INFLATION: THE INVISIBLE FOOT OF MACROECONOMICS

Michael Carter and Rodney Maddock*

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We take a simple, well known macroeconomic model and treat it as a game between two players - the government and an all-embracing union. The results are surprising. Almost invariably the payoffs have the form of a prisoners' dilemma. The equilibrium outcome produces unwanted inflation and is not Pareto optimal. This is despite the fact that all participants are assumed to have full information. This result is shown to be quite robust to the form of the model and is not affected if one of players is forced to announce its strategy in advance. This we call the invisible foot of macroeconomics.
INFLATION: THE INVISIBLE FOOT OF MACROECONOMICS *

In recent years Western economies have been characterized by sustained inflation. In the search for scapegoats the government and the workers have attracted a fair share of the blame. For many the existence of inflation is regarded as a failure of government policy – the pursuit of too high a level of output whether from ignorance or avarice. Other commentators point to organized labour as the villains – unions pursuing wage claims which are beyond the capacity of the economy to meet. In this paper we show that inflation which nobody wants results inevitably from the rational pursuit of self-interest. This result does not arise from any information failure. All participants have full information concerning the economic structure and the objectives of the other agents.

We take a simple, well known macroeconomic model and treat it as a game between two players. The results are surprising. Almost invariably the payoffs have the form of a prisoner's dilemma. The prisoner's dilemma is the antithesis of Adam Smith's invisible hand. Rather than promoting the social optimum, individual self-interest in

*We gratefully acknowledge the assistance of Malcolm Gray, Fred Gruen and Doug Whaites while absolving them from any responsibility for errors.
the prisoner's dilemma leads to collective ruin. This phenomenon has often been termed the invisible foot. In a prisoner's dilemma, the players are led "as if by an invisible foot" to a clearly sub-optimal outcome.1

The traditional approach to macroeconomics is a one player game against nature. The government is perceived as the only strategic macroeconomic agent. This approach has spawned a voluminous literature on optimal control in which large-scale macroeconomic models are solved to find optimal values for the policy instruments available to government in order that it might achieve its objectives such as high levels of employment and stable prices. This traditional view has been consistently challenged over the last fifteen years by the hypothesis of rational expectations.2 Proponents of this hypothesis have argued that the effectiveness of much government policy is reduced as a result of consequent changes in the actions of other economic agents.

1. While game theory has seldom been explicitly applied to macroeconomics, the notion that inflation is a form of market failure is a common theme. It runs consistently through the writings of Keynes and has been pursued by many subsequent authors. Naietal and Benjamins (1980) review this literature. Paul (1975) contains an interesting application of game theory to macroeconomics which complements our paper. He derives the Nash equilibrium and Pareto optimal solutions for a model of the Danish economy and shows that the actual historical policies are closer to the Nash equilibrium than the Pareto optimum. Other recent contributions include Selten & Guth (1982) and van der Ploeg (1983). The use of the term invisible foot to describe the workings of the prisoner's dilemma is part of the oral tradition.

Rational economic agents will foresee the consequences of any
government policy and will act so as to offset it. Typically, in
rational expectations models, the government is the only economic actor
with significant market power. Inflation in these models is the result
of misguided government policy.

Our treatment differs in that we recognise other significant
economic agents. Specifically we model the economy as a two player
game. One player is of course the government. We call the second
player "the union". It might be a large, pace-setting union, a union
council or a national wage-setting authority. Many countries have
groups which have the power to set the nominal wage for a significant
portion of the economy and hence fulfill the role of the union in our
model. In Australia the Conciliation and Arbitration Commission has
the authority to set the nominal wage for most of the workforce. In
Japan the unions involved in the Spring offensive exert an influence
which extends well beyond their membership. In Western European
countries nominal wages are often determined in national collective
bargaining. The choice of the nominal wage may be the result of a
subsidiary game - between unions, or between unions and employers. The
important point is that the nominal wage rate is determined
collectively and independently of government policy.

We assign employers a subsidiary role in our model. That the
policy debate often takes place within the tripartite framework of
government, unions, and employers suggests that a three player game
might be more realistic but that would severely complicate the analysis. Competitive pressures may constrain employers to act more mechanically and less strategically than the other actors. Accordingly we assign employers no strategic role - employment simply adjusts to equilibrate marginal productivity and real wages. Since this process assumes away the long run investment choices of employers, we are not able to consider questions of longer run growth where capital formation plays a central role. Our focus is on the short run.

