Auction Design without Commitment

Hannu Vartiainen

NOTA DI LAVORO 24.2003

MARCH 2003

PRIV – Privatisation, Regulation, Antitrust

Hanu Vartiainen, *Yrjö Jahnsson Foundation and University of Helsinki, Finland*

Auction Design without Commitment

Summary

We study auction design when parties cannot commit themselves to the mechanism. The seller may change the rules of the game and the buyers choose their outside option at all stages. We assume that the seller has a leading role in equilibrium selection at any stage of the game. Stationary equilibria are characterized in the language of vonNeumann-Morgenstern stable sets. This simplifies the analysis remarkably. In the one buyer case, we obtain the Coase conjecture: the buyer obtains all the surplus and efficiency is reached. However, in the multiple buyer case the seller can achieve more: she is able to commit to the English auction. Typically the converse also holds, the English auction is the only stable auction mechanism.

Keywords: Auction theory, commitment, stable sets

JEL: C72, D44, D78

This paper has been presented at the EuroConference on "Auctions and Market Design: Theory, Evidence and Applications" organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 26-28, 2002.
The author thanks Hamid Sabourian, Rafael Repullo, Klaus Kultti, Hannu Salonen, and Juuso Välimäki for useful discussions.

Address for correspondence:

Hannu Vartiainen
Yrjö Jahnsson Foundation
Ludviginkatu 3-5
FIN-00130 Helsinki
Finland
E-mail: hannu.vartiainen@yjs.fi

Auction Design without Commitment*

Hannu Vartiainen†
Yrjö Jahnsson Foundation
and
University of Helsinki

This version Aug 28, 2002

Abstract

We study auction design when parties cannot commit themselves to the mechanism. The seller may change the rules of the game and the buyers choose their outside option at all stages. We assume that the seller has a leading role in equilibrium selection at any stage of the game. Stationary equilibria are characterized in the language of vonNeumann-Morgenstern stable sets. This simplifies the analysis remarkably. In the one buyer case, we obtain the Coase conjecture: the buyer obtains all the surplus and efficiency is reached. However, in the multiple buyer case the seller can achieve more: she is able to commit to the *English auction*. Typically the converse also holds, the English auction is the *only* stable auction mechanism.
Keywords: Auction theory, Commitment, Stable sets.
JEL: C72, D44, D78.

1 Introduction

The optimal auctions literature starts by asking how does seller's revenue maximizing mechanism look like.[1] Cremer and McLean (1988) and McAfee and Reny (1991) provide a largely definitive solution to the problem: they introduce a mechanism which, in almost all scenarios, extracts *all* the buyers' surlus. From the viewpoint of the mechanism design theory, this is a negative result. Even if the Cremer-McLean mechanism solves the optimal auctions question, it is only rarely, if ever, used in practice. Why is it that we commonly see mechanisms such as the English auction used instead? This paper provides an answer to the question by appealing to commitment problems.

Full commitment is (one of) key assumptions of the optimal auctions literature. Ability to commit to the auction rules implies that (i) the seller cannot

*I thank Hamid Sabourian, Rafael Repullo, Klaus Kultti, Hannu Salonen, and Juuso Välimäki for useful discussions.

†Yrjö Jahnsson Foundation, Ludviginkatu 3-5, FIN-00130 Helsinki. E-mail: hannu.vartiainen@yjs.fi.

[1] Vickrey (1961), Myerson (1981), and Riley and Samuelson (1981) are seminal contributions in the optimal auctions literature. For general survey, see e.g. Klemperer (1999).

change rules of the game in the middle of the play (unilaterally or jointly with buyers), (ii) buyers cannot leave the game once they participate it. Under full commitment one needs not to worry about the dynamics of a bargaining process. However, one can easily imagine why commitment is hard to reach. It may be difficult to prevent seller from "schill bidding", and thereby forming artificial competition, or it may be difficult to prevent the seller changing the terms of trade once the auction has been finalized.[2] It should be particularly difficult to prevent renegotiation under inefficient occurrences. In fact, it is safe to argue that no trading scenario is not subject to potential commitment problems.

We analyse auction design under the hypothesis that parties do not have *any* commitment power: the seller is allowed to change rules of the auction mechanism at any stage of the game without *any* cost, and the buyers cannot ever be forced to participate (the value of their outside option is fixed). Thus, we take the opposite view to the commitment issue than the standard optimal auctions literature.

Allowing the seller to reformulate the auction game means that focusing on direct incentive compatible individually rational mechanisms no longer suffices. This is true even if a mechanism only reveals a recommendated allocation, given buyers' messages to the mechanism. Namely a particular recommendation together with the commonly known structure of the mechanism allows players to make inferences about other players' types. Therefore, the seller typically is tempted to change the rules of the mechanism once a recommendation is revealed. Forward looking buyers of course anticipate this and adjust their play accordingly at the communication stage. Thus, the incentive compatibility of the mechanism breaks down. It can easily be shown that (generically) *there is no incentive compatible mechanism whose rules the seller does not want change.* Thus, full commitment is critical to the optimal auctions theory.

To analyze auction design without commitment, we focus on an extensive form bargaining game which imposes as little restrictions as possible on the strategic alternatives available to the seller. The grand game: (i) the seller declares an extensive form game, to be played by the buyers, (ii) at any stage of the declared game, the seller can propose an allocation or declare a new game which is to be played thereafter by the buyers (there is no limitations on the number of reformulations), (iii) at any stage of the game, the buyers can choose their status quo payoff rather than participate the game. If the buyers agree on a proposed allocation then this allocation is implemented. There is no discounting (as there is no cost of changing the rules), but if the game continues forever, all parties get their status quo payoff (zero).

It is clear at the outset that the game has many potential (perfect Bayesian) equilibria. Which to focus? Like in the standard optimal auctions analysis, we allow the *seller to choose the equilibrium.* However, she controls the equilibrium selection *at any stage of the game.* This implies that any equilibrium selection rule must be *dynamically consistent* with respect to seller's own choices. This

[2] Examples of this are the recent umts-auctions in Europe. In many countries the governments have been trying to change the effective prices of the licences afterwards, depending on the developments of the market situation.

is a very forceful restriction.

We will focus on stationary (or Markovian) equilibria of the grand game. As noted by Chatterjee and Sabourian (1999), stationarity can be justified by appealing complexity considerations.[3] Two nested notions of stationarity are introduced: weak form of stationarity implies that mechanism selection is independent of the history of the game, it only depends on the current beliefs. Strong form of stationarity implies weak stationarity and a property that only differences in terms of expected payoff should affect choices.

Weak stationarity together with the appropriate incentive and participation constraits allows us to characterizate the equilibria in the language of vonNeumann-Morgenenstern *stable sets*. This approach simplifies the equilibrium identification problem remarkably. Demonstrating the usefulness of this approach in complex game theoretic environments is one of the contributions of the paper.[4] [5]

1.1 Stable set

Stable set consists of two ingredients. First, by the standard revelation argument we note that any equilibrium of the grand game must be implementable by a direct (veto-)incentive compatible[6] mechanism, augmented by an information revealing device. Equilibrium selection problem then reduces to one of identifying direct mechanisms that can be implemened given their informational properties. This observation simplifies the problem considerably but does not affect the set of equilibrium outcome functions.

Second, we argue that the equilibrium can be conveniently analyzed in its reduced form by using stables sets. The graph of mechanisms satisfying veto-incentive compatibility restrictions is called the *set of agreeable mechanisms*. Over this set we define a dominance relation which we call *upsetting* relation: an agreeable mechanism is upset by another agreeable mechanism if (i) the latter is defined with respect to prior that is derived by updating on a recommendation of the former mechanism, and if (ii) the latter is mechanism at least as profitable to the seller than the recommendation of the former mechanism. Then, based on

[3] For a closely related argument, see e.g. Anderlini-Sabourian (1999) or Chatterjee-Sabourian (2000). For introduction, see Osborne-Rubinstein (1995).

[4] Greenberg (1990) generalizes this approach, and argues that abstract stable sets can be viewed as a fundamental approach from which many game theoretic solution concepts can be derived from. Recently, several contributors have applied stable sets to noncooperative problems. Kahn and Mookherjee (1992, 1995) use stable sets to characterize coalition-proof equilibria, and to refine equilibria in a class of adverse selection problems. Asheim (1991, 1992) and Tadelis (1996) apply stable sets to refine subgame perfect equilibria in repeated games. Our exposition is most closely connected to Blume and Sobel (1997), who use stable sets to construct a criterion to refine equilibria in a class of cheap-talk games.

[5] In the mechanism design scenario, Forges (1993, 1994) addresses a closely related question of posterior efficiency. This property requires that once a recommendation of the mechanism has been generated by the mechanism, there should not be a mutually profitable deviation to another mechanism, given the updated posterior beliefs. However, Forges' solution is unapplicable here: in the auction scenario the set of posteriorly optimal mechanisms would typically be empty.

[6] Veto-incentive compatibility = incentive compatibility + individual rationality after *all* histories (e.g. Forges, 1998).

the upsetting relation we partition the set of agreeable mechanisms into *stable* and *unstable* ones. Two stability criteria are imposed on a partition: any stable agreeable mechanism can only be upset by an unstable agreeable mechanism, and any unstable agreeable mechanism must be upset by a stable one. We argue that *a set of stable mechanisms, the stable set, contains the graph of stationary equibria of the mechanism reformulation game.* As described below, the converse is typically true also.

1.2 Results and Connections to the Literature

Much of the discussion on bargaining and commitment has circulated around the famous *Coase conjecture* saying that as the commitment ability of the seller becomes weak, all the surplus goes to the buyer. Gul, Sonnenschein and Wilson (1986) and Fudenberg, Levine and Tirole (1985) confirm this conjecture in the one buyer situation under the "Gap" case. In the "No Gap" case a stationarity assumption is needed to obtain the same result.[7] Analogously, McAfee and Vincent (1997) study in the auction design context seller's ability to commit to a minimum reservation price. In the limit, as the time period becomes short and a seller's commitment power vanisges, a version of the Coase conjecture holds true: trade takes place instantaneously with a price equivalent to static mechanism without a reservation price. However, McAfee-Vincent only address the problem of committing to a reservation price, the mechanism itself is fixed (second-price or first-price). Instead, we allow the seller to reformulate also the mechanism.

It is worth scetching our results, and relate them to the discussion on Coase conjecture. In the single buyer situation, we show that in the Gap case the unique stable set is single valued and the stable mechanism allocates the object to the buyer with the price equal to the minimum of buyer's positive probability valuations. In the No Gap case this is true for any strongly stationary stable mechanisms. Thus the results parallel to those by Gul *et.al.* and Levine *et.al.* on the Coase conjecture. Of course, we allow the seller to use arbitrary trading mechanisms, not just simple one sided offers.

