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Price level targeting with strategic fiscal policy and the value of fiscal leadership

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Abstract

This paper investigate the stabilization bias that arises in a model of non-cooperative monetary and fiscal policy stabilisation of the economy, when monetary authority implements price level targeting but fiscal policy remains benevolent. We demonstrate the gain in welfare improvement depends on the level of steady state debt. If the steady state level of the government debt is low, then the monetary price level targeting unambiguously leads to social welfare gains, even if the fiscal authority acts strategically and faces different objectives and has incentives to pursue its own benefit and therefore offsets some or all of monetary policy actions. Moreover, if the fiscal policymaker is able to conduct itself as an intra-period leader, the social welfare gain of the monetary price level targeting regime can be further improved. However, if the economy has a high steady state debt level, the gain of the price level targeting is outweighed by the loss arising from the conflicts between the policy makers, and leads to a lower social welfare than under cooperative discretionary inflation targeting.

Key Words: Monetary and Fiscal Policy Interactions, Distortionary Taxes, Discretionary policy, LQ RE models

JEL References: E31, E52, E58, E61, C61

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1   Introduction

The last several years have seen the increase of interest in macroeconomic control policies which would reduce the risk of the economy getting into the 'liquidity trap' i.e. approaching the zero low bound for nominal interest rates. Monetary price level targeting and stabilizing fiscal policy have been proposed and discussed.

Price level targeting requires that the central bank stabilize the aggregate price level around a predetermined target price path, hence the policy becomes historical dependence. This regime has been considered as a serious alternative to inflation targeting in the monetary policy literature, due to its more appealing over inflation targeting: First, by definition the PLT reduces the uncertainty of future price level, which produces a more certain future purchasing power of the money. Second, the PLT improves the trade-off between inflation and output (Svensson, 1999) (Vestin, 2006). Third, by allowing the monetary policy maker adjust interest rate less to economic disturbance, the PLT lowers the likelihood of hitting the zero lower bound (Billi, 2008). Even if interest rate is close to zero, the higher inflation expectation reduces the real interest rate which helps to stimulate the economy, this makes the price level targeting particularly appealing when there is deflationary pressures due to economic shocks, such as the recent financial crisis. It appears that current policies were not very effective in improving the economic conditions, the price-level targeting may be an attractive option for the central bankers.

Nevertheless, little research has been done in an economy with that fiscal policy also behaves optimally. The literature on fiscal policy as a macroeconomic stabilization tool is relatively new, and policy proposals are typically motivated by the need to design a powerful stabilization instrument in situations when monetary policy is constrained. Before making a decision to change policy to price level targeting, it has to be proved that the appealing features discussed above are still robust in models with more complex features of modern economies. One of the first in line would be a model with optimal fiscal policy. An institutional implementation of these proposals would create two different mandates for two policy makers. This might result in a conflict between the optimizing policy makers as one of them will try to 'undo' the perceived harm done by the other.[1]

The central questions addressed in this paper follow on from this. If the policy makers are unable to precommit, how does the monetary policy targeting price level affect the social welfare if fiscal policy is made strategic? What is the value of such delegation? What are the welfare consequences of different intra-period leadership regimes for monetary and fiscal policies?

To address these questions we study a version of the familiar sticky price model modified to incorporate debt accumulation (Benigno and Woodford, 2003) with strategic monetary and fiscal policy, pursuing different objectives. This model contains all the features as at the heart of many DSGE models used in policy analysis which makes it a 'representative agent' for our policy analysis. Government uses tax rate as a policy instrument to stabilize the economy, while Central Bank assigns different weight to price level and inflation in order to allow temporary drift in the price level when these 'intermediate' regimes may be relevant, following the method by Batini and Yates (2003). We concentrate on macroeconomic effects of differing policy objectives and the ability of the fiscal policy to conduct itself as an intra-period leader.[2]

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[1] See e. g. Dixit and Lambertini (2003), Lambertini (2006), Blake and Kirsanova (2011).

[2] Empirical evidence (Fragetta and Kirsanova, 2010) suggests that in countries without fiscal decentralization,

The main theoretical finding of this paper is that whether the PLT can outperform inflation targeting in New Keynsian model depends on the level of steady state debt. We demonstrate that when steady state debt level is low, PLT reduces the fluctuations in inflation and output. In particular, only a small weight on price level target can make a substantial improvement on social welfare, this finding also provides us a way to avoid some of the cost of changing the completely policy target; Fiscal leadership results much better social welfare than letting government and central bank make the decisions simultaneously; Despite their different policy objectives, in the low debt case, PLT also weakens the dynamic complementarity between fiscal and monetary policy makers, which further helps the economy stabilization and avoid the multiple equilibriums.

However the results reverse when the steady state level of debt is high. In this case, the conflicts between the two policy makers due to the PLT overweigh the merits PLT brings. In relatively high debt case, the welfare loss in PLT is higher than inflation targeting. PLT has two opposite effects, on one hand it lowers inflation after the disturbance by lowering expected future inflation, which makes the task of stabilization easier; on the other hand an overshot of inflation is required in order to return the price level, which causes a higher volatility of inflation. To maintain a higher steady state government debt level, there will be higher tax, and initially lowered interest rate which cause the realized inflation is almost as high as under inflation targeting; when inflation is at the same level, due to the higher volatility of inflation required to deliver price level, PLT causes higher loss. Hence, we argue that steady state debt level matters to whether PLT improves or deteriorate the stabilization results.

This paper is organized as follows. In the next section we outline the model and discuss the calibration. Section 3 contains the theoretical analysis of the five cases we consider. The first three cases – commitment of benevolent policy makers which delivers the lowest possible loss among all regimes, cooperation of benevolent discretionary policy makers which results in substantial stabilization bias, and the cooperative PLT by both policy makers – describe the three benchmark scenarios, to which we compare and contrast the two cases of our main interest: monetary PLT either in the regime of simultaneous moves or in the regime of fiscal leadership. Section 4 shows the value of delegation as exemplified by the monetary PLT in the regime of simultaneous moves. Section 5 discusses the value of leadership, it compares and contrasts the two different non-cooperative regimes. Section 6 explores the impact of steady state debt level. Section 7 concludes.

2 The Model

We consider the now-mainstream macro 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 policy makers, 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

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like the UK, the regime of fiscal leadership is the most relevant.

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[3] and by issuing one-period risk-free nominal bonds.

We assume that all public debt consist of riskless one-period bonds. The nominal value $\mathfrak{B}_t$ of end-of-period public debt then evolves according to the following law of motion:

$$\mathfrak{B}_t = (1 + i_{t-1})\,\mathfrak{B}_{t-1} + P_t G_t - \tau_t P_t Y_t, \tag{1}$$

where τ_t is the share of national product Y_t that is collected by the government in period t, and government purchases G_t are treated as exogenously given. P_t is aggregate price level and i_t is interest rate on bonds. The national income identity yields

$$Y_t = C_t + G_t, \tag{2}$$

where C_t is private consumption. For analytical convenience we introduce $B_t = (1+i_{t-1})\mathfrak{B}_{t-1}/P_{t-1}$ which is a measure of the real value of debt observed at the beginning of period t, so that (1) becomes

$$B_{t+1} = (1 + i_t)\left(B_t \frac{P_{t-1}}{P_t} - \tau_t Y_t + G_t\right). \tag{3}$$