Our focus is also short run in that we only consider a single period game. This does not undermine our principal result since it is well-known that repetition does not solve the prisoner's dilemma.3

A feature of our model which deserves emphasis is that there is no uncertainty regarding the structure of the economy or the motives of the players. Each participant has full information. Each player is fully rational. The only uncertainty for each player is the strategy chosen by its opponent.

We proceed in two stages. In Section 1 we introduce a very simple macroeconomic model and analyse it as a two-player game. We demonstrate that in this simple model inflation is an inevitable outcome of noncooperative behaviour. In Section 2 we generalize the model of Section 1 and show that an inflationary prisoner's dilemma

3. Specifically the Nash equilibrium of a prisoner's dilemma game remains the Nash equilibrium if the game is repeated a finite number of times (Luce & Raiffa, 1957:97-102)
results under quite unrestrictive conditions.

1 A simple model

In this section will outline a very simple macroeconomic model to motivate the more general treatment in the next section and to illustrate the main result. Though simple, this model contains all the essential ingredients of the general result.

Output is produced according to a Cobb-Douglas production function. Assuming constant capital stock, this can be written:

\[ Y = bN^a \quad 0 < a < 1 \]  

where \( Y \) is the level of output, \( N \) is the level of employment and \( b \) is a constant which incorporates the contribution of capital. The parameter \( a \) is the output elasticity of employment. Employment is determined by the marginal productivity condition:

\[ V = abN^{a-1} \]  

where \( V \) is the real wage. The real wage is defined by

\[ V = W/P \]  

Where \( W \) is the nominal wage and \( P \) is the price level. Equations (1),
Figure 1: The Determination of Aggregate Supply
(2), and (3) imply the aggregate supply equation:

\[ Y = b^{1/\alpha} \left( \frac{aP}{W} \right)^{\alpha/1-\alpha} \]

the derivation of which is illustrated in the four quadrant diagram Figure 1.

The aggregate supply function depends parametrically upon the nominal wage \( W \). Increasing the nominal wage shifts the supply curve upward. Through its control of the nominal wage the union can effectively select the aggregate supply curve which prevails. In the general propositions developed in the next section, we will assume that the aggregate supply function is concave in \( P \). In the simplified model of this section concavity is ensured provided that the output elasticity of employment \( a \) is greater than one-half. This assumption can be justified on empirical grounds. Henceforth we will assume that:

\[ 0.5 < a < 1 \]

We assume that the demand for real balances is the following function of income:

\[ \frac{M}{P} = dY^c \quad 0 < c \]

where \( M \) the money supply, \( P \) the price level, and \( c \) is the income elasticity of demand for money. For simplicity we assume that \( M \) is scaled so that \( d \) is equal to 1. Then the preceding equation can be rearranged to generate the aggregate demand curve:
\[ Y = (M/P)^{1/c} \]

The assumption that \( c > 0 \) guarantees that the aggregate demand curve is downward sloping and convex in \( P \) as depicted in Figure 1.

The aggregate demand curve depends parametrically upon the money supply. Through its control of the money supply, the government can effectively select the aggregate demand curve. The higher the money supply the higher the demand curve. For a given aggregate supply curve, an upward shift in the aggregate demand schedule boosts employment and output through the conventional multiplier process.\(^4\)

The macroeconomic model is quite standard. The level of income and the price level will be determined by the intersection of the aggregate demand and supply curves. The government has control over the aggregate demand curve through its control of the money supply. Our innovation is that the supply curve can be moved strategically by the union through its choice of the nominal wage. Any combination of output and price can be achieved by an appropriate selection of \( M \) and \( W \). The actual outcome achieved will depend upon the interaction of the two players.

The strategy of each player depends upon (i) its objective function and (ii) its expectations regarding the choice to be made by the other player. The latter are in turn dependent upon the opponent's

\(^4\) The impact of government policy within the framework of this model is analysed in Chapter 3 of Carter and Maddock (1984).
objective function. We stress that each player is assumed to have full information regarding both the economy and the objectives of the other party. We proceed by outlining the objectives for each player and then deriving their optimal choices for each possible strategy on the part of their opponents.\(^5\)

We assume that the government is concerned about the level of employment and the rate of inflation. These concerns can be motivated by the need to maintain electoral support. Since there is a one-to-one relationship between the level of employment and the level of income, the government's preferences can be defined over prices and income. Specifically, we assume that the government has a target output level \(Y_g\) and that its objective is to minimise deviations from the pair \((Y_g, P_{-1})\). That is

\[
G = \min (Y - Y_g)^2 + j(P - P_{-1})^2
\]

where \(P_{-1}\) is the price level inherited from the previous period and \(G\) is a measure of the loss the government suffers from not achieving its objective. The constant \(j\) represents the relative weight on inflation in the government's objective function.

