Countercyclical Fiscal Policy, Simple Rules and Price Dispersion

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Preliminary

Abstract

In this paper we explore the benefits of a supply side oriented fiscal tax policy that remarkably reduces the impact of nominal frictions on an efficient allocation. We set up a calibrated version of a New Keynesian DSGE model augmented by a simple tax rule that engineers an efficient path for the evolution of marginal cost at the firm level and prevents any inefficient built up of price dispersion across firms. Taxes are levied on value added. We highlight that such a policy can be implemented by simple rules in contrast to optimal commitment solutions and are also effective under a balanced budget regime.

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1 Introduction

Can fiscal policy eliminate the welfare costs of nominal frictions by means of simple tax rules? We address this question by setting up a calibrated version of a New Keynesian DSGE model augmented by simple tax rules that builds on a rich strand of literature which has stressed the role of monetary policy to enhance welfare in an environment of nominal rigidities (Woodford, 2003). However this strand of literature has paid so far little attention to the role of fiscal policy. In particular only few studies analyze the role of distortionary taxation and debt financed expenditures and their implications for nominal frictions. In this respect, the paper aspires to extend the existing literature in proposing simple fiscal policy rules that eliminate price dispersion. The government sector is assumed to maximize the lifetime utility of the representative agent. As instrument it relies on a value-added tax, debt-financed expenditures and government expenditures. Our framework shares most of the features of recent dynamic optimization sticky price models as e.g. in Woodford (2003), and Gali, Lopez-Salido and Valles (2007).

In the basic New Keynesian framework there is no reason for output to be different across firms, except as a result of price distortions that accrue from staggered price setting (Woodford, 2003). Through this channel infrequent price adjustments create undesired variations in the relative prices of goods across firms. Under standard assumptions on preferences this creates welfare losses on the consumption side as households buy more of the relatively cheaper goods and less of the more expensive ones. On the production side the increased cost of producing some goods more is greater than the cost saving of producing less of other goods. Through these channels price stability turns out to be a dominant target of monetary policy (Woodford 2003, p. 396). A sufficiently strong feedback from movements in the inflation rate is argued to be the best response to limit the adverse effects of cost-push shocks on lifetime utility of a representative consumer. Notwithstanding the previous argument the welfare costs of nominal rigidities are estimated to be up to three percent in consumption equivalents (Canzoneri, Cumby and Diba, 2007; and Gertler and Lopez-Salido, 2007).

This highlights that monetary policy does not have a direct leverage on the supply side and thus the price setting behavior of firms. Monetary authorities can only control price dispersion through the aggregate demand channel and thus the reallocation of intratemporal consumption plans. In the event of a supply shock firms are tempted to increase prices. As best response monetary authorities raise the real rate of interest to encourage consumers to reallocate consumption to the future which depresses contemporaneous demand and thus demand driven production plans. As production plans have to be consistent with the labor supply schedules of workers an equilibrium only occurs if wages and thus marginal cost decline. This stands in contrast to demand shocks which can be wiped out at zero cost (Clarida, Gali, Gertler, 1999). In essence it is the lack of an additional instrument on the supply side of the economy on part of monetary authorities which makes markup shocks costly in terms of welfare. To that extend we follow the Tinbergen logic and propose that fiscal policy should use its value-added tax as an additional instrument in a state contingent way such that the evolution of marginal cost is stabilized around its deterministic steady state (Tinbergen, 1959). Those firms that are called upon to reset prices will then built on the promise of fiscal authorities to smooth away cost push shocks and set prices in the neighborhood of those price setters that have to leave prices unchanged.

A key finding of our paper is that fiscal authorities can create a path for value-added taxes that evolves countercyclical to markup shocks and thus prevents large movements in marginal cost by using simple tax rules. This seems in particular important as Schmidt-Grohe and Martin Uribe (2006) report evidence from a medium-scale model which comprises a number of real and nominal frictions that price stickiness emerges as the single most important distortion.

When fiscal policy is allowed to cushion changes in tax rates by debt rather than government expenditures we report evidence that debt prevails a near-random walk behavior in the presence of cost-push shocks. Schmitt-Grohe and Uribe (1997) pointed out that distortionary taxes might produce multiple equilibrium if they are conditioned on the state of the cycle. Notwithstanding these results it has prevailed in DSGE models that multiple equilibrium can be ruled out if fiscal authorities react sufficiently strong with the tax rate to the level of existing debt (Canzneri, Cumbi and Diba, 2001; Schabert and Linnemann, 2003). In particular the steady state levels of tax rates and government expenditure is determined by long-run solvency conditions such that in steady state the budget is balanced.

Although the general idea of simple fiscal rules is not new previous authors mainly focused on the idea of classical demand management, where government expenditures are conditioned on the output gap such as J.B. Taylor (2001). Only few studies consider stochastic taxation, and its role for nominal frictions. A notable exception is Leith and Wren-Lewis (2007), who explore the role of countercyclical fiscal policy in a full-fledged DSGE model and analyze commitment solutions. They report evidence that price dispersion can be completely wiped out by commitment solutions when fiscal authorities employ three instruments, namely debt, government expenditures and tax rates on labor and value added. We differ from there work in several aspects: (i) instead of modeling commitment solutions we show that simple rules are sufficient to substantially improve welfare. (ii) We report evidence that such rules are also effective under a balanced budget regime by means of MSV-solutions. (iii) We obtain results from a sensitivity analysis with respect to deep parameters.

Our findings suggest that countercyclical supply-side taxation rules can virtually wipe out the impact of cost-push shocks on welfare by reducing the welfare loss substantially.

The paper is structured as follows: In Section 2, the basic model is introduced. Section 3 presents analytical results on simple rules and price dispersion. In Section 4 we exhibit the numerical findings with debt financed expenditures. In Section 5 we conduct robustness analysis. Section 6 summarizes the main findings and concludes.

2 The model

In this section we present a New Keynesian DSGE model that consists of firms, households, the central bank and fiscal authorities. As standard firms are partitioned into the final good sector and a continuum of intermediate good producers. Intermediate good producers have some monopoly power over prices that are set in a staggered way following Calvo (1983). Households obtain utility from consumption, leisure and invest in state contingent securities. Monetary authorities are guided by a simple Taylor rule. The government sector is financed by distortionary taxes levied on value added or debt. Fiscal policy is implemented by simple tax and spending rules.

The model builts on the framework of Gali, Lopez Salido and Valles (2007), Leith and Wren Lewis (2007) and Linnemann and Schabert (2003) by sharing the same kind of features such as debt financed expenditures, state contingent tax rules and staggered price setting as in Calvo (1983). In particular we highlight the role of an active fiscal policy compared to a neutral stance to fight the welfare costs of price dispersion.

2.1 Final Good Producers

The final good is bundled by a representative firm which operates under perfect competition. The technology available to the firm is:

$$Y_t = \left[\int_0^1 X_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{1}$$

where Y_t is the final good, $X_t(i)$ are the quantities of the intermediate goods, indexed by $i \in (0,1)$ and $\varepsilon > 1$ is the elasticity of substitution.

