by $p(z)$, and the aggregate price level is P. An individual chooses optimal consumption C_v and work effort h_v to maximize criterion (1) subject to the demand system and the flow budget constraint:

$$P_tC_t + P_t^S B_t^S + P_t^M B_t^M \leq B_{t-1}^S + \left(1 + \rho P_t^M\right) B_{t-1}^M + (1 - \Upsilon_t)\left(w_t(z)h_t(z) + \Pi_t(z)\right) + P_tT, \tag{2}$$

where $P_tC_t = \int_0^1 p(z)c(z)dz$ is nominal consumption. The household's period-t income includes: wage income from providing labour services to goods producing firms, $w_t(z)h_t(z)$, profits from monopolistically-competitive firms $\Pi_t(z)$, a constant lump sum transfer from the government T and payments on the portfolio of assets, B_t^S and B_t^M. Υ_t is a tax rate on income. Households hold two forms of government bond. The first is the familiar one period debt, B_t^S, which has a price equal to the inverse of the gross nominal interest rate, $P_t^S = R_t^{-1} = \frac{1}{1+i_t}$. The second type of bond is actually a portfolio of many bonds which, following Cochrane (2000) pay a declining premium of ρ^j, j periods after being issued, where $0 < \rho < \beta^{-1}$. The duration of the bond, assuming stable prices, is $\frac{1}{1-\beta\rho}$, which means that ρ can be varied to capture changes in the

[4] We could use distortionary consumption taxes to finance the deficit. The transmission mechanism would be the same.

maturity structure of debt. We only need to price a single bond, since any existing bond issued j periods ago is worth ρ^j of new bonds.

There is an associated transversality condition derived as follows. The household wealth in period t can be written as

$$D_t = \left(1 + \rho P_t^M\right) B_{t-1}^M + B_{t-1}^S$$

so that

$$\lim_{T\to\infty} \mathbb{E}_t R_{t,T} \frac{D_T}{P_T} \geq 0$$

where $R_{t,T} = \prod_{s=t}^{T-1} \left(\frac{\left(1+\rho P_{s+1}^M\right)}{P_s^M} \frac{P_s}{P_{s+1}} \right)$ for $T \geq 1$ and $R_{t,t} = 1$.

Each individual consumes the same basket of goods. Goods are aggregated into a Dixit and Stiglitz (1977) consumption index with the elasticity of substitution between any pair of goods given by $\epsilon > 1$, $C_t = \left[\int_0^1 c_t^{\frac{\epsilon-1}{\epsilon}}(z)dz \right]^{\frac{\epsilon}{\epsilon-1}}$

We assume the specific functional form for the utility from consumption component, $u(C_v, \xi_t) = \frac{C_v^{1-1/\sigma}}{1-1/\sigma}$. Household optimization leads to the following dynamic relationship for aggregate consumption:

$$1 = \beta R_t \mathbb{E}_t \left(\left(\frac{C_{t+1}}{C_t} \right)^{-1/\sigma} \frac{P_t}{P_{t+1}} \right) \tag{3}$$

$$P_t^M = \beta \mathbb{E}_t \left(\left(\frac{C_{t+1}}{C_t} \right)^{-1/\sigma} \frac{P_t}{P_{t+1}} \left(1 + \rho P_{t+1}^M\right) \right) \tag{4}$$

Additionally, aggregate (nominal) asset accumulation is given by

$$R_t^{-1} B_t^S + P_t^M B_t^M = B_{t-1}^S + \left(1 + \rho P_t^M\right) B_{t-1}^M + (1 - \Upsilon_t)\left(W_t N_t + \Pi_t\right) + T - P_t C_t, \tag{5}$$

where W_t and N_t are aggregate wages and employment.

It is convenient to define the stochastic discount factor

$$Q_{t,t+1} = \beta \mathbb{E}_t \left(\left(\frac{C_{t+1}}{C_t} \right)^{-1/\sigma} \frac{P_t}{P_{t+1}} \right)$$

We linearize equation (3) around the steady state (here and everywhere below for each variable X_t with steady state value X, we use the notation $\hat{X}_t = \ln(X_t/X)$). Equation (3) leads to the following Euler equation (intertemporal IS curve):

$$\hat{C}_t = \mathbb{E}_t \hat{C}_{t+1} - \sigma \left(\hat{\imath}_t - \mathbb{E}_t \hat{\pi}_{t+1}\right). \tag{6}$$

Inflation is $\pi_t = \frac{P_t}{P_{t-1}} - 1$ and we assume steady state inflation is zero.

Linearization of (4) yields

$$\hat{P}_t^M = \beta\rho\mathbb{E}_t\hat{P}_{t+1}^M - \hat{\imath}_t$$

where in steady state $P^M = \frac{\beta}{(1-\beta\rho)}$.

2.2 Firms

Price setting is based on Calvo contracting as set out in Woodford (2003). Each period agents recalculate their prices with fixed probability $1-\gamma$. If prices are not recalculated (with probability γ), they remain fixed. Following Woodford (2003) and allowing for government consumption terms in the utility function, we can derive the following Phillips curve for our economy[5]:

$$\hat{\pi}_t = \beta\mathbb{E}_t\hat{\pi}_{t+1} + \frac{(1-\gamma\beta)(1-\gamma)\psi}{\gamma(\psi+\epsilon)}\hat{s}_t, \tag{7}$$

where marginal cost is

$$\hat{s}_t = \frac{1}{\psi}\hat{Y}_t + \frac{1}{\sigma}\hat{C}_t + \frac{\tau}{(1-\tau)}\hat{\Upsilon}_t - \hat{\zeta}_t + \hat{\eta}_t.$$

The shock $\hat{\eta}_t$ is a mark-up shock and $\hat{\zeta}_t$ is a technology shock, as we assume the production function $y_t = Z_t h_t$, $Z_t = Z_{t-1}\zeta_t$, where ζ_t has a mean of unity. Here $\psi = v_y/v_{yy}y$ and τ is the steady state income tax rate.

Under flexible prices and in the steady state the real wage is always equal to the monopolistic mark-up $\mu = -(1-\epsilon)/\epsilon$. Optimization by consumers then implies:

$$\frac{\mu^w}{\mu} = \frac{v_y(y_t^n(z))}{\left(1-\hat{\Upsilon}_t^n\right)u_C(C_t^n)}, \tag{8}$$

where superscript n denotes natural levels (see Woodford (2003)), and μ^w is a steady state employment subsidy which we discuss below. Linearization of (8) yields

$$\hat{Y}_t^n\frac{1}{\psi} + \hat{C}_t^n\frac{1}{\sigma} + \frac{\tau}{(1-\tau)}\hat{\Upsilon}_t^n - \hat{\zeta}_t = 0. \tag{9}$$

[5] The derivation is identical to the one in Woodford (2003), amended by the introduction of mark-up shocks as in Beetsma and Jensen (2004).

2.3 Fiscal Constraint

The government buys goods (G_t), taxes income (with tax rate Υ_t), raises lump-sum taxes, pays an employment subsidy and issues nominal debt B_t^M.The value B_t^M of end-of-period public debt then evolves according to the following law of motion:

$$P_t^M B_t^M = \left(1 + \rho P_t^M\right) B_{t-1}^M + P_t G_t - \Upsilon_t P_t Y_t - P_t T, \tag{10}$$

where we assumed that the aggregate stock of one-period bonds is in zero net supply, $B_t^S = 0$.

Lump-sum taxes (T) are constant and cannot be used to stabilize the economy. For analytical convenience we introduce $B_t = B_t^M / P_t$, so that (10) becomes

$$P_t^M B_t = \left(1 + \rho P_t^M\right) \frac{B_{t-1}}{1 + \pi_t} + G_t - \Upsilon_t Y_t - T. \tag{11}$$

The first-order approximation of equation(11) about the non-stochastic zero-inflation and zero-debt steady state yields

$$b_t = (\rho - 1)\,\chi \hat{P}_t^M + \frac{1}{\beta}\left(b_{t-1} - \chi\pi_t + (1 - \beta\rho)\left((1 - \tau)\frac{G}{Y}\hat{G}_t - \tau\frac{C}{Y}\hat{C}_t - \tau\hat{\Upsilon}_t\right)\right), \tag{12}$$

where we denote $b_t = \frac{B}{Y}\hat{B}_t$ and $\chi = \frac{B}{Y}$.

2.4 Aggregate Relationships

Output is distributed as wages and profits:

$$Y_t = W_t N_t + \Pi_t. \tag{13}$$

Government expenditures constitute part of demand, so the national income identity can be written as

$$Y_t = C_t + G_t, \tag{14}$$

2.5 Evolution of the Economy

We now write down the final system of equations for the 'law of motion' of the out-of-steady-state economy. We simplify notation by using lower case letters to denote 'gap' variables, where the gap is the difference between actual levels and natural levels i.e. $x_t = \hat{X}_t - \hat{X}_t^n$. The model consists of an intertemporal IS curve (6), the Phillips curve (7), national income identity (14), and an equation explaining the evolution of debt (12). The system is:

$$c_t = \mathbb{E}_t c_{t+1} - \sigma \left(i_t - \mathbb{E}_t \pi_{t+1}\right) \tag{15}$$

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \varkappa c_t + \vartheta g_t + \nu \tau_t + \eta_t \tag{16}$$

$$p_t = p_{t-1} + \pi_t \tag{17}$$

$$y_t = \theta c_t + (1-\theta)\, g_t \tag{18}$$

$$\begin{aligned} b_t = & -(1-\rho)\,\chi p_t^M + \frac{1}{\beta}\left(b_{t-1} - \chi \pi_t + (1-\beta\rho)(1-\theta)(1-\tau)\, g_t \right. \\ & \left. - (1-\beta\rho)\,\tau\theta c_t - (1-\beta\rho)\,\tau\tau_t\right) - A\hat{\zeta}_t \end{aligned} \tag{19}$$

$$p_t^M = \beta\rho \mathbb{E}_t p_{t+1}^M - i_t \tag{20}$$

where coefficients $\theta = C/Y$, $\chi = B/Y$, $\varkappa = \kappa\left(\frac{1}{\sigma} + \frac{\theta}{\psi}\right)$, $\nu = \kappa\frac{\tau}{(1-\tau)}$, $\vartheta = \frac{\kappa(1-\theta)}{\psi}$, $\eta_t = \kappa\hat{\eta}_t$, $A = \frac{(1-\rho)\chi\left(1-\rho_\zeta\right)}{\left(1-\beta\rho\rho_p\right)\left(\frac{\sigma\theta}{\psi} - \frac{\sigma\tau\theta}{(1-\tau)} + 1\right)}$. Debt b_{t-1} and price p_{t-1} are endogenous predetermined state variables.