The first-order approximation of equation(3) about the non-stochastic zero-inflation and zero-debt steady state yields

$$b_{t+1} = \frac{1}{\beta}\left(b_t + \left(1 - \frac{C}{Y}\right) g_t - \tau\left(\tau_t + y_t\right)\right),$$

where $b_t = \frac{B_t}{Y}$, $c_t = \ln\left(\frac{C_t}{C}\right)$, $\tau_t = \ln\left(\frac{\tau_t}{\tau}\right)$, $g_t = \ln\left(\frac{G_t}{G}\right)$, $y_t = \ln\left(\frac{Y_t}{Y}\right)$ and letters without time subscript denote steady state values of corresponding variables in zero inflation steady state. The private sector's discount factor $\beta = 1/(1 + i)$. We have assumed $B = 0$ in order to make the presentation of the model particularly simple. This assumption results in no first-order effects of the interest rate and inflation on debt, so that the final version of the linearized debt accumulation equation can be written as

$$b_{t+1} = \frac{1}{\beta}\left(b_t + (1 - \tau)(1 - \theta)\, g_t - \tau\theta c_t - \tau\tau_t\right), \tag{4}$$

where we used the linearized (2) to substitute out output and denoted $\theta = C/Y$.[4]

The derivation of the appropriate Phillips curve that describes Calvo-type price-setting decisions of monopolistically competitive firms is standard (Benigno and Woodford, 2003, Sec. A.5) and marginal cost is a function of output and taxes. A log-linearization of the aggregate supply

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

[4]Because we work with one-period debt only, its proportion in the total stock of debt is not very large.

relationship around the zero-inflation steady state yields the following New Keynesian Phillips curve

$$\pi_t = \beta\mathbb{E}_t\pi_{t+1} + \kappa\left(\left(\frac{1}{\sigma} + \frac{\theta}{\psi}\right)c_t + \frac{(1-\theta)}{\psi}g_t + \frac{\tau}{(1-\tau)}\tau_t\right) + \eta_t, \tag{5}$$

where $\kappa = \frac{(1-\gamma\beta)(1-\gamma)}{\gamma}\frac{\psi}{(\psi+\epsilon)}$ is the slope of Phillips curve. Parameter γ is Calvo parameter, parameter ψ is Frisch elasticity of labour supply, σ is elasticity of intertemporal substitution and parameter ϵ is the elasticity of substitution between differentiated goods. Cost push shock η_t follows an autoregressive process.

To summarize, the law of motion of the economy can be written as:

$$c_t = c_{t+1} - \sigma\left(i_t - \pi_{t+1}\right) \tag{6}$$

$$\pi_t = \beta\pi_{t+1} + \varkappa c_t + \nu\tau_t + \eta_t \tag{7}$$

$$p_t = p_{t-1} + \pi_t, \tag{8}$$

$$b_{t+1} = \chi i_t + \frac{1}{\beta}\left(b_t - \chi\pi_t - \tau\theta c_t - \tau\tau_t\right), \tag{9}$$

where coefficients $\theta = C/Y$, $\chi = B/Y$, $\varkappa = \kappa\left(\frac{1}{\sigma} + \frac{\theta}{\psi}\right)$, $\nu = \kappa\frac{\tau}{(1-\tau)}$. Debt b_t and price p_{t-1} are endogenous predetermined state variables.

The social loss is defined by the quadratic loss function[5]

$$L = \frac{1}{2}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left(\pi_t^2 + \lambda c_t^2\right). \tag{10}$$

while the monetary and the fiscal policy makers can have different policy objectives, $L^J = \frac{1}{2}\mathbb{E}_0\sum_{t=0}^{\infty}\beta_J^t Q^J\left(\pi_t, c_t, \tau_t, b_t, p_t\right)$, $J \in \{M, F\}$. Each policy maker knows the laws of motion (4)-(5) of the aggregate economy and takes them into account when formulating policy.

3 Monetary and Fiscal Policy Regimes

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

$$L^{SOC} = \frac{1}{2}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left(\pi_t^2 + \lambda c_t^2\right). \tag{11}$$

while the monetary and the fiscal policymakers can have different policy objectives, $L^J = \frac{1}{2}\mathbb{E}_0\sum_{t=0}^{\infty}\beta_J^t Q^J\left(\pi_t, c_t, \tau_t, b_t, p_t\right)$, $J \in \{M, F\}$. Each policymaker knows the laws of motion (6)-(9) of the aggregate economy and takes them into account when formulating policy.

In what follows we study several policy regimes.

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[5] 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.

[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.

Benevolent Commitment Policy   Ramsey allocation in the LQ framework minimises

$$\min_{\{i_t,\tau_t\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\pi_t^2 + \lambda c_t^2\right) \tag{12}$$

subject to constraints (6)-(9). This allocation requires full commitment to policies and full co-operation between the authoritioes. In what follows we call this the commitment solution. The commitment solution delivers the highest possible welfare, so the performance of all other policies can be naturally compared with it. In models with debt accumulation the commitment solution is known to generate a unit-root-type behaviour of economic variables, see e.g. Schmitt-Grohe and Uribe (2004).

Benevolent Discretionary Policy   The discretionary policy is standard, and discussed in e.g. Backus and Driffill (1986), Oudiz and Sachs (1985), Clarida et al. (1999), and Woodford (2003). Both policymakers cooperate and choose instruments to solve (12) subject to constraints (6)-(9) and a time-consistency constraint. Dicretionary solution is found numerically, using a standard algorithm by Söderlind (1999).

Cooperative Discretionary Price Level Targeting   As an additional benchmark case we also consider cooperative discretionary price level targeting, where both auth,ries jointly minimise the loss

$$\min_{\{i_t,\tau_t\}} \sum_{t=0}^{\infty} \beta^t \left((p_t - (1-\alpha)\, p_{t-1})^2 + \lambda c_t^2 \right)$$

subject to system (6)-(9) and a time-consistency constraint. This regime is 'intermediate' between the well known benevolent regimes and the regime of our primary interest. Studying it allows us to understand interactions between monetary and fiscal policies better.

Non-Cooperative Discretionary Policy with Monetary Price Level Targeting   Motivated by the observation that the monetary policy reaction function is much more transparent and predictable, so a strategic fiscal policymaker is able to take it into account when formulating policy, we assume the regime of fiscal intra-period leadership.

The general LQ RE optimisation problem is explained in details in Blake and Kirsanova (2011). It consists of two steps. First, the the monetary policymaker, who acts as an intra-period follower, minimises its own loss function

$$L^M = \frac{1}{2} \sum_{t=0}^{\infty} \beta^t \left((p_t - (1-\alpha)\, p_{t-1})^2 + \lambda c_t^2 \right)$$

subject to the system of constraints (6)-(9) and a time-consistency constraint. The monetary policymaker treats the state of fiscal policy parametrically when choosing optimal policy. Second, the the fiscal policymaker who conduscts itself as an intra-period leader, minimises its own loss function

$$L^F = \frac{1}{2} \sum_{t=0}^{\infty} \beta^t \left(\pi_t^2 + \lambda c_t^2 \right)$$

subject to the system of constraints (6)-(9), the monetary policy reaction function, and a time consistency constraint.

The following assumption follows Clarida et al. (1999) and substantially simplifies the exposition of the model.

Assumption 1 (policy instruments) *The monetary policy maker chooses real interest rate i_t and then, conditional on subsequent optimal evolution of c_t and π_t, decides on the value of interest rate that achieves the desired c_t and π_t. The fiscal policy maker uses the tax rate τ_t as policy instrument.*

In what follows we assume that both policy makers and the private sector know that the decision making is sequential and a different policy maker may be in the office in future periods. We refer to this policy as policy under discretion. Formally, we make the following assumption.

