Countercyclical Fiscal Policy and Cyclical Factor Utilization

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April 25, 2008

Abstract

In a neoclassical growth model with monopolistic competition in the product market, the presence of cyclical factor utilization enhances the stabilization role of countercyclical taxes. The costs of varying capital utilization take the form of varying rates of depreciation, which in turn have amplifying effect on investment decisions as well as the volatility of most aggregate variables. This creates an additional channel through which taxes affect the economy, a channel that enhances the stabilization role of countercyclical taxes, with particularly strong effects in the labor market. However, in terms of welfare, countercyclical taxes are welfare inferior due to reduced precautionary saving motives.

- JEL Classification: E62, E32
- Key Words: countercyclical taxes, capital utilization, stabilization, welfare

1 Introduction

This paper analyzes the stabilization role and welfare consequences of countercyclical tax policy in an environment characterized by the presence of monopolistic competition and cyclical factor utilization.

Countercyclical fiscal policies are generally believed to have stabilizing effects which help smooth out business cycle fluctuations.[1] There is also a consensus that this type of policy is most effective when it works via automatic stabilizers, which do not require active intervention from policy makers and therefore do not suffer from implementation lags. The focus of this paper is on the automatic stabilizer element of tax policy: the government in the model economy adopts an endogenous simple rule where, in a

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[1] See, for example, Auerbach and Feenberg (2000), Cohen and Follette (2000), Taylor (2000), Jones (2002), Auerbach (2003), Auerbach (2005), Kletzer (2006), Kim and Kim (2006).

manner which mimics the progressivity of the tax system, the income tax rate responds positively to contemporaneous output fluctuations. In a recession, the reduced income implies lower income tax rates, which attenuate the negative effects of the economic downturn. The policy is evaluated for a range of empirically relevant parameters values.

Faced with temporary changes in economic conditions, firms may first choose to use their existing factors of production more intensively, potentially due to the high costs of adjusting factor inputs along the extensive margin. While not explicitly modeled here, it is believed that the costs of hiring employees or of adding new equipment to production lines are significant. The variation in the degree of factor utilization becomes an optimal decision and will depend on existing and expected government policies.

Here, the focus is restricted to the case of varying capital utilization. A more intensive use of the existing capital stock incurs costs in the form of higher rates of depreciation, which in turn has an amplifying effect on investment decisions as well as the volatility of most aggregate variables. This creates an additional channel through which taxes affect equilibrium outcomes, a channel that enhances the stabilization role of countercyclical taxes.

While it is generally true that countercyclical taxes reduce the volatility of some aggregate variables like output, investment, and consumption, these effects are larger in the presence of cyclical factor utilization. Furthermore, employment variability is now reduced when taxes are countercyclical for all plausible parameter configurations. This stands in contrast with the standard model without varying capital utilization, where countercyclical taxes have little stabilizing effect in the labor market and only for low values of the income elasticity of the tax rate.

Considering the welfare implications of such policies, there is a direct welfare benefit from the reduced volatility. However, when people take direct account of the level of uncertainty when making decisions, then the reduced volatility lowers the precautionary saving motive, which reduces capital accumulation and, therefore, consumption in the long run. This negative mean effect outweighs the gains from stabilization, thus making countercyclical taxes welfare reducing. And while the enhanced stabilization role of countercyclical taxes under capital utilization brings a stronger welfare benefit, it also implies a larger welfare loss due to the relatively lower average long-run consumption, as compared to the standard model.

The real business cycle literature has focused on the role of cyclical factor utilization as a propagation mechanism of business cycle shocks, identifying either varying capital utilization (see Taubman and Wilkinson (1970) and Greenwood, Hercowitz, and Huffman (1988)) or labor hoarding (Burnside, Eichenbaum, and Rebelo (1993)) as playing this role.[2] Along the same dimensions but in a model of monetary policy, Christiano,

[2] The theoretical and empirical consequences of variable utilization of both capital and labor have been addressed in work by Bils and Cho (1994), Burnside and Eichenbaum (1996), and Basu and Kimball (1997).

Eichenbaum, and Evans (2005) find variable capital utilization to be an important feature (alongside staggered wage contracts) in explaining inflation inertia and persistence output movements in response to a monetary policy shock.

The results of this paper highlight the importance of cyclical capital utilization for the effectiveness of tax policy.

The next section lays out the model, the solution method, and the choice of parameter values used in simulations. The results are contained in section three and the last section concludes.

2 The Model

The economy consists of a perfectly competitive final goods sector, a monopolistically competitive intermediate goods sector, households, and the government. There is one composite good used for consumption and investment and a continuum of differentiated goods used as inputs in the production of the final good.

2.1 The Private Sector

The Final Goods Sector Final goods are produced by an infinite number of firms in a perfectly competitive market, using an aggregator function of the Dixit-Stiglitz type

$$Y_t = \left(\int_0^1 Y_{it}^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{1}$$

where Y_{it} is the amount of intermediate good i and ϵ is the constant elasticity of substitution between intermediate goods. The markup, denoted by $\mu = \frac{\epsilon}{\epsilon-1}$, represents the degree of monopoly power of intermediate goods producers. Taking prices as given and subject to the available technology, firms choose intermediate goods to maximize profits, $\Pi_t = Y_t - \int_0^1 P_{it} Y_{it} di$. The first order condition yields the following demand for intermediate goods

$$Y_{it} = P_{it}^{-\epsilon} Y_t, \quad \forall i. \tag{2}$$

which has a constant price elasticity that is inversely related to the markup, μ. The aggregate price level, normalized to unity, can then be expressed as $1 = \left(\int_0^1 P_{it}^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$.

The Intermediate Goods Sector The intermediate sector comprises of a continuum of monopolistically competitive firms indexed by i and of measure 1. Each firm i produces a unique good using labor (H_{it}) and effective units of capital ($u_{it} K_{it-1}$):

$$Y_{it} = z_t \left(u_{it} K_{it-1} \right)^{\alpha} H_{it}^{1-\alpha} - \phi, \qquad \alpha \in (0,1).$$

Total factor productivity, z_t, affects all firms symmetrically and follows an exogenous stationary process, $\ln z_t = \rho_z \ln z_{t-1} + \varepsilon_t^z$, with persistence parameter $\rho_z \in (0,1)$ and random shocks $\varepsilon_t^z \sim iidN\left(0, \sigma_z^2\right)$.