With this objective function, the government's preferences can be represented by circular indifference curves in \((Y, P)\) space as shown in

\[----------\]

5. In this section we will be specific about the objectives of each player and treat their objectives more generally in the next section.
Figure 2: Locus of Optimal Choices for the Government
Figure 2. The supply curve acts as an effective constraint on the outcomes available to the government. For any given supply curve (i.e., strategy of the union), the government's optimal policy choice is given by the point where supply curve is tangential to the highest possible indifference curve. For example, if the supply curve is $S^1$, the optimal outcome for the government is the point $A_1$. For the supply curve $S^2$, the optimal outcome is $A_2$. Mapping these optimal choices as the supply curve moves around the first quadrant traces out a locus of optimal outcomes for the government. This locus is depicted as a dashed line in Figure 2. Each point on this optimal locus represents the optimal outcome for the government given that the supply curve is the one that intersects the locus at that point. Such an outcome can be achieved by choosing the money supply such that the aggregate demand curve intersects the aggregate supply curve on the optimal locus.

In this section we assume that the union is concerned only with the level of employment and the real wage. It is not concerned about inflation. (This restriction is relaxed in Section 2.) Since the union has full information regarding the structure of the economy, it understands that it is constrained (by the behaviour of employers) to outcomes which lie on the labour demand schedule in quadrant 3 of Figure 1. We assume that it has a most preferred real wage-employment pair on this curve $(Y_u, N_u)$. It is unnecessary at this stage to specify the union's objectives more elaborately. This target pair might be motivated by the assumption that the union is concerned to maximize
employment subject to the real wage $W_u$. Alternatively it might be concerned to maximise the real wage subject to achieving a minimum level of employment $Y_u$.

Consider the optimal choices for the union (Figure 3). For any given demand curve, the union can ensure that real wage and employment are equal to its most preferred outcome by appropriate choice of the nominal wage. For example, if the demand curve is $D^1$, the union can ensure its desired outcome by choosing $W_1$ as the nominal wage. For the aggregate demand curve $D^2$, the union can ensure its most desired outcome by choosing $W_2$ as the nominal wage. Therefore the locus of optimal outcomes for the union is a vertical line at $Y_u$, where $Y_u$ is the output generated by its desired level of employment. That is:

$$Y_u = b(W_u)^a$$

We assume that $Y_u < Y_g$.

Figure 4 combines the optimal locus for each player. The outcome labelled A is a simultaneous optimum. Should the demand and supply functions intersect at point A, neither player would have an incentive

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5. This assumption does not mean that the government is more concerned with the level of employment than the union. It simply means that the government's target is higher than that consistent with the union's real wage goal.
Figure 3: Locus of Optimal Choices for the Union

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Figure 4: The Nash Equilibrium
to alter its policy. The point A is a Nash equilibrium in the macroeconomic game. Given that each player has full information regarding the nature of the game and the objective function of the opponent, they may reasonably expect that their opponent will play the Nash equilibrium strategy.

Now we come to the fundamental point of the paper. At the Nash equilibrium the price level is higher than that inherited from the previous period. The point A lies above the line $p = P_{-1}$. There is non-zero inflation. Consequently the Nash equilibrium is not Pareto optimal. There exist alternative outcomes which are better for at least one of the players and no worse for the other player. In particular the outcome marked B is Pareto superior to A. At B income is the same as it is in the Nash equilibrium while inflation is zero. The outcome B is equally satisfactory to the union and more satisfactory to the government. Noncooperative maximising behaviour in this game inevitably leads to inflation which neither player wants. Inflation results because the non-inflationary outcome cannot be sustained by noncooperative optimising behaviour.

