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Resale Markets and the Assignment of Property Rights

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The consumption of an indivisible good causes identity-dependent externalities to non-consumers. We analyse resale markets where the current owner designs the trading procedure, but cannot commit to future actions. We ask the following questions: (1) *Does the identity of the initial owner matter for the determination of the final consumer?* (2) *Is the outcome always efficient?* The major conclusion of our paper is that the irrelevance of the initial structure of property rights arises in resale processes even if there are transaction costs that hinder efficiency. This result complements the Coasian view where the irrelevance of the assignment of property rights is a consequence of efficiency.

1. INTRODUCTION

In two seminal papers Coase (1959, 1960) argued that in a zero-transaction costs world the allocation of property rights has no effect on efficiency, and that the *laissez-faire* always yields optimal outcomes irrespective of the assignment of property rights. He writes: "While the delimitation of rights is an essential prelude to transactions... the ultimate result (which maximizes the value of production) is independent of the legal decision" (Coase (1959)). It is important to note that Coase sees the independence property as a consequence of the efficiency property. His line of argument is as follows: The ultimate outcome must be Pareto-efficient. Otherwise anybody could propose a Pareto-improving outcome, which would be accepted. Moreover, if there are no income effects (agents' utilities are transferable), all Pareto-efficient outcomes maximize welfare, and are thus welfare-equivalent. The independence result follows.

We follow Coase by considering a situation with a few agents whose utilities are transferable. An indivisible good can be consumed by one of the agents. In addition to the benefit he enjoys from consumption, the consumer of the good imposes identity-dependent externalities on the other agents. As suggested in Jehiel, Moldovanu and Stacchetti (1996), this situation is common and covers diverse contexts such as the sale of patents, the sale of pollution rights, the sale of spectrum rights, changes in ownership in imperfectly competitive markets (*e.g.* privatizations, mergers, takeovers). In general, the externalities stand as a reduced form for the effects of the interaction between agents after the close of a particular transaction.

Jehiel and Moldovanu (1995) and Jehiel, Moldovanu and Stacchetti (1996) consider the sale of goods involving externalities in a framework without resales.

An important question that we wish to address here is whether resale markets that permit the sequential internalization of external effects can replace contracts including commitments to future actions as a vehicle towards achieving efficiency. In a context with externalities, we show below that contracts leading to efficient allocations may require a certain degree of commitment (*e.g.* to sell to a particular agent, or not to sell at all). Such commitments are not necessarily *credible*, and we wish to relax the possibility of exogenous commitment. While allowing for resale markets, we make the extreme assumption that commitments to future actions are not feasible.[1]

The role of commitments in strategic interactions is well recognized at least since Schelling (1960). Interestingly, Coase considered the problem faced by a durable good monopolist that cannot commit not to sell (or to sell only for a certain price) in the future. The inability to commit often prevents a trader from extracting much surplus from a transaction. This phenomenon, called the "Coase conjecture", has been the subject of an extensive literature.[2]

Another kind of transaction cost that we wish to consider is that induced by the constraint of bilaterality. Most of the observed transaction forms are bilateral, *i.e.* involve a transfer of goods and money between two parties. When externalities are present, achieving an efficient allocation may require, however, a multilateral contract. Such multilateral agreements are natural and often observed in frameworks with externalities. For example, Guinness and Grand Metropolitan, two merging British drinks and food firms, agreed to pay £250 million to LVMH, a French drinks and luxury goods company with a stake in Guinness (see *The Economist*, October 18th, 1997). LVMH's chairman, Bernard Arnault, strongly opposed the merger, and delayed the deal for 5 months. He claimed that LVMH's share in the merged company would generate less revenue than before. Arnault finally accepted the deal, but only after getting the hefty side-payment.

A question of interest is whether a series of bilateral transactions achieved through repeated resales (which allow a sequential internalization of externalities) can form a substitute for a multilateral contract.[3]

Within our setup, the main contribution of this paper is to answer the following questions:

(1) *Does the identity of the original property right owner matter for the determination of the final consumer?*
(2) *Is the final outcome always efficient?*

In an appropriate setting, the Coasian view is that a negative answer to the first question is a logical consequence of an affirmative answer to the second question. It is instructive to recall that Coase first expressed the views which are collectively known as "The Coase Theorem" in an article that advocated the use of auctions for allocating spectrum rights (Coase (1959)). This idea has only recently been implemented with, apparently, great success (see for example, McMillan (1994)). Previous to auctioning, spectrum has been allocated by lottery. At a first glance, lotteries seem incompatible with efficiency.[4] One may argue, however, that efficiency will nevertheless be achieved provided that resale

1. Without commitment and without a resale market, it is easily shown that the outcome may be inefficient. See Example 4.14 below.
2. See Coase (1972), and Gul *et al.* (1986) for a more recent treatment.
3. Gale (1986) addresses a related question in a general equilibrium framework without externalities. He analyses whether a sequence of bilateral tradings can replace a Walrasian auctioneer.
4. Of course, lotteries in which spectrum is allocated for free deprive the Government of a substantial source of revenue. It is estimated that during the 1980s cellular licenses worth $46 billion were given away.

markets are well functioning (*e.g.* resales are not constrained, delays do not occur,[5] *etc...*). Such an argument has been formulated by opponents to the sophisticated, centralized auction. It is an application of the idea that the initial allocation of property rights is ultimately immaterial in *laissez-faire*. For example, McMillan (1994) reports a "not atypical case" where an obscure partnership was awarded by lottery the license to run cellular telephones on Cape Cod. Not surprisingly, the license was promptly sold to Southwestern Bell for $41 million.

The paper is organized as follows. In Section 2 we describe the economic situation and the dynamic resale market. The resale market is modelled as a T-stage undiscounted game where the last stage T stands for the deadline. At the beginning of each stage t, $t < T$, the current owner of the good may *either* use the *trading procedure*, *or* he may keep the object till the next stage. At stage T the good may be consumed, and that consumption creates externalities on the other agents.

Possible interpretations of the deadline T include: (1) The good to be traded is a bond with maturity T; (2) The good to be traded is a control right starting at time T. Note that imposing a deadline is a simple way to create a changing environment. The deadline expresses a change in regime after some known time.

In Section 3 we define the trading procedures that may be used at each stage of the resale market, and the time structure that connects the various stages.

The stage trading procedures involve a change in the identity of the owner and side-payments from the acquirer and possibly the non-acquirers to the seller. In line with the *mechanism design* approach, we assume that the current owner can choose the trading procedure. That is she can make a proposal to a subset of agents of her choice. Given a class of feasible trading procedures, the owner will choose the one that maximizes her revenue (while taking into account the possibility of resales in the future).

Concerning the time structure, we follow the *dynamic bargaining* literature: we assume that if one of the approached agents refuses to participate in the mechanism organized by the owner, there is a delay (see Rubinstein's bargaining model), and the owner must optimize again. The ability to delay captures an essential feature of the LVMH–Guiness–Grand Metropolitan story reported above, and it is a crucial feature of all dynamic bargaining models following Rubinstein's contribution.

As a benchmark, we consider the class of mechanisms where the current owner can commit in advance to the allocation he is going to implement at future stages. In this framework we show that the outcome of the resale market is always efficient.

A major drawback within the above class of mechanisms is the fact that the seller's ability to extract revenue hinges on commitments to threats that are not credible. These threats are embodied by the allocations that the seller commits to implement at future stages. In Section 4 we restrict the class of feasible mechanisms to mechanisms that employ only credible threats. Each approached agent has the possibility to delay the transaction by not participating, but the set of approached agents need not consist of the whole society. Given the time friction, the inability to commit represents a transaction cost: without the possibility of resale, this transaction cost may induce inefficiencies, and the final outcome may depend on the identity of the initial owner. In Subsection 4.1 we look at resale markets where, at each stage, only bilateral mechanisms are feasible, *i.e.* the owner chooses the revenue-maximizing procedure among all bilateral mechanisms without commitment. The main result is that, for a long enough horizon, the outcome is always

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5. The fear of delays was an important reason for the decision to switch to an allocation system based on a well-designed auction mechanism.

independent of the identity of the initial owner, although the outcome need not be efficient. Bilaterality is a serious constraint in frameworks with externalities, and we next relax it by allowing for multilateral trades. In Subsection 4.2 we briefly consider resale markets where the current owner cannot choose the subset of agents to which he makes a proposal, *i.e.* he must address the whole society in order to trade. Even though such a unanimity requirement is not realistic in most applications,[6] we find it of interest to observe that the outcome is then always efficient. We illustrate how the constraint of unanimity reduces the seller's ability to extract surplus and how, without this constraint, sellers may wish to exclude various agents from proposed multilateral trades.

