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Publication date:
1990

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Citation for published version (APA):

Driffill, E. J., & Schultz, C. (1990). *Wage Setting and Stabilization Policy in a Game with Renegotiation*. (CentER Discussion Paper; Vol. 1990-3). CentER.

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* C I N O O 9 4 3 *

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**WAGE SETTING AND STABILIZATION POLICY
IN A GAME WITH RENEGOTIATION**

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by John Driffill 331.215
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January, 1990

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Wage Setting and Stabilization Policy in a Game with Renegotiation

December 1989.

Abstract: This paper analyses an infinitely repeated game between a government and a union situated in a simple macroeconomic model. The economy is subject to a stochastic shock. The union sets wages and the government can stabilize the economy. Results are that for some parameter values and a high discount factor the set of subgame perfect equilibria includes an equilibrium where the wage rate and degree of stabilization in each period is optimal for the government, and the same holds true for the union. However, some subgame perfect equilibria rest on punishment phases where both players are hurt. When players can communicate during play such punishments seem not credible. Therefore we investigate **Weakly Renegotiation Proof Equilibria (WRP)**. It is shown that the set of Weakly Renegotiation Proof Equilibria does not include equilibria where in each period the most preferred actions for the government (or union) are taken. Also it is shown that in this game there is no WRP which for all discount factors less than one is also Strongly Renegotiation Proof.

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Acknowledgement: The authors are grateful to Morten Hviid for helpful suggestions. They retain all responsibility for all errors of omission and commission.

1. Introduction.

Many new interesting insights have been gained by viewing the interaction between trade unions and governments as non-cooperative games. Important questions are whether the non-cooperative structure of the interaction between the players leads to inefficiencies, in what sense the outcome is satisfactory seen from the government's point of view, and how the outcome is affected by the fact that the interaction takes place repeatedly. (The papers brought together in Calmfors and Horn (1986), for example, discuss a number of these issues).

One aspect of this interaction, upon which we focus in this paper, is the effect of stabilization policy on union wage setting, and vice versa. Calmfors and Horn (1985) argued that the tendency of governments to take up labour market slack in recessions may, through its effect on union wage setting, have been one cause of stagflation in Sweden and other corporatist and semi-corporatist European countries in the 1960's and 1970's. Driffill (1984, 1985), using a similar model, argued that stabilization policy in the face of random shocks to the economy may have made unions less concerned about the unemployment consequences of high real wages, leading to a higher mean level, although to a lower variance, of unemployment. This outcome results from a situation in which the government and the trade union are playing a non-cooperative one-shot game against each other. The union is assumed to set the wage rate, and the government to choose the degree with which it stabilizes employment against shocks. The outcome is inefficient for these two players, and could clearly be improved upon if, for example, they were able to play cooperatively.

The inefficiency gives unions and governments an incentive to find alternative arrangements which make one or both better off, and in practice there have been episodes

in which some kind of social contract between labour and government has been sought, trading wage moderation for a more active stabilization policy. In the absence of the ability to make binding contracts with each other to enforce a contract, repeated interaction can, as is well known (Fudenberg and Maskin (1986)), provide the means for sustaining such an outcome in a non-cooperative game.

Repeated interaction was considered in Driffill (1985), where a simple trigger strategy was assumed. The punishment which the government would use to discipline the union was assumed to be the government's preferred action in the one-shot non-cooperative game. Under appropriate conditions, it was shown that an equilibrium could be found in which the players came closer to efficient outcomes. However, there are a number of issues raised by that analysis.

Firstly, the proposed punishment strategy does not exploit all the possibilities which the game affords for supporting a better outcome. The folk theorems state, loosely speaking, that all payoffs dominating the minmax point can be sustained by subgame perfect equilibria of the infinitely repeated game with discounting, provided the discount factor is high enough. In the game described in Driffill (1985), that implies that any efficient outcome of the one-shot game could be sustained, with a high enough discount factor. Thus, in this sense, the government has less difficulty in achieving its most-preferred point on the Pareto-frontier of the stage game than was claimed in that paper.

Secondly, the proposed punishment involves the players in pursuing indefinitely a pair of strategies which lead to inefficient outcomes of the stage-game. This may be unreasonable if the players have the ability to communicate with each other and renegotiate strategies. This criticism applies equally to many of the subgame perfect equilibria which rely on more unpleasant punishments to which the folk theorem points. A number of authors, (including

Farrell (1983), Farrell and Maskin (1987), Pearce (1987), and van Damme (1989)), have argued that not all of the subgame perfect equilibria seem reasonable from this perspective, they involve threats which hurt the punisher as well as the punished. Such threats can be part of a subgame perfect equilibrium, despite fact that when player 1 punishes player 2 he hurts himself, because, if he stops punishing player 2 too soon, he will be punished by player 2 for failing to carry out the punishment, and so it goes on.

In circumstances where the players have the possibility of communicating during play, this kind of self-lacerating punishment does not seem reasonable. Why shouldn't both players agree to let bygones be bygones and move to the "good" phase of the game, rather than get stuck in a bad phase where they are both hurt for a long time? Such considerations render the most severe punishments incredible, and hence tend to restrict the set of possible outcomes. According to this line of thought, credible punishments should benefit the executor while punishing the punished.

In this paper, therefore, we investigate the possibilities of achieving efficient outcomes in an infinitely repeated non-cooperative game when the union and the government can renegotiate in the punishment phase. We explore the ability of either player to achieve his own most preferred outcome from the set of Pareto-efficient outcomes of the stage game.

The setting is a simple macroeconomic model, essentially described by an aggregate labour demand function which is decreasing in the real wage. The position of the curve is affected by a stochastic shock which hits the economy, and also by governmental stabilization policy.

The players have the same target level for employment (e.g. full employment) and are averse to variance in employment. The union likes high wages, whereas the government

dislikes budget deficits. The trade union sets the real wage. The government can decide on the degree of stabilization it will exert. The government is subject to a "Gramm–Rudmann act": The expectation of government intervention in a single period should be zero. This restriction is chosen, not because we find it compulsory that government budgets always balance, but because we want to focus on pure stabilization policy. Hence, the question is, whether the government, even with this restricted set of strategies, is able to achieve its goals, which are to stabilize the economy and achieve full employment while budget deficits are avoided. This set up is close to, but not identical to, the one in Driffill (1985).