In the many-buyer case, we show that a versdion of the *English* auction[8] is always strongly stable.[9] The reason is that the English auction effectively reveals two things: (i) the buyer with the highest valuation (the winner), and (ii) the valuations of all but the winner. The seller then faces a similar situation as in the one-buyer case in that now there remains only one relevant bargaining partner whose valuation is unknown. Again, in the absence of commitment the

[7] For other studies on bilateral contracting, renegotiation and commitment, see Freixas, Guesnerie and Tirole (1985), Hart and Tirole (1988), and Laffont and Tirole (1990). For studies on the No Gap case in the durable good monopoly scenario, see Ausubel and Deneckere (1989a,b)

[8] In the *English* (ascending, progressing, open, oral) auction successively higher prices are called until only one bidder remains. He claims the object with the price equal to the last call.

[9] Even if the Second Price auction is payoff equivalent with the English auction, the latter is *informationally* less demanding in the following sense: it does not require winner to reveal his type to the seller.

seller is forced to sell the good to the winner with the price equal to the lowest possible winner's valuation. As this outcome is equivalent with the original recommendation, she can safely commit to implementing it when designing the mechanism.

Ther result that the English auction is always stronlgy stable is used to prove that a strongly stable set of mechanism always exists, and it contains *efficient* only efficient mechanisms. Efficiency follows from the fact that it is always profitable to reject potentially inefficient recommendation by employing the English auction instead. Finally, and remarkably, if valuations are drawn from a finite set, then the strongly stable the English auction is *only* stable mechanism under *any* belief. Discretization can be interpreted as a consequence of the existence of a smallest monetary unit.

It is noteworthy that (in discrete case) the seller cannot commit to any other mechanism that the English auction, even if this auction is typically suboptimal among all auction mechanisms. Hence, this result may partly explain why the English auction is, according to casual empiricism, so commonly used. In more general terms, *the Coase conjecture can be rephrased as follows: in the absence of commitment (a version of) the English auction is the only feasible trading procedure.* Note that this statement applies also to the one buyer case.

This brings us back to the optimal auctions literature. One unattractive feature of the approach is that optimal auctions are typically difficult to describe in natural economic terms. For this reason, many studies have focused only on mechanisms having natural economic interpretation. Milgrom and Weber (1982) study a class of such mechanisms, and identify rather mild conditions under which the English auction is the optimal *within this class*.[10] This result has been viewed as one major explanation for the popularity of the English auction.[11] In the broader context, however, it is unclear why the seller would disregard more profitable mechanisms. One could imagine evolutionary or competitive forces that would eventually lead one towards more profitable mechanism if such were available. Thus, what is needed is a more general story of why a seller should select the English auction among all possible mechanisms. Our theory can be considered as such theory.

The paper is organized as follows: Section 2 defines the set-up, and Subsection 2.2 explores the game and our introduces our solution. Subsection 3.1 deals with the one buyer problem, and Subsection 3.2 the many-buyer case. Section 4 discusses about the robustness of the model. In the Appendix, we formalize the notion complexity and derive our stationarity restrictions as a *consequence* of complexity considerations.

[10] Including the English, the second-price, the Dutch, and the first-price auctions. However, Matthews (1987) and Maskin and Riley (1984) show that *risk-aversion* would make either the Dutch or the first-price auction more profitable than the other auction forms.

[11] Lopomo (1998) shows that the English auction is *optimal* in a class of "simple" mechanisms.

2 Framework

There is a single seller, selling a single indivisible object, and a set $N = \{1, ..., n\}$, $n < \infty$, of buyers with typical elements i, j, potentially willing to buy the object. Normalize seller's reservation value, which is public information, to 0. Buyer i's reservation valuation is represented by random variable θ_i which is i's *private information*.and distributed on a bounded set $\Theta_i \subseteq \mathbb{R}_+$. The set of possible valuation profiles is $\Theta = \times_{i \in N} \Theta_i$ with an element $\theta = (\theta_i)_{i \in N}$,. Write $\Theta_{-i} = \times_{j \neq i} \Theta_i$ with an element $\theta_{-i} = (\theta_j)_{j \neq i}$. For profile θ, denote the $k-$order statistics by $\theta_{(k)}$, and the vector of all other valuations than the $\theta_{(k)}$ order statistic by $\theta_{-(k)}$. Let p be a probability measure on Θ with support $S(p)$,[12] and $\mathcal{Y}$ the set of all (Lebesgue) measurable sets in $\mathbb{R}^n$. Let Δ^{Θ} be the set of all probability measures p on Θ. Denote the least upper and greatest lower bounds of i's support by $\overline{\theta}(p_i) = \sup S(p_i)$ and $\underline{\theta}(p_i) = \inf S(p_i)$.

2.1 Direct Mechanisms

Denote by a_i the probability that the object is allocated to buyer $i = 1, ...n$ or to the seller $i = 0$. The set of possible random object allocations is then an n-dimensional unit simplex Δ^n. Scalar $t_i \in \mathbb{R}$ represents the pure monetary transfer from buyer i to the seller.[13] Use the vector notation $a = (a_0, a_1, ..., a_n) \in \Delta^n$ and $t = (t_1, ..., t_n) \in \mathbb{R}^n$. A standard auction mechanism specifies an outcome for all valuation profiles $\theta = (\theta_1, ..., \theta_n) \in \Theta$. We define a (Lebesgue) measurable function $\mathbf{r}$, *augmented direct auction mechanism*, which specifies for each valuation profile in the support of p a physical outcome and signal in $\mathcal{Y}$ (hence the attribute "augmented")

$$\mathbf{r}(\cdot : p) : S(p) \rightarrow \Delta^n \times \mathbb{R}^n \times \mathcal{Y}. \tag{1}$$

An output of $\mathbf{r}$, a *recommendation,* is written compactly $r = (a, t, Y)$. Denote the family of all $\mathbf{r}$ functions by $\mathbf{R}$. Given p, the set of recommendations that mechanism $\mathbf{r}$ generates with positive probability is $\mathbf{r}(S(p) : p)$ or, compactly, $\mathbf{r}(S : p)$.

The role of signal Y is to allow revelation of finer information than is contained in (a, t) -part of the recommendation. W.l.o.g. we focus on mechanisms that satisfy $Y = \mathbf{r}^{-1}(a, t, Y : p) \subseteq S(p)$, for all $(a, t, Y) \in \mathbf{r}(\Theta)$. Thus $\mathbf{r}^{-1}(a, t, \mathcal{Y} : p)$ generates a partition on the set of types generating allocation (a, t). The aim is to simulate not only the outcome function but also the *posterior belief formation* of any (non-direct) auction mechanism. E.g. first and second price auctions are fully revealing[14] and hence the augmented direct mechanisms simulating (equilibria of) these auctions satisfy $Y = \{\theta\}$ for all generated recommendations (a, t, Y). With the English auction $Y = \{\theta_i \in S(p_i) : \theta_i \geq \theta_{(2)}\} \times \{\theta_{-i}\}$, where i has the highest valuation, $\theta_{(2)}$ is the second order statistic and θ_{-i} the vector types of all buyers but i. The auction re-

[12] Support of p is a smallest closed set Y such that $p(Y) = 1$.

[13] Because of risk neutrality, this is without loss of generality.

[14] There is one-to-one mapping from types to equilibrium bids.

veals all but the winner's exact valuation, and the greatest lower bound of his possible valuations (the second highest bid).

A *constant* mechanism does not change beliefs with probability one:[15] it sends the same recommendation, say $r = (a, t, S(p))$, for all $\theta \in S(p)$. In such case we write $\mathbf{r}(\cdot : p) = \mathbf{1}_r(p)$. If more than one recommendation is sent with positive probability, then posteriors necessarily change some times, and some information is revealed.

Given p, a *posterior* belief is unique up to variations in countably many measure zero events. In restrict beliefs in measure zero events, we assume that the conditional measure $p(\cdot : Y)$ satisfies $S(p(\cdot : Y)) = Y$, for any state $Y \subseteq S(p)$. The restriction binds only when Y is a probability zero event.[16] Also denote conditional measures $p(\theta : Y)$ for $Y = \Theta_{-i} \times \{\theta_i\}$ or $Y = \Theta_i \times \{\theta_{-i}\}$ by $p_{-i}(\theta_{-i} : \theta_i)$ and $p_i(\theta_i : \theta_{-i})$, respectively, for any $\theta \in S(p)$. Now $p_{-i}(\cdot : \theta_i)$ is the *interim* belief of i given θ_i, and $p_i(\cdot : \theta_{-i})$ is the belief concerning i's type were all other buyers' types publicly known. In the case of independent valuations, $p_i(\cdot : \theta_{-i}) = p_i$.

Given prior p, mechanism $\mathbf{r}$, and recommendation r, the conditional measure has the form $p(\theta : \mathbf{r}^{-1}(r))$ for all $\theta \in \Theta$. Support $S(p(\cdot : \mathbf{r}^{-1}(r : p)))$ is uniquely determined by our assumption. To simplify notation, write $p(\mathbf{r}, r)$ instead of $p(\cdot : \mathbf{r}^{-1}(r : p))$ when referring to posterior generated from p according to mechanism $\mathbf{r}$ and recommendation r. Note that Δ^{Θ} is closed under updating operation: $p \in \Delta^{\Theta}$ implies $p(\mathbf{r}, r) \in \Delta^{\Theta}$. Further, denote $p(\mathbf{r}, r)(\mathbf{r}', r')$ the posterior measure generated from $p(\mathbf{r}, r)$ according to $\mathbf{r}'$ and r', and so forth for any chain of mechanisms and recommendations.

We analyze the situation where players have no ability to commit to the continuation of a mechanism as planned. This means that the buyers can, if they wish, choose their outside option rather than to complete the trading game as planned. We now describe the constraint that is imposed by the this restriction (the other restriction is due the assumption that the seller can *re*design the mechanism).

We assume *private valuations* and *risk neutrality*.[17] Denote buyer i's payoff, given realized recommendation $r = (a, t, Y)$ and his type θ_i by $u_i(r, \theta_i)$. This *ex post* payoff of buyer i is of the form

$$u_i(r, \theta_i) = \theta_i a_i - t_i$$

Then, given buyer i's privately known valuation and publicly known trading mechanism $\mathbf{r}$, i's payoff is a random variable $u_i(\mathbf{r}(\cdot, \theta_i'), \theta_i)$ on Θ_{-i} whose ex-

[15] Note that any mechanism is defined over the whole domain Θ whereas the definition of a constant mechanism only requires that a constant mechanism, say π , should be constant over $S(p)$ (less a null set), given p. When referring to constant mechanisms we assume that $r_i = (0, 0)$ for all i and all $\theta \in \Theta \setminus S(p)$. That is, in all zero probability events π implements the no-trade -allocation. Of course, this restriction neither affects the expected payoffs of any player nor incetives of the buyers (this is easy to check).

