Progressive Taxation, Nominal Wage Rigidity, and Business Cycle Destabilization*

Miroslav Gabrovski
University of Hawaii at Manoa†

Jang-Ting Guo
University of California, Riverside‡

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Abstract

In the context of a prototypical New Keynesian model, this paper examines the theoretical interrelations between two tractable formulations of progressive taxation on labor income versus (i) the equilibrium degree of nominal wage rigidity as well as (ii) the resulting volatilities of hours worked and output in response to a monetary shock. In sharp contrast to the traditional stabilization view, we analytically show that linearly progressive taxation always operates like an automatic destabilizer which leads to higher cyclical fluctuations within the macroeconomy. We also obtain the same business cycle destabilization result under continuously progressive taxation if the initial degree of tax progressivity is sufficient low.

Keywords: Progressive Taxation, Nominal Wage Rigidity, Automatic Stabilizer, Business Cycles.

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†Department of Economics, University of Hawaii at Manoa, 2424 Maile Way, Saunders 516, Honolulu, HI 96822, USA; Phone: 1-808-956-7749, Fax: 1-808-956-4347, E-mail: mgabr@hawaii.edu

‡Corresponding Author. Department of Economics, 3133 Sproul Hall, University of California, Riverside, CA 92521, USA; Phone: 1-951-827-1588, Fax: 1-951-827-5685, E-mail: guojt@ucr.edu.

1 Introduction

In the context of a traditional Keynesian macroeconomy, progressive income taxation operates as an automatic stabilizer that will dampen the magnitude of fluctuations in households' disposable income and consumption expenditures. It follows that *ceteris paribus* the cyclical volatilities of output and labor hours are smaller when the economy is subject to a more progressive tax policy. As it turns out, such a conventional viewpoint continues to hold in a one-sector real business cycle (RBC) model as well as in a stylized New Keynesian model. In particular, Guo and Lansing (1998) and Dromel and Pintus (2007) incorporate a progressive tax schedule, whereby the representative household's marginal tax rate is monotonically increasing in its own level of taxable income, into Benhabib and Farmer's (1994) indeterminate one-sector RBC model with a social technology that exhibits increasing returns-to-scale. These authors find that a sufficiently high degree of tax progressivity can stabilize the economy against macroeconomic fluctuations driven by agents' animal spirits.[1] On the other hand, Agell and Dillén (1994, section 2) study a simple New Keynesian model with worker-producer units (or farmers) and nominal price rigidities. In response to an aggregate demand disturbance, these authors find that more progressive taxation raises the flexibility of relative price adjustment, which in turn will mitigate business cycle fluctuations. In this paper, we analytically show that these previous results can be overturned within a more realistic New Keynesian macroeconomy, developed by Kleven and Kreiner (2003), whereby households and firms are separately analyzed.[2]

In our model economy, households derive utility from leisure and a continuum of differentiated consumption goods. Each household possesses some monopoly power in the labor market through supplying a distinct type of labor input, and also faces a cash-in-advance constraint on its consumption expenditures. On the production side of the economy, a unit measure of monopolistically competitive firms produce differentiated output with a decreasing returns-to-scale technology. Our main focus is to explore the theoretical interrelations between two tractable formulations of progressive taxation on labor income[3] versus (i) the equilibrium degree of nominal wage rigidity as well as (ii) the resulting volatility of hours worked in response

[1] In a similar vein, Schmitt-Grohé and Uribe (1997) show that equilibrium indeterminacy and belief-driven fluctuations can arise within a standard one-sector RBC model under constant returns-to-scale in production and perfectly competitive markets, together with a balanced-budget rule where fixed government spending is financed by proportional taxation on labor or total income. This countercyclical fiscal formulation is qualitatively equivalent to regressive income taxation that may destabilize the macroeconomy.

[2] The Kleven-Kreiner model is built upon the standard New Keynesian frameworks of Blanchard and Kiyotaki (1987) and Ball and Romer (1989, 1990, 1991).

[3] While progressive taxation on labor income is consistent with the empirical evidence within OECD countries, as reported in Mattesini and Rossi (2012, Table 1), progressive taxation on other types of income is not.

to a monetary shock. To this end, output prices are assumed to be fully flexible and other forms of taxes (e.g. sales, profit, payroll or value-added) are not considered.