In Subsection 4.3 we study the resale market where, at each stage, the current owner may use any multilateral trading mechanism which is based only on credible threats. Here the owner need only satisfy the participation constraints of an (optimally) chosen subset of agents in order to trade with them. Non-approached agents do not have the option to delay agreement. The main result is that, for long enough horizons, the outcome is always independent of the identity of the initial owner. Although efficiency is always obtained for cases with no more than three agents, this need not be the case if there are at least four agents. We observe that the resulting outcome in the multilateral case need not coincide with its counterpart in the bilateral case. Therefore, a sequence of bilateral trades cannot always replace a multilateral agreement.

To sum up, the major conclusion of our paper is that the irrelevance of the initial structure of property rights arises in resale processes even if there are transaction costs that hinder efficiency. This result complements the Coasian argument that views the irrelevance of the assignment of property rights solely as a consequence of efficiency in a zero transaction costs world.

Several concluding comments are gathered in Section 5.

2. THE DYNAMIC RESALE MARKET

The market we consider consists of a set N of n agents, $A_1, A_2, \ldots, A_n$, and an indivisible good. The good has known values to each agent, and the values are contingent on the identity of the consumer. If A_i is the consumer, he derives payoff $\pi_i > 0$, and agent A_j ($j \neq i$) derives payoff $-\alpha_{ij}$.[7] In other words, we consider identity-dependent externalities between the agents.

The good can be consumed at a given period T, and it can be sold and resold before this period. The resale market is modelled as a T-stage game where stage T stands for the deadline. At the beginning of each stage t, $1 \leq t < T$, the current owner of the good may either *trade*, or he may *wait* for one period. A trade at period t determines the owner at period $t+1$, and a vector of monetary transfers among agents. In the next section we detail the considered trading procedures. At the final stage T, there is no further sale, and the current owner can only consume the good with the effects on payoffs as described above. We assume that there is no discounting during the resale phase. Hence, besides possible side-payments during trading, the final payoffs to the agents depend only on the identity of the consumer of the good. The owner of the good at stage 1 is called the *initial*

6. It is not very realistic because (1) it gives too much power to agents who may not be concerned with the trade and (2) the authority in charge of implementing the unanimity requirement may not be aware of who is really concerned with the trade.

7. We adopt this convention of sign because in competitive interactions externalities are, in general, negative so that $\alpha_{ij} > 0$. However, our analysis and results are valid whether externalities are positive or negative, and we make no assumption on the sign of these.

owner.[8] It should be clear that, for a given stage trading procedure, we obtain for each initial owner a different resale game.

We focus our attention on *Subgame Perfect Nash Equilibria* (SPNE) of the various games. Thus, at each stage, agents take into account the consequences of their actions for the future. In particular, they have to consider the channel of future resales.

Definition 2.1. The outcome of the resale process is said to be efficient if, in equilibrium, the consumer is necessarily agent $A_{\hat{\imath}}$ such that $\hat{\imath} \in \text{ArgMax}_i(\pi_i - \sum_{j \neq i} \alpha_{ij})$. The outcome of the resale process is said to be independent of the identity of the initial owner if, no matter who the initial owner was (*i.e.* in all possible resale games resulting from a given stage trade procedure), in equilibrium the good is consumed by the same agent.

If the outcome is always efficient, then it is necessarily independent of the identity of the initial owner. (This is the Coasian argument discussed in the Introduction.)

We assume that valuations and externalities are generic in the following sense: Consider any two sets of coefficients $\{\varepsilon_i\}_{i \in \{1,...,n\}}$, and $\{\varepsilon_{ij}\}_{i,j \in \{1,...,n\}, i \neq j}$ such that not all coefficients are null, and such that $\forall i, \varepsilon_i \in \{-1, 0, 1\}$, and $\forall i, j, i \neq j, \varepsilon_{ij} \in \{-1, 0, 1\}$. Then it must hold that

$$\sum_i \varepsilon_i \pi_i + \sum_i \sum_j \varepsilon_{ij} \alpha_{ij} \neq 0. \tag{2.1}$$

The genericity assumption ensures that, for each set of parameters and for each horizon T, either there exists a unique SPNE, or all SPNE are payoff-equivalent. It also ensures that all efficient outcomes are associated with the consumption of a unique agent. The above assumption requires that a finite set of equations is not satisfied. The set of excluded parameters has Lebesgue measure zero. Finally, note that the genericity assumption is sufficient for all our results below, but not necessary. All our results have analogues for non-generic settings,[9] but in those settings one must keep track of certain symmetries.

3. TIME FRICTIONS AND COMMITMENT

The static mechanism design paradigm is usually modelled as a three-step game (see for example, Fudenberg and Tirole (1991)): In step 1, the principal proposes a mechanism (*i.e.* a game form in which agents send costless signals, and in which, based on the signals, an allocation is implemented). In step 2, the agents accept or refuse to participate in the mechanism. In step 3, the agents who agreed to participate play according to the rules specified in the chosen mechanism, and an allocation is implemented accordingly. In a complete information framework the principal (*i.e.* the current owner of the good) can implement any feasible allocation subject to participation constraints, and step 3 in the mechanism design approach is trivial. In a "direct revelation approach" the only signals agents need to send concern their participation decisions.

The dynamic bargaining literature (see Osborn and Rubinstein (1990)) considers repeated interactions between two bargaining parties. At each step, one party (the "proposer") offers a way to split the surplus. The other party (the "responder") may either accept or reject the offer. Accepted offers are implemented, and the game proceeds to the

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8. The initial owner may have been determined by history, or he may have been selected at random, or he may have been selected through a mechanism not described here.

9. For example, all our illustrations below use non-generic parameters in order to simplify calculations. Nevertheless, our results hold unchanged also for those non-generic frameworks.

next stage after a rejected offer. From the point of view of mechanism design, the proposer plays the role of the principal, and the mechanisms at each given period specify a surplus division that applies only for that period. If the responder rejects an offer—this can be interpreted as the responder's refusal to participate in the mechanism—there is a time friction (some time elapses), and the game proceeds to the next stage.

We take from the bargaining literature the time friction feature. We take from the mechanism design literature the feature that the current owner is free to choose a mechanism that maximizes her expected payoff.

Our primary interest is the class of mechanisms in which only actions to be taken in the current stage are involved:

Definition 3.1. A mechanism without commitment for A_i at stage t is given by $m_i^t = (S_i^t, f_i^t, g_i^t)$ such that:

- $S_i^t \subseteq N \setminus \{A_i\}$;
- f_i^t is an agent in $S_i^t \cup \{A_i\}$;
- g_i^t is a vector of payments in $\Re^{|S_i^t|}$, where $|S_i^t|$ is the cardinality of S_i^t.

We denote by M_i^{nc} the set of all mechanisms without commitment for agent A_i.

The interpretation is as follows: The current owner A_i chooses a set of agents S_i^t to whom he wishes to propose a mechanism. The agents in S_i^t simultaneously decide whether they want to participate or not.[10] If all agents in S_i^t participate, then in stage t an allocation is implemented such that the good is transferred to $f_i^t \in S_i^t \cup \{A_i\}$ (it stays with the current owner if $f_i^t = A_i$), and the members of S_i^t make payments to the A_i according to the vector g_i^t (a negative payment means that the owner pays a compensation). We denote by g_{ij}^t the payment from agent $A_j \in S_i^t$ to the owner A_i according to g_i^t.

If at least one agent in S_i^t refuses to participate, the game proceeds to stage $t+1$ without the good changing hands and without side payments. In other words, there is a time friction in case at least one addressed agent refuses to participate.

The above definition implicitly assumes that the good cannot be dumped upon an agent who does not participate, and that no payments can be obtained from agents who do not participate.[11]

We want first to establish results for the case where agents can employ mechanisms that allow for commitments to actions in future stages (which would be the natural assumption in the static mechanism design literature).

Definition 3.2. A mechanism with commitment for A_i at stage t is given by $m_i^t = (S_i^t, f_i^{t'}, g_i^{t'})_{t' \geq t}$ where:

- $S_i^t \subseteq N \setminus \{A_i\}$ is the set of addressed agents;
- For t', $t \leq t' < T$, $f_i^{t'}$ is a function that associates to each subset $R \subseteq S_i^t$ an agent in $R \cup \{A_i\}$[12];

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10. We restrict attention to equilibria which are robust to trembling. (We could equivalently consider the SPNE of the corresponding sequential game where each agent is asked, in turn, whether he wishes to participate.) This restriction allows us to rule out equilibria where everybody objects because if another agent objects all announcements are equivalent.

11. In principle, the owner may compensate non-participating agents, but, since she is interested in revenue maximization, this never occurs.

12. Additional consistency requirements on the functions $f_i^{t'}$ are needed. For the sake of brevity, we omit these requirements here.

- For $t', t \leq t' < T$, $g_i^{t'}$ is a function that associates to each subset $R \subseteq S_i^t$ a vector of payments $g_i^{t'}(R) \in \Re^{|R|}$, where $|R|$ is the cardinality of the subset R;
- For $R \neq S_i^t, f_i^t(R) = A_i$, and $g_i^t(R) = 0^{|R|}$.