Assumption 2 (policy) *Monetary and fiscal policy mix satisfies the following assumptions.*
(i) Monetary and fiscal authorities act non-cooperatively.
(ii) Both authorities are assumed to optimize sequentially under time-consistency constraint.
(iii) Each policy maker minimizes its loss criterion in the form:

$$L^M = \frac{1}{2} \sum_{t=0}^{\infty} \beta^t \left((p_t - (1-\alpha) p_{t-1})^2 + \lambda c_t^2 \right) \tag{13}$$

$$L^F = \frac{1}{2} \sum_{t=0}^{\infty} \beta^t \left(\pi_t^2 + \lambda c_t^2 \right) \tag{14}$$

where α measures the degree of price-level-targeting in the monetary policy objectives.

The hybrid price level target monetary policy objective is the same as studied in Roisland (2006) and Batini and Yates (2003). The following assumption substantially simplifies the exposition without the loss of generality.

Assumption 3 *The model is perfect-foresight deterministic.*

In the standard New Keynesian model the only meaningful trade-off for the monetary policy maker is created by cost-push shocks. In contrast, both policy instruments in this model can completely insulate this economy against the cost push shock, but they will face with fiscal consequences of such policy – the effect on debt. In what follows, therefore, we can only consider shocks to debt, if we reinterpret policy instruments as those adjusted for movements needed to eliminate the consequences of cost-push shocks. However, we can go further and only consider the deterministic version of the model where the only disturbance can be generated by initially higher level of debt, b_0. First, because of certainty equivalence in LQ models all results on stability, existence and uniqueness do not depend on the presence of stochastic component, see Anderson, Hansen, McGrattan, and Sargent (1996). Second, in this model the welfare loss generated by either cost push or debt shocks is simply the normalized loss generated by initial state b_0. Because of the transformation is monotonic the welfare analysis for the deterministic model applies to its stochastic counterpart. We illustrate the second point in Section 4

3.1 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 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 intertemporal elasticity $\sigma = 0.3$. 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 $\epsilon = 11.0$.

4 Value of Delegation

We conduct the following policy experiment. Suppose in the initial moment of time the debt to output ratio is above its steady state. How do monetary and fiscal policies stabilise the economy? Figure 2 plots dynamic responses of the economy to a unit-increase in the level of government debt for the following four policy regimes with different level of B, under fiscal leadership. We first explore the case when debt level is low, then we proceed to high steady state debt level.

I: Cooperation of benevolent policy makers under commitment. This is the first of benchmark scenarios which we discussed in Section 4. As a result of initial disturbance, there is an unexpected raise in government debt. To stabilize the economy, policy makers face two options: balancing the budget at a new higher level of debt, by a permanently increased tax rate which leads to a permanently lowered consumption; or bringing the debt back to its initial level, at the cost of much higher inflation volatility. Benigno and Woodford (2003) and Schmitt-Grohe and Uribe (2004) showed that under commitment, inflation stability outweighs the cost of sustaining a permanently higher debt level. Therefore, the debt under commitment exhibits random walk behavior. To achieve the minimum social welfare loss, government debt level is chosen as the absorber to the shock, rather than inflation. We confirmed this in our impulse responses shown in Figure (1): the level of debt remains permanently higher, tax rate is permanently raised but only to a level which is enough to serve the new higher level of debt, so inflation is pushed-up only slightly, and is brought back within one period; consumption is permanently below its initial level. This regime delivers the lowest level of social loss. The first column in Table 1 which presents the welfare loss in terms of compensating consumption – the permanent fall in the steady state consumption level, as percentage of steady state consumption, that would balance the welfare gain from eliminating the volatility of consumption and leisure (Lucas, 1987).
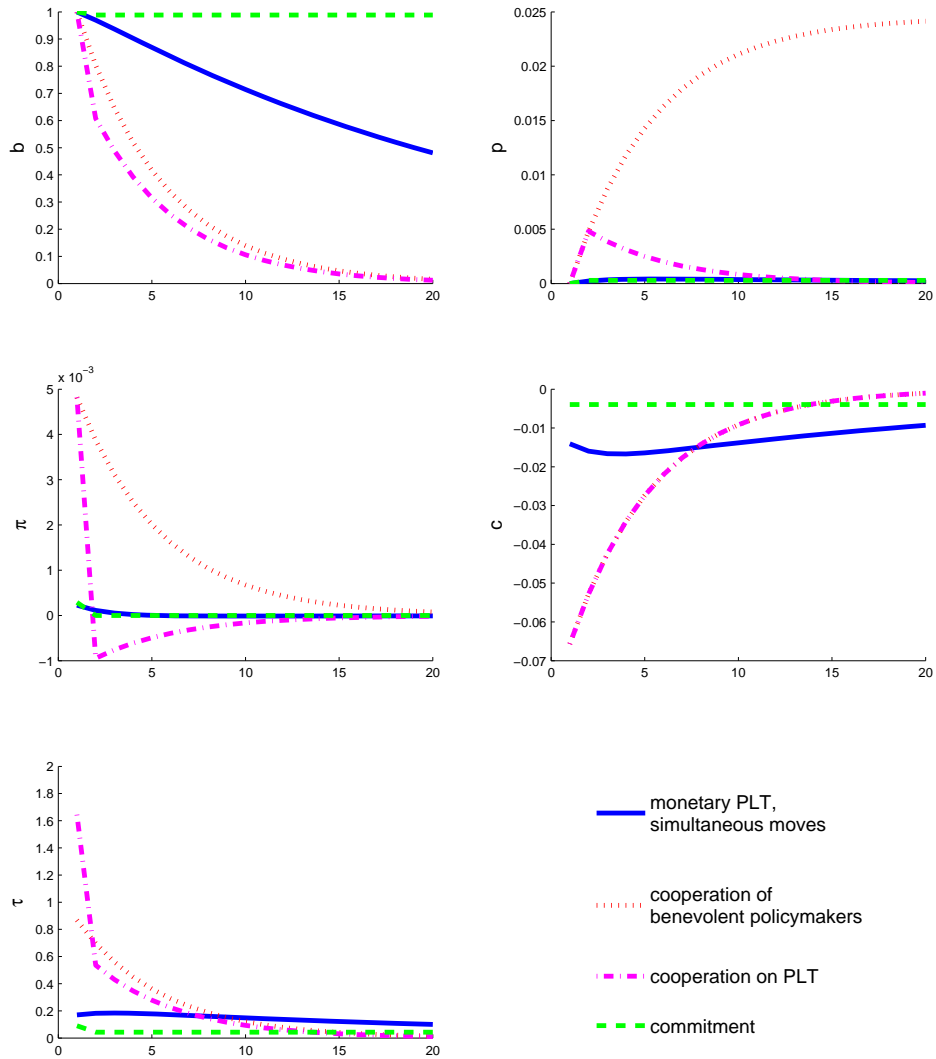
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Figure 1: Impulse Responses of an unexpected initial debt level deviation

Table 1: Social Welfare Loss

| | Absolute loss, % of steady state consumption | | Relative Loss, normalized |
type of disturbance →	initial debt	cost-push shock	any
Commitment of benevolent policy makers	0.0028	0.0117	1.000
Discretion of benevolent policy makers	0.0471	0.1938	16.625
Cooperative PLT under discretion	0.0317	0.1304	11.183
Monetary PLT, simultaneous moves ($\alpha = 1$)	0.0075	0.0308	2.6454
Monetary PLT, fiscal leadership ($\alpha = 1$)	0.0056	0.0232	1.9915

II: Cooperation of benevolent policy makers under discretion. In presence of an endogenous pre-determinant state, Markov-perfect discretionary policy is unable to manipulate the private agents' expectation anymore. When a disturbance to debt level happens, the households expect the government to bring debt level back to its original steady state. The change in tax rate will be significantly larger than in the commitment case. Now the private agents' decision on inflation depends on the level of debt, for an unexpectedly increased debt, households expect a higher inflation. The optimal time-consistent policy has to stabilize debt at the original steady state; the expectation of the households is validated. When steady state debt level is zero, stationary equilibrium exists and unique, all relevant economic variables are brought back to the steady state. The base line calibration suggests that a unit-change in consumption is about 10 times more effective than a unit change in tax rate in terms of stabilizing inflation, but nearly equally effective in their effects on debt. Therefore the optimal policy brings debt to the steady state by raising tax rates, and stabilize inflation by reducing demand to lower the marginal costs. The stabilization is relatively slow. Inflation goes back to steady state gradually while price level reaches a new high level and stays. The loss of this policy in consumption equivalent is about 15 times greater than the loss under commitment, see Table 1. Price will be stabilized at a permanently higher level in this regime.

