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INFLATION, WAGES AND THE ROLE OF MONEY UNDER DISCRETION AND RULES: A NEW INTERPRETATION

by

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INFLATION, WAGES AND THE ROLE OF MONEY UNDER DISCRETION AND RULES: A NEW INTERPRETATION

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Abstract

This paper models a game-theoretic interaction between the monetary authority and a strategically active private sector. It aims to explore the real effects of monetary policy, wage setting behaviour and the consequences of stabilization and indexation policy.

We find that when the private sector has an active role, "rules" and "discretion" are not as far apart as implied by the standard model prevalent in the literature. Both regimes are not Pareto-optimal equilibria and inflation may be positive even under "rules."

We show that monetary policy may have real effects on output in the short-run due to strategic considerations by rational, perfectly informed wage-setters. The latter may act "tough" or "soft" depending upon the preferences of the policymaker facing them.

We investigate the consequences of inflation stabilization policy and the means open to the government to mitigate its output costs. We also find that the prevalent intuition whereby more indexation should lead to more inflation is not always correct.

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Inflation, Wages and the Role of Money
Under Discretion and Rules:
A New Interpretation*

1. Introduction

This paper models the interaction between the monetary authority and the private sector as a non-cooperative game. The aim of the paper is to explore the real effects of monetary policy, wage setting behaviour and the policy issues of stabilization and indexation under a set-up where the private sector has a strategically active role.

The prevalent model on policy games is the seminal work of Barro and Gordon (1983), which generated a new strand in the monetary policy literature. This model sought to provide an explanation as to why inflation rates seem to be excessive relative to an efficiency criterion and why governments pursue activist, counter-cyclical monetary policies. The Barro-Gordon model continues to serve as the basic paradigm in this literature, although recent models assume various forms and are used to explore a variety of issues.[1] This paper shows that when catering for real-world characteristics of certain economies, in which the private sector plays an active role, the results of the basic model are changed in a fundamental way.

The Barro - Gordon model depicts a policymaker who has an incentive to deviate from a

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[1] For recent surveys of this literature see Blackburn and Christensen (1989), Fischer (1990), Persson and Tabellini (1990) and Rogoff (1987).

pre-announced inflation rate in order to reap some gains. These gains may include output increases, debt reductions, etc. In terms of the time-inconsistency literature, initiated by Kydland and Prescott (1977) and Calvo (1978), the policymaker's optimal rate of inflation is time-inconsistent. However the private sector is aware of this incentive and sets expectations rationally at the policymaker's optimal level. In doing so the gains sought by the authorities are eliminated. The outcome is therefore sub-optimal, with unemployment staying at its natural rate and inflation being higher than its level had binding (or credible) pre-commitment been possible.[2]

This paradigm implies a somewhat passive role for the private sector: it has no direct effect on inflation and its only concern is to set expectations "correctly," i.e., to minimize unanticipated inflation. However this is not realistic in countries where there is some representative agent who plays a significant part in the economy. The best example is probably a strong trade union which represents a large majority of the labor force. This may apply, for example, to some Western European countries (especially the Nordic countries and Austria), to some Latin American economies (in particular Argentina) and to several other countries (such as Israel).[3] In such cases the private sector plays an active role in the following sense: (i) it has a direct effect on price inflation by being the setter of wage inflation, and (ii) it is concerned by the level of inflation, i.e. it incurs inflationary costs.

We show that if the standard paradigm is modified so as to explicitly model the active role of the private sector significant results emerge: "rules" and "discretion" are not as diametrically opposed as implied by the standard model and in fact inflation is positive even under "rules"; both "discretion" and "rules" do not generate a Pareto-optimal equilibrium; wage indexation is determined as the result of

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[2] This level is not necessarily zero. It may be some positive level, derived from an optimal control program of deficit finance [see for example Mankiw (1987) and Yashiv (1989)].

[3] The Barro-Gordon model has already been used in the context of trade unions but not with the present modifications [see, for example, Horn and Persson (1988) and Tabellini (1988)]. These models do not generate the results obtained here.

optimizing behaviour within the context of strategic interaction and optimal indexation is not necessarily 100%; monetary policy may have real effects in the short run due to strategic considerations of rational, perfectly informed wage-setters; this holds even without nominal contracts but contracts do generate "tougher" or "softer" wage-setting behaviour depending upon the policymaker's output-inflation preferences; inflation stabilization policy may be aided by income tax policy; and indexation mechanisms play ambiguous roles in the determination of inflation and output.

The paper proceeds as follows: Section 2 outlines the macroeconomic background and presents the basic framework of the monetary policy game. We discuss the rationale that underlies the objective functions of the policymaker and of the trade union. Section 3 studies the Nash equilibrium solution ("discretion") with respect to wages, money and prices and Section 4 discusses the results of the solution with respect to output, highlighting the real effects of money. These two sections stress the differences between Nash equilibrium in this model and in the standard one. Section 5 conducts a comparative analysis, examining the effects of changes in the players' objective functions. Using this analysis we look at stabilization policy and at the effects of indexation and point to some empirical evidence that supports the analysis. Section 6 first presents the Stackelberg (or "rules") solution with the policymaker as the leader and compares it to the Nash equilibrium. We then look at the Stackelberg solution with the trade union leading, discuss the role of contracts in this context and compare the two Stackelberg solutions. Finally, Section 7 offers some concluding comments and outlines possible extensions. Technical matters are discussed in the Appendix.

2. The Basic Set-Up

In this section we present the macroeconomic background to the game (2.1), characterize the players (2.2) and their objectives (2.3), and finally discuss the structure of the game (2.4).

2.1 The Economy

We begin by formulating a simple aggregate supply/aggregate demand model of the economy. Aggregate demand is a function of real money balances while aggregate supply is a function of the real wage (derived from competitive firms' demand for labor):

$$y^d = \mu\ (m-p)\ ,\ \mu'>0 \tag{1}$$

$$y^s = \theta\ (p-w)\ ,\ \theta'>0. \tag{2}$$

where y^d, y^s, p, m, and w are logs of real output demand, real output supply, prices, nominal money and nominal wages, respectively. Henceforth we will assume these to be linear functions for the sake of simplicity. This structure serves as the background for the game, in which m and w (and therefore y and p) will be determined as the result of a strategic interaction between the policymaker and wage setters.

Using the lagged version of (1) and (2) we present these functions in the dynamic form:

$$y_t^d = y_{t-1}^d + \mu\ (\hat{m}-\pi) \tag{3}$$

$$y_t^s = y_{t-1}^s + \theta\ (\pi-\hat{w}) \tag{4}$$

where

$$\hat{m}=m_t-m_{t-1}$$

$$\hat{w}=w_t-w_{t-1}$$

$$\pi=p_t-p_{t-1}$$

Assuming that supply equals demand in each period we get the following inflation equation:

$$\pi=u\hat{m}+(1-u)\hat{w} \tag{5}$$

where

$$u=\frac{\mu}{\theta+\mu}\ ,\ 0<u<1.$$

2.2 The Players

The model is concerned with a game-theoretic interaction between two players: the policymaker (henceforth denoted by PM) and a single trade union (henceforth denoted by TU). The trade union may be either a central, national trade union or a coalition of trade unions which share common aims at the macroeconomic level. Each player seeks to minimize a loss function by setting his control variable optimally: the PM sets $\hat{m}$ while the TU sets $\hat{w}$. Note that by this formulation the role of the TU is "active" in the following sense: wage inflation is set strategically to attain some optimal level of the loss function subject to the appropriate constraint, and this in turn determines to some extent the overall rate of price inflation. Thus this model differs from the standard formulation whereby wages or inflationary expectations are set passively to equal inflation while the latter is totally determined by the government.

