Do the New Keynesian Microfoundations Rationalise Stabilisation Policy?*

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Abstract

Systematic monetary policy is analysed in a two period extension of standard, static New Keynesian models. It is shown that countercyclical policies increase the band of inaction of the price setters, and that this feed-back effect on price rigidity may make such policies "self-justifying"; that is, the policies themselves cause the fluctuations that they are stabilising. Moreover, countercyclical policies may in general reduce welfare. In fact, socially optimal policies may very well involve a commitment to enhance shocks.

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The presence of small price adjustment costs has been one of the prominent explanations of money non-neutrality since the seminal work of Mankiw (1985), Akerlof and Yellen (1985), and Blanchard and Kiyotaki (1987), and by now there are several empirical studies that support the so-called menu cost hypothesis: For instance, Levy et al. (1997) and Dutta et al. (1999) find non-trivial costs of price adjustments in their empirical studies of large super market and drugstore chains in the United States; Wilson (1998) finds considerable price stickiness in the short run in an experimental investigation of the consequences of menu costs; and Ravn and Sola (1998) find evidence in favour of the menu cost prediction that "small" unanticipated money-supply disturbances have real effects whereas "big" ones are neutral using US macro data.

One of the main theoretical insights is that menu costs and imperfectly competitive behaviour interact in a way such that nominal demand disturbances give rise to inefficiently large fluctuations in output. It has therefore been argued that the New Keynesian theory may have provided the micro foundation for pursuing traditional stabilisation policies.[1] For example, it seems reasonable to expect that a negative shock, which pulls the underlying optimal prices below the actual prices, may be neutralised by a monetary

[1] For instance, David Romer writes on New Keynesian models that "they suggest the possibility that nominal frictions may lead to an inefficiently high level of volatility and that government stabilization policy may therefore be desirable" (Romer, 1993, p. 13).

expansion that drives the underlying optimal prices back towards the actual prices.

Despite this, little has been done to actually analyse such macroeconomic policies within menu cost frameworks.[2] Instead, it is common to analyse macroeconomic policy in models where price rigidity is assumed rather than derived – and then maybe justify the assumption of price rigidity by referring to the menu cost literature.[3] This procedure is probably an innocent short-cut if there are no feed-back effects from the policy to the degree of price rigidity. However, as this paper demonstrates this is unlikely to be the case: macroeconomic policies influence the consequences of shocks and therefore also the agents' decisions on whether to adjust prices or not following a shock. To see this, consider an economy that is hit by a single shock which creates a permanent difference between actual and optimal prices. Without any policy the agents have great incentives to pay the menu costs and adjust their prices to the new optimal levels. On the other hand, if the agents know that the

[2] To my knowledge, only one previous paper has examined such issues, namely Hansen (1996). He shows that an asymmetric monetary policy that exactly offsets negative disturbances and leaves the economy to itself in the case of positive disturbances increases the average output of a firm facing price adjustment costs. It is not addressed whether it is socially optimal to pursue such inflationary policy. Ball and Mankiw (1994) conclude that trend inflation creates asymmetric responses to shocks but that the optimal rate is zero. This paper abstracts from this issue by only considering symmetric monetary policy.

[3] For example, Obstfeld and Rogoff (1995) assume that nominal prices are predetermined and argue that all results can be reinterpreted in a setting with menu costs. Clarida et al. (1999) call their analysis a New Keynesian perspective although it is assumed that each agent's price is fixed with a given probability, and therefore that price rigidity is independent of economic circumstances.

central bank will adjust the underlying optimal prices to the actual levels through money supply changes immediately after (if they themselves decide not to adjust) then they have no incentives to pay the menu costs.

Of course, it is not realistic that a central bank can react immediately after a shock. Instead, this paper assumes that it takes some time before the central bank can observe and react to a downturn or an upturn. Following a shock the agents decide whether or not to adjust prices and in case they do not, there will be a downturn or an upturn on which the central bank reacts with a lag. If the central bank simply chooses to offset all shocks then it removes the consequences of a shock after the intervention, but it also increases the band of inaction of the price setters who will accept larger shocks before they adjust prices. In this sense, simple stabilisation policies increase price rigidity, and as a consequence such policies may become "self-justifying". That is, countercyclical policies may themselves contribute to the occurrence of the fluctuations that they are stabilising. This occurs when the agents do adjust prices without a policy but do not adjust with the policy. In this case, stabilisation policy certainly stabilises output, but in the absence of such a policy there would not be any fluctuations to stabilise. Moreover, the increase in price rigidity following a countercyclical policy is socially suboptimal because the price setters accept too large price deviations even without intervention due to the imperfectly competitive behaviour. Therefore, a countercyclical policy may reduce welfare even though the policy by itself is costless. In fact, the optimal policy may be procyclical. This somewhat paradoxical result arises because the central bank by committing to enhance shocks can force down the adjustment levels of the price setters to the socially optimal levels. Finally, it is shown that a higher degree of imperfectly competitive behaviour, which increases the inefficiency of fluctuations, also increases the likelihood of the optimal policy being procyclical.

To make the analysis compatible with the existing literature the results are derived in a simple two period extension of standard static models. These models can, in general, be divided into two groups depending on when the menu costs are paid relative to the emergence of shocks and on how initial prices are determined. Consequently, results do sometimes differ depending on the choice of framework. In the following, both types of frameworks are considered, and it turns out that the overall conclusions are the same.

The remainder of the paper is organised as follows. Section 1 describes the basic framework and the equilibrium with flexible prices. Section 2 analyses the consequences of stabilisation policy in the presence of menu costs under two different set of assumptions. One subsection follows the approach initiated by Mankiw (1985) and Blanchard and Kiyotaki (1987) and another subsection follows the approach initiated by Ball and Romer (1989; 1990). Section 3 and 4 discuss how the optimal policy depends on imperfectly competitive behaviour and on the reaction time of the central bank. Finally, Section 5 concludes.

1 The Basic Framework and the Flex Price Equilibrium

The economy is populated by a continuum of agents indexed by i and distributed uniformly on $[0,1]$. The agents live for two periods, $t=0,1$. In both periods they each produce a differentiated good using their own labour and demand goods produced by the other agents. The discounted utility stream of agent i equals

$$U_i = \sum_{t=0}^{1} \theta_t \left(\left\{ \int_{j=0}^{1} \left[c_t(i,j)\right]^{1-\mu} dj \right\}^{\frac{1}{1-\mu}} - \tfrac{\gamma}{\gamma+1} \left[l_t(i)\right]^{\frac{\gamma+1}{\gamma}} \right), \tag{1}$$

where $c_t(i,j)$ is consumption of good j at time t, $l_t(i)$ is the number of working hours at time t, and the parameters fulfill $0<\mu<1$, $\gamma>0$, and $\theta_t>0$ for $t=0,1$. The elasticity of substitution between any two goods is given by $1/\mu$, whereas $1/\gamma$ equals the elasticity of marginal disutility of work. Finally, θ_0 and θ_1 measure the length of the two periods and may also include discounting. The consumer price index corresponding to the utility function is defined as

$$p_t \equiv \left\{ \int_{j=0}^{1} \left[p_t(j)\right]^{1-\frac{1}{\mu}} dj \right\}^{\frac{\mu}{\mu-1}},$$

where $p_t(j)$ denotes the price of good j.