3 Monetary and Fiscal Policy Regimes

The social loss is defined by the quadratic loss function[6]

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\pi_t^2 + \frac{\kappa\theta}{\sigma\epsilon} c_t^2 + \frac{\kappa}{\psi\epsilon} y_t^2 + \frac{\kappa(1-\theta)}{\sigma\epsilon} g_t^2\right). \tag{21}$$

The sequence of events and actions within a period is as follows. At the beginning of every period t the states, debt b_{t-1} and the price level p_{t-1}, are known and shock η_t realizes. Then the two policymakers choose the value of their instruments, interest rate i_t and either taxes τ_t or spending g_t. We assume a particular order of moves, the fiscal policymaker moves moves first and chooses the best point on the monetary policymaker's reaction function. The monetary policymaker moves second. Both policymakers observe the states $\{b_{t-1}, p_{t-1}, \eta_t\}$ and take the process by which private agents behave as given. After the policymakers have moved, in the next stage the private sector simultaneously adjusts its choice variables, inflation π_t and consumption c_t. The optimal π_t, c_t and policy i_t, τ_t result in the new level of b_t and p_t by the beginning of the next period $t+1$.

We study four policy regimes: (i) Benevolent Commitment, (ii) Benevolent Discretion, (iii) Monetary Price Level Targeting (MPLT), and (iv) Monetary Nominal Income Targeting (MNIT).

[6] The criterion is derived under the assumption of steady state labour subsidy. Here parameter λ is a function of model parameters, $\lambda = \theta\kappa/\epsilon$, and ϵ is the elasticity of substitution between any pair of monopolistically produced goods. Derivation is presented in Kirsanova and Wren-Lewis (2011) and/or available upon the request.

The first regime is benevolent commitment policy, or, equivalently, the Ramsey allocation. It is the solution which minimizes the social welfare criterion (21) subject to constraints (15)-(20). This allocation requires full commitment to policies and full cooperation between the monetary and fiscal authorities. In what follows we call this 'commitment policy'. The commitment solution delivers the highest possible welfare, so the performance of all other policies can be naturally compared with it.

The second regime is benevolent discretionary policy. We keep identical social objectives for both policymakers as this provides us with a benchmark measure of the social welfare loss due to the inability to commit. The resultant stabilization bias can be reduced with an appropriately chosen delegation scheme, and we study two such schemes in the remaining two scenarios.

The third regime is monetary price level targeting (MPLT). This regime is thoroughly investigated in models without fiscal policy, where it generally yields a substantial reduction of the stabilization bias, and could perfectly mimic the commitment solution were our model to exclude fiscal policy and assume all shocks are iid (see Vestin, 2006). In a model with fiscal policy, however, this regime allows us to evaluate the welfare implications of price stability in the environment with debt accumulation and where non-cooperative fiscal policy can potentially offset the actions of the monetary policy maker. Following the standard applications of a price level target (Svensson, 1997; Vestin, 2006), we assume that the monetary policymaker minimizes the loss in the form of the social objective (21), but where the term in inflation is replaced by the term in price level:

$$\sum_{t=0}^{\infty} \beta^t \left(p_t^2 + \Phi_p \left(\frac{\kappa\theta}{\sigma\epsilon} c_t^2 + \frac{\kappa}{\psi\epsilon} y_t^2 + \frac{\kappa(1-\theta)}{\sigma\epsilon} g_t^2 \right) \right) \tag{22}$$

The fiscal policymaker continues to minimize the social loss (21).

Finally, the fourth regime is monetary nominal income targeting (MNIT). As with MPLT it imposes a requirement of price stability, which may be resisted through the non-cooperative actions of the fiscal policy maker. However, it can also behave differently with respect to debt accumulation. We assume that the monetary policymaker minimizes the following loss

$$\sum_{t=0}^{\infty} \beta^t \left(\left(p_t + y_t + \omega\hat{\zeta}_t \right)^2 + \Phi_n \left(\frac{\kappa\theta}{\sigma\epsilon} c_t^2 + \frac{\kappa}{\psi\epsilon} y_t^2 + \frac{\kappa(1-\theta)}{\sigma\epsilon} g_t^2 \right) \right) \tag{23}$$

Again, the fiscal policymaker minimizes the social loss (21).

4 Calibration

This model is highly stylized and involves relatively few parameters. Calibration of $\beta = 0.99, \gamma = 0.75$ and $\theta = 0.75$ corresponds to the most frequently estimated values of the steady state annual interest rate of 4%, the average frequency of price changes of one year, and consumption to output share of 75%. We calibrate $\tau = 0.25$ so the steady-state lump sum taxes exactly offset the steady-state employment subsidy. We calibrate the Frisch elasticity of labour supply $\psi = 3.0$, consistent with macro-evidence of Peterman (2012) based on the empirical work which matches volatilities of aggregate worked hours and of wages. The empirical evidence for σ is quite far-ranging from near 0.1 reported in e.g. Hall (1988) and Campbell and Mankiw (1989), to above 1 reported in e.g. Rotemberg and Woodford (1997). Attanasio and Weber (1993, 1995) find that the estimate of σ increases from 0.3 for the aggregate data to 0.8 for cohort data, suggesting that the aggregation, which is implicit in the macro data, may cause a significant downward shift in the estimate of σ. Based on this evidence we calibrate the intertemporal elasticity as $\sigma = 0.5$. The elasticity of substitution between goods, ϵ, determines the monopolistic mark up. Chari et al. (2000) argue for a markup of 11% for the macroeconomy as a whole. Rotemberg and Woodford (1997) obtain elasticity of substitution 7.88, corresponding to a markup of 14.5%. We calibrate $\epsilon = 11.0$.

Given the geometrically declining debt maturity structure, the average maturity of debt is given by $m = \frac{1}{1-\beta\rho}$, and we consider a range of maturities between one quarter, $m = 1$, and 8 years, $m = 32$. Most developed countries have government debt which average maturity is between 3 and 8 years, see Chart A.2 in HM Treasury (2014). Calibration of m gives us $\rho = \frac{1}{\beta} - \frac{1}{\beta m}$.

Finally, the debt to output ratio which prevails in the economy in absence of shocks is $\chi = \frac{B}{Y} = \frac{(\tau+\theta-1)(1-\beta\rho)}{1-\beta}$, where ρ is determined by maturity. We introduce the annualized value of debt to output ratio $\Theta = \frac{BP^M}{4Y} = \frac{\chi\beta}{4(1-\beta\rho)}$ We consider several levels of Θ between 0 and 1, with the corresponding level of steady state tax rates $\tau = \frac{\chi(1-\beta)}{(1-\beta\rho)} + 1 - \theta$, given the same government share $1-\theta$. We, therefore, cover the range of steady state debt value between 0 and 100% of output. We argue that this range is sufficiently wide to warrant our conclusions, as we shall see that qualitative results do not change with an even higher level of Θ.

We calibrate the productivity shock as an AR(1) process $\hat{\zeta}_t = \rho_\zeta \hat{\zeta}_{t-1} + \varepsilon_{qt}$ with $\rho_\zeta = 0.9$ and $\sigma(\varepsilon_{\zeta t}) = 0.0075$. This is broadly in line with the values used in Canzoneri et al. (2006) $(\rho_\zeta, \sigma(\varepsilon_{\zeta t})) = (0.92, 0.0090))$, Ireland (2004) $(\rho_\zeta, \sigma(\varepsilon_{\zeta t})) = (1.00, 0.0109))$ and those used in Schmitt-Grohe and Uribe (2007) $(\rho_\zeta, \sigma(\varepsilon_{\zeta t})) = (0.86, 0.0064))$. [7] Among these three studies, only

[7] Schmitt-Grohe and Uribe (2007) do not consider cost-push shocks.

Ireland (2004) uses a cost-push shock, which is AR(1) with a standard deviation of 0.0044. Smets and Wouters (2003) reports an i.i.d. cost push shock with a much smaller standard deviation in the model with inflation persistence, while Rudebusch (2002) estimates a standard deviation of 0.01 for an i.i.d. cost push shock. In the analysis below, we calibrate the standard deviation of an i.i.d. cost-push shock η_t as 0.005.

5 Value of Delegation

5.1 Policy Experiments and Overview of Results

In order to assess the value of delegation we conduct the following policy experiment. We assume that the economy is operating at an acceptable (target) level of debt χ when it is hit by a cost push shock. This ensures the outcome can be directly compared with well known results for the standard NK model, where cost push shocks are the only source of a meaningful policy trade-off.

We assume that the fiscal policymaker can use either the tax rate or government spending as its policy instrument. They affect the economy in different ways and so we study our four different policy regimes for each of these two instruments separately.

Table 1 presents social loss for two benchmark cases. In the first case we consider relatively small debt to output ratio and long maturity (we have chosen $\Theta = 0.2$ and $m = 28$) and in the second case we have large debt to output ratio with short maturity ($\Theta = 0.6$ and $m = 1$). The data are given in terms of compensating consumption, which is the permanent fall in the steady state consumption level that would balance the welfare gain from eliminating the volatility of consumption and leisure (Lucas, 1987). Immediately, we can see that with fiscal adjustment occurring through taxation, a price level target can help mimic the commitment outcome when debt levels are low and maturities long. However, with a larger stock of debt and shorter maturity, delegation through price level targets actually worsens welfare losses and it would be better to adopt a nominal income target. However, when we consider government consumption to the appropriate fiscal instrument delegation of a price level target to the monetary authority does not achieve significant welfare gains regardless of debt levels and maturity length, although a nominal income target may be appropriate at high debt to GDP ratios and long maturities.

More generally, Figures 1-4 present pictograms for each combination of the debt to output ratio and maturity. Each pictogram consists of two squares, and conveys information about the relative size of welfare gain from delegation and on the 'activism' of monetary policy. The right square is dark shaded if monetary policy is 'passive'. Its size is fixed. Assuming that the area of

Table 1: Social Welfare Loss

	low debt to output ratio, $\Theta = 0.2$ long maturity, $m = 28$	high debt to output ratio, $\Theta = 0.6$ short maturity, $m = 1$
Taxes		
Commitment	0.0203	0.0187
Discretion	0.5242	0.2505
PLT	0.0208	0.2552
NIT	0.2224	0.1953
Spending		
Commitment	0.4626	0.5689
Discretion	0.6210	0.7566
PLT	0.4627	0.6750
NIT	0.6741	0.7302

the right square is equal to one, the left square measures the relative loss from delegation, $\frac{L_D - L_c}{L_d - L_c}$, where L_c, L_d and L_D are losses under commitment, discretion and delegation correspondingly. Therefore, if the area of the left square is smaller than one it means that delegation improves social welfare; if the loss is greater than one then we also light shade such square for better identification and this indicates that delegation is welfare worsening. The relative size of the left square measures, therefore, the share of stabilization bias which is not eliminated by the corresponding delegation scheme. And when that square is shaded delegation actually worsens welfare relative to the stabilization bias associated with cooperative discretion.