The instability of the Pareto optimum is illustrated in Figure 5. The point B can be attained if the government offers the demand curve $D^1$ and the union offers the supply curve $S^1$. However there are points on the supply curve $S^1$ which are preferable to B for the government. That is, given the supply curve $S^1$, the government would like to trade
Figure 5: The Prisoner's Dilemma
off some inflation for additional output. A preferable outcome for the
government can be achieved by expanding aggregate demand. The union is
aware of this and it would be irrational for the union to offer the
supply curve $S^1$. The union can offer the supply curve $S^2$ confident in
the belief that the government will choose the demand curve $D^2$.
Similarly the government will deduce that the union will offer the
supply curve $S^2$ and therefore will itself offer the demand curve $D^2$. In
this sense, A is the expected outcome of the game.

In game theory such phenomena are called prisoner's dilemmas. The
nature of the prisoner's dilemma in the macroeconomic game can be seen
in a more conventional format by considering just two strategies for
each player – the Nash strategy and the Pareto optimal strategy as
depicted in Figure 5. The government's strategies are the demand curves
$D^1$ and $D^2$. The union's strategies are the supply curves $S^1$ and $S^2$. The
four combinations of the possible strategies leading to four possible
outcomes – A, B, C, D. Specifying parameters values 7 we can calculate
the payoffs to the government for each of these outcomes. These are $A$
$= 2$, $B = 1$, $C = 2.7$ and $D = 0.4$. The union is indifferent between $A$ and
$B$, it prefers these outcomes to $C$ and $D$. We assume that it is also
indifferent between $C$ and $D$. Attaching ordinal payoffs for the union to

7. The parameter values are $a=0.5$, $b=1$, $c=1$, $j=0.25$, $y_g=3$, $y_u=2$, $p_{-1}=2
these outcomes, we can derive the following payoff matrix:

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<th>g¹</th>
<th>g²</th>
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<tbody>
<tr>
<td>**D¹</td>
<td>2.0</td>
<td>2.7,2</td>
</tr>
<tr>
<td>**D²</td>
<td>0.4,2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Each entry represents the payoff to the player of the combination of strategies indicated by the respective row and column. Both players wish to minimise their respective payoffs. The Pareto optimal outcome is achieved by the strategy pair (D¹,g¹). But this cannot be a Nash equilibrium. Assuming that the union plays g¹, the government is better off playing D² which decreases its payoff to 0.4. But given that the government plays D², the union will play g². At (D²,g²), neither player can improve its outcome by playing a different strategy. (D²,g²) is a Nash equilibrium. The macroeconomic game is a typical prisoner's dilemma.

As is characteristic of the prisoner's dilemma, suboptimality can be avoided by cooperation. If the government and the union enter into a binding agreement to play the strategy pair (D¹,g¹), the Pareto optimal outcome will be attained. But there must be some reason for each party to trust the other. In this game the government has an incentive to defect from such an agreement. To overcome the dilemma,
the agreement must be believed by both parties.

Since this is a simple model, the reader may wonder how general is this result. For example the reader might question whether the dilemma might be resolved if the union was concerned about inflation or if the union was forced to announce its strategy in advance. In the next section we demonstrate that the prisoner's dilemma is not an artefact of the simplicity of the model. Specifically we show that the dilemma does not result from the assumption that the union is not concerned about inflation. In Section 3 we show that it is does not arise from the assumption that the players have to choose their strategies in ignorance of the choice of the other player. The result is quite robust.

2 A general result

Essentially the assumptions which are sufficient to generate the result are (1) the government can move the aggregate demand curve, (2) the union can move the aggregate supply curve, and (3) the players have convex preferences over outcomes in income and prices. Specifically we make the following assumptions. Assumption 4 is not required to establish the existence and non-optimality of the Nash equilibrium. It will be used in the next section.
1. The location of the aggregate supply curve is determined by the parameter \( W \) which is under the control of the union. Aggregate supply is given by

\[ Y = f(P, W) \]

with

\[ f(0, W) = 0 \quad \text{for all } W \]

where \( f \) is continuous and concave in \( P \). There is an upper limit \( Y_{\text{max}} \) on the output of the economy. The function \( f \) is monotonically increasing in \( W \). For given \( W \), \( f \) is monotonically increasing in \( P \) until \( Y \) achieves its maximum \( Y_{\text{max}} \). That is for given \( W \) the aggregate supply curve is vertical at \( Y_{\text{max}} \) and has positive and finite slope for all \( Y < Y_{\text{max}} \).