We first examine the linearly progressive fiscal policy rule *à la* Dromel and Pintus (2007) whereby the government is postulated to impose a positive constant marginal tax rate on the portion of each household's labor income that is strictly higher than a pre-specified threshold level. Upon a change in the quantity of money supply around the model's initial symmetric equilibrium, fixed nominal wages will prevail when the associated loss of utility is lower than the requisite cost of wage adjustment. We analytically show that when the tax rate is zero, the resulting utility loss from non-adjustment is higher than that under positive income taxation because households are more capable of paying the menu cost in the former case, hence adjusting nominal wages is more likely to occur. This in turn implies that the economy will exhibit a higher degree of equilibrium nominal-wage rigidity as the tax progressivity (an increasing function of the marginal tax rate) rises. Given our maintained assumption of flexible output prices, money is neutral under fully-adjusted nominal wages since the equilibrium real wage as well as labor hours are unaffected. It follows that hours worked and output will become more volatile when there is an increase in the equilibrium degree of nominal-wage rigidity, captured by a reduction in the loss of utility from non-adjustment. Our analysis thus shows that in sharp contrast to the traditional stabilization view, linearly progressive taxation *always* operates like an automatic destabilizer in the context of Kleven and Kreiner's (2003) prototypical New Keynesian model.

We then investigate Guo and Lansing's (1998) nonlinear tax schedule that possesses a progressive property, characterized by a single slope/elasticity parameter, whereby the average and marginal tax rates are continuously increasing with respect to each household's taxable income relative to a baseline level. In response to a monetary disturbance, we show that the Kleven-Kreiner macroeconomy will exhibit a higher degree of equilibrium nominal-wage rigidity and higher volatilities in labor hours and output *if* the initial tax progressivity is smaller than a critical degree. Intuitively, start the model with a given tax progressivity and consider a positive shock to the economy's money supply. Regardless of how an individual household responds by maintaining or adjusting its nominal wage, the resulting taxable income and marginal tax rate will be higher. Since the elasticity of demand for labor is postulated to be greater than unity, the increases in the tax base as well as the marginal tax rate are comparatively lower under flexible nominal wages. This will yield two opposite effects: the relatively smaller increase in the marginal tax rate strengthens the household's incentive to adjust nominal wages, whereas the relatively larger increase in the taxable income enhances the likelihood of nominal wage rigidity. Next, when the fiscal policy rule becomes more progressive, households are less willing to raise their labor supply in response to a higher aggregate demand, which in turn reduces the aforementioned increases in their wage income and marginal tax rate. As a result, the sign for the overall effect of an increase in the tax-slope parameter on the degree of equilibrium nominal-wage rigidity is theoretically ambiguous. Our analysis finds that the impact of a larger tax base outweighs the opposing effect of a higher marginal tax rate provided the initial degree of tax progressivity is "sufficiently low". It follows that more progressive taxation will decrease the utility loss from non-adjustment, hence the economy is more prone to exhibit rigid nominal wages and higher cyclical fluctuations. In sum, we derive a *sufficient* condition under which the Guo-Lansing continuously progressive tax policy may destabilize Kleven and Kreiner's (2003) New Keynesian macroeconomy.

The remainder of this paper is organized as follows. Section 2 presents the model, discusses its equilibrium conditions, and then examines the interrelations between equilibrium nominal-wage rigidity versus business cycle destabilization under linearly progressive taxation. Section 3 studies our model economy under continuously progressive taxation. Section 4 compares our analysis with Kleven and Kreiner (2003, section 3) under flat income taxation. Section 5 concludes.

2 The Economy

Our study begins with incorporating the linearly progressive fiscal policy rule *à la* Dromel and Pintus (2007), which levies a positive constant marginal tax rate on each household's taxable income when it is higher than an exemption level, into a simplified version of the New Keynesian macroeconomy analyzed by Kleven and Kreiner (2003). In particular, since this paper's primary objective is to explore the theoretical interrelations between progressive labor-income taxation versus (i) the equilibrium degree of nominal wage rigidity as well as (ii) the resulting magnitude of business cycle fluctuations in response to a monetary disturbance, we postulate that output prices are fully flexible and that other types of taxes are not considered. Households derive utility from a continuum of differentiated consumption goods and leisure; and they possess some monopoly power in the labor market. Moreover, their entire consumption expenditures are financed by the economy's nominal money supply via a cash-in-advance constraint. The economy's production side consists of a unit measure of monopolistically competitive firms which produce differentiated output with a decreasing returns-to-scale technology. The government undertakes labor taxation and balances its budget through lump-sum transfers to households. To facilitate comparison with Kleven and Kreiner (2003), we will follow their notation as closely as possible.

2.1 Households

The economy is inhabited by a large number of households that are indexed by i and distributed uniformly over [0, 1]. The utility function for household i is given by

$$u_i = \left(\int_{j=0}^{1} c_{ij}^{1-\mu} dj \right)^{\frac{1}{1-\mu}} - \frac{\gamma}{1+\gamma} l_i^{\frac{1+\gamma}{\gamma}}, \quad 0 < \mu < 1, \quad \gamma > 0, \tag{1}$$

where c_{ij} is consumption of type $j \in [0, 1]$, l_i is hours worked, μ is the inverse for the elasticity of substitution between two distinct consumption goods, and γ is the wage elasticity of labor supply. The budget constraint faced by household i is

$$\int_{j=0}^{1} p_j c_{ij} dj = w_i l_i - \underbrace{\tau(w_i l_i - E)}_{Tax\ Payment} + \int_{j=0}^{1} \pi_{ij} dj + S_i, \quad 0 \leq \tau < 1, \quad E > 0, \tag{2}$$

where p_j denotes the market price for good j, w_i is the nominal wage, π_{ij} represents the after-tax profits as lump-sum dividends from household i's ownership of firm j, and S_i is the lump-sum transfers received from the government such that its balanced budget can be maintained, *i.e.* $\int_{i=0}^{1} \tau(w_i l_i - E) di = \int_{i=0}^{1} S_i di$.

