The International Coordination of Monetary Policy: A Game-Theoretic Reformulation[1]

Luca Lambertini
Dipartimento di Scienze Economiche
Università degli Studi di Bologna
Strada Maggiore 45
40125 Bologna, Italy
fax 39-51-6402664
e-mail: lamberti@spbo.unibo.it

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Abstract

This paper reformulates the issue of the international coordination of monetary policy in the framework of an extended game with observable delay, where governments are required to set the timing of their respective actions before proceeding to the actual choice of their monetary policies. This allows to shrink signi…cantly the set of equilibria.

JEL Classi…cation: D43, E61, F41, F42

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1 Introduction

The issue of the distribution of roles and, consequently, equilibrium selection in non-cooperative games has been largely investigated in the literature on oligopolistic interaction. In quantity games, leadership is preferred to simultaneous play, and both are preferred to followership, while in price games followership is preferred to leadership and both are preferred to simultaneous play (see Gal-Or, 1985; Dowrick, 1986; Boyer and Moreaux, 1987a,b, inter alia).[1] In this literature, though, the sequence of moves is exogenously determined, and there emerges no reason to believe that players select the Nash solution rather than the Stackelberg one, or vice versa.

A recent contribution (Hamilton and Slutsky, 1990; HS henceforth) explicitly models the strategic choice of timing, which is often possible in reality. HS investigate the endogenous choice of roles, i.e., the endogenous arising of Stackelberg or Cournot equilibria, in non-cooperative two-person games, by considering an extended game where players must set both the actions they want to undertake in the basic game, and the time at which such actions will be implemented. When players choose to move at di¤erent times, sequential equilibria are observed, while if they decide to act at the same time, simultaneous Nash equilibria obtain. The choice of timing occurs in a preplay stage which is not taking place in real time, so that there is no need of discounting the payo¤s. The decision to play early or late is not su¢cient per se to yield sequential play.

The range of applicability of such a framework is extremely wide. Here, I shall focus on the issue of the international coordination of monetary policies. A variety of models have been described in the relevant literature, with either …xed or ‡exible exchange rates/prices (see Mundell, 1968; Hamada, 1976, 1979, 1985; Canzoneri and Gray, 1983, 1985; Cooper, 1985; Turnovsky and D'Orey, 1986; Canzoneri and Henderson, 1991). All of these models highlight the strategic aspects of the interdependence between national economic policies, complaining at the same time the lack of a mechanism allowing for the selection of a speci…c equilibrium in each of the situations described. Moreover, non-cooperative behaviour generates externalities that are likely to lead to ine¢cient outcomes for all the countries involved. A remedy to the ine¢ciency due to strictly non-cooperative solutions consists in considering the possibility that governments succeed in reaching cooperative agreements in a repeated-game setting, thereby internalizing externalities in a way that all countries might bene…t. As a consequence, it has often been argued that policy-makers should be forced to accept a set of rules that implicitly establish a coordination amongst their policies. Unfortunately,

[1] The same conclusions on the preferences over the distribution of roles can be reached through a quick examination of the slopes of the reaction functions, de…ning the concept of strategic complementarity/substitutability (Bulow, Geanakoplos and Klemperer, 1985).

the feasibility of such a cooperative arrangement is largely questionable, in that there always exists an inherent incentive to defect from it. Likewise, one or all countries may be better o¤ in Stackelberg equilibria than in the simultaneous equilibrium, but this solutions are a¤ected by the same credibility problems as a cooperative agreement. The commitment to adopt a particular policy di¤erent from the Nash equilibrium one, on the part of one or more policy-makers, can hardly be credible in single-stage, one-shot games.

In this paper, I intend to show that the instruments provided by HS allow to signi…cantly shrink the set of admissible equilibria for the basic one-shot game, when the possibility for governments to set the timing of their respective moves is duly taken into account. This is likely to happen whenever policy-makers can take their decisions through the intervention of supernational organizations. It is particularly worth stressing that the mechanism envisaged here to extend the basic game does not require any cooperative attitude on their part. Moreover, they are not required to take precommitments, in that the game is conceived in such a fashion that they have no incentive to deviate.

The remainder of the paper is structured as follows. Section 2 describes the nature of the extended game with observable delay. Section 3 introduces a simple …xed-price and …xed-exchange rate Keynesian setting. The issue of coordinating monetary policy across countries is then dealt with in section 4. Finally, section …ve provides concluding comments.