2. The position of the aggregate demand curve is determined by the parameter \( M \) which is controlled by the government. Aggregate demand is given by

\[ Y = g(P, M) \]

where \( g \) continuous, convex and monotonically decreasing in \( P \), and monotonically increasing in \( M \).

3. The objectives of the players can be represented by continuous, strictly convex preference orderings over the price level and income. The government has a target level of employment \( Y_g = Y_{\text{max}} \).
at the inherited price level $P_{-1}$. That is

$$(Y_g, P_{-1}) >_g (Y, P_{-1}) \text{ for all } Y < Y_g$$

where $>_g$ denotes the preference ordering of the government.

Similarly the union has a target level of employment $Y_u$ such that

$$(Y_u, P_{-1}) >_u (Y, P_{-1}) \text{ for all } Y < Y_u$$

with

$$Y_u < Y_g$$

Both players prefer constant prices at all levels of income, that is for all $Y$

$$(Y, P_{-1}) >_g (Y, P) \text{ for } P < P_{-1}$$

$$(Y, P_{-1}) >_u (Y, P) \text{ for } P < P_{-1}$$

This implies the indifference curves of both players are vertical about the line $P = P_{-1}$

4. Preferences are separable in the sense that the output targets do not vary with the price level, that is for all $P$

$$(Y_g, P) >_g (Y, P) \text{ for } Y < Y_g$$

$$(Y_u, P) >_u (Y, P) \text{ for } Y < Y_u$$

This implies the indifference curves of the government are horizontal about the line $Y = Y_g$ and similarly that the union's indifference curves are horizontal about the line $Y = Y_u$. 

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Proposition 1

Given assumptions 1 to 3, the macroeconomic game has a Nash equilibrium. (Note: The Nash equilibrium is not necessarily unique.)

Proof: Assumption 1 guarantees that through any point $(Y,P)$ with $Y < Y_{\text{max}}$ there passes a unique supply curve and that there is a unique nominal wage associated with each supply curve. Let $W_g$ denote the wage level for which the supply curve passes through the target point of the government. That is $W_g$ is defined by:

$$Y_g = f(P_{-1}, W_g)$$

By concavity of the supply curve and convexity of preferences, there exists a unique optimal choice of $\mathbf{N}$ for all $W > W_g$. Let $I^g$ denote the locus of these optimal choices as $W$ ranges over $\{W : W > W_g\}$. Let $I^g$ be the indifference curve passing through the point $(0, P_{-1})$. Then $I^g$ is bounded by $A$ and the lines $P = P_{-1}$ and $Y = Y_{\text{max}}$.

Furthermore $L^g$ is continuous. To see this, choose some $W^* > W_g$

8. If $Y_g = Y_{\text{max}}$ then let $W_g$ denote

$$\max \{W : Y_g = f(P_{-1}, W)\}$$
and let $(W_i)$ be an increasing sequence which converges to $W^*$, that is

\[ (W_i) \rightarrow W^*, \quad W_i > W_j \text{ for } i > j \]

Let $(Y_i, P_i)$ be the optimal choice for each $W_i$. Then $(Y_i, P_i)$ is a sequence of points on the optimal locus $L^W$. Since $(Y_i, P_i)$ lies in a compact set it has a convergent subsequence $(Y_j, P_j)$. Let

\[ (Y', P') = \lim_{j \to \infty} (Y_j, P_j) \]

Let $(Y^*, P^*)$ denote the optimal choice when $W = W^*$. To show that $L^W$ is continuous we need to show that $(Y', P') = (Y^*, P^*)$.

Assume not (see Figure 6). $(Y', P')$ must lie on the supply curve through $(Y^*, P^*)$ since the supply curves are continuous. That is

\[ Y' = f(P', W^*) \]

This implies that

\[ (Y^*, P^*) >_6 (Y', P') \]

since $(Y^*, P^*)$ is the unique optimal point on this supply curve. By continuity of preferences there exists an integer $N$ such that

\[ (Y^*, P^*) >_6 (Y_j, P_j) \text{ for all } j > N \]

Define $B$ to be the set of all points which are preferred to $(Y^*, P^*)$, that is
Figure 6: Establishing the Continuity of $L^p$
\[ B = \{(Y,P) \mid (Y,P) \succeq (Y^*,p^*)\} \]

The sequence of supply curves
\[ Y = f_1(p, w_j), \quad j \geq 0 \]

all pass through the set \( B \). Choose some \( j > N \). Then there exists some \((Y^+, p^+)\) belonging to \( B \) such that
\[ Y^+ = f_1(p^+, w_j) \]
and
\[ (Y^+, p^+) \succeq (Y^*, p^*) \succeq (Y_j, p_j) \]
which contradicts the construction of \( (Y_j, p_j) \).

