CESifo *Working Paper Series*

THE ROLE OF TAXES AS AUTOMATIC DESTABILIZERS IN NEW KEYNESIAN ECONOMICS

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Working Paper No. 399

December 2000

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* We are grateful to Peter Birch Sørensen for his comments on an earlier draft of this paper. The activities of EPRU (Economic Policy Research Unit) are financed through a grant from The Danish National Research Foundation.

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Abstract

This paper analyses the effects of taxation in New Keynesian economics. The results show that taxes contribute to price and wage stickiness and, moreover, that the resulting fluctuations in welfare are magnified by the presence of taxes. These results are at odds with the old Keynesian idea of automatic stabilizers.

Keywords: New Keynesian economics, taxation, automatic stabilizers

JEL Classification: E32, E62

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1 Introduction

How do taxes influence business cycles? An old insight due to traditional Keynesian theory is that taxes, which depend positively on income, serve as automatic stabilizers by reducing effective demand in upturns and increasing effective demand in downturns. The result is intuitively appealing but, as argued forcefully by Lucas and his collaborators, the whole framework builds on a theoretically unfounded assumption of rigid prices. As a response to this critique, New Keynesian theory has shown that price rigidity may arise because of small price adjustment costs and empirical research has shown that these so-called menu costs are within realistic limits, see Levy et al. (1997) and Dutta et al. (1999). Consequently, the theory resurrects many of the traditional Keynesian results, for example that nominal demand disturbances may give rise to inefficiently large fluctuations in output, see e.g. Romer (1993). In this paper we ask if the old Keynesian idea of automatic stabilizers also carries over to New Keynesian theory.

To our knowledge only one previous paper, Agell and Dillén (1994), has analyzed this issue. They show that the inefficiencies present in New Keynesian models can be remedied by Pigouvian taxes and subsidies, and conclude moreover that

> "The derived policy rules are kindred in spirit to standard Keynesian policy prescriptions: progressive taxes may serve a useful purpose in combating wasteful economic fluctuations." Agell and Dillén (1994), Abstract, p. 111.

However, in their normative analysis the optimal marginal and average income tax rates are negative, so that income is effectively subsidized, and these subsidies are then financed in a lump sum fashion. Consequently, progressive taxation in the Agell and Dillén terminology really means subsidizing income at a decreasing marginal rate.[1] Accordingly, their results do not give any indication on how real-world tax systems affect the business cycle. This paper aims at doing so by making

[1] In order to see this, note from their equations (12) and (16) that the two optimal tax parameters are characterized by $\tau_0 > 1$ and $\tau_1 < 1$. As real income is always below one in equilibrium, this implies from equation (7) that each individual receives a subsidy as a function of real income. In fact, it is quite misleading that the authors call τ_0 and τ_1 tax-parameters and T lump-sum transfers from the government as the τ parameters determine the shape of a subsidy function while T in equilibrium is a lump-sum tax.

a positive analysis of the impact of taxes in New Keynesian theory. To broaden the scope we move the analysis from a simple farmer economy to a more realistic setting with both firms and workers and, in addition, we examine the impact of different types of taxes such as profit taxes, sales taxes, payroll taxes, wage income taxes, and value added taxes.

In general, our conclusions are opposite to those of Agell and Dillén (1994): taxes contribute to price and wage stickiness and, furthermore, the welfare consequences of nominal disturbances are magnified by the presence of taxes. The impact of the various kinds of taxes differs, however. Profit taxes, sales taxes, and value added taxes contribute to price rigidity, while wage income taxes and value added taxes contribute to wage rigidity. Finally, payroll taxes are neutral for the occurrence of price and wage rigidity but, like the other types of taxes, they contribute to an enlargement of the welfare fluctuations.

The next section sets up a model of imperfect competition in goods and labor markets. Apart from the introduction of a tax system, the model is essentially similar to the standard frameworks of Blanchard and Kiyotaki (1987) and Ball and Romer (1989, 1990, 1991). The third section derives our main results while the fourth section concludes.

2 The Model

The economy is populated by a continuum of households indexed by i and distributed uniformly on $[0, 1]$. There is a continuum of goods indexed by $j \in [0, 1]$. The utility level of household i is given by

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

where c_{ij} is consumption of good j, l_i is the number of working hours, μ is the reciprocal of the elasticity of substitution between any two goods (or, equivalently, the Lerner index), and γ is the reciprocal of the elasticity of marginal disutility of work which, in this formulation, corresponds to the labor supply elasticity.