The results are that, for some parameter values (specifically, with a sufficiently high discount factor) for any pair of actions on the one period contract curve, there is a subgame perfect equilibrium of the discounted repeated game where this pair of actions are chosen in each period. This is also true for the pair of actions forming the bliss point of the government's preferences (as well as the pair of actions forming the bliss point of the union's preferences). So, in this sense, the government is able to achieve its goals even with the very limited set of strategies allowed here. However, as discussed above, some subgame perfect equilibria do not seem reasonable. Therefore we introduce the concept of "weak renegotiation proofness" of Farrell and Maskin (1989). We show that the set of Pareto efficient weakly renegotiation proof equilibria is strictly contained within the set of Pareto efficient subgame perfect equilibria. In particular, neither player is able to achieve his bliss point in a Pareto efficient weakly renegotiation proof equilibrium. Lastly, it is showed that there exists no weakly renegotiation proof equilibrium which for all discount factors strictly less than one is strongly renegotiation proof.

2. The Economy

The model is the following:

$$\begin{aligned} U[(w_t, N_t)_{t=0}^{\infty}] &= \sum_{t=0}^{\infty} \delta^t u(w_t, N_t); \\ u(w_t, N_t) &= w_t - \beta(N_t - \bar{N})^2, \quad 0 < \delta < 1, \beta > 0 \end{aligned} \quad (1)$$

$$N_t = \alpha_0 - \alpha_1 w_t + G_t + \theta_t, \quad \alpha_0 > 0, \alpha_1 > 0. \quad (2)$$

$$G_t = \gamma_t \theta_t \quad (3)$$

$$\begin{aligned} V[(N_t, G_t)_{t=0}^{\infty}] &= \sum_{t=0}^{\infty} \delta^t v(N_t, G_t); \\ v(N_t, G_t) &= -(N_t - \bar{N})^2 - \varphi G_t^2, \quad \varphi > 0 \end{aligned} \quad (4)$$

$U(\cdot, \cdot)$ and $V(\cdot, \cdot)$ given by (1) and (4) are the utility functions of the union and the government respectively. $u(\cdot, \cdot)$ and $v(\cdot, \cdot)$ we call the period (expected) utilities. δ is the (common) discount factor. We will assume throughout that it is less than one, i.e. we only consider the case where discounting takes place. The average utility corresponding to $U[(w_t, N_t)_{t=0}^{\infty}]$ is: $(1-\delta)\sum_{t=0}^{\infty} \delta^t u(w_t, N_t)$. N_t is employment, w_t the real wage, G_t the government expenditures, and θ_t a stochastic disturbance. It is assumed that θ_t is identically and independently distributed for all t , that its mean and variance exist, and that $E(\theta_t) = 0$ and $E(\theta_t^2) > 0$. $\bar{N}$ we will call full employment, and it is assumed that $\alpha_0 > \bar{N}$. The unions objective function in (1) is not standard, but it has a number of desirable features and at the same time makes for analytical tractability. It is quasi-concave in (N, w) -space, and downward sloping for employment less than full employment (at which

point it is horizontal). (2) is the labour demand function. (3) is the policy rule. It is clear that with this rule $E(G_t) = 0$ for all t , (3) is the implementation of the Gramm–Rudmann act. In period t an action for the trade union is to set the real wage, w_t , the government's action is to choose the degree of stabilization, γ_t . Both actions have to be taken before the realization of θ_t is known. Nature selects θ_t . The way things are modeled here, government intervention becomes a stochastic variable.

The purpose of the restrictive form of (3) is to ensure that we consider purely stabilization policy, and no attempt is made by the government to systematically increase or decrease labour demand on average. This could be interpreted as being the consequence of a restriction on government expenditure via the budget identity. It is more natural to think of the government as being concerned with the size or variation in the national debt D rather than with variation in stabilization activities G_t in a particular period. However the formulation we have used simplifies the analysis, and has similar long run implications, since the smaller the variance of G_t the smaller the variance of D in the long run.

The model is close to the one analyzed in Driffill (1985), but there are some minor differences in the specification motivated primarily by analytical convenience.

At each stage in the game the players move simultaneously (this feature is at variance with Driffill (1985)). We will only consider pure strategies. The history of the game in period t , h_t , is a list of all actions taken through period 1 to $t-1$: $(w_1, \gamma_1, w_2, \gamma_2, \dots, w_{t-1}, \gamma_{t-1})$. The action chosen by a player in period t may depend on this history. Thus, we assume perfect recall and that there is perfect monitoring, the trade union can after each period t observe the value of γ_t that the government selected. A strategy, σ_i , for a player in the infinitely repeated game is a function that in each period t , for each possible previous history, prescribes an action in period t . A Nash–Equilibrium in the infinitely repeated game is a

pair of strategies, such that for each player there does not exist another strategy which, given the strategy of the other player, gives higher expected utility. The subgame from period t and onwards is just the game started in period t . A **Subgame-perfect equilibrium** is a pair of strategies such that the restriction of the strategies to each subgame forms a Nash-equilibrium in that subgame. If h_t is a history and $\sigma = (\sigma_1, \sigma_2)$ a strategy pair then the continuation of σ after h_t , σ_{h_t} , is the strategy pair prescribed by σ in the subgame occurring after h_t . The pay off to player i in that subgame is the continuation pay off to i attached to the pair of continuation strategies $(\sigma_{1h_t}, \sigma_{2h_t})$. Finally a Nash equilibrium of the stage game (also called the one shot Nash-equilibrium) is a pair of actions, such that for both players it is true that there does not exist an action which, given the action of the other, gives higher period utility.

3. The Stage Game.

In this section we will analyze the stage game in some detail. Using (2) and (3) we may derive the indirect (expected) period utility functions $\tilde{u}$, and $\tilde{v}$ defined on action pairs (w_t, γ_t) .

$$\tilde{u}(w_t, \gamma_t) = w_t - \beta(\alpha_0 - \alpha_1 w_t - \bar{N})^2 - \beta(1 + \gamma_t)^2 E(\theta_t^2) \quad (5)$$

$$\tilde{v}(w_t, \gamma_t) = -(\alpha_0 - \alpha_1 w_t - \bar{N})^2 - ((1 + \gamma_t)^2 + \varphi \gamma_t^2) E(\theta_t^2) \quad (6)$$

Then we have $U[(w_t, N_t)_{t=0}^{\infty}] = \Sigma_{t=0}^{\infty} \delta^t \tilde{u}(w_t, \gamma_t)$ and $V[(w_t, N_t)_{t=0}^{\infty}] = \Sigma_{t=0}^{\infty} \delta^t \tilde{v}(w_t, \gamma_t)$, where it is implicitly understood that N_t is determined by (2) and (3).