2.3. The Players' Objectives

The loss functions contain two elements: (i) inflation and (ii) output (or, equivalently, real wages). Basically, both parties are concerned with deviations of these two variables from targeted values. We shall conisder the following specification:

$$L^{PM}=\frac{\alpha}{2}\pi^2+\frac{\epsilon}{2}(y-ky^*)^2 \tag{6}$$

$$L^{TU}=\frac{\lambda}{2}\pi^2+\frac{\beta}{2}[(w-p)-(w-p)^*]^2=\frac{\lambda}{2}\pi^2+\frac{\beta}{2}(\frac{y-y*}{\theta})^2$$

2.3.1 The Output/Real Wage Objective

Consider the second element first. The TU has some real wage target denoted by (w-p)*. Using (2) this accords with a level of output that satisfies:

$$y^*=-\theta(w-p)^* \tag{7}$$

Thus the output level implied by the targeted real wage is y^*. The notion of a targeted real wage corresponds to the monopoly approach to trade union behavior [see Oswald (1985)]. This approach models the union as maximizing a utility function in wages and employment subject to competitive firms' demand for labor. The equilibrium in the labor market is attained at the tangency point between the firm's demand for labor and the union's indifference curve.

The PM for his part targets a bigger value of output, i.e. ky^* ($k > 1$). Note that this divergence of targets is essential for generating a game-theoretic type of interaction. Otherwise, as will become clear with the formulation of the loss functions, there is no incentive for either side to deviate from a simple inflationary scheme (in our case, zero inflation).

There may be several economic as well as political reasons for the divergence of output targets:

(i) The TU may be representing the labor force while the PM may have the welfare of other segments of the economy in mind.

(ii) The monopoly union model shows that the real wage is set above the competitive level if there are unemployment benefits (see above reference).

(iii) In some cases the PM is unable to levy non-distortionary taxes. Thus he may resort to distortionary taxes on labor income driving output below its level in the absence of taxes. He may therefore aim at "compensating" for the loss of output by lowering real wages through inflation. This, of course, is one of the standard arguments in the monetary policy game literature.

(iv) The PM may want higher output in order to demonstrate his competence in attaining economic "prosperity." On the other hand the TU leadership may strive, for a similar reason, to increase real wages.

Note that arguments (i) and (iv) may be supported by the "insiders-outsiders" approach to labor markets: the TU, representing "insiders", seeks a certain level of the real wage. It is not interested in a higher level as this causes an increase in unemployment. On the other hand it cares more about the welfare of its members than about the unemployed ("outsiders") so it is reluctant to go below the targeted value. Note too that the PM may find it useful to lower unemployment for both political and "benevolence" reasons.

2.3.2 The Inflation Objective

We turn now to the inflation element in the players' loss functions. In general there may be inflationary costs shared by both players and inflationary losses which are unique to one player. There may even be cases in which one player's loss is the other player's gain. The following discussion illustrates what such costs may be:[4]

First consider costs shared by both players:

(i) Inflation constitutes a tax on real currency holdings and thus generates welfare losses.

(ii) Empirical evidence shows that higher anticipated inflation is associated with increased price variability [see for example Fischer (1981a)]. This may lead to more resources being diverted by private agents to search, insurance against inflation or speculation on inflation.

These arguments of course apply to the "benevolent" PM. In addition the TU loses from inflation for the following reasons, which possibly are not shared by the PM:

(iii) Higher inflation leads to taxation of a larger proportion of labor income if nominal tax brackets in a progressive tax system do not fully adjust. One often observes pressure exerted by the trade union on the government in high-inflation economies to adjust tax brackets. This clearly demonstrates that TU leaders have this consideration in mind.

(iv) Higher inflation leads to a reduction in the after-tax real rate received by lenders if pre-tax interest rates do not adjust. A similar argument pertains to return on equity. The TU which represents workers who save part of their labor income must take this financial income effect into account.

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[4] For surveys on the costs of inflation see Driffill, Mizon and Ulph (1990) and the special August 1991 issue (part 2) of the Journal of Money, Credit, and Banking. For the specific arguments discussed below see in particular Fischer and Modigliani (1978), Fischer (1981 a,b) and Benabou (1989).

These arguments imply that TU losses from inflation are dependent on tax policies and on the behavior of rates of return. We assume that for a given game these are fixed and reflected in the parameters of the TU loss function. We discuss the effects of changes in these parameters in Section 5 below. Under certain circumstances these TU losses may be the PM gains if, for example, they imply an income redistribution which is welfare-enhancing.

The PM for his part may incur the following losses :

(v) Costs of inflation which pertain to the production side of the economy such as price-adjustment costs and inefficient production decisions.

(vi) A political loss of popularity . As much as he may want to demonstrate competence through higher output he may want to demonstrate it by a low rate of inflation.

2.4. The Structure of the Game

The game is a differential game with two players, quadratic loss functions and complete information. We examine two types of equilibrium: the Nash equilibrium, corresponding to "discretion," and the Stackelberg equilibrium. For the latter we examine both the case of PM leadership (corresponding to "rules") and the case of TU leadership. This is essentially a static game in the sense that the players take into account the loss from one period only, i.e. a "myopic" type of behavior. Such behavior may be justified in cases where changes in governments or trade union leadership are frequent enough so both players are mainly concerned by their common period in office. In the concluding section we comment on possible extensions of this formulation.

A detailed discussion of the properties of these games and solution methods is to be found in Basar and Olsder (Chapter 4.6, 1982).

3. Nash Equilibrium: Money, Wages and Prices

In this section we look at the behaviour of the nominal variables, i.e. money,wages and prices as determined by the strategic interaction. First consider the determination of the control variables - money injection by the PM and wage inflation by the TU. Differentiating each player's loss function (6) with respect to his control variable and setting it equal to zero yields the following reaction functions:

$$\hat{m}=-\frac{\epsilon\bar{y}\theta}{u(\alpha+\epsilon\theta^2)}-\frac{[\alpha u(1-u)-\epsilon\theta^2u^2]\hat{w}}{u^2(\alpha+\epsilon\theta^2)}$$

$$\hat{w}=\frac{\beta\tilde{y}u}{\lambda(1-u)^2+\beta u^2}+\frac{[\beta u^2-\lambda u(1-u)]\hat{m}}{[\beta u^2+\lambda(1-u)^2]} \tag{8}$$