Optimally, the price of good i is set at a markup over marginal cost

$$P_{it} = \mu MC_{it} = \mu \left(\Omega r_t^{\alpha} w_t^{1-\alpha} \frac{1}{z_t} \right)$$

where $\Omega \equiv \left[\alpha^{-\alpha} (1-\alpha)^{\alpha-1}\right]$. The choices of capital and labor inputs are such that their marginal products exceed rental prices by the same constant markup μ. (See Appendix A for more details.)

Focusing on a symmetric equilibrium, the firm specific capital, the capital utilization rate, and employment are the same across firms ($K_{it-1} = K_{t-1}$, $u_{it} = u_t$, $H_{it} = H_t$) and the aggregate final goods production can be expressed as

$$Y_t = F_t - \phi$$

where $F_t \equiv z_t \left(u_t K_{t-1}\right)^{\alpha} H_t^{1-\alpha}$ denotes aggregate output inclusive of fixed costs. Aggregate profits of intermediate producers, $\pi_t = \left(1 - \frac{1}{\mu}\right) F_t - \phi$, are rebated to households in lump-sum fashion.

Households The economy is populated by a continuum of identical households, each of which derives utility from consumption of final goods and leisure. At the beginning of every period, households rent labor and units of effective capital to intermediate goods producing firms. At the end of the period, they receive from firms capital rental payments, wages, and dividends, all of which are being taxed by the government at a single income tax rate, τ_t. Also included in the household income is the undepreciated capital stock, while lump-sum taxes further reduce the available income, which can be expressed as:

$$I_t = (1-\tau_t)\left(r_t u_t K_{t-1} + w_t H_t + \pi_t\right) + (1-\delta_t) K_{t-1} - T_t. \tag{3}$$

In response to changes in economic conditions, the existing capital stock can be used more or less intensively. Following Greenwood, Hercowitz, and Huffman (1988), it is assumed that when capital is used more intensively, it will also depreciate more, hence a direct relationship between the utilization and depreciation rates of capital of the form

$$\delta_t = \frac{1}{\varphi} u_t^{\varphi}, \qquad \varphi > 1.^3 \tag{4}$$

The choice of the capital utilization rate is modeled on the side of capital owners, i.e.

[3] Similar specifications can be found in Burnside and Eichenbaum (1996) and Arias, Hansen, and Ohanian (2007).

the households. Implicit in this setup is the assumption that households and firms can trade state-contingent rental contracts on capital, specifying the quantity of capital traded and the rental rate. In equilibrium, the capital rental rate depends on the rate of capital utilization.

The representative household chooses consumption, C_t, capital, K_t, the utilization rate of the existing capital stock, u_t, and hours worked, H_t, to maximize expected lifetime utility:

$$\max_{\{C_t,H_t,u_t,K_t,B_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t, 1-H_t\right)$$

subject to the budget constraint (3) and the capital depreciation relation (4).

The optimal capital utilization rate is given by the first order condition:

$$\left(1-\tau_t\right) r_t = \varphi \frac{\delta_t}{u_t}.$$

This, together with the first order condition for labor, the Euler equation for consumption and the transversality condition for capital, characterize the households' optimal choices. (See Appendix A for the detailed expressions.)

2.2 The Government

The government consumes an exogenous amount of final goods, that it finances via a mix of distortionary and lump-sum taxes. The period government budget constraint is then

$$G_t = \tau_t Y_t + T_t \tag{5}$$

where G_t represents government consumption, $\tau_t Y_t$ distortionary tax revenues, and T_t lump-sum taxes. Government consumption follows a stationary AR(1) process, $\ln G_t = (1-\rho_G)\ln \overline{G} + \rho_G \ln G_{t-1} + \varepsilon_t^G$, with persistence parameter $\rho_G \in (0,1)$ and random shocks $\varepsilon_t^G \sim iidN\left(0, \sigma_G^2\right)$.

The income tax rate τ_t responds to contemporaneous output fluctuations as follows

$$\ln \tau_t = d + \theta \ln Y_t, \qquad \theta \geq 0. \tag{6}$$

where d is a constant term. The dependence of the tax rate on output reflects the stabilization aspect of tax policy which occurs automatically, without systematic intervention from policy makers. In a broad way, the policy is reflective of a progressive tax system. A positive θ indicates a countercyclical tax policy, an automatic response of the tax rate, which declines during recessions and increases during booms.

2.3 Equilibrium

A symmetric equilibrium for this economy can be defined as follows:

Definition 1 *A symmetric equilibrium is an allocation sequence* $\{C_t, H_t, K_t, u_t, \delta_t\}_{t=0}^{\infty}$*, a price sequence* $\{P_t, w_t, r_t\}_{t=0}^{\infty}$*, a sequence of government policy variables* $\{G_t, \tau_t\}_{t=0}^{\infty}$*, and initial conditions* $\{K_{-1}, z_0\}$ *such that:*

(i) *given prices, government policies, and initial conditions, the allocation sequence solves the households' utility maximization problem and the final goods producers' profit maximization problem,*

(ii) *given factor prices, government policies, and initial conditions, the allocation sequence and the price sequence* $\{P_t\}_{t=0}^{\infty}$ *solve the profit maximization problem of intermediate goods producing firms,*

(iii) *fiscal policy variables follow the specified processes and the government budget constraint is satisfied at all times, and*

(iv) *all markets clear.*

2.4 The Solution

In the absence of a closed-form solution, the equilibrium conditions are approximated around the deterministic steady state. To compute welfare, a second-order accurate solution of the model was employed, using the algorithm in Schmitt-Grohe and Uribe (2004).