From Table 1 and Figures 1-4 it is immediately apparent that

i for each policy regime the level of loss depends on the level of debt to output ratio, Θ, and the average maturity, m.

ii using taxes results in good outcomes for almost all policy scenarios,

iii the MPLT works well and nearly replicates the loss under commitment, but only when Θ is relatively small or maturity is relatively long. As the debt to output ratio rises there is a significant deterioration in the the welfare achieved under the MPLT. If fiscal policy uses spending as policy instrument, then the area of welfare-improving delegation is not as wide as in the case of using taxes.

iv if fiscal policy uses taxes as its policy instrument then the MNIT reduces the stabilization bias for the very wide range of Θ and m. Even for the relatively high Θ the stabilization bias is at least halved.

v If the fiscal authority uses spending as policy instrument then MNIT does not result in large welfare gains, but does not lead to large welfare losses. A small welfare gain is achieved for short maturity and large debt under MNIT, where all other delegation scenarios may bring substantial welfare losses.

It is not surprising that the target debt to output ratio χ has a quantitative effect on losses. Indeed, combining the debt accumulation equation with the Phillips curve, we arrive at

$$\begin{aligned} b_t &= \chi\left(\left(1-\frac{1}{\beta}\left(1-\frac{1}{m}\right)\right)i_t - \mathbb{E}_t\pi_{t+1}\right) \qquad (24)\\ &\quad -\chi\left(1-\frac{1}{\beta}\left(1-\frac{1}{m}\right)\right)\left(1-\frac{1}{m}\right)\mathbb{E}_t p^M_{t+1} \\ &\quad +\frac{1}{\beta}\left(b_{t-1}-\left(\chi\varkappa+\frac{\tau\theta}{m}\right)c_t-\left(\chi\nu+\frac{\tau}{m}\right)\tau_t+\left(\frac{(1-\tau)(1-\theta)}{m}-\chi\vartheta\right)g_t-\chi\eta_t\right)\end{aligned}$$

so that it is apparent that the higher χ raises the the sensitivity of debt to the real interest rate, while the sensitivity to spending is reduced, and the sensitivity to the tax rate is increased. An increase in maturity reduces the effectiveness of both fiscal instruments. Moreover, with sufficiently high maturity the effect of fiscal spending on debt is negative as the fiscal-induced inflation plays the dominant role in the decumulation of real debt. It is therefore natural to expect some quantitative differences in policy responses once the level of debt becomes higher, but it is a clear non-linearity in welfare losses that we want to investigate. This will be shown to depend on changes in the nature of policy interactions.

In order to understand these results we study dynamic responses to a one standard error cost-push shock, plotted in Figures 5-10. The dynamic responses differ depending on the choice of fiscal instrument, so the two alternatives are considered separately. For each policy instrument we first discuss the two benchmark regimes, commitment and discretion, where the authorities have identical social objectives. The benevolent policy under discretion suffers from the stabilization bias, which the proposed MPLT and MNIT delegation schemes are designed to reduce.

5.2 Using Tax Rate as Fiscal Policy Instrument

I: The benchmark commitment policy of benevolent policymakers. This regime is extensively studied as, by construction, it delivers the lowest level of social loss. In a similar model with debt Benigno and Woodford (2003) and Schmitt-Grohe and Uribe (2004) demonstrate that the gains from stabilizing inflation outweigh costs of sustaining a permanently higher level of debt. We confirm the finding here for the whole range of maturities we consider.

In discussing the impulse responses we need to distinguish between the initial period and all subsequent periods. In the initial period, expectations are taken as given while in all subsequent periods the policy maker honours the commitments they make when forming the initial plan. Therefore, in response to a positive cost push shock the tax rate is lowered in the first period in order to offset the effect of the shock, but this has consequences for debt accumulation, see Figure 5, the 'low debt and high maturity' case. In the second - and subsequent - periods there is an increase in the tax rate to a new permanent level which ensures that the permanent rise in the debt stock is sustainable. Inflation is raised in the first period but nearly stabilized within one period. There is little difference in responses when Θ is greater or m is shorter: the nominal interest rate falls by a little bit more in the first period before coming back to the zero benchmark level. This ensures the required reduction in consumption to put inflation exactly to the zero base line in the second period.

The resulting social loss is relatively small in all cases. The social loss depends on the size of the permanent deviation of consumption and inflation, and on the size of the initial jump of inflation and consumption. Although the initial consumption is greater in the case with high debt and long maturity, there is a permanent deviation of inflation from steady state in the case with low debt and high maturity. The corresponding permanent loss explains the small welfare advantage to have high debt and short maturity. The value and variation of losses across different regimes remain relatively small.

II: Discretionary policy of benevolent policymakers and stabilization bias. Discretionary policy is sequential; it is as if a new policymaker takes office every period and there are therefore limited opportunities to manipulate the expectations of the private sector, except through the state variables the policy maker bequeaths to the future. It therefore leads to greater volatility of macroeconomic variables, with an associated welfare loss which and has been termed the 'stabilization bias' (Svensson, 1997).

If the economy is hit by a cost-push shock, then the discretionary adjustment is similar to the one in the standard NK model, but only if Θ is relatively small and maturity is long, see Figure 5. In this case the first-order effect of interest rate on debt – measured by Θ and m – is also relatively small, so the interest rate can have a large effect on demand without quickening the accumulation of debt through raised debt service costs. Moreover, a unit-change in consumption is about 10 times more effective than a unit change in the tax rate in terms of the effect on inflation, but nearly equally effective in terms of its effect on debt.[8] Therefore, there is some initial reduction in taxes in order to reduce the effect of the cost push shock, but the reduction is small in order to avoid the debt accumulation. As a result, the effect of the shock on inflation is not completely offset. The value of debt is slowly stabilized with subsequently higher taxes, while inflation is reduced as monetary policy raises the nominal interest rate and reduces demand.

This mechanism does not work if the value of debt to output ratio Θ is relatively large and maturity is short, see Figure 5. The nominal interest rate is lowered in the first period, and raised in the second, see Figure 5. The positive effect of higher interest rate and lower demand on debt cannot be offset by higher taxes. It becomes optimal to increase consumption on impact – by reducing the interest rate sharply – in order to immediately reduce the level of debt below the steady state level, reduce consumption in the next moment and consequently bring inflation down. Effectively monetary policy is seeking to control inflation through government debt – by overshooting the long-run value of debt expectations of inflation in the next period are reduced, which moderates the increase in inflation today. Fiscal policy further moderates that increase in inflation by cutting rather than raising taxes which reduces marginal costs. We shall see that it is occurrence of this overshooting of debt that signals the deterioration in welfare marked by large left-bottom squares in Figures 1-4, across our various policy regimes. At higher debt levels and shorter maturity the welfare consequences of our two delegation schemes, MPLT and MNIT, will depend crucially on whether they discourage this overshooting in debt.

III: Monetary price level targeting. In this regime the discretionary fiscal policymaker remains benevolent in that their objective is synonymous with social welfare, while the discretionary monetary policymaker flexibly targets the price level as part of a delegation scheme.

Recall that in the time-consistent equilibrium future inflation is a function of the future state, and, in turn, the future state is a function of current policy. Therefore as soon as *any* policymaker targets the price level, the price-setting private sector knows that any positive current inflation will have to follow by a dynamic path of predetermined states such that demand will be sufficiently low to make it optimal for a firm to set negative inflation in the future. This expectational effect results in firms optimally adopting pricing decisions which will reduce initial inflation, *cet. par.* Essentially, the expectations of the private sector are being manipulated through the effect of the future state, which is itself history-dependent. Such history-dependence – and the partial ability of policymakers to affect private sector expectations even in a discretionary setting – may bring

[8] These numbers are obtained for the base line calibration of (15) and (20).

a reduction in the stabilization bias. However, as we have already seen in the case of debt, the temptation to use debt to influence inflationary expectations in this way by overshooting in the stabilization of debt can actually worsen the inflationary bias, so that we need to explore the interactions between the price level and debt dynamics implied by our two delegation schemes, and, in particular, whether or not the stabilization of one affects the policy makers' ability to stabilize the other. Nevertheless, although the policymakers are able to affect expectations through the impact of current policy on the debt stock – which is also predetermined variable in this model – affecting prices directly may be thought to be more effective in welfare terms, as the main component of the social loss is the volatility of inflation.

In the standard NK model without fiscal policy price stability is achieved by ensuring low demand for a *long* time. Inflation falls and eventually overshoots the base level. Demand is then gradually raised back to the base level so that inflation converges back to its steady state value from below. In our model the monetary policymaker treats fiscal policy parametrically and the monetary equilibrium reaction depends on the fiscal stance. If the debt to output ratio Θ is relatively small and maturity is not too short so that the effect of higher interest rates or lower demand on debt is not too big, and if fiscal policy reacts to debt sufficiently strongly to ensure the eventual stabilization of debt, then monetary policy behaves in the 'standard' way as described above. However, if debt is only weakly controlled, i.e. taxes are not raised in response to higher debt then the optimal monetary policy reaction must also consistent with debt stabilization.

The fiscal policymaker does not aim for price stability but still aims to bring inflation down at the preferred speed, taking into account the response of the monetary policymaker and the private sector. Because the fiscal policymaker does not have a price level target, it is generally unwilling to use the fiscal instrument to deliver inflation overshooting, it is the monetary policymaker who will have to deliver the future negative inflation. Moreover, the fiscal policymaker is generally unwilling to raise taxes even to the extent it did in the case of benevolent discretionary policymaking. Such an increase would result in cost-push inflation, and the monetary policymaker, who is now even tougher on inflation, will have to reduce demand by more than in the case of cooperation over social objectives, so the overall result for the fiscal policymaker will be worse off than in the case of benevolent cooperation. These are the interactions we observe in the two scenarios we study.

If the economy is hit by a cost-push shock, and the level of debt is small then, as in the standard NK model, MPLT nearly replicates the commitment solution. In response to a positive cost push shock the tax rate is lowered in the first period in order to offset the effect of the shock, but this has consequences for debt accumulation, see Figure 6. In the second - and subsequent - periods there is an increase in the tax rate level which ensures that the accumulated debt stock is eventually stabilized. There is a quantitatively small reaction in interest rate and inflation. Monetary policy does not attempt to induce an overshooting of debt in order to reduce inflationary expectations; the initial reduction in the interest rate is not large enough to reduce the level of debt below the base line, this movement is rather a consequence of the loss minimization as it prevents large reduction in consumption. As a result, there is a substantial welfare gain, as inflation and consumption remain close to the base line for the whole period of adjustment.

