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Non-Cooperative Bargaining and Imperfect Competition: A Survey

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Non-cooperative bargaining theory provides a tool for analysing the formation of prices in markets with bilateral trading. The paper describes this approach and gives an overview of its applications to imperfectly competitive markets. In simple models with perfect and imperfect information it is shown how market frictions affect the traders' bargaining position and the equilibrium outcome. Of particular interest is the relationship between this outcome and the competitive Walrasian equilibrium.

1. Introduction

The purpose of this paper is to describe some developments in analysing the formation of market prices by means of two-person bargaining games.[1] This approach relies on market imperfections which preclude direct multilateral trade among economic agents. The terms of trade are determined as the outcome of a non-cooperative bilateral bargaining game which is imbedded in a market with many other traders. Each pair of traders is in a situation of partial bilateral monopoly because market frictions make switching to another trader costly. The bargaining positions of the agents are thus affected by the conditions prevailing in the market and the agreements reached by different pairs of traders are interdependent. Since the equilibrium reflects the level of market frictions, it is possible to address the question of whether the competitive Walrasian outcome emerges in the limit when these frictions become small.

Traditional competitive analysis has little to say about the formation of prices. In a Walrasian economy traders are assumed to have no market power and treat prices as parameters. It is not explained how prices are established through the interaction between the traders. Instead, a Walrasian auctioneer is postulated to adjust prices in a way such that in equilibrium all markets are cleared. A similar critique applies to *Cournot's*[2]

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[1] This survey focusses on non-cooperative bargaining theory as a foundation of equilibrium analysis in imperfectly competitive markets. There are related surveys on bargaining by *Rochet* (1987), *Rubinstein* (1987), *Sutton* (1986), and *Wilson* (1987).

[2] *Cournot* (1838).

approach to imperfect competition. He assumes that firms choose quantities as their strategic variables. Each firm takes the supply of competing firms as fixed and anticipates the impact of its own decision upon the market clearing price. Like in the Walrasian model, an auctioneer has to find the equilibrium prices once the firms have supplied their quantities to the market.

A related critique against the Cournot model has been brought forward by *Bertrand*.[3] He argues that the use of prices rather than quantities might be strategically advantageous for the firms. By slightly undercutting the prices of his competitors each single producer could attract the whole market. Price competition of this kind indeed turns out to be rather effective. As Bertrand observed, in the case of constant marginal costs the competitive outcome emerges even with two price setting firms.

The Bertrand approach thus has the attractive feature to generate competitive conditions without requiring a fictitious Walrasian auctioneer. This aspect is particularly important for the analysis of markets in which the Walrasian equilibrium is not well-defined. This is the case, for example, in search markets in which the buyers are imperfectly informed about prices. Similarly, in the presence of asymmetric information the Walrasian auction market is often replaced by a more complicated market for contracts because the traders engage in signalling activities.[4] The competitive equilibrium of such markets is typically identified with the Bertrand equilibrium. But, this notion of competition may prove in fact to be too strong. Already *Edgeworth*[5] discovered that price competition may have no equilibrium in pure strategies if the suppliers are capacity constrained.[6] Similar problems of existence of equilibrium arise in markets with search costs, in differentiated commodity markets, and in markets with asymmetric information.[7]

These problems seem to be related to the asymmetric treatment of buyers and sellers. The concept of Bertrand competition presumes that the sellers can commit themselves to setting prices while buyers cannot. As a consequence, the price of a commodity is no longer negotiable when a consumer wishes to make a purchase. In contrast, the bargaining approach rules out such possibilities of commitment and treats both sides of the market symmetrically. In this way, the sellers' market power is weakened and competition becomes consistent with the existence of equilibrium.

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[3] *Bertrand* (1883).

[4] See, e.g., *Rothschild / Stiglitz* (1976).

[5] *Edgeworth* (1925).

[6] *Dasgupta / Maskin* (1986) have shown that there exists a mixed strategy equilibrium in Bertrand-Edgeworth markets. The relationship between this equilibrium and the competitive outcome is analysed in *Allen / Hellwig* (1986).

[7] See *Stiglitz* (1979), *d'Aspremont / Gabszewics / Thisse* (1979), and *Rothschild / Stiglitz* (1976), respectively.

Non-cooperative bargaining theory describes the bargaining situation as a game and derives a solution by applying non-cooperative solution concepts. This differs from the traditional axiomatic approach developed by *Nash*[8], in which the outcome is determined by some set of postulates or axioms.[9] For the analysis of trading processes the non-cooperative approach appears to be more attractive because it is not a priori clear which set of axioms should be appropriate. Moreover, the specification of an extensive game allows for a detailed description of the economic environment, which includes the agents' preferences, their information, and their payoffs from breaking off negotiations.

Section 2 of this paper explains the basic tools of non-cooperative bargaining theory. Applications of the bargaining approach to non-Walrasian markets are surveyed in sections 3 and 4. In sections 5 and 6 we show how the Bertrand paradigm may be replaced by the bargaining approach in markets with search costs and in markets with differentiated commodities. Bargaining models with incomplete information are surveyed in sections 7 and 8.