We denote by M_i the set of all possible mechanisms for agent A_i.

A set $R \subseteq S_i^t$ represents the subset of approached agents who accepted to participate in the proposed mechanism; $f_i^{t'}(R)$ is the agent to whom the object is transferred at stage t' when the subset R participates in the mechanism; similarly $g_i^{t'}(R)$ is the corresponding transfer at stage t. If at least one approached agent refuses to participate, i.e. $R \neq S_i^t$, there is a delay, and therefore there is no trade at stage t. Compared to the definition of mechanisms without commitment, the difference lies in the fact that actions at future stages $t' > t$ may be included in a mechanism with commitment.[13]

Proposition 3.4 below shows that efficiency is always achieved if agents can employ mechanisms with commitments. A simple illustration is given in the example below.

Example 3.3.   There are three agents, $A_i, i = 1, 2, 3$. Payoffs are given by: $\pi_1 = \pi_2 = \pi_3 = 5$, $\alpha_{21} = \alpha_{31} = 100$, $\alpha_{23} = 10$, $\alpha_{32} = 10$, $\alpha_{12} = \alpha_{13} = 0$.

The efficient consumer is A_1. Assume the initial owner A_i is free to choose any mechanism with commitment $m_i \in M_i$. Consider stage $t = T - 2$. If A_1 is the owner at that stage, then a revenue maximizing procedure is as follows: A_1 addresses the other two agents and proposes the following mechanism: If both A_2 and A_3 participate then A_1 keeps the object till T (hence he consumes at stage T), and asks for payments of 10 from both A_2 and A_3. If A_2 refuses to participate, then A_1 transfers the good to A_3 for free at $t = T - 1$. If A_3 refuses to participate then A_1 transfers the good to A_2 for free at $t = T - 1$. If both A_2 and A_3 refuse to participate, then A_1 keeps the object till stage T and no payments are made.[14] Given this mechanism, both A_2 and A_3 choose to participate.[15]

Assume now that A_2 owns the object at stage $T - 2$. A revenue maximizing procedure is as follows: The good is transferred to A_1 for a payment of 105, and A_3 is required to pay 10. If either A_1 or A_3 refuses to participate, then A_2 keeps the good, and no payments are made. Given this mechanism, both A_1 and A_3 choose to participate. The mechanism for A_3 is analogous. It follows that the outcome of the resale game for any $T \geq 3$ is always efficient, since A_1 always consumes the good at stage T.

Proposition 3.4.   *Let $T \geq 3$, and assume that the initial owner A_i can choose a mechanism with commitment $m_i \in M_i$. Then the final outcome is always efficient, irrespective of the identity of the initial owner.*

Proof.   The proof is an adaptation to the present model with a time friction of Proposition 1 in Jehiel, Moldovanu and Stacchetti (1996). From that proposition, a revenue maximizing mechanism $\tilde{m}_i^1 = (\tilde{S}_i^1, \tilde{f}_i^t, \tilde{g}_i^t)_{t \geq 1}$ has the following properties: (1)

$\tilde{S}_i^1 = N \backslash \{A_i\}$. (2) All members of $N \backslash \{A_i\}$ choose to participate. (3) $\tilde{f}_i^{T-1}(\tilde{S}_i^1)$ is the efficient consumer. $\parallel$

Note that classical mechanisms such as first-price auctions, second-price auctions, *etc* . . . are mechanisms with commitment. In order to implement the outcome of a standard auction, the rules of the direct mechanism are such that in case an agent chooses not to participate, the owner commits to sell to another. Also, if the auction has a reserve price, then the owner commits not to sell in some cases even if all agents participate. In the presence of externalities classical auction mechanisms are, in general, neither efficient nor revenue-maximizing.

4. TRADE WITHOUT COMMITMENT

Example 3.3 illustrates a serious drawback of trading mechanisms with commitment: For example, A_1s ability to extract payments when he is the stage $T-2$ owner crucially depends on A_1s commitment to sell the good for free at stage $T-1$ if one of the other agents refuses to participate. Clearly, given the large negative externality imposed on A_1 in case of a sale, this threat is not credible. In this secion we focus on mechanisms that do not suffer from this drawback, and we thus restrict attention to mechanisms without commitment as defined above.

As we shall see below, in the framework without commitment, a crucial part in the seller's revenue maximization problem is the choice of the set of agents to whom a mechanism is proposed, *i.e.*, the choice of S_i^t.[16] We first look at two cases where this choice is either simple or trivial: In Subsection 4.1 we study bilateral mechanisms, where the owner at stage $t < T$ is constrained to address a single other agent; In Subsection 4.2 we study unanimous mechanisms, where the owner at stage $t < T$ needs the consent of *all* other agents for a trade. Finally, in Subsection 4.3 we study the unconstrained revenue maximizing mechanism without commitment.

4.1. *Bilateral trading*

We start the analysis with bilateral trading procedures because these are the simplest and most common forms of sales. Moreover, the comparison with multilateral mechanisms without commitment provides some insight about the effect of the additional constraint of bilaterality.

Definition 4.1.   A bilateral mechanism without commitment for A_i is a mechanism without commitment $m_i^t = (S_i^t, f_i^t, g_i^t)$ such that $|S_i^t| = 1$. We denote by M_i^{bil} the set of all bilateral mechanisms without commitment for agent A_i.

We now describe the form taken by the revenue-maximizing mechanism in this framework. Let $X_j^i(t+1)$ be the payoff to agent A_j when agent A_i owns the good at stage $t+1$, and assume that agent A_i owns the good at stage t. If agent A_i decides to keep the object, then he can extract no money from agent A_j, $j \neq i$, since otherwise A_j would refuse the proposal. Hence if agent A_i keeps the object at stage t he gets $X_i^i(t+1)$. If agent A_i decides to sell the object to agent A_j, $j \neq i$, then agent A_j must be willing to participate in the

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16. Recall that S_i^t always contains all potential agents in the revenue maximizing mechanism with full commitment.

mechanism organized by A_i. Moreover, A_j is ready to pay at most $X^j_j(t+1) - X^i_j(t+1)$, since at a higher price agent A_j could profitably decide that he does not participate in A_is mechanism. Thus, if A_i decides to sell to A_j, he will choose $m^t_i \in M^{bil}_i$ such that $S^t_i = \{A_j\}$, $f^t_i = \{A_j\}$ and $g^t_{ij} = X^j_j(t+1) - X^i_j(t+1)$. Agent A_i thus obtains $X^i_i(t+1) + X^j_j(t+1) - X^i_j(t+1)$ by selling to A_j. Revenue maximization means that A_i will sell to A_k such that $k = \text{Argmax}_j X^j_i(t+1) + X^j_j(t+1) - X^i_j(t+1)$ if $X^k_i(t+1) + X^k_k(t+1) - X^i_k(t+1)$ exceeds $X^i_i(t+1)$, and will keep the object otherwise.

Note that the above described mechanism is just a *take-it-or-leave-it* bargaining procedure where the current owner is free to choose the agent to whom he wishes to sell. If there were no externalities (*i.e.* $\alpha_{ij} = 0$, $\forall i, j, i \neq j$) any owner would choose to make a take-it-or-leave-it offer to the efficient consumer $\hat{i} = \text{argmax}_i \pi_i$ at a price of π_i, and $A_{\hat{i}}$ would always consume. Without externalities, this procedure (which is bilateral and without commitment) is the overall revenue maximizing procedure (*i.e.* in the class of general feasible mechanisms). In our framework, the determination of the buyer to whom the offer is addressed, and of the asked price is slightly more complex.

Lemma 4.2. *Assume that the parameters values are generic and that at all stages $t, t < T$, an owner A_i can choose any mechanism $m^t_i \in M^{bil}_i$. Let Γ^t_i be the subgame starting at stage t with A_i being the current owner. Then, in all SPNE of Γ^t_i the good is consumed by the same consumer, denoted by $FC(A_i, t, T)$. Moreover, for any agent A_j, all SPNE of Γ^t_i yield the same payoff to A_j, denoted by $X^i_j(t)$. It holds that*

(i) $\forall t, \forall i, j, j \neq i, \exists k$,   s.t. $X^i_j(t) = -\alpha_{kj}$,

(ii) $\forall t, \exists \varepsilon_{jk} \in \{-1, 0, 1\}$ s.t. $X^i_i(t) = \pi_{i*} + \sum_j \sum_k \varepsilon_{jk} \alpha_{jk}$,

where $A_{i*} = FC(A_i, t, T)$.