III: Cooperation on price level targeting of discretionary policy makers. If we are to delegate a different target to the monetary policy maker, it is imperative to look at the cooperative delegation first, as usually different targets increase the conflicts between the policy makers and offset the effects of each other's action. This scenario illustrates some important properties of PLT policymaking, which are likely to realize under any type of price-level targeting, whether cooperative or not.

When the price level becomes explicit policy target the private sector recognize that, if inflation is higher than steady state level, the future policy makers will have to arrange for a negative inflation to achieve price stability. No commitment policy plan is required, just the presence of price stability among the targets will lead the future policy makers to generate the path of future endogenous states required for a negative inflation to happen.

In this case, given the same initial conditions, expected future inflation ($E_t \pi_{t+1}$) is lower than in the scenario of cooperative inflation targeting discussed above. Adjusting their expectation on

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next period price with smaller scale, the households react less to the same level of disturbance, which results in less violent current inflation. This is represented by a smaller feedback of inflation on state variables in our system. Moreover, as past period price level is a state variable which will be considered when the firms setting new price, inflation becomes more persistent.

The fiscal policy maker can exploit this to stabilize debt faster, by implementing a tax rate higher than that under inflation targeting, without causing extra increase in current inflation. Due to the lowered future inflation expectation, every same sized increase in tax corresponds to lower level of inflation. Similarly, the monetary policy maker who implements the same reduction in demand, will engineer lower inflation, due to the reduced future inflation expectation. Figure 2 suggests that when steady state debt level is low (first and second and column), the transmission path of consumption in this regime is the same as under both discretionary policy targeting inflation (for any degree of PLT, α)-only partially pull down inflation. Although changing demand has stronger impact on inflation, volatility of consumption is costly. As the fiscal policy maker cooperates towards the same price level targeting, it is more beneficial to change tax rate for the common target-price stabilization. Figure 2 shows that, compare to the benevolent discretionary case, it is optimal for the fiscal policy maker to increase tax rate initially by more to ensure the first-period reduction in the level of debt, while its cost-push effect on inflation is mitigated by the lower expected inflation; then tax rate drops sharply to a lower level, to deliver the required inflation overshooting baseline. Then tax rate gradually reduces to base-line level, with inflation also gradually increases back. When inflation overshoots, the price level is reduced. With inflation gradually goes back to steady state, the price level converges to its steady state.

The economy converges back to the steady state at the same speed under the price level targeting and under the cooperation of benevolent policy makers. This is apparent from the identical reaction of consumption in both cases taking into account that there is unique rate of convergence of all variables in linear models. The half-lives of both processes are identical.[7] Here the welfare gain can only be obtained because of the difference in the magnitude of inflation deviation from the steady state. Table 2 reports numerical values of policy and the private sector reaction functions. The equilibrium feedback of demand on debt is the same in these two scenarios, while consumption feedback negatively on last period price level as well in the latter scenario. The same dynamic path for demand is only possible if debt level is lower during the whole convergence process with price level targeting than with inflation targeting, otherwise consumption would be even lower due to the required action on positive price level. This lower debt is realized optimally by tax rate increase.

Two conclusions follow. First, cooperation on PLT improves the social welfare. By definition price level targeting delivers the long-term price stability. Even if social welfare still only cares inflation stability not price stability, welfare still gains from this regime due to smaller inflation volatility. The essential difference which leads to this improvement comparing to inflation targeting, is that the expectation of future inflation is lowered when policy makers target price level. Although discretionary policy makers cannot affect expectations directly, they can affect the states to achieve their targets. Knowing that the policy makers target price level stability, the private sector expects declining prices following an above steady state inflation, and a negative inflation will happen in the future in order to drive price back, even if there will be another new

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[7]We can check this numerically, and the result holds for all calibrations of the model.

Table 2: Agent's reactions in discretionary equilibrium

	structural form	reduced form
Benevolent cooperation	$c_t = 0.000p_{t-1} - 0.033b_t - 0.037\tau_t$ $\tau_t = 0.000p_{t-1} + 0.192b_t - 10.269c_t$ $\pi_t = 0.000p_{t-1} + 0.005b_t + 0.065c_t + 0.005\tau_t$	$c_t = 0.000p_{t-1} - 0.066b_t$ $\tau_t = 0.000p_{t-1} + 0.867b_t$ $\pi_t = 0.000p_{t-1} + 0.005b_t$
PLT cooperation	$c_t = -3.931p_{t-1} - 0.044b_t - 0.013\tau_t$ $\tau_t = -117.32p_{t-1} + 1.123b_t - 7.943c_t$ $\pi_t = -0.443p_{t-1} + 0.003b_t + 0.036c_t + 0.003\tau_t$	$c_t = -2.680p_{t-1} - 0.066b_t$ $\tau_t = -96.036p_{t-1} + 1.645b_t$ $\pi_t = -0.804p_{t-1} + 0.005b_t$
Monetary PLT, simultaneous	$c_t = -7.145p_{t-1} - 0.007b_t - 0.042\tau_t$ $\tau_t = -36.259p_{t-1} + 0.020b_t - 10.701c_t$ $\pi_t = -0.320p_{t-1} + 0.000b_t + 0.045c_t + 0.004\tau_t$	$c_t = -10.222p_{t-1} - 0.014b_t$ $\tau_t = 73.123p_{t-1} + 0.170b_t$ $\pi_t = -0.476p_{t-1} + 0.000b_t$
Monetary PLT, fiscal leadership	$c_t = -5.448p_{t-1} - 0.006b_t - 0.032\tau_t$ $\tau_t = 9.475p_{t-1} + 0.142b_t$ $\pi_t = -0.359p_{t-1} + 0.000b_t + 0.042c_t + 0.002\tau_t$	$c_t = -5.751p_{t-1} - 0.010b_t$ $\tau_t = 9.475p_{t-1} + 0.142b_t$ $\pi_t = -0.565p_{t-1} + 0.000b_t$
Benevolent commitment	$c_t = 0.000p_{t-1} - 0.0040b_t + 0.1612\psi_t$ $\tau_t = 0.000p_{t-1} + 0.0897b_t + 159.4472\psi_t$ $\pi_t = 0.000p_{t-1} + 0.0003b_t + 0.9882\psi_t$	

policy maker re-optimize in the next periods, as long as they still undertake price level targeting. This results in lower expected inflation set by price-setters, which improves the welfare.