2. Non-Cooperative Bargaining Equilibrium

The non-cooperative approach describes the bargaining procedure as an extensive game. In this game, the strategies of the players consist of proposals how to split the bargaining surplus and of replies to the offers made by the opponent. The simplest such game is the single stage game in which one party makes a 'take-it-or-leave-it-offer' and the other party replies by either accepting or rejecting. Consider an agent a who seeks to sell one unit of an indivisible good to some agent b. Agent b's valuation of the good is $q > 0$ and agent a's valuation is zero. In the single stage game one of the two parties proposes a price p at which it is willing to trade the good. If the proposal is accepted, then the payoffs of agent a and b are given by p and $q - p$, respectively. In the case of disagreement the two players receive v_a and v_b. The payoffs $v = (v_a, v_b)$ describe the 'status quo' point or the agents' 'outside options'.[10] In what follows, the bargaining game will typically be considered as being imbedded in a market so that v describes the agents' utilities that they can achieve on this market after breaking off negotiations. To give the two parties an incentive to reach an agreement, the bargaining surplus $q - v_a - v_b$ is taken to be non-negative.

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[8] *Nash* (1950).

[9] With respect to the outcome, the two approaches need not be inconsistent with each other. Their relationship is analysed in *Binmore / Rubinstein / Wolinsky* (1985). The axiomatic approach is surveyed by *Roth* (1979).

[10] For a discussion of outside options in bargaining, see *Binmore* (1985), *Shaked / Sutton* (1984), and *Sutton* (1986).

The bargaining outcome is now identified with a non-cooperative solution of the game. A Nash equilibrium is a pair of strategies each of which is an optimal response to the other. But this notion of equilibrium is in general too weak in the sense that the bargaining solution remains indeterminate. In fact, in the single stage game any price $v_a \leq p \leq q - v_b$ can be supported as a Nash equilibrium. Consider, for example, the game in which agent a makes the offer. Let agent b select the strategy of accepting a's proposal if and only if it does not exceed p, where p is any price such that $v_a \leq p \leq q - v_b$. Agent a's strategy consists of proposing exactly p. It follows immediately that each strategy is a best response to the other. The source of this indeterminacy is that the Nash equilibrium admits the use of incredible threats. If agent a would deviate from his equilibrium strategy and propose a price p' such that $p < p' < q - v_b$, then agent b would get the payoff $q - p' > v_b$ by accepting p'. His threat to reject any price above p is thus no longer optimal once such an offer actually occurs.

The concept of 'subgame perfect' equilibrium proposed by Selten (1965) eliminates the use of incredible threats by requiring rational behavior in each part of the game. A subgame perfect equilibrium is a Nash equilibrium in which the strategies of the players constitute a Nash equilibrium for every subgame of the entire game. This concept has been surprisingly fruitful in determining a unique solution of bargaining games under perfect information.[11] Consider again the single stage game in which agent a makes the offer. Rationality on the part of agent b requires to accept any price p such that $q - p > v_b$ and to reject any price p such that $q - p < v_b$. Thus, the highest price that is acceptable for agent b satisfies $q - p = v_b$. Accordingly, the optimal strategy of agent a is to propose

$$p_a^* = q - v_b \; . \tag{1}$$

As a result, the single stage game has a unique subgame perfect equilibrium. Agent a proposes p_a^* and agent b accepts. By an analogous argument, the equilibrium price of the single stage game which starts by an offer of agent b is given by

$$p_b^* = v_a \; . \tag{2}$$

Note that in equilibrium there is no disagreement and the object is always exchanged between the two parties.

Equilibrium strategies that involve immediate agreement are a general feature of bargaining games under perfect information. A very attractive

[11] This only true as long as two-person bargaining games are considered, see *Haller* (1986) and *Sutton* (1986).

game of this kind is *Rubinstein's* model because it imposes no restrictions on the number of bargaining stages.[12] The game starts by a proposal made by one of the two parties. If the opponent agrees, the bargaining ends. Otherwise, the opponent makes a counteroffer at the next stage, and so on. In this way, the two parties alternate to make proposals and the game ends by acceptance of an offer. The bargainers have an incentive to reach an early agreement because their preferences exhibit impatience. For simplicity, let both agents discount future payoffs by a common discount factor $0 < \delta < 1$. Thus, if the price p is accepted at stage t of the game, the agents' payoffs are $\delta^t p$ and $\delta^t \left[q - p\right]$, respectively. Both agents get zero payoffs if there is no agreement within a finite number of stages.

It turns out that this game has a unique subgame perfect equilibrium.[13] The equilibrium strategies are characterized by a pair of prices $\left\{p_a^*, p_b^*\right\}$ such that agent $i \in \left\{a, b\right\}$ proposes p_i^* whenever it is his turn to make an offer. Agent a accepts any offer $p \geq p_b^*$, and similarly agent b accepts only price offers which leave him no worse off than $q - p_a^*$. The equilibrium values of p_a^* and p_b^* may be derived from the equilibrium of the one-stage game by reinterpreting the status quo point v. In the infinite horizon model, v_i simply describes agent i's payoff from rejecting the proposal of his opponent and making a counteroffer at the next stage. Since along the equilibrium path p_i^* is always accepted, one obtains

$$v_a = \delta p_a^* \quad \text{and} \quad v_b = \delta\left[q - p_b^*\right] . \tag{3}$$

By combining (1) - (3) we obtain the equilibrium outcome of the Rubinstein game

$$p_a^* = \frac{q}{1+\delta} \quad \text{and} \quad p_b^* = \frac{\delta q}{1+\delta} . \tag{4}$$

Note that $p_a^* > p_b^*$. The bargaining outcome gives an advantage to the agent who makes the first offer. Indeed, in the single stage game he appropriates the entire surplus. In the infinite horizon model the difference between p_a^* and p_b^* disappears in the limit $\delta \to 1$.