Given the action of the government, γ_t , the best reply (with respect to the expected period utility function) of the union can be found by maximizing (5) over w , one gets:

$$w(\gamma_t) = \frac{1}{2\beta\alpha_1} + \frac{\alpha_0 - N}{\alpha_1} \quad (7)$$

$w(\gamma_t)$ is seen to be independent of γ_t , a feature which greatly simplifies our analysis. The union's most preferred action pair (w^u, γ^u) is found by maximizing (5) over (w_t, γ_t) . One gets

$$w^u = \frac{1}{2\beta\alpha_1} + \frac{\alpha_0 - N}{\alpha_1}; \gamma^u = -1 \quad (8)$$

Not surprisingly the most preferred pair of actions for the union involves full stabilization. We see that in (w_t, γ_t) -space the unions indifference curves are convex, closed orbits.

Likewise the (one period) best reply of the government, $\gamma(w_t)$, is found by maximizing (6) over γ_t given w_t , one gets:

$$\gamma(w_t) = -\frac{1}{1+\varphi} \quad (9)$$

which is independent of w_t . The negative sign of γ corresponds to the fact that the government stabilizes the economy. The most preferred pair of actions for the government we denote (w^g, γ^g) . It is easily found to be :

$$w^g = \frac{\alpha_0 - N}{\alpha_1}; \gamma^g = -\frac{1}{1+\varphi} \quad (10)$$

We see that the most preferred pair of actions for the government involves less than full stabilization. Full stabilization would involve too big a variance in government expenses. By inserting it in (3) one sees (again, not surprisingly) that w^g is the wage rate making the expected employment equal to full employment. Also government indifference curves in (w_t, γ_t) -space are convex closed orbits.

(7) and (9) directly gives the Nash equilibrium of the stage game. We see that the one shot Nash equilibrium is in fact an equilibrium in dominant strategies in this game and that it is given by (w^u, γ^g) .

The expected employment of the one shot Nash-equilibrium is:

$$E(N) = N - \frac{1}{2\beta\alpha_1} \quad (11)$$

which is less than full employment, also stabilization is less than full stabilization. For expected employment to be positive in the one shot Nash equilibrium, it is necessary that $N > \frac{1}{2\beta\alpha_1}$ which we will assume.

The way the model is specified, it is possible to have negative employment rates (choose a very high wage rate). Negative employment is hard to accept for empirically oriented economists like us. Therefore we will constrain the union to choose wage rates leading to a non-negative **expected** employment, i.e. $w \leq \alpha_0/\alpha_1$. It is possible for the government to destabilize the economy by choosing γ positive or very negative. This however hurts the government itself, so we will (quite arbitrarily) restrict the government's set of actions to $\gamma \in [-1, 0]$, corresponding to all possibilities between full stabilization ($\gamma = -1$) and no stabilization ($\gamma = 0$). This restriction is not essential for our analysis as it turns out that enlarging the set will not change the results qualitatively. With these restrictions on the

action sets the minmax actions (w^m, γ^m) become:

$$w^m = \alpha_0 / \alpha_1, \gamma^m = 0 \quad (12)$$

giving rise to the minmax utility levels:

$$\begin{aligned} \bar{u}(w^u, \gamma^m) &= \frac{1}{4\beta\alpha_1^2} + \frac{\alpha_0 - N}{\alpha_1} - E(\theta_t^2); \\ \bar{v}(w^m, \gamma^e) &= -N^2 - \frac{\varphi}{1+\varphi} E(\theta_t^2) \end{aligned} \quad (13)$$

Indifference curves in the (w_t, γ_t) plane are depicted in figure 1 along with bliss points, the one shot Nash equilibrium point, the minmax point, the one period contract curve and the period reaction functions, $w(\gamma)$ and $\gamma(w)$. The contract curve can be calculated as

$$w = \frac{1}{2\alpha_1^2\varphi\beta} \frac{1}{\gamma} + \frac{1 + \varphi + \frac{2\alpha_1\varphi\beta(\alpha_0 - N)}{2\alpha_1^2\varphi\beta}}{2\alpha_1^2\varphi\beta}, \gamma \in [-1, -\frac{1}{1+\varphi}] \quad (14)$$

which is part of a hyperbola (in (γ, w) -space). (14) gives w as a function of γ , we call that function for $w_{cc}(\gamma)$.

Figure 1.

The contract curve consist of action pairs which are efficient in the stage game. If we depict the one period expected utilities associated with the action pairs on the contract curve we get the utility frontier of the one stage game. See figure 2.

Figure 2.

Only if this utility frontier is concave will repeated play of any point on the contract curve yield outcomes which are efficient in the repeated game. Otherwise there will be action pairs on the contract curve such that playing them repeatedly is dominated by shifting between two different action pairs on the contract curve. Henceforth we will concentrate on repeated play of action pairs on the contract curve. Proposition 1 below shows that this indeed corresponds to outcomes which are efficient in the repeated game.

Proposition 1. The utility frontier of the stage game is strictly concave.

Proof: Consider $(w_{cc}(\gamma^0), \gamma^0)$ and $(w_{cc}(\gamma^1), \gamma^1)$, where $\gamma^0 > \gamma^1 > \gamma^u$.

Denote the associated utilities $u^0 \equiv \tilde{u}(w_{cc}(\gamma^0), \gamma^0)$; $v^0 \equiv \tilde{v}(w_{cc}(\gamma^0), \gamma^0)$; $u^1 \equiv \tilde{u}(w_{cc}(\gamma^1), \gamma^1)$; $v^1 \equiv \tilde{v}(w_{cc}(\gamma^1), \gamma^1)$. At an intermediate point $(w^\lambda, \gamma^\lambda)$ between $w_{cc}(\gamma^0)$, γ^0 and $w_{cc}(\gamma^1)$, γ^1 defined by

$$w^\lambda = \lambda w_{cc}(\gamma^0) + (1-\lambda)w_{cc}(\gamma^1), \gamma^\lambda = \lambda \gamma^0 + (1-\lambda)\gamma^1 \text{ for } 0 < \lambda < 1,$$

the associated utilities can be denoted u^λ, v^λ and are given by

$$u^\lambda = \tilde{u}(w^\lambda, \gamma^\lambda); v^\lambda = \tilde{v}(w^\lambda, \gamma^\lambda).$$

By the strict concavity of $\tilde{u}(\cdot, \cdot)$ and $\tilde{v}(\cdot, \cdot)$: $u^\lambda > \lambda u^0 + (1-\lambda)u^1$ and $v^\lambda > \lambda v^0 + (1-\lambda)v^1$.

Thus there exist feasible combinations (u^λ, v^λ) of utilities which lie strictly above and to the right of the straight line joining any two points (u^0, v^0) and (u^1, v^1) on the Pareto frontier. Hence the Pareto frontier is strictly concave. $\square$

4. Subgame Perfect Equilibria.

The one shot Nash equilibrium is inefficient. It is well known that repetition of a game helps, in the sense that there are subgame perfect equilibria, where actions which are Pareto better than those corresponding to the one shot Nash equilibrium are chosen in each period. In this section we will investigate whether all the points on the contract curve can be implemented in subgame perfect equilibria. To be precise: Given any pair of actions on the contract curve, does there exist a subgame perfect equilibrium where these actions are taken in each period? Theorem 1 gives the conditions under which the answer is affirmative.