2.5 Model Calibration

The model is calibrated to a quarterly frequency and follows the usual parameterization in the literature.[4] Table 1 gives some of the assumed and implied parameter values. The relative weight on leisure, χ, is such that the proportion of time spent working averages 20%. The capital depreciation rate δ matches the average investment-output ratio of 0.17 in the U.S. data (1947:1-2005:4). The implied average capital utilization rate u is 0.108 and the corresponding parameter φ equals 1.65. The fixed cost parameter ϕ is such that profits are zero in the steady-state. With a markup value μ of 1.4, the degree of monopolistic competition is moderate, in the context of a range 1.1 to 2.4 identified in the literature and, furthermore, consistent with values most commonly encountered in real models. Productivity shocks are persistent with $\rho_z = 0.95$ and standard deviation $\sigma_z = 0.006$. For the government spending process, the first-order correlation ρ_G is set to 0.925 and the standard deviation σ_G to 0.014. The average marginal income tax rate τ is set at 0.22.[5]

The elasticity of the tax rate with respect to output, θ, is allowed to vary in the $[0, 2]$ range. This parameter represents the magnitude of the endogenous response of the income tax rate to output fluctuations, i.e. how countercyclical tax policy is. The specific

[4] See, for example, Braun (1994), Jones (2002), Trabandt and Uhlig (2006), and Leeper and Yang (2008).

[5] This value of τ lies in the range of estimates in the literature: Akhand and Liu (2002) give a rate of approximately 0.2, while Braun (1994) and Auerbach and Feenberg (2000) report a value of 0.25.

range reflects available evidence: Blanchard and Perotti (2002) rely on institutional information to estimate the quarterly elasticity of tax *revenues* with respect to output and obtain an average over the post-war period of 2.08, with specific values ranging from 1.58 in 1947:Q1 to 1.63 in 1960:Q1 to 2.92 in 1997:Q4. This implies an average value of θ of approximately 1 with plausible values of almost 2. Auerbach and Feenberg (2000) and Cohen and Follette (2000) give similar estimates.[6]

3 Discussion

The economic environment considered here is characterized by the presence of market power and variable capital utilization. In combination with the dynamics induced by the government's tax policy, this aspect will prove important for the stabilization properties of countercyclical taxes.

Monopolistic competition changes the relative weight of the income and substitution effects that arise from shocks to the economy. As firms set prices above marginal costs and make profits on the margin, any increase in output exceeds the corresponding increase in real labor costs.[7] Consequently, changes in employment tend to be lower, while variations in output, consumption, and investment are larger.

Allowing for variable capital utilization tends to amplify the responses of aggregate variables to shocks. A change in the degree to which the existing capital stock is utilized impacts directly on its rate of depreciation and therefore on the choice of investment and work effort. This represents an additional channel through which stabilization tax policies of the type specified here can affect the economy. For illustration of the mechanism at work, the next subsection presents the responses of key macroeconomic variables to exogenous technology and government spending shocks.

3.1 Impulse Responses to Exogenous Shocks

A Positive Technology Shock A persistent increase in technology raises the demand for capital services and labor. Higher wages make households substitute current work for future leisure. Capital is used more intensively which causes additional changes in employment, due to the complementarity in production between the two factors. At the same time, the rate of capital depreciation increases, causing the need for additional investment. Overall, there is a strong rise in equilibrium employment, output, consumption and investment, of a larger magnitude than in the absence of varying capital utilization.

[6] Auerbach and Feenberg (2000) use the TAXSIM model of tax returns to provide annual evidence on the change in the income tax rate for a one percent change in income. This implies an approximate value of θ between 0.32 and 0.92.

[7] See Blanchard and Kiyotaki (1987), Rotemberg and Woodford (1995), and Benassy (2002) for detailed expositions on monopolistic competition.

When taxes are countercyclical, the increased output leads to a contemporaneous increase in the income tax rate, which has adverse effects on all aggregate variables. Figure 1 shows the impulse responses associated with a positive technology shock, under constant taxes ($\theta = 0$, solid lines) and countercyclical taxes ($\theta = 1$, dash lines). The higher tax rate reduces the positive income effect via higher tax payments but also lowers after-tax real wages and capital rental rates. The substitution effect dominates and the positive response of employment is significantly reduced and so is the increase in output. With $\theta = 1$, hours worked still increase on impact but decline below the long-run average within a year. [8] Persistence of the shock creates expectations of higher future tax rates and lower expected after-tax rates of return on capital, which diminish the change in investment.

In addition, the increase in tax rate lowers the intensity with which the existing capital stock is being utilized, which in turn reduces its depreciation rate. This has the effect of further reducing the need for investment and hence the need for extra hours of work. It represents the additional channel through which countercyclical taxes have a stabilizing effect on the economy.

A Positive Government Spending Shock Exogenous and persistent increases in government spending reduce the present value of privately available after-tax income and determine an increase in the labor supply which leads to higher equilibrium employment and output. Due to the complementarity between factors in production, the rise in employment determines an increase in the degree of capital utilization. With changes in both factor inputs, the increase in output is slightly larger than in the standard model without varying capital utilization. However, there is still a crowding out effect of private consumption. With the existing capital being used more intensively, its depreciation rate rises which creates an incentive to save more. However, the negative income effect is strong enough to cause a decline in investment. Figure 2 illustrates the impulse responses of key variables of interest.

In the presence of countercyclical taxes, there is an increase of the income tax rate associated with the above-average level of output. The higher tax rate has adverse effects on both hours worked and the degree of capital utilization. Consequently, the change in output is significantly diminished, while the crowding out effects on consumption and investment are exacerbated.

3.2 Stabilization Effects

The conventional notion of stabilization policies is that they reduce the volatility of aggregate variables, and especially the volatility of output. However, as households are

[8] In this environment, employment can actually *decline* contemporaneously in response to a positive technology shock when taxes are countercyclical. The presence of market power enhances this effect.

primarily concerned with the utility derived from the consumption of various quantities (including leisure), the volatility of consumption and hours worked is of high relevance.

