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MACROECONOMIC EXTERNALITIES: ARE PIGOVIAN TAXES THE ANSWER?

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MACROECONOMIC EXTERNALITIES:

ARE PIGOVIAN TAXES THE ANSWER?*

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Abstract. Basic welfare economics tells us that many types of externalities can be remedied by proper use of corrective taxes and subsidies. This paper shows that this notion also extends to the macroeconomic externalities discussed in recent Keynesian literature on nominal price rigidities. The derived policy rules are kindred in spirit to standard Keynesian policy prescriptions: Progressive income taxes may serve a useful role in combating wasteful economic fluctuations. However, unlike older fix–price models of automatic stabilizers, progressive taxes work in our monopolistic economy because they directly affect the pricing mechanism.

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I. Introduction

A main message of modern Keynesian theories of the business cycle is that individually efficient nominal price stickiness may come hand–in–hand with socially inefficient and demand–driven output fluctuations.[1] At the heart of the problem is a negative macroeconomic externality. In the words of Ball, Mankiw and Romer [1988, p. 15], "rigidity in one firm's price contributes to rigidity in the price level, which causes fluctuations in real aggregate demand and thus harms all firms". Basic welfare economics tells us that many types of externalities can be remedied by proper use of corrective taxes and subsidies. This paper shows that this notion also extends to the macroeconomic externalities emphasized in recent literature.

Using a simple macroeconomic model of a monopolistically competitive economy, where agents face small costs of changing prices, we demonstrate that any degree of price flexibility can be accomplished by a suitably designed tax system. We also show the existence of an optimal tax and subsidy scheme, which allows the government to realign private and social costs of individual price rigidity. In this interventionist equilibrium, aggregate output fluctuations are indeed optimal; for any given distribution of nominal demand shocks, the remaining output fluctuations simply reflect a socially optimal trade–off between the costs of changing prices and the costs of aggregate output fluctuations.

The optimal tax system is progressive, and the tax base is defined in terms of real incomes. By punishing quantity adjustments around some "natural" production level, a progressive tax system makes price setters more prone to price adjustments in response to aggregate demand disturbances. The idea that a progressive tax structure may mitigate harmful business cycle fluctuations is of course central to traditional Keynesian theories of automatic stabilizers. However, unlike older

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[1]For recent expositions of the literature, see Blanchard and Fischer [1989] and Gordon [1990].

fix–price models of automatic stabilizers, progressive taxes work in our monopolistic economy because they directly affect the pricing mechanism.

II. The Model

Our model is a simplified version of that of Blanchard and Kiyotaki [1987], also used by e.g. Ball and Romer [1989, 1990]. To this simple work–horse model of monopolistic competition we add a flexible formulation of an income tax system, which allows us to investigate the effects of taxes on economic stability and efficiency. The model consists of N producer–household units, each of them producing a good which is an imperfect substitute for other goods, and taking each others' prices as parametrically given. Household i has the utility function

$$(1) \qquad u_i = c_i - \frac{1}{\gamma} l_i^{\gamma} - zD_i, \quad \gamma > 1, \text{ where}$$

$$(2) \qquad c_i = N\left[\frac{1}{N}\sum_{j=1}^{N} c_{ij}^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}.$$

The utility function is additively separable in utility from a consumption index, c_i, and disutility of supplying labor, $\frac{1}{\gamma} l_i^{\gamma}$, where γ–1 is the elasticity of marginal disutility of labor (γ>1), and $1/\gamma$ is a normalization factor. The term $(\epsilon-1)/\epsilon$ measures the substitutability between goods (ϵ>1). If the household decides to change the price of its product a small 'menu–cost', z, occurs and $D_i = 1$, otherwise D_i equals zero. The production function is of the constant returns to scale variety:

$$(3) \qquad y_i = l_i.$$

The demand for the product of household i, implied by (1), is[2]

[2]For the derivations of equations (4)–(6), see Blanchard and Kiyotaki [1987].

$$y_i^d = \left(\frac{p_i}{p}\right)^{-\epsilon} c, \text{ where} \tag{4}$$

$$c = \frac{1}{N} \sum_{j=1}^{N} c_j \tag{5}$$

$$p = \left[\frac{1}{N} \sum_{j=1}^{N} p_j^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}. \tag{6}$$

Here p_i is the price of good i, p is the price index for the consumption basket, and c is a per capita measure of aggregate consumption.