Theorem 1. If

$$\frac{1+2\varphi}{(1+\varphi)^2} E(\theta^2) > \frac{1}{4\beta\alpha_1^2} \quad (15)$$

$$N^2 - \frac{1}{4\beta^2\alpha_1^2} > \left(\varphi^2 - \frac{\varphi}{1+\varphi}\right) E(\theta^2) \quad (16)$$

are both fulfilled then for any pair of actions (w, γ) belonging to the contract curve there exists a $\underline{\delta} < 1$ such that if $\underline{\delta} < \delta < 1$ there exists

a subgame perfect equilibrium where (w, γ) are the actions taken in each period.

Proof: The proof is a simple application of theorem 1 in Fudenberg and Maskin (1986). According to that theorem for any pair of payoffs dominating the payoff of the minmax point there exists a $\underline{\delta} < 1$ such that if $\underline{\delta} < \delta < 1$ then this pair of payoffs can be realized in a subgame perfect equilibrium. Hence, we shall demonstrate that for any point (w, γ) on the contract curve the one period payoff to each player is greater than the payoff of the minmax point.

First note that while (w^u, γ^u) is the best point on the contract curve for the union then (w^g, γ^g) is the worst point on the contract curve for the union. Exactly the opposite is true for the government (see figure 1). Therefore it is sufficient to prove that:

$$\tilde{u}(w^g, \gamma^g) > \tilde{u}(w^u, \gamma^m) \text{ and } \tilde{v}(w^u, \gamma^u) > \tilde{v}(w^m, \gamma^g)$$

Using (5), (10), and (13) it is easily seen that the first inequality is equivalent to (15). Similarly one sees by use of (6), (8) and (13) that the second inequality is equivalent to (16). $\square$

The condition (15) is necessary for making the minmax point worse for the union than the government optimum. High α_1 and high β tends to make it fulfilled. High α_1 means that wage rate increases have severe employment effects. High β means that these effects hurt the union much. Hence in this case the gains for the union in case it defects from taking the actions that the government prefers most are small, and by using a non-stabilizing

strategy, the government can punish the union hard. Further, low φ and high $E(\theta)^2$ tends to make (15) fulfilled. High $E(\theta^2)$ means that variance in employment is high and hence that the non-stabilizing punishment of the government hurts the union much. Low φ means that the government does not care so much about variance in its expenses and hence that it stabilizes quite a lot in the government optimum, (w^g, γ^g) , which makes this point more favorable to the union.

Under the maintained assumption that employment is positive in the one shot Nash equilibrium the left hand side of (16) is positive. The right hand side is negative for $\varphi < \frac{\sqrt{5}-1}{2}$. Thus (16) can be fulfilled. High N , $E(\theta^2)$ and low α, β and φ tend to make it fulfilled. It is left to the reader to check that this conforms with intuitions. Finally it is seen that it is perfectly possible to have (15) and (16) fulfilled at the same time.

Theorem 1 tells us that for some parameter values the government has the ability to achieve its goals in the sense that there is a subgame perfect equilibrium in which the actions chosen in each period are the most preferred by the government. Of course exactly the same can be said about the ability of the union to enforce its goals. Figure 3 illustrates a case where both (15) and (16) are fulfilled.

Figure 3.

5. Weakly Renegotiation Proof Equilibria.

As remarked in the introduction not all subgame perfect equilibria seem reasonable, at least in cases where the players have a possibility of communicating during play. In our case it seems a highly artificial assumption to assert that the government and the union cannot communicate e.g. between periods.

The problem is that some subgame perfect equilibria rest on punishment strategies which (for a number of periods) hurt both players, including the player (the government say) who punishes the other (the union) for a defection. This can be a subgame perfect equilibrium strategy for the government because if it defects on the punishment, then the union will

punish the government for not exercising the punishment. This, again, the union will do because if it does not, then it will be punished, and so forth. Clearly, once in the punishment phase the players have an incentive to agree on not carrying out all the punishments — to let bygones be bygones. If the players can communicate during play it seems likely that they will agree to evade such mutual punishments. This, however, renders such punishments incredible, and hence the equilibrium set becomes smaller if one takes these objections seriously.

There are, in the literature several suggestions for equilibrium concepts which take considerations such as those discussed above into account. See, e.g., Farrell (1983), Farrell and Maskin (1987),(1989), Pearce (1987), and van Damme (1989). It would be fair to say that there has not emerged a unanimous agreement on what is "the right concept". The differences between the concepts pertain to what the abilities of the players are when they renegotiate. Can they freely choose any new pair of strategies — in which case the past has no influence at all — or are they to some extent constrained to renegotiate only within a subset of all pairs of strategies? Farrell and Maskin (1989) consider what they call "weak renegotiation proofness". A **weakly renegotiation proof equilibrium**, (WRP), is a pair of strategies $\sigma = (\sigma_1, \sigma_2)$ which are subgame perfect and which has the property that there does not exist two continuations of σ , σ' and σ'' such that σ' strictly dominates σ'' .

WRP equilibria are renegotiation proof in the sense that no matter what happens players will never end up playing according to a pair of continuation strategies of σ which are dominated by another pair of continuation strategies of σ . Hence they will not have a mutual interest in switching to another pair of continuation strategies of σ . Expressed another way the idea is that punishments should benefit the player exercising the punishment. The motivation of course being that in this case he will not be willing to give up the punishment earlier than when (perhaps) prescribed by the equilibrium strategy pair.

Let $(\gamma^P, \bar{\gamma})$ be the unique solution to the two equations

$$\begin{aligned}\tilde{v}(w^g, \gamma^P) &= \tilde{v}(w_{cc}(\bar{\gamma}), \bar{\gamma}) \\ \tilde{u}(w^u, \gamma^P) &= \tilde{u}(w_{cc}(\bar{\gamma}), \bar{\gamma})\end{aligned}\tag{17}$$

see figure 4. The action pair $(w_{cc}(\bar{\gamma}), \bar{\gamma})$ yields the best normal phase payoff for the government and the worst for the union, which at the same time allows the government to inflict a punishment pair (w^g, γ^P) , where, if the union accepts the punishment, the government is no worse off in the punishment phase than it was in the normal phase, and where the union would be no better off by cheating on the punishment (w^g, γ^P) , than it would have been by sticking to normal phase play. If $\gamma < \bar{\gamma}$ then the union is in fact better off in the normal phase $(w_{cc}(\gamma), \gamma)$ than when it cheats on the punishment (w^g, γ^P) .