Therefore \((Y', p')\) must be equal to \((Y^*, p^*)\) and \( \mathcal{L} \) is continuous from below (i.e., for any increasing sequence \( \langle w_i \rangle \)). By an analogous argument it can be shown that \( \mathcal{L} \) is continuous from above. Hence \( \mathcal{L} \) is a continuous curve which connects the points \((0, p_{-1})\) and \((Y_g, p_{-1})\).

Similarly there exists a continuous optimal locus \( \mathcal{L}' \) for the union which originates from the point \((Y_u, p_{-1})\) and which is bounded by the line \( P = p_{-1} \) and the aggregate demand curve which passes through the point \((Y_u, p_{-1})\).

Let \( P = h(Y) \) denote the equation of the upper branch of the indifference curve \( \mathcal{I}^* \). Then \( h(Y) \) is continuous and achieves a maximum \( P_{\max} \) on the interval \([0, Y_{\max}]\). Choose \( M \) such that the aggregate demand
Figure 7: Illustrating the Proof of Propositions 1 and 2
curve passes through the point \((Y_{\text{max}}, P_{\text{max}})\). Let \((Y', P')\) denote the optimal choice of the union for this demand curve. Then \(L^u\) joins \((Y_u, P_{-1})\) to \((Y', P')\) and these points lie on opposite sides of the locus \(L^d\). Therefore the optimal loci must intersect (see Figure 7). Any such intersection is a Nash equilibrium.

Proposition 2

Given assumptions 1 to 3 any Nash equilibrium is inflationary, that is

\[ P_{\text{Nash}} > P_{-1} \]

Proof: Since the indifference curves of the two players are vertical about the line \(P = P_{-1}\), this line constitutes the Pareto optimal locus (see Figure 7). But no point on that line can be a Nash equilibrium. Since the aggregate supply curves are upward sloping the optimal locus of the government cannot intersect the line \(P = P_{-1}\) to the left of \(Y_g\). Similarly the union's optimal locus cannot intersect the line \(P = P_{-1}\) to the right of \(Y_u\). Consequently the optimal loci cannot intersect on this line. Every point on the line joining the target points is non-optimal for at least one of the players.
Not only is the Nash equilibrium necessarily inflationary, but the Nash equilibrium output may be greater than or less than that desired by either party. The optimal loci may intersect anywhere in the region bounded by the demand curve through the union's target, the supply curve through the government's target, the line \( P = P_{-1} \) and the the indifference curve \( I^g \). A case in which the Nash equilibrium yields an outcome which has less employment than that desired by the union is illustrated in Figure 8. The union's preferences are such that its optimal locus passes to the left of the line \( Y = Y_u \) where it intersects the optimal locus of the government. Similarly the optimal locus of the government might include points \((Y, P)\) with \(Y > Y_g\) and yield a Nash equilibrium with output greater than that desired by either party. A sufficient condition to eliminate such equilibria is given by Assumption 4.

Under Assumption 3 the players have preferences over both output and prices. We now briefly consider some alternative objectives. Consider the situation in which both players are concerned about output but that only one is concerned about inflation. If only the government is concerned about inflation\(^9\), the union's optimal locus is the

\[^9\text{This is the case considered in Section 1.}\]
Figure 8: A Case in Which $Y_{\text{Nash}} < Y_u$
vertical line through its target employment $Y_u$ whereas the Pareto optimal set remains the line $P = P_{-1}$.

The optimal loci intersect at a point $P > P_{-1}$. There exists a Nash equilibrium which is not Pareto optimal. If only the union is concerned about inflation, a Nash equilibrium cannot be guaranteed. However if a Nash equilibrium does exist, it will not be Pareto optimal. When neither party is concerned about inflation, there is no Nash equilibrium.

When one of the players is not concerned about the level of income, the target point of the opposing player is the unique Nash equilibrium and the outcome is zero inflation. If neither player is concerned about the level of output, any point on the line $P=P_{-1}$ is a Nash equilibrium. The distinction between these cases and those in which one of the players is not concerned about inflation is that players are assumed to have identical price targets but distinct output targets.