To keep the framework as simple as possible, we rule out savings and assume that all goods are non-storable. Consequently, the budget constraint of agent i equals

$$\int_{j=0}^{1} p_t(j)\, c_t(i,j)\, dj \leq p_t(i)\, y_t(i) \equiv I_t(i) \qquad \forall\, t = 0, 1, \tag{2}$$

where $I_t(i)$ is the income of the agent which is identical to the agent's revenue from selling good i to the other agents. Maximising (1) subject to (2) yields the following demand for good j of household i

$$c_t(i,j) = \left[\frac{p_t(j)}{p_t}\right]^{-1/\mu} \frac{I_t(i)}{p_t}. \tag{3}$$

We follow Ball and Romer (1989; 1990) by assuming that some (unspecified) transactions technology determines the relation between aggregate spending of the households and money balances. More specifically, we assume that

$$\int_{i=0}^{1} I_t(i)\, di = v m_t, \tag{4}$$

where m_t is the stock of money at time t controlled by the central bank whereas v may be thought of as the velocity of money. Both v and m_t are observed by the agents and, in the flex price model, any change in v or m_t implies instant price adjustment of the agents.

The aggregate demand for the good produced by agent i is found by aggregating over households in equation (3) and using equation (4). This yields

$$y_t(i) = \left[\frac{p_t(i)}{p_t}\right]^{-1/\mu} \frac{vm_t}{p_t}. \tag{5}$$

The household can transform one unit of labour, $l_t(i)$, into on unit of final good, $y_t(i)$. When prices are flexible the production decision of the agent can be separated into two identical static problems: the agent simply has to maximize the difference between the real revenue, $\frac{p_t(i)y_t(i)}{p_t}$, and the utility loss of working, $\frac{\gamma}{\gamma+1}[y_t(i)]^{\frac{\gamma+1}{\gamma}}$ for $t = 0, 1$. Using equation (5) to substitute for $y_t(i)$ implies that the solution can be found by maximising the indirect flow utility function

$$u\left[\frac{p_t(i)}{p_t}, \frac{vm_t}{p_t}\right] \equiv \left[\frac{p_t(i)}{p_t}\right]^{1-\frac{1}{\mu}} \frac{vm_t}{p_t} - \frac{\gamma}{\gamma+1}\left[\frac{p_t(i)}{p_t}\right]^{-\frac{\gamma+1}{\mu\gamma}} \left(\frac{vm_t}{p_t}\right)^{\frac{\gamma+1}{\gamma}}, \tag{6}$$

with respect to $p_t(i)$ for $t = 0, 1$. From the first order conditions and the symmetry of the households, implying that $p_t(i) = p_t$, we get the solution

$$y_t(i) = \frac{vm_t}{p_t} = \bar{y} \equiv (1-\mu)^{\gamma} < 1 \quad \forall i, t. \tag{7}$$

Thus, when prices are flexible money is neutral and, in this simple setting, all real variables are the same in the two periods. As in standard static models, the aggregate output level is below the socially optimal level, 1, due to the imperfect competition, and output decreases if either the Lerner index, μ, or the labour supply elasticity, γ, increase.

2 Price Rigidity and Stabilisation Policy

In what follows it is assumed that price changes are costly. Thus, each agent responds to changes in nominal demand by either adjusting the production level or the price level taking into account that the latter involves payment of a lump sum price adjustment cost. Contrary to the preceding section this makes the assumption concerning the development of vm_t crucial for the real activity of the economy.

We assume that the economy evolves as follows. The initial prices of the agents are predetermined. At the beginning of period 0 a new value of the stochastic variable v is realised. This alters the (nominal) demand for the different goods, and this is observed by the producers. Depending on the size of the price adjustment cost, each producer will either change the price or the production level. To keep it as simple as possible, we assume that an agent who has paid the menu cost can choose a new price level for period 0 and a new, not necessarily the same, price level for period 1.[4] If the agents have not paid the menu costs, the shock causes output to change in period 0. The central bank cannot observe v in period 0, but can observe the change in aggregate output, and may, accordingly, at the start of period 1 change the

[4]Note, that no new information occurs after the realisation of the shock in period 0. If the agents after paying menu costs in period 0 had to stick to the same price level in period 0 and period 1, they may had preferred to pay menu costs again after the reaction of the central bank. This would strengthen the overall conclusion that the monetary policy contributes to price stickiness.

money supply, m_1, in order to accommodate the shock. More specifically, we assume that the central bank follows the rule[5]

$$\frac{m_1 - \bar{m}}{\bar{m}} = -\alpha \frac{y_0 - \bar{y}}{y_0}, \quad \alpha \leq 1, \tag{8}$$

where the parameter α reflects how the monetary policy depends on the output gap in period 0; the policy is countercyclical if $\alpha > 0$ and procyclical if $\alpha < 0$ whereas $\alpha = 0$ corresponds to a "laissez-faire" policy.

So far, we have not described how the initial prices are determined and whether the agents have to chose between price stickiness or price flexibility before of after the realisation of the shock. Previous static models can in general be divided into two groups. One group, including Mankiw (1985) and Blanchard and Kiyotaki (1987), assumes that initial prices are equal to the equilibrium levels of a frictionless economy, and that the decision on whether to pay the menu costs or not has to be made after realisation of the shock. The second group, including Ball and Romer (1989; 1990), assumes that firms set initial prices that maximise their expected profits knowing the distribution of shocks, and that the choice between fixed prices and flexible prices has to be made before realisation of the shock.

[5] To simplify matters the uninteresting case where the central bank reverses the output gap, i.e. $\alpha > 1$, is excluded from the analysis. Also, to focus entirely on stabilisation policy, there is no intercept in the policy rule, i.e. no trend growth in the stock of money. Note finally, that there does not have to be an explicit policy rule. The basic assumption is just that the agents have rational expectations concerning the behaviour of the central bank.

In the first framework, a shock occurs although the agents are completely sure that it will not, implying that the agents do not really have rational expectations. On the other hand, the second framework presumes that it is impossible at any costs to change prices after the realisation of a shock if menu costs were not paid prior to the shock. Thus, the two frameworks have different advantages and limitations, and we therefore examine the effects of monetary policy in both types of settings.

Due to menu costs, the discounted utility stream of agent i is no longer given by equation (1), but instead equal to

$$U_i = -\varphi d(i) + \sum_{t=0}^{1} \theta_t u \left[\frac{p_t(i)}{p_t}, \frac{v m_t}{p_t} \right], \tag{9}$$

where $u(\cdot, \cdot)$ is the indirect flow utility function defined in (6), φ is the cost of adjusting prices (measured in utils), and $d(i)$ is a dummy variable which equals one or zero depending on whether the agent chooses to adjust or not.

2.1 *An Unanticipated, Adverse Shock*

In this subsection, we assume that initial prices are equal to their optimal levels in a frictionless economy, and that the decision on whether to pay the menu costs has to be made after realisation of the shock. Consider an initial equilibrium of a frictionless economy where $v = \bar{v}$ and $m = \bar{m}$ implying from (7) that initial prices are equal to $\bar{p} = \bar{v}\bar{m}/\bar{y}$. In the beginning of period 0 a (small) shock, ε, implies that the velocity of money is reduced to

$v = (1 - \varepsilon)\, \bar{v}$, where $\varepsilon < 1$.