Similarly let $w^P, \underline{\gamma}$ be the unique solution to the two equations

$$\begin{aligned}\tilde{u}(w^P, \gamma^u) &= \tilde{u}(w_{cc}(\underline{\gamma}), \underline{\gamma}) \\ \tilde{v}(w^P, \gamma^g) &= \tilde{v}(w_{cc}(\underline{\gamma}), \underline{\gamma})\end{aligned}\tag{18}$$

See again figure 4. It is important to notice that:

$$-1 < \underline{\gamma} < \bar{\gamma} < -\frac{1}{1 + \varphi}\tag{19}$$

We now have the following theorem.

Theorem 2. Assume that (15) and (16) are fulfilled. There exists a weakly renegotiation proof equilibrium (σ_1, σ_2) such that $(w_{cc}(\gamma), \gamma)$ are the pair of actions taken in each period only if:

$$\underline{\gamma} < \gamma < \bar{\gamma}$$

Conversely, if $\underline{\gamma} < \gamma < \bar{\gamma}$ then there exists a $\underline{\delta} < 1$ such that if $\underline{\delta} < \delta < 1$ there exists a weakly renegotiation proof equilibrium with $(w_{cc}(\gamma), \gamma)$ the pair of actions taken in each period.

Proof: We will prove the "only if" part first. The proof draws on the proof of theorem 1 in Farrell and Maskin (1989).

Assume that (σ_1, σ_2) is a WRP equilibrium such that $(w_{cc}(\gamma), \gamma)$ is the action pair taken in each period, and assume that $\gamma \notin]\underline{\gamma}, \bar{\gamma}[$. To be specific assume that $\gamma \geq \bar{\gamma}$. See figure 5.

Figure 5.

If the union deviates optimally in a period from playing $w_{cc}(\gamma)$ it will in that period get the expected utility $\tilde{u}(w^u, \gamma) > \tilde{u}(w_{cc}(\gamma), \gamma)$. In order to deter deviations the continuation strategy pair must yield an average utility for the union **strictly less** than $\tilde{u}(w, \gamma)$. Now, consider the pair of continuation strategies $(\hat{\sigma}_1, \hat{\sigma}_2)$ of (σ_1, σ_2) which is the worst for the union and the sequence of action pairs $(\hat{w}_\tau, \hat{\gamma}_\tau)_{\tau=0}^\infty$ prescribed by $(\hat{\sigma}_1, \hat{\sigma}_2)$ (in case there are more than one such pair choose the one which is best for the government). That such a pair exist can be shown fairly easy from the fact that the action space $[0, \alpha_1/\alpha_2] \times [-1, 0]$ is compact and from the fact that the indirect utility functions are continuous – for details the reader is referred to Farrell and Maskin (1989), lemma 2.

Let $\hat{u} = (1-\delta) \sum_{\tau=0}^\infty \delta^\tau \tilde{u}(\hat{w}_\tau, \hat{\gamma}_\tau)$. Then $\hat{u} < \tilde{u}(w, \gamma)$ and since (σ_1, σ_2) is a WRP equilibrium we must have $\hat{v} \geq \tilde{v}(w, \gamma)$ where $\hat{v} \equiv (1-\delta) \sum_{\tau=0}^\infty \delta^\tau \tilde{v}(\hat{w}_\tau, \hat{\gamma}_\tau)$. Note that $\hat{v} = (1-\delta) \tilde{v}(\hat{w}_0, \hat{\gamma}_0) + \delta(1-\delta) \sum_{\tau=1}^\infty \delta^{\tau-1} \tilde{v}(\hat{w}_\tau, \hat{\gamma}_\tau)$, i.e. a convex combination of $\tilde{v}(\hat{w}_0, \hat{\gamma}_0)$ and the average continuation payoff in period $\tau = 1$. From this it is clear that if $\tilde{v}(\hat{w}_0, \hat{\gamma}_0) < \hat{v}$, then $(1-\delta) \sum_{\tau=1}^\infty \delta^{\tau-1} \tilde{v}(\hat{w}_\tau, \hat{\gamma}_\tau) > \hat{v}$. Since (σ_1, σ_2) is a WRP equilibrium this must imply that the average continuation payoff to the union in period $\tau = 1$: $(1-\delta) \sum_{\tau=1}^\infty \delta^{\tau-1} \tilde{u}(\hat{w}_\tau, \hat{\gamma}_\tau) \leq \hat{u}$. But this contradicts the definition of $(\hat{\sigma}_1, \hat{\sigma}_2)$. Therefore $\tilde{v}(\hat{w}_0, \hat{\gamma}_0) \geq \hat{v}$, which since $\hat{v} \geq \tilde{v}(w, \gamma)$ yields $\tilde{v}(\hat{w}_0, \hat{\gamma}_0) \geq \tilde{v}(w, \gamma)$. Finally, $\tilde{u}(w^u, \hat{\gamma}_0) \leq \hat{u}$, since otherwise it would be profitable for the union to deviate in the first period and then accept the average payoff $\hat{u}$ (which, remember, is the worst average payoff the union can get) contradicting that $(\hat{\sigma}_1, \hat{\sigma}_2)$ is subgame perfect. Remembering that $\hat{u} < \tilde{u}(w, \gamma)$, we now have $\tilde{u}(w^u, \hat{\gamma}_0) < \tilde{u}(w, \gamma)$

Taken together we have shown that there exists a strategy pair $(\hat{w}_0, \hat{\gamma}_0)$ such that

$$\tilde{v}(\hat{w}_0, \hat{\gamma}_0) \geq \tilde{v}(w, \gamma) \text{ and } \tilde{u}(w^u, \hat{\gamma}_0) < \tilde{u}(w, \gamma)$$

But, this contradicts the assumption that $\gamma \geq \bar{\gamma}$. The proof excluding $\gamma \leq \underline{\gamma}$ is similar.

Now we turn to the "if" part of theorem 2.

Suppose that $\underline{\gamma} < \gamma < \bar{\gamma}$. Consider the pair of simple (in the sense of Abreu (1988)) strategies (σ_1, σ_2) for the union and government respectively, described by the following prescriptions:

- a. Play $(w_{cc}(\gamma), \gamma)$ in each period as long as $(w_{cc}(\gamma), \gamma)$ was played in the last period.
- b. If the union deviated in the last period play $w^g(\gamma^p)$ for T^u periods, then restart phase a.
- c. If the government deviated in the last period play $w^p(\gamma^u)$ for T^g periods. Then restart a.
- d. In case of simultaneous deviations by both players ignore it.

Note that also deviations by the union (government) in any of the punishment phases induces a restart of phase b (c).