[16] This condition is clearly met by any version of conditional measure whenever $p(Y) > 0$ (use Bayes' rule).

[17] These assumptions can be weakened significantly. See the remarks in the final section.

pected value at the *interim* stage is[18]

$$\mathbb{E}_{p_{-i}}[u_i(\mathbf{r}\left(\theta_{-i},\theta_i':p\right),\theta_i)] = \int_{\Theta_{-i}} u(\mathbf{r}\left(\theta_{-i},\theta_i':p\right),\theta_i)p_{-i}\left(\theta_{-i}:\theta_i\right)d\theta_{-i}.$$

In particular, given private values,

$$\mathbb{E}_{p_{-i}}[u_i(\mathbf{1}_r\left(\theta:p\right),\theta)] = u_i(r,\theta).$$

The trading mechanism must be (interim) *incentive compatible* (IC):

$$\mathbb{E}_{p_{-i}}[u_i(\mathbf{r}\left(\theta:p\right),\theta_i)] \geq \mathbb{E}_{p_{-i}}[u_i(\mathbf{r}\left(\theta_{-i},\theta_i':p\right),\theta_i)], \quad \text{for all } \theta_i,\theta_i' \in S(p_i), \text{ for all } i \in N.$$

Since participation to the mechanism is voluntary, and buyers lack any commitment power, a feasible mechanism must satisfy *individual rationality* constraint at *any* point of the game (assume the value of the outside option is zero for all buyers), including the *ex post* stage. Note that any *ex post individually rational* mechanism exhibits individual rationality also at the interim and ex ante stages. More formally, given prior p and an allocation r, ex post individual rationality (EXP-IR) requires that

$$u_i(r,\theta_i) \geq 0, \quad \text{for all } \theta_i \in S(p_i), \text{ for all } i \in N.$$

Hence, at the (truthful) equilibrium path, EXP-IR requires that any generated recommendation must be at least as profitable than the outside option in any state for any player. Although EXP-IR is implied by veto right at the ex post stage, but not vice versa, it is useful to introduce the concept for expositional reasons.

One cannot use the combination of interim IC and EXP-IR to obtain a characterization of a mechanism which, on the one hand, can be played with truthful strategies and, on the other, is individually rational at *all* information sets: IC and EXP-IR are not measured at the same information set, and hence they need not be independent.[19] Namely, if a player is entitled to use his veto power at any information set, then he should be able do that also outside the equilibrium path and, consequently, interim IC may be violated even if mechanism at hand meets EXP-IR constraint in the truthful path. To cope with the problem, define the following constraint.[20]

Definition 1 *Given $p \in \Delta^{\Theta}$, mechanism $\mathbf{r}$ satisfies VETO-IC iff*

$$\mathbb{E}_{p_{-i}}[u_i(\mathbf{r}\left(\theta:p\right),\theta_i)] \geq \mathbb{E}_{p_{-i}}[\max\{u_i(\mathbf{r}\left(\theta_{-i},\theta_i':p\right),\theta_i),0\}], \quad \textit{for all } i \in N, \textit{for all } \theta_i,\theta_i' \in S(p_i).$$

[18] We use the notation $E_p f(\theta) = \int_{\theta\in\Theta} f(\theta)p(d\theta)$ for any measurable real-valued random variable f on Θ and, similarly, the interim expectation $E_{p_{-i}} f(\theta) = \int_{\theta\in\Theta} f(\theta_{-i},\theta_i)p_{-i}(d\theta_{-i}:\theta_i)$.

[19] In the literature, one typically imposes *interim* IR constraint on mechanism. Relative to EXP-IR, interim individual rationality is easier to analyze but hardly more natural (however, EXP-IR excludes important and quite realistic features of mechanisms, such as entry fees or transaction costs). Exceptions from this practice include Forges (1993, 1998) and Gresik (1991, 1996).

[20] VETO-IC is defined by Forges (1998), and is closely related to IC* of Matthews and Postlewaite (1989).

Thus, VETO-IC requires that truthful reporting forms a Bayes-Nash equilibrium in the mechanism even if untruthful strategies may be followed by the use of the veto option. To interpret VETO-IC, consider a mechanism which, after being played by the buyers and after a recommendation is generated, is subject to vetoing by some of the buyers. If this mechanism is playable in truthful strategies such that no player ever uses his veto right, then it satisfies VETO-IC. The interpretation is that the players can refuse unprofitable transactions and fully anticipate this possibility when they report their type.

Remark 1 *Let mechanism* $\mathbf{r}$ *satisfy VETO-IC. Then* $\mathbf{r}$ *satisfies IC and EXP-IR (a.s.).*

Proof. It is obvious that any $\mathbf{r}$ satisfying VETO-IC also satisfies IC. To verify the EXP-IR part, take i and choose $\theta_i = \theta_i'$. Then

$$\mathbb{E}_{p_{-i}}\left[u_i(\mathbf{r}\left(\theta : p\right), \theta_i) - \max\{u_i(\mathbf{r}\left(\theta : p\right), \theta_i), 0\}\right] = \mathbb{E}_{p_{-i}}[\min\{u_i(\mathbf{r}\left(\theta : p\right), \theta_i), 0\}] \geq 0.$$

Thus, if $u_i(r, \theta_i) < 0$ then $\mathbb{E}_{p_{-i}}[I(\mathbf{r}\left(\theta : p\right) = r)] = 0$ and, consequently, if $\theta \in S(p)$ then $r \neq \mathbf{r}(\theta)$.[21] ■

By a version of the "revelation principle" (Myerson 1982), outcomes of a (pure strategy) equilibrium of any mechanism (without random elements) *with veto right* can be simulated by a truthful equilibrium of a *direct mechanism* satisfying VETO-IC. Denote the set of trading mechanisms, given p, satisfying VETO-IC by

$$\mathbf{R}(p) = \left\{\mathbf{r}\left(\cdot : p\right) \in \mathbf{R} : \mathbf{r}\left(\cdot : p\right) \text{ satisfies VETO-IC}\right\}.$$

Thus, if buyers lack any commitment ability, we can, without loss of generality, confine our attention to the class $\mathbf{R}(p)$ of mechanisms. Mechanisms outside this set are not playable in truthful strategies, or subject to nonparticipation at the some stage of the game. It should be emphasized, however, that our results below are *not* dependent on the difference between VETO-IC and EXP-IR + IC. All the arguments remain valid also with the latter restriction. VETO-IC assumption is adopted because it is the right way to model situations where participants do not have commitment ability.

Let us next focus on the seller's problem. Given recommendation $\mathbf{r}(\theta : p) = (a, t, Y)$, seller's payoff is the sum of transfers specified by $t:$

$$v(\mathbf{r}(\theta : p)) = \sum_{i \in N} t_i.$$

Given p and $\mathbf{r}$, seller's *expected* payoff is then

$$v(\mathbf{r}, p) = \mathbb{E}_p[v(\mathbf{r}(\theta : p))] = \int_{\Theta} v(\mathbf{r}(\theta : p))p(\theta)d\theta \tag{2}$$

By definition, if $\mathbf{r}(\theta : p) \neq \mathbf{r}'(\theta : p)$ implies $\theta \notin S(p)$, then $v(\mathbf{r}, p) = v(\mathbf{r}', p)$.

[21] Where $I(\cdot)$ is an indicator function.

2.2 The Grand Game

In the standard optimal auctions literature, the seller maximizes (2) subject to (interim) IC and IR. There the seller is enpowered to choose the mechanism and the equilibrium generated by the mechanism. The mechanism-equilibrium pair solving the optimizing problem can be interpreted as a full commitment benchmark. If, instead, the seller changes the rules after buyers have submitted their announcements, then rational buyers would take the rule change into account in their decisions, and the incentive compatibility of the mechanism would break down. In this section, we construct a mechasnims design game which allows the seller can change the rules of the mechanism infinitely many times.

Consider the following *grand game.*[22]

- Stage 0: Nature chooses distribution $p^0 \in \Delta^\Theta$. Buyers' types are drawn according to p^0. Seller designs a finitely long game ending in an outcome recommendation. The game is played by the buyers, and ends in recommendation r^0.

- Stage $t = 1, ...,$: Seller either (a) proposes recommendation r^{t-1}, or (b) publicly designs a finitely long game which ends in a recommendation.

  (a) If all buyers accept proposal r^{t-1}, then it is implemented. Otherwise the game moves to stage $t+1$ with $r^t = r^{t-1}$.

  (b) The game is played by the buyers, and ends in recommendation r^t.

- If the game does not end with finite time, then status quo outcome (payoff 0 for all players) is implemented. There is *no* discounting.

For simplicity, assume there are no random elements in games and players only use pure strategies. It is clear that the grand game may support many perfect Bayesian equilibria (PBE). We maintain the hypothesis that the buyers are passive in the following sense: at any point of the game the seller chooses her most desirable PBE of the continuation game given that she is enpowered to do this in the continuation game. Thus PBE must be *dynamically consistent.* Note that PBE is defined for *any* prior $p^0 \in \Delta^\Theta$.

Let us focus on PBEa that for each p ends in finite time with probability one. Then, by the *revelation principle,* there is no loss of generality in focusing on PBE strategies having the property that (i) the game ends in stage 1, (ii) the seller designs a VETO-IC mechanism $\mathbf{r}(\cdot : p^0)$, (iii) $\mathbf{r}(\cdot : p^0)$ is played truthfully by the buyers, and (iv) any recommendation r of $\mathbf{r}(\cdot : p^0)$ is obediently implemented. Moreover, any belief consistent with the PBE beliefs at a terminal node can be generated by appropriately defining the Y element of the mechanism. The crucial restriction on feasible mechanism is dynamical consistency: which mechanisms in $\mathbf{R}(p^0)$ can the seller commit to?

[22] Details of the game are not crucial. They can be altered as long as the seller is allowed redesign the rules before the outcome is excuted, and the buyers have access to their outside option any time.

As in Chatterjee-Sabourian (1999), to narrow further the set of feasible equilibria we appeal to complexity considerations. In the Appendix we argue explicitly that due to (lexicographic) aversion towards more complex strategies, the seller will not condition her actions to the past occurrences when choosing her strategy. Therefore, given that the seller chooses the PBE at each stage, we obtain that any mechanism selection PBE must be *stationary* in the sense that *seller's choice of a mechanism is dependent only on current beliefs* p.