In the current model, and consistent with the conventional wisdom, countercyclical tax policies reduce output volatility measured as the standard deviation of fluctuations around the long-run average. Countercyclical taxes are also found to decrease the volatility of investment and consumption. Allowing for intensive capital utilization creates an additional channel through which taxes affect equilibrium outcomes, a channel that enhances the stabilization role of countercyclical taxes. Figure 3 shows the percent changes in aggregate volatility induced by a countercyclical tax ($\theta > 0$) relative to a non-countercyclical tax ($\theta = 0$) in the model with and without variable capital utilization. It is easily noticeable that, in the presence of intensive capital utilization, countercyclical taxes have a stronger positive effect on volatility. For θ equal to 1, for example, the volatility of these variables is reduced by about 20-30% in the basic model and by 30-40% in the model of capital utilization.

With respect to employment however, the stabilizing effects of countercyclical income tax rates are vastly different when variable capital utilization is taken into consideration and results are a lot more sensitive to the values of the progressivity parameter θ. Employment volatility is generally a *non-monotonic* function of θ, decreasing for relatively smaller responses of the tax rate to output fluctuations, and then increasing as these endogenous changes become larger. In the basic model without capital utilization, the stabilizing effects of countercyclical taxes on employment are very small and limited to the lower range of θ values. In fact, fluctuations in hours worked *increase* for most values of θ. The picture changes significantly when variable factor utilization is allowed for: countercyclical taxes reduce employment volatility by up to 35%, for the entire range of θ values considered. This is an important aspect in light of the fact that the variability of hours worked has direct implications for welfare, as shown below.

3.3 Welfare Implications

This section examines the welfare implications of the tax policy. Although countercyclical taxes reduce the volatility of most economic variables, they may have negative welfare effects if agents take direct account of the level of uncertainty when making decisions.

Welfare is measured as the unconditional expectations of lifetime utility, based on a second-order solution to the model. The use of a second-order solution was prompted by the findings that linear models, which abstract from the effects of uncertainty on optimal decisions, may lead to spurious welfare results (Kim and Kim (2003)). Let W^r denote welfare under the *reference* regime of constant tax rates

$$W^r = E \sum_{t=0}^{\infty} \beta^t U\left(C_t^r, H_t^r\right).$$

An *alternative* regimes of countercyclical taxes yields welfare W^a. Following Schmitt-Grohe and Uribe (2006), the welfare benefit, ξ, of countercyclical tax policy is expressed as the fraction of the consumption process under the non-countercyclical policy (or reference) regime that households must be given in order to be equally happy under the two types of tax policy:

$$W^a = E\sum_{t=0}^{\infty}\beta^t U\left(C_t^a, H_t^a\right) = E\sum_{t=0}^{\infty}\beta^t U\left(\left(1+\xi\right)C_t^r, H_t^r\right)$$

A positive ξ means that the alternative regime welfare dominates the reference one. With logarithmic utility in both consumption and leisure, the expression for ξ in percentage terms is

$$\xi = \left[\exp\left(\left(1-\beta\right)\left(W^a - W^r\right)\right) - 1\right] \times 100. \tag{7}$$

To obtain a measure of welfare, the momentary utility function is approximated by a second-order Taylor expansion, which gives an expression in which period-t utility depends on percent deviations and percent squared deviations of consumption and hours worked from the deterministic steady state (Appendix B shows the more general expression):

$$\begin{aligned} W_t &= E_0\sum_{t=0}^{\infty}\beta^t U\left(C_t, H_t\right) \\ &= \frac{\overline{U}}{1-\beta} + E_0\sum_{t=0}^{\infty}\beta^t\left[\hat{C}_t - \chi\frac{H}{1-H}\hat{H}_t\right] + E_0\sum_{t=0}^{\infty}\beta^t\frac{1}{2}\left[-\chi\frac{H}{\left(1-H\right)^2}\right]\hat{H}_t^2. \end{aligned} \tag{8}$$

Optimal decisions depend both on the levels of state variables and on the amount of uncertainty in the economy. With greater uncertainty, risk-averse agents increase their savings and accumulate more of the available asset, which is capital in this economy. This raises the long-run level of the capital stock, output, and consumption, although in the short run agents would possibly have to work more and consume less. The welfare measure can therefore be decomposed into a first-order component, due to changes in the means of consumption and leisure, and a second-order component, due to the magnitude of fluctuations in these variables:

$$W_t^{FirstOrder} = \frac{\overline{U}}{1-\beta} + E_0\sum_{t=0}^{\infty}\beta^t\left[\hat{C}_t - \chi\frac{H}{1-H}\hat{H}_t\right]$$

$$W_t^{SecondOrder} = \frac{\overline{U}}{1-\beta} + E_0\sum_{t=0}^{\infty}\beta^t\frac{1}{2}\left[-\chi\frac{H}{\left(1-H\right)^2}\right]\hat{H}_t^2.$$ [9]

The welfare cost of each component $\left(\xi^{FirstOrder}, \xi^{SecondOrder}\right)$ can be determined by

[9] Similar decompositions can be found in Kollmann (2002), Kim and Kim (2006), and Bergin, Shin, and Tchakarov (2007).

applying the formula in expression (7).[10]

Table 2 shows that welfare in a stochastic economy with countercyclical tax policies ($\theta > 0$) is lower than when tax rates do not change with output ($\theta = 0$). As shown in the previous section, countercyclical taxes have a stabilizing effect in the economy by reducing aggregate volatility. With the logarithmic specification of utility adopted here, the element that directly affects welfare is the volatility of hours worked which decreases under countercyclical taxes and varying capital utilization. This is reflected in the positive second-order component $\xi^{SecondOrder}$. In the basic model, $\xi^{SecondOrder}$ is generally negative, indicating increased volatility and lower welfare. The welfare benefits/costs of reduced volatility are expectedly small and comparable with those obtained by Lucas (1987). Overall, uncertainty is lower in the economy with countercyclical taxes. Less uncertainty reduces the precautionary saving motive and results in lower capital accumulation and therefore consumption in the long run. This mean effect, captured in the negative values of $\xi^{FirstOrder}$ outweighs the stabilization effects and make countercyclical taxes welfare reducing. For an income elasticity of the tax rate of 1.0, the overall welfare costs are 0.037% in the basic model and 0.077% in the model of cyclical factor utilization. While the enhanced stabilization role of countercyclical taxes under capital utilization is a stronger welfare benefit, it also implies a larger welfare loss due to lower average long-run consumption.