As in Dromel and Pintus (2007), the government is postulated to impose a positive tax rate $\tau \in (0,\ 1)$ on the portion of household i's wage income that is strictly higher than the pre-specified threshold E. When $w_i l_i \leq E$, households are not taxed thus $\tau = 0$. This parsimonious two-income-bracket formulation is able to to capture the piecewise linear feature commonly observed in real world tax systems. In addition, this tax schedule is progressive under $w_i l_i > E$ since the resulting average tax rate, given by $ATR_i = \tau(1 - \frac{E}{w_i l_i})$, is lower than the constant marginal tax rate $MTR_i = \tau$. We also follow Dromel and Pintus (2007, p. 27) to define the associated tax progressivity on household i as

$$\theta_i \equiv \frac{MTR_i - ATR_i}{1 - ATR_i} = \frac{\tau E}{(1-\tau) w_i l_i + \tau E}, \quad \text{where} \quad \frac{\partial \theta_i}{\partial \tau} > 0 \quad \text{and} \quad \frac{\partial \theta_i}{\partial E} > 0, \tag{3}$$

hence an increase in the tax rate τ or the exemption threshold E will raise the degree of tax progressivity.[4]

On the other hand, household i faces the following cash-in-advance (CIA) or liquidity constraint:

$$\int_{j=0}^{1} p_j c_{ij} dj \leq M_i, \tag{4}$$

[4] These features remain qualitatively robust to alternative tax-progressivity measures as in Musgrave and Thin (1948): (i) average rate progression $\frac{\partial(ATR_i)}{\partial(w_i i_i)}$, and (ii) residual income progression $\frac{1-MTR_i}{1-ATR_i}$.

thus all consumption purchases must be financed by its nominal money balance M_i. Furthermore, the economy's aggregate money supply is given by $M = \int_{i=0}^{1} M_i di$. Taking aggregation over each household's first-order condition with respect to c_{ij} yields that the total demand for consumption good j is

$$c_j = \int_{i=0}^{1} c_{ij} di = \left(\frac{p_j}{P}\right)^{-\frac{1}{\mu}} \frac{M}{P}, \quad \text{where} \quad P = \left(\int_{j=0}^{1} p_j^{\frac{\mu-1}{\mu}} dj\right)^{\frac{\mu}{\mu-1}} \tag{5}$$

is the aggregate price index for the consumption basket.

2.2 Firms

The economy is also populated by a large number of firms that are indexed by j and distributed uniformly over [0, 1]. The production function for firm j is given by

$$y_j = \frac{1}{\alpha}\left(\int_{i=0}^{1} l_{ij}^{1-\rho} di\right)^{\frac{\alpha}{1-\rho}}, \quad 0 < \alpha, \ \rho < 1, \tag{6}$$

where y_j is output, l_{ij} is hours worked of type i, ρ is the inverse for the elasticity of substitution between two distinct labor inputs, and α governs the degree of returns-to-scale in production. The first-order condition for firm j's cost minimization problem leads to the demand function for labor of type i

$$\ell_{ij} = \left(\frac{w_i}{W}\right)^{-\frac{1}{\rho}} (\alpha y_j)^{\frac{1}{\alpha}}, \quad \text{where} \quad W = \left(\int_{i=0}^{1} w_i^{\frac{\rho-1}{\rho}} di\right)^{\frac{\rho}{\rho-1}} \tag{7}$$

is the aggregate nominal-wage index. Using (5), (6), and (7), we obtain the expression for the indirect profit function for firm j as follows:

$$\pi(p_j, \ M) = p_j \left(\frac{p_j}{P}\right)^{-\frac{1}{\mu}} \frac{M}{P} - W \left(\frac{p_j}{P}\right)^{-\frac{1}{\alpha\mu}} \left(\alpha \frac{M}{P}\right)^{\frac{1}{\alpha}}. \tag{8}$$

Since $0 < \mu < 1$, equation (5) shows that the demand curve for consumption good j is downward sloping, which in turn implies that each firm has some monopoly power in the goods market. From the first-order condition of maximizing (8), it is straightforward to show that p_j is set according to

$$\frac{p_j}{P} = \left[\frac{1}{1-\mu} \frac{W}{P} \left(\alpha \frac{M}{P}\right)^{\frac{1-\alpha}{\alpha}}\right]^{\frac{\alpha\mu}{\alpha\mu+1-\alpha}}. \tag{9}$$