To simplify the exposition, we will use the one-stage game as a basis for the current survey. In order to eliminate the asymmetry between the outcomes in (1) and (2), each party will be assumed to have an equal chance to initiate the bargaining procedure. This yields the expected equilibrium price

$$p^* = 0.5\left[q + v_a - v_b\right] . \tag{5}$$

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[12] *Rubinstein* (1982).

[13] For a simplified version of *Rubinstein's* (1982) original proof, see *Shaked / Sutton* (1984).

Of course, this kind of randomization may be regarded as somewhat unsatisfactory. In this respect, non-cooperative bargaining theory needs to be supplemented by arguments that explain which side of the market initiates the trading process. *Perry*[14] has addressed this question by taking account of the agent's costs of bargaining.

3. Wage Bargaining and Job Rationing

A first application of *Rubinstein's*[15] model to the analysis of a market with frictions has been presented by *Shaked / Sutton*.[16] They generalize the alternating offers model by allowing one of the bargainers to exchange his current opponent at certain stages of the game. This extended game is then used to study wage bargaining between a monopolistic employer and a prospective employee. Since there is assumed to exist a pool of unemployed workers, the Walrasian wage rate of this labor market would make the worker indifferent between being employed and being unemployed. But, Shaked and Sutton show that the introduction of frictions into the competitive model may lead to involuntary unemployment. They assume that the employer can bargain at most with a single worker at a time; he cannot make simultaneous offers to different workers. Moreover, when the employer is engaged in negotiating a wage with some potential worker, he is not able to switch to another worker at every stage of the game. The bargaining has to continue for some minimum number of stages before the firm can replace its current bargaining partner by another unemployed worker. In the subgame perfect equilibrium of this bargaining game, the worker receives a wage rate above his reservation wage so that he is better of than his unemployed colleagues. The equilibrium is thus non-Walrasian and entails job rationing. The Walrasian outcome is obtained only as a limiting case when the frictions which reduce the employer's ability to switch workers vanish.

A simplifying illustration of this result may be given using the framework developed in the foregoing section. Let agent b represent the employer. If he hires one agent of type a, he can produce the gross output q. The firm's profit is $q - p$, where p denotes the wage rate. The reservation wage of type a agents is normalized to zero. If the wage negotiations between agent b and one of the type a agents yield no agreement, then the type a agent remains unemployed. Therefore, $v_a = 0$. The employer, however, can bargain with another worker after Δ time units. Therefore,

$$v_b = \delta^{\Delta}\left[q - p^*\right] , \tag{6}$$

[14] *Perry* (1986).

[15] *Rubinstein* (1982).

[16] *Shaked / Sutton* (1984).

where $0 < \delta < 1$ denotes the employer's discount factor and p^* the equilibrium wage rate. By inserting (6) into (5) one obtains the following solution for the equilibrium wage rate:

$$p^* = \frac{1 - \delta^\Delta}{2 - \delta^\Delta}\, q \; . \tag{7}$$

Notice that $p^* > 0$ as long as $\Delta > 0$. That is, the worker who receives the job earns a wage rate above his reservation wage. The bargaining outcome yields the competitive wage rate only if the employer incurs no delay in switching to another laborer, i.e. only if $\Delta = 0$.

4. Equilibrium in Random Meetings Markets

An interesting model of non-cooperative bargaining in an economy with many traders has been developed by *Rubinstein / Wolinsky*.[17] They consider the steady state of a market with two types of agents who randomly meet in pairs. When a seller and a buyer have been matched, they bargain over the terms of the transaction. The bargaining exhibits competitive pressure because each trader faces the risk that his current partner finds another trader and quits. In this case, the abandoned party incurs delay costs until a new partner is found. A a consequence, in equilibrium the agreement is always reached immediately.[18] A pair of agents which has concluded a transaction leaves the market. It is assumed that the flow of new agents who enter the market equals the flow of agents who complete their transactions. Thus, the agents' probabilities of being matched are kept constant.

The meeting probabilities influence the traders' bargaining positions and the equilibrium outcome. Each agent of type a and b has a constant probability α and β, respectively, of finding an agent of the opposite type per period. All traders have a common discount factor $0 < \delta < 1$. Given that all transactions take place at the price p^*, agent a's and b's expected utility before being matched can be calculated as

$$v_a = (1 - \alpha)\, \delta v_a + \alpha \delta p^* \; , \quad v_b = (1 - \beta)\, \delta v_b + \beta \delta \left[q - p^*\right] \; . \tag{8}$$

Note that (8) also defines each trader's utility if no agreement is reached in bargaining. We may now simplify the bargaining structure considered by

[17] *Rubinstein / Wolinsky* (1985).

[18] *Butters* (1984) considers a random meetings market in which each agent has imperfect information about the other agent's preferences. This leads to the possibility of disagreement in bargaining. For a model in which the agents can increase their probability of being matched through search activities, see *Wolinsky* (1987).