In an economy where uncertainty matters, the long-run level of the economy will differ according to the degree of uncertainty and the implied accumulation of capital. Accordingly, the average tax level will be different. Simulation results indicate that, the more countercyclical the tax rate, the higher is average marginal tax. While this is a feature of progressive tax systems, it represents a second source of lower long-run consumption under countercyclical taxes. In welfare calculations, it strengthens the mean effect.

4 Conclusion

This paper examined the stabilization role of countercyclical taxes in a neoclassical growth model with monopolistic competition and cyclical factor utilization. The countercyclical aspect of tax policy is defined by the automatic response of the average marginal income tax rate to output fluctuations, capturing the progressivity of tax systems. Allowing for varying capital utilization creates an additional channel through which taxes affect the economy, a channel that enhances the stabilization role of countercyclical taxes. Furthermore, and different from the basic model without capital utilization, countercyclical taxes reduce the volatility of hours worked.

Countercyclical taxes are however welfare reducing, when the amount of uncertainty

[10] Numerically, all welfare measures are computed using the unconditional first and second moments of consumption and labor, which are obtained from the solution method.

in the economy directly affects optimal decisions. While the reduced level of uncertainty has a positive effect on welfare, it also leads to lower precautionary saving motive and lower long-run consumption. This latter effect dominates in welfare calculations.

A Analytical Details

A.1 The Intermediate Goods Sector

The optimization problem of the monopolistically competitive firm is split into two parts: a constrained cost minimization problem and a constrained profit maximization problem.

The firm chooses labor and effective units of capital to minimize the cost of production subject to the available technology

$$\begin{aligned} C\left(r_t, w_t, Y_{it}, \phi\right) &= \min_{k_{it-1}, h_{it}} \left[r_t u_{it} K_{it-1} + w_t H_{it}\right] \\ s.t.\ z_t \left(u_{it} K_{it-1}\right)^{\alpha} H_{it}^{1-\alpha} &= F_{it} + \phi \end{aligned}$$

Define $F_{it} \equiv Y_{it} + \phi$ as the total output (inclusive of fixed costs) that each firm i produces. The fixed costs ϕ are in terms of the produced good i. Use the constraint to solve for H_{it}, $H_{it} = \left[\frac{F_{it}}{z_t}\left(u_{it} K_{it-1}\right)^{-\alpha}\right]^{\frac{1}{(1-\alpha)}}$, and then substitute for it in the cost minimization problem. The resulting demand functions for labor and effective units of capital are:

$$u_{it} K_{it-1} = \left[\frac{\alpha w_t}{(1-\alpha) r_t}\right]^{1-\alpha} \left(\frac{F_{it}}{z_t}\right) \tag{9}$$

and

$$H_{it} = \left[\frac{\alpha w_t}{(1-\alpha) r_t}\right]^{-\alpha} \left(\frac{F_{it}}{z_t}\right). \tag{10}$$

The total cost function is then:

$$\begin{aligned} TC_{it} &\equiv C\left(r_t, w_t, Y_{it}, \phi\right) = r_t u_{it} K_{it-1} + w_t H_{it} \\ &= \left[\alpha^{-\alpha}(1-\alpha)^{1-\alpha}\right] r_t^{\alpha} w_t^{1-\alpha} \left(\frac{F_{it}}{z_t}\right) = \Omega r_t^{\alpha} w_t^{1-\alpha} \left(\frac{F_{it}}{z_t}\right) \end{aligned}$$

where $\Omega \equiv \left[\alpha^{-\alpha}(1-\alpha)^{\alpha-1}\right]$. The marginal cost follows directly:

$$MC_{it} = \frac{\partial C\left(r_t, w_t, Y_{it}, \phi\right)}{\partial Y_{it}} = \Omega r_t^{\alpha} w_t^{1-\alpha} z_t^{-1}$$

Then, given the minimum total cost of production and the demand for its own good (2), each firm $i, \forall i$, chooses the price of its good P_{it} to maximize profits:

$$\begin{aligned} \max_{P_{it}} \pi_{it} &= P_{it} Y_{it} - C\left(r_t, w_t, Y_{it}, \phi\right) \\ s.t.\ Y_{it} &= P_{it}^{-\epsilon} Y_t \end{aligned}$$

$$FOC\,(P_{it}): \qquad Y_{it} + P_{it}\frac{\partial Y_{it}}{\partial P_{it}} - \frac{\partial C\left(r_t^k, w_t, Y_{it}, \phi\right)}{\partial Y_{it}}\frac{\partial Y_{it}}{\partial P_{it}} = 0$$

Re-arrange the first order condition to obtain the characteristic relationship of a markup of the price over marginal cost:

$$P_{it} = \mu MC_{it}. \tag{11}$$

The final step is to combine equations (9), (10), and (11) to derive the optimal choices of capital and labor given both the technology constraint and the demand constraint:

$$P_{it}\left[\alpha\frac{F_{it}}{u_{it}K_{it-1}}\right] = \mu r_t$$

and

$$P_{it}\left[(1-\alpha)\frac{F_{it}}{H_{it}}\right] = \mu w_t.$$

A.2 The Households' Utility Maximization

The solution to the problem is obtained by solving the Lagrangian function below, where the function describing the dynamics of the depreciation rate has already been substituted in:

$$L = E_0\sum_{t=0}^{\infty}\beta^t\left\{U\left(C_t, 1-H_t\right) - \lambda_t\left[\begin{array}{c} C_t + K_t - (1-\tau_t)\left(r_t u_t K_{t-1} + w_t H_t + N_t\pi_t\right) \\ -\left(1-\frac{1}{\varphi}u_t^{\varphi}\right)K_{t-1} + T_t \end{array}\right]\right\}$$