The budget constraint of household i is given by

$$\int_{j=0}^{1} p_j c_{ij} dj \leq w_i l_i - T_w (w_i l_i) + \int_{j=0}^{1} \pi_{ij} dj + S_i \equiv I_i, \tag{2}$$

where p_j denotes the price of good j, w_i denotes the wage rate, $T_w(\cdot)$ is a differentiable and increasing wage tax function, π_{ij} is lump-sum dividends net of tax obtained on shares in firm j, and S_i is lump-sum transfers which are adjusted to balance the government budget.[2]

The type of labor supplied by any given worker is imperfectly substitutable for the labor supply of other workers, leaving each worker with some monopoly power in the labor market. Accordingly, household i maximizes (1) with respect to c_{ij}, l_i, and w_i subject to equation (2) and the downward sloping labor demand schedule of firms.

To analyze the effects of nominal disturbances, we introduce money into the model. Following Ball and Romer (1989, 1990, 1991), we assume that some transactions technology, for example a cash-in-advance constraint, determines the relation between aggregate spending and money balances

$$\int_{i=0}^{1} I_i di = m. \tag{3}$$

On the production side of the economy, we have a continuum of firms indexed by j and distributed uniformly on $[0, 1]$. The technology of firm j is described by the production function

$$y_j = \frac{1}{\alpha}\left(\int_{i=0}^{1} (l_{ij})^{1-\rho} di\right)^{\frac{\alpha}{1-\rho}}, \quad 0 < \alpha < 1, \quad 0 < \rho < 1, \tag{4}$$

where l_{ij} is input of labor of type i, ρ is the reciprocal of the elasticity of substitution between any two types of labor (i.e. the Lerner index), and α determines the homogeneity of the production function. Profits of firm j are given by

$$\pi_j = p_j y_j - \int_{i=0}^{1} w_i l_{ij} di - T_p\left(p_j y_j - \int_{i=0}^{1} w_i l_{ij} di\right) - T_{pr}\left(\int_{i=0}^{1} w_i l_{ij} di\right), \tag{5}$$

where $T_p(\cdot)$ and $T_{pr}(\cdot)$ are differentiable and increasing functions, denoting profit and payroll taxes, respectively. Each firm is selling a product which is an imperfect substitute for the output of other firms, implying that each firm has some monopoly power in the goods market. Thus, firm j maximizes (5) with respect to p_j, y_j, and l_{ij} subject to equation (4) and the goods demand function of households.

[2]Rather than using lump sum transfers to balance the budget, we could obtain similar results by including government purchases.

From the first order conditions of the wage and price setters as well as the symmetry of the model, implying that $p_j = p \ \forall j$ and $w_i = w \ \forall i$, we get the following equation for aggregate production (see Appendix A)

$$y \equiv \int_{j=0}^{1} y_j dj = \frac{1}{\alpha} \left(\frac{(1-t_w)(1-t_p)}{1-t_p+t_{pr}} (1-\mu)(1-\rho) \right)^{\frac{\gamma\alpha}{1+\gamma(1-\alpha)}} \leq \frac{1}{\alpha}, \tag{6}$$

where $t_w \equiv T'_w(\cdot)$, $t_p \equiv T'_p(\cdot)$, and $t_{pr} \equiv T'_{pr}(\cdot)$ denote marginal tax rates. The first best level of production $1/\alpha$ is obtained as the Lerner indices, μ and ρ, as well as the tax rates go to zero. As in standard New Keynesian models, aggregate production is below its first best level due to imperfect competition in goods and labor markets. In the present model, the existence of distortionary taxation also hampers the incentives to participate in economic activity, thereby moving output further below the first best level.