Second, fiscal policy plays important role in achieving price stability. The required inflation overshooting is generated by a tax cut, together with the reduction in consumption. This is only possible if the fiscal policy maker also targets the price. Additionally, the initial-period increase in taxes leads to lower level of debt in all consequent periods, which helps to lower inflation and prevents consumption to fall more. As shown in Table2, inflation is positively related to the debt level while consumption reacts to debt negatively. The parameters in these two regimes are very close; therefore a lower debt level leads to smaller volatility in both consumption and inflation, which means higher welfare. The initial-period increase of inflation due to higher taxes is outweighed by a reduction of inflation in the following periods caused by expectations of negative future inflation. The initial inflation is not higher than that in the inflation targeting case, hence no extra cost occurs.

Following the intuition from Blake and Kirsanova (2011), that non-coincide policy objectives may lead to one strategic policy maker tries to offset some actions of the other policy maker, we would expect the welfare worsened comparing to the case with only central bank is assigned price level targeting. However, in the following analysis, we show that our case counters this conventional intuition: different targeting can improve social welfare.

IV: Monetary price level targeting. In this Section we study the case when the policy makers have different objectives: the discretionary fiscal policy maker remains benevolent, while the discretionary monetary policy maker targets the price level to some degree (the degree is measured by parameter α in objective (13)).We firstly focus on comparing the delegation merits, so we consider the case of pure price level targeting ($\alpha = 1$) and both policy makers optimize simultaneously. Table 1 demonstrates that the social welfare loss with pure PLT ($\alpha = 1$) is greatly reduced: it is only 25% of the loss under the cooperative price level targeting. This is despite the main component of the social loss is the inflation volatility, and the reduction of inflation volatility was helped by fiscal policy maker who now does not have an incentive to do the same.

It is instructive to compare all the impulse responses in this case to those in benevolent discretion and under discretionary PLT cooperation. We plotted the dynamic responses of the economy to an initial increase in debt, see Figure 1. The monetary price level targeting is assumed to be strict, with $\alpha = 1$. All dynamic responses of monetary policy targeting price level with inflation targeting fiscal policy are plotted using the solid line. Figure 1 shows that when monetary policy targets price level and fiscal policy targets inflation, the transition path is the closest to the benchmark commitment case.

Recall that in the time-consistent equilibrium the future inflation is a function of future states. As soon as any policy maker targets the price level, the price-setting private sector knows that any positive current inflation will be followed by a dynamic path of predetermined states such that demand will be sufficiently lowered to make it optimal for a firm to set negative inflation in the future. This expectation results in optimal firms decide to set initial inflation lower than inflation targeting regime, for same level of marginal cost, cet. par.

Table 2 shows that when only monetary policy targets price level, demand is far more sensitive

to price level deviation. Fiscal policy maker knows that cost-push inflation due to tax raise will cause a strong monetary reaction. To ensure price stability, an inflation overshooting is required, which will cause larger inflation volatility and demand reduction, both harm the inflation targeting fiscal policy's benefit. Fiscal policy maker's expectation of monetary policy's stronger reaction to cost-push inflation makes it optimal to set a smaller feedback of tax on debt deviation, leading to a slower return of debt. The resulted cost-push inflation is relatively small and price is stabilized by the monetary policy maker. To bring the future inflation below the base line to achieve the price-level target, monetary policy maker reduces demand by a relatively smaller amount but keeps consumption below the steady state level for a sufficiently longer time. Due to the expectations effect and moderate cost-push inflation, the required fall in demand is not too large. The tax rate has to stay high for a long time, to offset the effect of demand on debt and ensure the debt stabilization.

In this regime, the different targets actually prevent policy makers' volatile behaviors which would lead to large fluctuations. Each policy authority expects the other will react to its own action stronger, causing significant loss to them. It is optimal to avoid the large volatility by moving the policy instruments carefully and gently. To reduce fluctuation in inflation, it is better for fiscal policy to adjust tax rate only at a small scale, to avoid a big overshooting of the inflation. Households with rational expectations understand these, and set a lower inflation accordingly. The policy makers and the economic variables behave more like under commitment regime. 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.

In this case, expected future inflation can still be lowered due to monetary policy targeting price level. On top of this beneficial influence, the inflation targeting fiscal policy maker prefers to avoid inflation overshooting by not changing tax as violently as before. Therefore, this further gain of welfare, comparing to the case with both policy makers targeting price level, is due to fiscal expectation towards monetary policy. Therefore an inflation targeting fiscal policy maker tries to avoid the inflation variance due to overshooting by not starting the fight with the monetary policy maker, who will be determined to produce the overshooting large enough for price stability.

To summarize, the fiscal policy maker acts as an intra-period leader and anticipates the relatively low future demand which will be generated in response of current high taxes, it therefore decides not to raise taxes by much and avoids the fight with the monetary policy maker despite the difference in targets. Under fiscal leadership, the benefit of price level targeting can be captured with only a small weight.