If the agents decide to pay the menu costs, the only impact of the shock is a corresponding reduction of prices in both periods, whereas both output and money supply stay at their predetermined levels. By contrast, if they do not pay the menu costs, they will keep their prices fixed and instead reduce production in period 0 by $\varepsilon \cdot 100\%$, see equation (5). This change in production is observed by the central bank who adjust the money supply according to the rule (8) which, in combination with equation (5), implies that the period 1 output gap becomes

$$\frac{y_1 - \bar{y}}{\bar{y}} = \frac{m_1 v - \bar{m}\bar{v}}{\bar{m}\bar{v}} = -(1 - \alpha)\, \varepsilon.$$

Thus, a countercyclical policy reduces the impact of the shock on period 1 output, y_1, and a fully countercyclical policy, $\alpha = 1$, completely neutralises the shock. These findings correspond more or less to the result of a standard IS-LM model where prices are assumed to be sticky. However, since price stickiness here is determined by the agents the question is whether the monetary policy influences the degree of price rigidity.

After the shock each farmer has to decide in period 0 on whether to pay the menu cost or not, taking into account the monetary rule of the central bank. Each agent balances his private utility loss from having an actual price that deviates from the optimal level, $p_t^*(i)$, against the payment of the menu costs, φ. Therefore, price rigidity is an equilibrium if no agent has an incentive to pay the menu costs.[6] This implies from equation (9) that price rigidity is an equilibrium if

$$\sum_{t=0}^{1} \theta_t \left\{ u \left[\frac{p_t^*(i)}{\bar{p}}, \frac{v m_t}{\bar{p}} \right] - u\left(1, \frac{v m_t}{\bar{p}}\right) \right\} < \varphi,$$

where $m_0 = \bar{m}$ since the central bank has not yet observed any change in output, whereas $m_1 = \bar{m}\frac{1-(1-\alpha)\varepsilon}{1-\varepsilon}$ due to the monetary policy rule. The first term inside the curly brackets is the utility level (excluding payment of menu costs) if the agent chooses to adjust the price whereas the second term is the utility level if the agent chooses to keep the price at the predetermined level. Taking a second-order Taylor expansion on the LHS of the above inequality implies that the inequality can be approximated by (see Appendix A)

$$L_P(\alpha, \varepsilon) \equiv \frac{1}{2} \frac{1-\mu}{\gamma(1+\mu\gamma)} \left[\theta_0 + \theta_1 (1-\alpha)^2\right] \varepsilon^2 < \Phi, \tag{10}$$

where Φ is the size of the price adjustment costs in proportion of aggregate production, i.e. $\varphi/\bar{y}$. As $L_P(\alpha, \varepsilon)$ is decreasing in α, it follows that a more countercyclical policy reduces the agent's private loss from not adjusting the price thereby increasing the likelihood of price rigidity.

[6] Here, we follow the standard procedure of only focusing on the size of menu costs required to sustain price rigidity as an equilibrium. Note though that the strategic complementarity in price setting implies, as first shown by Ball and Romer (1991), that there exists a range of menu costs for which both price rigidity and price flexibility are equilibria. It turns out, however, that the menu cost threshold for price flexibility is unaltered by the policy. As a consequence, Proposition 1 and 3 imply that the range of menu costs sustaining multiple equilibria is widened.

Let $x_P(\alpha)$ denote the value of ε that solves $L_P(\alpha, \varepsilon) = \Phi$. Solving this equation yields

$$x_P(\alpha) = \sqrt{\frac{2\gamma(1+\mu\gamma)\Phi}{(1-\mu)\left[\theta_0 + \theta_1(1-\alpha)^2\right]}}, \tag{11}$$

from which it follows that

Proposition 1 (***i***) *Rigidity is an equilibrium if the shock* ε *lies in the band of non-adjustment* $[0, x_P(\alpha)]$. (***ii***) *A countercyclical policy,* $0 < \alpha \leq 1$, *widens the band of non-adjustment.* (***iii***) *A countercyclical policy is causing the fluctuations that it is stabilising if the shock* ε *lies in the range* $[x_P(0), x_P(\alpha)]$.

Proof. (*i*) $\varepsilon < x_P(\alpha)$ implies that $L_P(\alpha, \varepsilon) < \Phi$. (*ii*) $x_P(\alpha)$ is monotonously increasing in α. (*iii*) For all shocks, ε, fulfilling $x_P(0) < \varepsilon < x_P(\alpha)$ the agents would have changed their prices without the countercyclical policy ($\alpha = 0$), whereas with the policy they chose not to adjust their prices, which creates the output gap that makes the central bank adjust the money supply. □

The proposition reveals that the degree of price rigidity does depend on the monetary policy. A more countercyclical policy reduces the private losses of the agents making them more reluctant to change prices. This effect may make such policies self-justifying. This arises if the private loss of the agents under a laissez-faire policy is above the menu cost, whereas the private loss with a countercyclical policy is below the menu cost. In this case, output would be unaffected by the shock under a laissez-faire policy, whereas the countercyclical policy implies that the shock affects output which is then brought back towards its original level in the next period by the policy.

We now consider the welfare implications of price rigidity by comparing the aggregate utility of the agents when they chose not to adjust prices with the cases where they do adjust prices. From equation (9), we get that price stickiness is socially optimal if

$$\sum_{t=0}^{1} \theta_t \left[u\left(1, \bar{y}\right) - u\left(1, \frac{vm_t}{p}\right) \right] < \varphi,$$

where again $m_0 = \bar{m}$ and $m_1 = \bar{m}\frac{1-(1-\alpha)\varepsilon}{1-\varepsilon}$. The first term inside the square brackets is the aggregate utility level (excluding payment of menu costs) if the agents adjust the prices whereas the second term is the utility level if the agents keep the prices at the predetermined level. Taking a second-order Taylor expansion on the LHS of the above inequality implies that price stickiness is socially optimal if (see Appendix B)

$$L_W\left(\alpha, \varepsilon\right) \equiv \mu \left[\theta_0 + \theta_1 \left(1-\alpha\right)\right] \varepsilon + \frac{1-\mu}{2\gamma} \left[\theta_0 + \theta_1 \left(1-\alpha\right)^2\right] \varepsilon^2 < \Phi, \qquad (12)$$

where Φ again measures the price adjustment costs in proportion of production. Note, that $L_W\left(\alpha, \varepsilon\right)$, like $L_P\left(\alpha, \varepsilon\right)$, is decreasing in α implying that a more countercyclical policy, ceteris paribus, reduces the welfare consequences of rigid prices.

Unlike the private loss, the welfare loss contains both a second order effect and a first order effect. This difference, first noted by Mankiw (1985), is due to imperfect competition, which implies that the initial equilibrium is inefficient (note that the first-order effect vanishes when $\mu \to 0$). Since,

$$L_W(\alpha, \varepsilon) = \mu [\theta_0 + \theta_1 (1 - \alpha)] \varepsilon + (1 + \mu\gamma) L_P(\alpha, \varepsilon),$$

it follows that the welfare loss of price rigidity, $L_W(\alpha, \varepsilon)$, is larger than the private loss, $L_P(\alpha, \varepsilon)$. This discrepancy implies that the agents tend to adjust too little making the implied price rigidity inefficient. However, excessive price rigidity is not necessarily an argument for a countercyclical policy.