2.3 Symmetric Equilibrium

We first use equations (2) and (4)-(5) to rewrite the household utility (1) as

$$u_i = \frac{(1-\tau)\, w_i l_i + \tau E}{P} + \int_{j=0}^{1} \frac{\pi_{ij}}{P} dj + \frac{S_i}{P} - \frac{\gamma}{1+\gamma} l_i^{\frac{1+\gamma}{\gamma}}. \tag{10}$$

Next, plugging the demand function for l_i as in (7) into (10) leads to the following indirect utility function for household i:

$$V(w_i,\ M) = \frac{(1-\tau)\, w_i}{P} \left(\frac{w_i}{W}\right)^{-\frac{1}{\rho}} \left(\alpha \frac{M}{P}\right)^{\frac{1}{\alpha}} + \frac{\tau E}{P} + \int_{j=0}^{1} \frac{\pi_{ij}}{P} dj + \frac{S_i}{P} - \frac{\gamma}{1+\gamma} \left[\left(\frac{w_i}{W}\right)^{-\frac{1}{\rho}} \left(\alpha \frac{M}{P}\right)^{\frac{1}{\alpha}}\right]^{\frac{1+\gamma}{\gamma}}. \tag{11}$$

Following Dromel and Pintus (2007), we postulate that households take into account the way in which the tax schedule affects their net earnings when they decide nominal wages and labor supply. As a result, it is the marginal tax rate τ that governs the household's economic decisions. Hence, our analysis below will not involve the income exemption threshold E since it only affects the average tax rate.

At the model's symmetric equilibrium with $w_i = w$ and $l_i = l\ \forall i$, it is straightforward to show that from the first-order condition of maximizing (11), w_i is set according to

$$\frac{w_i}{W} = \left[(1-\rho)(1-\tau)\frac{W}{P}\right]^{-\frac{\gamma\rho}{1+\gamma\rho}} \left(\alpha \frac{M}{P}\right)^{\frac{\rho}{\alpha(1+\gamma\rho)}}. \tag{12}$$

2.4 Nominal Wage Rigidity and Business Cycle Destabilization

This subsection first derives the condition(s) under which household i will choose not to adjust its nominal wage w_i in response to a monetary shock. As in Kleven and Kreiner (2003) and many previous New Keynesian studies, there exists a lump-sum adjustment cost (*i.e.* the so-called menu cost) $F > 0$ associated with changing the nominal wage when a monetary disturbance dM takes place. Therefore, the equilibrium w_i will be held constant when the menu cost is not lower than the loss of utility generated from non-adjustment of nominal wages. Taking a second-order Taylor expansion on the indirect utility function around the initial symmetric equilibrium (denoted as V^0) yields that the utility loss from nominal-wage rigidity is given by

$$\Delta V \equiv V^A - V^N \simeq V_{12} dw_i dM + \frac{1}{2} V_{11} (dw_i)^2, \tag{13}$$

where V^A and V^N are the utility levels under flexible (or fully adjusted) and fixed nominal wages, respectively; $V_{12} = \frac{\partial^2 V}{\partial w_i \partial M}$ and $V_{12} = \frac{\partial^2 V}{\partial M^2}$.[5] Using equations (11) and (12), it can be shown that ΔV is equal to

$$\Delta V = \frac{\left[(1-\mu)(1-\rho)(1-\tau)\right]^{\frac{1+\gamma}{1+\gamma(1-\alpha)}}}{2\alpha^2\gamma(1+\gamma\rho)} \left(\frac{dM}{M}\right)^2, \tag{14}$$

Since $0 < \alpha$, μ, $\rho < 1$, $0 \leq \tau < 1$ and $\gamma > 0$, it is immediately clear that $\Delta V > 0$. It follows that in response to a shock to the economy's aggregate demand dM, our model will exhibit equilibrium nominal-wage rigidity when $F \geq \Delta V$; or equilibrium nominal-wage flexibility when $F < \Delta V$. Moreover, for a given (fixed) level of adjustment cost F, a decrease in the utility loss ΔV will raise the degree of nominal-wage rigidity within our model economy.

Next, given the linearly progressive tax schedule under consideration, we analytically examine the effects of a monetary disturbance on the economy's equilibrium degree of nominal wage rigidity (represented by ΔV) and the resulting magnitude of cyclical fluctuations measured by variations in labor hours dl_i:

Proposition 1. Under a monetary shock dM and linearly progressive income taxation, the model economy that starts with a positive constant $\tau \in (0,\ 1)$ will (i) exhibit a higher degree of equilibrium nominal-wage rigidity and (ii) yield higher volatilities in labor hours and output compared to those under $\tau = 0$.