The presence of an income tax does not affect the optimal composition of consumption goods.[3] However, the tax system does affect the choice between consumption of leisure and consumption of the composite good. The tax system is based on real income, and the budget constraint of household i is

$$c_i = \tau_0 \left[\frac{p_i y_i}{p}\right]^{\tau_1} + \frac{T}{p}, \tag{7}$$

where τ_0 and τ_1 are tax–parameters, and T is a nominal lump–sum transfer from the government. In the absence of taxes, $\tau_0 = \tau_1 = 1$ and T=0, and (7) reduces to the no–tax budget constraint of Ball and Romer [1989].

Our isoelastic specification of the tax system is sufficiently flexible to describe a variety of income tax systems. In the following a key parameter is τ_1, which is the elasticity of disposable labor income – the first term on the RHS of (7) – with respect to changes in real gross labor income. Whenever τ_1 is less than unity, the tax system is progressive in the sense that the implied marginal tax rate is an increasing function of real labor income; when τ_1 is greater than unity, the tax system is regressive. Also, following the discussion of Jakobsson [1976] of elasticity based measures of tax progression, we say that the degree of tax progression

[3]Equations (1)–(6) correspond to the first six equations in Ball and Romer [1989].

increases with decreases in τ_1.

Assume, as Ball and Romer, a linear monetary transactions technology. Equilibrium in the money market then implies

(8)
$$\frac{M}{p} = c,$$

where M is per capita nominal money supply. Combining (1), (3), (4), (7) and (8), household i's utility can be written as

(9)
$$u_i = \tau_0\left(\frac{M}{p}\right)^{\tau_1}\left[\frac{p_i}{p}\right]^{(1-\epsilon)\tau_1} - \frac{1}{\gamma}\left[\frac{M}{p}\right]^{\gamma}\left[\frac{p_i}{p}\right]^{-\gamma\epsilon} + \frac{T}{p} - zD_i,$$

i.e. the leisure–consumption decision of household i reduces to a price setting problem. Maximizing (9) with respect to p_i, for the time being disregarding the menu cost term, gives us the optimal price rule,

(10)
$$\frac{p_i^*}{p} = A\left[\frac{M}{p}\right]^{\beta},$$

where $\beta = \dfrac{\gamma-\tau_1}{\tau_1-\tau_1\epsilon+\gamma\epsilon}$

$$A = \left[\frac{\epsilon}{\epsilon-1}\,(\tau_0\tau_1)^{-1}\right]^{\frac{1}{\tau_1-\tau_1\epsilon+\gamma\epsilon}}.$$

The second–order condition reduces to $\gamma\epsilon-\tau_1\epsilon+\tau_1>0$. For this to hold for any $\epsilon>1$, we must have that $\tau_1<\gamma$. As $\gamma>1$, this means that the tax system must not be "too" regressive.

In what follows, an important parameter is β, which is the elasticity of household i's relative price with respect to aggregate demand.[4] As should be expected, β is a decreasing function of the demand elasticity ϵ, and an increasing

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[4]From the second–order condition, it is easy to show that β must be greater than zero but less than unity.

function of the elasticity of marginal disutility of labor, $\gamma-1$.

More interesting, however, is the fact that β also depends on the progressivity parameter τ_1. In particular, we have that $\frac{\partial\beta}{\partial\tau_1}<0$, i.e. more tax progression increases the flexibility of relative prices. A lower value of τ_1, and therefore a higher degree of tax progression, makes the household less willing to accommodate an increase in aggregate demand by increasing labor supply, and more prone to relative price adjustment.[5] Conversely, a decrease in aggregate demand now has a smaller negative effect on household production, since the induced decrease in the marginal tax rate stimulates labor supply.