Proposition 2 (***i***) *If* $L_W(1, \varepsilon) < \Phi$ *then* $\alpha = 1$ *maximises welfare.* (***ii***) *If* $\Phi < L_W(1, \varepsilon)$ *then:*

(***iia***) *If* $L_P(1, \varepsilon) > \Phi$ *then the welfare implications are independent of* α*.*

(***iib***) *If* $L_P(0, \varepsilon) > \Phi > L_P(1, \varepsilon)$ *then there exists* $\hat{\alpha} \in (0, 1)$ *such that* $\alpha < \hat{\alpha}$ *maximises welfare.*

(***iic***) *If* $\Phi > L_P(0, \varepsilon)$ *then there exists* $\hat{\alpha} < 0$ *such that* $\alpha < \hat{\alpha}$ *maximises welfare.*

Proof. (i) $L_W(\alpha, \varepsilon)$ is decreasing in α and is therefore minimised for $\alpha = 1$. Since $L_W(1, \varepsilon) < \Phi$ welfare is maximised when $\alpha = 1$ provided that the agents do not adjust prices. However, the agents will not adjust the prices since $L_P(1,\varepsilon) < L_W(1,\varepsilon)$. (ii) Note, that $\Phi < L_W(1,\varepsilon)$ implies that welfare is maximised if the agents chose to pay the menu cost and adjust prices. (iia) Since $L_P(\alpha,\varepsilon) > \Phi$ for all values of α the agents adjust independently of α giving a welfare loss equal to Φ. (iib) Let $\hat{\alpha}$ be defined implicitly by $L_P(\hat{\alpha},\varepsilon) = \Phi$, which from the stated condition implies that $\hat{\alpha} \in (0,1)$. Now, if $\alpha < \hat{\alpha}$ then the welfare loss due to the shock is Φ as the agents will chose to adjust. If $\alpha > \hat{\alpha}$ then the agents chose to adjust which yields the welfare loss $L_W(\alpha,\varepsilon) > L_W(1,\varepsilon) > \Phi$. (iic) As the proof of (iib) except that the stated condition implies that $\hat{\alpha} < 0$. $\square$

Thus, in the trivial case where the welfare consequences of fluctuations are below the menu costs, i.e. regime (i), it is optimal to conduct a fully countercyclical policy. However, this case is not particular interesting since realistic magnitudes of menu costs are small making the potential welfare gains from stabilisation policy negligible. Regime (iia) is also trivial since the menu costs are so small that the agents always prefer price flexibility to price stickiness. Thus, the New Keynesian literature has focused on situations where menu costs are larger than the private gains from adjusting but smaller than the welfare implications of price rigidity, i.e. the two remaining regimes. In both of these regimes it is not optimal to conduct a fully countercyclical policy. The reason is that such policy makes it suboptimal for each agent to adjust the price, although adjustment yields the highest welfare level. In regime (*iib*) a countercyclical policy where $\alpha > \hat{\alpha}$ reduces welfare compared to a laissez-faire policy, $\alpha = 0$, because the agents only make the necessary price adjustments when $\alpha < \hat{\alpha}$. In regime (*iic*) the menu cost is larger than each agent's private loss when there is no monetary policy. This implies that the agents do not adjust under the laissez-faire policy, and a countercyclical policy therefore improves welfare. However, the policy is not optimal. It is better to conduct any procyclical policy where $\alpha < \hat{\alpha}$, since such policy enforces the agents to adjust their prices, which yields the highest welfare level. Thus, the optimal policy is to commit to a destabilisation rule.

2.2 *Shocks with Known Distribution*

In this subsection, we show that similar results are obtained by using the approach initiated by Ball and Romer (1989; 1990). Now, the choice between fixed prices and flexible prices has to be made before realisation of the shock, ε. The shock is drawn from a given distribution which is known by the agents when deciding initial prices and when deciding whether to pay the menu costs. Everything else is unchanged.

Let the mean of ε be equal to 0 and define the standard deviation as σ. Before exploring the conditions for price rigidity note that the expected price level will depend on whether the agents chose to pay the menu costs. If they do pay the menu costs the expected price level will equal the frictionless level, $\bar{p}$, but if they do not the price level will in general differ from $\bar{p}$ since utility is not quadratic, i.e. the certainty equivalence property is not fulfilled. Let $\tilde{p}(i)$ be the price chosen by agent i if he decides not to pay the menu cost and $\tilde{p}$ the corresponding price index when all agents chose not to pay the menu costs. Then $\tilde{p}(i)$ is found by solving

$$\tilde{p}(i) = \arg\max E\left\{\sum_{t=0}^{1} \theta_t u\left[\frac{\tilde{p}(i)}{\tilde{p}}, \frac{vm_t}{\tilde{p}}\right]\right\},$$

where again $m_0 = \bar{m}$ and $m_1 = \bar{m}\frac{1-(1-\alpha)\varepsilon}{1-\varepsilon}$. Making a second-order Taylor expansion around the frictionless equilibrium, it is possible to show that the fixed price equilibrium is characterised by a price level, $\tilde{p}$, and an average output level in both periods, $\tilde{y}$, that (approximately) correspond to (see Appendix C)

$$\frac{\bar{v}\bar{m}}{\tilde{p}} = \tilde{y} \simeq \bar{y}\left[1 - \frac{\gamma+1}{2\gamma}\frac{\theta_0 + \theta_1(1-\alpha)^2}{\theta_0+\theta_1}\sigma^2\right]. \qquad (13)$$

This equation shows that the agents chose to set their predetermined prices higher than the frictionless level, which implies that the average output level under price rigidity in both periods is lower than the flex price output level. As in the previous model, a countercyclical policy reduces the impact of a shock on period 1 output, such that the variance of period 1 output declines.

But apart from this effect, equation (13) shows that a countercyclical policy also increases the average output level provided that prices are fixed. However, like in the previous model the question is whether the degree of price rigidity is influenced by the policy.

Reasoning parallel to the derivation of (10) implies that price rigidity is an equilibrium if

$$L_P(\alpha, \sigma) \equiv \frac{1}{2} \frac{1-\mu}{\gamma(1+\mu\gamma)} \left[\theta_0 + \theta_1 (1-\alpha)^2\right] \sigma^2 < \Phi, \tag{14}$$

where the only difference is that ε^2 in (10) has been replaced by the expected value of ε^2, namely σ^2. Thus, rigidity is an equilibrium if σ lies within the band of non-adjustment $[0, x_P(\alpha)]$, where $x_P(\alpha)$ is given by (11). This implies that

Proposition 3 (***i***) *Rigidity is an equilibrium if the standard deviation* σ *lies in the band of non-adjustment* $[0, x_P(\alpha)]$. (***ii***) *A countercyclical policy,* $0 < \alpha \leq 1$, *widens the band of non-adjustment.* (***iii***) *A countercyclical policy is causing the fluctuations that it is stabilising if* σ *lies in the range* $[x_P(0), x_P(\alpha)]$.