FOCs:

$$(C_t): \qquad U_1(C_t, 1-H_t) = \lambda_t$$

$$(H_t): \qquad U_2\left(C_t, 1-H_t\right) = U_1(C_t, 1-H_t)\ (1-\tau_t)\, w_t$$

$$(u_t): \qquad (1-\tau_t)\, r_t = u_t^{\varphi-1}$$

$$(K_t): \qquad U_1(C_t, 1-H_t) = \beta E_t U_1(C_{t+1}, 1-H_{t+1})\ \left[(1-\tau_{t+1})\, r_{t+1}u_{t+1} + 1 - \delta_{t+1}\right]$$

$$TVC\,(K_t): \qquad \lim_{T\to\infty}\beta^T E_t U_1(C_{t+T}, 1-H_{t+T})\, K_{t+T} = 0$$

With utility given by $U\left(C, 1-H\right) = \log\left(C\right) + \chi\log\left(1-H\right)$, the first derivatives are

$$U_1\left(C, 1-H\right) = \frac{1}{C} \qquad \textit{and} \qquad U_2\left(C, 1-H\right) = \chi\frac{1}{1-H}$$

A.3 System of Non-linear Equations

The system of equations characterizing the dynamics of this equilibrium comprises of:

$$U_2\left(C_t, 1-H_t\right) = U_1(C_t, 1-H_t)\ \left(1-\tau_t\right) w_t$$

$$\left(1-\tau_t\right) r_t = u_t^{\varphi-1}$$

$$U_1(C_t, 1-H_t) = \beta E_t U_1(C_{t+1}, 1-H_{t+1})\ \left[\left(1-\tau_{t+1}\right) r_{t+1} u_{t+1} + 1 - \delta_{t+1}\right]$$

$$r_t = \frac{1}{\mu}\left(\alpha \frac{F_t}{u_t K_{t-1}}\right)$$

$$w_t = \frac{1}{\mu}\left[\left(1-\alpha\right)\frac{F_t}{H_{t-1}}\right]$$

$$X_t = K_t - \left(1-\delta_t\right) K_{t-1}$$

$$\delta_t = \frac{1}{\varphi} u_t^{\varphi}$$

$$Y_t = F_t - \phi$$

$$F_t = z_t \left(u_t K_{t-1}\right)^{\alpha} H_t^{1-\alpha}$$

$$Y_t = C_t + X_t + G_t$$

$$G_t = \tau_t Y_t + T_t.$$

A.4 The Deterministic Steady State

The non-stochastic long-run equilibrium is characterized by constant real variables and nominal variables growing at a constant rate. Assuming all profits are zero in the long run implies a value of the fixed costs of

$$\phi = \left(1 - \frac{1}{\mu}\right) F$$

and then aggregate output can be written as:

$$Y = \frac{1}{\mu} F = \frac{1}{\mu}\left[z \left(uK\right)^{\alpha} H^{1-\alpha}\right]. \tag{12}$$

The rest of the equilibrium conditions reduce to:

$$U_2\left(C, 1-H\right) = U_1\left(C, 1-H\right)\ \ \left[\left(1-\tau\right) w\right] \tag{13}$$

$$\left(1-\tau\right) r = u^{\varphi-1} \tag{14}$$

$$1 = \beta\left[\left(1-\tau\right) r u + 1 - \delta\right] \tag{15}$$

$$r = \frac{1}{\mu}\left(\alpha \frac{F}{uK}\right) = \alpha \frac{Y}{uK} \tag{16}$$

$$w = \frac{1}{\mu}\left[(1-\alpha)\frac{F}{H}\right] = (1-\alpha)\frac{Y}{H}. \tag{17}$$

$$X = \delta K \quad \Rightarrow \quad \delta = \frac{X}{K}$$

$$\delta = \frac{1}{\varphi} u^{\varphi} \tag{18}$$

$$\frac{C}{Y} = 1 - \frac{X}{Y} - \frac{G}{Y}$$

To obtain an expression for the depreciation rate, combine the first order conditions for capital from the household's problem (15) and the intermediate firms' problem (16):

$$\delta = \left[(1-\tau)\alpha \frac{Y}{X} - 1\right]^{-1} \left(\beta^{-1} - 1\right).$$

Use the first order condition (14) together with the firms' first order condition for capital (16) and the depreciation rate equation (18) to find φ, the factor defining the degree to which capital utilization affects capital depreciation:

$$\varphi = (1-\tau)\alpha \frac{Y}{X}.$$

Then, the utilization rate obtains directly from equation (18).

The steady state capital stock is determined using the definition of aggregate output (12) in conjunction with the capital-output ratio $\left(\frac{K}{Y} = \frac{X}{Y}\frac{1}{\delta}\right)$ and the assumed value of steady state employment

$$K = \left[\frac{1}{\mu}\left(z u^{\alpha} H^{1-\alpha}\right)\frac{K}{Y}\right]^{\frac{1}{1-\alpha}}.$$

Given the definition of aggregate output, equations (16) and (17) give the capital rental rate r and the real wage rate w, while aggregate consumption, investment and government spending obtain as $\left(\frac{C}{Y}\right)Y$, $\left(\frac{X}{Y}\right)Y$, and $\left(\frac{G}{Y}\right)Y$. Finally, solve (13) for χ to get

$$\chi = (1-\tau) w \frac{1-H}{C}.$$

B Approximation of the Utility Function

To calculate the welfare associated with a given fiscal policy rule, the momentary utility is approximated by a second-order Taylor expansion. First, take a second-order Taylor expansion of $U(C_t, H_t)$ with respect to (C_t, H_t) around the deterministic steady state values $\overline{C}, \overline{H}$ and express it in algebraic percent deviations:

$$\begin{aligned} U(C_t, H_t) \quad &\approx \quad \overline{U} + \left[U_C\left(\overline{C}, \overline{H}\right)\ \overline{C}\right] \frac{dC_t}{\overline{C}} + \left[U_H\left(\overline{C}, \overline{H}\right)\ \overline{H}\right] \frac{dH_t}{\overline{H}} + \\ &+ \frac{1}{2} \left\{ \begin{array}{c} \left[U_{CC}\left(\overline{C}, \overline{H}\right)\ \overline{C}^2\right] \left(\frac{dC_t}{\overline{C}}\right)^2 + 2\left[U_{CH}\left(\overline{C}, \overline{H}\right)\ \overline{C}\ \overline{H}\right] \left(\frac{dC_t}{\overline{C}}\right)\left(\frac{dh_t}{\overline{H}}\right) \\ + \left[U_{HH}\left(\overline{C}, \overline{H}\right)\ \overline{H}^2\right] \left(\frac{dH_t}{\overline{H}}\right)^2 \end{array} \right\} \end{aligned}$$