Symmetric equilibrium requires that $p_i/p = 1$, which means, from (8) and (10), that equilibrium consumption in the absence of menu costs becomes

$$c = \left[(\frac{\epsilon-1}{\epsilon})\tau_0\tau_1\right]^{\frac{1}{\gamma-\tau_1}}, \tag{11}$$

where $c = c_i = y_i = l_i = M/p$.

III. The Optimal Tax System

The economy just described exhibits two market failures compared to a competitive Walrasian world. First, due to monopolistic competition the initial – or "natural" – production level is too low. Second, if we take on board the existence of

[5]Here a note of caution is in order. Both price and quantity adjustments increase the tax base of the household. However, as the demand elasticity ϵ is greater than unity, the tax base increases by a smaller amount in the case of a relative price adjustment. The negative relation between the labor supply elasticity and τ_1 is easy to demonstrate. Combining (3), (4) and (10) we obtain labor supply as a function of real aggregate demand:

$$l_i = (M/p)^{\pi},$$

where $\pi = \tau_1/(\tau_1-\tau_1\epsilon+\gamma\epsilon)$. Clearly, π decreases with decreases in τ_1.

small menu costs of changing prices there is scope for excessive nominal price stickiness in response to fluctuations in aggregate demand.

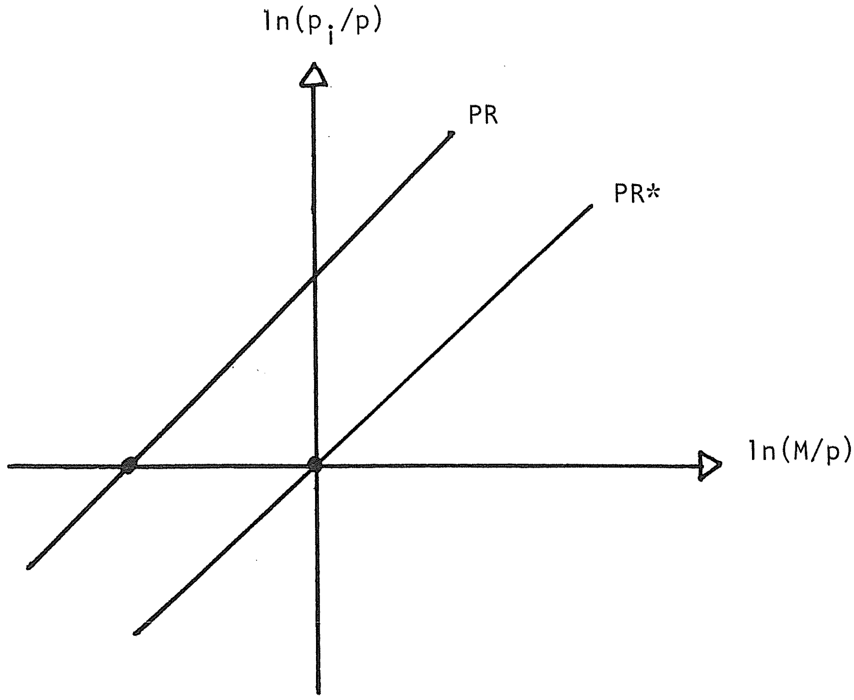
The inefficiency associated with monopolistic competition per se is easy to remedy. Assuming no taxes ($\tau_0=\tau_1=1$) and taking the limit when ϵ goes to infinity, we see from (11) that the competitive and Pareto optimal production level is unity. It is a standard exercise to transform the monopolistic equilibrium into a first–best optimum. From (11), the optimal tax rule in the absence of money shocks becomes

$$\tau_0\tau_1 = \frac{\epsilon}{\epsilon-1}\,, \tag{12}$$

which increases output to unity and eliminates the suboptimality associated with monopolistic competition. The optimal tax system implies a subsidy proportional to the mark–up factor, financed by a uniform lump–sum tax.