With a higher debt to output ratio and shorter maturity, however, monetary policy does induce an overshooting of debt and lowers interest rate by much more, see Figure 7. This is associated with a significant fall in welfare in Table 1. Once debt is reduced below the base line in this way, the interest rate is raised to support the reduction of inflation below steady state and ensure the achievement of the price target. Therefore, with an even higher Θ and shorter maturity interest rates becomes even more effective in affecting the debt accumulation process, and taxes are not raised even in the first period, see Figure 7. There is no need to create additional inflation and the loss is reduced with higher Θ, see Figure 1.

Finally, 'strict' MPLT with zero weight on real terms in the monetary policy objective function, $\Phi_p = 0$, is optimal with longer maturity and lower debt to output ratio. As soon as the maturity is greater than 5 years, even for the 100% debt to output ratio the 'strict' MPLT is optimal.

To summaries, the requirement to maintain stability of the price level, which works extremely well in the case of simple NK model, continues to work in this model, as soon as the maturity of debt is greater than 3 years. If this is satisfied then even the relatively large stock of debt is efficiently stabilized by means of fiscal policy, without constraining monetary policy in its actions. However, once the debt has relatively short maturity – one year or less then even a moderate stock of debt creates undesired trade-offs, and delegating policy to the monetary policymaker who targets the price level can greatly increase the stabilization bias.

IV: Monetary Nominal Income Targeting. This scenario produces results which are strikingly different in several respects.

First, similarly to commitment, the qualitative dynamics remains the same for all the debt-to-output ratios and maturities we consider, such that there is no attempt to overshoot in the correction of debt across any of the debt to GDP ratios we consider. Figure 2 reports that in practically all cases there is a gain from the MNIT delegation. The gain is not as big as under the MPLT if the debt-to-output ratio is relatively small, but the share of eliminated stabilization bias remains relatively constant, so the absolute level of the gain is very substantial in all cases of relatively large debt-to-output ratio.

Given the form of monetary objectives, the loss of the monetary authorities will be eliminated if $p_t = -y_t = -\theta c_t$ so a reduction in consumption can increase the monetary authority's tolerance of positive inflation, cet. par. This is exactly what we observe in responses to a cost push shock in Figures 6 and 7. Overall, these dynamics of adjustment are very similar to those observed under the MPLT, but this similarity only holds when there is a small debt to output ratio Θ and long maturity. Once Θ increases and/or maturity shortens, the MPLT policy leads to monetary policy seeking to overshoot in its debt correction which results in volatile inflation, but faster debt and price stabilization but at a high cost in welfare terms. However, MNIT works well for higher Θ too, see Figure 2 as soon as maturity is just above one quarter. Keeping maturity m, fixed with higher Θ an identical increase in the tax rate would produce the same increase in inflation, and the nominal interest rate can be adjusted to generate the same real interest rate, which affects consumption at the same rate, but there will be greater *decumulating* effect on debt. So the optimal fiscal policy chooses to change the tax rate *by less*, and this simply results in slower stabilization. As soon as the dynamics of consumption and the price level are strongly negatively correlated – and slow processes are easier to correlate – the loss of the monetary policymaker is small. The loss to the fiscal policymaker – and the social loss – falls with lower inflation and output volatility, hence the overall gain in welfare.

Therefore, the reason why the MPLT does not result in a good outcome if Θ is large and maturity is relatively short is that the explicit requirement of price stabilization encourages fast adjustment of all macroeconomic variables. MNIT is consistent with slower adjustment and thus results in smaller welfare losses.

Expectations of future price stabilization play a very important role in both regimes. These expectations drive the level of consumption down, sufficient to generate the required reduction in marginal cost. In this sense inflation is stabilized by mere expectations of future policy. While the price stabilization is expected, it does not need to be achieved as quickly as under MPLT. For the monetary policymaker, who determines the speed of adjustment, the desire to reduce the increased price level is offset by lower real income, and these variables can only move in opposite directions if the adjustment is slow. Therefore at high debt levels MNIT successfully slows the speed of debt and price level adjustment bringing the equilibrium outcome closer to that of commitment.

Finally, 'strict' MNIT with zero weight on real terms in the monetary policy objective function, $\Phi_n = 0$, is optimal with longer maturity and a lower debt to output ratio. As soon as the debt to output ratio Θ is 40% or less, then strict MNIT is optimal for all maturities beyond single period debt.

5.3 Using Spending as Fiscal Policy Instrument

I: The benchmark commitment policy of benevolent policymakers. The commitment policy results in unit-root debt-dynamics, see Figure 8. If the economy is hit by a cost-push shock then, as in the standard NK model, the nominal interest rate is raised and consumption falls. Although the volume of bonds increases, the price of bonds is reduced and the second effect dominates so there is a small reduction in the value of debt to output ratio.

With a higher level of debt to output ratio, Θ, and with short maturity the nominal interest rate is cut in the first period and raised in the second period, so the monetary policy seeks to overshoot in its initial debt reduction. Monetary policy generates initially higher demand and higher inflation. This contributes to debt stabilization. Volatility of inflation increases with Θ and this implies an increase in the social welfare loss, see Table 1. Debt accumulates slowly to its new permanent level.

II: Discretionary policy of benevolent policymakers and stabilization bias. In contrast to benevolent commitment, discretionary policy conducted by benevolent policymakers results in a stationary equilibrium. The dynamics under discretion resemble those under commitment, although they are less smooth.

With high Θ and short m the sensitivity of debt to spending is reduced. Lower spending still contributes to debt stabilization as in the low debt case, but a greater reduction in the interest rate is required to offset the greater effect on inflation. A large reduction in the interest rate reduces the number of bonds below the steady-state level, but also generates higher inflation which depresses bond prices. Inflation is reduced in consequent periods, when the nominal interest rate is raised above the base line. The resulting 'zigzag' stabilization of debt, consumption and inflation results in high welfare losses – the stabilization bias – relative to the case of commitment policy.

Therefore, once the debt to output ratio is sufficiently high and the maturity is short, it is monetary policy – not fiscal policy – ensures the existence of stationary equilibrium. The switch to such debt overshooting through monetary policy happens at much smaller levels of Θ than happens in the case of using taxes as a fiscal instrument simply because taxes remain highly effective in influencing real debt due to their simultaneous cost-push effect on inflation.

III: Monetary price level targeting. If the debt to GDP ratio Θ is very small and maturity is relatively long then the MPLT equilibrium can closely replicate the commitment equilibrium, similar to what we find in the standard NK model without fiscal policy, see Figure 9. Expectations of price stabilization result in inflation overshooting and, subsequently in lower inflation than under benevolent discretion.

However, once the debt to output ratio is sufficiently high the MPLT equilibrium is closer to the equilibrium under benevolent discretionary policy. As we discuss above the stabilization is mostly done by means of monetary policy, which lowers interest rate to stabilize debt below the base line case and then raises interest rates to stabilize inflation. Under MPLT the monetary policymaker raises interest rate by more to ensure the overshooting of inflation and thereby achieve the price level target. The leader – the fiscal policymaker – allows the monetary policymaker to do so without interference.

When monetary policy seeks to overshoot in its stabilization of debt – with high Θ and a moderate average length of maturity m – the loss under MPLT exceeds the loss under the benevolent discretion. When price stabilization is required then, given the reaction of the fiscal policymaker, the monetary policymaker will have to generate even lower inflation, as the same loss to the monetary policymaker will be produced by the percentage deviation of prices, not inflation. As discretionary policymakers cannot manipulate expectations directly, they have to affect the state by more if they want to achieve this greater reaction of inflation. Interest rates will, therefore, have to move by more and the implied volatility of variables is greater than under the benevolent discretion. The relative loss diminishes with shorter maturity and there even is a moderate gain relatively to the benevolent discretion when maturity approaches one quarter, but this results is due to the sharp increase in social loss of the benevolent discretionary regime.

For the range of parameters we consider we did not find optimality of the 'strict' MPLT with zero weight on real terms in the monetary policy objective function, $\Phi_p = 0$. Although targeting the price level is clearly welfare improving in cases of low debt and long maturity, it is still optimal to use 'flexible' MPLT with is optimal with longer maturity and lower debt to output ratio. As soon as the maturity is greater than 5 years, even for the 100% debt to output ratio 'strict' MPLT is optimal.

IV: Monetary Nominal Income Targeting. If fiscal policy uses government spending as a policy instrument then, similarly to MPLT and the benevolent discretion regime, but unlike the MNIT regime with taxes, there is again an attempt to overcorrect debt if the debt to GDP ratio is sufficiently large and maturity relatively short.

Under MPLT there is a relatively large reduction in output and relatively small increase in prices. MNIT should change this as the monetary intra-period loss $p_t + y_t$ implies the central bank would be more tolerant of the higher price level as a result of the fall in output. So MNIT needs to generate price stabilization but will allow prices to remain above target, as long as output is reduced. If the economy is hit by a cost push shock the monetary policymaker with such objectives should raise interest rate by less than under MPLT. This would lead to higher inflation as desired. Although the fiscal policymaker does not like the outcome, being the Stackelberg leader in the game between the two policymakers she does not resist the central banks' actions. Moreover, spending is raised in the first period but then reduced below the base line. This helps the monetary policymaker to achieve the monetary target: inflation is increased, but output is not reduced too much. The consequent reduction in spending helps to stabilize debt slowly.

With a higher debt to GDP ratio and shorter maturity the interest rate cannot be raised too much and then it actually falls so that inflation is accommodated. Both policymakers work to keep debt just below the base line. There is a first period inflation, which is costly, but quick stabilization after that. There is some welfare gain because of smaller inflation volatility.

For a given maturity, the switch to the monetary policy induced overshooting in the debt happens at greater debt to output ratios Θ than for MPLT and for the benchmark benevolent discretion. When monetary policy under MNIT refrains from over-correcting debt following shocks, but the benevolent monetary policy does not, there is a reduction in stabilization bias and gain from delegation in the form of MNIT. In all other cases there is no substantial reduction in the stabilization bias, regardless the type of actual disturbance. When the debt to output ratio is close to zero and the maturity is not too short then there is, in fact, a loss from such delegation. In all cases we find that 'strict' MNIT is optimal.

5.4 Taxes vs. Spending and the Debt-to-Output Ratio

To summaries, using the tax rate as policy instrument – rather than spending – typically leads to the smallest social welfare loss, see Table 1. This result is only partly explained by the desire to stabilize spending in the social loss function, as the implied volatility of other welfare-relevant variables could be much higher in case of using the tax rate if that was an inappropriate instrument. The observed small losses are mostly because the tax rate directly affects marginal costs, and so changing the tax rate can be used to minimize the effect of cost-push shocks on inflation (which, of course, has consequences for the debt accumulation process). Marginal costs are much less sensitive to spending, so greater changes in spending are required to achieve the same disinflation effect.