Clearly when the players have identical output targets (that is $Y = Y_g$) and identical inflation targets, then these targets constitute a Pareto optimal Nash equilibrium. The players have a coincidence of interests and there is essentially no strategic game. However, if the output targets are different, it is necessary that $Y_g$ is greater than

10. This case violates the strict convexity of preferences in Assumption 3. The monotonicity of the aggregate demand curve ensures a unique optimal choice for each value of $N$. 

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3 The order of play

A feature of this game as we have described it is that each player is assumed to choose its strategy independently of any knowledge of the strategy of its opponent. In the macroeconomic game, one or other of the players may be forced to choose first leaving the second player to make its choice in the full knowledge of its opponent's choice. Presumably the government might legislate that the union be required to announce the nominal wage at the beginning of the period and cannot change during the course of the game. In Australia for example the Conciliation and Arbitration Commission could be required to announce award wages at the beginning of the financial year and to refuse to sanction any changes until the next announcement. In these circumstances the government would know the nominal wage and hence the supply curve when determining monetary policy. Does this solve the prisoner's dilemma?

The equilibrium of a non-cooperative game in which one of the players plays first is traditionally called a Stackelberg equilibrium. The player who plays first is called the leader and the second player the follower. The following proposition demonstrates that, except in
special circumstances, the Stackelberg equilibrium will be inflationary. Forcing one of the players to play first will not solve the prisoner's dilemma.

Proposition 3

Given assumptions 1 to 4, a Stackelberg equilibrium will be non-inflationary (Pareto optimal) iff the follower is not concerned about inflation.

Proof: Assume that the union is a Stackelberg leader (i.e. plays first). Then the optimal locus of the government represents the essential constraint on the choice of the union. The union will choose its optimal point on this locus. The only points at which the government's optimal locus intersects the Pareto optimal set are \( (0, P_{-1}) \) and \( (Y^*, P_{-1}) \). Assumption 4 ensures that the government's optimal locus cannot have a positive slope at \( (Y^*, P_{-1}) \). The government's target will be optimal for the government iff the government's optimal locus is vertical at that point and this will be the case iff the government is not concerned about inflation. Similarly \( (0, P_{-1}) \) cannot be optimal for the union. Therefore the Stackelberg equilibrium cannot lie in the Pareto optimal set. A similar argument applies if the government is a Stackelberg leader.
Forcing the union to play first will not prevent inflation unless the government is completely unconcerned about inflation. If the government is at all concerned about inflation, forcing the union to play first will not solve the prisoner's dilemma. The equilibrium outcome will still involve unnecessary inflation in the sense that there is an outcome with the same income and zero inflation which both parties would prefer. In general the Stackelberg equilibria differ from the Nash equilibria. In the special case in which the union is unconcerned about inflation (as in Section 1) and the union is forced to play first, the Nash and Stackelberg equilibria coincide.

Proposals are frequently made which would remove the government's discretion in monetary policy. Examples include determinate money growth rules and explicit policy rules. These proposals in effect force the government to play first. They will not eliminate inflation except where the union is completely unconcerned about inflation.

4 Conclusion

We have shown that under very general conditions indeed
noncooperative action on the part of two macroeconomic agents one of which has some control over the aggregate demand curve while the other controls the aggregate supply curve will almost inevitably produce inflation. Noncooperative action cannot be relied upon to achieve optimal outcomes. This is because the payoffs in the macroeconomic game have the form of a prisoner's dilemma. The participants are led as if by an invisible foot to an inflationary outcome which is in no player's individual interests.

This result does not depend on uncertainty or any information failure. In particular it does not depend on the assumption that each player chooses its strategy in ignorance of the strategy choice of the opponent. Even where one of the players is made to play first so that the opponent can choose its strategy with full knowledge of the strategy choice of the first player, the equilibrium outcome will be inflationary except (paradoxically) where the second player is completely unconcerned about inflation.

Cooperation is the only reliable escape from the prisoner's dilemma. Provided that the government and the union agree to play the appropriate strategies, they can achieve the non-inflationary Pareto optimal outcome. This provides a rationale for incomes policies which can be regarded as binding agreements to coordinate macroeconomic strategies. But note that there is still an incentive to defect. The agreement must be binding.
References


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