Proof. See Appendix. ||

Proposition 4.3. *Assume that at all stages $t, t < T$, an owner A_i can choose any mechanism $m^t_i \in M^{bil}_i$. Assume that the parameter set takes generic values. Then, if T is large enough, the identity of the final consumer (and thus the equilibrium total welfare) is independent of the identity of the inital owner. That is,*

$$\exists T^* \quad \text{such that } \forall T, T' > T^*, \forall i, j, \quad FC(A_i, 1, T) = FC(A_j, 1, T').$$

Proof. See Appendix. ||

The strategy of the proof is as follows. We first observe that, in equilibrium, a finite, fixed number of stages is sufficient to exhaust all gains from trade. Moreover, at a stage where no profitable transaction exists between agents A_i and A_j, the sum of equilibrium payoffs for A_i and A_j when A_i is the owner must be the same as the sum when A_j is the owner. (Otherwise, either A_i or A_j would be willing to transact.) From Lemma 4.3, we know that both these sums are combinations of valuations and externalities with coefficients that belong to the set $\{-1, 0, 1\}$. This allows us to conclude that, for generic parameters, the two sums of payoffs must be associated with the consumption of the same agent. Hence, the final consumer must be the same, irrespective of whether A_i or A_j was the initial owner.

To get some idea of how the resale market as well as the independence result work, consider the following example.

Example 4.4.   There are three agents, A_i, $i = 1, 2, 3$. Payoffs are given by: $\pi_1 = \pi_2 = \pi_3 = 5$, $\alpha_{12} = 2$, $\alpha_{23} = 3$, $\alpha_{31} = 3$, and all other externality terms are null. The total number of stages is $T = 4$.
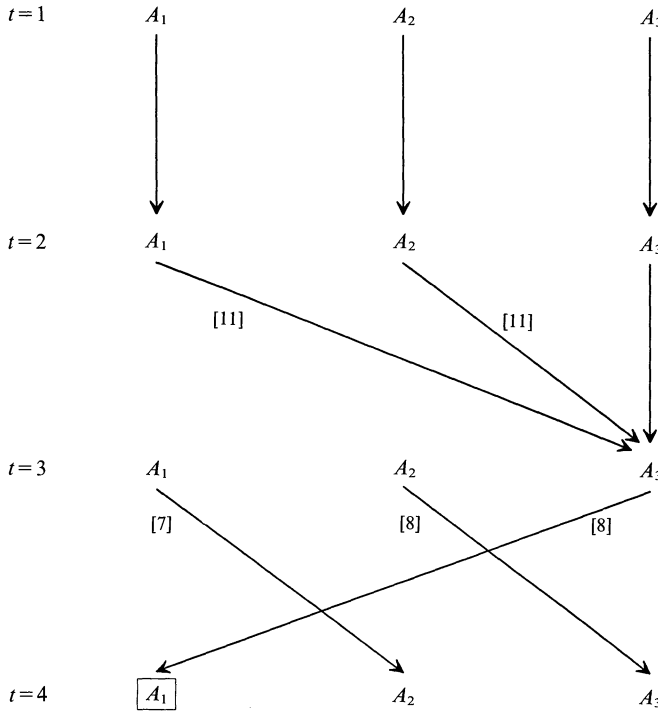

FIGURE 1

Numbers in brackets are prices

The equilibrium process of sales is described by the following flow diagram.

At stage $t = T = 4$, if agent A_i owns the good, he consumes it (since $\pi_i > 0$).

At stage $t = 3$, if agent A_1 owns the good, he sells it to agent A_2 at price $\pi_2 + \alpha_{12} = 7$. He then obtains: $\pi_2 + \alpha_{12} - \alpha_{21} = 7$, which is more than what he could get by: (1) not selling ($\pi_1 = 5$), or (2) by selling to agent A_3 ($\pi_3 + \alpha_{13} - \alpha_{31} = 2$). The vector of equilibrium payoffs to agents A_1, A_2, A_3 is $(7, -2, -3)$. Similarly, if agent A_2 owns the good he sells it to agent A_3 at price 8, and the payoffs are $(-3, 8, -3)$. If agent A_3 is the owner, he sells to A_1 at price 8, and the payoffs are $(-3, -2, 8)$.

At stage $t = 2$, when agent A_1 is the owner he sells to agent A_3 at price 11. The payoff to A_1 is then $11 - 3 = 8$ (since -3 is A_1s payoff when A_3 is the owner at $t = 3$). This is more than what A_1 could have got by selling to agent A_2, i.e. $8 + 2 - 3 = 7$, or by waiting, i.e. 7. The resulting payoff vector is $(8, -2, 3)$. Similarly, A_2 sells to A_3 at price 11, and the resulting payoffs are $(-3, 9, -3)$. Finally, A_3 chooses to wait and the resulting payoffs are $(-3, -2, 8)$.

At stage $t = 1$, whoever owns the good finds it optimal to keep it.

Observe that, irrespective of who owns the good at stage $t = 1$, the final consumer is invariably A_1. The same result applies for all $T \geq 4$, since equilibrium behaviour requires

then that all initial owners wait till stage $T-3$. Moreover, when A_1 is the initial owner, the good goes first to A_3 and then goes back to A_1. Hence the SPNE displays cycles in terms of ownership. Such cycles may seem, at first glance, paradoxical, and one may wonder why agent A_1 rationally sells to A_3 if he knows that he will eventually buy the good back. He does so because agent A_3 is so afraid that agent A_1 sells to agent A_2 at a later stage (α_{23} is large) that A_3 is ready to pay a lot today. As a result, A_1 finds is strictly more advantageous to sell to A_3 rather than keep the good till the deadline.

If no resales were permitted, the outcome would be that of stage $t=3$. That is, if agent A_1 is the initial owner, agent A_2 gets the good. If agent A_2 is the initial owner, agent A_3 gets the good. If A_3 is the initial owner, agent A_1 gets the good. Thus, if resales were not permitted the identity of the initial owner would matter for the determination of the final owner, and welfare would be affected accordingly.

Finally, observe that agent A_1 is the welfare-maximizing consumer. Hence, in Example 4.4 bilateral trade with resales leads to an efficient outcome. In particular, it is superior to the institution where resales are not permitted, in which case the final outcome is efficient only if A_3 is the initial owner.

Example 4.4 illustrates the independence property of Proposition 4.3. It also suggests that the final outcome may be efficient. The efficiency result always holds when there are only two agents, but, as shown in Example 4.5, may fail with three or more agents.

Example 4.5.   There are three agents, A_i, $i=1,2,3$. Payoffs are given by: $\pi_1 = \pi_2 = \pi_3 = 10$, $\alpha_{12} = 5$, $\alpha_{21} = 6$, $\alpha_{31} = 1$, and all other externality terms are null. The total number of stages is $T=4$.

The sale process is given by the following flow diagram:

The final consumer is invariably A_1, which leads to a suboptimal allocation, since the optimum is achieved when A_3 is the final consumer.

We now briefly explain the role of the various constraints that lead to inefficiency in Example 4.5. Assume that agent A_3 (the welfare maximizing agent) owns the good at stage 3. The optimal, full commitment, contract for A_3 (which, by Proposition 3.3, necessarily leads to an efficient outcome) has the following form: Agent A_3 commits not to sell the good in exchange for a payment of 5 from A_2 and a payment of 6 from A_1. If A_1 (resp. A_2) refuses to pay, agent A_3 commits to sell to agent A_2 (resp. A_1). Our noncommitment paradigm does not allow for such contracts. (If A_3 does not sell the good at stage 3, then he is the owner of the good at stage 4, the deadline, and therefore agent A_3 is unable to make his threats to the other two agents credible.) Moreover, the bilateral trading constraint does not permit multilateral agreements that involve all three agents, even if those agreements are based on credible threats for the future. In fact, we show below (see Subsection 4.3) that, when multilateral agreements without commitment are feasible, the introduction of resale markets is sufficient to restore efficiency in situations with no more than 3 agents.

So far we have shown that the identity of the final consumer is the same irrespective of the initial owner, and that the final consumer need not be the welfare-maximizing agent. It is of interest to identify the final consumer as a function of valuations and externalities. The general identification is difficult, but, to get some insight, we now briefly consider two special cases.