To compare the required level of adjustment costs for keeping nominal wages unchanged under two distinct values of τ at the model's initial symmetric equilibrium, we use equation (14) to find that

$$\Delta V(\tau > 0) - \Delta V(\tau = 0) = \left\{ \underbrace{\frac{\left[(1-\mu)(1-\rho)\right]^{\frac{1+\gamma}{1+\gamma(1-\alpha)}}}{2\alpha^2\gamma(1+\gamma\rho)} \left(\frac{dM}{M}\right)^2} \right\}_{\text{positive}} \left[(1-\tau)^{\frac{1+\gamma}{1+\gamma(1-\alpha)}} - 1\right] < 0, \tag{15}$$

which in turn implies that the presence of positive income taxation raises the degree of nominal-wage rigidity. Intuitively, since each household receives the full amount of its labor income when $\tau = 0$, changing nominal wages is more likely to occur in response to a monetary shock. When $\tau > 0$, each household is less able to pay the menu cost F needed for wage adjustment

[5] In particualr, V^A and V^N can be approximated by

$$V^A \simeq V^0 + V_1 dw_i + V_2 dM + \frac{1}{2}V_{11}(dw_i)^2 + \frac{1}{2}V_{22}(dM)^2 + V_{12} dw_i dM,$$

$$\text{and} \quad V^N \simeq V^0 + V_2 dM + \frac{1}{2}V_{22}(dM)^2.$$

because of a lower disposal income. In sum, the negative income effect associated with a higher tax rate will reduce households' incentive to adjust their nominal wages.

With regard to the impact of different values of τ on the magnitude of business cycles, we consider a positive monetary impulse that raises the economy's aggregate demand and thus shifts the demand curve for labor to the right. Given our maintained assumption of flexible output prices, the neutrality of money prevails under fully-adjusted nominal wages because the equilibrium real wage as well as hours worked remain unaffected $\left(\frac{dl_i}{dM}=0\right)$. It follows that the volatilities of labor hours and output will rise when there is an increase in the equilibrium degree of nominal-wage rigidity, captured by a reduction in the utility loss from non-adjustment ΔV. Based on the derivation of (15) and subsequent discussion, the economy with $\tau \in (0,\ 1)$ exhibits higher cyclical fluctuations than those under $\tau = 0$. Since the measure of tax progressivity is *ceteris paribus* monotonically increasing in τ (see equation 3), our analysis shows that linearly progressive taxation *always* operates like an automatic destabilizer in the context of a prototypical New Keynesian model developed by Kleven and Kreiner (2003). Hence, this result overturns the traditional stabilization view of progressive income taxation within a macroeconomy.

3 Continuously Progressive Taxation

This section examines our model economy that is subject to Guo and Lansing's (1998) progressive fiscal policy rule with continuously increasing average and marginal tax rates. In this case, household i's budget constraint is changed to

$$\int_{j=0}^{1} p_j c_{ij} dj = (1 - t_i)\, w_i l_i + \int_{j=0}^{1} \pi_{ij} dj + S_i, \tag{16}$$

where t_i is the tax rate taking on the functional form which is continuously increasing and differentiable in the labor income $w_i l_i$:

$$t_i = \eta \left(\frac{w_i l_i}{wl}\right)^{\phi}, \quad 0 < \eta < 1, \quad 0 < \phi < 1, \tag{17}$$

where wl denotes the average level of nominal wage income across all households, hence $w = \int_{i=0}^{1} w_i di$ and $l = \int_{i=0}^{1} l_i di$; and the parameters η and ϕ govern the level and slope (or elasticity) of the tax schedule, respectively. Using (17), we find that the marginal tax rate t_i^m, defined as the change in taxes paid by household i divided by the change in its income level, is given by

$$t_i^m = \frac{\partial\left(t_i w_i l_i\right)}{\partial\left(w_i l_i\right)} = \eta\,(1+\phi)\left(\frac{w_i l_i}{wl}\right)^{\phi}. \tag{18}$$

Our analyses will focus on the environment in which $0 < t_i,\ t_i^m < 1$ such that the government can not confiscate productive resources, and households have an incentive to provide labor services to firms. At the economy's symmetric equilibrium with $w_i = w$ and $l_i = l$ for all i, these considerations imply that $\eta \in (0,\ 1)$ and $\phi \in \left(-1,\ \frac{1-\eta}{\eta}\right)$, where $\frac{1-\eta}{\eta} > 0$. Given these restrictions on η and ϕ, it is obvious that when $\phi > 0$, the marginal tax rate (18) is higher than the average tax rate given by (17). In this case, the tax schedule is said to be "progressive". When $\phi = 0$, the average and marginal tax rates coincide at the constant level of η, thus the tax schedule is "flat". When $\phi < 0$, the tax schedule is "regressive". As a result, the degree of tax progressivity associated with (17) is governed by the elasticity parameter ϕ. In addition, we note that the U.S. federal individual income tax schedule is progressive as it is characterized by several tax "brackets" (branches of income) which are taxed at progressively higher rates; and that the listed statutory marginal tax rate t_i^m is an increasing and concave function with respect to taxable-income ($w_i l_i$) brackets. Based on these empirical observations, the tax-progressivity parameter ϕ is further limited to the interval $(0,\ 1)$ in this section.