Profit maximization implies the following demand schedules for all $i \in (0,1)$:

$$X_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} Y_t . \tag{2}$$

The zero-profit theorem implies $P_t = \left[\int_0^1 P_t(i)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$, where $P_t(i)$ is the price of the intermediate good $i \in (0,1)$.

2.2 Intermediate Good Producers

Firms indexed by $i \in (0,1)$ operate in an environment of monopolistic competition. The typical production technology is given by:

$$Y_t(i) = N_t(i)\,, \tag{3}$$

where $N_t(i)$ denotes labor services. Nominal profits by firm are given by:

$$\Pi_t(i) = \left(1 - \tau_t^{VAT}\right) P_t(i) Y_t(i) - W_t\, N_t(i)\,, \tag{4}$$

with $Y_t(i) = X_t(i)$ and τ_t^{VAT} denotes a value-added tax with $\tau_t^{VAT} \in \left]0,1\right[$. As cost minimization implies that marginal cost are equal to wages with $\varphi_t = w_t$ the profit function can be rewritten as:

$$\Pi_t(i) = \left[\left(1 - \tau_t^{VAT}\right) P_t(i) - P_t\, \varphi_t \right] Y_t(i)\,. \tag{5}$$

The representative firm is assumed to set prices as in Calvo (1983), which implies that the price level is determined in each period as a weighted average of a fraction of firms $\left(1 - \theta_p\right)$ which resets prices and a fraction of firms θ_p that leaves prices unchanged:

$$P_t = \left[\left(1 - \theta_p\right) \left(\tilde{P}_t\right)^{1-\varepsilon} + \theta_p P_{t-1}^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}, \tag{6}$$

where $\tilde{P}_t$ is the optimal reset price in period *t*. Profit maximization comprises the following first-order condition:

$$E_t \left\{ \sum_{k=0}^{\infty} \left(\theta_p \beta\right)^k \Delta_{t+k} Y_{t+k}(i) \left[\tilde{P}_t(i) \left(1 - \tau_{t+k}^{VAT}\right) - \Phi_{t+k} P_{t+k} \varphi_{t+k}(i) \right] \right\}, \tag{7}$$

where Δ_{t+k} denotes the stochastic discount factor of shareholders to whom profits are redeemed and Φ_t denotes the gross frictional markup prevailing in an environment of flexible prices and zero inflation. The deterministic counterpart of Φ_t is $(\varepsilon-1)\varepsilon^{-1}$.

2.3 Households

We assume a continuum of households indexed by $j \in (0,1)$. A typical household seeks to maximize lifetime utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t U_t(j), \tag{8}$$

where β denotes a discount factor $\beta \in (0,1)$ and period utility is given by:

$$U_t(j) = (1-\chi)\left(\frac{1}{1-\sigma} C_t(j)^{1-\sigma}\right) + \chi G_t - \frac{1}{1+\varphi} N_t(j)^{1+\eta}. \tag{9}$$

σ is a coefficient of risk aversion, η is the inverse of the Frisch elasticity of labor supply. C_t are the real consumption expenditures of household *j*. The sequence of budget constraints reads:

$$C_t(j) + \frac{B_{t+1}(j)}{R_t P_t} \leq \frac{W_t N_t(j)}{P_t} + \frac{\Pi_t(j)}{P_t} + \frac{B_t(j)}{P_t}. \tag{10}$$

Each household decides on consumption expenditures $C_t(j)$ and bond holdings $B_t(j)$ and receives labor income $W_t N_t(j)$, dividends from profits $\Pi_t(j)/P_t$ and the gross return on bonds purchased $B_{t+1}(j) \cdot (R_t P_t)^{-1}$.

Maximizing the objective function subject to the intertemporal budget constraint with respect to consumption and bond holdings delivers the following first-order conditions:

$$(1-\chi)C_t^{-\sigma} = \lambda_t, \tag{11}$$

$$N_t^{\eta} = \lambda w_t, \tag{12}$$

where λ_t denotes the Lagrangian from relaxing the budget constraint. Consolidating the first order conditions yields the consumption Euler equation:

$$C_t^{-\sigma} = \beta R_t E_t \left[C_{t+1}^{-\sigma} \frac{P_t}{P_{t+1}} \right]. \qquad (13)$$

2.4 Fiscal Authorities

The government issues bonds and collects value-added taxes. It uses its receipts either to finance government expenditures or interest on outstanding debt. The real government budget constraint reads:

$$B_{t+1} + \tau_t^{VAT} Y_t = R_t B_t + G_t. \qquad (14)$$

Letting $b_t = \frac{(B_t/P_{t-1})}{\overline{Y}} - \frac{(\overline{B}/\overline{P})}{\overline{Y}}$ and $\overline{B} = 0$, the budget constraint can be rewritten as:

$$b_{t+1} + \tau_t^{VAT} \frac{Y_t}{\overline{Y}} = R_t b_t \frac{P_{t-1}}{P_t} + \frac{G_t}{\overline{Y}}. \qquad (15)$$

Government purchases are assumed to move countercyclical to output:

$$G_t = Y_t^{o_Y}, \qquad (16)$$

where o_Y<0 denotes the expenditure elasticity with respect to income Y_t. The tax rule reads:

$$\tau_t^{VAT} = \Phi_t^{\chi_1} b_{t+1}^{\chi_2}, \qquad (17)$$

which is conditioned on the stochastic markup shock Φ_t and outstanding debt b_{t+1}. In principle a sufficient strong response to the level of outstanding debt $\chi_2 > 0$ assures uniqueness and determinacy. A parameter $\chi_1 < 0$ denotes a countercyclical fiscal tax policy.

2.5 Market Clearance

In clearing of factor markets and good markets the following conditions are satisfied:

$$Y_t = C_t + G_t \qquad\qquad Y_t(j) = X_t(j)$$

$$N_t = \int_0^1 N_t(j)dj \, .$$

2.6 Linearized Equilibrium Conditions

In this section we summarize the model by taking a log-linear approximation of the key equations around a symmetric equilibrium steady state with zero inflation and zero debt. A variable $\hat{X}_t$ denotes in the following the log-linear deviation from the steady state value: $\hat{X}_t = \ln(X_t) - \ln(\bar{X})$, where $\bar{X}$ represents the steady state.

Households The consumption Euler equation reads:

$$\hat{C}_t = E_t \hat{C}_{t+1} - \sigma^{-1}\left(\hat{R}_t - E_t \hat{\pi}_{t+1}\right), \tag{18}$$

where $\hat{\pi}_t$ is defined as $\hat{\pi}_t = \hat{P}_t - \hat{P}_{t-1}$. Under perfectly competitive labor markets the labor supply schedule is equal to:

$$\hat{w}_t = \eta \hat{N}_t + \sigma \hat{C}_t \, . \tag{19}$$

Firms Log-linearization of (6) and (7) around a zero inflation steady state yields the dynamics of inflation as a function of the wage $\hat{w}_t$, a stochastic markup $\hat{\Phi}_t$ and tax rates $\hat{\tau}_t^{VAT}$:

$$\hat{\pi}_t = \beta \hat{\pi}_{t+1} + \kappa \left[\hat{w}_t + \iota \hat{\tau}_t^{VAT} + \hat{\Phi}_t \right], \qquad (20)$$

where $\kappa = \left[(1-\theta_P)(1-\beta\theta_P) \right] (\theta_P)^{-1}$.