2 The extended game with observable delay

In HS, a simple two-person non-cooperative one-stage game is extended by allowing players to choose also the timing of their respective actions in the basic game. If they choose to move at di¤erent times, the one playing later observes the move selected by the player who has played …rst. This leads to the arising of a sequential equilibrium in the basic game. If instead both choose to move at the same time, then a simultaneous equilibrium is observed. HS consider the stage of choosing the timing as a preplay stage which is not taking place in real time, so that there is no need of discounting the payo¤s pertaining to the basic game.

The structure of the extended game is as follows. First, players announce the instant at which they will undertake their actions. They are committed to that timing, although they do not specify which action they shall take. Then, they proceed to play by undertaking the sequence of actions they …nd optimal, knowing when the rival is going to move.

Consider an extended game where players can set a single strategic variable and must choose between moving …rst or second.[2] I shall adopt here a symbology

[2] Notice that players are not required to commit to a particular action in the basic game. HS (1990, section IV) take into account the latter possibility in describing an extended game with action commitment, where each player announces a speci…c action and must stick to it, whether the rival tries to lead or follow. This yields multiple equilibria.

which is largely analogous to that in HS (1990, p.32). Define $\Gamma_1 = (N, \Sigma_1, U_1)$ the extended game with observable delay. The set of players (or firms) is $N = \{A, B\}$, and α and β are the compact and convex intervals of $\mathbb{R}^1$ representing the actions available to A and B in the basic game. U_1 is the payoff function. Payoffs depend on the actions undertaken in the latter, according to the following functions, $U^A : \alpha \times \beta \to \mathbb{R}^1$ and $U^B : \alpha \times \beta \to \mathbb{R}^1$. Let U^i, $i = A, B$, be monotone in the rival's action.[3] The set of times at which firms can choose to move is $T = \{F, S\}$, i.e., first or second. The set of strategies for player i is $\Sigma_1^i = \{F, S\} \times \Psi_i$, where Ψ_i is the set of functions that map $\{T \times \beta (\text{or } \alpha)\}$ into $\alpha (\text{or } \beta)$. If both players choose to move at the same time, they obtain the payoffs associated with the simultaneous Nash equilibrium, (U_n^A, U_n^B), otherwise they get the payoffs associated with the Stackelberg equilibrium, e.g., (U_l^A, U_f^B) if A moves first and B moves second, or vice versa. The game can be described in normal form as in matrix 1 (cfr. HS, 1990, p.33).

		B	
		F	S
A	F	U_n^A, U_n^B	U_l^A, U_f^B
	S	U_f^A, U_l^B	U_n^A, U_n^B

Matrix 1

Examine first the cases where both players' payoff ranking is the same. To begin with, consider the following sequence:

$$U_l^i > U_n^i > U_f^i, \; i = A, B. \tag{1}$$

This holds, e.g., in a standard Cournot duopoly with substitute goods (see Singh and Vives, 1984). In such a case, both players move at the earliest occasion in order to avoid following, and the subgame perfect equilibrium of the extended game involves simultaneous moves (HS, 1990, Theorem II). If we have instead:

$$U_f^i > U_l^i > U_n^i, \; i = A, B, \tag{2}$$

as in a standard Bertrand duopoly with substitute goods (see Singh and Vives, 1984), the extended game with observable delay has multiple equilibria, in that both sequential play equilibria of the basic game are subgame perfect (HS, 1990, Theorem III). Moreover, there exist also a correlated equilibrium[4] and a mixed-strategy equilibrium where players randomize over F and S, so that they attach a positive probability to simultaneous play.

[3] Monotonicity of the best reply functions is not sufficient for HS's theorems to hold generally. This has been pointed out by Amir (1995).

[4] For the concept of correlated equilibrium, see Osborne and Rubinstein (1994), ch. 3.

Finally, consider the asymmetric case where payoff rankings differ across players:

$$U_l^i > U_n^i > U_f^i; U_f^j > U_l^j > U_n^j; i; j = A; B; i \neq j: \quad (3)$$

In this setting, player i strictly prefers leading, while player j strictly prefers following, so that the unique subgame perfect equilibrium of the extended game involves sequential play and is described by the pair (F; S). This is what happens in a duopoly where one firm is a quantity-setter and the other is a price-setter (Singh and Vives, 1984).

In the existing literature the issue of the distribution of roles has been solely investigated in relation to oligopoly. In the next section, I propose an example of what can be achieved by adopting HS's approach in a well known model of monetary policy.