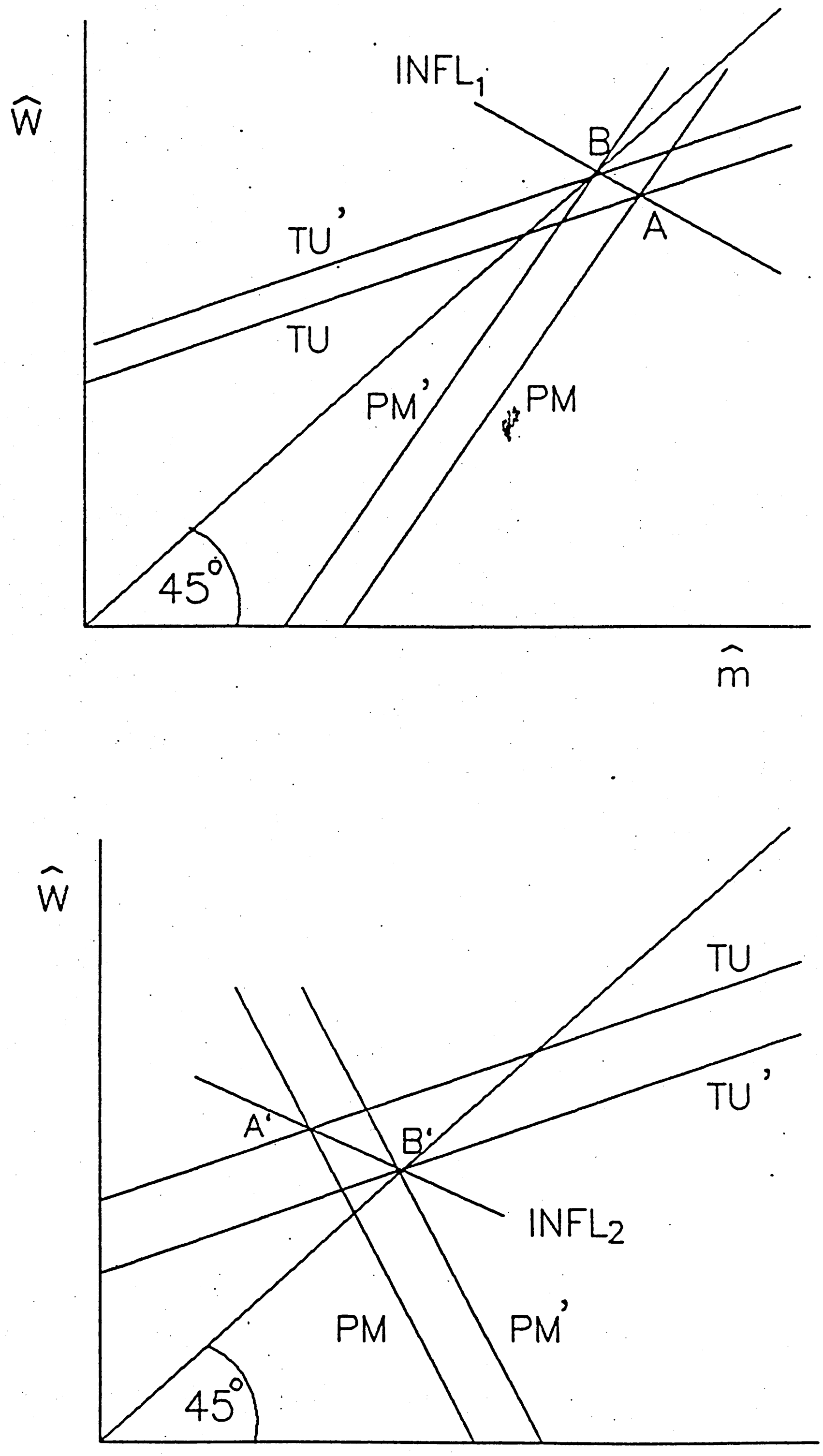
where

$$\bar{y}=y_{t-1}-ky^* \ ; \ \tilde{y}=\frac{y_{t-1}-y^*}{\theta}$$

These functions represent the optimal response of the player given a certain value of the control variable set by the other player. Their intersection represents the Nash equilibrium as shown in Figure 1. As seen by examining equations (8), there are two possible slopes for each player's reaction curve - positive or negative. These depend on the relative weight placed by each player on the inflation and output targets. Figure 1 is drawn under the assumption that $\beta u^2 > \lambda u(1-u)$, i.e. that the output (or real wage) target is sufficiently more important for the TU so that its reaction curve is positively sloped. The two graphs in Figure 1 represent the two possible cases for the PM.

Figure 1

The intersection at points A and A' shows that $\hat{m}$ does not necessarily equal $\hat{w}$ at this stage of the game as these points lie outside the 45° line. This stems from the fact that the TU is concerned by inflation; at a point such as A the TU sets nominal wage increase at a slower rate than the rate of monetary expansion in order to bring down inflation. Note that under the standard formulation the TU reaction curve would simply be the 45° line.



$\hat{w}$
$INFL_1$
B
A
TU'
TU
PM'
PM
45°
$\hat{m}$
$\hat{w}$
TU
TU'
A'
B'
$INFL_2$
PM
PM'
45°
$\hat{m}$

FIGURE 1

Here the discrepancy between the rate of monetary expansion and nominal wage inflation is generated by strategic considerations. This means that the indexation of nominal wages is not 100% in the "short-run", i.e. at this stage of the interaction. The aversion of wage-setters to inflation "restrains" their wage adjustment. This consideration may explain the fact that even with strong trade unions one does not observe full indexation of nominal wages. This analysis also serves to show that wage indexation may be the result of optimizing behaviour in the framework of strategic interaction rather than a solution to an optimal control problem.

The gap between money injection and wage inflation creates output movements which shift the reaction curves so that in the next period the intersection is at points B and B' where the game "ends" (and where now money and wages grow at the same rate). Note that inflation does not change between points A and B (and A' and B') and the economy moves along the iso-inflation curves $INFL_1$ or $INFL_2$. Algebraically this may be seen by the Nash solution for the rate of inflation which is obtained by combining equations (5) and (8):[5]

$$\pi_N=\delta^{-1}\epsilon\theta\beta u^3 y^*(k-1) \qquad (9)$$

where

$$\delta=\alpha\beta u^3+\epsilon\lambda\theta^2 u^2(1-u)$$

The following properties are noteworthy with respect to this rate of inflation:[6]

(i) It is independent of the value of actual output, hence its constancy across points A and B (or A' and B').

(ii) It is a function of the parameters of the loss functions and of the structural equations of the economy.

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[5] A full derivation of the Nash solution is presented in the Appendix.

[6] Basar (1976) shows that if $\delta\neq 0$ then this solution exists and is unique.

(iii) It is positive unless one of the players is unconcerned by an output target (i.e. $\epsilon=0$ or $\beta=0$) or if there is no divergence in output targets (i.e. k=1).

The difference between this solution and the standard one is better appreciated by looking at the inverse of (9):

$$\pi_N^{-1}=\frac{\alpha}{\epsilon}[\theta y^*(k-1)]^{-1}+\frac{\lambda}{\beta}\frac{(1-u)}{u}\theta\ [y^*(k-1)]^{-1} \tag{9'}$$

The first term on the RHS represents the PM's incentive to try to increase output by money creation. This rate is chosen so as to balance losses from inflation with output gains at the margin. This term corresponds to the standard result.