Fiscal authorities Log-linearizing the budget constraint around a zero steady state debt yields the following approximation up to first order:

$$b_{t+1} + \gamma_G \left(\hat{\tau}_t^{VAT} + \hat{Y}_t \right) = \beta^{-1} b_t + \gamma_G \hat{G}_t, \qquad (21)$$

where for the case of a balanced budget (21) simplifies to $\hat{G}_t = \hat{\tau}_t^{VAT} + \hat{Y}_t$. The parameter γ_G denotes the steady state government share which is equal to $\overline{\tau}^{VAT}$ implied by a balanced budget in steady state. The fiscal spending rule is the log-linearized version of (16):

$$\hat{G}_t = o_Y \hat{Y}_t . \qquad (22)$$

The simple tax rule is the log-linearized complement to (17):

$$\hat{\tau}_t^{VAT} = \chi_1 \hat{\Phi}_t + \chi_2 b_{t+1} . \qquad (23)$$

In the following we will refer to a passive fiscal policy if $\chi_1 = 0$ which comprises that movements in tax revenues $\hat{\tau}_t^{VAT} + \hat{Y}_t$ are passively absorbed by movements in debt b_{t+1} and changes in the tax rate $\hat{\tau}_t^{VAT} = \chi_2 b_{t+1}$ such that (21) holds.

Monetary policy Monetary policy is assumed to follow the Taylor rule:

$$\hat{R}_t = (1-\rho) \hat{R}_{t-1} + \rho \left[\phi_\pi \hat{\pi}_t + \phi_x x_t \right], \qquad (24)$$

where ϕ_π and ϕ_x capture the reaction coefficients with respect to the inflation rate and the output gap x_t as defined below. The rule satisfies the Taylor-principle as long as $\phi_\pi > 1$, which is a necessary requirement for uniqueness and stability (Woodford, 2003).

Market Clearing Market clearing requires that the following holds:

$$\hat{Y}_t = \gamma_C \hat{C}_t + \gamma_G \hat{G}_t, \qquad (25)$$

where γ_C denotes the consumption share.

Using (22) and (25) we can rewrite the consumption Euler-equation as follows:

$$\hat{Y}_t = E_t\hat{Y}_{t+1} - \gamma_C \left(\sigma\left(1-\gamma_G o_Y\right)\right)^{-1}\left(\hat{R}_t - E_t\hat{\pi}_{t+1}\right). \qquad (26)$$

Flex-price equilibrium The flex-price equilibrium is obtained by equating $\hat{w}_t = \varphi\hat{N}_t + \sigma\hat{C}_t$ and $\hat{\varphi}_t = \hat{w}_t$ which combines the real marginal product of labor to the marginal rate of substitution between consumption and leisure:

$$\hat{\varphi}_t^f = \Gamma_\varphi \hat{Y}_t^f, \qquad \Gamma_\varphi = \left[\varphi + \sigma\gamma_C^{-1}\left(1-\gamma_G o_Y\right)\right], \qquad (27)$$

where we additionally used the fiscal spending rule (22) and market clearance condition (25). The superscript *f* denotes flexible prices. From the optimal price-setting behavior of firms operating in the intermediate good sector under flexible-prices we know that:

$$\varphi_t^f = \Phi_t^{-1}\left(1-\tau_t^{VAT,f}\right), \qquad (28)$$

where we assumed that fiscal policy sets $\chi_1 = 0$ if prices are flexible as no price dispersion prevails in the flex-price equilibrium such that $\tilde{\tau}_t^{VAT,f} = \chi_2 b_{t+1}^f$. Accordingly the log-deviation of real marginal cost from its deterministic counterpart $(\varepsilon-1)\varepsilon^{-1}$ can then be written in log-linearized terms as: $\hat{\varphi}_t^f = -\left(\hat{\Phi}_t + \iota\tau_t^{VAT,f}\right)$. If we define $x_t = \hat{Y}_t - \hat{Y}_t^f$ as the welfare gap, i.e. the gap between the actual output gap and the output gap under flexible prices the log-deviation of marginal cost can be written as:

$$\hat{\varphi}_t = \Gamma_\varphi\left(x_t + \hat{Y}_t^f\right), \qquad (29)$$

with $\hat{Y}_t^f = -\Gamma_\varphi^{-1}\left(\hat{\Phi}_t + \iota\tau_t^{VAT,f}\right)$. We can rewrite the Phillips curve in terms of x_t as:

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \kappa\left[\Gamma_\varphi x_t + \iota\left(\hat{\tau}_t^{VAT} - \hat{\tau}_t^{VAT,f}\right)\right], \qquad (30)$$

From the Euler-equation we know that the natural rate of interest under flexible prices is equal to:

$$r_t^n - \rho = \sigma E_t \Delta \hat{Y}_{t+1}^f - \sigma \Delta \hat{G}_{t+1}^f \,, \tag{31}$$

where $\rho = -\log \beta$. Inserting $\Delta \hat{Y}_{t+1}^f$ and $\Delta \hat{G}_{t+1}^f$ the natural rate can be expressed in terms of the exogenous shock $\Delta \hat{\Phi}_{t+1}$ and the tax rule $\Delta \hat{\hat{\tau}}_t^{VAT}$ under flexible prices:

$$\hat{r}_t^n = -\sigma (1 - o_Y) \Gamma_\varphi^{-1} \left[E_t \Delta \hat{\Phi}_{t+1} + \iota E_t \Delta \hat{\hat{\tau}}_t^{VAT} \right]. \tag{32}$$

Using the definitions of the welfare gap x_t it holds that:

$$x_t = E_t x_{t+1} - \gamma_C \left(\sigma (1 - \gamma_G o_Y) \right) \left[\hat{R}_t - E_t \hat{\pi}_{t+1} - \hat{r}_t^n \right], \tag{33}$$

and

$$b_{t+1} - \gamma_G \iota \Lambda \hat{\hat{\tau}}_t^{VAT} = \beta^{-1} b_t + \gamma_G (o_Y - 1) x_t + \gamma_G \Lambda \hat{\Phi}_t - \gamma_G \hat{\tau}_t^{VAT} \,. \tag{34}$$

$$\text{With: } \Lambda = \Gamma_\varphi^{-1} (1 - o_Y)$$

Discussion Notwithstanding that most of the features in the model are standard in particular the value-added tax augmented Phillips-curve is worth stressing. First, notice that the inflation rate is simply a weighted average of the expected path of wage costs, the mark-up shock and the evolution of the value-added taxes. As we will show below this enables the government to design a path for value-added taxes which almost completely offsets any movement in marginal cost such that price dispersion across firms can be reduced. Secondly, as we formulate state contingent tax and spending rules government debt necessarily works as a buffer to accommodate movements in the spending rule and movements of the tax rate. For the case of a balanced budget regime movements in the tax rate call for adjustments in fiscal spending.