3 A simple Keynesian setting

I borrow the basic setting from Hamada (1985). Assume the world economy consists of two countries, A and B, connected by international trade and free capital flows. They are of comparable size and have the same economic system. The price level in each country, p^i, i=A, B, is fixed, while the income level Y^i is variable. Exchange rates are also fixed.[5] The money market is in equilibrium in each country if real money supply and demand coincide:

$$\frac{M^i}{p^i} = L^i(r^i; Y^i); \quad (4)$$

where L^i is the money demand expressed by agents living in country i, as a function of the real interest rate and income. The nominal money supply in country i consists of the sum of international reserves, R^i, and the liabilities of the banking system, D^i:

$$M^i = R^i + D^i; \quad (5)$$

where the price of country i's currency in terms of country j's currency has been normalized to one without loss of generality. Total international reserves are assumed to be constant in the short run:

$$R^A + R^B = \overline{W}: \quad (6)$$

Moreover, provided price levels are fixed, nominal and real interest rates coincide, and perfect capital mobility implies $r^A = r^B$.

Monetary policy takes the form of a change in the liabilities of the banking system, i.e., domestic credit D^i. Mundell (1968) established that the following

[5] For an exhaustive discussion of the opportunity of fixing exchange rates or limiting the degree of their flexibility, see Giavazzi and Giovannini (1988).

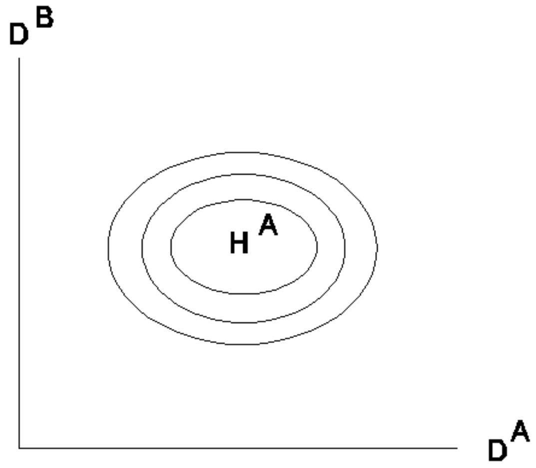

Figure 1: Country A's indifference curves map

comparative statics properties hold:

$$\frac{\partial Y^i}{\partial D^i} > 0; \frac{\partial Y^i}{\partial D^j} > 0; \frac{\partial R^i}{\partial D^i} < 0; \frac{\partial R^i}{\partial D^j} > 0. \tag{7}$$

Assume government spending is constant. Under fixed exchange rates, each country's problem consists in choosing the optimal monetary policy, under the hypothesis that its welfare depends on the current condition of its real income and balance of payments, represented by international reserves. Accordingly, country's i objective function can be represented as $U^i = U^i(Y^i; R^i)$. To our aims, in order to explicitly model strategic interaction between the two countries, it is more convenient to rewrite such objective function as follows:

$$U^i = U^i(D^i; D^j); \tag{8}$$

i.e., in terms of both countries' domestic credit. I shall assume that there U^i is single-peaked and at least quasi-concave for all admissible values of D^i and D^j. Hence, country i's objective function can be represented by a map of indifference curves, as in Figure 1, where the indifference curves mapping of country A is illustrated. Its satisfaction level decreases as country i departs from its maximum point H^i.

I am now in a position to investigate the interplay between the monetary policies of the two countries, expressed in terms of the levels of their respective domestic credit, D^i. This is done in the next section.

4 The monetary policy game

I shall now proceed to present the relevant cases without going into a detailed analytical treatment. Consider first the situation where both countries prefer a balance of payments surplus. This setting is depicted in Figure 2. Provided that countries are symmetric, the 45-degree line OB defines the locus of all the combinations of D^A and D^B that equilibrate the balance of payments for both countries, $BP^A = BP^B = 0$. Thus, above and to the left of OB, country A runs a surplus, while below and to the right of OB, country A runs a deficit. The opposite obviously holds for country B. Country A's indifference curves map is drawn with solid lines, while country B's is dashed. The nature of the strategic interaction is described by the slope of the reaction functions, $G^A = g^A(D^B)$ and $G^B = g^B(D^A)$. Their intersection along OB gives the Nash equilibrium pair $(D^A_n; D^B_n)$. The tangency point between country i's map and country j's reaction point identifies the Stackelberg equilibrium point $S^i(D^i_l; D^j_f)$ where country i takes the lead and country j follows. Since the reaction functions are both decreasing, and both countries order the payoffs as in (1) above, the outcome of the extended game can be summarized by the following proposition:

Proposition 1 When both countries prefer a balance of payments surplus and exhibit decreasing reaction functions, the subgame perfect equilibrium of the extended game involves simultaneous play.