Proof. Follows directly by replacing ε with σ in the proof of Proposition 1.

□

Thus, the only difference between Proposition 1 and Proposition 3 is whether it is the actual size of the shocks, ε, or the variance of the distribution, σ, that matter for the agents' decisions.

The welfare loss from price rigidity cannot be derived simply by replacing ε with σ in equation (12). Price rigidity is socially optimal if

$$\sum_{t=0}^{1} \theta_t \left\{ u(1, \bar{y}) - E\left[u\left(1, \frac{v m_t}{\tilde{p}}\right)\right]\right\} < \varphi,$$

where again $m_0 = \bar{m}$ and $m_1 = \bar{m}\frac{1-(1-\alpha)\varepsilon}{1-\varepsilon}$. The first term inside the curly brackets is the aggregate utility level (excluding payment of menu costs) if the agents adjust the prices whereas the second term is the expected utility if the agents keep the prices at the predetermined level. A second-order Taylor expansion implies that rigidity is socially optimal if (see Appendix D)

$$L_W(\alpha, \sigma) \equiv \frac{1}{2}\frac{\mu\gamma + 1}{\gamma}\left[\theta_0 + \theta_1 (1-\alpha)^2\right]\sigma^2 < \Phi. \tag{15}$$

Note, that the first order welfare effect found in the previous section vanishes when considering both positive and negative shocks as noted by Ball and Romer (1989). Nevertheless, it is easy to show that $L_W(\alpha, \sigma) > L_P(\alpha, \sigma)$ still holds, which implies that

Proposition 4 (***i***) *If* $L_W(1, \sigma) < \Phi$ *then* $\alpha = 1$ *maximises welfare.* (***ii***) *If* $\Phi < L_W(1, \sigma)$ *then:*

(***iia***) *If* $L_P(1, \sigma) > \Phi$ *then the welfare implications are independent of* α.

(***iib***) *If* $L_P(0, \sigma) > \Phi > L_P(1, \sigma)$ *then there exists* $\hat{\alpha} \in (0, 1)$ *such that* $\alpha < \hat{\alpha}$

maximises welfare.

(***iic***) *If* $\Phi > L_P(0,\sigma)$ *then there exists* $\hat{\alpha} < 0$ *such that* $\alpha < \hat{\alpha}$ *maximises welfare.*

Proof. The proof is identical to the proof of Proposition 2 except that ε is replaced by σ and $L_W(\cdot)$ is given by equation (15) instead of equation (12). □

Thus, although equations (12) and (15) are different the qualitative results are the same in the two frameworks.

3 Stabilisation Policy and the Extent of Imperfections

Imperfectly competitive price setting is a crucial element of New Keynesian theory. A higher degree of imperfect competition, here measured by the Lerner index μ, reduces the size of the menu costs required for price rigidity, $L_P(\cdot)$,[7] and increases the wedge between the private loss from price rigidity and the aggregate welfare loss, $L_W(\cdot)$.[8] Thus, imperfect competition increases not only the likelihood of price rigidity, but also the welfare loss of the fluctuations that follow. Moreover, it is well-known that many

[7]Let $L_P(\cdot)$ refer to both of the equations (10) and (14) and, similarly, let $L_W(\cdot)$ refer to both of the equations (12) and (15).

[8]Imperfect competition is also important for other reasons. One is, that the theory needs to abolish the Walrasian auctioner in order to analyse why "somebody" choses to keep prices fixed.

other imperfections work in the same way.[9] Hence, μ can be thought of more generally as a measure of the extent of imperfections.

How does the optimal policy depend on μ? First, note that when μ approaches zero (perfect competition) $L_W(\cdot) \rightarrow L_P(\cdot)$ implying that the economy is always in one of the two trivial regimes, i.e. (*i*) or (*iia*). When μ rises $L_W(\cdot)$ increases and $L_P(\cdot)$ decreases. So, if Φ is not too large the economy eventually enters the two New Keynesian regimes (*iib*) and (*iic*). In these regimes it is easy to show that $\hat{\alpha}$ is decreasing in μ,[10] implying that the optimal policies become less and less countercyclical as the extent of imperfections increases, and, furthermore, if μ is large enough the optimal policies are procyclical. To illustrate this point Fig. 1 plots $\hat{\alpha}$ as a function of μ for "reasonable" values of the other parameters: $\gamma = 0.15$, $\Phi = 0.007$, $\theta_0 = 1$, $\theta_1 = 0.95$ and, finally, $\varepsilon = 0.05$ or $\sigma = 0.05$ depending on whether equation (10) or (14) is used. The values of the labour supply elasticity, γ, and the shock (standard deviation), ε (σ), are identical to the values considered by Ball and Romer (1990) in their base case. The parameter value of Φ implies that the menu costs comprise 0.7% of firm revenue, which

[9] Ball and Romer (1990) show, for instance, that this is the case if the output market is extended with imperfect information and customer markets or if the labour market is characterized by efficiency wages. Basu (1995) shows how monopolistic competitive markets for intermediate goods act as a multiplier for price stickiness. Dixon and Hansen (1999) show that a mixed industrial structure leads to misallocation of inputs, which increases both the likelihood and the welfare implications of price rigidity.

[10] $\hat{\alpha}$ is detemined implicitly by $L_P(\cdot) = \Phi$. Implicit differentiation of (10) or (14) shows that $d\hat{\alpha}/d\mu < 0$.

is the rough estimate given by Levy et al. (1997). Finally, the choices of θ_t correspond to a period length of one year and a discount factor equal to 0.95. For these parameter values the economy is always in one of the three regimes $(iia)-(iic)$ depending on the extent of imperfections. For $\mu < 0.14$ the economy is in regime (iia) and the agents always adjust prices independently of the monetary policy conducted. For $\mu > 0.14$ it is suboptimal to conduct a fully countercyclical policy but always optimal to conduct a procyclical policy, and for $\mu > 0.53$ an optimal policy is always procyclical. Finally, note that $\hat{\alpha}$ decreases very fast in regime (iic) implying that the optimal policy becomes extremely procyclical when μ is high. The reason is that the private loss of price rigidity decreases rapidly when μ increases, which implies that the policy needs to be very procyclical in order to enforce the price setters to adjust the prices.

< Fig. 1 here >

4 Optimal Policy and the Reaction Time of the Central Bank

It is a crucial assumption that the central bank cannot react instantly after a shock, i.e. that $\theta_0 > 0$. To see this note that $L_W(1, \varepsilon) \to 0$ when $\theta_0 \to 0$ implying, according to Proposition 2, that a fully countercyclical policy maximises welfare. In this case, prices are never changed but it has no consequences as the central bank continuously adjusts output to its frictionless level. To investigate how the reaction time of the central bank in general influences the results consider a rise in θ_0 and an equivalent reduction of θ_1 (corresponding to no discounting and a fixed total length of time of the two periods). The slower reaction time of the central bank implies that $L_P(1, \varepsilon)$ and $L_W(1, \varepsilon)$ rise whereas $L_P(0, \varepsilon)$ and $L_W(0, \varepsilon)$ are both unchanged. It then follows from Proposition 2 that the likelihood of the economy being in regime (i) with a fully contercyclical policy is reduced. On the other hand, if the economy is initially in regime (iib) where the optimal policy is less than fully countercyclical it may move to regime (iia) where the policy does not matter. In that sense, changes in the reaction time of the central bank have ambiguous effects on the optimal stabilisation policy.