When all externality terms are equal, it is readily verified that the outcome of the resale game is efficient (it is the same insight as that when there are no externalities). We
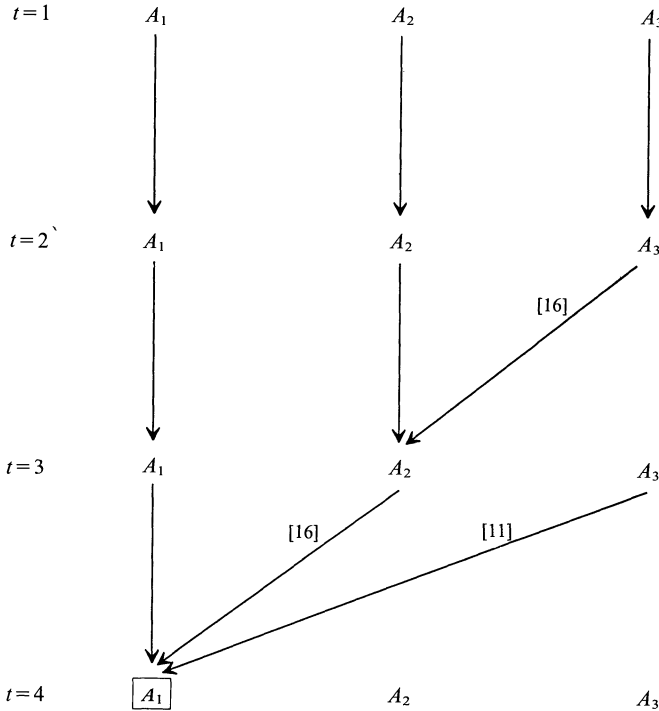
FIGURE 2

Numbers in brackets are prices

now prove a stronger version of this result (Proposition 4.6), and exhibit another class of parameter sets for which the final consumer can be explicitly identified (Proposition 4.7).

Proposition 4.6.   *Assume that externalities depend only on the identity of the sufferer, i.e.* $\alpha_{ij} = \alpha_{kj} = \alpha_j$ *for all* $i, k \neq j$. *Let* $T \geq 2$, *and assume that at all stages* t, $t < T$, *an owner* A_i *can choose any mechanism* $m_i^t \in M_i^{bil}$. *Then the outcome of the resale game is always efficient.*[17]

Proof.   The efficient consumer $A_{\hat{i}}$ satisfies $\hat{i} \in \text{argmax}_j (\pi_j - \sum_{k \neq j} \alpha_k)$. Consider period $T - 1$, and assume that the owner at that period is A_i. The maximum price that any agent $A_j, j \neq i$ is willing to pay is given by $\pi_j + \alpha_j$. Owner A_i can obtain a maximum payoff of

$$\max (\pi_i, \max_{j \neq i}(\pi_j + \alpha_j - \alpha_i)) = \max_j (\pi_j + \alpha_j) - \alpha_i$$
$$= \max_j (\pi_j + \alpha_j - \sum_k \alpha_k) - \alpha_i + \sum_k \alpha_k$$
$$= \max_j (\pi_j - \sum_{k \neq j} \alpha_k) - \alpha_i + \sum_k \alpha_k,$$

by selling to the efficient consumer. Hence, no matter what happens before stage $T - 1$, the efficient consumer will consume at stage T. ||

17. This is not a generic setting, but, as we show in the proof, the independence results holds as well. To be consistent with the genericity assumption made throughout the paper, we could consider generic parameters that lie in a sufficiently small neighbourhood of the parameters considered here. The proof trivially extends to that case as well. The same comment applies to Propositions 4.7 and 4.12(iii) below, and will not be repeated there.

Proposition 4.7. *Assume that externalities depend only on the identity of the consumer i.e. $\alpha_{ij} = \alpha_{ik} = \alpha^j$ for all $j, k \neq i$. Let $T \geq 2$, and assume that at all stages $t, t < T$, an owner A_i can choose any mechanism $m_i^t \in M_i^{bil}$. Then, the final consumer is always $A_{i'}$ where $i' =$ argmax$_i (\pi_i - \alpha^i)$.*

Proof. Consider stage $T - 1$, and let A_i be the owner at that stage. The maximum price that any agent $A_j, j \neq i$ is willing to pay is given by $\pi_j + \alpha^i$. Hence A_i can obtain a maximum payoff of $\max(\pi_i, \max_{j \neq i}(\pi_j + \alpha^i - \alpha^j)) = \max_j(\pi_j - \alpha^j) + \alpha^i$ by selling to $A_{i'}$. $\|$

When there are n agents the above result shows that the outcome is efficient only if $\pi_{i'} - n\alpha^{i'}$ is maximal among all $\pi_i - n\alpha^i$. This need not be the case in general, but if all α^i are equal, *i.e.* $\alpha^i = \alpha$, the final outcome is always efficient (since Proposition 4.6 applies).

4.2. *Unanimous trading*

A simple form of multilateral trading without commitment is that where the owner of the good must address *all* agents in order to trade. Hence, the owner cannot maximize over the set of agents to whom he wishes to make a proposal.

Definition 4.8. A unanimous mechanism without commitment for A_i is a mechanism without commitment $m_i^t = (S_i^t, f_i^t(\cdot), g_i^t(\cdot))$ such that $S_i = N \backslash \{A_i\}$. We denote by M_i^u the set of unanimous mechanisms without commitment.

Proposition 4.9. *Let $T \geq 2$, and assume that at all stages $t, t < T$, an owner A_i can choose any mechanism $m_i^t \in M_i^u$. Then the outcome of the resale process is always efficient (and hence independent of the identity of the initial owner).*

Proof. Let A_i be the owner at stage $T - 1$. Waiting one more stage yields π_i. Assume that A_i wants to sell to A_j. This trade needs the approval of all agents. Agent A_j is prepared to pay $\pi_j + \alpha_{ij}$ for the good, and causes an externality of $-\alpha_{ji}$ on A_i. Any other agent A_k, is prepared to pay $\alpha_{ik} - \alpha_{jk}$ for the good to be transferred to A_j (note that the "payment" may be negative, in which case A_k must be compensated for the transfer). Owner A_i obtains the highest possible payoff $\max(\pi_i, \max_j(\pi_j + \alpha_{ij} - \alpha_{ji} + \sum_{k \neq i,j}(\alpha_{ik} - \alpha_{jk})) = \max_j(\pi_j - \sum_{k \neq j} \alpha_{jk}) + \sum_{k \neq i} \alpha_{ik}$ by selling to the efficient consumer. Hence, no matter what happens before stage $T - 1$, the efficient consumer will consume at stage T. $\|$

Although institutions with the above feature do exist, they seem hardly compatible with the common sense of "property rights". Quite often such institutions are inefficient because there is a risk that trades are delayed by agents who are not actually harmed by the transaction.

4.3. *Revenue maximizing trading without commitment*

The analysis above shows that the requirement of unanimity imposes severe constraints on the seller, since she is sometimes obliged to compensate agents for her actions. We now wish to study the channel of sales and resales where each stage t owner can choose any mechanism without commitment. It will now be in the interest of the seller to sometimes exclude agents from a transaction.

Let us describe the form of the revenue-maximizing mechanisms. Let $X^i_j(t+1)$ be the payoff to agent A_j when agent A_i owns the good at stage $t+1$, and assume that agent A_i owns the good at stage t.

If agent A_i decides to keep the object, then he can extract no money from agent A_j, $j\neq i$, since otherwise A_j would refuse the proposal. Hence if agent A_i keeps the object at stage t he gets $X^i_i(t+1)$. If agent A_i decides to sell the object to agent A_j, $j\neq i$, then agent A_j must be willing to participate in the mechanism organized by A_i. Moreover, as in the take-it-or-leave-it institution, A_j is ready to pay at most $X^j_j(t+1) - X^i_j(t+1)$. Whether A_i will choose to exclude agent A_k or not from his mechanism depends on whether agent A_k prefers agent A_i or agent A_j having the good at stage $t+1$. If agent A_k prefers agent A_i having the good, then agent A_i will exclude A_k from the mechanism, since in case A_k were to be included, obtaining A_ks participation would require that A_i pays something to A_k. Symmetrically, if agent A_k prefers agent A_j having the good, then A_i will include A_k in his mechanism and ask for a side payment equal to the difference between what A_k gets in the two situations, i.e. $X^j_k(t+1) - X^i_k(t+1)$.

To summarize, if the owner A_i chooses to sell to A_j he will choose a mechanism m^t_i such that $S^t_i = \{A_j\} \cup \{A_k$ such that $X^j_k(t+1) - X^i_k(t+1) \geq 0\}$, $f^t_i = A_j$, and $g^t_{ik} = X^j_k(t+1) - X^i_k(t+1)$ for all $A_k \in S^t_i$ (including A_j). Thus, A_i overall obtains $X^i_i(t+1) + X^j_j(t+1) - X^i_j(t+1) + \sum_{k\neq i,j} \text{Max} (0, X^j_k(t+1) - X^i_k(t+1))$ by selling to A_j. Note that the main addition to the bilateral revenue maximizing procedure is that the seller is able to extract revenue also from non-acquirers.