The second term on the RHS represents the role of the private sector which is usually absent (as usually λ = 1-u = 0). This term is positive, so that inflation is reduced with respect to its rate by the first term alone. Note that as the private sector's role in determining inflation increases [i.e. {(1-u)/u} increases] or as its relative losses from inflation increase (i.e. λ/β increases) the equilibrium rate of inflation decreases. Thus the TU's concern for inflation lowers the Nash equilibrium rate of inflation, making the first term an upper bound on this rate. "Discretionary" inflation may not be as high as the standard model claims it is.

4. Nash Equilibrium: Output

In this section we look at the determination of output. We now employ an alternative graphical device to illustrate the Nash equilibrium of the game by looking at inflation - output space. We combine each of the reaction functions as defined by (8) with the AS-AD equations (4) and (5) to obtain:

$$TU: Y_t=\frac{\theta u(1-a)}{u+(1-u)a}\pi+Y^* \tag{10}$$

$$PM : Y_t = \frac{\theta u(c-1)}{uc+1-u}\pi + kY^* \qquad (11)$$

where

$$a = \frac{\beta u^2 - \lambda u(1-u)}{\beta u^2 + \lambda(1-u)^2} \ ; \ c = 1 - \frac{\alpha u}{\epsilon\theta^2 u^2 + \alpha u^2}$$

This allows us to draw PM and TU curves which depict the combination of inflation rates and output levels that satsify both the optimal reaction of the player and the equality of demand and supply. This is shown in Figure 2.

Figure 2

The interpretation of this figure is as follows: in the standard model the TU is indifferent with respect to the rate of inflation and therefore the TU curve is vertical at its target y*. In this model the TU is prepared to sacrifice real wages in order to bring down inflation and so its curve is positively sloped. The PM curve in both the standard model and in this one is negatively sloped. The intuition is that the PM is concerned by inflation and therefore is prepared to have a lower level of output (with respect to his target of ky*) rather than have a higher rate of inflation. The more "conservative" is the PM the flatter will the PM curve be.

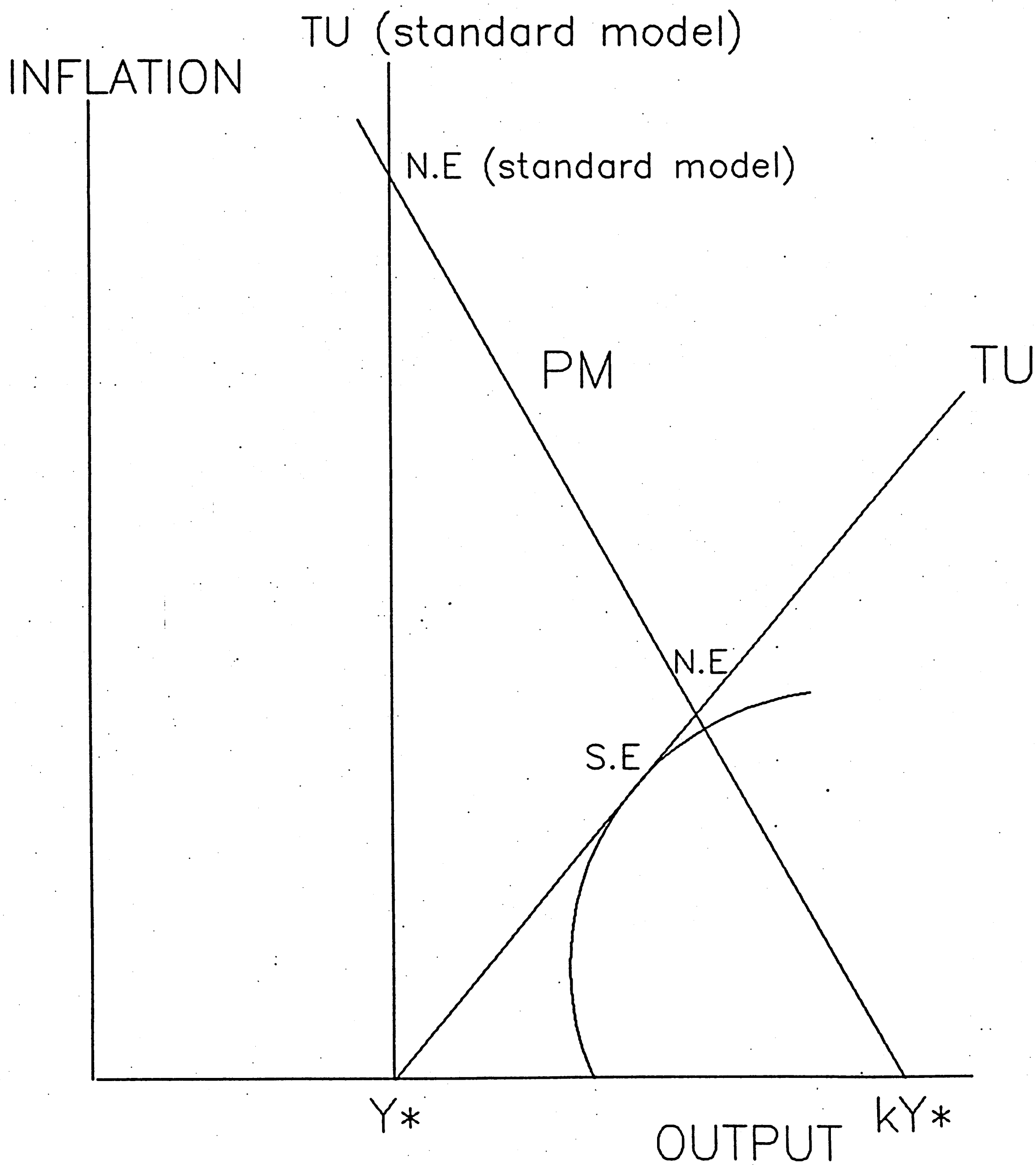
As is clear from the figure, Nash equilibrium (marked by N.E.) is at an output level which is between the two targets. Algebraically this is given by (full derivation-in the appendix):

$$y_N = z_N\, ky^* + (1-z_N)\, y^* \qquad (12)$$

where

$$z_N = \frac{\epsilon\theta^2\lambda u^2(1-u)}{\epsilon\theta^2\lambda u^2(1-u) + \alpha\beta u^3}$$

FIGURE 2



TU (standard model)
INFLATION
N.E (standard model)
PM
TU
N.E
S.E
Y*
OUTPUT
kY*

Note that this level of output is in fact a weighted average of the two players' targets, with the weights being z_N and $(1-z_N)$. To gain further insight, consider the inverse of z_N:

$$z_N^{-1} = 1 + \frac{\alpha}{\epsilon}\frac{\beta}{\lambda}\frac{u}{(1-u)}\frac{1}{\theta^2} \tag{12'}$$

As (α/ϵ) increases, i.e. as the PM's losses from inflation relative to output losses increase, z_N decreases and output moves towards the TU's target (y^*).

As (λ/β) increases, i.e. as the TU's losses from inflation relative to its losses from real wage deviations from the target increase, z_N increases and output moves towards the PM's target (ky^*). This also happens if the TU's role in inflation determination grows, i.e. when $[u/(1-u)]$ declines. The last result may be understood as follows: as the TU plays a more significant role in determining inflation, so does it display greater "restraint" in nominal wage increases. Thus a real wage cut is facilitated and hence an increase in output.