5 Concluding Remarks

In the traditional IS-LM model stabilisation policy, i.e. countercyclical monetary or fiscal policy, reduces the impact of demand fluctuations. As the New Keynesian theory has provided micro foundation for the assumption of rigid prices in the short run and also shown that the resulting fluctuations are inefficient, it is tempting to argue that the New Keynesian theory has rationalised stabilisation policy. The results of this paper show that the stabilisation issue may be more subtle than expected: Firstly, countercyclical policies may themselves be a cause of the fluctuations that they are stabilising. Secondly, a simple policy that fully offsets all shocks may reduce welfare. Thirdly, a socially optimal policy may very well involve a commitment to enhance shocks. And finally, a high degree of imperfectly competitive behaviour, which increases the inefficiency of fluctuations, also increases the likelihood of the optimal policy being procyclical. These results are all due to a positive feed-back effect from the stabilisation policy to the degree of price rigidity: the policy reduces the consequences of shocks, and this makes the price setters more reluctant to make the required price adjustments.

The model is very stylised and it is of course an open question whether the results carry over to a more realistic setting. Unfortunately, it is still very difficult to provide a tractable stochastic dynamic general equilibrium framework where price rigidity is created by menu costs.[11] However, a more realistic setting would probably just make it even more problematic to pursue an active stabilisation policy. For instance, the shock structure is rather special in the model because the central bank reacts on shocks with a lag but knows that no new disturbances occur meanwhile. It would be more realistic, but also complicate stabilisation policy further, if such disturbances

[11] For instance, Caplin and Spulper (1987), Caplin and Leahy (1991), and Caballero and Engel (1993) look at dynamic frameworks where firms follow price strategies that are not optimal. Sheshinski and Weiss (1977; 1983) derive optimal price strategies in a dynamic framework but looks only at a single firm. Danziger (1999) and Dotsey et al. (1999) are probably the only examples of dynamic general equilibrium models though still rather specialised.

could occur. The analysis disregards also the possibility of heterogeneity in price adjustments, which may undermine the effect of money on aggregate activity, see Caplin and Spulper (1987). However, the results demonstrate that important effects may be lost when analyses of macroeconomic policies exclude the microfoundation for price rigidity.

Since Keynes there has been a long tradition of analysing how the consequences of macroeconomic policy depend on price rigidity. The New Keynesian microfoundation suggests instead an interdependence between the two which, I believe, deserves further study.

Appendix

A Derivation of Inequality (10)

The second-order Taylor expansion around the initial equilibrium yields

$$\hat{L}_P(\alpha,\varepsilon) \equiv \sum_{t=0}^{1} \theta_t \left[u(1,\bar{y}) + \left\{ u_1 \frac{d\left[p_t^*(i)/\bar{p}\right]}{d\left(vm_t/\bar{p}\right)} + u_2 \right\} x_t \right.$$
$$+\frac{1}{2}\left(u_{22} + 2u_{12}\frac{d\left[p_t^*(i)/\bar{p}\right]}{d\left(vm_t/\bar{p}\right)} + u_{11}\left\{\frac{d\left[p_t^*(i)/\bar{p}\right]}{d\left(vm_t/\bar{p}\right)}\right\}^2 + u_1\frac{d^2\left[p_t^*(i)/\bar{p}\right]}{d\left(vm_t/\bar{p}\right)^2}\right) x_t^2$$
$$\left. - \left[u(1,\bar{y}) + u_2 x_t + \frac{1}{2}u_{22}x_t^2 \right]\right]$$

where $x_t \equiv \frac{vm_t - \bar{v}\bar{m}}{\bar{p}}$ and where the arguments of the derivatives of the indirect utility function are suppressed. Simplifying this equation and noting that $u_1 = 0$ at the initial equilibrium due to the first-order conditions of the agents, we have

$$\hat{L}_P(\alpha,\varepsilon)=\sum_{t=0}^{1}\theta_t\left(u_{12}\frac{d\left[p_t^*(i)/\bar{p}\right]}{d\left(vm_t/\bar{p}\right)}+\frac{1}{2}u_{11}\left\{\frac{d\left[p_t^*(i)/\bar{p}\right]}{d\left(vm_t/\bar{p}\right)}\right\}^2\right)x_t^2.$$

From the first-order condition $u_1\left(\frac{p_t^*(i)}{p},\frac{vm_t}{p}\right)=0$, we obtain

$$u_{11}\left(\frac{p_t^*(i)}{\bar{p}},\frac{vm_t}{\bar{p}}\right)d\left[p_t^*(i)/\bar{p}\right]+u_{12}\left(\frac{p_t^*(i)}{\bar{p}},\frac{vm_t}{\bar{p}}\right)d\left(vm_t/\bar{p}\right)=0,$$

implying that

$$\frac{d\left[p_t^*(i)/\bar{p}\right]}{d\left(vm_t/\bar{p}\right)}=-\frac{u_{12}}{u_{11}}.$$

Inserting this in the above equation yields

$$\hat{L}_P=\sum_{t=0}^{1}\theta_t\left[-\frac{\left(u_{12}\right)^2}{2u_{11}}\right]x_t^2.$$

Differentiation of the indirect utility function (6) gives

$$\begin{aligned}u_{12}(1,\bar{y}) &= \frac{1-\mu}{\mu\gamma},\\ u_{11}(1,\bar{y}) &= -\frac{(1-\mu)(1+\mu\gamma)}{\mu^2\gamma}\bar{y},\end{aligned}$$

implying that

$$\hat{L}_P=\sum_{t=0}^{1}\theta_t\left[\frac{1}{2}\frac{1-\mu}{\gamma(1+\mu\gamma)\bar{y}}\right]x_t^2=\frac{1}{2}\frac{1-\mu}{\gamma(1+\mu\gamma)\bar{y}}\left(\theta_0x_0^2+\theta_1x_1^2\right).$$

From the definition of x_t, we get

$$\begin{aligned}x_0 &= \frac{vm_0-\bar{v}\bar{m}}{\bar{p}}=\bar{y}\frac{vm_0-\bar{v}\bar{m}}{\bar{v}\bar{m}}=\bar{y}\frac{v-\bar{v}}{\bar{v}}=\bar{y}\frac{\bar{v}(1+\varepsilon)-\bar{v}}{\bar{v}}=\bar{y}\varepsilon,\\ x_1 &= \bar{y}\frac{vm_1-\bar{v}\bar{m}}{\bar{v}\bar{m}}=\bar{y}\frac{\bar{v}(1+\varepsilon)\bar{m}\left[\frac{1+(1-\alpha)\varepsilon}{1+\varepsilon}\right]-\bar{v}\bar{m}}{\bar{v}\bar{m}}=\bar{y}(1-\alpha)\varepsilon,\end{aligned}$$

where we have used $v = (1-\varepsilon)\bar{v}$, $m_0 = \bar{m}$, and $m_1 = \frac{1-(1-\alpha)\varepsilon}{1-\varepsilon}\bar{m}$ derived from the policy rule (8). Inserting x_0 and x_1 in the equation above and measuring the private loss of the agent in proportion of initial aggregate production, we get

$$L_P(\alpha,\varepsilon) \equiv \hat{L}_P/\bar{y} = \frac{1}{2}\frac{1-\mu}{\gamma(1+\mu\gamma)}\left[\theta_0 + \theta_1(1-\alpha)^2\right]\varepsilon^2,$$

which is the LHS of inequality (10).