3 Simple Rules and Price Dispersion

In this Section we analytically examine the role of simple tax rules on the equilibrium allocation of inflation, output, consumption, interest rates and government expenditures. To keep the analysis analytically tractable, we assume that the budget is balanced such that (23) reduces to $\hat{\tau}_t^{VAT} = \chi_1 \hat{\Phi}_t$ and government expenditures are adjusted passively such that the budget equation (21) holds. Additionally we reduced the system by inserting the natural rate of interest $\hat{r}_t^n$ and the tax rule (23) into the Phillips curve (30) and the Euler-equation (33). Then the model can be reduced to the following set of expectational difference equations:

$$x_t = E_t x_{t+1} - \sigma^{-1}\left(\hat{R}_t - E_t \hat{\pi}_{t+1}\right) + \left(\gamma_G \gamma_C^{-1} \chi_1 + (\sigma + \varphi)^{-1}\right)\hat{\Phi}_t \tag{35}$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa\left[(\sigma + \varphi) x_t + (1 - \sigma)\gamma_G \gamma_C^{-1} \chi_1 \hat{\Phi}_t\right] \tag{36}$$

$$\hat{R}_t = \phi_\pi \hat{\pi}_t , \tag{37}$$

where the coefficient χ_1 serves as a parameter which can be freely chosen by fiscal authorities. The following propositions summarize the main results[1].

Proposition 3.1 Suppose that a social planer is only concerned about price dispersion. Then choosing a coefficient $\chi_1 = -\gamma_C \gamma_G^{-1}(1+\varphi)^{-1}$ completely eliminates any price dispersion across firms at any date *t*.

Proof Since the simplified model with $b_{t+1} = b_t = 0$ exhibits no endogenous state variables the fundamental solution takes the form: $\hat{\pi}_t = \delta_\pi \hat{\Phi}_t$. Applying the methods of undetermined coefficients leads to the following solution: $\delta_\pi = \left[1 + \kappa(\sigma+\varphi)\sigma^{-1}\phi_\pi\right]^{-1} \kappa\left[1 + \gamma_G \gamma_C^{-1} \chi_1 (1+\varphi)\right]$. Inflation is completely stabilized if $\delta_\pi = 0$ which holds for $\chi_1 = -\gamma_C \gamma_G^{-1}(1+\varphi)^{-1}$.

Thus according to Proposition 3.1 fiscal authorities can completely stabilize the inflation rate by choosing χ_1 appropriately. For the applied calibration χ_1 would take a numerical value of $\chi_1 = -2.00$ $(\gamma_G = 0.2; \varphi = 1)$. Interestingly the coefficients χ_1 only depends on

[1] For the MSV-solutions, see Appendix B.

two deep parameters, namely $\overline{\tau}^{VAT} = \gamma_G$ and φ. In line with intuition an increasing steady state government share γ_G increases the leverage of fiscal authorities on real marginal costs and on prices such that the same effects on equilibrium allocations can be achieved by smaller movements of the instrument τ_t^{VAT}. Additionally the responsiveness of the coefficient χ_1 decreases in the Frisch elasticity φ of labor supply. Thus if labor supply is more responsive to wage changes equilibrium wages will be less responsive over the cycle such that smaller movements in the tax instrument are sufficient to yield the same effects on the evolution of marginal cost.

Proposition 3.2 Suppose that we compare two economies which are identical except that in one economy fiscal policy implements the simple rule $\hat{\tau}_t^{VAT} = \chi_1 \hat{\Phi}_t$ whereas in the other economy fiscal policy remains passive with $\overline{\tau}^{VAT} = \tau_t^{VAT} \wedge \overline{G} = G_t \vee t$. Then for any policy choice with $\chi_1 < 0$ the evolution of the inflation rate $\hat{\pi}_t$, the welfare gap x_t and nominal interest rates $\hat{R}_t$ evolve smoother than in an economy where $\chi_1 = 0$.

Proof Since in both economies the simplified model exhibits no endogenous state variable the fundamental solution takes in both cases the following form, with $\hat{X}_t = \delta_X \hat{\Phi}_t$ with $\hat{X}_t = \begin{bmatrix} \hat{\pi}_t & x_t & \hat{R}_t \end{bmatrix}$ and $\delta_X = [\delta_\pi \quad \delta_x \quad \delta_R]$. Thus a necessary and sufficient condition for a smoother evolution of the economy is $\left|\delta_X^A\right|_{i,1} < \left|\delta_X^P\right|_{i,1}$ for i=1,2,3, where the superscripts *A* denote active and *P* passive. As shown in Appendix B a necessary and sufficient condition for this inequality to hold is that $\chi_1 < 0$.

Thus according to Proposition 3.2 it holds that any policy choice with $\chi_1 < 0$ accommodates a smoother evolution of the economy.

Without any statement on welfare, we can already conjecture that an active fiscal stance is welfare improving if government expenditure is pure waste as the welfare function for this case would only built on the inflation rate $\hat{\pi}_t$ and the welfare gap x_t. Note that we know by the Taylor Rule that the nominal interest rate will be smoothed as it is just a linear transformation of the inflation rate itself. This in turns implies that a smoother evolution of the real interest rate fosters a stable consumption path $\left(\hat{C}_t / \hat{C}_{t+1}\right)$ as can be seen from the Euler-equation:

$$\frac{1}{\beta} = E_t\left[\left(\frac{\hat{C}_t}{\hat{C}_{t+1}}\right)^{\sigma} \cdot \left(\frac{\hat{R}_t}{\hat{\pi}_{t+1}}\right)\right], \tag{38}$$

which states that the product of the real interest rate and the ratio of the transformed log-deviations of consumption will always be equal to the inverse of the discount factor. For the case of a balanced budget changes in the tax rate have to be cushioned by fiscal spending. Therefore fiscal spending $\hat{G}_t$ is by definition more volatile than under a passive fiscal stance. Notwithstanding the argument the output gap $\hat{Y}_t$, defined as the weighted sum $\gamma_C \hat{C}_t + \gamma_G \hat{G}_t$ evolves less volatile. This reflects that the additional volatility in government expenditure is overcompensated by the stable evolution of consumption, which implies that such a policy is welfare improving as long as consumers attach a higher weight to consumption than to government expenditures in their welfare metric.