Here the situation is such that it would pay to be the leader, but the other country would incur a significant loss accepting to follow. Since by moving at the first occasion both governments can avoid the burden of followership, a simultaneous equilibrium obtains. Due to the presence of a strictly dominant strategy, i.e., playing at the earliest occasion (which shapes the negative slope of both reaction functions), the inefficient outcome associated with the Nash equilibrium generated by simultaneous play, which typically replicates the prisoner's dilemma, cannot be improved upon in any way other than cooperative behaviour.

Consider now a situation where both countries prefer a balance of payments deficit. Here, both countries exhibit increasing reaction functions. A quick inspection of Figure 3 reveals that this leads to a Nash equilibrium characterized by an expansive distortion. Moreover, both countries rank simultaneous and sequential outcomes as in (2) above.

Analogous considerations hold when in the asymmetric setting where, e.g., country A desires a balance of payments deficit while country B desires a limited surplus, as illustrated in Figure 4. Again, the ranking is described by (2). Accordingly, I can state what follows:

Proposition 2 When at least one country prefers a balance of payments deficit and both countries exhibit increasing reaction functions, the extended game with

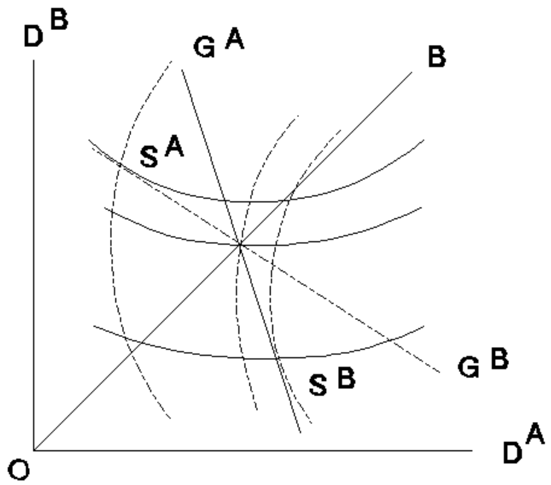

Figure 2: The symmetric setting where both countries prefer a surplus

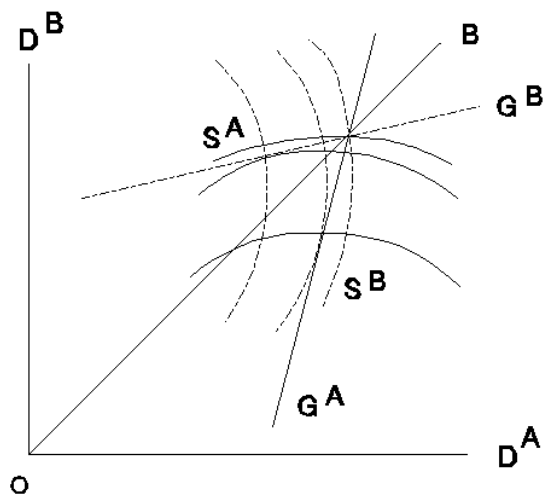

Figure 3: The symmetric setting where both countries prefer a de…cit

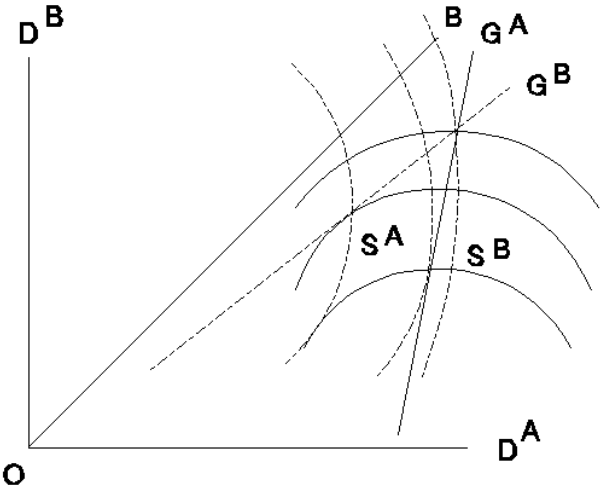

Figure 4: The asymmetric case where A desires a de…cit and B desires a surplus

observable delay exhibits multiple equilibria. There exist two equilibria in pure strategies entailing sequential play. Moreover, there exist (i) a mixed-strategy equilibria where countries randomize over playing early and delaying, so that they play simultaneously with positive probability, and (ii) a correlated equilibrium.