Since $\underline{\gamma} < \gamma < \bar{\gamma}$ we have:

$$\tilde{v}(w^g, \gamma^p) > \tilde{v}(w_{cc}(\gamma), \gamma) \text{ and } \tilde{u}(w^g, \gamma^p) < \tilde{u}(w_{cc}(\gamma), \gamma) \quad (20)$$

and

$$\tilde{u}(w^p, \gamma^u) > \tilde{u}(w_{cc}(\gamma), \gamma) \text{ and } \tilde{v}(w^p, \gamma^u) < \tilde{v}(w_{cc}(\gamma), \gamma) \quad (21)$$

(see figure 4) so (σ_1, σ_2) described by a – d has the property that there exist no continuation strategies dominating other continuation strategies.

Hence it just rests to show that there exist T^u and T^g such that (σ_1, σ_2) , given by the prescriptions a through d, forms a subgame perfect equilibrium. Here (as Abreu (1988) notes) it is sufficient to check that one shot deviations do not pay. By a one shot deviation is understood that the player deviates in one period only and then conforms ever after. To see this suppose on the contrary it is not true. Suppose that a player could gain by deviating an infinite number of times. Due to discounting ($\delta < 1$), he could gain by deviating a finite number, T say, of times then. If he gains by deviating in the last period, T , we have a contradiction. If not then he gains from deviating in $T-1$ periods. Now continue until the first period of deviation is reached. Then we have a contradiction. Hence, if no one shot deviation pays then no deviation pays. This is known as the "unimprovability principle" of dynamic programming.

The best deviation for the union is to play w^u . The average utility of the union, if it makes a one-shot deviation in phase a, is given by:

$$\begin{aligned} (1-\delta)[\bar{u}(w^u, \gamma) + \sum_{t=1}^{T^u} \delta^t \bar{u}(w^g, \gamma^p) + \delta^{T^u+1} \cdot \sum_{\tau=0}^{\infty} \delta^{\tau} \bar{u}(w_{cc}(\gamma), \gamma)] = \\ (1-\delta)[\bar{u}(w^u, \gamma) + \frac{\delta - \delta^{T^u+1}}{1-\delta} \cdot \bar{u}(w^g, \gamma^p) + \frac{\delta^{T^u+1}}{1-\delta} \cdot \bar{u}(w_{cc}(\gamma), \gamma)] = \\ (1-\delta)\bar{u}(w^u, \gamma) + (\delta - \delta^{T^u+1}) \cdot \bar{u}(w^g, \gamma^p) + \delta^{T^u+1} \cdot \bar{u}(w_{cc}(\gamma), \gamma) \end{aligned}$$

Hence, the union does not gain by deviating in phase a if:

$$\bar{u}(w_{cc}(\gamma), \gamma) \geq (1-\delta)\bar{u}(w^u, \gamma) + (\delta - \delta^{T^u+1}) \cdot \bar{u}(w^g, \gamma^p) + \delta^{T^u+1} \cdot \bar{u}(w_{cc}(\gamma), \gamma)$$

which is equivalent to

$$-\frac{1}{\delta} \cdot [\tilde{u}(w_{cc}(\gamma), \gamma) - (1-\delta)\tilde{u}(w^u, \gamma)] \geq (1-\delta^{T^u}) \cdot \tilde{u}(w^g, \gamma^P) + \delta^{T^u} \cdot \tilde{u}(w_{cc}(\gamma), \gamma) \quad (22)$$

Correspondingly, the condition that it does not pay for the union to deviate in the start of the punishment phase, is:

$$(1-\delta^{T^u}) \cdot \tilde{u}(w^g, \gamma^P) + \delta^{T^u} \cdot \tilde{u}(w_{cc}(\gamma), \gamma) \geq \tilde{u}(w^u, \gamma^P) \quad (23)$$

Taken together (22) and (23) means that it does not pay for the union to make a one shot deviation in phase a or in the start of phase b if:

$$\frac{1}{\delta} \cdot [\tilde{u}(w_{cc}(\gamma), \gamma) - (1-\delta)\tilde{u}(w^u, \gamma)] \geq (1-\delta^{T^u}) \cdot \tilde{u}(w^g, \gamma^P) + \delta^{T^u} \cdot \tilde{u}(w_{cc}(\gamma), \gamma) \geq \tilde{u}(w^u, \gamma^P) \quad (24)$$

By (20) for δ close to one we have that: $\frac{1}{\delta} \cdot [\tilde{u}(w_{cc}(\gamma), \gamma) - (1-\delta)\tilde{u}(w^u, \gamma)] > \tilde{u}(w^u, \gamma^P)$. Also for δ close to one, the middle part of (24), $(1-\delta^{T^u}) \cdot \tilde{u}(w^g, \gamma^P) + \delta^{T^u} \cdot \tilde{u}(w_{cc}(\gamma), \gamma)$, varies almost continuously with integers T^u . For $T^u \rightarrow \infty$ this term tends to $\tilde{u}(w^g, \gamma^P)$ (δ is less than one, remember) which is less than $\tilde{u}(w^u, \gamma^P)$ (see figure 4). For $T^u = 0$ the middle term of (24) reduces to $\tilde{u}(w_{cc}(\gamma), \gamma)$ and it is straightforward to show that this is greater than $\frac{1}{\delta}[\tilde{u}(w_{cc}(\gamma), \gamma) - (1-\delta)\tilde{u}(w^u, \gamma)]$. By (almost) continuity in integers T^u we then have that for δ close enough to one there exists an integer T^u such that (24) is fulfilled. Hence it is not optimal for the union to deviate in phase a as well as in the start of phase b, and of course it is not optimal, then, to deviate later in phase b.

Finally by (21) $\tilde{u}(w^P, \gamma^u) > \tilde{u}(w_{cc}(\gamma), \gamma)$ so it is not optimal for the union to deviate in phase c. Altogether we have shown that there exist a T^u such that for the union, the

strategy described above is optimal regardless of the history of the game. In a completely similar way one can show that the same holds true for the government. Together this means that (σ_1, σ_2) forms a subgame perfect equilibrium. $\square$

The set of action pairs on the contract curve sustainable by a weakly renegotiation proof equilibrium is illustrated in figure 4.

An immediate implication of theorem 2 (see figure 4) is that the two bliss points are not contained in the set of action pairs sustainable by a weakly renegotiation proof equilibrium, cf. also (19). Hence, in this sense the government is not able to enforce its goals, contrary to the case when we allow all subgame perfect equilibria. Thus one important conclusion is that the restriction to weakly renegotiation proof equilibria excludes strategy pairs favouring one of the parties alone.

The proof of theorem 2 reveals that we have the following corollary to be used later.