Unlike the standard monetary policy game, whereby output is fixed at a technologically given rate, here output changes with changes in the loss functions. This result also characterizes some "insiders-outsiders" models [see for example Lindbeck and Snower (1988)]. The reason is that the labor market is not characterized solely by tastes, technologies, and endowments of agents (and therefore tends to exhibit some natural rate of unemployment). In this model this market is also affected by the behavior of the TU ("insiders"). Specifically it is affected here by the TU's real wage and inflation targets and by its strategic response to policy moves. Thus if either these targets (or preferences) change or the policy measures change, one should not expect in general to see the market return to some natural rate.

In order to gain further insight into the effects of the different parameters on the nature of the solution we will turn now to a comparative analysis.

5. Nash Equilibrium: A Comparative Analysis

In this section we explore the role of the parameters of the objective functions in determining the equilibrium solution.

5.1 Changes in the Players' Targets

When the TU aims at a higher real wage target, y^* falls and output will unambiguously decline [see equation (12)]. But the inflationary consequences depend on the PM's behavior. If the PM aims at an absolute level of output it will raise k so that ky^* will remain constant. In such a case inflation will increase [see equation (9)], because now the divergence in output targets has increased. If, however, the PM has a fixed k then inflation declines, as the output targets are less divergent in absolute terms. This analysis serves to illustrate the point that in this model the targets of both players are essential in the determination of the equilibrium levels of output and inflation. Note that in the standard model inflation is a function of the PM's desire to increase output beyond a fixed level (the one that corresponds to the natural rate of unemployment).

5.2 Changes in the Players' Preferences

Consider now changes in the ratios (α/ϵ) and (λ/β). We discuss two interpretations for such changes: stabilization policy and changes in indexation arrangements.

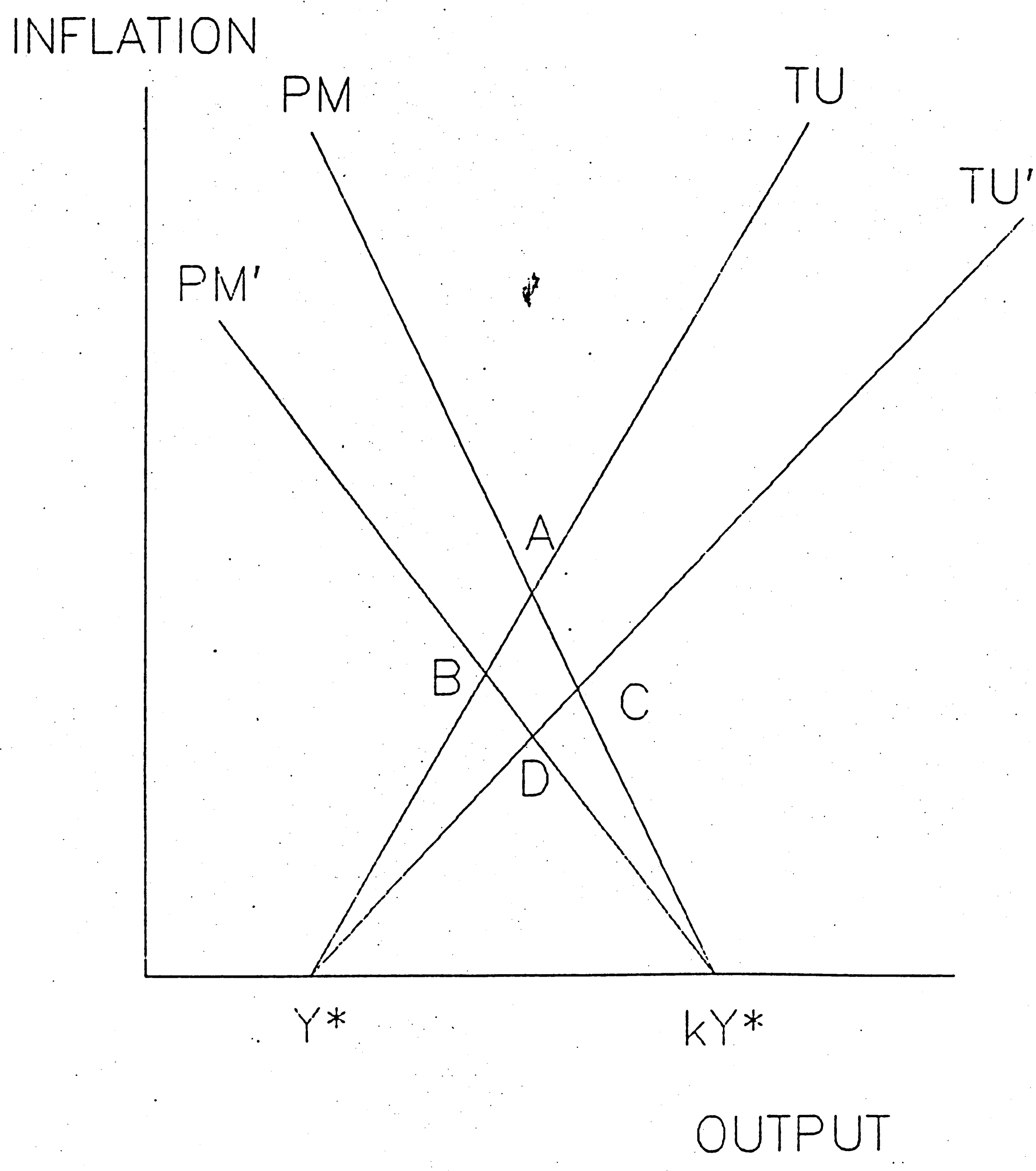
5.2.1 Stabilization Policy

In the framework of this model stabilization policy means an increase in the ratio α/ϵ. In this case the PM curve in inflation - output space rotates to the left. This movement is portrayed in Figure 3.

Figure 3

The economy moves from A to B. This means that stabilization is acheived together with a decline in output or equivalently an increase in the real wage. In terms of Figure 1 this means that the economy has moved to a point like A' and wage inflation is faster than money expansion so there is an

FIGURE 3



increase in the real wage and a decline in output. The reaction curves then shift and the new steady state equilibrium is achieved at point B' with lower inflation and lower output.

Such consequences explain why governments may be interested under such circumstances in "social pacts" with the trade union. If the PM is able to convince the TU to be less "aggressive" in its wage demands the TU curve in Figure 3 either shifts to the right or rotates to the right as illustrated. In such a case the economy moves to a point like D with no loss of output but with lower inflation. In fact if cooperation is feasible the economy could move from a Pareto-inferior Nash equilibrium to a Pareto-optimal point on the horizontal axis between y^* and ky^*. Otherwise stabilization policy has to involve some loss of output and does not result in an efficient equilibrium. Note however that it is a Preto-improving move. In the standard model there is obviously no room for such considerations as output is always at its natural rate.

Suppose now (λ/β) increases. This is shown in Figure 3 as the movement from A to C. This is a kind of "stabilization policy" by the TU and involves an increase in output. Thus "weaker" or "softer" TUs promote lower inflation and increased output. In the context of the European Monetary Union this may mean that countries with more militant TUs will exhibit lower output and higher inflation given an identical monetary policy.