Thus stationary PBE can be defined by a function $PBE : \Delta^{\Theta} \to \mathbf{R}$. When identifying function PBE, the central question if of dynamic consistency. In PBE the seller can commit *not to* change the rules given posterior beliefs generated by the mechanism, whereas outside of PBE the seller can*not* commit not to change the rules. More formally, dynamically consistent stationary PBE satisfies the following:

- If $\mathbf{r}(\cdot : p) = PBE(p)$ then there is *no* $r \in \mathbf{r}(S : p)$ such that $\mathbf{r'}(\cdot : p(\mathbf{r}, r)) \neq \mathbf{1}_r(p(\mathbf{r}, r))$, for $\mathbf{r'}(\cdot : p(\mathbf{r}, r)) = PBE(p(\mathbf{r}, r))$.
- If $\mathbf{r}(\cdot : p) \neq PBE(p)$ then there is $r \in \mathbf{r}(S : p)$ such that $\mathbf{r'}(\cdot : p(\mathbf{r}, r)) \neq \mathbf{1}_r(p(\mathbf{r}, r))$, for $\mathbf{r'}(\cdot : p(\mathbf{r}, r)) = PBE(p(\mathbf{r}, r))$.

Let $\mathbf{r} = PBE(p)$. By the definition of PBE, the seller obediently implements any outcome $r \in \mathbf{r}(S : p)$ given that mechanism $\mathbf{r'} = PBE(p(\mathbf{r},r))$ becomes available. This implies that, in fact, $\mathbf{r'}(\cdot : p(\mathbf{r}, r)) = \mathbf{1}_r(p(\mathbf{r}, r))$. Conversely, if $\mathbf{r} \neq PBE(p)$ then the seller does not obediently implement some outcome $r \in \mathbf{r}(S(p))$ implying $\mathbf{r'}(\cdot : p(\mathbf{r}, r)) \neq \mathbf{1}_r(p(\mathbf{r}, r))$ for $\mathbf{r'} = PBE(p(\mathbf{r}, r))$.

2.3 Stable set

It is convenient to characterize stationary PBE of the grand game directly in the language of *stable sets.* [23] In order to define a stable set we construct a set of *agreeable mechanisms,* and establish an *upsetting relation* over this set. For fixed $p \in \Delta^{\Theta}$, set $\mathbf{R}(p)$ is referred as the set of *agreeable* mechanisms. If commitment by the seller would not be a problem, then any $\mathbf{r} \in \mathbf{R}(p^0)$ could be implemented. The set of all agreeable mechanisms is the graph of $\mathbf{R}$

$$\mathbf{A} = \left\{ \mathbf{R}(p) : p \in \Delta^{\Theta} \right\}.$$

Formally, the upsetting relation is defined as follows.[24]

Definition 2 *Mechanism* $\mathbf{r}(\cdot : p) \in \mathbf{A}$ *is* upset *by mechanism* $\mathbf{r'}(\cdot : p(\mathbf{r}, r)) \in \mathbf{A}$ *if* $v(\mathbf{r'}(\cdot : p(\mathbf{r}, r))) \geq v(r)$ *for some* $r \in \mathbf{r}(S : p)$, $\mathbf{r'}(\cdot : p(\mathbf{r}, r)) \neq \mathbf{1}_r(p(\mathbf{r}, r))$.

[23] VonNeumann and Morgenstern (1944) introduced the idea of stable sets. Greenberg (1990) later used the idea to develop a unifying Theory of Social Situations. For applications of the stable set approach, see e.g. Kahn and Mookherjee (1993, 1995). Blume and Sobel (1997) employed stable sets in a closely related manner to characterize communication in a cheap-talk game.

[24] Assumption (**??**) is very convenient here since now we can restrict our attention to ageements generated by measures in Δ^{Θ} rather than general measures which would complicate the analysis without changing the main conclusions (see the Remarks -section).

Alternatively, mechanism $\mathbf{r}'(\cdot : p(\mathbf{r}, r))$ does not upset $\mathbf{r}(\cdot : p)$ if $v(\mathbf{r}'(\cdot : p(\mathbf{r}, r))) \geq v(r)$ implies $\mathbf{r}'(\cdot : p(\mathbf{r}, r)) = \mathbf{1}_r(p(\mathbf{r}, r))$. Note that the upsetting relation is not complete nor transitive. However, the relation *is* antisymmetric, two agreeable mechanism cannot upset one another.

To describe which agreeable mechanisms are feasible stationary PBE we appeal to vonNeumann-Morgenstern's notions of *external* and *internal stability.* These together define a *stable set.*

Definition 3 $\mathbf{G}$ *is a* stable set *of* $\mathbf{A}$ *relative to upsetting relation if and only if*

1. (Internal stability) $\mathbf{r}(\cdot : p) \in \mathbf{G}$ *implies there is no* $\mathbf{r}'(\cdot : p(\mathbf{r}, r)) \in \mathbf{G}$ *such that* $\mathbf{r}'(\cdot : p(\mathbf{r}, r))$ *upsets* $\mathbf{r}(\cdot : p)$,
2. (External stability) $\mathbf{r}(\cdot : p) \notin \mathbf{G}$ *implies there is* $\mathbf{r}'(\cdot : p(\mathbf{r}, r)) \in \mathbf{G}$ *such that* $\mathbf{r}'(\cdot : p(\mathbf{r}, r))$ *upsets* $\mathbf{r}(\cdot : p)$.

In the sequel, our aim is to characterize a stable set relative upsetting relation.

Remark 2 *Let* $\mathbf{G}$ *be a stable set, and let* $\mathbf{r}(\cdot : p) \in \mathbf{A}$. *Then* $\mathbf{r}(\cdot : p) \in \mathbf{G}$ *if and only if* $\mathbf{1}_r(p(\mathbf{r}, r)) \in \mathbf{G}$ *for all* $r \in \mathbf{r}(S : p)$.

Proof. "If": Suppose that $\mathbf{1}_r(p(\mathbf{r}, r)) \in \mathbf{G}$ for all $r \in \mathbf{r}(S : p)$, but $\mathbf{r}(\cdot : p) \in \mathbf{A} \setminus \mathbf{G}$. By external stability there is $r \in \mathbf{r}(S : p)$ such that $\mathbf{r}'(\cdot : p(\mathbf{r}, r)) \in \mathbf{G}$ upsets $\mathbf{r}(\cdot : p)$. But then $\mathbf{r}'(\cdot : p(\mathbf{r}, r))$ also upsets $\mathbf{1}_r(p(\mathbf{r}, r))$, violating internal stability.

"Only if": Suppose that $\mathbf{r}(\cdot : p) \in \mathbf{G}$, but $\mathbf{1}_r(p(\mathbf{r}, r)) \notin \mathbf{G}$ for some $r \in \mathbf{r}(S : p)$. Then, as $\mathbf{r}(\cdot : p) \in \mathbf{A}$ we have that $\mathbf{1}_r(p(\mathbf{r}, r)) \in \mathbf{A}$. By external stability there is $\mathbf{r}'(\cdot : p(\mathbf{r}, r)) \in \mathbf{G}$ which upsets $\mathbf{1}_r(p(\mathbf{r}, r))$. But then $\mathbf{r}'(\cdot : p(\mathbf{r}, r))$ also upsets $\mathbf{r}(\cdot : p)$, violating internal stability. ■

Thus, by construction, any recommendation of a stable auction must be itself a stable *constant* mechanism, given the updated beliefs. We now argue that for any stationary PBE we can conctruct a stable that contains it.

Theorem 1 *The graph of a stationary PBE is contained by a stable set.*

Proof. Let function $PBE : \Delta^{\Theta} \rightarrow \mathbf{R}$ reflect stationary PBE choices of the seller. We construct a stable set which contains $PBE(\Delta^{\Theta})$. Let

$$\mathbf{G} = \{\mathbf{r}(\cdot : p) \in \mathbf{A} : \mathbf{r}' \text{ does not upset } \mathbf{r}(\cdot : p), \text{ for } \mathbf{r}' = PBE(p(\mathbf{r}, r)),\ r \in \mathbf{r}(S : p)\}.$$

Let $\mathbf{r}(\cdot : p) = PBE(p)$ for any p. Then $\mathbf{r}'(\cdot : p(\mathbf{r}, r)) = \mathbf{1}_r(p(\mathbf{r}, r))$ for $\mathbf{r}' = PBE(p(\mathbf{r}, r))$, $r \in \mathbf{r}(S : p)$. Thus, $\mathbf{r}(\cdot : p) \in \mathbf{G}$.

Internal stability: Conversely, if $\mathbf{r}'(\cdot : p(\mathbf{r}, r))$ upsets $\mathbf{1}_r(p(\mathbf{r}, r))$ for some $r \in \mathbf{r}(S : p)$, $\mathbf{r}(\cdot : p) \in \mathbf{G}$, then $\mathbf{r}'(\cdot : p(\mathbf{r}, r)) \neq PBE(p(\mathbf{r},r))$. Thus there is $r' \in \mathbf{r}'(S : p(\mathbf{r}, r))$ such that $\mathbf{r}'(\cdot : p(\mathbf{r}, r)(\mathbf{r}', r')) = PBE(p(\mathbf{r},r)(\mathbf{r}', r')) \neq \mathbf{1}_{r'}(p(\mathbf{r}, r)(\mathbf{r}', r'))$ and $v(\mathbf{r}', p(\mathbf{r}, r)(\mathbf{r}', r')) \geq v(\mathbf{1}_{r'}, p(\mathbf{r}, r)(\mathbf{r}', r'))$. But then $\mathbf{r}'(\cdot : p(\mathbf{r}, r)) \notin \mathbf{G}$.

External stability: By contruction, $\mathbf{r}'(\cdot : p) \in \mathbf{A} \setminus \mathbf{G}$ implies there is $\mathbf{r}(\cdot : p(\mathbf{r}', r')) \in \mathbf{G}$ such that $\mathbf{r}(\cdot : p(\mathbf{r}', r'))$ upsets $\mathbf{r}'(\cdot : p)$,for $r' \in \mathbf{r}'(S : p)$. ■

As a consequence, whenever the graph drawn by stable set is singleton, we have a unique PBE of the grand game. At this point, it is too early to state the converse result that any stable set contains a graph of a stationary PBE. However, this indeed shows up to be case. The result is proven in the Subsection 3.2

It follows from Remark 2 that $\mathbf{1}_r(p), \mathbf{1}_{r'}(\cdot : p) \in \mathbf{G}$ implies $r = r'$. Thus the notion of stable set contains some degree of "Markov" flavor in that it does not matter which stable mechanism generates a posterior, stable recommendation depends only on posterier. However, we sometimes want to strengthen this property of the solution.