Then, following Woodford (2003), approximate the algebraic percent change by a **second**-order expansion in terms of logarithmic changes

$$\frac{x_t - \overline{x}}{\overline{x}} = \frac{dx_t}{\overline{x}} \approx \hat{x}_t + \frac{1}{2}\hat{x}_t^2 \qquad where : \hat{x}_t \equiv \ln x_t - \ln \overline{x}$$

Finally, substitute the logarithmic changes for the algebraic percent changes and keep only the terms of order $O(1)$ and lower to get

$$\begin{aligned} U(C_t, H_t) &\approx \overline{U} + \left[U_C\left(\overline{C}, \overline{H}\right)\ \overline{C}\right] \widehat{C}_t + \left[U_H\left(\overline{C}, \overline{H}\right)\ \overline{H}\right] \widehat{H}_t + \\ &+ \frac{1}{2} \left\{ \begin{array}{c} \left[U_{CC}\left(\overline{C}, \overline{H}\right)\ \overline{C}^2 + U_C\left(\overline{C}, \overline{H}\right)\ \overline{C}\right] \widehat{C}_t^2 + 2\left[U_{CH}\left(\overline{C}, \overline{H}\right)\ \overline{C}\ \overline{H}\right] \left(\widehat{C}_t \widehat{H}_t\right) \\ + \left[U_{HH}\left(\overline{C}, \overline{H}\right)\ \overline{H}^2 + U_H\left(\overline{C}, \overline{H}\right)\ \overline{H}\right] \widehat{H}_t^2 \end{array} \right\}. \end{aligned}$$

Given the functional form adopted here, the approximation reduces to:

$$U(C_t, H_t) \approx \overline{U} + \widehat{C}_t - \chi \frac{H}{1-H} \widehat{H}_t - \frac{1}{2}\left[\chi \frac{H}{(1-H)^2}\right] \widehat{H}_t^2$$

which is equation (8) in the text. Note that, when the momentary utility is logarithmic in consumption, the variability of consumption does not directly affect lifetime utility (the last term in the last equation only includes the squared value of percent deviations in hours worked).

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Parameter	**Value**	**Parameter**	**Value**
β	0.99	τ	0.22
χ	3.16	ρ_G	0.925
α	0.36	σ_G	0.014
ϕ	0.05	ρ_z	0.95
δ	0.015	σ_z	0.006
u	0.108	μ	1.4
φ	1.65	θ	$[0, 2]$
G/Y	0.2		

Table 1: Parameter values used in simulations

	Total (ξ)	Mean Effect $\left(\xi^{FirstOrder}\right)$	Second Order Effect $\left(\xi^{SecondOrder}\right)$
	Basic Model		
$\theta = 1.0$ vs. $\theta = 0.0$	-0.037	-0.037	~0
$\theta = 2.0$ vs. $\theta = 0.0$	-0.063	-0.060	-0.003
$\theta = 2.0$ vs. $\theta = 1.0$	-0.026	-0.023	-0.003
	Model of Capital Utilization		
$\theta = 1.0$ vs. $\theta = 0.0$	-0.077	-0.089	0.012
$\theta = 2.0$ vs. $\theta = 0.0$	-0.113	-0.124	0.011
$\theta = 2.0$ vs. $\theta = 1.0$	-0.035	-0.035	~0

Table 2: The welfare cost of countercyclical taxes in model without government debt (values are in percentage points)

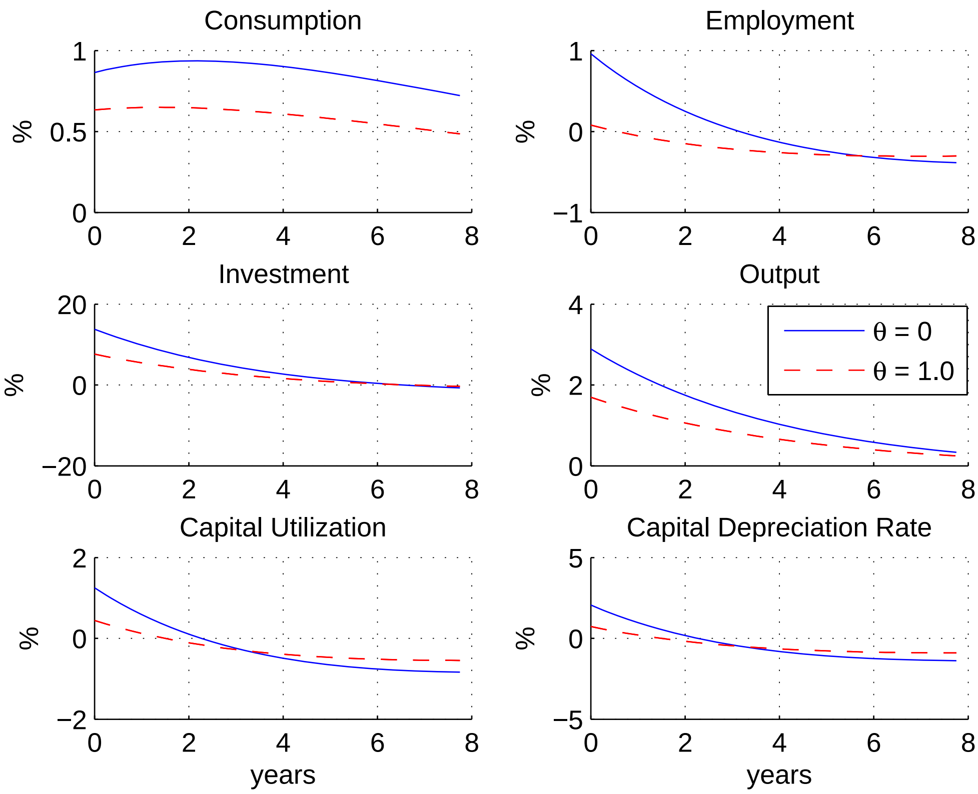

Figure 1: Impulse responses to a 1% increase in *the technological factor*: acyclical taxes ($\theta = 0$, solid lines) and countercyclical taxes ($\theta = 1$, dash lines).