In such a setting, the leader's role is still preferred by both countries, but following turns out to be preferable to playing simultaneously. As a consequence, the clearly suboptimal simultaneous Nash equilibrium is ruled out, at least in pure strategies. Notice that the absence of a dominant strategy generates the need to coordinate. The fact that playing in mixed strategies entails attaching a positive probability to moving simultaneously, leads one to think that countries could alternatively play the leader's role in a repeated game. This is precisely what would happen if the solution concept were the correlated equilibrium, where each country's utility level is the weighted sum of the leader's and follower's payo¤s, with weights equal to 1/2.

Finally, consider the setting where one country desires a surplus while the other desires a de…cit, and their objective functions are such that the reaction functions are characterized by opposite slopes.

In Figure 5, country A prefers a balance of payments surplus and has a decreasing reaction function, while country B desires a balance of payments de…cit and has an increasing reaction function. The exam of Figure 5 reveals that country A is better o¤ moving second than in any other situation, while country B is better o¤ playing …rst than in any other situation. Moreover, country B prefers simultaneous play to followership, while country A prefers both leadership and

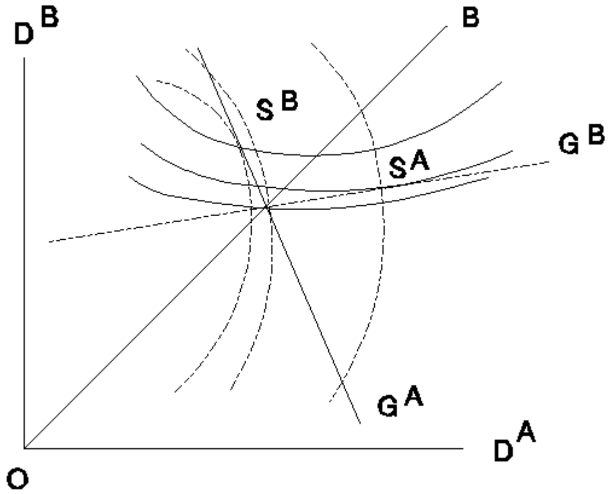

Figure 5: The asymmetric case where reaction functions have opposite slopes

followership to simultaneous play. This is precisely the situation described by (3). Accordingly, the outcome of such a game can be summarized by the following:

Proposition 3 When at least one country prefers a balance of payments deficit and the two countries' reaction functions exhibit opposite slopes, the extended game with observable delay has a unique subgame perfect equilibrium which is in pure strategies and involves sequential moves, with the country characterized by an increasing reaction function in the leader's position.

Here, the country characterized by an increasing reaction function (in this example, B) has a strictly dominant strategy consisting in playing immediately, while the country with a decreasing reaction function (A) has no dominant strategy. This yields as a result a unique equilibrium for the extended game, which drastically differs, though, from the simultaneous equilibrium of the basic game corresponding to the intersection of the reaction functions. It is worth noting that this is the only case where both countries' desires turn out to be fulfilled at equilibrium. In the Stackelberg equilibrium point S^B, country B is leading and running a deficit, while country A is following and running a surplus, so that the extension of the basic monetary policy game to consider a preplay stage where countries establish the order of moves provides a clearcut answer to the problem of the multiplicity of equilibria that characterized the earlier literature in this field.

5 Concluding remarks

In this paper, I have reformulated the issue of the international coordination of monetary policies within the extended game framework due to HS. I have thus shown that accounting for the possibility for governments to set the timing of their respective actions before proceeding to determine their respective monetary policy leads to a signi…cant shrinking of the set of equilibria. Such a possibility is very likely to arise where supernational organizations can intervene in the process of coordinating national policies. Speci…cally, the most striking result is that when countries have opposite and non-con‡icting interests, the equilibrium of the extended game is unique and completely ful…lls their respective desires. Such a result was far beyond the reach of standard single-stage models, which were a¤ected by the lack of an equilibrium selection mechanism. The solution consisted in resorting to repeated-game settings where endogenous cooperation could arise (see Hamada, 1985, ch. 4; Canzoneri and Henderson, 1991, ch.2). Here, instead, outcomes that Pareto-dominate the Nash equilibrium can be reached in one-shot games, through strictly non-cooperative behaviour.

I con…ned my attention to a simple Keynesian setting, under the assumptions of …xed prices and …xed exchange rates, in order to illustrate the results that can be reached by resorting to the tool kit provided by HS. The replication of such analysis in a setting characterized by ‡exible exchange rates and prices (see Cooper, 1985; Hamada, 1985, chs. 4 and 5; Canzoneri and Henderson, 1991, ch.2) is straightforward and would lead to largely analogous conclusions.

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