4 Welfare

Next we characterize the model if we allow for debt financed expenditures by means of numerical analysis. As shown in the appendix C a second order approximation around a steady state to the average utility of a household can be written as follows (see Erceg, Henderson, and Levine, 2000, Gali and Monacelli, 2007, and Woodford 2003).

$$W_t = \sum_{t=0}^{\infty} \beta^t L_t \,, \tag{39}$$

where

$$L_t = \frac{\varepsilon}{\kappa}\pi_t^2 + (1+\varphi)\tilde{Y}_t^2 + \iota\left(\tilde{G}_t - \tilde{Y}_t\right)^2 . \tag{40}$$

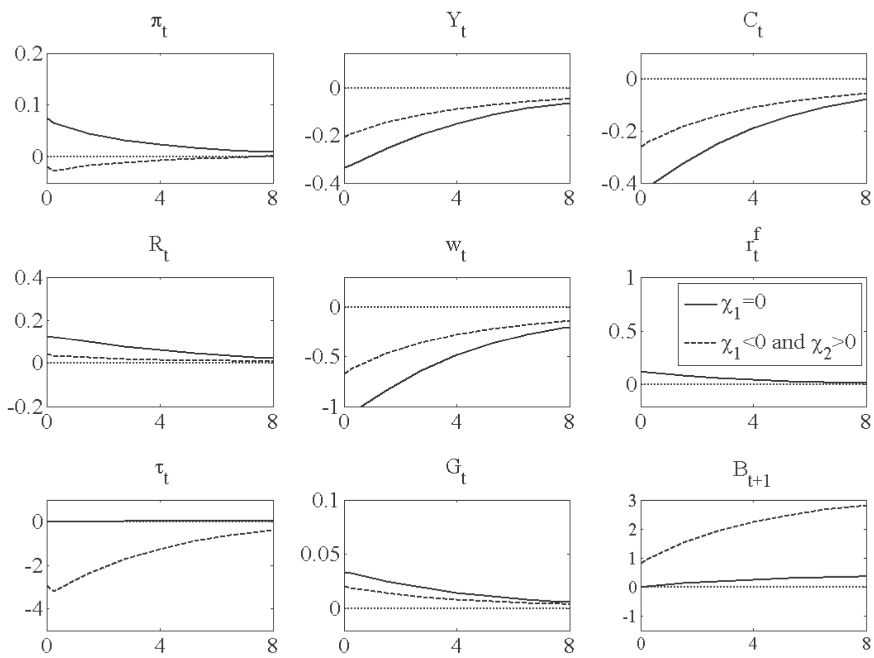
In the following we discuss the implementation of the proposed tax rule (23). Since we do not have a distinctive imagination for appropriate numerical parameters in a model with debt financed expenditures of χ_1 and χ_2 except that $\chi_1 < 0$ and that $\chi_2 > 0$, we opt to choose the parameters such that the welfare function (39) is minimized. This does not mean that we want to propagate simple optimized rules but it simply means that due to the lack of parameters to calibrate this seems to be the most reasonable way to proceed as a first guess.

Figure 1 portrays the dynamic responses of selected variables to a markup shock. For the baseline case fiscal policy remains passive with $\chi_1 = 0$ whereas for the active stance with $\chi_1 < 0$ fiscal policy aspires to improve welfare by controlling the evolution of marginal cost. The following remark summarizes the main findings:

Remark *The implementation of rule (23) largely disconnects the evolution of the inflation rate from exogenous markup shocks. If free to choose fiscal authorities prefer long debt cycle to cushion the exogenous markup shock.*

The impulse responses portray that a sharp cut in taxes $\hat{\tau}_t$ levied on the value-added prevents any built up in cost pressure. The tax cut occurs in particular in the first and second quarter, when the geometrically decaying markup shock hits strongest. As a fraction of firms θ_P is called upon to reset prices they foresee that any price pressure is undone by fiscal authorities by the targeted tax path that keeps the sum of wage path, markup shock and tax path flat. Due to the moderate evolution of the inflation rate monetary authorities are prevented from sharply raising nominal interest rates. This in turn detains Ricardian households to reallocate planned consumption expenditures by large into the future. As consumption accounts for 80% of output we do not observe a substantial drop in production. If fiscal authorities are free to choose, they absorb the tax cut by a near random walk behavior in debt. Note as markup shocks are symmetrically distributed a near-random walk behavior in debt is a free lunch as the persistent swings chancel out each other. Contemporaneous government expenditure changes on the contrary are welfare reducing as they increase the expected variability in government expenditures.

Figure 1: Stabilization by Fiscal Tax Rules



Notes: Responses of selected variables to a markup shock. Dotted lines indicate a state independent passive fiscal policy with $\chi_1 = 0$. The dashed-dotted line shows the impulses of the model when fiscal policy is active with $\chi_1 < 0$ and $\chi_2 > 0$. For the applied baseline calibration see appendix A.

For the baseline scenario the simulations indicate that the implementation of the simple rule reduces the value of the loss function by 66 percent. The numerical values are given by $\chi_1 = 0.06$ and $\chi_2 = -1.85$. Note that the numerical value is close to the one found in the analytical section of the paper.

5 Relevance of the Tax-Rule

Markup shocks are costly in terms of welfare as monetary authorities lack an instrument on the supply side of the economy to cushion the adverse effects of cost pressure. Following the Tinbergen (1959) logic we have shown that a state contingent tax, conditioned on the state of the markup shock and the level of debt, can improve welfare remarkably.

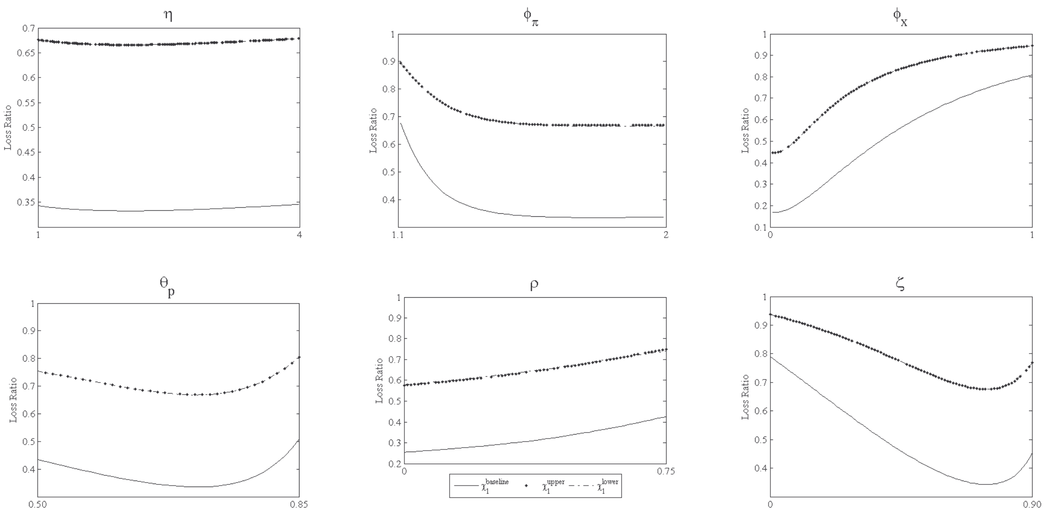
In the following we discuss the implications of these issues by computing welfare gains using different parameter constellations. This exercise has two main purposes. On the one hand we want to analyze whether the proposed rule is robust to perturbations of the baseline parameterization. On the other hand we present further insights why the rule works from a micro founded perspective.

Precisely speaking we computed the expected value of the loss $E_0\left\{\sum_{t=0}^{\infty}\beta^t L_t\right\}$ for the active and the passive fiscal policy stance and then take the ratio of the two. If the ratio takes the value one, then the loss would be equal under the two regimes. If the value of the ratio is below (above) one, then the loss under an active (passive) fiscal policy is smaller (larger) than the loss under the passive (active) fiscal stance.