Overall, if the debt to output ratio is relatively small and the maturity is relatively long then, regardless of the fiscal instrument adopted, we observe a substantial welfare gain from MPLT, and it is achieved by means of active monetary policy: monetary policy stabilizes inflation with little consequences for debt accumulation while fiscal policy stabilizes debt. Similar to what is observed in the standard New Keynesian model, expectations of future negative inflation drive current inflation down and the stabilization bias is offset. Overall, the speed of debt stabilization is slow. In contrast, if the debt to output ratio is relatively large and maturity relatively short then the qualitative dynamics of the economy change: monetary policy joins fiscal policy in the first-period reaction aimed at reducing debt *below* the steady state level, and only after that has been achieved is the interest rate raised in order to reduce the created inflation. This shift in policy making as debt levels rise heralds a significant fall in welfare.

Note that, the switch between active and passive policy regimes depends on the choice of fiscal instrument. For all regimes and instruments the monetary policy remains active if the maturity is longer than four years. However, if maturity is shorter than 4 years then the switch depends on the combination of maturity and the debt to output ratio.

In the MPLT regime the use of taxes results in active monetary policy for wider range of maturity and debt to output ratio. Only the debt with maturity of one year or less requires passive monetary policy to stabilize the economy. For the quarterly debt the threshold between active and passive policy is $\Theta = 10\%$. If the fiscal policymaker uses spending as its instrument and under MPLT this threshold for quarterly debt is much lower, around 2.5% of the annualized output. Again, this result is mainly due to differential sensitivity of marginal cost to taxes and to spending, respectively.

MNIT works extremely well if fiscal policy uses the tax rate as policy instrument. It ensures the reduction of the stabilization bias in all except one cases we consider, and it results in active monetary policy even all cases of Θ and m which we consider. If fiscal policy instrument is public consumption, then the main advantage of using MNIT is for a mid-range of debt to output ratio, as monetary policy becomes concerned with debt stabilization at a much higher debt-to-output ratio than under the benevolent discretionary policy and/or MPLT. In all other cases there is no gain from using MNIT.

6 Conclusion

This paper revisits the idea that the discretionary monetary price level and nominal income targeting delegation schemes can reduce the stabilization bias. We demonstrate that in an economy with a strategic fiscal policymaker who can act as an intra-period leader and who seeks to following a policy which minimizes the social welfare loss as a policy objective then delegating a price level target to the monetary policymaker results in a substantial welfare gain for a wide range of debt to output ratios and 'not too short' maturities, but only if fiscal policy uses the tax rate as policy instrument. Using spending substantially limits the range of acceptable combinations to the very low debt to output ratios and long maturity.

Similarly, delegating a nominal income target to the monetary policymaker results in a substantial welfare gain at most debt levels and maturities when taxes are the instrument. Monetary nominal income targeting when combined with fiscal policy operating with spending, however, is only welfare improving for a narrow range of short-term debt, where there is large welfare loss from benevolent discretionary policy.

Although recent proposals of fiscal consolidations have tended to be heavily skewed towards adjustment of government spending, our comparison of the relative efficacy of fiscal instruments in stabilization of the economy reveals the relative preeminence of taxes. Not only they are best suited to mitigate the effects of cost-push shocks on inflation, the optimal fiscal policy results in effective debt stabilization, so that monetary policy is not concerned with debt instability issues for greater range of debt-to-output ratios.

Despite demonstrating these results using a particular model, this model is at the core of more general and empirically relevant DSGE models widely used in policy analysis. The economic mechanisms discussed here are likely to work and our results to remain valid for this wide class of models.

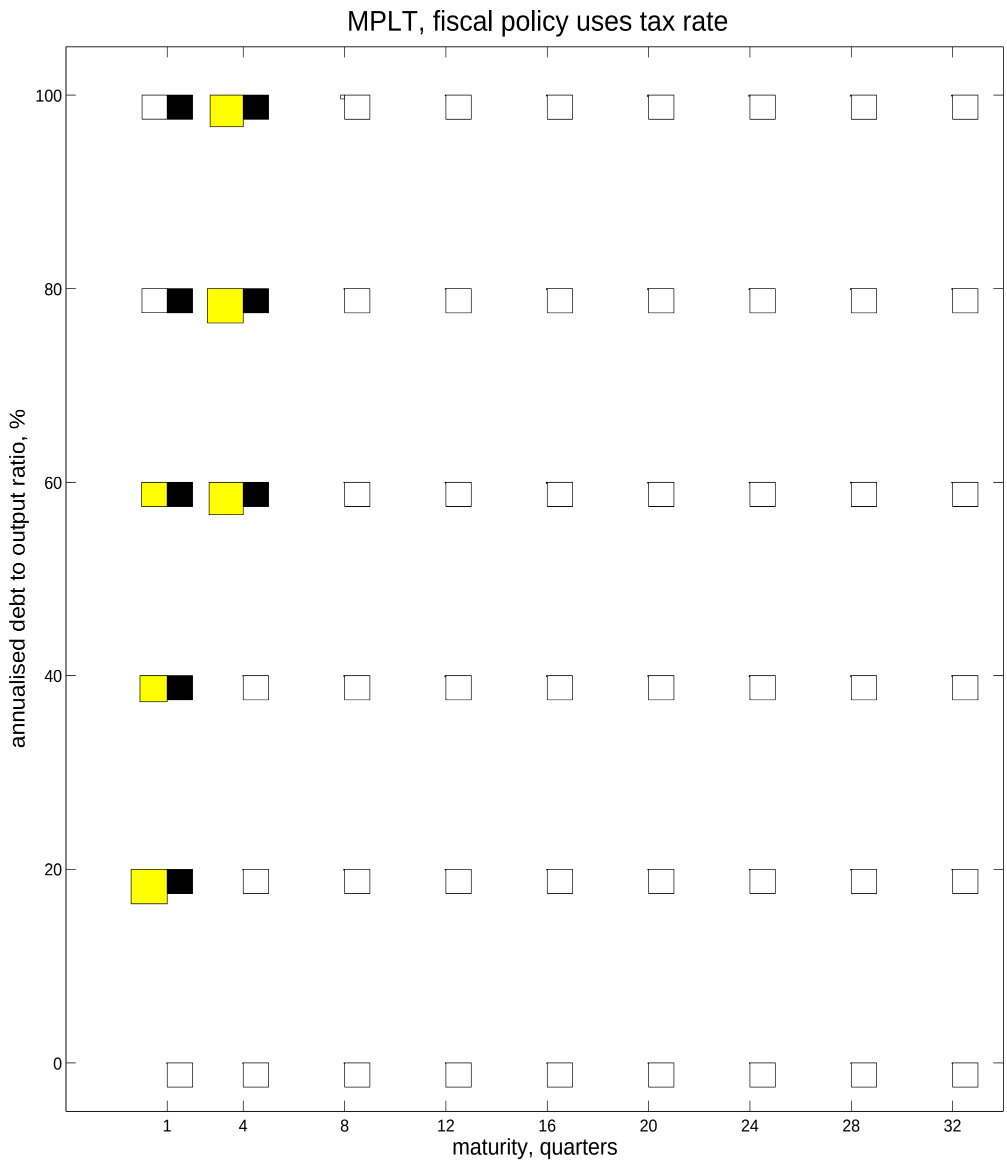

Figure 1: Price level targeting with tax rate as fiscal policy instrument. For each combination of maturity and debt to output ratio the pictogram shows whether (a) monetary policy is passive if the right square is filled (b) whether the delegation scheme brings any loss so the left square is filled. A small un-shaded lhs square measures the residual size of the stabilisation bias not eliminated through delegation.

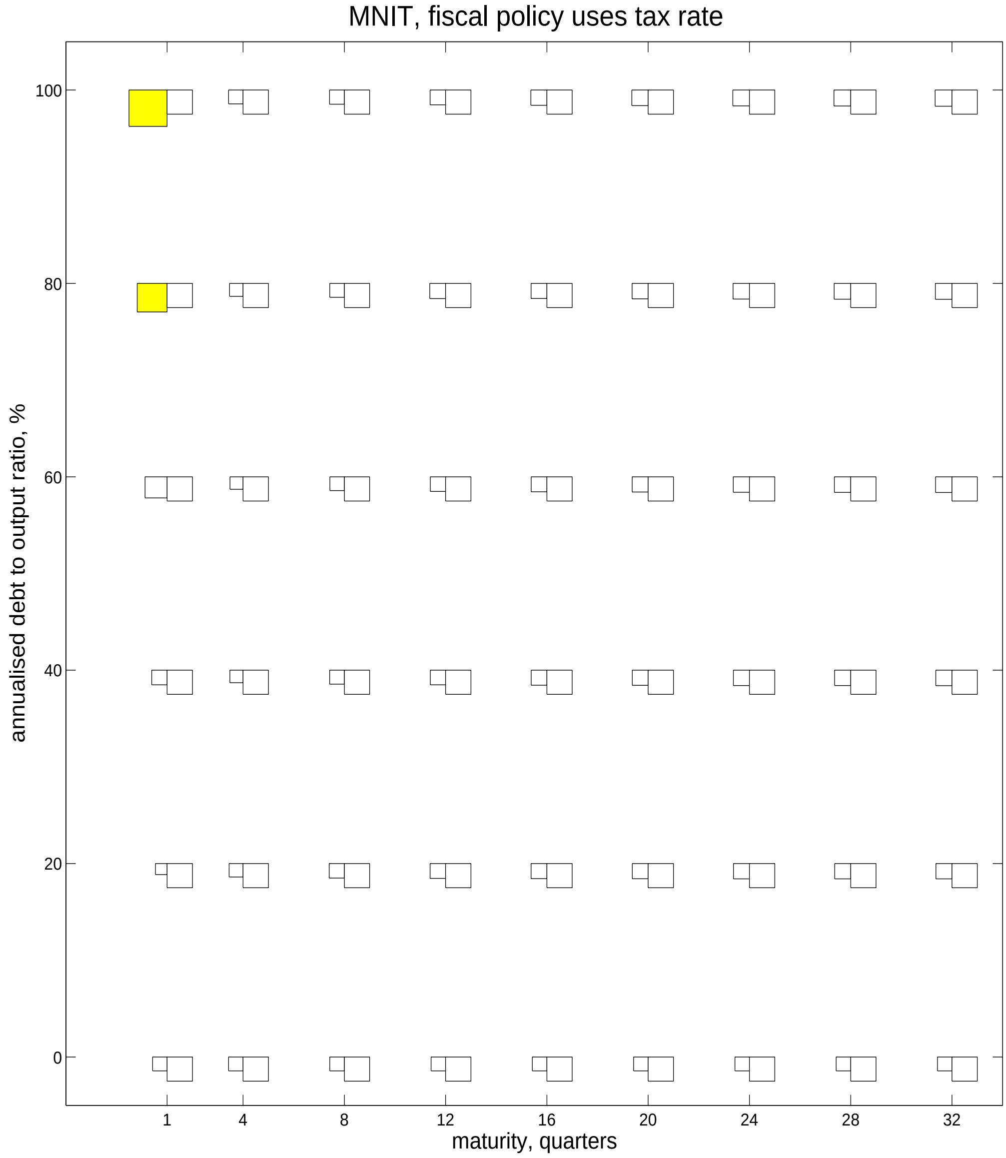

Figure 2: Nominal income targeting with tax rate as fiscal policy instrument. For each combination of maturity and debt to output ratio the pictogram shows whether (a) monetary policy is passive if the right square is filled (b) whether the delegation scheme brings any loss so the left square is filled.A small un-shaded lhs square measures the residual size of the stabilisation bias not eliminated through delegation.