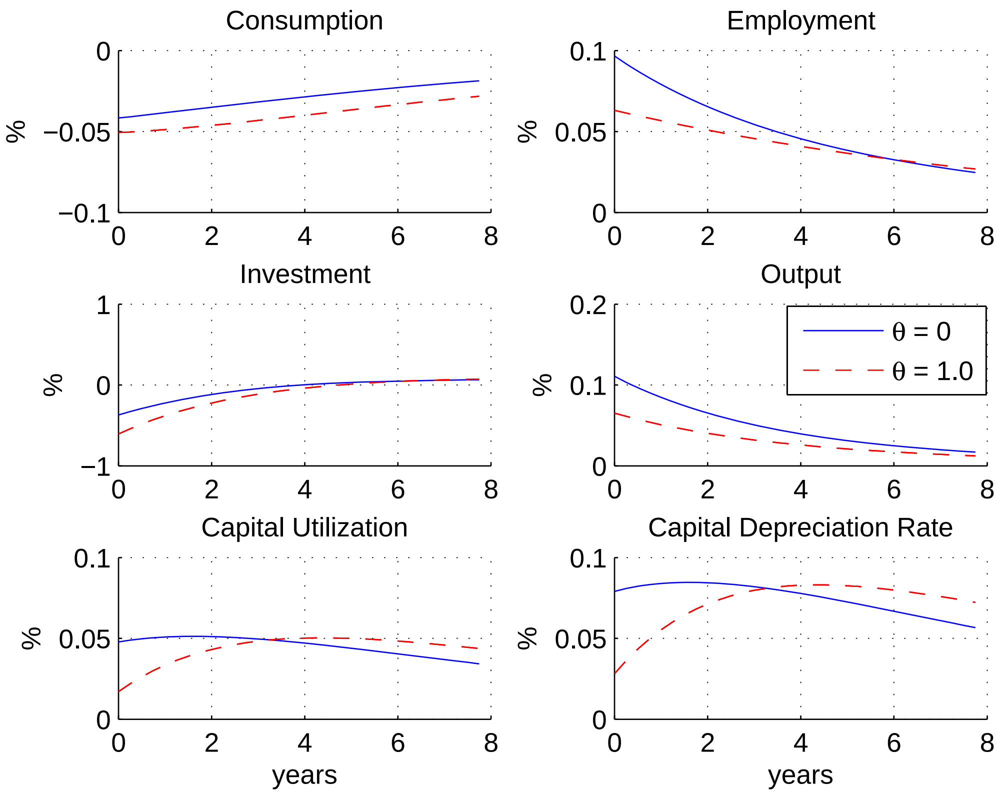

Figure 2: Impulse responses to a 1% increase in *government spending*: acyclical taxes ($\theta = 0$, solid lines) and countercyclical taxes ($\theta = 1$, dash lines).

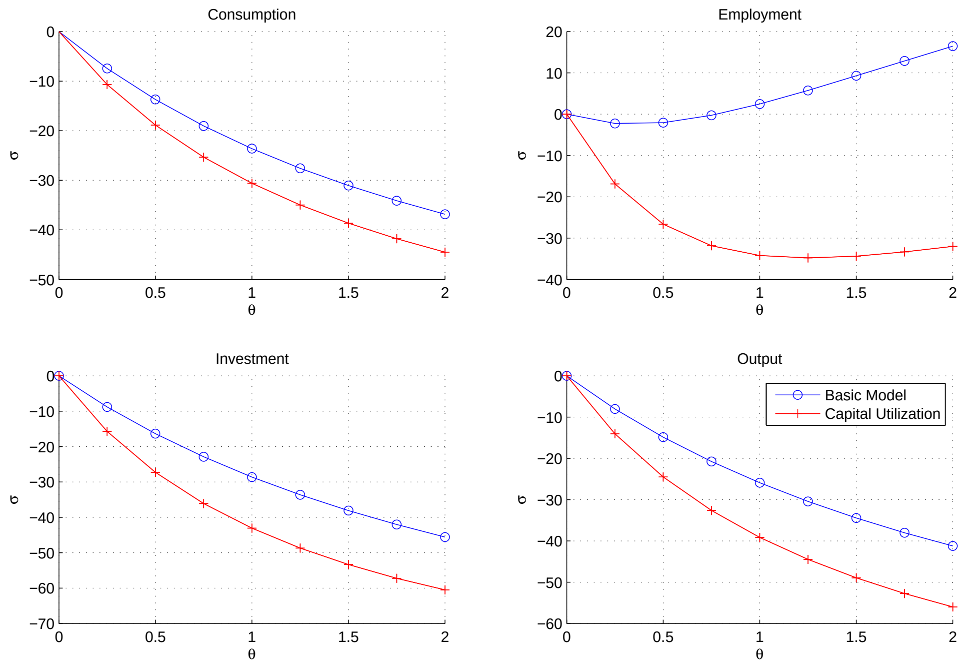

Figure 3: Percent changes in aggregate volatility as the tax rate becomes more countercyclical ($\theta > 0$) relative to acyclical taxes ($\theta = 0$): basic model (circles) and model of varying capital utilization (pluses). Volatility is measured as the standard deviation of fluctuations around the long-run average