Rubinstein / Wolinsky and use the single stage solution (5) to compute the equilibrium price. Equations (5) and (8) then yield:

$$p^* = \frac{1 - \delta + \alpha\delta}{2(1 - \delta) + \alpha\delta + \beta\delta}\, q \,. \tag{9}$$

The market exhibits frictions because waiting to be matched requires time. For this reason, Rubinstein / Wolinsky refer to the limiting economy as the discount factor approaches one as a 'frictionless' market. Surprisingly, the bargaining outcome of this market may not be the competitive equilibrium. From (9) it follows that

$$\lim_{\delta \to 1} p^* = \frac{\alpha}{\alpha + \beta}\, q \,. \tag{10}$$

In contrast, in the Walrasian equilibrium of this economy the short side of the market would appropriate the entire surplus. For instance, the competitive price is zero if the majority of traders in the market is of type a. This observation led Rubinstein and Wolinsky to conclude that frictionless markets need not be Walrasian.[19]

This disturbing result has been criticized by *Binmore / Herrero*[20] and *Gale*.[21] These authors argue that the stationarity of the *Rubinstein / Wolinsky*[22] market is responsible for its non-competitiveness. At each date a constant flow of new traders has to enter the market in order to keep the meeting probabilities α and β fixed over time. Therefore, the set of all agents in the economy has infinite measure. *Binmore / Herrero*[23] find that the bargaining solution leads to the competitive outcome if the population of traders in the market is fixed. *Gale*[24] considers a general exchange economy of the Arrow-Debreu type with a finite measure of agents. As in *Rubinstein / Wolinsky*[25] the traders are matched by a stochastic process. Whenever two agents meet, one of them is selected at random to propose a take-it-or-leave-it offer. But, in contrast to *Rubinstein / Wolinsky*[26] each trader may stay in the market to continue trading as long as he wishes. Gale assumes that there is no discounting and shows that any equilibrium outcome is a Walrasian equilibrium of the underlying exchange economy.[27] In a similar vein, *Gale*[28]

[19] *Binmore / Herrero* (1988b) have even generalized the conditions under which this conclusion can be derived.

[20] *Binmore / Herrero* (1988a).

[21] *Gale* (1986), (1987).

[22] *Rubinstein / Wolinsky* (1984).

[23] *Binmore / Herrero* (1988a).

[24] *Gale* (1986).

[25] *Rubinstein / Wolinsky* (1984).

[26] *Rubinstein / Wolinsky* (1984).

[27] For a simplified derivation of this result, see *McLennan / Sonnenschein* (1986).

redefines the competitive equilibrium relative to the flow of agents who enter the market and shows that the bargaining equilibrium yields the competitive solution when the rate of time preference converges to zero.

Rubinstein / Wolinsky[29] argue, however, that even in the models considered by *Binmore / Herrero*[30] and *Gale*[31] the bargaining equilibrium does not necessarily coincide with the Walrasian equilibrium. They point out that as long as each trader has full knowledge of his personal history in the market, the bargaining solution may be indeterminate. The reason is that this kind of information may be used to create special relationships between certain traders which keep the market from being competitive. The competitive result is obtained only when the bargaining strategies are restricted to depend only upon impersonal information like the number of active traders. This indicates that anonymity may be an important prerequisite of perfect competition.

5. Price Uncertainty and Search

Firms have some degree of monopoly power in markets in which consumers have imperfect information about prices. The consumer has to search for low prices if he knows only the distribution of prices in the market and not the particular price at each store. In the presence of search costs it will be optimal to visit only a limited number of stores. As a consequence, competition between the sellers is reduced. Starting with *Stigler's*[32] article, the simplest models of such markets take the distribution of prices as given and focus on optimal consumer search strategies. But, as *Rothschild*[33] has pointed out, this approach is incomplete because it fails to explain how the distribution of prices emerges as an equilibrium. In the equilibrium of a fully specified model, the consumer's search behavior and the determination of prices would be interdependent. To complete the model it is typically assumed that the sellers set the prices and the consumers take prices as given. Yet, *Diamond*[34] has demonstrated that this approach leads to an important difficulty. Even when search costs are very small and the number of sellers is very large, the equilibrium price in all stores may turn out to be the monopoly price.[35] Indeed, as long as some prices are below the buyer's

[28] *Gale* (1987).
[29] *Rubinstein / Wolinsky* (1986).
[30] *Binmore / Herrero* (1988a).
[31] *Gale* (1987).
[32] *Stigler* (1961).
[33] *Rothschild* (1973).
[34] *Diamond* (1971).
[35] In fact, an equilibrium may fail to exist. This happens when each firm has an incentive to charge the buyer's reservation price and entering the market is costly for the buyer.

reservation price, the seller with the lowest price could gain by raising his price by an amount less than the consumer's search cost. Such a price increase would induce no consumer to leave and visit another store. The monopoly price result is rather disturbing for two reasons. First, it shows that one needs a more elaborate model to explain the persistence of price uncertainty when the concept of Bertrand competition is employed. Second, the fact that the monopoly price emerges, regardless of how small the costs of search are, casts some doubt on the appropriateness of competitive analysis.