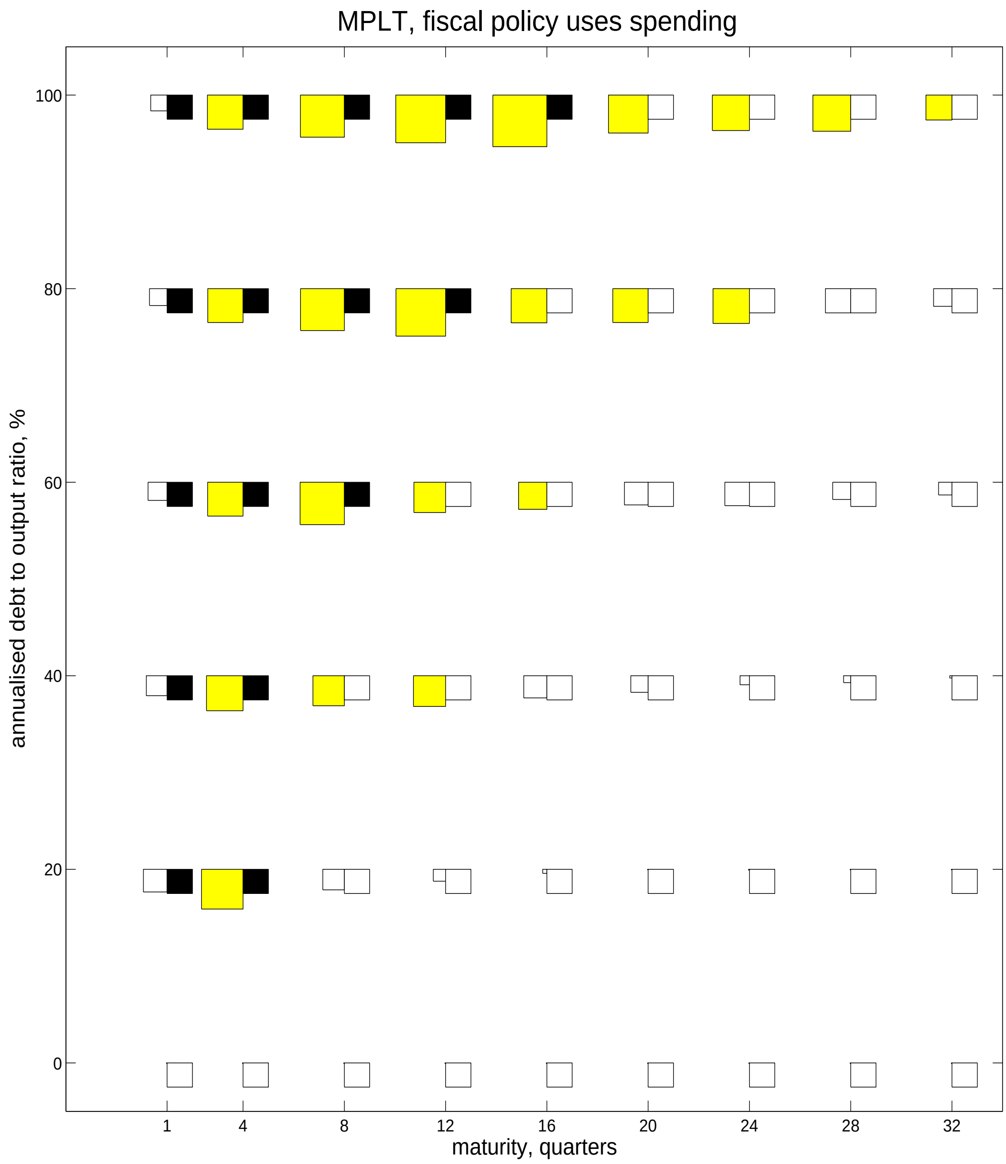

Figure 3: Price level targeting with spending as fiscal policy instrument. For each combination of maturity and debt to output ratio the pictogram shows whether (a) monetary policy is passive if the right square is filled (b) whether the delegation scheme brings any loss so the left square is filled.A small un-shaded lhs square measures the residual size of the stabilisation bias not eliminated through delegation.

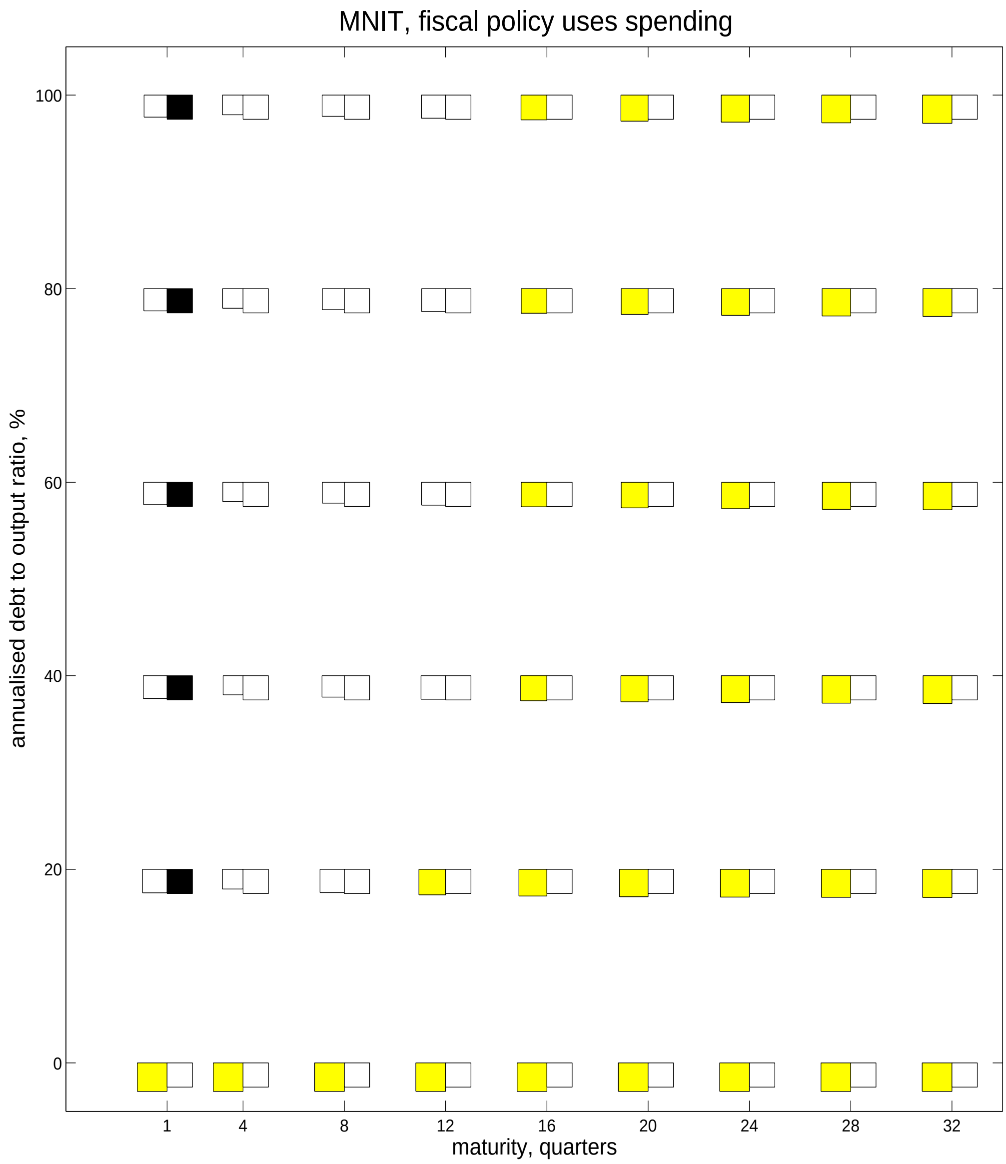

Figure 4: Nominal income targeting with spending as fiscal policy instrument. For each combination of maturity and debt to output ratio the pictogram shows whether (a) monetary policy is passive if the right square is filled (b) whether the delegation scheme brings any loss so the left square is filled.A small un-shaded lhs square measures the residual size of the stabilisation bias not eliminated through delegation.