In fact empirical studies lend some support for this view. More "corporatism" or centralization in wage setting should lead to a broader view of the economy and its problems by the unions and therefore to moderation in wage claims (i.e. a relatively high y^* or λ/β). We would then expect to see lower inflation and higher output according to the foregoing analysis. Calmfors and Driffill (1988) present a number of empirical studies for OECD economies which show that increasing centralization (from moderate to strong) promoted higher output and lower inflation in the 1970's and 1980's.

5.2.2 Indexation

Recently Fischer and Summers (1989) have suggested using the monetary policy games framework to analyze the effects of indexation arrangements. We take up the idea here by looking at the effects of indexation changes on each of the players in turn.

First suppose that the PM adjusts income tax brackets less frequently. This means that income loss for the TU at any given rate of inflation increases. This should generate an increase in the ratio (λ/β) and thus a movement from A to C in Figure 3. Thus changes in indexation of labor income taxes serve to "stabilize" inflation in a way which is favourable to the PM. This then may be a way for a PM, who cannot obtain cooperation, to "discipline" the TU. This exercise also shows that the prevalent intuition that more indexation will lead to more inflation is correct: were the PM to adjust tax brackets more often, TU losses will decline and inflation will increase together with real wages.

However this intuition is not always right. Suppose the economy starts from a point like C (in Figure 3) and there is more indexation in capital markets, for example when the PM issues indexed bonds. In such a case TU losses decrease rotating the TU curve leftwards. This again implies more inflation (movement from C to A). However such a change in indexation may increase the PM's losses from inflation. For example now the PM has less revenues from inflation erosion of nominal debt. This implies that the PM curve rotates leftwards and the economy moves to a point like B. B may lie above or below C (or may be at just the same rate of inflation) so the net effect of the indexation change with respect to inflation is ambiguous. Output however has declined.

These examples serve to illustrate the following general conclusions:

(i) If changes in indexation affect both the PM and the TU in a similar way then both (α/ϵ) and (λ/β) increase or decrease simultaneously. As shown by the preceding analysis this means that inflation unambiguously rises when there is more indexation while the net change of output is uncertain (compare points A and D in Figure 3).

(ii) If the change in indexation affects the players non-symmetrically (α/ϵ) declines while (λ/β) increases or vice versa. Output will now rise or fall unambiguously while the net effect on inflation is uncertain (compare points B and C in Figure 3).

6. Stackelberg Equilibria

We now look at those situations whereby one of the players is "leading" the game in the sense that he is determining his control variable before the other player does. We begin with the case of the PM as the leader.

6.1. PM Leadership

This case corresponds to a "rule" situation, i.e., when the PM can credibly pre-commit so that the game is played as a Stackelberg leader-follower game with the PM leading. The solution in output and inflation is as follows (the full derivation is given in the Appendix):

$$\pi_S = \frac{\beta u z_S (k-1) y^*}{\lambda (1-u) \theta} \tag{13}$$

$$y_S = z_S\, k y^* + (1-z_S)\, y^* \tag{14}$$

where

$$z_S = \frac{\epsilon \theta^2 u^2 \lambda^2 (1-u)^2}{\epsilon \theta^2 u^2 \lambda^2 (1-u)^2 + \beta^2 u^4 \alpha} < z_N$$

Graphically this solution is shown in Figure 2 as point S.E. Note that the Stackelberg or "rule" equilibrium is not $\hat{m}=\hat{w}=\pi=0$ as in the standard model. To see how this result is generated consider the following argument: the equilibrium of this game in the steady state has to be on the TU reaction curve (as this is the follower), with $\hat{m}=\hat{w}=\pi$, i.e. on the 45° line in the $\hat{w}$-$\hat{m}$ space. This can be at either $\pi=0$ or $\pi > 0$. From the TU reaction function [see equation (8)], $\hat{w}$ will be set at zero only if $y = y^*$ (and $\hat{m}=0$). However, this is not the optimal outcome for the PM who is the leader in the game. This can be seen when comparing the loss functions for the PM at the $\pi=0$ point and at some $\pi_S > 0$:

$$L^{PM}(\pi=0,\ y=y^*) = (\epsilon/2)(y^*-ky^*)^2$$

$$L^{PM}(\pi_S > 0,\ y_S > y^*) = (\alpha/2)\pi_S^2 + (\epsilon/2)(y_S-ky^*)^2$$

The PM can always find some $\pi_S > 0$ so that

$$(\epsilon/2)(y^*-ky^*)^2 \quad > (\alpha/2)\pi_S^2 + (\epsilon/2)(y_S-ky^*)^2$$

or

$$(\epsilon/2)[(y^*-ky^*)^2 - (y_S-ky^*)^2] > (\alpha/2)\pi_S^2$$

for some y_S which satisfies $ky^* > y_S > y^*$.

Thus the PM would rather choose $\hat{m} > 0$ and attain a higher value for his objective function. Note that this is possible in this model because the TU cares about inflation. In the standard model $y > y^*$ is unattainable no matter how high is inflation and therefore the PM is content to stay at $\pi = 0$. Note too that the equilibrium outcome cannot be at $y > y^*$ with $\pi = 0$ either. This is so because, looking at the TU reaction function, we see that with $\hat{m} = 0$ and $y > y^*$ the TU sets $\hat{w} > 0$ which is a contradiction.

It is therefore the fact that the TU cares about inflation that makes the "rule" equilibrium exhibit a positive rate of inflation. This fact is "exploited" by the PM to achieve an optimal outcome which takes into account both inflationary losses and output losses. The PM is prepared to have some inflation in order to have some output gains. Thus the same property which reduced the Nash rate of inflation is the one that raises the Stackelberg rate above zero.

Another interesting feature of this equilibrium [as seen in equation (14) and proven in the Appendix] is that output is lower than the Nash equilibrium output. The PM raises output above y^* but to a lesser extent than under "discretion." Note that this outcome is favorable to both parties. For the PM the loss function attains a lower value with respect to the Nash outcome by virtue of his leadership in the game. The TU has output deviate less from its target while inflation is lower (see Appendix).

Therefore the regime of "rules" remains a Pareto-superior outcome, although it is still an inefficient point as the Pareto-optimal points are those of zero inflation and of output between y* and ky*.

6.2 TU Leadership

In many cases the wage is determined in contracts and thus the appropriate representation of the game is such that the TU moves first. In this case two outcomes are possible as depicted in Figure 4[7].

Figure 4

The interpretation of this solution is as follows: when the PM is relatively more concerned by inflation the TU will choose a point on his reaction curve which lies to the North West of the Nash equilibrium point (S'_2 in Figure 4). This is so because the TU knows that when faced with higher wage inflation this PM will not raise money injection too much so as to not increase inflation too much. Therefore some real wage gains can be acheived. Thus in this case the Stackelberg solution is non-concurrent: the TU is better off but the PM is worse off. Taking the Nash equilibrium as the point of reference, the TU "expolits" the PM concern with inflation to push up real wages. On the other hand when the PM gives relatively less weight to inflationary losses the TU would rather have lower real wages and gain a decrease in inflation. This is so because in a sense this PM cannot be "exploited". The Stackelberg equilibrium in this case (point S'_1) is concurrent, i.e. both sides are better off with respect to the Nash equilibrium.