In order to determine whether A_i will sell the good, and if yes to whom, it is convenient to define

$$W^j(t+1) = \sum_k X^j_k(t+1), \tag{4.1}$$

as the welfare associated with the ownership of agent A_j at stage $t+1$, and

$$\Delta^k_{ji}(t+1) = \text{Max} (X^j_k(t+1) - X^i_k(t+1), 0) - (X^j_k(t+1) - X^i_k(t+1))$$
$$= \text{Max} (X^i_k(t+1) - X^j_k(t+1), 0). \tag{4.2}$$

It is readily verified that A_i prefers to wait rather than sell to A_j if

$$X^i_i(t+1) \geq X^j_i(t+1) + X^j_j(t+1) - X^i_j(t+1) + \sum_{k\neq i,j} \text{Max} (0, X^j_k(t+1) - X^i_k(t+1)),$$

or, after simple manipulations, if

$$W^j(t+1) + \sum_{k\neq i,j} \Delta^k_{ji}(t+1) \leq W^i(t+1). \tag{4.3}$$

Similarly A_i prefers to sell to A_j rather than to $A_{j'}$ if

$$W^{j'}(t+1) + \sum_{k\neq i,j'} \Delta^k_{j'i}(t+1) < W^j(t+1) + \sum_{k\neq i,j} \Delta^k_{ji}(t+1). \tag{4.4}$$

Note that $\Delta^k_{ji}(t+1)$ is always non-negative. When A_i sells to A_j, he excludes A_k if $\Delta^k_{ji}(t+1) > 0$, and includes A_k in the mechanism if $\Delta^k_{ji}(t+1) = 0$. The conditions above allow us to find out the mechanism chosen by the owner A_i at stage t, given expected equilibrium payoffs $X^j_i(t+1)$.

Lemma 4.10. *Assume that the parameters values are generic, and that at all stages t, $t < T$, an owner A_i can choose any mechanism $m^t_i \in M^{nc}_i$. Let Γ^t_i be the subgame starting at stage t with A_i being the current owner. Then, in all SPNE of Γ^t_i the good is consumed by the same agent, denoted by $FC(A_i, t, T)$. Moreover, for any agent A_j, all SPNE of Γ^t_i yield*

the same payoff to A_j, denoted by $X_j^i(t)$. It holds that

    (i) $\forall t, \forall i, j \neq i, \exists k,$ s.t. $X_j^i(t) = -\alpha_{kj},$

    (ii) $\forall t, \exists \varepsilon_{jk} \in \{-1, 0, 1\}$ s.t. $X_i^i(t) = \pi_{i*} + \sum_j \sum_k \varepsilon_{jk} \alpha_{jk},$

where $A_{i*} = FC(A_i, t, T)$.

    Proof. See Appendix. ‖

    Proposition 4.11. *Assume that at all stages $t, t < T$, an owner A_i can choose any mechanism $m_i^t \in M_i^{nc}$. Assume that the parameter set takes generic values. Then, if T is large enough, the identity of the final consumer and thus the equilibrium total welfare is independent of the identity of the initial owner. That is,*

$$\exists T^* \text{ such that } \forall T, T' > T^*, \forall i, j, \quad FC(A_i, 1, T) = FC(A_j, 1, T').$$

    Proof. See Appendix. ‖

    The intuition for the proof is very similar to that for the proof of Proposition 4.3, and we omit it here. We now wish to analyse whether the final consumer (who is well defined because of the independence property) maximizes total welfare, *i.e.* whether the process is efficient.

    Proposition 4.12. *Assume that at all stages $t, t < T$, an owner A_i can choose a mechanism $m_i^t \in M_i^{nc}$. Assume that the parameter set takes generic values, and that T is large enough.*

    (i) *If $n \leq 3$, the outcome is always efficient.*
    (ii) *If $n > 3$, the outcome is not necessarily efficient.*
    (iii) *Assume that externalities depend only on the identity of the consumer i.e. $\alpha_{ij} = \alpha_{ik} = \alpha^i$ for all $j, k \neq i$. Then, the outcome is always efficient, irrespective of the number of agents.*

    Proof. The proof of (i) is relegated to the Appendix. The proof of (ii) is by means of Example 4.14 below. For the proof of (iii), let $i^* = \text{ArgMax}_i \, \alpha^i$. It is enough to show that when agent A_{i*} is the stage $t, t < T$, owner, the final consumer is the welfare-maximizing agent. Together with the independence property, this yields the wished for result. Consider stage $T - 1$. If A_{i*} sells to A_j he invites every other agent A_k to participate because A_k fears A_{i*} more than A_j. In other words, $\forall k, j, \Delta_{ji*}^k(T) = 0$. Conditions 4.3 and 4.4 allow us to conclude for stage $T - 1$. The argument for earlier stages is obtained by induction. ‖

    To illustrate Proposition 4.12(i) we revisit Example 4.5 which yielded inefficiency in the bilateral framework.

    Example 4.13. There are three agents, $A_i, i = 1, 2, 3$. Payoffs are given by: $\pi_1 = \pi_2 = \pi_3 = 10$, $\alpha_{12} = 5$, $\alpha_{21} = 6$, $\alpha_{31} = 1$, and all other externality terms are null.
    Note first that without resale possibilities the outcome is not necessarily efficient, even if agents can use any mechanism without commitment: When A_3 (the efficient consumer) is the initial owner he sells to A_2, and this agent consumes.

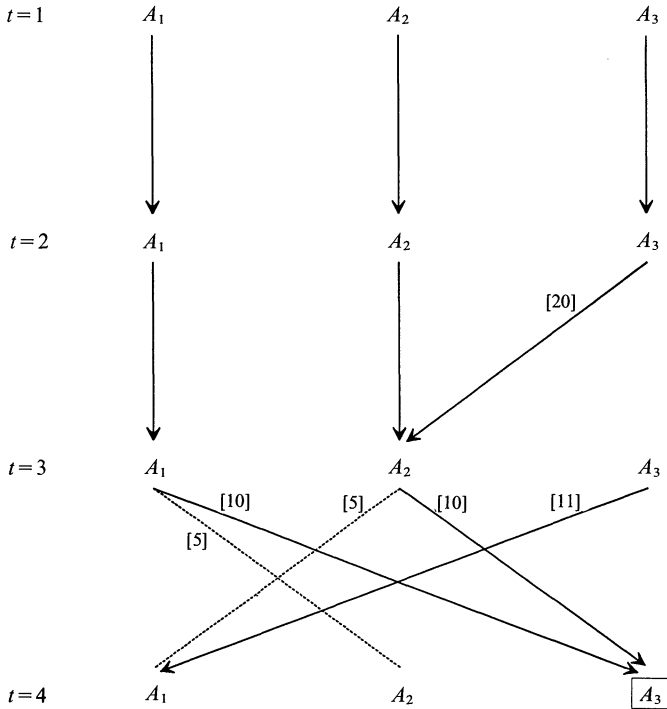When resales are possible, the sequence of equilibrium sales is described in the following flow diagram.

FIGURE 3

It invariably leads to A_3 (the welfare maximizing agent) consuming the good. The comparison of the flows in Figures 2 and 3 shows that at stage 3, A_2 sells to A_1 in the bilateral trading institution and to A_3 in the general noncommitment trading institution. The reason is that, in the general noncommitment trading institution, by selling to A_3, A_2 is also able to extract some payment from A_1 (because A_1 fears A_2 more than A_3), and that sale is more profitable.

The following example illustrates Proposition 4.12(ii).

Example 4.14.   Let $n = 4$, $T \geq 2$, $\pi_1 = 6.5$, $\pi_2 = 10$, $\pi_3 = 9$, $\pi_4 = 7$, $\alpha_{12} = 0$, $\alpha_{13} = 0$, $\alpha_{14} = 0$, $\alpha_{21} = 1$, $\alpha_{23} = 1$, $\alpha_{24} = 2$, $\alpha_{31} = 2$, $\alpha_{32} = 0$, $\alpha_{34} = 1$, $\alpha_{41} = 0$, $\alpha_{42} = 0$, $\alpha_{43} = 1$.

We show that no matter who is the owner at stage $T - 1$, the good is never sold to A_1 (nor does A_1 choose to wait at that stage). Since consumption by agent A_1 yields a higher welfare than the consumption by the other three agents, the final outcome cannot be efficient.

At stage $T - 1$ agent A_1 sells to A_2 (while excluding the other two agents). Agent A_2 sells to A_3 (while inviting agent A_4 and excluding agent A_1). Agent A_3 sells to A_2 (while inviting agent A_1 and excluding agent A_4). Agent A_4 sells to A_2 (while excluding the other two agents).

Propositions 4.11 and 4.12(ii) show together that the independence property may hold in resale markets even if the outcome is not efficient. Proposition 4.12(iii) shows that

the externality terms must be sufficiently heterogenous to get an inefficient outcome. Points (i) and (iii) of Proposition 4.12 show together that resale markets can sometimes restore efficiency, even if commitments are not possible. Recalling the inefficiencies obtained in the same contexts with bilateral mechanisms (see Example 4.5 and Proposition 4.7), it is important to note the crucial role played here by multilaterality. Finally, point (ii) shows that resale markets are not sufficient to restore efficiency, even if multilateral agreements are feasible. More precisely, the remaining source of inefficiency can be attributed to two elements: (1) the lack of commitment to future actions which forces the threats used by the agents to be credible, and (2) the possibility of exclusion (recall that unanimous mechanisms without commitment yield efficient outcomes).