Next, it is straightforward to show that under continuously progressive income taxation, the equilibrium conditions that characterize the aggregate demand and market price for consumption good j, as in equations (5) and (9), remain unchanged. Moreover, the indirect utility function for household i now becomes

$$V(w_i,\ M) = \frac{(1-t_i)\,w_i}{P}\left(\frac{w_i}{W}\right)^{-\frac{1}{\rho}}\left(\alpha\frac{M}{P}\right)^{\frac{1}{\alpha}} + \int_{j=0}^{1}\frac{\pi_{ij}}{P}dj + \frac{S_i}{P} - \frac{\gamma}{1+\gamma}\left[\left(\frac{w_i}{W}\right)^{-\frac{1}{\rho}}\left(\alpha\frac{M}{P}\right)^{\frac{1}{\alpha}}\right]^{\frac{1+\gamma}{\gamma}}, \tag{19}$$

where t_i is given by (17). Given each household's economic decisions are governed by the common marginal tax rate at the model's symmetric equilibrium ($t_i^m = t^m$ for all i), we find that w_i will be set according to

$$\frac{w_i}{W} = \left\{(1-\rho)\left[1-\underbrace{\eta\,(1+\phi)}_{t^m\in(0,1)}\right]\frac{W}{P}\right\}^{-\frac{\gamma\rho}{1+\gamma\rho}}\left(\alpha\frac{M}{P}\right)^{\frac{\rho}{\alpha(1+\gamma\rho)}}. \tag{20}$$

Using equations (17), (19) and (20), it can then be shown that the loss of utility from non-adjustment of nominal wages in response to a monetary shock dM is equal to

$$\Delta V \equiv V^A - V^N = \frac{(1-\mu)\,(1-\rho)\,\Pi^2}{2\alpha^2\gamma\,(1+\gamma\rho)\,\Omega}\underbrace{\{(1-\mu)\,(1-\rho)\,[1-\eta\,(1+\phi)]\}^{\frac{\alpha\gamma}{1+\gamma(1-\alpha)}}}_{=\frac{WL}{P}}\left(\frac{dM}{M}\right)^2, \tag{21}$$

where $\Pi \equiv 1-\eta\,(1+\phi)\,(1-\gamma\phi)$, $\Omega \equiv 1-\eta\,(1+\phi)+\frac{\gamma\eta\phi(1-\rho)(1+\phi)}{1+\gamma\rho}$, and $\frac{WL}{P}$ denotes the total real-wage income. Since $0 < \alpha,\ \mu,\ \rho,\ \eta\,(1+\phi) < 1$ and $\gamma > 0$, it is immediately clear that

$\Delta V > 0$. As in the preceding section, our model will exhibit rigid nominal wages when the menu cost $F \geq \Delta V$; or fully flexible nominal wages when $F < \Delta V$.

Under the postulated continuously progressive tax schedule (17), we use equation (21) to show that while keeping other model parameters the same

$$\frac{\partial\left(\Delta V\right)}{\partial\phi} = 2\left(\frac{\Delta V}{\Pi}\right)\frac{\partial\Pi}{\partial\phi} - \left(\frac{\Delta V}{\Omega}\right)\frac{\partial\Omega}{\partial\phi} + \left(\frac{\Delta V}{\frac{WL}{P}}\right)\frac{\partial\left(\frac{WL}{P}\right)}{\partial\phi}, \tag{22}$$

where $\frac{\partial\Pi}{\partial\phi} = \eta\left[-1+\gamma\left(1+2\phi\right)\right]$, $\frac{\partial\Omega}{\partial\phi} = -\eta+\frac{\gamma\eta(1-\rho)(1+2\phi)}{1+\gamma\rho}$, and $\frac{\partial\left(\frac{WL}{P}\right)}{\partial\phi} = -\frac{\alpha\gamma\eta}{[1+\gamma(1-\alpha)][1-\eta(1+\phi)]}\frac{WL}{P}$. Since the tax-slope parameter ϕ enters (22) in a rather complicated manner, the sign of $\frac{\partial(\Delta V)}{\partial\phi}$ can be positive or negative. Given the main objective of our analysis is to find circumstances under which progressive taxation may affect the business cycle as an automatic destabilizer, we derive the following *sufficient* condition:

Proposition 2. Under a monetary shock dM and continuously progressive income taxation, an increase in the tax progressivity will lead to (i) a higher degree of equilibrium nominal-wage rigidity and (ii) higher volatilities in labor hours and output *if* the initial level of $\phi < \hat{\phi} = \frac{(1-\eta)(1-2\gamma)}{\eta+2\gamma(2-\eta)} \in (0,\, 1)$ holds.[6]

Proof. See the Appendix.