5 Value of Leadership

In the previous section we demonstrated that the large welfare gain observed under the monetary PLT was merely the result of expectations of the price setters that any current inflation will have to be followed by a period of low demand and (optimally set) negative inflation. The substantial gain was achieved despite the non-cooperative behavior with different objectives of the two policy makers, and potential incentives of the two policy makers to offset each other's actions in the regime of simultaneous moves. In this section we investigate the effect of intra-period leadership
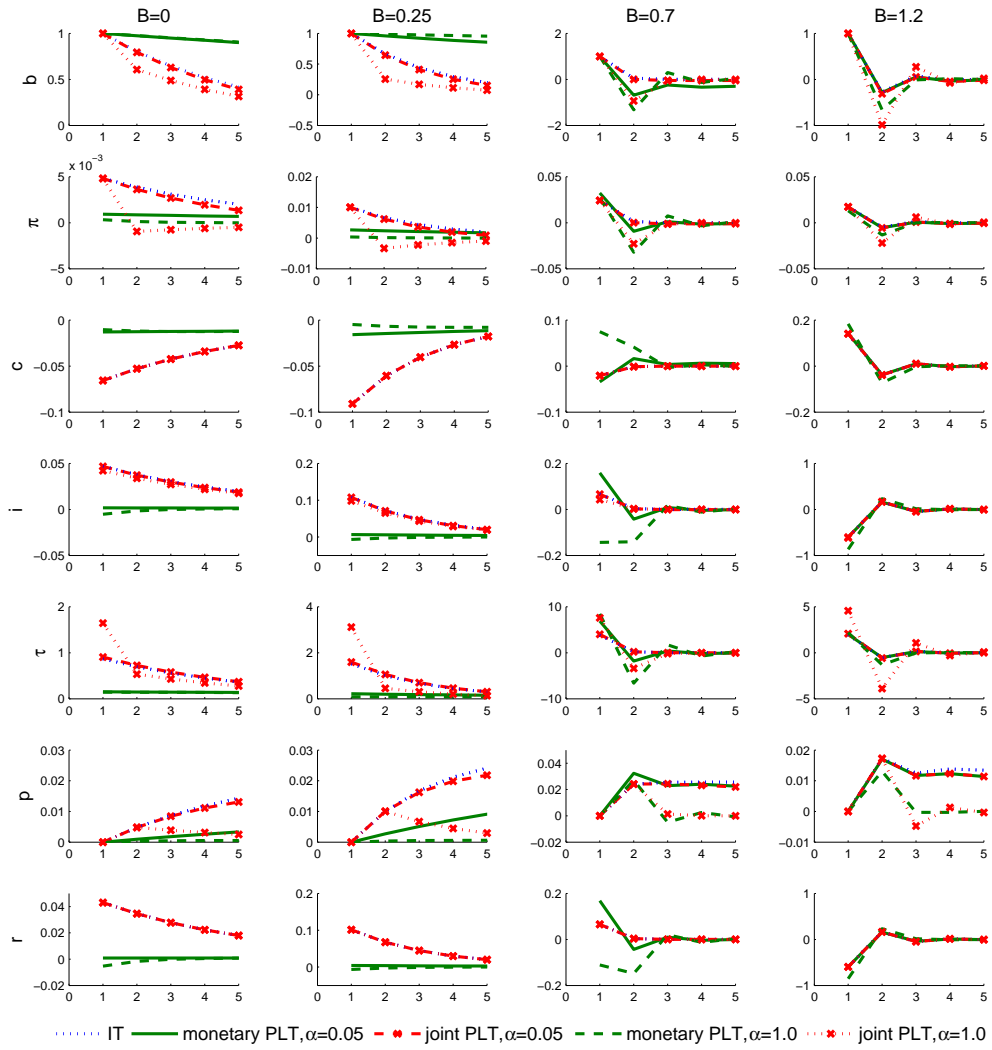
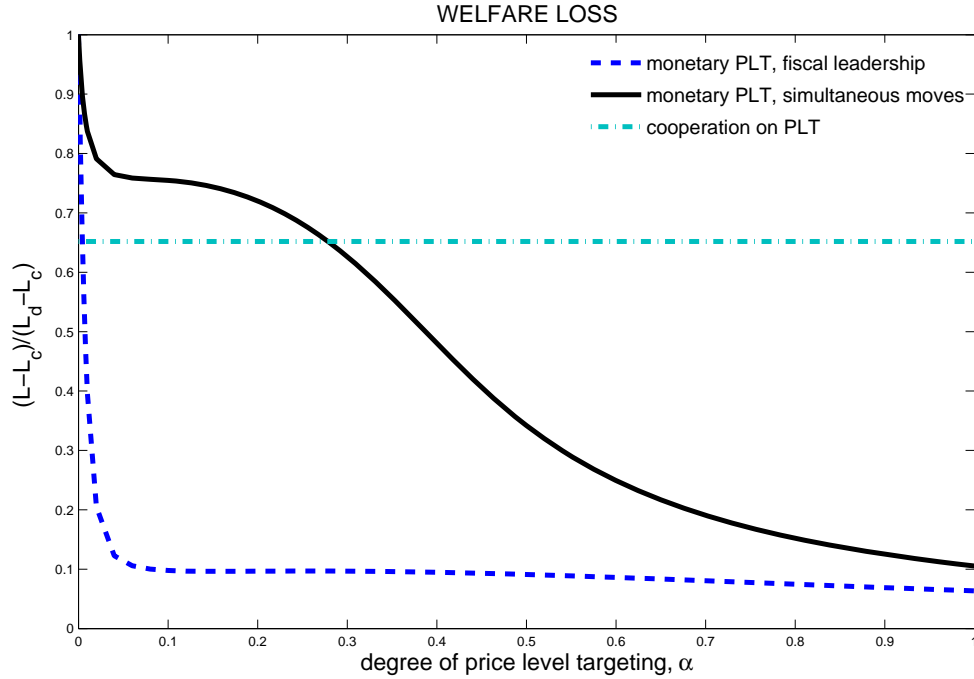Figure 2: Dynamic Responses in Discretionary Regimes

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Figure 3: Welfare loss under different leadership with different degree of PLT

on social welfare, with different weight on price level and inflation to check the intermediate regimes.

Figure 3 plots the social welfare loss for three regimes, cooperative PLT regime and two monetary PLT regimes as function of the degree of price level targeting, α. One of these two monetary PLT regimes is with the intra-period fiscal leadership; the other characterizes both policy makers making decisions simultaneously. The loss values are renormalized so that the zero loss level corresponds to the loss under commitment, while the level of one corresponds to the loss under discretionary cooperation of benevolent policy makers.

Two observations are apparent. First, the regime of fiscal leadership substantially outperforms all other PLT regimes. Second, the graph of loss in the regime of simultaneous shows that, with a positive α the initial gain of introducing PLT is quickly increasing until $\alpha \simeq 0.05$, then the increase in gain is substantially slowed down until $\alpha \simeq 0.1$ before the loss is relatively quickly and steadily reduced achieving its global minimum in the strict PLT regime with $\alpha = 1$.

In order to understand these results, we plot dynamic responses to a unit-increase level of debt in the initial period in Figure 4. We plot responses for three values of $\alpha = \{0.05, 0.1, 1.0\}$. Each panel contains impulse responses for three regimes: cooperation of benevolent policy makers, monetary PLT under fiscal leadership, monetary PLT with simultaneous moves.

There are two effects of higher degree of PLT, α: 1) the expectation effect of price level targeting and 2) the effect of different policy objectives of the two policy makers.
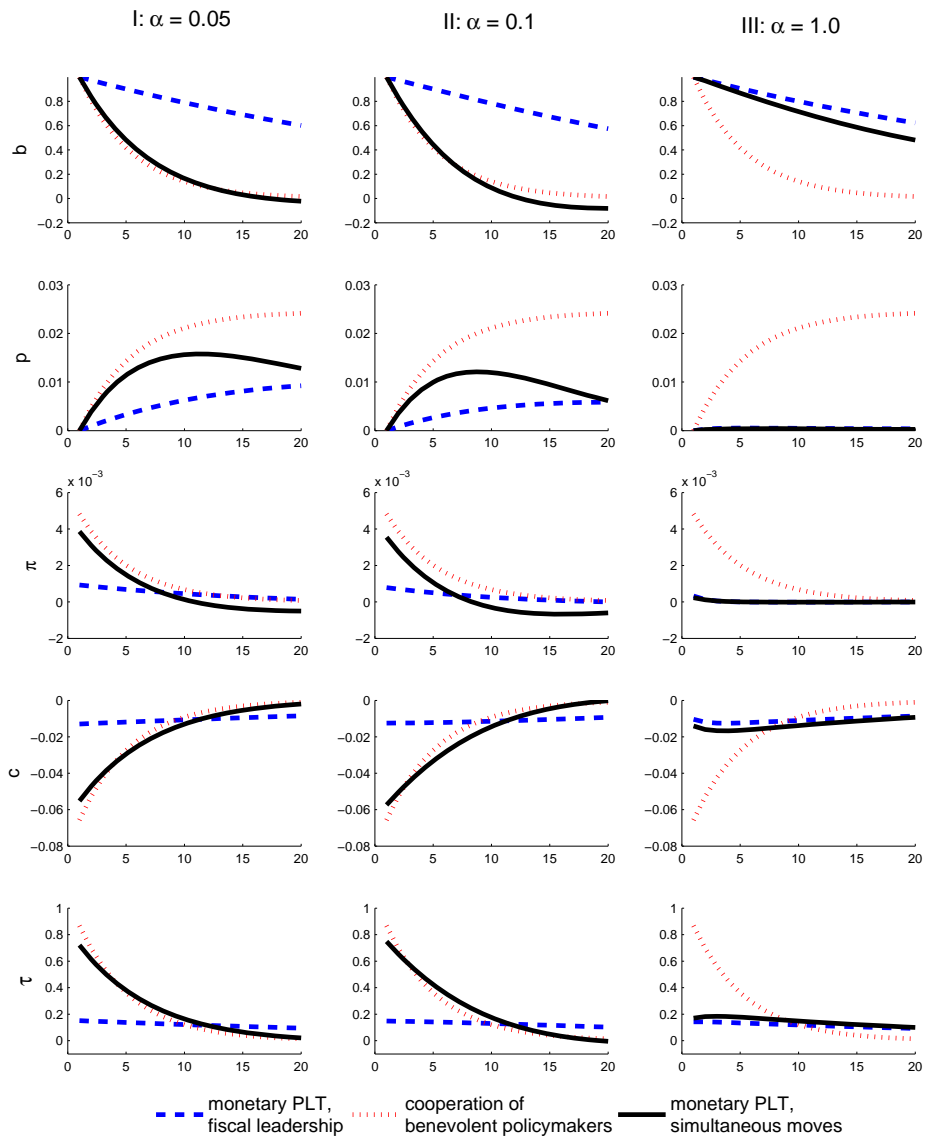
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Figure 4: Impulse Responses after initial debt deviation with different degree of PLT