5. CONCLUSION

In a framework with externalities, and where commitments to future actions are not available, we have shown that the outcome of resale markets need not be efficient, even though it is independent of the initial structure of property rights. This result has several policy implications: (1) Well-functioning resale markets may not be enough to achieve efficiency. (2) There may be no way to achieve efficiency, even if a sophisticated rule for the assignment of initial property rights is used. (3) Legal frameworks for multilateral trading negotiations may be desirable (and do not necessarily constitute a form of collusion).

It is interesting to recall that one of the main reasons for the creation of the FCC was that, prior to 1927, the courts held that the Secretary of Commerce (who granted licenses to use spectrum) was not authorized to deny licenses on the ground that they would cause interference, nor limit the licensees' power, frequency, or hours of operation. As a consequence, airwaves became filled with interfering signals, severely reducing the ability to make use of spectrum. The present FCC has the power to regulate the use of a licence after it has been awarded, but the Commission's Deputy Chief Economist (see Rosston and Steinberg (1997)) thinks that the Commission should:

(1) "avoid mandating that spectrum be used to provide specific services";
(2) "create mechanisms for voluntary changes in spectrum use, including where appropriate, procedures for new licensees and incumbents to negotiate compensated relocation of incumbents" and "also consider expanding spectrum users' flexibility to negotiate among themselves interference limitations that may differ from those specified in the rules";
(3) "continue to define the extent to which each spectrum user may expect freedom from interference ... Under some circumstances, this definition may consist of a determination that particular users enjoy little or no freedom from interference".

It seems to us that the above quotations point to a trading framework that is somewhat similar to the one studied in this paper: there are resale possibilities, multilateral agreements are encouraged, and the Commission does not force users to commit to certain future actions (such as not selling to someone who creates interferences).

We can relate our model to two strands of the literature. The noncommitment paradigm also appears in the dynamic mechanism design literature which identifies the *ratchet* effect in contexts where the principal is uninformed about the agent's type, and the principal's as well as the agent's type do not change over time (see Freixas *et al.* (1985), Laffont and Tirole (1988)). In contrast, our focus here has been on the dynamic change in ownership in a complete information setting.

Most of the bargaining literature (see Osborne and Rubinstein (1990)) considers models where only bilateral trades are feasible, and where resale markets are not available.[18] Groes and Tranaes (1995) study a model of bargaining with resale possibilities between a seller and two buyers with different valuations where trades are constrained to be bilateral. In the case of a durable good, they show how resales may correct the rather artificial inefficiency appearing in such a decentralized model of trading. Even with a non-durable good inefficiencies would disappear in their framework if multilateral trades were allowed. In contrast, our analysis shows that externalities may be a robust source of inefficiency when commitments to future actions are not feasible even if there are resale possibilities and multilateral trades are allowed.

We now briefly mention some results obtained when other departures from the zero-transaction costs paradigm are considered. First, when utilities are non-transferable, the independence property is no longer true, even though the final outcome may be Pareto-efficient. Second, as shown by Myerson and Satterthwaite (1983), the outcome of the bargaining between two asymmetrically informed parties is not, in general, *ex post* efficient. Hence asymmetric information induces inefficient bargaining.[19] Third, the incomplete contract literature shows that the structure of ownership has efficiency implications and derives the optimal structures of ownership (see Grossman and Hart (1986), and Hart and Moore (1990)), assuming contracts cannot be signed on unforeseen and unverifiable contingencies.

APPENDIX

Proof of Lemma 4.2

The proof is by induction on $T - t$. At stage T, the property is immediate given the payoffs described in Section 2 and the fact in equilibrium the period T owner finds it optimal to consume the good (given that $\pi_i > 0$ for all i).

Assume that Lemma 4.2 holds at all stages t', $t < t' \leq T$, and for every stage t' owner. We will show that it holds for the t stage game.

At stage t, the current owner A_i may either decide to wait for one more stage, which yields a payoff of $X_i^i(t + 1)$ for him and of $X_j^i(t + 1)$ for every agent A_j, $j \neq i$, or he may decide to sell to some agent A_j, $j \neq i$. In the latter case, agent A_j would refuse any offer such that his resulting payoff is less than $X_j^i(t + 1)$, since in case of non-acceptance, A_i has to keep the object for one more stage, and thus A_j can guarantee $X_j^i(t + 1)$. In equilibrium, agent A_i will optimally make a proposal such that agent A_j is kept at his minimum payoff. It follows that if agent A_i sells to A_j, A_i obtains $X_j^j(t + 1) + X_i^i(t + 1) - X_j^i(t + 1)$, agent A_j obtains $X_j^j(t + 1)$ and all other agents $A_{i'}$, $i' \neq i, j$ obtain $X_{i'}^j(t + 1)$ (since there are no side-payments from $A_{i'}$ who does not acquire the good).

If agent A_i strictly prefers one of the above alternatives, then there is a unique SPNE of Γ_i^t. Moreover, if agent A_i optimally decides to wait for one more period, then $X_j^i(t) = X_j^i(t + 1)$ for all j, and therefore $X_j^i(t)$, $j \neq i$, and $X_i^i(t)$ satisfy the properties (i) and (ii), respectively. If agent A_i optimally decides to sell to agent A_j, then $X_j^i(t) = X_j^i(t + 1)$ and $X_{i'}^i(t) = X_{i'}^j(t + 1)$ for all $i' \neq i, j$, and thus property (i) is satisfied. Regarding property (ii), note that the welfare term $W(t) = X_i^i(t) + \sum_{k \neq i} X_k^i(t)$ must be associated with the consumption of some agent A_{i*}, i.e. $W(t) = \pi_{i*} - \sum_{k \neq i*} \alpha_{i*k}$; given the form of $X_k^i(t)$ just shown, we conclude that $X_i^i(t)$ satisfies property (ii).

Consider now the case where A_i is indifferent between several alternatives. Assume that A_i is indifferent between selling to A_j or to A_k, where $j \neq k \neq i$. (The proof for the case where A_i is indifferent between waiting and selling is completely analogous.) It must be the case that $X_j^j(t + 1) + X_i^i(t + 1) - X_j^i(t + 1) = X_k^k(t + 1) + X_i^i(t + 1) - X_k^i(t + 1))$. By the genericity assumption, and by the assumed form of the terms $X_{i'}^{i'}(t + 1)$, we can conclude that the equilibrium final consumer in Γ_j^{t+1} is the same as that in Γ_k^{t+1}. But then the welfare terms $X_j^j(t + 1) + \sum_{i' \neq j} X_{i'}^j(t + 1)$ and $X_k^k(t + 1) + \sum_{i' \neq k} X_{i'}^k(t + 1))$ are the same. The genericity assumption,

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18. A notable exception is Gul (1989). However Gul does not derive inefficiency results.

19. For the dissolution of a partnership, Cramton *et al.* (1987) show that *ex-post* efficiency can be achieved if ownership is sufficiently diffused. Hence, the structure of ownership affects the efficiency of the final outcome.

the fact that $X_i^j(t+1) + X_i^j(t+1) - X_i^i(t+1) = X_k^k(t+1) + X_i^k(t+1) - X_i^i(t+1)$, and the form of $X_{i'}^{i'}(t+1)$, imply that $X_{i'}^j(t+1) = X_{i'}^k(t+1)$ for $i' \neq j, k$, and that $X_k^i(t+1) = X_k^i(t+1)$ and $X_j^i(t+1) = X_j^k(t+1)$). Hence, whatever optimal choice made by agent A_i, the ensuing equilibrium payoffs are the same for every agent, and they satisfy properties (i) and (ii). $\|$

Proof of Proposition 4.3

For any $T > \tau$ we define $Y_i^i(\tau)$ as the equilibrium payoff of A_i in the subgame starting at stage $T - \tau$ with current owner A_i (this is well defined by Lemma 4.2). With the notation of Lemma 4.2, we have $Y_i^i(\tau) = X_i^i(T - \tau)$. By Lemma 4.2(i) we know that $\forall \tau$, $Y_i^i(\tau)$ is of the form $\pi_h + \sum_j \sum_k \varepsilon_{jk} \alpha_{jk}$ where $h \in \{1, \ldots, n\}$ and $\forall j, k$, $\varepsilon_{jk} \in \{-1, 0, 1\}$. When $h \in \{1, \ldots, n\}$ and $\varepsilon_{jk} \in \{-1, 0, 1\}$ vary, the set of terms of the form $\pi_h + \sum_{j,k} \varepsilon_{jk} \alpha_{jk}$ is finite. Hence, for each $i, \mu_i = \max_{1 \leq \tau < \infty} Y_i^i(\tau)$ is well defined, and there exists a τ_i such that $\mu_i = Y_i^i(\tau_i)$.