One would wish to have a model of market uncertainty in which the equilibrium with small search costs is similar to the competitive equilibrium. *Bester*[36] shows that a model with these properties can be obtained by applying the bargaining approach. The underlying idea is that search costs generate a situation of partial bilateral monopoly between the buyer and the seller in each store. In the bargaining process the buyer may threaten to visit another store. Therefore, his bargaining position depends upon the costs of search. As an illustration consider the following example which uses the bargaining model of section 2. The agents of type a are identified as the sellers and the agents of type b as the consumers. There is a continuum of potential sellers each of whom costlessly produces commodities of some quality $q \in [0, \bar{q}]$. Across the set of producers the parameter q is taken to be uniformly distributed on $[0, \bar{q}]$. When a buyer arrives at some store, he bargains with the seller about the price. The price $p^*(q)$ of a good quality q is given by the bargaining solution (5). Only those sellers are active in the market whose products yield non-negative profits. It follows from (5) that only qualities $q \geq v_b - v_a$ are supplied. If the buyer refuses to purchase the good, the seller receives zero profits from this consumer so that $v_a = 0$. The buyer selects randomly one of the stores which are active in the market. For each visit he has to pay a search cost $k > 0$. Therefore, his expected utility from entering the market is given by[37]

$$v_b = E\{q - p^*(q) \mid q \geq v_b\} - k , \tag{11}$$

where E denotes the expectation with respect to q. Equations (5) and (11) yield the solution

$$v_b = \bar{q} - 4k . \tag{12}$$

[36] *Bester* (1988a).

[37] To ensure non-negativeness of v_b it is assumed that $k \leq \bar{q}/4$.

The set of active sellers thus consists of those who produce a quality of at least $\bar{q} - 4k$. They sell their output at the price

$$p^*(q) = 2k - \frac{1}{2}\left[\bar{q} - q\right]. \tag{13}$$

When the consumer enters the market, he draws from a random distribution of prices and qualities. His utility is a random variable. Notice that a reduction in k reduces the set of operating firms and increases the mean quality of products in the market. When k approaches zero, only producers of the highest quality $\bar{q}$ remain active and their profits become zero. In this model, information costs generate market uncertainty for the consumer. The sellers enjoy some degree of monopoly power and earn positive profits. But the uncertainty disappears from the market and the competitive equilibrium is attained in the limit when search costs become negligible.

6. Differentiated Commodity Markets

Hotelling[38] and *Chamberlin*[39] have developed the idea that firms may use product differentiation in order to attain monopoly power. A seller is in a quasimonopolistic position if his clientele regards the products of his competitors only as poor substitutes. The intensity of competition between different sellers is therefore negatively related to the substitutability of their products. A particular kind of product differentiation is considered in the 'location' models in which brands are represented as point in a geographical space. In these models the distance between different stores reduces competition because the consumers have to pay transportation costs.

While product heterogeneity is certainly relevant for many markets, it creates problems for the analysis of price competition. As in Bertrand-Edgeworth markets, an equilibrium with price setting firms may fail to exist. Thus, *d'Aspremont / Gabszewicz / Thisse*[40] have shown that the Hotelling duopoly possesses no price equilibrium if the two sellers are located to closely to each other. The reason is that as long as profits are positive each seller has the incentive to undercut the price of his competitor in order to attract the whole market. A zero profit equilibrium, however, does not exist either because the duopolists have local monopoly power. This existence problem is relevant for any kind of differentiated commodity markets.[41]

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[38] *Hotelling* (1929).

[39] *Chamberlin* (1933).

[40] *D'Aspremont / Gabszewicz / Thisse* (1979).

One possible way out of this dilemma is to use a bargaining game for the analysis of price formation in such markets. The aspect of product substitutability is important for this game because the consumer may switch to a neighboring seller if no agreement is reached in the price negotiations. Consider, for example, a market with two sellers, indexed $a = 1, 2$, each of whom produces at zero cost a different brand of some commodity. There a two groups of consumers, indexed $b = 1, 2$, who seek to purchase one unit of the good. Their valuations for the two brands are q_{b1} and q_{b2}. It is assumed that type 1 consumers prefer brand 1 whereas type 2 consumers prefer brand 2. This means $q_{11} > q_{12}$ and $q_{22} > q_{21}$. In the equilibrium of this market, each consumer purchases his preferred brand and bargains with its producer about the price. If no agreement is reached, the producer gets no profit from the respective customer, i. e. $v_a = 0$. The single stage bargaining game, therefore, leads to the following prices of the two brands:

$$p_1^* = 0.5\left[q_{11} - v_1\right], \quad p_2^* = 0.5\left[q_{22} - v_2\right]. \tag{14}$$

The consumer's outside option consists of purchasing the less preferred brand.[42] Therefore,

$$v_1 = q_{12} - p_2^*, \quad v_2 = q_{21} - p_1^*. \tag{15}$$

From (14) and (15) one obtains the market equilibrium

$$\begin{aligned} p_1^* &= \frac{2}{3}\left[q_{11} - q_{12}\right] + \frac{1}{3}\left[q_{22} - q_{21}\right], \\ p_2^* &= \frac{2}{3}\left[q_{22} - q_{21}\right] + \frac{1}{3}\left[q_{11} - q_{12}\right]. \end{aligned} \tag{16}$$

This solution nicely illustrates how the producers' profits depend upon the substitutability of the two brands from the consumer's viewpoint. The competitive prices $p_1^* = p_2^* = 0$ emerge in the limit when all buyers are indifferent between the two brands.[43]

Bester[44] applies a similar procedure to *Hotelling's*[45] model of spatial competition. By means of the bargaining approach he establishes existence of a

[41] For this reason many authors use the Cournot framework for the analysis of these markets, see e.g. *Spence* (1976), *Hart* (1979), and *Dixit / Stiglitz* (1977). *Hart* (1985) weakens Bertrand competition by considering ε-equilibria.