We discuss the monetary PLT with simultaneous moves first. With small α, the monetary policy maker has to deliver the overshoot of the inflation eventually, but with little motivation to sacrifice with dramatic inflation fluctuation. Both policy makers expect the other behave similar to under cooperation benevolent case, as the similar objectives: to stabilize the economy the fiscal policy maker raises taxes slightly less than in the cooperation case, because the fiscal policy maker takes into account the expectations of the private sector which are affected by the future negative inflation.

Once the degree of the price level targeting α increases further, the incentives of the two policy maker to offset each other's actions increase in the regime of simultaneous moves. With higher α, the fiscal policy maker raises taxes by more and keeps them high, the monetary policy maker generates lower demand and keeps it low. As a result, inflation does not rise by much in the initial moment, but a long period with large negative inflation is generated. There is practically no extra welfare gain relative to the case with $\alpha = 0.05$, as the high welfare loss of the prolonged period of negative inflation and low consumption nearly outweighs the gain of the lower initial-period inflation.

With further increase in α the fight between the two policy makers in the regime of simultaneous moves becomes counterproductive. Stronger monetary and fiscal response would create a greater negative inflation, and smaller initial increase in inflation, but to keep the price level stability the integral under the graph of inflation should be equal to zero. In order to engineer this, and given temporarily higher taxes, the monetary policy maker has an incentive to lower initial demand less but keep it positive and small in the future for infinitely long time. Conversely, with not too low current demand, the fiscal policy maker will choose not to increase taxes too high; a moderate increase in taxes will not create inflation and is sufficient to stabilize the debt.

However when the fiscal policy takes action before monetary policy, the tax rate is raised by much less in all these cases with different values of α. Because the fiscal policy maker takes monetary reactions into account and knows that higher taxes will only result in lower demand, but similar inflation, while a moderate tax can avoid demand fall by too much. The fiscal leadership can completely avoids the fight between policy makers we described before in the simultaneous case, and takes most of the advantage of PLT from a small α, when increasing α this gain stays. When the fiscal policy maker targets inflation but not price level at all, fiscal instrument will not be used to deliver inflation overshooting, and it is the monetary policy maker who will have to deliver the future negative inflation. Moreover, the fiscal policy maker is unwilling to raise taxes as high as in the case of benevolent cooperative policy makers. Such an increase would result in cost-push inflation, the monetary policy maker would have to reduce demand by more than in the case of inflation targeting cooperation, so the overall result for the fiscal policy maker would be worse.

However, stabilization of inflation in a time-consistent way requires stabilization of debt, so the fiscal policy maker does raise the tax rate. This increase in taxes results in debt reduction with relatively small consequent increase in inflation. The monetary policy maker responses to this raise in inflation by more than in the benevolent case, to reduce demand and bring the future inflation below the steady state line. Expectations of this result in lower present inflation.

As a result, inflation does go up, but by much smaller amount than in other regimes. The monetary policy maker does generate negative inflation, but with a substantial delay; inflation remains negative for a long time, but the size of this negative bias is relatively small. Therefore,

there is a large social welfare gain.

Figure 3 demonstrates that although the maximum welfare gain is achieved with strict PLT ($\alpha = 1$) the loss is relatively flat in α. This shape of the loss is easy to understand. Once $\alpha > 0$ the negative inflation is inevitable and the described above mechanism is at work. This leads to a sharp immediate reduction in the strength of policy responses and in large welfare gains.

When with fully price targeting monetary policy, fiscal leadership delivers better welfare than simultaneous moves. In the former case, fiscal policy knows that if tax rate does not increase a lot, monetary policy as the follower has no incentive to generate a large reduction in consumption to let inflation overshoot more. However in the case of simultaneous moves, fiscal policy expects the monetary policy expecting a higher tax rate so will reduce the demand in order to pull the inflation to a negative level, it is optimal for fiscal policy to validate this expectation by increase tax rate by more than the value in the fiscal leadership case.

To summarize, the fiscal policy maker acts as an intra-period leader and anticipates the relatively low future demand which will be generated in response of current high taxes, it therefore decides not to raise taxes by much and avoids the fight with the monetary policy maker despite the difference in targets.

The price level targeting brings two major effects to the economy: long term price stabilization and short term inflation fluctuation in the form of overshooting. With rational expectations, a pure price level targeting can actually lower this inflation fluctuation due to the lowered expected future inflation. Two factors decide the volatility: how forceful the policy maker is to deliver the overshooting for price stability, which increases with the weight on price level target; and how much of the future inflation expectation can be lowered, which is also increasing with the weight of price level target. They increase at different rate. In simultaneous movement setting, in a small range of alpha, the loss of fluctuation from overshooting can go up with increasing alpha, until the expectation effect catches up (which lowers the fluctuation). While under fiscal leadership, the benefit of price level targeting can be captured with only a small weight.

6   Impact of steady state level of debt

Up till now we have analyzed the impact of PLT under different regime but all under the assumption of zero steady state debt level, which is far-fetched in current economy. In order to understand if the merit of price level targeting remains with higher level of steady state debt, in this Section we compare the impulse responses of economic variables with three different positive level of debt to our previous results.

The first column shows the cases we discussed before with $B = 0$. Then we increase B by a small value ($B = 0.25$), the transmission paths behave similar as before but fluctuate to a larger scale: the pure monetary PLT delivers the results closest to the commitment benchmark case (MISSED CURVE) comparing to all the other regimes we considered, followed by monetary PLT with $\alpha = 0.05$ showing that even just a small degree of PLT can help to reduce most of the stabilization bias.

However, when B is raised to 0.7 and higher in our framework, the direction of the impact of monetary fiscal interactions start to change. See the last two columns in Figure 2. If the fiscal policy maker does not raise taxes it knows that the monetary policy maker will be forced
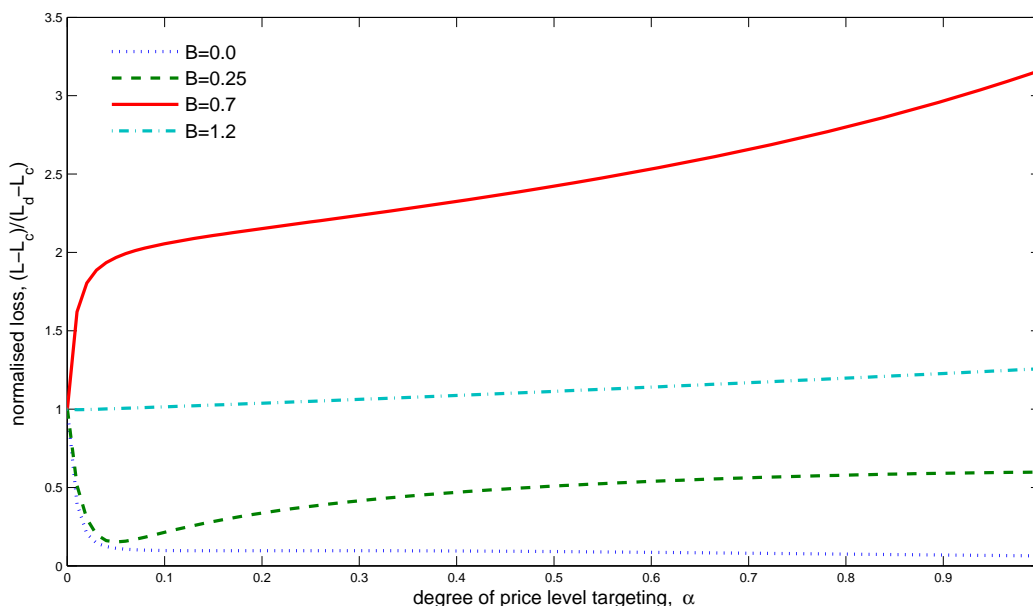
Figure 5: Welfare Loss under fiscal leadership with different steady state debt level and degree of PLT