Turning to the inefficiency associated with excessive output volatility in response to nominal demand shocks, some intuition is gained from Figure 1, which shows the optimal price rule (in logarithms) given in (10). Only points located on the horizontal axis are consistent with a symmetric equilibrium. In the absence of corrective taxes the price rule (PR) intersects the horizontal axis somewhere to the left of the origin. With tax rates determined as in (12) the price rule shifts to the right (PR*), and intersects the vertical axis at the origin, where log A is zero and output is unity. The important observation is that the government for any given value of our progressivity measure τ_1 can find a value of τ_0 which satisfies (12). As the slope of the price rule is nothing but the elasticity β, which depends on τ_1 but not on τ_0, the government is left with enough degrees of freedom to simultaneously move the economy to the origin and determine β at its own discretion. As β measures the flexibility of individual prices in response to changes in aggregate demand, this suggests the existence of an optimal tax policy which also remedies the macroeconomic externality due to excessive nominal price stickiness.

Figure 1



To formalize this intuition, consider an initial monopolistic equilibrium where prices are chosen optimally by all agents. Consider then a small and unexpected change in nominal money supply, such that $M_1 = M_0(1+\delta)$, where M_0 is intial nominal money supply, and δ is some small (positive or negative) money shock.[6] The envelope theorem now suggests that the representative household's private loss from not changing its relative price, given that the other households' prices remain unchanged, is of second–order importance. Price changes will occur only if this private loss, $L_p(\delta)$, is larger than the menu–cost, z. Invoking expressions derived in the previous section, it is a standard exercise (see Appendix) to approximate the private loss function by a second–order Taylor expansion around $\delta=0$:

$$L_p(\delta) \simeq \frac{1}{2}\epsilon\beta(\gamma - \tau_1)c_0^{\gamma}\delta^2, \tag{13}$$

where c_0 is the initial consumption level. If the menu cost is sufficiently large compared to the money disturbance δ, price stickiness prevails, and the new equilibrium is obtained by quantity adjustment. Given c_0 we note that $L_p(\delta)$ increases as the degree of tax progression increases.[7]

However, price changes create a macroeconomic externality which the price–setting agent ignores. To account for this externality we need a measure of the social cost of price stickiness, $L_s(\delta)$. We may think of the social cost as the

[6]From a theoretical standpoint a more satisfying approach would be to follow Ball and Romer [1989] in considering the decision problem of the household when confronted with a distribution of shocks. However, for our purpose it is sufficient to proceed in a more simplistic manner and only consider the response to a single money supply shock.

[7]For the interpretation of (13), note that the product $\epsilon\beta$ defines the percentage change in individual production induced by a one percent change in aggregate demand. From (9) we note that the term $\gamma-\tau_1$ represents the net utility effect of a ceteris paribus change in aggregate demand. The higher is γ, or the smaller is τ_1, the larger is the net utility loss of increasing labor supply in response to an increase in aggregate demand.

difference between the utility when all households change their prices optimally and the utility when no one changes price. The implied loss function can be approximated (see Appendix) as

$$L_s(\delta) \simeq (c_0^{\gamma}-c_0)\delta + \tfrac{1}{2}(\gamma-1)c_0^{\gamma}\delta^2 . \tag{14}$$

The first–order term in (14) simply reflects the fact that the initial output level c_0, in the absence of corrective taxes, is too low under monopolistic competition. As a consequence, any money shock (positive or negative) has "large" effects on social welfare [Mankiw, 1985]. With an optimal tax system satisfying (12) the initial output level is unity, and the first–order term in (14) vanishes. In a first–best social optimum the envelope principle again applies: Small departures from the optimal allocation create only second–order losses in social welfare.[8]

Calculating the ratio between social and private losses, R, when (12) holds, we obtain

$$R = \frac{L_s(\delta)}{L_p(\delta)} = \frac{(\gamma-1)(\tau_1-\tau_1\epsilon+\gamma\epsilon)}{\epsilon(\gamma-\tau_1)^2} . \tag{15}$$

In a taxless society, R is always greater than one, implying that the social costs of price stickiness always exceed the private costs.