[42] To ensure non-negativeness of v_1 and v_2 it is assumed that $q_{11} \geq 2\,[q_{22} - q_{21} - q_{12}]$ and $q_{22} \geq 2\,[q_{11} - q_{12} - q_{21}]$.

[43] Notice that in a Walrasian competitive equilibrium prices are equal to marginal costs.

[44] *Bester* (1989).

[45] *Hotelling* (1929).

price-location equilibrium, in which both the firms' prices and their locations are endogenously determined. In this framework, the competitive outcome is attained in two limiting parameter constellations, namely if the consumers' transportation costs become negligible and if the number of sellers tends to infinity. The latter result holds because an increase in the number of sellers reduces the equilibrium distance between any pair of neighboring sellers so that in the limit each seller has to compete with other sellers in his immediate neighborhood.

7. Bargaining with Incomplete Information

In the models discussed in the foregoing sections, the players were assumed to know all about the characteristics of their opponents. In this situation the bargaining equilibrium involves immediate agreement. Indeed, it would be inefficient to divide the surplus at a later stage of the game if delay is costly. To explain disagreement in bargaining it seems necessary to introduce imperfect information which may lead to inefficient outcomes.[46] In fact, *Myerson / Satterthwaite*[47] have shown that any bargaining mechanism which the agents might wish to use cannot avoid ex-post inefficient outcomes if there is asymmetric information about preferences.[48]

The solution concept commonly used for bargaining games with imperfect information is the sequential equilibrium of *Kreps / Wilson*.[49] This concept basically extends the subgame perfect equilibrium to games with imperfect information. It requires each player to form beliefs concerning where in the game he is whenever it is his turn to select an action. Given his beliefs, each player's equilibrium strategy is a best response at every point of the game, including out-of-equilibrium points. Of course, in equilibrium the players' beliefs have to be consistent with the strategies actually chosen along the equilibrium path.

In bargaining games with asymmetric information delay of agreement is used as a screening device. The more patient players reject initial proposals in order to obtain a more favorable offer at a later stage. In the simplest form of such a game, only the buyer's valuation of the good is unknown and the seller makes repeated offers until the buyer accepts. *Sobel / Takahashi*[50] show that the sequential equilibrium then entails a sequence of decreasing

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[46] An alternative explanation which is based on possibilities of commitment is offered by *Crawford* (1982).

[47] *Myerson / Satterthwaite* (1983).

[48] The optimal mechanism under asymmetric information about product quality is studied in *Samuelson* (1984). Mechanisms for public goods are analysed in *Güth / Hellwig* (1986).

[49] *Kreps / Wilson* (1982).

[50] *Sobel / Takahashi* (1983).

price offers. After each rejection of a proposal, the seller updates his beliefs regarding the buyer's valuation and, given his new probability assessment, he makes another offer. It turns out that in equilibrium the buyer's true valuation is negatively related to the number of stages before the agreement is reached.[51]

As a simple example, consider a two-stage bargaining game with two possible types of buyers, indexed $b = h, l$. With probability $0 < \lambda < 1$ the buyer's valuation is q_h and with probability $1 - \lambda$ it is q_l, where $q_h > q_l > 0$. The seller owns a single indivisible good and his reservation price is zero. Seller and buyer have a common discount factor $0 < \delta < 1$. In equilibrium, the seller believes that he faces a buyer of type l if his first offer p_1^* is rejected. Since the type l buyer's optimal strategy at the second stage is to accept any proposal $p \leq q_l$, the seller optimally sets $p_2^* = q_l$. Of course, a buyer of type h anticipates the second stage offer p_2^*. He is inclined to accept the first offer p_1 if and only if

$$q_h - p_1 \geq \delta \left[q_h - p_2^* \right] . \tag{17}$$

For the seller's optimal first stage strategy this restriction must be binding. Therefore, the equilibrium sequence of price offers is given by

$$p_1^* = (1 - \delta)\, q_h + \delta q_l \, , \quad p_2^* = q_l \, . \tag{18}$$

The seller's expected payoff in the bargaining equilibrium is $\lambda\,(1 - \delta)\, q_h + \delta q_l$. If he could commit himself to setting a price, he would get λq_h by setting $p_1 = p_2 = q_h$. This strategy would yield a higher payoff than the bargaining equilibrium unless $\lambda \leq q_l / q_h$. Indeed, *Riley / Zeckhauser*[52] have shown that the optimal strategy of a seller who can commit himself to a sequence of offers is to charge a constant price without making concessions over time. The sequential equilibrium rules out such behavior because the seller knows that his opponent is of type l when the first offer has been rejected. Therefore, charging $p_2 > q_l$ is not optimal at the second stage.

Interestingly, the equilibrium of this bargaining game is identical to the optimal pricing rule of a monopolist who seeks to maximize profits through intertemporal price discrimination, as in *Stockey*.[53] The monopolist seeks to sell some stock of a durable good over time. Assume that, like in the above example, there are two groups of consumers who correctly anticipate prices and that at every point in time the monopolist sets his price so as to

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[51] *Sobel / Takahashi* (1983) first analyse a game with a finite number of stages and then look for an infinite horizon equilibrium as the limit of finite horizon equilibria. For an analysis of the infinite horizon model, see *Fudenberg / Levine / Tirole* (1985).

[52] *Riley / Zeckhauser* (1983).