The intuition for this Proposition is as follows. Start the model with a given (positive) level of tax progressivity and consider a positive monetary shock that causes the economy's aggregate demand to rise. Regardless of how household i responds by maintaining or changing its nominal wage, the resulting taxable income $w_i l_i$ and marginal tax rate t_i^m *à la* (18) will be higher. Since the demand elasticity for labor is greater than unity $(0 < \rho < 1)$, the increases in the tax base as well as the marginal tax rate are comparatively lower under flexible nominal wages. This will generate two opposite effects: the relatively smaller increase in the marginal tax rate strengthens the household's incentive to adjust nominal wages, whereas the relatively larger increase in the taxable income enhances the likelihood of nominal wage rigidity. Next, when the tax schedule becomes more progressive (as ϕ rises), households are less willing to raise their labor supply in response to a higher aggregate demand, which in turn reduces the aforementioned increases in their wage income and marginal tax rate. As a result, the sign for the overall consequence of an increase in the tax-elasticity parameter on the degree of equilibrium nominal-wage rigidity is theoretically ambiguous. Proposition 2 shows that when the initial tax progressivity is lower than a certain threshold given by $\hat{\phi}$, more progressive taxation will decrease the utility loss from non-adjustment, *i.e.* $\frac{\partial(\Delta V)}{\partial\phi} < 0$, because the impact of a larger tax base outweighs the opposing effect of a higher marginal tax rate. It

[6] Since $0 < \eta < 1$ and $\gamma > 0$, the constraint $\hat{\phi} > 0$ requires that the household's labor supply elasticity $\gamma < \frac{1}{2}$. In addition, it is straightforward to show that $\hat{\phi} < 1$ for all feasible combinations of η and γ.

follows that the model economy is more prone to exhibit rigid nominal wages under a higher level of tax progressivity. In terms of how a tax-elasticity change affects the magnitude of labor-hour fluctuations driven by monetary impulses (represented by $\frac{dl_i}{dM}$), we use the chain rule to obtain

$$\frac{\partial\left(\frac{dl_i}{dM}\right)}{\partial\phi} = \underbrace{\frac{\partial\left(\frac{dl_i}{dM}\right)}{\partial\left(\Delta V\right)}}_{\text{Negative}} \underbrace{\frac{\partial\left(\Delta V\right)}{\partial\phi}}_{\text{Negative}} > 0, \tag{23}$$

where the negativity of the first term is based on the same reasoning as that in the previous subsection: the volatility in hours worked or output is monotonically increasing in the degree of equilibrium nominal-wage rigidity represented by ΔV. In sum, our analysis shows that Guo and Lansing's (1998) continuously progressive fiscal policy rule may destabilize the Kleven-Kreiner macroeconomy provided the initial level of tax progressivity is "sufficiently low".

4 Discussion: Flat Taxation

For a direct comparison with Kleven and Kreiner (2003), this section examines our model economy under a flat tax schedule whereby the average and marginal tax rates take on the same constant level at $t_i = t_i^m = \eta \in (0,\,1)$ for all households. Plugging $\phi = 0$ into (21) leads to the straightforward result that $\frac{\partial(\Delta V)}{\partial\eta} < 0$. This implies that a higher tax rate makes households more willing to maintain their nominal wages in response to a monetary shock. To understand the underlying intuition, we first consider the extreme case in which $\eta = 1$: each household has zero disposal income and is unable to pay the menu cost F needed for wage adjustment. As a result, the equilibrium nominal wage is always kept unchanged. On the contrary, since each household receives the full amount of its labor income when $\eta = 0$, flexible nominal wages are more likely to arise in equilibrium. Moreover, as in section 2, flat income taxation will always destabilize the macroeconomy with higher fluctuations in hours worked in that[7]

$$\frac{\partial\left(\frac{dl_i}{dM}\right)}{\partial\eta} = \underbrace{\frac{\partial\left(\frac{dl_i}{dM}\right)}{\partial\left(\Delta V\right)}}_{\text{Negative}} \underbrace{\frac{\partial\left(\Delta V\right)}{\partial\eta}}_{\text{Negative}} > 0. \tag{24}$$

The above findings can be summarized as follows:

Proposition 3. Under a monetary shock dM and flat income taxation, an increase in the (constant) tax rate will (i) raise the degree of equilibrium nominal-wage rigidity, and (ii)

[7] This result that a higher constant tax rate amplifies the magnitude of business cycles also holds within a standard one-sector real business cycle model; see King, Plosser and Rebelo (1988) and Greenwood and Huffman (1991).

operate like an automatic destabilizer that yields higher volatilities in labor hours and output.