The main message of this paper is that the implied negative macroeconomic externality can be dealt with by tax policies that directly aim at the pricing mechanism. By a proper choice of the progressivity parameter τ_1 the government may realign private and social costs of stickiness. Setting R equal to unity, we obtain a quadratic equation in τ_1, with roots:

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[8]This point is made by Ball and Romer [1989]. They also make the important additional point that the first–order welfare effects average to zero if we consider any symmetric distribution for δ with mean zero [see also Rotemberg, 1987].

$$(16) \qquad \tau_1 = \frac{\gamma+\epsilon+\gamma\epsilon-1}{2\,\epsilon} \pm \{(\frac{\gamma+\epsilon+\gamma\epsilon-1}{2\,\epsilon})^2 - \gamma\}^{1/2},$$

where the expression within brackets on the RHS is always positive.

It is easy to prove that the larger root is greater than γ.[9] But to satisfy the second–order condition for utility maximization we need τ_1 to be less than γ. The smaller root fulfils this condition, because it is always less than one (and greater than zero), thus satisfying our definition of progressivity.[10] From now on we restrict our attention to this second root and denote it τ_1^*.

The argument for tax progression can now be summarized. Just as social welfare increases if a firm has to pay the full social cost of its "downstreams" pollutions, tax progression increases social welfare by inreasing the private cost of excessive price rigidity. By setting the progressivity parameter at τ_1^* the government may internalize the implied negative macroeconomic externality. As price setters then face the true social cost of stickiness, an optimal degree of price flexibility comes forth. Given τ_1^*, (12) then suggests an optimal value of τ_0, which the government can choose to push the natural production level to that prevailing in a competitive first–best equilibrium.

It should be noted that the optimal tax system is independent of the

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[9]This follows from a proof of contradiction. Suppose that the larger root, τ_1^L, is such that $\tau_1^L \leq \gamma$. Then it must be the case that

$$(\gamma+\epsilon+\gamma\epsilon-1)/2\epsilon + \{((\gamma+\epsilon+\gamma\epsilon-1)/2\epsilon)^2 - \gamma\}^{1/2} \leq \gamma,$$

which after some manipulations reduces to

$$(\gamma-1)/\epsilon \leq 0,$$

which is impossible for any $\gamma > 1$, and any $\epsilon \in (1, \infty)$.

[10]That the smaller root, τ_1^S, is greater than zero follows directly from (16). To show that $\tau_1^S < 1$, we use a proof of contradiction similar to that given in the previous footnote.

magnitude of nominal demand disturbances. From (16) the optimal tax system depends on the preference parameters γ and ϵ, but not on the money shock δ. Our optimal tax system thus represents a systematic feedback rule, which stabilizes output for any given distribution of nominal demand shocks.[11]

IV. Some Illustrative Examples

Table 1 gives the externality measure R, evaluated when τ_1=1, and the optimal progressivity parameter τ_1^* for different values of γ and ϵ. Starting with the value of R the point of Ball and Romer [1989] stands out. For plausible values of ϵ and γ, R turns out to be small. Lest the special case of a very elastic labor supply the social cost of rigidity is never more, and typically less, than two times as large as the corresponding private cost.[12] For our purpose, however, the "smallness" of the reported externalities is of less concern. What matters is the fact that they are representative of a macroeconomic coordination failure, which in richer models – combining real and nominal sources of rigidity – is likely to be much larger.[13] The important point is that in either case the externality, be it large or small, can be dealt with by tax policies aiming directly at the pricing mechanism.

Turning to the tax elasticities, a clear pattern emerges. For any given value of γ, the optimal degree of tax progression decreases rapidly with the demand elasticity ϵ. When ϵ is small (i.e. when the economy is highly monopolistic), the externality from rigidity is relatively large. As a consequence, a rather progressive

[11]As an aside, we may note that our analysis also has a bearing on other issues discussed in related literature. In models with small menu costs there might be multiple equilibria. For monetary shocks within a certain interval, both flexibility and rigidity of prices are possible equilibrium outcomes. The existence of multiple equilibria implies that monetary shocks can cause coordination problems of the type discussed by Cooper and John [1988]. As shown by Ball and Romer [1987], the range of shocks for which we have multiple equilibria depends negatively on the elasticity β. A higher value of β due to increased tax progression makes this range smaller.

[12]As the compensated labor supply elasticity can be derived as $1/(\gamma-1)$, a γ equal to 2 implies an elasticity of unity.