Remark 3 *Let* $\mathbf{G}$ *be a stable set. If* $\mathbf{1}_r(p), \mathbf{1}_{r'}(\cdot : p(\mathbf{r}, r')) \in \mathbf{G}$ *for* $r \in \mathbf{r}(S : p)$, *then* $v(\mathbf{1}_{r'}, p(\mathbf{r}, r')) \geq v(\mathbf{1}_r, p)$.

Note that, by Remark **??**), if two constant stable mechanisms meet EXP-IR under two belief systems, then necessarily seller's payoff is the same under both recommendations. The next condition contains the idea that given such symmetric situation, where the seller is indifferent, she should make the same choice in both cases. Thus any situation seller's choices should depend only on her feasible payoffs, not what has happened before or the details of the beliefs. Thus the condition strengthens the Markovian flavor of the solution.

Definition 4 (Strong Stationarity) *Stable set* $\mathbf{G}$ *is strongly stationary if* $\mathbf{1}_r(: p), \mathbf{1}_{r'}(p(\mathbf{r}, r')) \in \mathbf{G}$ *and* $\mathbf{1}_r(p) \neq \mathbf{1}_{r'}(p(\mathbf{r}, r'))$ *implies* $v(\mathbf{1}_{r'}, p(\mathbf{r}, r')) > v(\mathbf{1}_r, p)$.

3 The Results

Lemma 1 *Let* $\mathbf{G}$ *be a stable set. Then* $\mathbf{r}(\cdot : p) \in \mathbf{G}$ *only if*

$$v(r) = \sup \{v(s) : \mathbf{1}_s \in \mathbf{R}(p(\mathbf{r}, r))\}, \quad \textit{for all } r \in \mathbf{r}(S : p). \tag{3}$$

Proof. Suppose that $\mathbf{r}(\cdot : p) \in \mathbf{G}$. Suppose that (3) does not hold. Then there is $r = (a, t) \in \mathbf{r}(S : p)$, and a constant mechanism $\mathbf{1}_s$ s.t.

$$v(s) > v(r) \text{ and } 0 \leq u_i(s, \theta_i), \text{ for all } \theta \geq \underline{\theta}(p_i(\mathbf{r}, r)), \text{ for all } i \in N.$$

Thus, $\mathbf{1}_s(p(\mathbf{r}, r))$ upsets $\mathbf{1}_r(p(\mathbf{r}, r))$. By Remark 2, $\mathbf{1}_r(p(\mathbf{r}, r)) \in \mathbf{G}$. Thus, by internal stability, $\mathbf{1}_s(p(\mathbf{r}, r)) \notin \mathbf{G}$. By external stability there is $\mathbf{r}'(\cdot : p(\mathbf{r}, r)) \in \mathbf{G}$ which upsets $\mathbf{1}_s(p(\mathbf{r}, r))$. But then $\mathbf{r}'(\cdot : p(\mathbf{r}, r'))$ also upsets $\mathbf{1}_r(p(\mathbf{r}, r))$, violating internal stability. Thus, (3) must hold. ■

The logic of Lemma 1 is straightforward. Recall that a mechanism is constant if it chooses the same recommendation in (almost) all possible states; a constant mechanism does not change beliefs with probaility one. If a constant mechanism is upset by some other constant mechanism, then the former must necessary not belong to $\mathbf{G}$, otherwise the latter would either be upset by an agreeable mechanism in $\mathbf{G}$, or it would itself be an element of $\mathbf{G}$. In both cases it follows that the original constant mechanism does not belong to $\mathbf{G}$.

Corollary 1 *Let* $\mathbf{G}$ *be stable set. Then* $\mathbf{r}(\cdot : p) \in \mathbf{G}$ *only if* $v(r) = \min_{i \in N} \underline{\theta}(p_i(\mathbf{r}, r))$ *for all* $r \in \mathbf{r}(S : p)$.

Of course, the condition is plausible mainly in situations where any form of commitment is absent. When the seller is indifferent between two recommendations she cannot make her decision contingent on the previous agreeable mechanism.

Finally, we can simplify the exposition by observing that typically one only needs to focus on mechanisms that are deterministic almost everywhere. The following corollary is a straightforward consequence of Corollary 1.

Corollary 2 *Let* $\mathbf{G}$ *be a stable set. Then* $\mathbf{1}_r(p) \in \mathbf{G}$ *only if* $r = (b_i(1, \underline{\theta}(p_i)))_{i \in N}$ *where* $b \equiv \arg\max \left\{ \sum_{i=1}^{n} b'_i \underline{\theta}(p_i) : b' \in \Delta^{n-1} \right\}$.

Thus, if $\underline{\theta}(p_i) > \underline{\theta}(p_j)$ for $j \neq i$, then $r_i = (1, \underline{\theta}(p_i))$ and $r_j = (0, 0)$.

3.1 The $n = 1$ case

First we focus on the special one buyer case (to ease the notation, drop the subscript i). First we discuss about the "Gap" case, and then the "No Gap" case.[25]

First we show that the notion of stable sets meeting the stationarity property is not overly strong: there exists a partition which meets the requirement. To do that, define a following simple mechanism. For any $\theta \in S(p)$, $\mathbf{r}^*(\theta : p) = (a, t, Y)$ satisfies $(a, t) = (1, \underline{\theta}(p))$. Thus $\mathbf{r}^*$ is *efficient* and the buyer pays a price equal to maximal price that he can always accept. Assume that $\mathbf{r}^*$ reveals as little information as possible: given outcome (a, t), signal Y satisfies $Y = (\mathbf{r}^*)^{-1}(a, t : p)$. By abusing notation, we write from now on simply $r = (a, t)$.

Construct set:

$$\mathbf{G}^* = \left\{ \mathbf{r}^*(\cdot : p) : p \in \Delta^{\Theta} \right\}.$$

Theorem 2 *Set* $\mathbf{G}^*$ *is stable and strongly stationary.*

Proof. Internal stability: Observe that $\{(1, \underline{\theta}(p))\} = \mathbf{r}^*(S : p)$ and $p = p(\mathbf{r}^*, (1, \underline{\theta}(p)))$. Thus $v(\mathbf{1}_r, p(\mathbf{r}^*, r)) = v(\mathbf{r}^*, p(\mathbf{r}^*, r))$ for $r = (1, \underline{\theta}(p))$.

External stability: Suppose that that there is no $r \in \mathbf{r}(S : p)$ such that $\mathbf{r}^*(\cdot : p(\mathbf{r}, r))$ upsets $\mathbf{1}_r(p(\mathbf{r}, r))$. Then $a = 1$ and $t \geq \underline{\theta}(p(\mathbf{r}, r))$ for all $r = (a, t) \in \mathbf{r}(S : p)$. On the other hand, by EXP-IR, we have $t \leq \underline{\theta}(p(\mathbf{r}, r))$. Thus $r = (1, \underline{\theta}(p(\mathbf{r}, r)))$ for all $r \in \mathbf{r}(S : p)$. In particular, $\mathbf{r}(\underline{\theta}(p) : p) = (1, \underline{\theta}(p))$. Since any $\theta \geq \underline{\theta}(p)$ can report $\underline{\theta}(p)$, it follows by IC that $a = 1$ and $t \leq \underline{\theta}(p)$ for all $r = (a, t) \in \mathbf{r}(S : p)$. But this implies that $\mathbf{r} = \mathbf{r}^*$, and thus $\mathbf{r}(\cdot : p) \in \mathbf{G}^*$. By Lemma 1, external stability is established. Finally, it is obvious that $\mathbf{G}^*$ meets the strong stationarity property. ∎

[25] See e.g. Fudenberg *et.al.* (1985), Gul *et.al.* (1986), Ausubel and Deneckere (1989a,b).

In the previous theorem we used the following argument: whenever $r = (1, \underline{\theta}(p)) \in \mathbf{r}(S : p)$, there cannot be any other $r' = (a', t')$ such that $a' = 1$ and $t' > \underline{\theta}(p)$ in $\mathbf{r}(S(p))$, otherwise θ generating r' would rather imitate type $\underline{\theta}(p)$ and IC would be violated.[26] Intuitively, the seller cannot commit to any price above the minimum possible valuation by the buyer since in case of a rejection she is always (weakly) tempted to sell the object with the minimum price. But this implies that the buyer is not willing to reveal any information to obtain the object since he is eventually going to get the object with the lowest possible price.

In literature on "durable good monopolies" (e.g. Fudenberg *et.al.* 1985, Gul *et.al.* 1986), the "Gap Case" $\underline{\theta}(p) > 0$ is well studied. The result is that as the time difference between successive offers approaches zero, seller's ability to gain any surplus above $\underline{\theta}(p)$. As both players anticipate that the seller is willing to sell the object at any price above her valuation, both parties benefit from speeding up the trade. The Coase conjecture the holds true: efficiency is reached and the buyer obtains most of the surplus. We now verify that this holds by using stable sets. Note that our set-up is more general in that we allow *any* trading mechanisms, not just simple price offers.

Lemma 2 *Suppose that* $\mathbf{G}$ *is a stable set. Take* p *such that* $\underline{\theta}(p) > 0$. *Then* $\mathbf{r}(\cdot : p) \in \mathbf{G}$ *if and only if* $\mathbf{r} = \mathbf{r}^*$.

Proof. "Only If": Suppose that $\mathbf{r}(\cdot : p) \in \mathbf{G}$ for $\underline{\theta}(p) > 0$, and $\mathbf{r} \neq \mathbf{r}^*$. By Corollary 2, $a = 1$, $t = \underline{\theta}(p(\mathbf{r}, r))$ for all $r = (a, t) \in \mathbf{r}(S : p)$. In particular, $\mathbf{r}(\underline{\theta}(p) : p) = (1, \underline{\theta}(p))$. Since any $\theta \geq \underline{\theta}(p)$ can report $\underline{\theta}(p)$, it follows by IC that $a = 1$ and $t \leq \underline{\theta}(p)$ for all $(a, t) \in \mathbf{r}(S : p)$. Thus, in fact, $\mathbf{r} = \mathbf{r}^*$.