Although prices are fully flexible, the model does not feature money neutrality unless we impose additional constraints on the tax system. This is because tax payments depend on nominal income. If, for instance, marginal tax rates are increasing functions of nominal tax bases, positive monetary disturbances will move agents up in higher tax brackets, thereby reducing economic incentives and aggregate output. To avoid such effects, we assume in the following that the tax system is linear in the neighborhood of the initial equilibrium, i.e. t_w, t_p, and t_{pr} are treated as constants. While this assumption excludes the possibility of continuously increasing marginal tax rates, it does not exclude tax progressivity as marginal tax rates may very well be higher than average tax rates.[3]

3 Taxation, Nominal Rigidities and Fluctuations

Now we introduce lump sum costs associated with the adjustment of prices and wages. In the presence of such adjustment costs, so-called menu costs, the equilibrium may involve rigidity of prices and wages, implying that changes in nominal

[3] The introduction of continuously increasing marginal tax rates would, ceteris paribus, reduce the degree of price and wage rigidity. However, real world tax systems do not involve such non-linearities but are, rather, piecewise linear. Consequently, only a minor fraction of people experience changes in marginal tax rates during economic fluctuations, implying that the effect for the representative agent is likely to be small. For the average US household the marginal tax rate response of a 1 percent increase in income is 0.08 percentage points (see Auerbach and Feenberg, 2000). Our calculations show that an elasticity of this magnitude will have a negligible effect on price and wage rigidity.

demand give rise to fluctuations in real variables. The key insight of New Keynesian Economics is that *small* menu costs are sufficient to generate monetary non-neutrality while the resulting fluctuations involve *large* effects on welfare. In this section we show that taxation mitigates the minimum effective menu costs even further and, at the same time, magnifies the welfare consequences of macroeconomic fluctuations.

First, we derive the levels of menu costs of firms and workers that are sufficient to make price and wage rigidity a Nash-equilibrium. For the firms to keep prices fixed, menu costs must be greater than or equal to the loss in profits resulting from non-adjustment of prices. Following the standard approach, we approximate the profit loss by making a second order Taylor expansion on the profit function around the initial equilibrium. This gives (see Appendix B)

$$L_f \simeq (1-t_p)\frac{(1-\alpha)^2(1-\mu)}{2\alpha(1+\alpha\mu-\alpha)}\left(\frac{dm}{m}\right)^2, \tag{7}$$

where the loss is measured in proportion of firm revenue.

Analogously, workers choose to hold wages constant if menu costs are greater than or equal to the loss in utility resulting from non-adjustment. By making a second order Taylor approximation on the indirect utility function around the initial equilibrium, it can be shown that the utility loss of non-adjustment in proportion of the total wage bill equals (see Appendix C)

$$L_w \simeq (1-t_w)\frac{1-\rho}{2\gamma\alpha^2(1+\rho\gamma)}\left(\frac{dm}{m}\right)^2. \tag{8}$$

By simple inspection of equations (7) and (8), we may state the following proposition.

Proposition 1 (i) *The menu costs required for price rigidity are decreasing in the profit tax, t_p, and independent of the wage tax, t_w, and the payroll tax, t_{pr}.* (ii) *The menu costs required for wage rigidity are decreasing in the wage income tax, t_w, and independent of the profit tax, t_p, and the payroll tax, t_{pr}.*

The implication of Proposition 1 is that the presence of taxation, for a given level of menu costs, increases the range of nominal demand shocks leading to fluctuations in real variables. In other words, wage taxation increases the degree of wage rigidity while taxation of profits increases the degree of price rigidity.

Our formulation of the tax system allows for studying other types of taxes such as a value added tax, t_v, or a tax on firm revenues (sales tax), t_R. A value added tax corresponds to a general income tax, i.e. $t_w = t_p = t_v$ and $t_{pr} = 0$, which implies more rigidity in both prices and wages. A firm revenue tax corresponds to a uniform rate on profits and payrolls, i.e. $t_p = t_{pr} = t_R$, and according to Proposition 1 such a tax system increases the degree of price rigidity while leaving wage rigidity unaffected.

It is interesting that some of the basic equivalence and neutrality results from the theory of taxation break down once we account for the presence of nominal rigidities. In a frictionless economy, a wage tax is equivalent to a payroll tax in terms of the effects on equilibrium resource allocation and, likewise, there is no difference between a tax on firm revenues and a general income tax. However, in the presence of nominal imperfections it becomes important who pays the tax, firms or workers, and accordingly these taxes have different implications for the degree of nominal rigidity. Moreover, the result that a tax on pure profits is neutral for the resource allocation no longer holds. By increasing the degree of price rigidity, the imposition of profit taxes has real implications for the economy.