[53] *Stockey* (1982).

maximize his remaining profit. Then his optimal pricing strategy consists of a sequence of two price offers so that at the first date all buyers of type h purchase the good. The remaining consumers buy the good at the second date. The equilibrium prices are given by (18). If there are n consumers and the monopolist's initial endowment e satisfies $\lambda n < e \leq n$, then the competitive price in this market would be q_l. Notice that also in the limit $\delta \rightarrow 1$ one obtains $p_1^* = p_2^* = q_l$. That is, price discrimination disappears and the prices chosen by the monopolist become identical to the competitive price as the time lag between sequential offers becomes insignificant. This observation confirmes *Coase's*[54] conjecture that the competitive outcome in a market for durable goods may be obtained even if there is only a single supplier. A general discussion of the validity of the Coase conjecture is offered by *Gul / Sonnenschein / Wilson*[55] and *Ausubel / Deneckere*.[56]

Fudenberg, Levine and *Tirole* (1987) have imbedded the above bargaining game in a market with many buyers. They allow the seller to switch to another buyer whenever his offer is rejected.[57] It turns out that if switching is costless the seller's optimal strategy is to set a single take-it-or-leave-it price and to switch immediately if this offer is rejected. If, however, switching is costly, then it may be optimal to make a sequence of decreasing price offers before switching to another buyer. A similar setting is studied in *Bester*.[58] In addition to the seller's uncertainty about the buyer's valuation, there is imperfect information of the buyer regarding the quality of the good. The structure of the equilibrium in this market depends upon the seller's costs of switching buyers. If these costs are sufficiently high, then there is a signalling equilibrium in which the seller's price proposal reveals the quality of his object. In this equilibrium the quality of the good is positively related to the seller's expected duration of search before he finds a buyer who purchases the object. In contrast, if the costs of switching are too low adverse selection occurs and the high-quality seller drops out of the market as in *Akerlof's*[59] market for 'lemons'.

8. Beliefs and Indeterminacy of Equilibrium

Closely related to the Coase conjecture is a result of *Gul / Sonnenschein*.[60] These authors argue that bargaining models with one-sided uncertainty can

[54] *Coase* (1972).

[55] *Gul / Sonnenschein / Wilson* (1986).

[56] *Ausubel / Deneckere* (1988).

[57] Similarly *Perry / Widgerson* (1986) consider a model in which the buyer may sequentially visit a finite number of sellers.

[58] *Bester* (1988b).

[59] *Akerlof* (1970).

[60] *Gul / Sonnenschein* (1988).

explain delay of agreement only to the extent that the delay between offers is significant. By reducing the period length between the offers the time interval required to conclude trade can be made arbitrarily small. It thus seems that two-sided uncertainty is required to explain a substantial amount of delay to agreement.[61]

A simple bargaining game with two-sided uncertainty is the sealed-bid mechanism studied by *Chatterjee / Samuelson*[62] and *Leininger / Linhart / Radner*.[63] This mechanism is a one-stage game in which seller and buyer submit simultaneous bids without knowing the valuation of their opponent.[64] Since the object is exchanged only if the two bids are compatible with each other, there is a chance that not all the gains from trade are realized. The sealed-bid mechanism may be criticized on the grounds that it requires a commitment not to reopen trading. The restriction to a single stage does not allow the bargainers to use the information that is revealed by their bidding strategies.

Information revelation is an important aspect of multi-stage bargaining. The equilibria of a two-stage game in which each player may have two possible valuations are characterized by *Fudenberg / Tirole*.[65] *Cramton*[66] studies an infinite horizon model with two-sided uncertainty. As *Fudenberg / Tirole*,[67] he assumes that the seller makes all of the offers. Infinite horizon models with two-sided uncertainty in which buyer and seller alternate to make offers are studied by *Rubinstein*[68] and *Grossmann / Perry*.[69]

Unfortunately, in these extensions of the model of *Sobel / Takahashi*[70] the sequential equilibrium is no longer unique. The reason is that now the players' price proposals reveal parts of their information. The inferences that may be drawn from their stragegies are, however, indeterminate. Therefore, different beliefs may support a large number of sequential equilibria.[71]

As a simple illustrating example consider the following one-stage bargaining game. A seller offers an indivisible good to a buyer who cannot

[61] For alternative explanations which maintain the one-sided uncertainty framework, see *Admati / Perry* (1987) and *Hart* (1986).

[62] *Chatterjee / Samuelson* (1983).

[63] *Leininger / Linhart / Radner* (1988).

[64] The sealed-bid mechanism with many buyers and sellers is studied in *Wilson* (1982).

[65] *Fudenberg / Tirole* (1983).

[66] *Cramton* (1984).

[67] *Fudenberg / Tirole* (1983).

[68] *Rubinstein* (1985a).

[69] *Grossmann / Perry* (1986b).

[70] *Sobel / Takahashi* (1983).

[71] A discussion of how the bargaining outcome depends upon the choice of conjectures is given in *Rubinstein* (1985b).

directly observe its quality. But the buyer knows that with probability $0 < \mu < 1$ the quality of the object is high and with probability $1 - \mu$ it is low. The buyer's valuation is either q_h or q_l according to whether quality is high or low. Let $q_h > q_l > 0$. The seller's reservation price is zero, independently of the quality of the good. When the seller names a price, the buyer conditions his beliefs concerning the quality of the good upon the observed price. In this game any price $q_l \leq p \leq \mu q_h + (1 - \mu)\, q_l$ can be obtained in a sequential equilibrium. To see this, consider the following system of beliefs for the buyer: There is a critical price $p^* \in \left[q_l, \mu q_h + (1 - \mu)\, q_l\right]$ such that any offer $p > p^*$ is regarded as a signal of low quality. Proposals $p \leq p^*$ are considered as uninformative. After such an offer the buyer's expected valuation equals $\mu q_h + (1 - \mu)\, q_l$. With these beliefs, the buyer purchases the good if and only if $p \leq p^*$. Therefore, the seller's equilibrium strategy is to demand exactly p^*, independently of the quality of the good. Thus, in equilibrium the buyer's beliefs are confirmed.