We assume here that the game is long enough in the sense that $T \geq \max_i \tau_i$.

The function $t \to X_i^i(t)$ is non-increasing since, at stage t, an owner A_i can always choose to wait one more stage and obtain $X_i^i(t+1)$. This monotonicity yields $X_i^i(t) = X_i^i(t+1)$ for all $t < T - \tau_i$. Note that $X_i^i(t) = X_i^i(t+1)$ implies that agent A_i can optimally choose to wait at stage t. Let $t^* = \min_i (T - \tau_i)$. At any stage $t < t^*$, any owner A_i finds it optimal to wait. Hence, $\forall i, j, X_j^i(t) = X_j^i(t+1)$. This implies that at stage $t < t^*$, agent A_i does not strictly prefer to sell to agent A_j rather than waiting, $i.e.$

$$X_i^i(t+1) \geq X_j^j(t+1) - X_i^j(t+1) + X_i^i(t+1). \tag{6.1}$$

The right-hand side of equation (6.1) is what agent can achieve by selling to A_j (altogether they can achieve $X_i^j(t+1) + X_i^i(t+1)$, and agent A_j is set to $X_j^j(t+1)$). Similarly, agent A_j does not strictly prefer to sell to agent A_i rather than waiting

$$X_j^j(t+1) \geq X_i^i(t+1) - X_i^j(t+1) + X_j^j(t+1). \tag{6.2}$$

Combining equations (6.1) and (6.2) yields

$$X_i^i(t+1) = X_j^j(t+1) - X_j^i(t+1) + X_i^j(t+1). \tag{6.3}$$

By Lemma 4.2 we have $X_i^i(t+1) = \pi_{i*} + \sum_{h,k} \varepsilon_{hk} \alpha_{hk}$, $X_j^j(t+1) = \pi_{j*} + \sum_{h,k} \varepsilon'_{hk} \alpha_{hk}$, and $X_j^i(t+1) = -\alpha_{kj}$, $X_i^j(t+1) = -\alpha_{k'i}$. Generically, equation (6.3) implies that $i^* = j^*$. Hence, the final consumer is the same whether agent A_i or agent A_j is the stage t owner. $\|$

Proof of Lemma 4.10

The proof is by induction on $T - t$, and it is very similar to that of Lemma 4.2. It is therefore omitted. Observe that, when at stage t the owner A_i sells to A_j and invites A_k to participate, the resulting payoff to A_k is $X_k^i(t) = X_k^i(t+1)$. This allows to conclude as in Lemma 4.2.[20] $\|$

Proof of Proposition 4.11

For the proof of Proposition 4.11 we first need the following.

   Lemma 6.1.   *Let agent A_i be the stage t owner, and let $W^j(t+1) = \sum_{i'} X_{i'}^j(t+1)$ be the welfare associated with the stage $t+1$ ownership of agent A_j, as defined in equation (4.1). If, at stage t, agent A_i optimally chooses to wait, then $\forall j, W^i(t+1) \geq W^j(t+1)$.*

   Proof.   At stage t, A_i prefers to wait rather than sell to A_j. Hence, by equation (4.3), $W^i(t+1) \geq W^j(t+1) + \sum_{k \neq i,j} \Delta_{ji}^k(t+1) \geq W^j(t+1)$, since $\Delta_{ji}^k(t) \geq 0$ for all t, and for all $i \neq j \neq k$. $\|$

Proof of Proposition 4.11.   The proof starts by an argument similar to that for the proof of Proposition 4.3. For every agent A_i, there exists τ_i such that, for any $T > \tau_i$ if agent A_i is the owner at stage $t, t \leq T - \tau_i$, he

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20. The proof of unique equilibrium payoffs is based on the observation that if at stage t agent A_i is indifferent between selling to agents A_j or A_k, then the final consumer whether A_j or A_k is the stage $t+1$ property right owner must be the same. This implies that $\sum_{i'} X_{i'}^j = \sum_{i'} X_{i'}^k$. Together with the genericity assumption and the fact that A_i obtains the same payoff in both alternatives, the last equation implies that $\text{Min}(X_{i'}^i, X_{i'}^j) = \text{Min}(X_{i'}^i, X_{i'}^k)$ for every i' (see Expression 4.4). Since $A_{i'}$ obtains $\text{Min}(X_{i'}^i, X_{i'}^j)$ when the good is sold to A_j, and $\text{Min}(X_{i'}^i, X_{i'}^k)$ when the good is sold to A_k, it follows that $A_{i'}$ obtains the same payoff in every SPNE.

optimally chooses to wait (because there is a finite number of terms $X_i^i(t)$ of the form shown in Lemma 4.10 and $X_i^i(t)$ is monotonically decreasing). Let $\tau^* = \text{Max}_i \, \tau_i$, and assume that $T > \tau^*$. At any stage $t < T - \tau^*$, any owner finds it optimal to wait. Since A_i prefers to wait rather than sell to A_j and vice-versa, Lemma 6.1 yields: $W^i(t+1) \geq W^j(t+1)$ and $W^j(t+1) \geq W^i(t+1)$. Together, these equations yield $W^i(t+1) = W^j(t+1)$. Hence, the welfare associated with the stage $t+1$ ownership of the good is constant, and independent of who is the owner at that stage. By the genericity condition, this implies that the final consumer is always the same agent. ‖

Proof of Proposition 4.12(i)

When there are two agents the result is trivially obtained. Assume $n = 3$. There are three possible subgames at stage t, depending on whether $A_1, A_2,$ or A_3 owns the good at that stage. We define the set $F(t)$ as follows: An agent A_i belongs to $F(t)$ if and only if A_i is the final consumer in one of the possible subgames at stage t. Note that $|F(T)| = 3$, while for large enough $T, |F(1)| = 1$. (This is the independence property of Proposition 4.11.)

    Claim. *Let t' be the latest stage such that $|F(t')| \leq 2$. The efficient consumer belongs to $F(t')$.*

    Proof. Assume first that $|F(t')| = 1$. Then one of agents A_1, A_2 or A_3 prefers to wait at stage t'. (Otherwise we would have at least two different final outcomes.) From Lemma 6.1 we can conclude that the final outcome is necessarily efficient.

    Assume now that $|F(t')| = 2$. If one of the agents prefers to wait, then Lemma 6.1 allows us to conclude as above. If no agent chooses to wait at stage t', then we can assume without loss of generality (*i.e.* up to permutations of the three agents) that at stage t', A_1 sells to A_2, A_2 sells to A_3, and A_3 sells to A_2. We have to show that A_1 cannot be the efficient consumer. Since A_3 and A_2 do not sell to A_1, we have

$$W^3(t'+1) + \Delta_{32}^1(t'+1) \geq W^1(t'+1) + \Delta_{12}^3(t'+1),$$

and

$$W^2(t'+1) + \Delta_{23}^1(t'+1) \geq W^1(t'+1) + \Delta_{13}^2(t'+1). \tag{6.4}$$

Since either $\Delta_{32}^1(t'+1) = 0$ or $\Delta_{23}^1(t'+1) = 0$, and for all $i \neq j \neq k$, $\Delta_{jk}^i(t'+1) \geq 0$, we obtain that $W^1(t'+1) \leq \max(W^2(t'+1), W^3(t'+1))$ ‖

    To complete the proof of Proposition 4.12(i), we need to show that if, for some $t, |F(t+1)| = 2$ and $|F(t)| = 1$, then the consumer in $F(t)$ is the more efficient one among the two consumers in $F(t+1)$. Without loss of generality, assume that one element in $F(t+1)$ corresponds to the outcome in the subgames Γ_1^{t+1} and Γ_3^{t+1}, while the other element corresponds to the outcome in the subgame Γ_2^{t+1}. As before, if one of the three agents prefers to wait at stage t we can immediately conclude using Lemma 6.1. We can therefore assume that no agent prefers to wait.

    The only way to eliminate one alternative at stage t, without having one agent whose most preferred action is to wait, is thus to assume that at stage t agent A_1 sells to A_3, A_3 sells to A_1, and A_2 sells to either A_1 or A_3. We have to show that A_2 cannot be the efficient consumer. At stage t agent A_1 prefers to sell to A_3 rather than to A_2, which gives

$$W^3(t+1) + \Delta_{31}^2(t+1) \geq W^2(t+1) + \Delta_{21}^3(t+1).$$

Similarly, at stage t agent A_3 prefers to sell to A_1 rather than A_3, which gives

$$W^1(t+1) + \Delta_{13}^2(t+1) \geq W^2(t+1) + \Delta_{23}^1(t+1).$$

Since either $\Delta_{31}^2(t+1) = 0$ or $\Delta_{13}^2(t+1) = 0$, and since for all $i \neq j \neq k$, $\Delta_{jk}^i(t+1) \geq 0$, we conclude that $W^2(t+1) \leq \max(W^1(t+1), W^3(t+1))$. ‖

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