If menu costs are sufficiently large, a change in nominal demand will affect production, employment, and welfare. The effect on welfare of a change in the money stock is derived by making a second order Taylor approximation on (1) around the initial equilibrium. As shown in Appendix D, the welfare effect in proportion of aggregate income amounts to

$$W \simeq \frac{dm}{m} - \frac{(1-t_w)(1-t_p)}{1-t_p+t_{pr}}(1-\mu)(1-\rho)\left[\frac{dm}{m} + \frac{\gamma+1-\alpha\gamma}{2\alpha\gamma}\left(\frac{dm}{m}\right)^2\right]. \quad (9)$$

Consider, for example, a positive demand shock. Then the first component on the right hand side is the increase in welfare resulting from more consumption while the second component constitutes the loss in welfare due to an increase in the number of working hours. As production is below its first best level, a positive demand shock boosts total welfare, implying that the first component will always be numerically larger than the second component. Therefore, we can state the following proposition on the welfare consequences of nominal disturbances.

Proposition 2 *Fluctuations in welfare are increasing in the wage income tax, t_w, the payroll tax, t_{pr}, and the profit tax, t_p.*

The intuition behind Proposition 2 is easy to grasp. The presence of distortionary taxation moves the equilibrium level of activity further below its first best level. Because of the concavity of the utility function, a reduction in the equilibrium level of activity increases the slope of utility. Accordingly, the introduction of a tax system implies that fluctuations in consumption and employment take place where the utility function is steeper than it would otherwise have been.

Note also that in the absence of payroll taxes, the effect on welfare is independent of profit taxes. This is because taxes on pure profits, in this case, do not affect the equilibrium level of activity. Finally, a corollary on the above proposition is that value added taxes (i.e. $t_w = t_p = t_v$ and $t_{pr} = 0$) and revenue taxes (i.e. $t_p = t_{pr} = t_R$) also magnify the fluctuations in welfare, which is seen by inserting the respective definitions in equation (9).

4 Conclusion

The linkage between taxation and business cycles is more complex than previously thought. In a world of imperfect competition and nominal frictions, taxation will affect the price and wage setting decisions of firms and workers. In the widely used New Keynesian framework, we have shown that taxes act as automatic destabilizers. Firstly, taxes destabilize by increasing the degree of wage and price rigidity and, secondly, the presence of taxation magnifies the welfare consequences of nominal disturbances. These results are in sharp contrast to Agell and Dillén (1994) who claim that progressive taxes will make firms more prone to price adjustments, implying less volatility in output and welfare.

Our findings are also at odds with the old Keynesian idea that taxes serve as automatic stabilizers. Note, however, one important difference between our model and the traditional Keynesian fix price models. We assume, like Agell and Dillén (op.cit.), that the government keeps a balanced budget, so that the traditional effect of taxes on effective demand is neutralized. Accordingly, our sole focus is on the supply side effect of taxation whereas the traditional Keynesian approach concentrates entirely on the demand side effect. In reality, the effect of taxation on fluctuations will be a mixture of the supply side effects, stressed by the present paper, and the conventional demand side effect.

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A Derivation of Equation (6)

We start by deriving the aggregate demand for good j. By maximizing (1) subject to (2) and aggregating over the households, we obtain

$$c_j = \left(\frac{p_j}{p}\right)^{-1/\mu} \frac{m}{p}, \quad \text{where } p \equiv \left(\int_{j=0}^{1} p_j^{\frac{\mu-1}{\mu}} dj\right)^{\frac{\mu}{\mu-1}}. \tag{10}$$

Next, we find the demand for workers of type i by solving the cost minimization problem of firm j. This gives

$$l_{ij} = \left(\frac{w_i}{w}\right)^{-1/\rho} (\alpha y_j)^{\frac{1}{\alpha}}, \quad \text{where } w \equiv \left(\int_{i=0}^{1} w_i^{\frac{\rho-1}{\rho}} di\right)^{\frac{\rho}{\rho-1}}. \tag{11}$$

Then we insert equations (4), (10), and (11) so as to get the indirect profit function of firm j:

$$\begin{aligned} \pi(p_j, m) = {} & p_j \left(\frac{p_j}{p}\right)^{-\frac{1}{\mu}} \frac{m}{p} - w \left(\frac{p_j}{p}\right)^{-\frac{1}{\alpha\mu}} \left(\alpha \frac{m}{p}\right)^{\frac{1}{\alpha}} \\ & - T_p \left(p_j \left(\frac{p_j}{p}\right)^{-\frac{1}{\mu}} \frac{m}{p} - w \left(\frac{p_j}{p}\right)^{-\frac{1}{\alpha\mu}} \left(\alpha \frac{m}{p}\right)^{\frac{1}{\alpha}} \right) \\ & - T_{pr} \left(w \left(\frac{p_j}{p}\right)^{-\frac{1}{\alpha\mu}} \left(\alpha \frac{m}{p}\right)^{\frac{1}{\alpha}} \right). \end{aligned} \tag{12}$$