Corollary. If (σ_1, σ_2) is a weakly renegotiation proof equilibrium with average payoffs $(\tilde{u}, \tilde{v})$ then there exists action pairs (w', γ') and (w'', γ'') such that

$$\begin{aligned}\tilde{v}(w', \gamma') &\geq \tilde{v} \text{ and } \tilde{u}(w', \gamma') < \tilde{u} \\ \tilde{v}(w'', \gamma'') &< \tilde{v} \text{ and } \tilde{u}(w'', \gamma'') \geq \tilde{u}\end{aligned}$$

The corollary corresponds to the "necessary" part of theorem 1 of Farrel and Maskin (1989).

Some of the WRP equilibria of theorem 2 rest on punishment strategies which are inefficient even in the stage game. E.g. equilibria where action pairs $(w_{cc}(\gamma), \gamma)$ close to $(w_{cc}(\bar{\gamma}), \bar{\gamma})$ are played in each period rest on punishments involving actions off the contract curve. See figure 4. One might wonder whether it is possible to sustain efficient WRP equilibria by punishments involving only actions which are efficient in the stage game. This requirement limits the severity of punishments e.g. the worst punishment action for the union becomes (w^g, γ^g) (see figure 4). Theorem 3 below implies that the set of actions on the contract curve which can be sustained by threats involving only action pairs on the contract curve itself is not empty but strictly smaller than the set sustainable by WRP equilibria. Needless to say the equilibria to which theorem 3 points are WRP.

Theorem 3. Assume that (15) and (16) are fulfilled. Let (w, γ) be an action pair on the contract curve. Then there exists a WRP equilibrium (σ_1, σ_2) such that, for all histories continuation strategies imply action pairs on the contract curve, with (w, γ) the pair of actions taken in each period, only if

$$\tilde{u}(w, \gamma) > \tilde{u}(w^u, \gamma^g) \text{ and } \tilde{v}(w, \gamma) > \tilde{v}(w^u, \gamma^g) \quad (25)$$

Conversely, if (w, γ) belongs to the contract curve and fulfills (25) then there exists a $\underline{\delta} < 1$ such that if $\underline{\delta} < \delta < 1$ there exists a WRP equilibrium, (σ_1, σ_2) , specifying action pairs on the contract curve for all histories, such that (w, γ) is the pair of actions taken in each period.

Proof: For "only if": Assume that (σ_1, σ_2) is a WRP equilibrium such that for all histories continuation strategies imply action pairs on the contract curve with (w, γ) the pair of actions taken in each period, but that (25) is not fulfilled, e.g. because $\tilde{u}(w, \gamma) \leq \tilde{u}(w^u, \gamma^g)$. If the union deviates optimally from playing w it will in the period of deviation get the expected utility $\tilde{u}(w^u, \gamma)$. Since (σ_1, σ_2) only specify action pairs on the contract curve the worst retaliation by the government is to choose $\gamma = \gamma^g$. If the union reacts by playing w^u it gets the expected utility $\tilde{u}(w^u, \gamma^g) \geq \tilde{u}(w, \gamma)$ by assumption. Hence, we see that it pays for the union to deviate from (w, γ) which can not be subgame perfect then. The proof of the "if" part follows exactly the lines of the corresponding proof of theorem 2 and is therefore omitted. $\square$

The set of action pairs on the contract curve sustainable by threats which are efficient in the stage game is depicted in figure 6.

Figure 6.

It should be noticed that, although the threats of the equilibria to which theorem 3 points

are efficient in the stage game, the strict concavity of the Pareto frontier implies that the continuation payoffs in the punishment phases are not efficient in the repeated game.

6. Strongly Renegotiation Proof Equilibria.

It might be argued that the requirement that a strategy pair should be a WRP equilibrium is too weak. Certainly it does not ensure efficiency and even though one looks for efficient equilibria continuation payoff pairs need not all be efficient, as e.g. in the case of theorem 3 of the preceding section. On the other hand it seems a very strong and even too strong a requirement that continuation payoff pairs of a WRP equilibrium must not be dominated by payoffs of subgame perfect equilibria which are not WRP themselves. If WRP equilibria form the universe of "credible" equilibria it should only be considered an objection to a proposed WRP equilibrium that some of its continuation payoff pairs are dominated by the payoff pair associated with another WRP equilibrium. This motivates the definition of a Strongly Renegotiation Proof Equilibrium.

A **Strongly Renegotiation Proof Equilibrium**, (SRP), is a pair of strategies $\sigma = (\sigma_1, \sigma_2)$ which is (i) a WRP equilibrium and (ii) has the property that none of its continuation payoff pairs are strictly dominated by the payoff pair of another WRP equilibrium.

Certainly for some discount factors there exist SRP equilibria. E.g. when the discount factor is very low infinite repetition of the one shot Nash equilibrium is the only subgame perfect equilibrium. Hence it is the only WRP equilibrium and accordingly it is SRP. As the discount factor grows, however, new WRP equilibria arise some of which have average

payoff pairs which dominate those of the one shot Nash equilibrium which then ceases to be SRP. From theorem 2 we know that for a discount factors close to one part of the Pareto frontier can be sustained by WRP equilibria hence it is clear that all payoff pairs dominated by this part of the frontier cannot be sustained by a SRP equilibrium. The question therefore becomes, whether some efficient payoff pairs can be sustained by SRP equilibria. Theorem 4 below does not exclude that this is the case for a given discount factor, but states that for any strategy pair this strategy pair cannot be a SRP if the discount factor is sufficiently close to but strictly less than one. Hence, contrary to the set of WRP equilibria, the set of SRP equilibria does not simply grow as the discount factor increases.

Theorem 4. Let $\sigma = (\sigma_1, \sigma_2)$ be any admissible strategy pair. There exist a $\underline{\delta} < 1$ such that if $\underline{\delta} < \delta < 1$ then σ is not SRP.

Proof: In this proof let $v^\delta(\sigma_1, \sigma_2)$ denote the average payoff to the government when (σ_1, σ_2) is the strategy pair and δ the discount factor. Define $u^\delta(\sigma_1, \sigma_2)$ similarly for the union. Let $W = \{(u, v) \mid \exists \delta \in]0, 1[\text{ and } (\sigma_1, \sigma_2) \text{ which is a WRP equilibrium s.t. } u = u^\delta(\sigma_1, \sigma_2), v = v^\delta(\sigma_1, \sigma_2)\}$. W is the set of payoff pairs which for some discount factor can be obtained as average payoff pairs for some WRP equilibrium strategy pair.