The results in our Proposition 3 turn out to be qualitatively identical to those obtained in section 3 of Kleven and Kreiner (2003) when "the tax system is linear in the neighborhood of the initial equilibrium", which stipulates a fixed tax rate for all levels of the household's labor income. Nevertheless, there are two important caveats that are worth pointing out. First, Kleven and Kreiner (2003; equation 8 on page 1128) consider the utility loss from non-adjustment in proportion to the total real-wage income $\left(= \frac{\Delta V}{WL/P}\right)$ for their analysis; whereas we examine ΔV as in (21) because $\frac{WL}{P}$ depends on the tax rate η, which in turn will affect the analytical expression (but not the sign) of $\frac{\partial(\Delta V)}{\partial \eta}$. Second, Kleven and Kreiner (2003; equation 9 on page 1129) study the welfare consequences of a monetary impulse by deriving the change of the household utility in proportion to the economy's aggregate income/output; whereas we investigate the business cycle effects of dM measured by the resulting fluctuations in hours worked $\frac{dl_i}{dM}$.[8]

5 Conclusion

This paper analytically examines the interrelations between progressive taxation on labor income and the magnitude of business cycle fluctuations in a prototypical New Keynesian model with nominal wage rigidity and shocks to aggregate money supply. In stark contrast to traditional Keynesian-type stabilization policies, we find that progressive taxation may operate like an automatic destabilizer which generates higher cyclical volatilities of labor hours and output within our model economy. Under Dromel and Pintus's (2007) linearly progressive tax policy, more progressive taxation always raises the degree of equilibrium nominal-wage rigidity and amplifies the resulting macroeconomic fluctuations. Under Guo and Lansing's (1998) continuously progressive tax schedule, we obtain the same business cycle destabilization result if the initial degree of tax progressivity is lower than a certain threshold level. These findings are valuable not only for their theoretical insights to the academic literature, but also for their important implications about the destabilization effect of progressive tax policies within a New Keynesian macroeconomy

[8] Under a general non-linear tax system, Kleven and Kreiner (2003, section 4) examine a change in the elasticity of the marginal tax rate with respect to the household's before-tax wage income, while keeping the level of the marginal rate unaffected. Using our postulated fiscal policy rule (17), their analysis corresponds to changing the tax-level and tax-slope parameters (η and ϕ) simultaneously such that the marginal tax rate at the model's symmetric equilibrium $\eta(1+\phi)$ remains unchanged. Since this paper considers a change in either ϕ or η, our results are not comparable to those in Kleven and Kreiner (2003, section 4).

6 Appendix

Proof of Proposition 2. Substituting the expressions of $\frac{\partial \Pi}{\partial \phi}$, $\frac{\partial \Omega}{\partial \phi}$ and $\frac{\partial\left(\frac{WL}{P}\right)}{\partial \phi}$ into equation (22) yields

$$\frac{1}{\Delta V}\frac{\partial(\Delta V)}{\partial \phi} = \frac{2\left[-1+\gamma(1+2\phi)\right]}{\Pi} + \frac{1-\frac{\gamma(1-\rho)(1+2\phi)}{1+\gamma\rho}}{\Omega} - \underbrace{\frac{\alpha\gamma}{\frac{WL}{P}\left[1+\gamma(1-\alpha)\right]\left[1-\eta(1+\phi)\right]}}_{\text{Positive}}, \tag{A.1}$$

where $\Delta V > 0$ is given by (21). Since $\frac{\gamma(1-\rho)(1+2\phi)}{1+\gamma\rho} > 0$ and the last term on the right-hand-side of (A.1) is positive,

$$\frac{1}{\Delta V}\frac{\partial(\Delta V)}{\partial \phi} < \frac{2\left[-1+\gamma(1+2\phi)\right]}{\Pi} + \frac{1}{\Omega} = \frac{2\left[-1+\gamma(1+2\phi)\right]}{1-t^m+\gamma\phi t^m} + \frac{1}{1-t^m+\frac{\gamma\phi t^m(1-\rho)}{1+\gamma\rho}}, \tag{A.2}$$

where $t^m = \eta(1+\phi) \in (0,1)$. Since $\frac{\gamma\phi t^m(1-\rho)}{1+\gamma\rho} > 0$, we can use (A.2) to further obtain that

$$\frac{1}{\Delta V}\frac{\partial(\Delta V)}{\partial \phi} < \frac{2\left[-1+\gamma(1+2\phi)\right]}{1-t^m+\gamma\phi t^m} + \frac{1}{1-t^m} = \frac{-1+t^m+2\gamma(1+2\phi)-2\gamma t^m-3\gamma\phi t^m}{(1-t^m+\gamma\phi t^m)(1-t^m)}. \tag{A.3}$$

Since $(1-t^m+\gamma\phi t^m)(1-t^m) > 0$ and $3\gamma\phi t^m > 0$, a sufficient condition for $\frac{\partial(\Delta V)}{\partial \phi} < 0$ is given by

$$-1+t^m+2\gamma(1+2\phi)-2\gamma t^m < 0, \tag{A.4}$$

which leads to $\phi < \hat{\phi} = \frac{(1-\eta)(1-2\gamma)}{\eta+2\gamma(2-\eta)} \in (0,\,1)$ in the main text.

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