The conclusion is that a given TU, in a situation of contracts, will have a "tougher" wage policy

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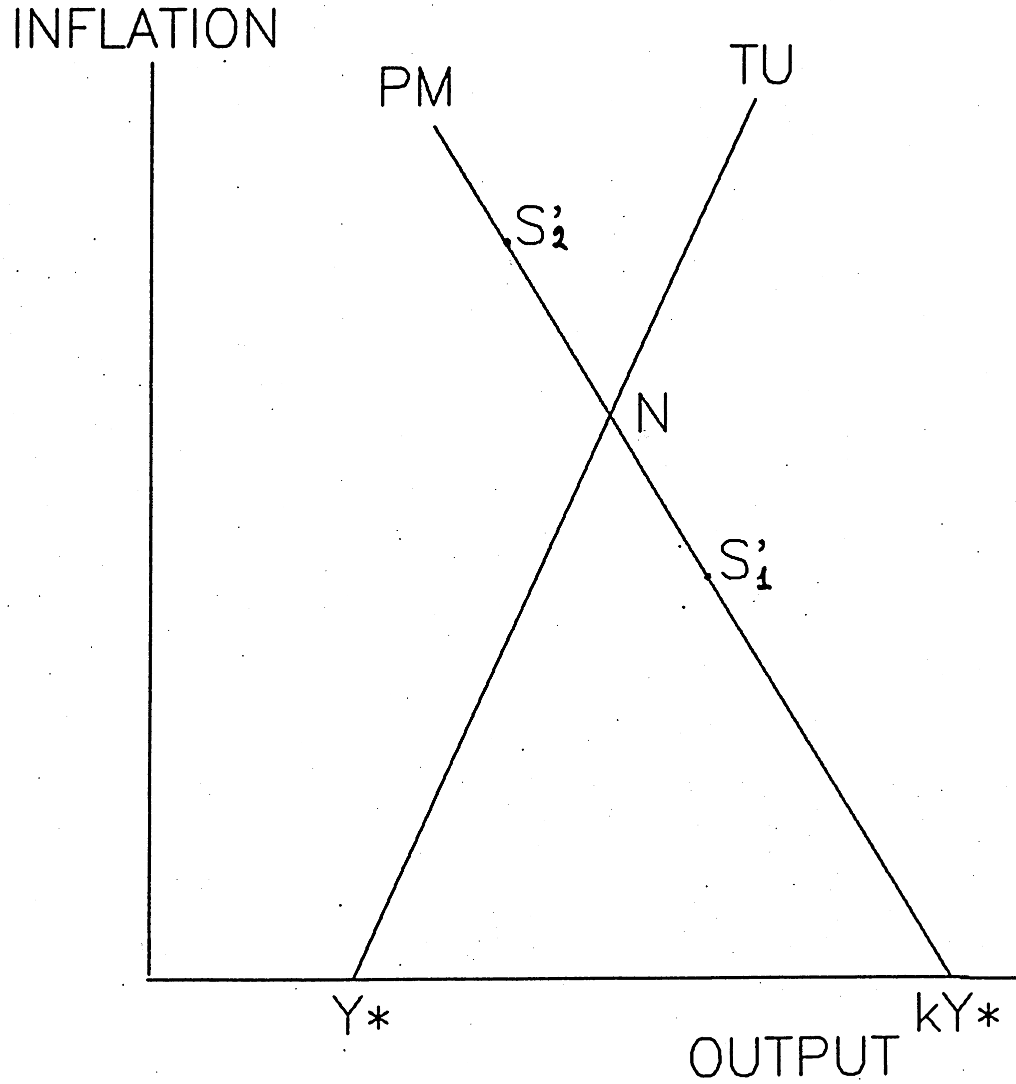
[7] Algebraically this is given by:

$$\pi_{s'} = \frac{\epsilon\theta z_{s'}(k-1)y*}{\alpha}$$

$$y_{s'} = z_{s'}y* + (1-z_{s'})ky*$$

FIGURE 4



relative to the no-contract situation when faced with an inflation-minded PM and a "softer" wage policy when faced with an output-minded PM.

Comparing the Stackelberg solutions for PM leadership and TU leadership we see that there are no unique relations with respect to inflation and output: inflation may be higher with TU leadership (compare point S.E in Figure 2 with point S'_2 in Figure 4) but in the case of a PM with relatively low α/ϵ TU leadership will be expressed by "soft" behaviour and possibly a low level of inflation (compare points S.E in Figure 2 and point S'_1 in Figure 4). Likewise output may be higher under TU leadership (point S'_1 in Figure 4 vs. point S.E in Figure 2) but could conceivably be lower when the TU is "tough" in face of an inflation-minded PM (point S'_2 in Figure 4 vs. point S.E in Figure 2).

7. Conclusions

The foregoing analysis has shown that whenever the private sector does not only act strategically but is also active in the determination of inflation then the consequences of monetary policy are quite different from those implied by the standard analysis. The major consequences are :

(i) "Rules" and "discretion" may not be so far apart as usually believed; in particular inflation may be positive even when monetary rules are credible and output will be lower; both solutions are not Pareto-optimal.

(ii) Monetary policy has real effects on output in the short run due to strategic considerations by the private sector even when the latter is perfectly informed and not subject to any rigidity.

(iii) The existence of wage contracts generates "tough" or "soft" wage setting behaviour by the TU depending upon the PM's preferences

(iv) Non-cooperative stabilization policy has output costs and cannot attain a Pareto-optimal outcome. Adjustment of income tax rates may possibly be used to eliminate or reduce such output costs.

(v) The inflationary and output effects of indexation depend on their differential effects on the players' loss function.

The preceding analysis brings to mind several possible extensions. One is to model the PM-TU interaction as a bargaining process. The present non-cooperative model may serve then as a benchmark for evaluating bargaining outcomes, for example by serving as the "disagreement point" in a bargaining model. Another possible extension is to introduce uncertainty into the model: each player may know only a probability distribution of the other player's parameters. Such modelling calls for a learning mechanism, such as a Bayesian updating of prior probabilities. Finally, the dynamic structure of the model may be enriched by considering longer horizons or repetitions of the game. This however may bring the interaction explored into the realm of multiple equilibria that usually characterizes repeated games.

This paper showed that even under a simple set-up the results of the standard game are substantially modified. The demonstrated effects of an active private sector are unlikely to disappear under the cited richer formulations, which are the subject of current research.

APPENDIX

This appendix is based on Basar and Olsder (1982), Section 4.6. We spell out briefly the general solution of quadratic games for the Nash and Stackelberg cases considered in this paper. For a more detailed discussion the reader is referred to the above reference.

THE LOSS FUNCTIONS

Each player i has a quadratic loss function of the following type:

$$L^i = \frac{1}{2}\sum_{j=1}^{N}\sum_{k=1}^{N} u_j{}' R^i_{jk} u_k + \sum_{j=1}^{N} r^i_j u_j + c^i \tag{1}$$

where

u_j is the decision variable of player j.