B Derivation of Inequality (12)

The second-order Taylor expansion around the initial equilibrium yields

$$\hat{L}_W = \sum_{t=0}^{1}\theta_t\left\{u(1,\bar{y}) - \left[u(1,\bar{y}) + u_2\frac{vm_t - \bar{v}\bar{m}}{\bar{p}} + \frac{1}{2}u_{22}\left(\frac{vm_t - \bar{v}\bar{m}}{\bar{p}}\right)^2\right]\right\}.$$

Noting that $\bar{p} = \bar{v}\bar{m}/\bar{y}$ and simplifying give

$$\hat{L}_W = -\sum_{t=0}^{1}\theta_t\left[u_2\frac{vm_t - \bar{v}\bar{m}}{\bar{v}\bar{m}}\bar{y} + \frac{1}{2}u_{22}\left(\frac{vm_t - \bar{v}\bar{m}}{\bar{v}\bar{m}}\right)^2\bar{y}^2\right].$$

Differentiation of the indirect utility function (6) yields

$$\begin{aligned} u_2(1,\bar{y}) &= \mu, \\ u_{22}(1,\bar{y}) &= -\frac{1-\mu}{\gamma\bar{y}}. \end{aligned}$$

Inserting these derivatives gives

$$\hat{L}_W = -\bar{y}\sum_{t=0}^{1}\theta_t\left[\mu\frac{vm_t - \bar{v}\bar{m}}{\bar{v}\bar{m}} - \frac{1-\mu}{2\gamma}\left(\frac{vm_t - \bar{v}\bar{m}}{\bar{v}\bar{m}}\right)^2\right].$$

Inserting $v = (1-\varepsilon)\bar{v}$, $m_0 = \bar{m}$, and $m_1 = \frac{1-(1-\alpha)\varepsilon}{1-\varepsilon}\bar{m}$ derived from the policy rule (8), we obtain

$$L_W(\alpha,\varepsilon) \equiv \hat{L}_W/\bar{y} = \mu\left[\theta_0 + \theta_1(1-\alpha)\right]\varepsilon + \frac{1-\mu}{2\gamma}\left[\theta_0 + \theta_1(1-\alpha)^2\right]\varepsilon^2,$$

which is the LHS of inequality (12).

C Derivation of equation (13)

The derivation follows Ball and Romer (1989). The problem is

$$\max_{\tilde{p}(i)} E\left[\sum_{t=0}^{1}\theta_t u\left(\frac{\tilde{p}(i)}{\tilde{p}}, \frac{vm_t}{\tilde{p}}\right)\right],$$

which yields the first-order condition

$$E\left[\sum_{t=0}^{1}\theta_t u_1\left(\frac{\tilde{p}(i)}{\tilde{p}}, \frac{vm_t}{\tilde{p}}\right)\right] = 0.$$

Due to symmetry, the equilibrium is characterised by $\tilde{p}(i) = \tilde{p}$ implying that

$$E\left[\sum_{t=0}^{1}\theta_t u_1\left(1, \frac{vm_t}{\tilde{p}}\right)\right] = 0.$$

Taking a second-order Taylor expansion around $\frac{\bar{v}\bar{m}}{\tilde{p}}$ gives

$$u_{12}\sum_{t=0}^{1}\theta_t E\left(\frac{vm_t}{\tilde{p}} - \bar{y}\right) + \frac{1}{2}u_{122}\sum_{t=0}^{1}\theta_t E\left[\left(\frac{vm_t}{\tilde{p}} - \bar{y}\right)^2\right] = 0.$$

The mean of vm_t is $\bar{v}\bar{m}$. The last term in the above equation equals

$$E\left[\left(\frac{vm_t}{\tilde{p}} - \bar{y}\right)^2\right] = E\left[\left(\frac{vm_t}{\tilde{p}}\right)^2 - 2\frac{vm_t}{\tilde{p}}\bar{y} + \bar{y}^2\right]$$

$$
\begin{aligned}
&= \frac{E\left(vm_t\right)^2}{\tilde{p}^2} - 2\frac{\bar{v}\bar{m}}{\tilde{p}}\bar{y} + \bar{y}^2 \\
&= \frac{E\left(vm_t\right)^2 - \left(\bar{v}\bar{m}\right)^2}{\tilde{p}^2} + \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y}\right)^2 \\
&= \left(\frac{\bar{v}\bar{m}}{\tilde{p}}\right)^2 \sigma_t^2 + \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y}\right)^2,
\end{aligned}
$$

where $\sigma_0 = \sigma$ and $\sigma_1 = (1-\alpha)\,\sigma$. Thus, we have

$$
\sum_{t=0}^{1} \theta_t \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y}\right) + \frac{1}{2}\frac{u_{122}}{u_{12}} \sum_{t=0}^{1} \theta_t \left[\left(\frac{\bar{v}\bar{m}}{\tilde{p}}\right)^2 \sigma_t^2 + \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y}\right)^2\right] = 0.
$$

From (6), we have $u_{12}\left(1,\bar{y}\right) = \frac{1-\mu}{\mu\gamma}$ and $u_{122}\left(1,\bar{y}\right) = \frac{1}{\bar{y}}\frac{1-\mu}{\mu}\frac{1}{\gamma}\frac{\gamma+1}{\gamma}$ implying that

$$
\sum_{t=0}^{1} \theta_t \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y}\right) + \frac{\gamma+1}{2\gamma}\frac{1}{\bar{y}} \sum_{t=0}^{1} \theta_t \left[\left(\frac{\bar{v}\bar{m}}{\tilde{p}}\right)^2 \sigma_t^2 + \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y}\right)^2\right] = 0.
$$

This equation determines $\tilde{p}$ implicit as a function of σ^2. Implicit differentiation around $\frac{\bar{v}\bar{m}}{\tilde{p}} = \bar{y}$ and $\sigma^2 = 0$ yields

$$
\left(\theta_0 + \theta_1\right) d\left(\frac{\bar{v}\bar{m}}{\tilde{p}}\right) + \frac{\gamma+1}{2\gamma}\frac{1}{\bar{y}} \sum_{t=0}^{1} \theta_t \left(\frac{\bar{v}\bar{m}}{\tilde{p}}\right)^2 d\sigma_t^2 = 0
$$

$\Leftrightarrow$

$$
\left(\theta_0 + \theta_1\right) d\left(\frac{\bar{v}\bar{m}}{\tilde{p}}\right) = -\frac{\gamma+1}{2\gamma}\bar{y}\left(\theta_0 d\sigma_0^2 + \theta_1 d\sigma_1^2\right)
$$