By means of computing these ratios we succeed to uncover those parameter constellations which improve or worsen the relative performance of the proposed policy rule compared to the fallback position of a passive fiscal policy. The solid line indicates how the computed ratio changes when the parameter displayed at the top of the figure is altered, while the rest remains fixed at the baseline calibration. For each altered coefficient, e.g.

for σ, the coefficients in the fiscal policy rule χ_1 and χ_2 are reoptimized such that (39) is minimized. As a robustness exercise we also report the ratio if we deviate from χ_1 according to $\chi_1 \pm (\chi_1/2)$ indicated by χ_1^{upper} and χ_2^{lower} in Figure 2. Generally the results indicate no large asymmetries when fiscal authorities tend to choose too high or too low coefficients χ_1, which indicates that the loss ratio behaves largely linearly when deviating from the baseline by altering χ_1. For the case of large asymmetries we would have expected the reported lines χ_1^{upper} and χ_2^{lower} to have a substantial distance from each other.

Figure 2: Recalibrating the Baseline Model – Loss Ratio



Notes: Evolution of the expected loss ratio defined as the ratio of the expected loss if fiscal policy is active with $\chi_1 < 0$ compared to a passive stance $\chi_1 = 0$. $E_0\left(\left\{\sum_{t=0}^{\infty}\beta^t L_t\right\}^{Active} \Big/ \left\{\sum_{t=0}^{\infty}\beta^t L_t\right\}^{Passive}\right)$. Appendix A summarizes the ranges of deep parameters typically found in literature. The dashed dotted and the dotted line indicate the evolution of the loss ratio if the reaction coefficient χ_1 is either reduced or augmented by fifty percent from the optimal value.

The inverse of the Frisch elasticity of labor η supply was varied one to four. Variations of the inverse of the Frisch elasticity η of labor supply are also of particular interest. In the case of increasing values for η firms need to give stronger incentives by changing wages in order to induce workers to change their labor supply. Due to an increasingly inelastic reaction of labor supply the economic cycle is smoothed. The robustness analysis indicates that irrespectively of where the parameter η is calibrated the relative advantages of the policy rule remains unaltered by a reduction in relative losses of round about 66%.

With respect to the Taylor rule coefficient ϕ_π the relative advantage of the fiscal policy rule increases if monetary policy gets somewhat more aggressive on inflation. This might reflect to a certain extend that a larger Taylor-rule coefficient ϕ_π implies that the real interest rate volatility and thus the variations in the consumption aggregate over time increase. One outstanding effect of the fiscal policy rule (23) is that it disencumbers monetary policy such that there is no need, even if monetary policy takes an aggressive stands towards inflation to use its real interest rate instrument.

The robustness analysis indicates that the relative advantageous of the proposed policy rule decreases if monetary policy reacts stronger on the welfare gap. Nevertheless the relative performance never decreases below twenty percent, even for a coefficient of $\phi_x = 1$, which is higher than the values typically found in literature. This might be explained by the fact that the proposed tax rule is successful in reducing inflation, but not so much in reducing output gap variability. This implies that a monetary authority that takes the output gap into account reintroduces real interest rate variability.

The performance of the rule worsens if interest rates are set in a highly inertial fashion.

The effectiveness of the rule increases with the degree of correlation in the markup shock ζ. The higher the degree of correlation the larger will be the price dispersion inflicted upon the economy. Those firms that are called upon to reset prices will anticipate further shocks in the same direction which triggers a larger adjustment of prices. Therefore the rule is in particular welfare enhancing in an environment of correlated shocks as it promises to firms a stable evolution of prices and thus a limited degree of price dispersion for the economy.

With respect to the value of the Calvo parameter θ_p there exists a considerable disagreement in the literature. Del Negro et. al. (2005) for instance estimate an average price duration of three quarters for the euro-area using full information Bayesian techniques; Gali, Gertler, and Lopez-Salido (2001) report a value round about four quarters using single equation GMM approach. Empirical work on price setting in the euro area using micro evidence report relatively low price durations with a median round about 3.5 quarters (see Alvarez et. al., 2006, for a summary of recent micro evidence). Comparable studies for the U.S. like Altig et. al. (2005) report much lower average price durations of just 1.6 quarters, which they claim to be more consistent wit recent evidence drawn from US micro-data. Based on this review of the literature it seems fair to conduct the robustness analysis in a range between 1.7 to five quarters, which corresponds to a θ_p ranging between 0.45 to 0.85. The figure illustrates that the ratio monotonically decreases from 0.9 to 0.5 when the Calvo parameter is altered from 0.4 to 0.8. Thus the rule performs better when the degree of nominal stickiness increases. This reflects that with an increase of nominal frictions a price distribution across firms unfolds if fiscal policy remains passive. The implementation of the policy rule prevents that a wedge can be driven between the production schedules and thus enhances welfare as the variability of inflation decreases.

6 Conclusions

In this paper we addressed the question whether fiscal policy can wipe out price dispersion by implementing a simple tax rule. Our motivation stems from the fact that there is a large strand of literature which stresses the role of monetary policy to enhance welfare in an environment of nominal rigidities (Woodford, 2003). However this strand of literature has paid so far little attention to the question whether fiscal policy can improve welfare with respect to nominal frictions. In the event of cost push shocks

Woodford (2003) shows that monetary policy faces a trade off between stabilizing the inflation rate and stabilizing the output gap. A sufficiently strong feedback from movements in the inflation rate is argued to be the best response to limit the adverse effects of cost-push shocks on lifetime utility of a representative consumer to generate a unique and determinate equilibrium. Notwithstanding, these arguments the costs of nominal rigidities are estimated to be still up to three percent in consumption equivalents (Canzoneri, Cunmby and Diba 2007).

This highlights that monetary policy does not have a direct leverage on the supply side of the economy. Therefore we followed the Tinbergen logic and proposed that fiscal policy should use its value-added tax, as an additional instrument in a state contingent way such that the evolution of marginal cost is stabilized around its deterministic steady state.

Our findings suggest that a countercyclical taxation approach can remarkably reduce the impact of cost push shocks on welfare. The reduction in expected losses, when fiscal authorities switch from a passive towards an active fiscal stance are quantified around about fifty percent and depend on the particular parameter settings. Key to the functioning of the tax-rule is that the fraction of firms that adjusts prices anticipates the promise of fiscal authorities to target a value-added tax path that eliminates any cost pressure at the firm level. Accordingly those firms that are called upon to reset prices set them in the neighborhood of those firms that leave prices unchanged. This prevents any inefficient built up in prices across firms at any date t.

The Keynesian tradition considers fiscal policy as operating over the aggregate demand effect. We showed that fiscal policy can use its distortionary instruments to unfold stabilizing effects on the economy upon an aggregate supply channel.

Appendices

A Calibrated Parameters

In Section 5 of the main text we conduct some sensitivity analysis to demonstrate the robustness of the proposed policy rule. While conducting this exercise we rely on ranges of the deep parameters chosen so as to best represent the uncertainty found in the literature as reported in Table 1.