[13]See e.g. Akerlof and Yellen [1985] and Ball and Romer [1990].

Table 1

	γ					
	1.01		2		5	
ϵ	R	τ_1^*	R	τ_1^*	R	τ_1^*
1.5	67.67	0.93	1.67	0.67	1.17	0.62
2	51.00	0.94	1.50	0.72	1.12	0.68
5	21.00	0.96	1.20	0.85	1.05	0.84
10	11.00	0.97	1.10	0.92	1.02	0.91

tax system is required in order to realign the private and social costs of rigidity. In the limiting case when ϵ goes to infinity (i.e. when the monopolistic equilibrium is transformed into a competitive one) the externality problem vanishes. There is no longer need for corrective taxes: τ_1^* is unity.

Turning to the relationship between γ and τ_1^* the intuition gets more involved. When γ is small (i.e. when the labor supply elasticity is large), households are more prone to quantity adjustments in response to changes in aggregate demand, which in turn implies a more pronounced externality problem. In the (unrealistic) case when γ is 1.01 and ϵ is 2, R becomes 51. However, taking care of this large externality requires only a small degree of tax progression. Setting τ_1 equal to .94, social and private costs of rigidity are equalized. As γ increases, while keeping ϵ fixed at 2, both R and τ_1^* decreases. Thus, somewhat paradoxically, the optimal degree of tax progression is a decreasing function of the magnitude of the externality without taxes. Intuitively, when marginal disutility of labor is almost constant (in the limiting case when γ goes to unity, the utility function becomes linear in labor) and the externality is large, only little progressivity is needed to drastically alter the trade–off between marginal utility of consumption (when τ_1 is unity marginal utility of consumption is also a constant) and marginal disutility of labor, which determines the optimal response to an aggregate demand shock.

V. Conclusions

Our results are kindred in spirit to traditional Keynesian policy prescriptions: Progressive taxes may serve a useful purpose in combating wasteful economic fluctuations. The mechanisms differ, however. In the old fix–price version of the Keynesian model automatic stabilizers, like progressive taxes, worked because they decreased the variability of disposable income. In our model with price setting agents, progressive tax rules work because they directly affect the pricing mechanism.[14] This finding appears robust, going beyond the confines of our specific model. In any story of nominal rigidity the slope of the relevant marginal cost curve is a decisive factor [Gordon, 1990]. Consider a textbook monopolist, facing a downward sloping marginal revenue curve, and using labor as the only input. In principle, any policy that increases the slope of the marginal cost curve of the monopolist will induce more price flexibility and less output variability in response to shifts in the marginal revenue curve. Clearly, one way to increase the steepness of the marginal cost curve is to introduce a progressive pay–roll tax (possibly combined with some subsidy scheme which simultaneously shifts the position of the curve).

Any exercise in optimal taxation should be taken with a grain of salt. Our crude representative–artisan model produces deceptively simple optimal tax formulas. An attempt at formulating practically useful tax rules along these lines would soon run into problems, not the least because of the heterogeneity of price setters in the real world. Furthermore, underlying our main results is the assumption that the government can maintain a balanced budget by use of lump–sum taxes. Hence, the government is left with enough degrees of freedom to simultaneously remedy the market failure associated with monopolistic competition per se, and that associated with the macroeconomic externality. In the absence of lump–sum taxes the optimal tax system must set the gains from output stabilization against the potential losses in terms of average production levels. However, viewed as an exercise in positive economics, the unrealism of our analysis seems less crucial. The institutional set–up, of which the tax system is an integral part, does affect the behaviour of price setters in the real world. To the extent that excessive nominal rigidities are the cause of important macroeconomic problems, intelligent tax policy might do something about it.

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[14]While the mechanisms differ the idea that tax policy can affect pricing decisions is also central to recent policy proposals concerning tax based incomes policies to fight inflation.