From figure 4, (17), (18) and the corollary to theorem 2 it is clear that if (σ_1, σ_2) is a WRP then $v^\delta(\sigma_1, \sigma_2) < \tilde{v}(w_{cc}(\bar{\gamma}), \bar{\gamma})$. On the other hand theorem 2 implies that for any $\epsilon > 0$ there exists a $\delta < 1$ such that there exists a WRP equilibrium (σ'_1, σ'_2) fulfilling $|v^\delta(\sigma'_1, \sigma'_2) - \tilde{v}(w_{cc}(\bar{\gamma}), \bar{\gamma})| < \epsilon$. Similarly $u^\delta(\sigma_1, \sigma_2) < \tilde{u}(w_{cc}(\underline{\gamma}), \underline{\gamma})$ and for any $\epsilon > 0$ for δ sufficiently

close to one $|u^\delta(\sigma_1, \sigma_2) - \tilde{u}(w_{cc}(\underline{\gamma}), \underline{\gamma})| < \epsilon$. This means that W is contained in the shaded set S in figure 7.

Figure 7.

Theorem 2 further implies that all points on the pareto frontier, P , lying strictly between point A and point B in figure 7 can be obtained as average payoff pairs in a WRP equilibrium for a sufficiently high δ . $P \cap W$ is thus open in P .

Clearly, if (σ_1, σ_2) is a WRP equilibrium then so are all its continuation strategy pairs. Hence, if (σ_1, σ_2) is a WRP equilibrium then its average continuation payoff pairs are contained in the set S in figure 7. As $W \subset S$ it is clear that for all $(u, v) \in W \setminus P$ there exist $(u', v') \in W \cap P$ strictly dominating (u, v) . This implies that if (σ_1, σ_2) is SRP for all discount factors δ , $0 < \delta < 1$ then $[u^\delta(\sigma_1, \sigma_2), v^\delta(\sigma_1, \sigma_2)] \in P \cap W$ and so do all its average continuation payoffs. Let us assume that (σ_1, σ_2) is such a SRP, yielding average payoffs (u, v) . Because of the strict concavity of the Pareto frontier (σ_1, σ_2) must specify repeated play of a single action pair on the contract curve, (w, γ) say, cf. the discussion in connection with proposition 1.

If the union deviates optimally in one period from playing w it gets in that period the expected utility $\bar{u}(w^u, \gamma) > \bar{u}(w, \gamma)$. Hence (σ_1, σ_2) must prescribe a punishment for the union in the case of defection, otherwise (σ_1, σ_2) is not subgame perfect. Due again to the strict concavity of the pareto frontier this punishment must specify repeated play of a particular action pair, (w^1, γ^1) say, for all subsequent periods. Of course (w^1, γ^1) should be on the contract curve and ensure that a one shot deviation does not pay for the union, i.e. (w^1, γ^1) should fulfill:

$$(1-\delta)\bar{u}(w^u, \gamma) + \delta\bar{u}(w^1, \gamma^1) < \bar{u}(w, \gamma) \quad \Leftrightarrow$$

$$\bar{u}(w, \gamma) - \bar{u}(w^1, \gamma^1) > \frac{1-\delta}{\delta} [\bar{u}(w^u, \gamma) - \bar{u}(w, \gamma)] \quad (26)$$

As $[\bar{u}(w^u, \gamma) - \bar{u}(w, \gamma)] > 0$ this requires $\gamma^1 > \gamma$ and $w^1 < w$. Similarly there must be a punishment (w^2, γ^2) ensuring that the union does not deviate from (w^1, γ^1) . Analogously to the above one gets that this implies:

$$\bar{u}(w^1, \gamma^1) - \bar{u}(w^2, \gamma^2) > \frac{1-\delta}{\delta} [\bar{u}(w^u, \gamma^1) - \bar{u}(w^1, \gamma^1)] \quad (27)$$

Since u is separable in w and γ and since $w_1 < w$ we also have that

$$\bar{u}(w^u, \gamma^1) - \bar{u}(w^1, \gamma^1) > \bar{u}(w^u, \gamma) - \bar{u}(w, \gamma) \quad (28)$$

Adding (26) and (27) and using (28) yields

$$\bar{u}(w, \gamma) - \bar{u}(w^2, \gamma^2) > 2 \frac{1-\delta}{\delta} [\bar{u}(w^u, \gamma) - \bar{u}(w, \gamma)] \quad (29)$$

Of course there must also be a punishment (w^3, γ^3) deterring deviation from (w^2, γ^2) and so forth. In this way we get a sequence of punishments (w^n, γ^n) where for each n we can derive in the same way as (29) that:

$$\bar{u}(w, \gamma) - \bar{u}(w^n, \gamma^n) > n \frac{1-\delta}{\delta} [\bar{u}(w^u, \gamma) - \bar{u}(w, \gamma)] \quad (30)$$

For $n \rightarrow \infty$ (30) implies that $\bar{u}(w^n, \gamma^n)$ eventually becomes less than $\bar{u}(w^E, \gamma^E)$ contradicting the assumption that (w^n, γ^n) is on the contract curve. $\square$

Theorem 4 excludes the possibility that any strategy pair (σ_1, σ_2) can be a SRP equilibrium for all discount factors less than one. We have not excluded the possibility that, for a given value of $\delta < 1$, there exist SRP equilibria. Should they exist, they must have all their continuation payoffs on the boundary of the set of WRP equilibrium payoffs in order that none of them is strictly Pareto dominated. This requires, inter alia, that for a given $\delta < 1$, the WRP equilibrium payoff set is closed, and this requirement appears to be satisfied in our game. These matters should be a subject for further research.

6. Concluding Remarks.

The object of this paper has been to investigate the abilities of the government to achieve its goals by means of pure stabilization policy in an infinitely repeated policy game between a union and the government. Results were that for some parameter values the set of subgame perfect equilibria included an equilibrium in which the wage rate and stabilization policy in each period was the best possible seen from the view point of the government and

similarly for the union. This result was proved by a simple application of a folk theorem.

However, taking into account the fact that some subgame perfect equilibria do not seem to be credible and restricting attention to weakly renegotiation proof equilibria it was shown that the equilibrium set for all parameter values only included equilibria which did not favour one party especially. Finally, it was shown that for any strategy pair when the discount factor becomes close to one that strategy pair is not a strongly renegotiation proof equilibrium.

The analysis was undertaken in a simple macroeconomic model essentially consisting of a decreasing demand function for labour. It would, in our eyes, be very interesting to see whether similar results can be obtained in a model with more solid general equilibrium foundations. This should be a subject for further research. Further we would find it interesting to see what happens if one releases the requirement that government policies should be purely stabilizing, i.e. to dismiss the Gramm–Rudmann act.

From a game theoretic perspective it seems interesting to see whether similar results as those obtained here can be obtained under more general conditions but in the same basic class of games, i.e. two player games with infinite action spaces, continuous reaction functions etc. This will be a subject for further research.

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