to stabilize debt in order to deliver price stability. This can be achieved with 'passive' monetary policy when interest rate is lowered in the immediate response to the higher debt but then raised to fight the consequent inflation. Moreover, because of the requirement of price stability the movements of interest rate are likely to be large so that inflation overshoots the base line. (Keeping interest rate high for a long time may not be optimal because of the confliction with debt stabilization.) Such policy naturally leads to high volatility of inflation, which the fiscal policy maker would like to avoid. Therefore, it becomes optimal for the fiscal policy maker to intervene. The third column in Figure 2 demonstrates that with higher debt and small degree of PLT ($\alpha = 0.05$, solid line) taxes are raised nearly as high as under the joint PLT, so the fiscal policy maker effectively tries to coordinate with monetary policy maker rather than to offset its actions. With higher degree of PLT, the fiscal policy maker moves taxes more violently, but initially higher taxes are not high enough to ensure debt stabilization so the monetary policy maker operates in 'passive' way: interest rate is lowered when $\alpha = 1$.

With further increase in the steady state level of debt all cooperative and non-cooperative regimes become very similar. The monetary policy maker finds it very difficult to stabilize debt and deliver overshooting of inflation, so the fiscal policy is forced to react more aggressively to debt and to inflation in the similar way as in all cooperative regimes.

When $B = 0$, Monetary PLT makes fiscal policy behaves like under Commitment as well. This is due to the fiscal policy maker's also expects Monetary policy maker will forcefully reduce and negatively overshoot the inflation if tax creates any, which does no good for the inflation

targeting fiscal policy.

With a higher B interest rate has a direct effect on the accumulation of debt, the increase in debt will induce a higher tax, which leads to higher inflation. Below certain threshold, further rise in B creates more problems for policy makers if monetary policy raises the interest rate in response to an increase in inflation. The higher interest rate will put upward pressure on debt accumulation which makes fiscal policy less effective on debt stabilization. When B is below this threshold, the gains from less volatility of targeted variables outweigh the losses from the slow stabilization of the economy. When B is above this threshold, it becomes welfare improving to stabilize debt quicker. As the first-order effect of interest rates on debt is large, a fall in interest rates reduces the level of domestic debt. Therefore, it becomes optimal to lower the interest rate in the first period after the shock and raise it in the second period. This policy leads to faster debt stabilization, also curtails inflation.

The impulse responses show that under PLT, this threshold is lower than that under Inflation targeting regime: in the case of $B = 0.7$, interest rate is lowered instead of increased after the initial disturbance. In order to stabilize price, Central Bank chooses to help tax to bring debt down by lowering interest rate to increase consumption. This way the lowered debt leads to a reduced tax which can deliver the negative overshoot of the inflation.

If steady state debt level goes up even more, e.g.$B = 1.2$, Central bank lowers interest by more, therefore tax does not need to raise as much as before. Fiscal Policy maker knows that monetary policy, the follower, will have to lower interest by larger size to pull back debt in order to achieve the price stability. All regimes are more similar in the case where $B = 1.2$.

Figure 5 shows that $B = 1.2$ has lower loss than $B = 0.7$ in all discretionary regimes with different α in our framework. This demonstrates that the social loss is a non-monotonic function of B, which is consistent with the striking change in the way the stabilization policy works.

In relatively high debt case (e.g. $B = 0.7$, $B = 1.2$), the welfare loss in PLT is higher than inflation targeting. PLT has two opposite effects, on one hand, it lowers inflation after the disturbance by lowering expected future inflation, which makes the task of stabilization easier; on the other hand, an overshoot of inflation is required in order to return the price level to baseline, which causes a higher volatility of inflation. With higher B, there will be higher tax, and initially lowered interest rate which cause the realized inflation almost as high as under inflation targeting; when inflation is at the same level, due to the higher volatility of inflation required to deliver price level stability, PLT causes higher loss.

7   Conclusion

This paper revisited the idea that the PLT delegation scheme can reduce the stabilization bias in monetary policy models. We present a detailed account of discretionary monetary and fiscal policy interactions assuming that the monetary policy maker implements the PLT while the fiscal policy maker remains benevolent and has incentives to pursue its own benefit and offset some or all of monetary policy actions. If steady state debt level is low, we demonstrate that delegating PLT to the monetary policy maker results in substantial reduction of the social welfare loss even in case of strategic fiscal policy. A comparison to the joint PLT suggests that fiscal policy should be prevented from maintaining price stability – unilateral monetary PLT substantially outperforms

the joint PLT regime. The ability of the fiscal policy maker to conduct itself as an intra-period leader results in greater welfare gain.

First we compared the case that both policy makers target price level and the case both of them target inflation. Our study confirms the appealing features of price level policy on general: price-level targeting lead the discretionary results closer to the best commitment results, in which: 1) price level will come back to initial path; 2) the volatility in inflation and consumption (output) is smaller 3) tax rate no longer increase dramatically as a response to a positive shock to debt , the dynamic complementarity between fiscal and monetary policy is weakened 4) welfare loss is reduced with a price level targeting.

Then we assign price level targeting to monetary policy only, and let fiscal policy targets inflation. Surprisingly, this non-cooperative setting-up can further reduce the welfare loss. Monetary PLT makes fiscal policy behaves like under Commitment as well. This is due to the fiscal policy maker expects Monetary policy maker to forcefully reduce and negatively overshoot the inflation in order to sustain price level, if any created by tax. This does no good for the inflation targeting fiscal policy. The conflict between the policy makers is lessened rather than increased.

Later, we compare the case of fiscal leadership with both policy makers making decision simultaneously. We found out that fiscal leadership improves the social welfare further, and just a small weight on price target can demonstrate the appealing features of price level, the economic variables behave similar to those under commitment regime, while if policy makers re-optimize at the same time, the interactions between them lead to a relatively higher cost at lower level of price target weight, and it behaves more like inflation targeting discretionary policy makers.

In both monetary PLT regimes the maximum welfare is achieved under strict price level targeting, i.e. in the case when the inflation stabilization term in policy objective is replaces by the price stabilization term.

However, when the steady state debt level is high, the strengthened dynamic complementarity between policy makers causes a higher inflation even under PLT, and the loss from volatility of inflation required by price level targeting dominates. This shows that PLT will deteriorate the economy and cause more violent fluctuation rather than improves the social welfare. PLT may only be a good alternative to inflation targeting when the steady state debt level is relatively low.

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. Our results are likely to remain valid for this wide class of models.

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