R^i_{jk} is a matrix with $R^i_{ii} > 0$; which is a $m_j \;x\; m_k$ dimensional

r^i_j is an m_j dimensional vector

c^i is a constant

.

THE NASH SOLUTION

To determine the Nash equilibria solution, differentiate L^i with respect to u^i, set the resulting expressions equal to zero and solve for u^i.

This set of equations can be written as:

$$Ru = -r \tag{2}$$

where

$$R = \begin{bmatrix} R^1_{11} & .... & R^1_{1N} \\ . & & \\ R^N_{1N} & .... & R^N_{NN} \end{bmatrix}$$

$$u = (u^1,\ u^2, ..., u^N)$$

$$r = (r^1_1,\ r^2_2, ..., r^N_N).$$

When R is invertible the Nash solution is given by

$$u_N = -R^{-1} r. \tag{3}$$

In this paper the problem reduces to:

$$\begin{pmatrix} \widehat{m}_N \\ \widehat{w}_N \end{pmatrix} = - \begin{pmatrix} \frac{R^2_{22}}{\delta} & \frac{-R^1_{21}}{\delta} \\ \frac{-R^2_{21}}{\delta} & \frac{R^1_{11}}{\delta} \end{pmatrix} \begin{pmatrix} r^1_1 \\ r^2_2 \end{pmatrix} \tag{4}$$

where $\delta = R^1_{11} R^2_{22} - R^1_{21} R^2_{21}$.

The Nash rate of inflation is then computed by using:

$$\pi_N = u\widehat{m}_N + (1-u)\widehat{w}_N. \tag{5}$$

THE STACKELBERG SOLUTION

Consider the case of two players. The follower's (Player 2) optimal response to the leader's (Player 1) strategy u^1 can be derived by differentiation of (1) and taking u^1 as given, i.e.:

$$u^2 = -(R^2_{22})^{-1}[R^2_{21}u^1 + r^2_2]. \tag{6}$$

The leader chooses his strategy by inserting (6) into L^1 and minimizing with respect to u^1. The resulting expression is:

$$\begin{aligned} u^1 = -[&R^1_{11} + R^{2\prime}_{21}(R^2_{22})^{-1}R^1_{22}(R^2_{22})^{-1}R^2_{21} \\ &-R^1_{21}(R^2_{22})^{-1}R^2_{21} - R^{2\prime}_{21}(R^2_{22})^{-1}R^{1\prime}_{21}]^{-1} \\ &[R^{2\prime}_{21}(R^2_{22})^{-1}R^1_{22}(R^2_{22})^{-1}r^2_2 - R^1_{21}(R^2_{22})^{-1}r^2_2 \\ &+r^1_1 - R^{2\prime}_{21}(R^2_{22})^{-1}r^1_2] \end{aligned} \tag{7}$$

MONEY CREATION, WAGE INFLATION, AND PRICE INFLATION

Denote

$R^1_{11} = a$

$R^1_{12} = b$

$R^2_{21} = c$

$R^2_{22} = d$

$R^1_{22} = e.$

Using equation (7) we get:

$$\widehat{m}_s = -\frac{r^1_1 + r^2_2\left(\frac{ce}{d^2} - \frac{b}{d}\right) - \frac{c}{d}r^1_2}{a + \frac{c^2e}{d^2} - 2\left(\frac{bc}{d}\right)}.$$

Multiplying both the numerator and the denominator by d:

$$\widehat{m}_s = -\frac{r^1_1 d - br^2_2 + r^2_2\left(\frac{ce}{d}\right) - r^1_2 c}{ad + \frac{c^2e}{d} - 2bc} \tag{8}$$

Using (6) we get:

$$\widehat{w}_S = \frac{\{\beta u^2 - \lambda u(1-u)\}}{\{\beta u^2 + \lambda(1-u)^2\}}\widehat{m}_S + \frac{\beta \tilde{y} u}{\lambda(1-u)^2 + \beta u^2}. \tag{9}$$

In equilibrium $\widehat{m}_S = \widehat{w}_S = \pi_S$.

Therefore,

$$\pi_S = \frac{\beta \tilde{y} u}{\lambda(1-u)^2 + \lambda u(1-u)}.$$

However, $\tilde{y} = \frac{y_S - y^*}{\theta}$ in equilibrium.

It will be shown that $y_S = z_S k y^* + (1 - z_S) y^*$. Therefore:

$$\pi_S = \frac{\beta u z_S (k-1) y^*}{\lambda(1-u)\theta}. \tag{10}$$

Note that by a similar procedure the Nash equilibrium rate of inflation can be shown to be:

$$\pi_N = \frac{\beta u z_N (k-1) y^*}{\lambda(1-u)\theta}.$$

Therefore, it is sufficient to show that $z_N > z_S$ in order to prove that $\pi_N > \pi_S$.

OUTPUT

In this section we derive y_S, the long run level of output in the Stackelberg equilibrium. Using (9) and the equality of $\widehat{m}$ and $\widehat{w}$ in the long run we get:

$$\widehat{w} = \frac{\beta u (y_S - y^*)}{\theta\{\lambda(1-u)^2 + \lambda u(1-u)\}}.$$

Similarly, using (8) we get:

$$\widehat{m} = \frac{-\epsilon\theta u(y_S - ky^*)(c+d) + \frac{\beta u}{\theta}(y_S - y^*)\left(\frac{ce}{d} - b\right)}{ad + \frac{c^2e}{d} - 2bc}.$$

To simplify the derivation, we denote:

$$\frac{\beta u}{\theta\{\lambda(1-u)^2 + \lambda u(1-u)\}} = V_1$$
$$\epsilon\theta u(c+d) = V_2$$
$$\frac{\beta u}{\theta}\left(\frac{ce}{d} - b\right) = V_3$$
$$ad + \frac{c^2e}{d} - 2bc = V_4.$$

Therefore, $\widehat{w} = \widehat{m}$ implies:

$$V_1(y_S - y^*) = \frac{-(y_S - ky*)V_2 + V_3(y_S - y^*)}{V_4}.$$

Thus,

$$y_S = \frac{V_2ky^* + (V_4V_1 - V_3)y^*}{V_2 + V_4V_1 - V_3}$$
$$y_S = z_Sky^* + (1 - z_S)y^*$$

where $z_S = \frac{V_2}{V_2 + V_4V_1 - V_3}$

which after some messy computations can be shown to be:

$$z_S = \frac{\epsilon\theta^2\lambda^2u^2(1-u)^2}{\alpha\beta^2u^4 + \epsilon\theta^2\lambda^2u^2(1-u)^2}.$$

Note that this share is in the Nash solution:

$$z_N = \frac{\epsilon\theta^2\lambda u^2(1-u)}{\alpha\beta u^3 + \epsilon\theta^2u^2(1-u)}$$

which implies that:

$$\frac{Z_N}{Z_s} = \alpha\beta u^3 X + \epsilon 0^2 \lambda u^2 (1 - u/[\alpha\beta u^3 + \epsilon 0^2 \lambda u^2 (1 - u)]$$

$$where \;\; \beta u/[\lambda(1-u)] = X.$$

As we have assumed throughout that $\beta u > \lambda(1 - u)$ then $Z_N > Z_S$.

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