"If": Suppose that $\mathbf{r}(\cdot : p) \notin \mathbf{G}$, for $\underline{\theta}(p) > 0$. But since $\mathbf{r} \neq \mathbf{r}^*$ implies $\mathbf{r}(\cdot : p) \notin \mathbf{G}$ by the "only if" part, $\mathbf{r}^*(p)$ cannot be upset by a mechanism in $\mathbf{G}$. ■

An obvious corollary of the previous result is that if *all* possible buyer's valuations are strictly higher than the seller's valuation, then the Gap Case is always valid and, hence, the Coase conjecture always holds. Thus, for a given probability measure there is a unique stable mechanism and, consequently, there is a unique stable set.[27]

Theorem 3 (Gap Case) *Let* $\Theta \subset \mathbb{R}_{++}$. *Then* $\mathbf{G}^*$ *is the unique strongly stationary stable set.*

Thus, would it be known that buyer's valuation is strictly higher than the seller's valuation, it follows that the seller *cannot* extract any surplus from the trade. The result is of interest since there may well be an optimal price for the object that the seller would wish to impose, while taking into account that some of the buyer's types would not be willing to pay the increased price. This phenomenon results from the fact that any "no-trade" situation would induce

[26] Typically the arguement is used when we apply the phrase "by IC, it follows that ...".

[27] Recall that Θ is closed by assumption.

the seller to propose another offer where some or all of the originally refused buyers would be willing to execute trade. In particular, an offer having a form of a constant mechanism would be profitable from the perspective of the seller and, by Lemma 1, the corresponding agreeable mechanism would be good.

However, in the No Gap case one obtains an completely reversed result: the amount of stable sets is very large (if Θ is infinite, then there are infinitely many stable sets).

Theorem 4 (No Gap Case) *Let $0 \in \Theta$. Then any price in Θ can be sustained by a stable mechanism.*

Proof. First, choose $\lambda \in \Theta$. Construct a transfer function

$$t^{\lambda}(p) = \inf \{\theta : \theta \in S(p), \theta \geq \lambda\},$$

and a mechanism

$$\mathbf{r}^{\lambda}(\theta : p) = (a^{\lambda}(\theta), t^{\lambda}(\theta)) = \begin{cases} (1, t^{\lambda}(p)), & \text{if } \theta \geq \lambda, \\ (0, 0), & \text{if } \theta < \lambda. \end{cases}$$

Now, construct set $\mathbf{G}^{\lambda}$ as follows

$$\mathbf{G}^{\lambda} = \left\{ \mathbf{r}(\cdot : p) : \begin{array}{l} \mathbf{r}^{\lambda}(\cdot : p) \text{ if } \underline{\theta}(p) = 0 \text{ and } \overline{\theta}(p) \geq \lambda, \\ \mathbf{r}^{*}(\cdot : p) \text{ if } \underline{\theta}(p) > 0 \text{ or } \overline{\theta}(p) < \lambda \end{array} \right\}.$$

We show that $\mathbf{G}^{\lambda}$ is a stable set. Clearly $\mathbf{G}^{\lambda}$ is internally consistent, thus it suffices to check it is externally consistent. Suppose there is no $\mathbf{r'}(\cdot : p(\mathbf{r}, r)) \in \mathbf{G}^{\lambda}$ which upsets $\mathbf{r}(\cdot : p) \notin \mathbf{G}^{\lambda}$, for any $r \in \mathbf{r}(S : p)$. There are two cases: (i) Case $\underline{\theta}(p) > 0$ or $\overline{\theta}(p) < \lambda$. For any $r \in \mathbf{r}(S : p)$, $\mathbf{1}_r(p(\mathbf{r}, r))$ is not upset by $\mathbf{r}^{*}(\cdot : p(\mathbf{r}, r))$ since necessarily $\underline{\theta}(p(\mathbf{r}, r)) > 0$ or $\overline{\theta}(p(\mathbf{r}, r)) < \lambda$. Thus it must be that $r = (1, \underline{\theta}(p(\mathbf{r}, r)))$. By IC it then follows that $\underline{\theta}(p(\mathbf{r}, r)) = \underline{\theta}(p)$ for all $r \in \mathbf{r}(S : p)$. But then $\mathbf{r}(\cdot : p) = \mathbf{r}^{*}(\cdot : p) \in \mathbf{G}^{\lambda}$, a contradiction. (ii) Case $\underline{\theta}(p) = 0$ and $\overline{\theta}(p) \geq \lambda$. By EXP-IR it follows that $\mathbf{r}(\underline{\theta}(p) : p) = r^{a} = (a, 0)$, $a \in [0, 1]$. Since $\mathbf{1}_{r^a}(p(\mathbf{r}, r^a))$ is not upset by $\mathbf{r}^{\lambda}(\cdot : p(\mathbf{r}, r^a))$ it follows that $\overline{\theta}(p(\mathbf{r}, r^a)) \leq \lambda$. But then, since $\mathbf{1}_{r^a}(p(\mathbf{r}, r^a))$ is not upset by $\mathbf{r}^{*}(\cdot : p(\mathbf{r}, r^a))$, it follows that $a = 1$. This implies, by IC, that $r = (1, 0)$ for all $r \in \mathbf{r}(S : p)$. Thus $\mathbf{r} = \mathbf{r}^{p}$. But then, since $\overline{\theta}(p) > \lambda$, $\mathbf{r}(\cdot : p)$ is upset by $\mathbf{r}^{\lambda}(\cdot : p) \in \mathbf{G}^{\lambda}$. Thus, $\mathbf{r}(\cdot : p) \notin \mathbf{G}^{\lambda}$. Hence, $\mathbf{G}^{\lambda}$ is stable. Finally, because λ can have any value on Θ, the theorem is proven. ■

The claim proven by constructing a partition whose good agreeable mechanisms have the property that first, for any p such that $\underline{\theta}(p) = 0$ and $\overline{\theta}(p) \geq \lambda$ for some number $\lambda > 0$, the corresponding stable mechanism $\mathbf{r}^{\lambda}$ is a take-it-or-leave-it offer for price λ : any valuation above or equal to λ accepts the offer and any valuation below λ rejects it. Second, if $\underline{\theta}(p) > 0$ or $\overline{\theta}(p) < \lambda$, then apply mechanism $\mathbf{r}^{*}$. To see why this partition is consistent, take the first situation. Suppose there is a good agrement $\mathbf{r}(\cdot : p)$ such that $\mathbf{r}$ is not the take-it-or-leave-it mechanism with price λ. Since $\mathbf{r}(\cdot : p)$ is not upset by a good agreeable mechanism, it is necessarily true that there is a no-trade recommendation r generating posterior $p(\mathbf{r},r)$ such that $\underline{\theta}(p(\mathbf{r},r))=0$ and $\overline{p}(\mathbf{r},r)\geq\lambda$. Otherwise mechanism $\mathbf{r}^*(p(\mathbf{r},r))$ would upset $\mathbf{1}_r(p(\mathbf{r},r))$. On the other hand, since $\mathbf{r}^\lambda(p(\mathbf{r},r))$ does not upset $\mathbf{1}_r(p(\mathbf{r},r))$, it must be that $\overline{p}(\mathbf{r},r)<\lambda$. Also, since $\mathbf{r}^*(p(\mathbf{r},r'))$ does not upset $\mathbf{1}_{r'}(p(\mathbf{r},r'))$ for any other recommendation r' of $\mathbf{r}$, it follows from VETO-IC that, in fact, $\mathbf{r}=\mathbf{r}^\lambda$. Thus, the partition is externally stable. Internal stability is easy to verify. Finally, since λ was chosen arbitrarily, the claim is proven.

The Theorem essentially says that in the No Gap case the seller can charge *any* price within a stable set. This result is analogous to Ausubel-Deneckere (1989) which proves that almost any outcome can be supported as a sequential equilibrium in the No Gap case. Their argument is based on reputational strategies: the seller can commit to any pricing behavior since deviating from such path would only trigger a subgame whose equilibrium gives the seller zero profit. However, such strategies do not satisfy the stationarity or a Markovian restriction imposed by Gul. *et al.*. We next establish an analogous result: agreeable mechanism formation in Theorem 2 contains "reputational" features that do not meet our stationarity restriction.

To identify agreeable mechanisms meeting the stationarity restriction, define function $\alpha:\Theta\to[0,1]$ such that

$$\alpha(\theta)=\arg\max_{a\in[0,1]}a\theta,\quad\text{for all }\theta\in S(p),$$

determining whether the object is allocated to the seller or the buyer. Note that α is efficient. Moreover, only in the case $\underline{\theta}(p)=0$ can it be that $0<\alpha(0)<1$. Thus, α's differ only by how the allocate the object in the case of a tie. Given p and α, construct mechanism $\mathbf{r}^\alpha$

$$\mathbf{r}^\alpha(\theta)=(a(\theta),t(\theta))=\alpha(\theta)\,(1,\underline{\theta}(p))\quad\text{for all }\theta\in\Theta.$$

Note that $\mathbf{r}^\alpha\in\mathbf{R}(p)$, for any α, and that $\mathbf{r}^\alpha=\mathbf{r}^*$ if $\underline{\theta}(p)>0$.

Theorem 5 *Let* $\mathbf{G}$ *be stable and strongly stationary. Then* $\mathbf{r}(\cdot:p)\in\mathbf{G}$ *only if* $\mathbf{r}=\mathbf{r}^\alpha$ *for some* α*, for any* $p\in\Delta^\Theta$*.*

Proof. We show that $\mathbf{r}(\cdot:p)\in\mathbf{G}$ implies $\mathbf{r}=\mathbf{r}^\alpha$ for some α. Suppose not. To obtain a contradiction, we proceed in number of steps.

Step 1: We claim that $\underline{\theta}(p)=0$. Suppose $\underline{\theta}(p)>0$. But then, by Lemma 2, $\mathbf{r}=\mathbf{r}^*$, a contradiction

Step 2: We claim that $\overline{\theta}(p)>0$ implies there is $r=(a,t)\in\mathbf{r}(S:p)$ such that $\overline{\theta}(p(\mathbf{r},r))>\underline{\theta}(p(\mathbf{r},r))=0$. Suppose not. Take any $\theta>0$ and $\mathbf{1}_r=\mathbf{r}(\theta:p)$ for $r=(a,t)$. By assumption $\underline{\theta}(p(\mathbf{r},r))>0$. By Corollary 2, $r=(1,\underline{\theta}(p(\mathbf{r},r)))$, $\theta\geq\underline{\theta}(p(\mathbf{r},r))$. Since this is true for any $\theta>0$, there is r^0 such that $r^0=(1,0)$. By IC it follows that $r'=(a',t')\in\mathbf{r}(S:p)$ implies $a'=1$ and $t'\leq0$. However, by Corollary 2, $t'=\underline{\theta}(p(\mathbf{r},r'))\geq0$. But then $r'=r$ and $p(\mathbf{r},r)=p(\mathbf{r},r')=p$. Thus $\overline{\theta}(p)=\overline{\theta}(p(\mathbf{r},r))>\underline{\theta}(p(\mathbf{r},r))=0$, a contradiction.