The source of this multiplicity of equilibria is the indeterminacy of the buyer's beliefs. The sequential equilibrium concept imposes no consistency restrictions upon beliefs which are conditioned on out-of-equilibrium strategies. But, the seller's behavior depends also upon such conjectures. In the example, the buyer's beliefs act as a threat which keeps the seller from raising his price above p^*.

One way out of this dilemma is to consider further refinements of the equilibrium concept and to impose additional restrictions upon beliefs.[72] One such example is the 'intuitive' criterion proposed by *Cho / Kreps*.[73] According to this criterion the buyer in the above example should revise his beliefs if there exists a price offer $\hat{p}$ with the following two properties: If the buyer interprets $\hat{p}$ as a signal of high quality, then proposing $\hat{p}$ rather than p^* is advantageous for the high-quality seller. The low-quality seller, however, would be worse off by proposing $\hat{p}$ irrespective of what the buyer is led to believe by observing $\hat{p}$. Cho and Kreps argue that under these circumstances the offer $\hat{p}$ should convince the buyer of high quality. It is easy to see that in the above example the intuitive criterion fails to narrow the set of sequential equilibria.[74] The reason is simply that whenever the high-quality seller could gain by proposing $\hat{p} > p^*$, then $\hat{p}$ must also be attractive for the low-quality seller.

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[72] For other refinements which go beyond subgame perfection, see *Selten* (1975), *Myerson* (1975), and *Kohlberg / Mertens* (1986). A comprehensive study of these concepts is provided by *Damme* (1987). Instead of restricting beliefs one may also restrict the set of possible offers in order to ensure uniqueness of the equilibrium, see *Chatterjee / Samuelson* (1988).

[73] *Cho / Kreps* (1987).

[74] *Cho / Kreps* (1987) show that the intuitive criterion leads to a unique sequential equilibrium in signalling games of *Spence's* (1974) type.

Grossmann / Perry's[75] 'perfect sequential equilibrium' imposes stronger restrictions on beliefs than the intuitive criterion. According to this concept, the buyer should ask himself in whose interest it is to propose $\hat{p}$ rather than p^* if he observes $\hat{p}$. The buyer's beliefs should then be 'self-fulfilling' in the sense that moving to $\hat{p}$ is indeed advantageous for the seller if and only if his type belongs to the support of the buyer's beliefs conditioned upon $\hat{p}$. In the above example, the perfect sequential equilibrium eliminates all sequential equilibria which involve a price $p^* < \mu q_h + (1 - \mu) q_l$. Indeed, as long as $p^* < \mu q_h + (1 - \mu) q_l$ would be in the interest of either type of the seller to sell the object at the price $\hat{p} = \mu q_h + (1 - \mu) q_l$.When the buyer is also led to believe that $\hat{p}$ reveals no information about the seller's type, he accepts $\hat{p}$. While the perfect sequential equilibrium generates a unique outcome in the above example, *Grossmann / Perry*[76] find that such an equilibrium may fail to exist for certain parameter constellations of their model. It is thus not always clear which restrictions are appropriate. Criteria that are useful for certain games may turn out to be too weak or too strong for others.

Summary

Non-cooperative bargaining theory has led to new insights not only in bilateral monopoly situations. It has also provided new tools for the analysis of imperfectly competitive markets. Bargaining games may be used to study the formation of prices in models of decentralized exchange. Of particular interest is the relationship between the market equilibria of such models and the Walrasian competitive outcome. In this area the bargaining approach has been helpful to develop a better understanding of the prerequisites of perfect competition. So far only a few models have imbedded bargaining under asymmetric information in a market context. The main reason for this seems to be that the non-cooperative bargaining approach still faces considerable conceptual difficulties in this area.

Zusammenfassung

Die nicht-kooperative Verhandlungstheorie beschränkt sich in ihren Anwendungsmöglichkeiten nicht auf die Analyse des bilateralen Monopols. Vielmehr bietet sie auch einen neuen Ansatz zur Analyse von Märkten mit unvollständigem Wettbewerb. Verhandlungsspiele können dazu verwandt werden, den Preisbildungsprozeß in Modellen dezentralen Tausches zu beschreiben. Von besonderem Interesse ist dabei die Beziehung zwischen den Marktgleichgewichten solcher Modelle und dem Walrasianischen Wettbewerbsgleichgewicht. In diesem Bereich hat die nicht-kooperative Verhandlungstheorie zu einem besseren Verständnis der Voraussetzungen vollständigen Wettbewerbs geführt. Bisher gibt es nur eine geringe Zahl von Modellen, die Verhandlungen bei asymmetrischer Information in einem Marktkontext untersuchen. Die Ursache hierfür scheint in den konzeptionellen Schwierigkeiten eines solchen Ansatzes zu liegen.

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[75] *Grossmann / Perry* (1986a).

[76] *Grossmann / Perry* (1986b).

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