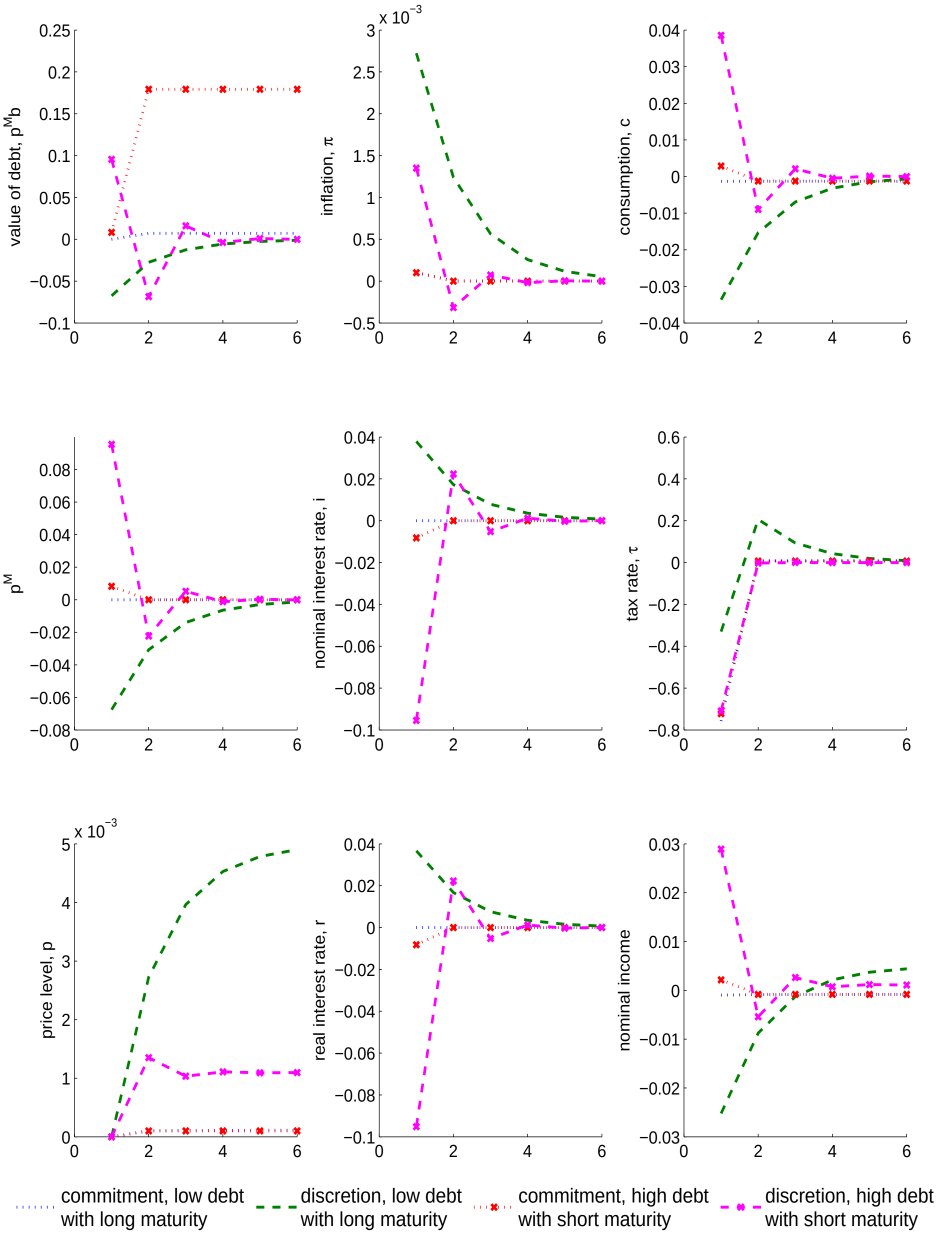

Figure 5: Impulse responses to one-standard-error cost push shock under joint commitment and discretion. Fiscal policy operates with taxes. Debt to output ratio is 20% and the maturity of debt is 28 quarters in low debt – long maturity case, debt to output ratio is 60% and the maturity of debt is 1 quarter in high debt – short maturity case.

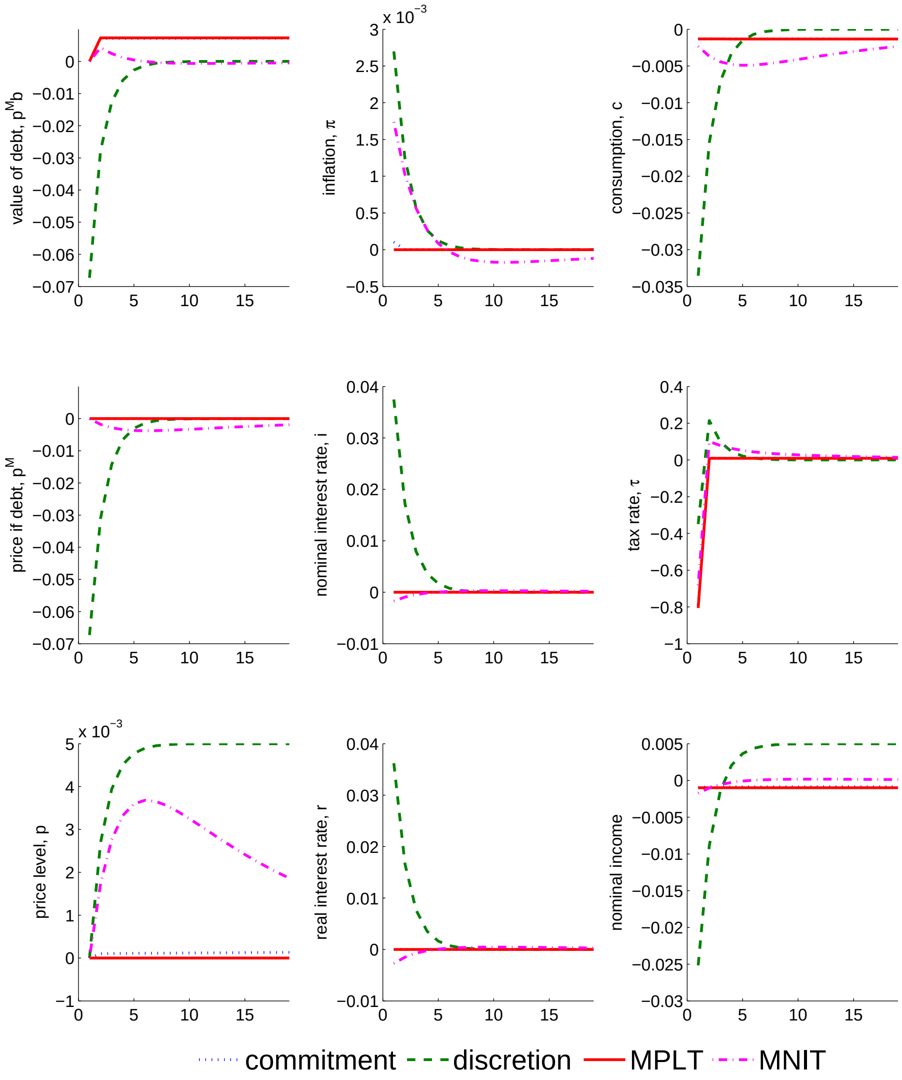

Figure 6: Impulse responses to one-standard-error cost push shock under joint commitment and discretion and both delegation schemes. Fiscal policy operates with taxes. Debt to output ratio is 20% and the maturity of debt is 28 quarters. $\Phi_n = \Phi_p = 0$.

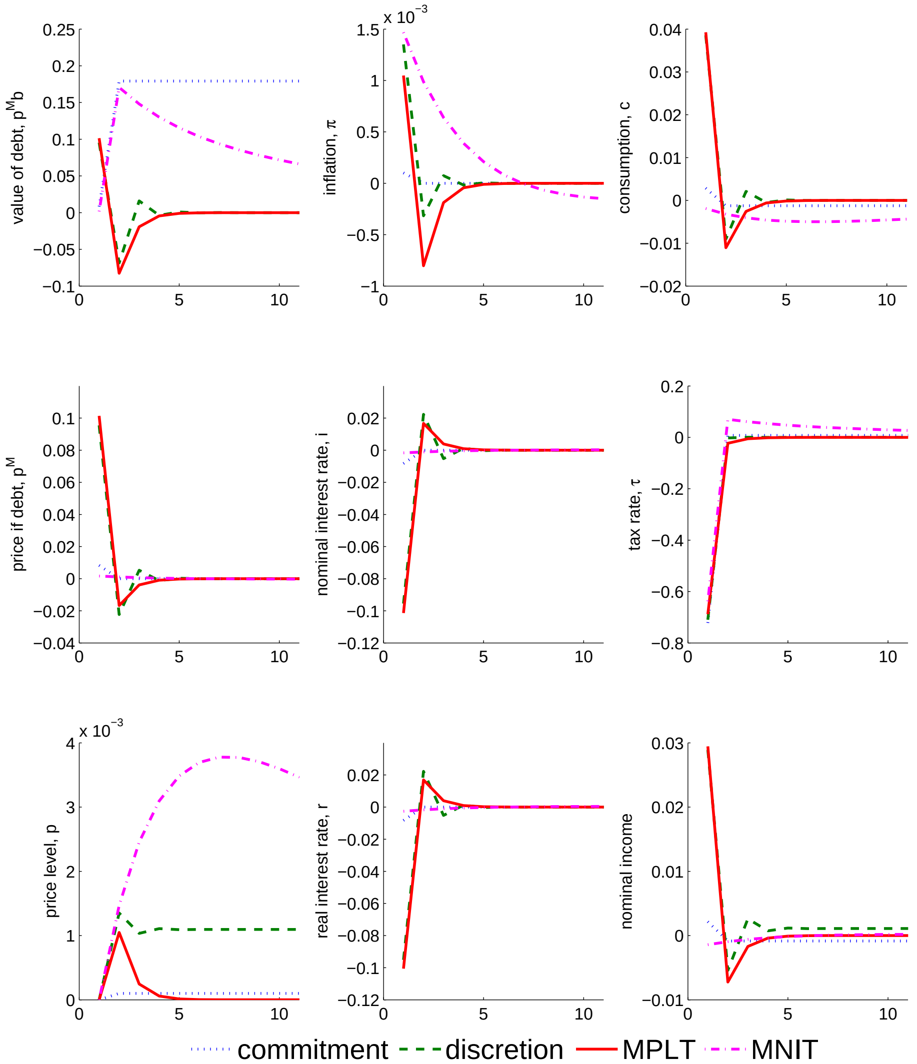

Figure 7: Impulse responses to one-standard-error cost push shock under joint commitment and discretion and both delegation schemes. Fiscal policy operates with taxes. Debt to output ratio is 60% and the maturity of debt is 1 quarter. $\Phi_n = \Phi_p = 1$.