Step 3: By Steps 1 and 2 there is $r\in\mathbf{r}(S:p)$ and λ such that $\overline{\theta}(p(\mathbf{r},r))\geq\lambda>\underline{\theta}(p(\mathbf{r},r))=0$. Define $\mathbf{r}^\lambda$ as in Theorem 4. Now $\mathbf{r}^\lambda(p(\mathbf{r},r))$ upsets

$\mathbf{1}_r(p(\mathbf{r},r))$. Thus, by internal stability, $\mathbf{r}^\lambda(p(\mathbf{r},r)) \notin \mathbf{G}$ implying, by Remark 2, that $\mathbf{1}_{r^\lambda}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)) \notin \mathbf{G}$ for some $r^\lambda \in \{(0,0),(1,t^\lambda(p(\mathbf{r},r))\}$. If $r^\lambda = (1,t^\lambda(p(\mathbf{r},r))$, then $\mathbf{1}_{r^\lambda}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)) = \mathbf{r}^*(\cdot : p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda))$. Thus, by Theorem 2, $\mathbf{1}_{r^\lambda}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)) \in \mathbf{G}$, a contradiction. Therefore, $r^\lambda = (0,0)$ and $\underline{\theta}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)) = \underline{\theta}(p(\mathbf{r},r)) = 0$. By external stability, there is $\mathbf{r}'\left(\cdot : p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)\right) \in \mathbf{G}$ which upsets $\mathbf{1}_{r^\lambda}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda))$.

Step 4: Define $\mathbf{R}' = \{\mathbf{1}_{r'} : r' \in \mathbf{r}'(S : p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)), \underline{\theta}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)(\mathbf{r}',r')) = 0\}$. Since $\mathbf{G}$ meets strong stationarity, it follows that $\mathbf{1}_{r'} = \mathbf{1}_r = \mathbf{1}_{r^\lambda}$ for all $r' \in \mathbf{R}'$, thus $\mathbf{R}' = \{\mathbf{1}_{r^\lambda}\}$. Moreover, since $\mathbf{r}' \neq \mathbf{1}_{r^\lambda}$, it must be that $\overline{\theta}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)) > \overline{\theta}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)(\mathbf{r}',r^\lambda)) \equiv \kappa$. Construct $\mathbf{r}^\kappa$ as in Theorem 4. Then $r^\lambda \in \mathbf{r}^\kappa(p(\mathbf{r},r))$. Note that $p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)(\mathbf{r}',r^\lambda) = p(\mathbf{r},r)(\mathbf{r}^\kappa,r^\lambda)$. Thus, $\mathbf{1}_{r^\lambda}(p(\mathbf{r},r)(\mathbf{r}^\kappa,r^\lambda)) \in \mathbf{G}$ and, by applying Theorem 2 to the recommendations $\mathbf{r}(\theta)$ in cases $\theta > \overline{\theta}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)(\mathbf{r}',r^\lambda))$, it follows that $\mathbf{r}^\kappa(p(\mathbf{r},r)) \in \mathbf{G}$. However, $v(\mathbf{r}^\kappa,p(\mathbf{r},r)) \geq v(r) = 0$ and $\mathbf{r}^\kappa(p(\mathbf{r},r)) \neq \mathbf{1}_r$. Thus $\mathbf{r}^\kappa(p(\mathbf{r},r))$ upsets $\mathbf{r}(\cdot : p) \in \mathbf{G}$. But this violates internal consistency. ■

Roughly, the proof proceeds as follows: for any good agreeable mechanism $\mathbf{r}(\cdot : p)$ of a stable set with nondegenerate p it must necessarily be true that either $\mathbf{r} = \mathbf{r}^*$, or there is $\lambda > 0$ and a no-trade recommendation $r \in \mathbf{r}(S : p)$ such that $\mathbf{r}^\lambda(p(\mathbf{r},r))$ upsets $\mathbf{1}_r(p(\mathbf{r},r))$. The first property follows from Lemma 2, and the latter from VETO-IC. Thus, if $\mathbf{r} \neq \mathbf{r}^*$, then there is a good agreeable mechanism $\mathbf{r}'\left(\cdot : p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)\right)$ which upsets $\mathbf{1}_{r^\lambda}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda))$, for some $r^\lambda \in \mathbf{r}^\lambda(p(\mathbf{r},r))$. Next we identify a recommendation r' of mechanism $\mathbf{r}'$ such that $\underline{\theta}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)(\mathbf{r}',r')) = 0 < \overline{\theta}(p(\mathbf{r},r)(\mathbf{r}^\lambda,r^\lambda)(\mathbf{r}',r')) \equiv \kappa$, and construct a take-it-or-leave-it mechanism $\mathbf{r}^\kappa$ for price $\kappa < \lambda$. Now, if the partition meets the stationarity restriction, then agreeable mechanism $\mathbf{r}^\kappa(\cdot : p(\mathbf{r},r))$ must be good. But $\mathbf{r}^\kappa(\cdot : p(\mathbf{r},r))$ also upsets $\mathbf{r}(\cdot : p)$ violating internal consistency. Thus, if $\mathbf{r}(\cdot : p)$ is a good agreeable mechanism of a stable set meeting the stationarity restriction, then necessarily $\mathbf{r} = \mathbf{r}^*$.

Even though the results in the one-buyer case should not be too surprising, more interesting is that the analysis can be extended to the many-buyer case without complications. It is not clear how one should extend a purely non-cooperative framework of durable good monopoly situation to the many-buyer case.

3.2 The $n \geq 2$ Case

We now turn to the many-buyer case. For simplicity, assume from now on that $\Theta \subset \mathbb{R}^n_{++}$.[28] We construct mechanism $\mathbf{r}^\alpha$ which is a version of the English auction. To do that, we develop some concepts. Recall that $p_i(\theta_i : \theta_{-i})$ is determined for all $\theta \in S(p)$. For short, write $p_i(\theta_{-i})$ for $p_i(\cdot : \theta_{-i})$ and $p_{-i}(\theta_i)$ for $p_{-i}(\cdot : \theta_i)$. Denote by $\theta_{(k)}$ the k^{th} order statistics of $\theta = (\theta_1, ..., \theta_n)$. Let $\theta_{-(1)} = (\theta_{(k)})_{k>1}$. Denote by $p_{(1)}$ the distribution of $\theta_{(1)}$ given p, and by $p_{(1)}(\cdot : \theta_{-(1)}) = p_{(1)}(\theta_{-(1)})$ the conditional measure of θ_i given that $\theta_i = \theta_{(1)}$ and $\theta_{-(1)}$ are known. Then also $\underline{\theta}(p_{(1)}(\cdot))$ is uniquely determined with

$$\underline{\theta}(p_{(1)}(\theta_{-(1)})) = \inf S(p_{(1)}\left(\cdot : \theta_{-(1)}\right)), \qquad \text{for all } \theta \in S(p).$$

[28] Assuming otherwise would not change the insight.

Thus, $\underline{\theta}(p_{(1)}(\theta_{-(1)}))$ identifies the least upper bound of *winner's*[29] possible valuation above the second highest valuation, given the knowledge of nonwinners' valuations. Of course, $\underline{\theta}(p_{(1)}(\theta_{-(1)})) \geq \theta_{(2)}$ with equality under symmetrically independent types. As another example, let $n = 2$ and suppose $\theta_1 = c\theta_2$ for $c > 1$ for all $(\theta_1, \theta_2) \in S(p)$. Then $\underline{\theta}(p_{(1)}(\theta_{(2)})) = c\theta_2$.

For given $p \in \Delta^{\Theta}$, let function $\alpha : \Theta \to \Delta^{n-1}$ satisfy

$$\alpha(\theta) = \arg \max_{\alpha \in \Delta^{n-1}} \sum \alpha_i \theta_i, \quad \text{for all } \theta \in \Theta.$$

Thus α not only selects a winner in each state but also it specifies a tie-breaking rule for situations when there are more than one highest valuation. Only under tie can it be that $0 < \alpha_i(\theta) < 1$ for some i.

Construct mechanism $\mathbf{r}^{\alpha}$ as follows. For any $\theta \in \Theta$, $\mathbf{r}^{\alpha}(\theta : p) = (a, t, Y)$ satisfies,

$$(a_i, t_i) = \alpha_i(\theta) \left(1, \underline{\theta}(p_{(1)}(\theta_{-(1)})\right), \text{ for all } i \in N.$$

Thus $\mathbf{r}^{\alpha}$ is *efficient* and the winner pays a transfer equal to his smallest possible valuation *above* the second highest valuation.[30] For any $\theta \in S(p(\mathbf{r}^{\alpha}, r))$, we have

$$(a_i, t_i) = \begin{cases} (1, \underline{\theta}(p_{(1)}(\theta_{-(1)})), & \text{if } \theta_i > \max_{j \neq i} \theta_j, \\ (a, a\theta_i), & \text{if } \theta_i = \max_{j \neq i} \theta_j, \\ (0, 0), & \text{if } \theta_i < \max_{j \neq i} \theta_j. \end{cases}$$

Thus, recommendation reveals the winner and the price he pays. The price is less or equal to winner's valuation and at more than equal to any nonwinner's valuation. Given publicly revealed r, posterior belief $p(\mathbf{r}^{\alpha}, r)$ then satisfies

$$\begin{aligned} \underline{\theta}(p_i(\mathbf{r}^{\alpha}, r)) &\geq \overline{\theta}(p_j(\mathbf{r}^{\alpha}, r)) \text{ if } a_i = 1, \\ \underline{\theta}(p_i(\mathbf{r}^{\alpha}, r)) &= \overline{\theta}(p_i(\mathbf{r}^{\alpha}, r)) \geq \overline{\theta}(p_j(\mathbf{r}^{\alpha}, r)) \text{ if } a_i \in (0, 1). \end{aligned}$$

Only in the case of a tie we may have $a_i \in (0, 1)$, revealing that i's valuation is t_i. Assume that $\mathbf{r}^{\alpha}$ does not reveal finer information that is needed to implement (a, t): signal Y satisfies $Y = (\mathbf{r}^{\alpha})^{-1}(a, t : p)$. Abusing notation, we continue writing simply $r = (a, t)$.

Note the familiar structure of the mechanism: winner's announcement does not affect his transfer to the seller as long as he wins. The transfer is determined by other buyers' announcements. In the case of independent p_i's, $\mathbf{r}^{\alpha}$ coincides with the English or the Second Price auctions in terms of payoffs and allocations. As VETO-IC is more restrictive than IC and interim IR, it may not be obvious that the mechanism meets it. To remove any doubts, the next Lemma argues this is the case.[31] For the proof, see Appendix A.1.

Lemma 3 $\mathbf{r}^{\alpha} \in \mathbf{R}(p)$, *for all* $p \in \Delta^{\Theta}$.

[29] Buyer with the highest valuation.