Table 1: Values and Ranges fort he Calibrated Parameters

Parameter		Baseline	Range
A. Household			
Discount Factor	β	0.99	/
Risk Aversion	σ	1.00	1.00 – 4.00
Inverse of the Labor Supply Elasticity	η	2.00	1.00 – 4.00
B. Firms			
Price Elasticity of Demand for an Intermediate Good Variety	ε	6.00	6.00 – 25.00
Price Stickiness	θ_p	0.75	0.40 – 0.95
C. Monetary Policy			
Taylor-Rule: Smoothing	ϕ_ρ	0.50	0.00 – 0.75
Taylor-Rule: Inflation	ϕ_π	1.50	1.10 – 2.00
Taylor-Rule: Welfare gap	ϕ_x	0.25	0.00 – 1.00
D. Fiscal Authorities			
Fiscal Rule: Markup shock	χ_1	-2.98	-1.49 - -4.47
Fiscal Rule: Debt	χ_2	0.65	/
Gross Steady State Tax Share	$\overline{\tau}^{VAT}$	0.20	0.10 – 0.50
E. Exogenous Shock			
Markup Shock: Persistence	ζ	0.75	0.00 – 0.95

Notes: The table displays the calibrated values. The respective upper and lower bounds are taken from related studies in literature. The reviewed literature is Smets and Wouters, 2003; Leith and Maley, 2005, Rabanal, 2003, Coenen, McAdam and Straub, 2006, Del Negro, Schorfleheide, Smets and Wouters, 2004, Welz, 2005.

B Derivation of the MSV Solution

Balanced budget and active stance Substituting out the tax-rate $\hat{\tau}_t^{VAT}$ and the natural rate $\hat{r}_t^n$ of interest the reduced form system can be written as:

$$x_t = E_t x_{t+1} - \sigma^{-1}\left(\phi_\pi \hat{\pi}_t - E_t \hat{\pi}_{t+1}\right) + \left(\frac{\gamma_G}{\gamma_C}\chi_1 + \left(\sigma+\varphi\right)^{-1}\right)\hat{\Phi}_t, \tag{B.1}$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa\left[\left(\sigma+\varphi\right)x_t + \left(\left(1-\sigma\right)\frac{\gamma_G}{\gamma_C}\chi_1\right)\hat{\Phi}_t\right], \tag{B.2}$$

$$\hat{\Phi}_t = \hat{\Phi}_t . \tag{B.3}$$

The rest of the system is recursive and can be solved afterwards. Let us posit a fundamental (minimum state variable) solution of the following generic form (McCallum, 1983): $\hat{\pi}_t = \delta_\pi \hat{\Phi}_t$ and $x_t = \delta_x \hat{\Phi}_t$, where the coefficients δ_π and δ_x remain to be determined. With $E_t x_{t+1} = E_t \delta_x \hat{\Phi}_t = 0$ and $E_t \hat{\pi}_{t+1} = E_t \delta_\pi \hat{\Phi}_{t+1} = 0$. This leads to the following conditions for the undetermined coefficients:

$$\delta_\pi = \kappa\left(\sigma+\varphi\right)\delta_x + \kappa\left(1-\sigma\right)\frac{\gamma_G}{\gamma_C}\chi_1, \tag{B.4}$$

$$\delta_x = -\sigma^{-1}\phi_\pi \delta_\pi + \left(\sigma+\varphi\right)^{-1} + \frac{\gamma_G}{\gamma_C}\chi_1 . \tag{B.5}$$

Inserting (A.5) δ_x into (A.4) δ_π :

$$\delta_\pi = \left[1+\kappa\left(\sigma+\varphi\right)\sigma^{-1}\phi_\pi\right]^{-1} \cdot \kappa\left[1+\gamma_G \gamma_C^{-1}\chi_1\left(1+\varphi\right)\right] \tag{B.6}$$

and,

$$\delta_x = \frac{1}{\left(\sigma+\varphi\right)}\frac{1}{\left(1+\sigma^{-1}\phi_\pi \kappa\left(\sigma+\varphi\right)\right)} + \frac{\gamma_G}{\gamma_C}\frac{\left(1+\kappa\phi_\pi\left(1-\sigma^{-1}\right)\right)}{\left(1+\kappa\sigma^{-1}\phi_\pi\left(\sigma+\varphi\right)\right)}\chi_1 . \tag{B.7}$$

Balanced budget and passive policy Let us define the neutral benchmark system as $\hat{G}_t = \hat{\tau}_t^{VAT} = 0$. Then the model can be stated as:

$$x_t = E_t x_{t+1} - \sigma^{-1}\left(\phi_\pi \hat{\pi}_t - E_t \hat{\pi}_{t+1}\right) + \left(\sigma + \varphi\right)^{-1} \hat{\Phi}_t \qquad \text{(B.8)}$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa\left(\sigma + \varphi\right) x_t \qquad \text{(B.9)}$$

where the MSV solution reads:

$$\delta_x = \left[1 + \sigma^{-1}\phi_\pi \kappa\left(\sigma + \varphi\right)\right]^{-1} \left(\sigma + \varphi\right)^{-1} \qquad \text{(B.10)}$$

And,

$$\delta_\pi = \kappa \cdot \left[1 + \sigma^{-1}\phi_\pi \kappa\left(\sigma + \varphi\right)\right]^{-1}. \qquad \text{(B.11)}$$

Comparison of active versus passive fiscal policy In the following we compare the MSV solutions for an economy where fiscal policy implements policy rule (22) versus an economy where fiscal policy remains passive with $\hat{G}_t = \hat{\tau}_t^{VAT} = 0$. The superscript P denotes passive whereas the superscript A denotes active.

Inflation

$$\begin{aligned}
&\delta_\pi^P > \delta_\pi^A \\
&\kappa\left[1 + \kappa\sigma^{-1}\left(\sigma + \varphi\right)\phi_\pi\right]^{-1} > \kappa\left[1 + \kappa\sigma^{-1}\left(\sigma + \varphi\right)\phi_\pi\right]^{-1}\left[1 + \gamma_G \gamma_C^{-1} \chi_1 \left(1 + \varphi\right)\right] \\
&1 > 1 + \gamma_G \gamma_C^{-1} \chi_1 \left(1 + \varphi\right) \\
&0 > \gamma_G \gamma_C^{-1} \left(1 + \varphi\right) \chi_1 \\
&\Leftrightarrow \chi_1 < 0, \quad \varphi, \gamma_G, \gamma_C > 0
\end{aligned}$$

Welfare gap

$$\begin{aligned}
&\delta_x^P > \delta_x^A \\
&\Rightarrow \left[1 + \kappa\sigma^{-1}\left(\sigma + \varphi\right)\phi_\pi\right]^{-1}\left(\sigma + \varphi\right)^{-1} > \left[1 + \kappa\sigma^{-1}\left(\sigma + \varphi\right)\phi_\pi\right]^{-1}\left(\sigma + \varphi\right)^{-1} \\
&\qquad \left[1 + \gamma_G \gamma_C^{-1}\left(1 + \kappa\phi_\pi\left(1 - \sigma^{-1}\right)\right)\chi_1\right] \\
&\Rightarrow 1 > 1 + \gamma_G \gamma_C^{-1}\left(1 + \kappa\phi_\pi\left(1 - \sigma^{-1}\right)\right)\chi_1 \\
&\Rightarrow 0 > \gamma_G \gamma_C^{-1}\left(1 + \kappa\phi_\pi\left(1 - \sigma^{-1}\right)\right)\chi_1 \\
&\Leftrightarrow \chi_1 < 0, \quad \gamma_G, \gamma_C, \kappa, \phi_\pi, \sigma
\end{aligned}$$

C Utility-Based Welfare Function

The utility function is given by:

$$U(C,N,G)=(1-\tau)\log C+\tau\log G-\frac{N^{1+\varphi}}{1+\varphi}. \qquad \text{(C.1)}$$

Note that the weight τ in the utility function is equal to the steady state share of government spending $\tau=(G/Y)$.