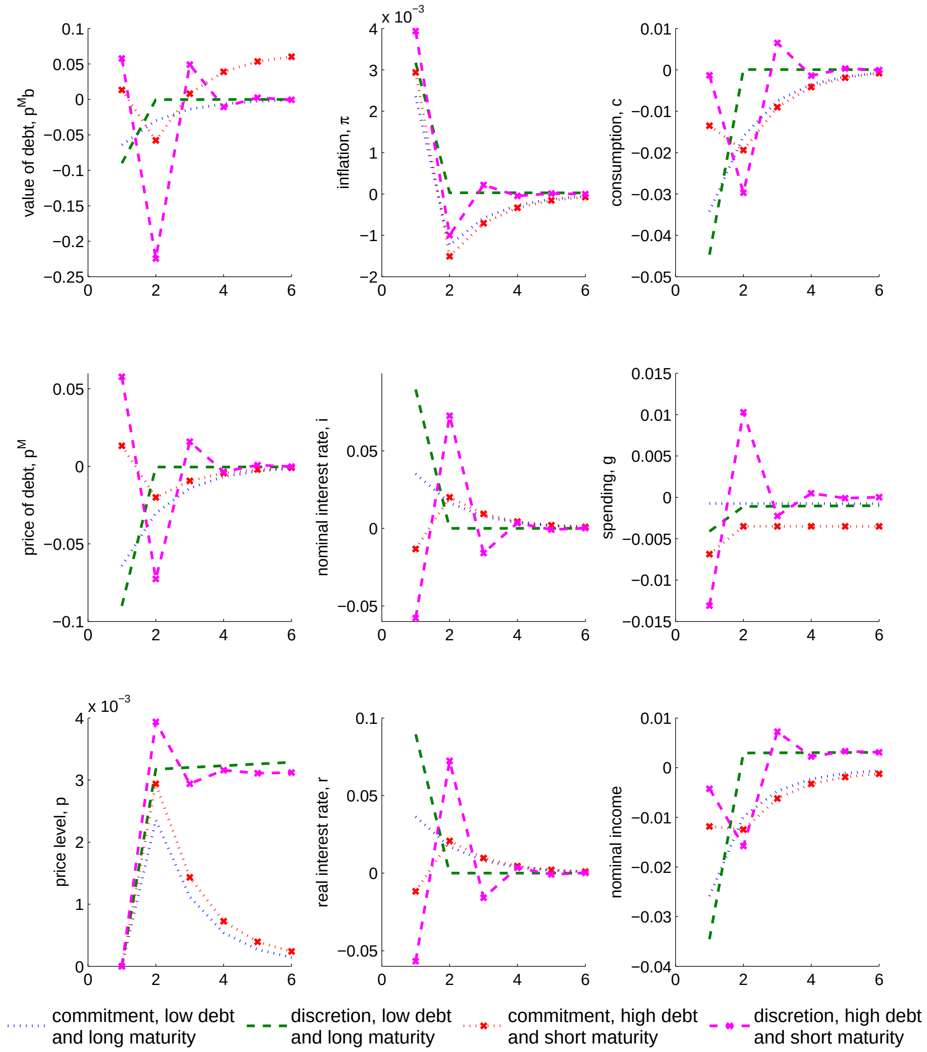

Figure 8: Impulse responses to one-standard-error cost push shock under joint commitment and discretion. Fiscal policy operates with spending. Debt to output ratio is 20% and the maturity of debt is 28 quarters in low debt – long maturity case, debt to output ratio is 60% and the maturity of debt is 1 quarter in high debt – short maturity case.

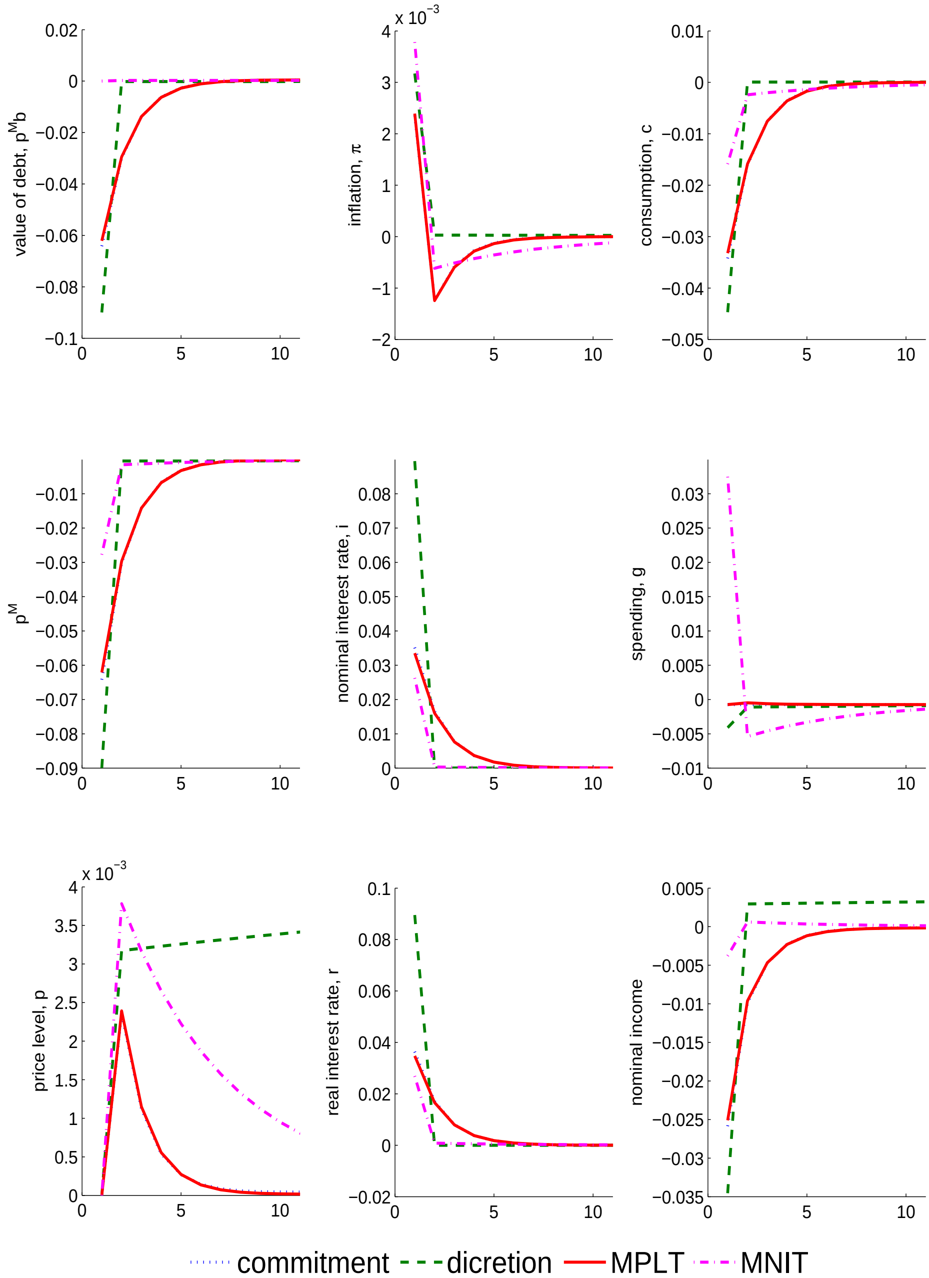

Figure 9: Impulse responses to one-standard-error cost push shock under joint commitment and discretion and both delegation schemes. Fiscal policy operates with spending. Debt to output ratio is 20% and the maturity of debt is 28 quarters. $\Phi_n = 0, \Phi_p = 1$.

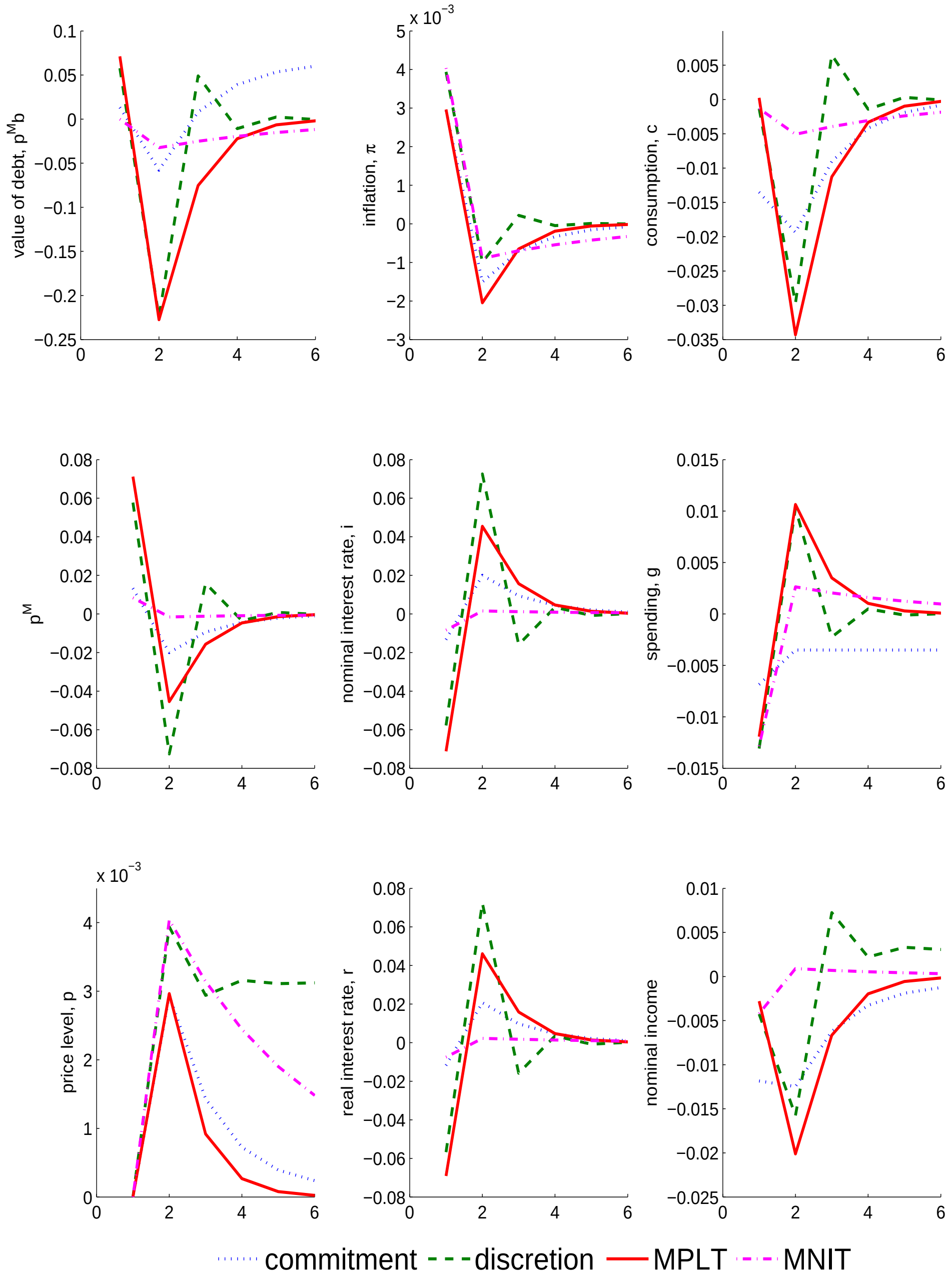

Figure 10: Impulse responses to one-standard-error cost push shock under joint commitment and discretion and both delegation schemes. Fiscal policy operates with spending. Debt to output ratio is 60% and the maturity of debt is 1 quarter. $\Phi_n = 0, \Phi_p = 1$.

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