Maximizing the above equation with respect to p_j gives

$$\frac{p_j}{p} = \left[\frac{1 - t_p + t_{pr}}{1 - t_p} \frac{1}{1-\mu} \frac{w}{p} \left(\alpha \frac{m}{p}\right)^{\frac{1}{\alpha}-1} \right]^{\frac{\mu\alpha}{\mu\alpha+1-\alpha}}. \tag{13}$$

The utility of household i can be expressed in the following way

$$u_i = \frac{w_i l_i}{p} - \frac{T_w(w_i l_i)}{p} + \int_{j=0}^{1} \frac{\pi_{ij}}{p} dj + \frac{S_i}{p} - \tfrac{\gamma}{\gamma+1} l_i^{\frac{\gamma+1}{\gamma}}. \tag{14}$$

The aggregate demand for the labor of worker i is derived from equation (11) and inserted into the above equation so as to get the indirect utility function

$$\begin{aligned} v(w_i, m) = {} & \frac{w_i}{p} \left(\frac{w_i}{w}\right)^{-1/\rho} \left(\alpha \frac{m}{p}\right)^{\frac{1}{\alpha}} - \frac{1}{p} T_w \left(w_i \left(\frac{w_i}{w}\right)^{-1/\rho} \left(\alpha \frac{m}{p}\right)^{\frac{1}{\alpha}} \right) \\ & + \int_{j=0}^{1} \frac{\pi_{ij}}{p} dj + \frac{S_i}{p} - \tfrac{\gamma}{\gamma+1} \left(\left(\frac{w_i}{w}\right)^{-1/\rho} \left(\alpha \frac{m}{p}\right)^{\frac{1}{\alpha}} \right)^{\frac{\gamma+1}{\gamma}}. \end{aligned} \tag{15}$$

Taking the derivative with respect to w_i, we obtain

$$\frac{w_i}{w} = \left((1 - t_w)(1 - \rho) \frac{w}{p} \right)^{-\frac{\rho\gamma}{1+\rho\gamma}} \left(\alpha \frac{m}{p} \right)^{\frac{\rho}{\alpha(1+\rho\gamma)}}. \tag{16}$$

A symmetric equilibrium satisfies $w_i = w \ \forall i$ and $p_j = p \ \forall j$. Using this and equations (13) and (16), we get

$$y = \frac{m}{p} = \frac{1}{\alpha} \left(\frac{(1 - t_p)(1 - t_w)}{1 - t_p + t_{pr}} (1 - \mu)(1 - \rho) \right)^{\frac{\alpha\gamma}{1+\gamma(1-\alpha)}}.$$

B Derivation of Equation (7)

The profit loss of non-adjustment is derived by making a second order Taylor expansion on (12) around the initial equilibrium, assuming that other firms do not change their prices and that workers keep wages fixed.

If firm j chooses not to adjust its price, profits equal

$$\pi^N \simeq \pi^0 + \pi_2 dm + \frac{1}{2}\pi_{22} (dm)^2,$$

where π^0 is profits in the initial equilibrium and π_2 and π_{22} are derivatives of (12) evaluated in the initial equilibrium. If the firm instead chooses to adjust its price, profits equal

$$\pi^A \simeq \pi^0 + \pi_1 dp_j + \pi_2 dm + \frac{1}{2}\pi_{11} (dp_j)^2 + \frac{1}{2}\pi_{22} (dm)^2 + \pi_{12} dp_j dm.$$

The loss of non-adjustment is found by subtracting π^N from π^A and using the envelope theorem, i.e. $\pi_1 = 0$:

$$d\pi = \pi^A - \pi^N \simeq \pi_{12} dm dp_j + \frac{1}{2}\pi_{11} (dp_j)^2. \tag{17}$$