Appendix

A. The derivation of (13)

Consider an initial equilibrium, denoted by subscript 0, where $M_0/p_0=c_0$ and $p_{i0}/p_0=1$. Consider then an unexpected money supply shock δ. The private loss from rigidity is then defined as

$$\text{(A1)} \qquad L_p(\delta)=u_i^*(\delta,\, p_0)-u_i(\delta,\, p_0,\, p_{i0}),$$

where $u_i^*(.)$ is the utility of household i with optimal price adjustment, and $u_i(.)$ is utility with no price adjustment. Combining (9) and (10), ignoring the menu cost term and using the fact that $M_1=(1+\delta)M_0$, we obtain

$$\text{(A2)} \quad L_p(\delta) = [\tau_0 c_0^{\tau_1} - \frac{1}{\gamma} c_0^{\gamma}](1+\delta)^{\frac{\gamma\tau_1}{\tau_1-\tau_1\epsilon+\gamma\epsilon}} - [\tau_0 c_0^{\tau_1}(1+\delta)^{\tau_1} - \frac{1}{\gamma} c_0^{\gamma}(1+\delta)^{\gamma}],$$

where the lump–sum tax T/p is canceled out. Invoking a second–order Taylor expansion around $\delta=0$, we obtain (13).

B. The derivation of (14)

The social cost of rigidity is defined as the difference between utility when all households change prices optimally and utility when no one changes price:

$$\text{(A3)} \quad L_s(\delta) = [\tau_0 c_1^{\tau_1} - \frac{1}{\gamma} c_1^{\gamma} + T_1/p_1] - [\tau_0 c_0^{\tau_1}(1+\delta)^{\tau_1} - \frac{1}{\gamma} c_0^{\gamma}(1+\delta)^{\gamma} + T_0/p_0],$$

where subscript 1 denotes the new equilibrium, when everyone changes prices optimally, and where $c_1=M_1/p_1$. In any symmetric equilibrium, a balanced government budget implies that lump–sum taxes must satisfy

(A4) $$T/p = c - \tau_0 c^{\tau_1}.$$

Combining (A3) and (A4), using that $M_1=(1+\delta)M_0$ and $p_1=(1+\delta)p_0$, we finally obtain

(A5) $$L_s(\delta) = c_0 - \frac{1}{\gamma}c_0^\gamma - [c_0(1+\delta) - \frac{1}{\gamma}c_0^\gamma(1+\delta)^\gamma].$$

Approximating (A5) by a second–order Taylor expansion, we obtain (14).

References

Akerlof, G. A. and Yellen, J. L. [1985], "A Near–Rational Model of the Business Cycle, with Wage and Price Inertia", **Quarterly Journal of Economics** (suppl.), 100, 823–38.

Ball, L., Mankiw, N. G. and Romer, D. [1988], "The New Keynesian Economics and the Output–Inflation Trade–Off", **Brookings Papers on Economic Activity**, 1988 (1), 1–65.

Ball, L. and Romer, D. [1987], "Sticky Prices as Coordination Failure", National Bureau of Economic Research, Working Paper No. 2327.

Ball, L. and Romer, D. [1989], "Are Prices too Sticky?", **Quarterly Journal of Economics**, 104, 507–24.

Ball, L. and Romer, D. [1990], "Real Rigidities and the Non–Neutrality of Money", **Review of Economic Studies**, 57, 183–203.

Blanchard, O. J. and Fischer, S. [1989], **Lectures on Macroeconomics** (Cambridge: MIT Press).

Blanchard, O. J. and Kiyotaki, N. [1987], "Monopolistic Competition and the Effects on Aggregate Demand", **American Economic Review**, 77, 647–66.

Cooper, R. and John, A. [1988], "Coordinating Coordination Failures in Keynesian Models", **Quarterly Journal of Economics**, 103, 441–63.

Gordon, R. J. [1990], "What is New–Keynesian Economics", **Journal of Economic Literature**, 28, 1115–171.

Jakobsson, U. [1976], "On the Measurement of the Degree of Progression", **Journal of Public Economics**, 5, 161–8.

Mankiw, N. G. [1985], "Small Menu Costs and Large Business Cycles", **Quarterly Journal of Economics**, 100, 529–37.

Rotemberg, J. [1987], "The New Keynesian Microfoundations", **NBER Macroeconomics Annual**, 69–104.