Taking a second-order approximation around the consumption part of the utility function yields:

$$log(C_t)\simeq\log(Y_t-G_t)=\frac{1}{1-\tau}(\tilde{y}_t-\tau\tilde{g}_t)-\frac{1}{2}\frac{\tau}{(1-\tau)^2}(\tilde{y}_t-\tilde{g}_t)^2+tip+o\left(\left\|a^3\right\|\right). \qquad \text{(C.2)}$$

Where it holds that: $\hat{x}_t=\tilde{x}_t+(\overline{x}_t-x)$. We denote the gap $\tilde{y}_t=y-\overline{y}_t$ and the fiscal gap $\tilde{g}_t=g_t-\overline{g}_t$. Note that $\hat{y}_t$ comprises the sum of the deviation of output from the distorted (short term) steady state and the deviation of the distorted steady-state output from the efficient long-term steady state. Taking a second-order approximation around the disutility of labor term yields:

$$\frac{N_t^{1+\varphi}}{1+\varphi}\simeq\hat{n}_t+\frac{1}{2}(1+\varphi)\hat{n}_t^2+tip+o\left(\left\|a^3\right\|\right). \qquad \text{(C.3)}$$

We find that the relationship $N_t=Y_tQ_t$, which is derived in the following:

$$N_t=\int_0^1 N_t(i)di=\int_0^1 Y_t(i)di=Y_t\int_0^1\frac{Y_t(i)}{Y_t}di$$

$$\Rightarrow N_t=\underbrace{Y_t\int_0^1\left(\frac{P_t(i)}{P_t}\right)^{-\varepsilon}di}_{\equiv Q_t}=Y_tQ_t$$

After log linearization, we obtain:

$$\hat{n}_t=\hat{y}_t+q_t. \qquad \text{(C.4)}$$

Where $q_t = (\varepsilon/2)\sigma_t^2$ and q_t is defined as:

$$q_t = \log \int_0^1 \left(\frac{P_t(i)}{P_t} \right)^{-\varepsilon} di . \tag{C.5}$$

The intertemporal welfare function is given by the discounted sum of the approximated utility functions:

$$W_t = \sum_{t=0}^{\infty} \beta^t U_t\left(C_t, N_t, G_t\right) = \sum_{t=0}^{\infty} \beta^t \left[\left(1+\varphi\right) \tilde{y}_t^2 + \iota\left(\tilde{g}_t - \tilde{y}_t\right)^2 + \varepsilon\sigma_t^2 \right]. \tag{C.6}$$

Now, we aim at expressing σ_t^2 in terms of π_t^2 while following the proof given in Woodford 2003:

$$\begin{aligned} \sum_{t=0}^{\infty} \beta^t \sigma_t^2 &\simeq \sum_{t=0}^{\infty} \beta^t \left[t.i.p + \sum_{s=0}^{t} \theta_p^{t-s} \frac{\theta_p}{1-\theta_p} \pi_s^2 + o\left(\|a\|^3\right) \right] \\ &= \frac{1}{\kappa} \sum_{t=0}^{\infty} \beta^t \pi_t^2 + t.i.p. + o\left(\|a\|^3\right) \end{aligned} \tag{C.7}$$

Using this result (C.6) can be rewritten as follows:

$$W_t = \sum_{t=0}^{\infty} \beta^t \left[\frac{\varepsilon}{\kappa} \pi_t^2 + \left(1+\varphi\right) \tilde{y}_t^2 + \iota\left(\tilde{g}_t - \tilde{y}_t\right)^2 \right]. \tag{C.8}$$

D Matrix Representation of the Model

The linearized equilibrium dynamics can be represented as follows (Söderlind, 1999).

$$A_0 \begin{bmatrix} X_{1,t+1} \\ E_t X_{1,t+2} \end{bmatrix} = A_1 \begin{bmatrix} X_{1,t} \\ E_t X_{1,t} \end{bmatrix} + B\hat{R}_t + \begin{bmatrix} \varepsilon_{t+1} \\ 0_{n2,t+1} \end{bmatrix} \qquad \text{and } \hat{R}_t = F \begin{bmatrix} X_{1,t} \\ E_t X_{1,t} \end{bmatrix}$$

$$\text{With: } X_{1,t+1} = \begin{bmatrix} \hat{\Phi}_{t+1} & \hat{R}_t & b_{t+1} & \hat{\tau}^{VAT}_{t+1} & \hat{r}^n_t \, b^f_{t+1} \end{bmatrix}, E_t X_{2,t+1} = \begin{bmatrix} E_t x_{t+1} & E_t \hat{\pi}_{t+1} \end{bmatrix}$$

$$A_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & \gamma_G (o_{Y-1} - 1)\Gamma_\varphi^{-1} \iota\chi_2 & 0 & 0 \\ 0 & 0 & -\chi_1 & 1 & 0 & 0 & 0 & 0 \\ \sigma(1-o_Y)\Gamma_\varphi^{-1}\left(B^{-1} - \iota\chi_2\right) & 0 & 0 & 0 & 1 & \sigma(1-o_Y)\Gamma_\varphi^{-1}\iota\chi_2\left(B^{-1} - \beta^{-1} - 1\right) & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & \left(1 + \gamma_G\chi_2 + \gamma_G(o_Y - 1)\Gamma_\varphi \iota\chi_2\right) & 0 & 0 \\ 0 & 0 & 0 & 0 & \gamma_C\left(\sigma(1-\gamma_G o_Y)\right)^{-1} & 0 & 1 & \gamma_C\left(\sigma(1-\gamma_G o_Y)\right)^{-1} \\ 0 & 0 & 0 & 0 & 0 & -\kappa\iota\chi_2 & 0 & \beta \end{bmatrix}$$

$$A_1 = \begin{bmatrix} \zeta & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -\gamma_G\Gamma_\varphi^{-1}(o_Y - 1) & 0 & \beta^{-1} & -\gamma_G & 0 & 0 & \gamma_G(o_Y - 1) & 0 \\ -\chi_2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \sigma(1-o_Y)\Gamma_\varphi^{-1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -\gamma_G(o_Y - 1)\Gamma_\varphi^{-1} & 0 & 0 & 0 & 0 & \beta^{-1} & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -\kappa\iota & 0 & 0 & -\kappa\Gamma_\varphi & 1 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ \gamma_c\left(\sigma(1-\gamma_G o_Y)\right)^{-1} \\ 0 \end{bmatrix}$$

$$F = \begin{bmatrix} 0 & \rho & 0 & 0 & 0 & 0 & (1-\rho)\phi_\pi & (1-\rho)\phi_x \end{bmatrix}'$$

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