Inserting $d\sigma_0 = d\sigma$ and $d\sigma_1 = (1-\alpha)\,d\sigma$ in the above equation gives

$$
\frac{d\left(\frac{\bar{v}\bar{m}}{\tilde{p}}\right)}{d\sigma^2} = -\frac{\gamma+1}{2\gamma}\bar{y}\frac{\theta_0 + \theta_1\left(1-\alpha\right)^2}{\theta_0 + \theta_1},
$$

which yields the approximation

$$
\frac{\bar{v}\bar{m}}{\tilde{p}} \simeq \bar{y}\left[1 - \frac{\gamma+1}{2\gamma}\frac{\theta_0 + \theta_1\left(1-\alpha\right)^2}{\theta_0 + \theta_1}\sigma^2\right].
$$

D Derivation of Inequality (15)

The second-order Taylor expansion around the initial equilibrium yields

$$\tilde{L}_W = \sum_{t=0}^{1} \theta_t \left\{ u(1,\bar{y}) - E\left[u(1,\bar{y}) + u_2 \left(\frac{vm_t}{\tilde{p}} - \bar{y} \right) + \frac{1}{2} u_{22} \left(\frac{vm_t}{\tilde{p}} - \bar{y} \right)^2 \right] \right\}$$

$\Leftrightarrow$

$$\tilde{L}_W = -\sum_{t=0}^{1} \theta_t \left[u_2 E \left(\frac{vm_t}{\tilde{p}} - \bar{y} \right) + \frac{1}{2} u_{22} E \left(\frac{vm_t}{\tilde{p}} - \bar{y} \right)^2 \right]$$

$\Leftrightarrow$

$$\tilde{L}_W = -\sum_{t=0}^{1} \theta_t \left[u_2 \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y} \right) + \frac{1}{2} u_{22} E \left(\frac{vm_t}{\tilde{p}} - \bar{y} \right)^2 \right]$$

From the previous section, we have that

$$E\left[\left(\frac{vm_t}{\tilde{p}} - \bar{y} \right)^2 \right] = \left(\frac{\bar{v}\bar{m}}{\tilde{p}} \right)^2 \sigma_t^2 + \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y} \right)^2$$

where $\sigma_0 = \sigma$ and $\sigma_1 = (1-\alpha)\sigma$. This implies that

$$\begin{aligned} \tilde{L}_W &= -(\theta_0 + \theta_1) u_2 \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y} \right) \\ &\quad -\frac{1}{2} u_{22} \left\{ \left(\frac{\bar{v}\bar{m}}{\tilde{p}} \right)^2 \sigma^2 \left[\theta_0 + \theta_1 (1-\alpha)^2 \right] + (\theta_0 + \theta_1) \left(\frac{\bar{v}\bar{m}}{\tilde{p}} - \bar{y} \right)^2 \right\}. \end{aligned}$$

Inserting (13), we have

$$\begin{aligned} \tilde{L}_W &= -(\theta_0 + \theta_1) u_2 \bar{y} \left[-\frac{\gamma+1}{2\gamma} \frac{\theta_0 + \theta_1 (1-\alpha)^2}{\theta_0 + \theta_1} \sigma^2 \right] \\ &\quad -\frac{1}{2} u_{22} \bar{y}^2 \left[1 - \frac{\gamma+1}{2\gamma} \frac{\theta_0 + \theta_1 (1-\alpha)^2}{\theta_0 + \theta_1} \sigma^2 \right]^2 \sigma^2 \left[\theta_0 + \theta_1 (1-\alpha)^2 \right] \\ &\quad -\frac{1}{2} u_{22} \bar{y}^2 (\theta_0 + \theta_1) \left[-\frac{\gamma+1}{2\gamma} \frac{\theta_0 + \theta_1 (1-\alpha)^2}{\theta_0 + \theta_1} \sigma^2 \right]^2. \end{aligned}$$

Neglecting terms of an order higher than two implies that

$$\tilde{L}_W = \frac{1}{2}\left[u_2\frac{\gamma+1}{\gamma} - u_{22}\bar{y}\right]\bar{y}\left[\theta_0 + \theta_1(1-\alpha)^2\right]\sigma^2.$$

Inserting $u_2 = \mu$ and $u_{22} = -\frac{1}{\gamma}(1-\mu)(\bar{y})^{-1}$, derived from the indirect utility function, and measuring the loss in proportion of aggregate output yield

$$L_W(\alpha,\varepsilon) \equiv L_W/\bar{y} = \frac{1}{2}\frac{\mu\gamma+1}{\gamma}\left[\theta_0 + \theta_1(1-\alpha)^2\right]\sigma^2.$$

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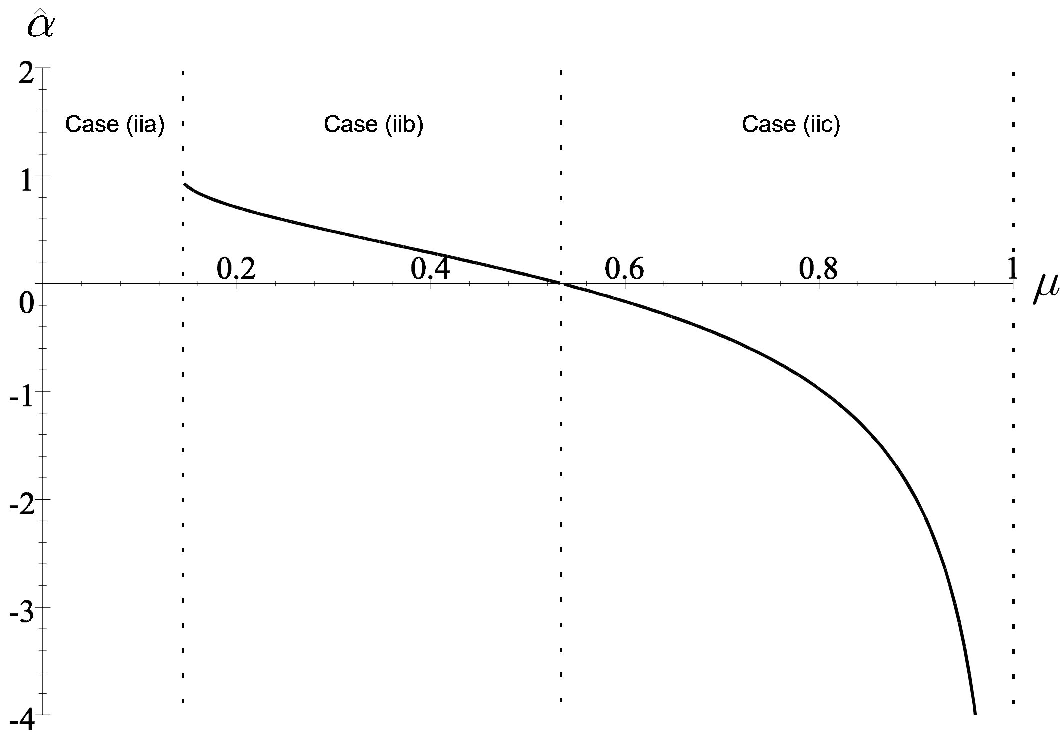

Fig. 1. Optimal Policy and the Extent of Imperfections