Differentiating (12) and using the fact that $\pi_1 = 0$ and $p_j = p \ \forall j$ in the initial equilibrium, we obtain

$$\begin{aligned} \pi_{11} &= (1 - t_p) \frac{1 + \alpha\mu - \alpha}{\alpha\mu} \left(1 - \frac{1}{\mu} \right) \frac{m}{p^2}, \\ \pi_{12} &= (1 - t_p) \left(1 - \frac{1}{\alpha} \right) \left(1 - \frac{1}{\mu} \right) \frac{1}{p}. \end{aligned}$$

From equation (13), we get

$$\frac{dp_j}{p} = \frac{dp_j}{p_j} = \frac{\mu\alpha}{\mu\alpha + 1 - \alpha} \left(\frac{1}{\alpha} - 1 \right) \frac{dm}{m} = \mu \frac{1 - \alpha}{1 + \alpha\mu - \alpha} \frac{dm}{m}.$$

By insertion of the three above equations in (17), we get

$$d\pi \simeq (1-t_p)\frac{(1-\alpha)^2(1-\mu)}{2\alpha(1+\alpha\mu-\alpha)}m\left(\frac{dm}{m}\right)^2.$$

Finally, by measuring the loss relative to firm revenue, $p_j y_j = m$, we obtain equation (7).

C Derivation of Equation (8)

Reasoning analogous to the derivation of (17) implies that the utility loss from not adjusting the wage, w_i, may be approximated by

$$dv \simeq v_{12}dmdw_i + \frac{1}{2}v_{11}(dw_i)^2, \tag{18}$$

where v_{12} and v_{11} are derivatives of equation (15) evaluated in the initial equilibrium. Differentiating (15) and using the fact that $v_1 = 0$ and $w_i = w\ \forall i$ in the initial equilibrium, we obtain

$$\begin{aligned} v_{11} &= (1-t_w)\frac{1+\rho\gamma}{\rho\gamma}\left(1-\frac{1}{\rho}\right)\frac{wl}{p}\frac{1}{w^2}, \\ v_{12} &= -(1-t_w)\frac{1}{\gamma\alpha}\left(1-\frac{1}{\rho}\right)\frac{wl}{p}\frac{1}{mw}. \end{aligned}$$

From equation (16), we have

$$\frac{dw_i}{w} = \frac{dw_i}{w_i} = \frac{\rho}{\alpha(1+\rho\gamma)}\frac{dm}{m}.$$

By insertion of the three above equations in (18), we obtain

$$dv \simeq (1-t_w)\frac{1-\rho}{2\gamma\alpha^2(1+\rho\gamma)}\frac{wl}{p}\left(\frac{dm}{m}\right)^2.$$

By measuring the loss in proportion of real wage income, wl/p, we obtain equation (8).

D Derivation of Equation (9)

In equilibrium the aggregate utility of households may be written in the following manner

$$u \equiv \int_{i=0}^{1} u_i di = \frac{m}{p} - \frac{\gamma}{\gamma+1}l^{\frac{\gamma+1}{\gamma}} = \frac{m}{p} - \frac{\gamma}{\gamma+1}\left(\alpha\frac{m}{p}\right)^{\frac{\gamma+1}{\alpha\gamma}},$$

where the last equality follows from the production function (4) and the fact that $l_{ij} = l \; \forall i, j$ and $y_j = y = m/p \; \forall j$ in equilibrium. A second order Taylor expansion around the initial equilibrium yields

$$du = \frac{dm}{p} - \left(\alpha \frac{m}{p}\right)^{\frac{\gamma+1}{\alpha\gamma}-1} \frac{1}{p} dm - \frac{1}{2}\left(\frac{\gamma+1}{\alpha\gamma} - 1\right) \alpha \left(\alpha \frac{m}{p}\right)^{\frac{\gamma+1}{\alpha\gamma}-2} \left(\frac{1}{p}\right)^2 (dm)^2,$$

or, equivalently,

$$du = \frac{dm}{m}\frac{m}{p} - \frac{1}{\alpha}\left(\alpha \frac{m}{p}\right)^{\frac{\gamma+1}{\alpha\gamma}} \frac{dm}{m} - \frac{1}{2}\left(\frac{\gamma+1}{\alpha\gamma} - 1\right) \frac{1}{\alpha} \left(\alpha \frac{m}{p}\right)^{\frac{\gamma+1}{\alpha\gamma}} \left(\frac{dm}{m}\right)^2.$$

By insertion of $m/p = y$ and (6) in the above equation and measuring the change in welfare in proportion of aggregate income, we obtain equation (9).