[30] Note that $\mathbf{r}^{\alpha}$'s differ only by tie-beaking rule. This does not affect the incentive properties of our mechanisms.

[31] See Riley (1988) for a closely related arguemtn.

Note that any mechanisms that is subject to ex post vetoing and whose price is not contingent to winner's exact valuation. Therefore, overreporting is not dominated since a buyer is entitled to veto if the price is less than his valuation whenever he wins. Thus, a nuisance strategy where a buyer chooses a very high report and then vetoes when EXP-IR is violated is a best response. Nevertheless, also the truthful strategy is a (weakly) *dominant strategy*. Problems with this multiplicity of equilibria can be avoided by modifying the VETO-IC constraint, e.g. by imposing a fee for vetoing at off-the-equilibrium path.[32] However, what really really matters in the present paper is the EXP-IR at the equilibrium path.

First we show there exists a strongly stationary stable set that contains $\mathbf{r}^{\alpha}$. Construct set $\mathbf{G}^{\alpha}$ as follows:

$$\mathbf{G}^{\alpha} = \left\{ \mathbf{r}\left(\cdot : p\right) : \mathbf{r}\left(\cdot : p\right) \text{ is not upset by } \mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)\right),\ r \in \mathbf{r}(S : p),\ p \in \Delta^{\Theta} \right\}.$$

Theorem 6 $\mathbf{G}^{\alpha}$ *is a strongly stationary stable set.*

Proof. First, note that $\mathbf{1}_r(p(\mathbf{r}^{\alpha}, r)) = \mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}^{\alpha}, r)\right)$ for all $r \in \mathbf{r}^{\alpha}(S : p)$. Thus $\mathbf{r}^{\alpha}\left(\cdot : p\right)$ is not upset by $\mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}^{\alpha}, r)\right)$ and, consequently, $\mathbf{r}^{\alpha}\left(\cdot : p\right) \in \mathbf{G}^{\alpha}$ for all $p \in \Delta^{\Theta}$.

Internal stability: Suppose that $\mathbf{1}_r\left(p(\mathbf{r}, r)\right)$ is upset by $\mathbf{r}'\left(\cdot : p(\mathbf{r}, r)\right),\ r \in \mathbf{r}(S : p)$, $\mathbf{r}\left(\cdot : p\right) \in \mathbf{G}^{\alpha}$. It suffices to show that then $\mathbf{r}'\left(\cdot : p(\mathbf{r}, r)\right)$ is upset by some $\mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)(\mathbf{r}', r')\right),\ r' \in \mathbf{r}'(S : p(\mathbf{r}, r))$. *Per absurdum*, suppose not.

By contruction, $\mathbf{1}_r(p(\mathbf{r}, r))$ is not upset by $\mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)\right)$ for $r = (a, t) \in \mathbf{r}(S : p)$. Then, in fact, $\mathbf{1}_r(p(\mathbf{r}, r)) = \mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)\right)$. Similarly, by supposition $\mathbf{1}_{r'}(p(\mathbf{r}, r)(\mathbf{r}', r'))$ is not upset by $\mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)(\mathbf{r}', r')\right)$, and it must be that $\mathbf{1}_{r'}(p(\mathbf{r}, r)(\mathbf{r}', r')) = \mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)(\mathbf{r}', r')\right)$. There are two cases to consider:

(i) There is winner i such that $a_i \in (0, 1)$. Then $\underline{\theta}(p_i(\mathbf{r}, r)) = \overline{\theta}(p_i(\mathbf{r}, r))$. But then $\mathbf{r}'\left(\cdot : p(\mathbf{r}, r)\right) = \mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)\right) = \mathbf{1}_r\left(p(\mathbf{r}, r)\right)$, and $\mathbf{r}'\left(\cdot : p(\mathbf{r}, r)\right)$ does not upset $\mathbf{1}_r\left(p(\mathbf{r}, r)\right)$.

(ii) There is winner i such that $a_i = 1$. Then $\underline{\theta}(p_i(\mathbf{r}^{\alpha}, r)) \geq \overline{\theta}(p_j(\mathbf{r}^{\alpha}, r))$ for $j \neq i$. Since $\mathbf{1}_{r'}(p(\mathbf{r}, r)(\mathbf{r}', r')) = \mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)(\mathbf{r}', r')\right)$ we have $a_i' = 1$, for all $r' = (a', t') \in \mathbf{r}'(S : p(\mathbf{r}, r))$. Consequently, by IC, $t' = \underline{\theta}(p_i(\mathbf{r}, r))$ for all $r' = (a', t')$. But then $\mathbf{r}'\left(\cdot : p(\mathbf{r}, r)\right) = \mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)\right) = \mathbf{1}_r\left(p(\mathbf{r}, r)\right)$, and $\mathbf{r}'\left(\cdot : p(\mathbf{r}, r)\right)$ does not upset $\mathbf{1}_r\left(p(\mathbf{r}, r)\right)$.

External stability: Take $\mathbf{r}\left(\cdot : p\right) \notin \mathbf{G}^{\alpha}$. Since $\mathbf{r}\left(\cdot : p\right) \neq \mathbf{G}^{\alpha}$, it follows that $\mathbf{r}\left(\cdot : p\right)$ is upset by some $\mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)\right),\ r = (a, t) \in \mathbf{r}(S : p)$. Since $\mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)\right) \in \mathbf{G}^{\alpha}$, by the first part of the proof, external stability is met.

Finally, by construction $\mathbf{r}^{\alpha}\left(\cdot : p(\mathbf{r}, r)\right) = \mathbf{1}_r\left(p(\mathbf{r}, r)\right)$ for all $r \in \mathbf{r}(S : p)$ such that $\mathbf{r}\left(\cdot : p\right) \in \mathbf{G}^{\alpha}$. Thus the partition meets the strong stationarity property. ■

Thus, $\mathbf{r}^{\alpha}$ mechanisms have the nice property that they are robust against commitment problems. The intuition behind the argument is exactly the same

[32] Under such construction one should be able to punish any player who vetoes given recommendation of the mechanism once one has taken the EXP-IR into account when designing the mechanism. Also, one could require EXP-IR to be satisfied only at the *equilibrium path*. This would be perhaps the most straightforward application of the EXP-IR constraint.

as in the one buyer case. The seller *can* commit to a mechanism which always delivers the good to the winner with a price separating the highest possible valuation of the other buyers from the winner valuation. The reason for this is by now familiar: she *cannot* commit to raising the price any further since in the case of a rejection in the continuation game she is always (weakly) tempted to sell the object to the winner with the minimum price. This is due the fact in any other reasonable scenario she would need to sell the object with a (weakly) lower price to some other buyer having at most as high valuation as the winner. Thus, if mechanism $\mathbf{r}^*$ is stable in the one buyer case, then also $\mathbf{r}^\alpha$ should be stable in the multiple buyer case.

Furthermore, it is interesting that $\mathbf{r}^\alpha$ mechanisms are the *only* ones that are robust against commitment problems in our sense. To prove this, we first show that for all priors there is always exists one α such that $\mathbf{r}^\alpha(\cdot : p) \in \mathbf{G}$ for stable set $\mathbf{G}$ which is strongly stationary.

Theorem 7 *Let* $\mathbf{G}$ *be a strongly stationary stable set. Then* $\mathbf{r}^\alpha(\cdot : p) \in \mathbf{G}$*, for all* $p \in \Delta^\Theta$.

Proof. To obtain a contradiction, suppose that there is $p \in \Delta^\Theta$ such that $\mathbf{r}^\alpha(\cdot : p) \notin \mathbf{G}$. By Remark 2 there is $r^\alpha \in \mathbf{r}^\alpha(S : p)$ such that $\mathbf{1}_{r^\alpha}(p(\mathbf{r}^\alpha, r^\alpha)) \notin \mathbf{G}$. By external stability, there is $\mathbf{r}(\cdot : p(\mathbf{r}^\alpha, r^\alpha)) \in \mathbf{G}$ which upsets $\mathbf{1}_{r^\alpha}(p(\mathbf{r}^\alpha, r^\alpha))$. Thus it suffices to show that existence of $\mathbf{r}(\cdot : p(\mathbf{r}^\alpha, r^\alpha))$ violates strong stationarity.

To proceed, we use the same argument as in the $n = 1$ case. We need to replace the seller (with valuation 0) to the buyers $j \neq i$ with valuation $\theta_j \leq \underline{\theta}(p_{(1)}(\theta_{-(1)}))$. In the $n = 1$ case the seller is indifferent between selling or not (= selling it to himself with price 0) the object with price 0 whereas here the seller is indifferent between selling the object to i with price $\underline{\theta}(p_{(1)}(\theta_{-(1)}))$ or selling it to some $j \neq i$ with the same price. We proceed in number of steps (analogous to those in Theorem 5). For simplicity, write $p^\alpha = p(\mathbf{r}^\alpha, r^\alpha)$.

Step 1: We claim that $\underline{\theta}(p_i^\alpha) = \overline{\theta}(p_j^\alpha)$ for some $j \neq i$. Suppose $\underline{\theta}(p_i^\alpha) > \overline{\theta}(p_j^\alpha)$ for all $j \neq i$. Since $\mathbf{r}(\cdot : p^\alpha) \in \mathbf{G}$, it follows that $\mathbf{1}_r(p) \in \mathbf{G}$ for all $r \in \mathbf{r}(S : p^\alpha)$. Since $\underline{\theta}(p_i^\alpha(\mathbf{r}, r)) \geq \underline{\theta}(p_i^\alpha) > \overline{\theta}(p_j^\alpha) \geq \overline{\theta}(p_j^\alpha(\mathbf{r}, r))$ for all $r \in \mathbf{r}(S : p^\alpha)$ we have, by Corollary 2, that $r_i = (1, \underline{\theta}(p_i^\alpha(\mathbf{r}, r)))$. But then, by IC it follows that $\underline{\theta}(p_i^\alpha(\mathbf{r}, r)) = \underline{\theta}(p_i^\alpha)$ for all $r \in \mathbf{r}(S : p^\alpha)$. Thus $\mathbf{1}_r(p^\alpha) = \mathbf{1}_{r^\alpha}(p^\alpha) = \mathbf{r}^\alpha(\cdot : p^\alpha)$, a contradiction.

Step 2: We claim that $\overline{\theta}(p_i^\alpha) > \underline{\theta}(p_i^\alpha)$ implies there is $r = (a, t) \in \mathbf{r}(S : p^\alpha)$ such that $\overline{\theta}(p_i^\alpha(\mathbf{r}, r)) > \underline{\theta}(p_i^\alpha(\mathbf{r}, r)) = \underline{\theta}(p_i^\alpha)$. Suppose not. Then $\underline{\theta}(p_i^\alpha(\mathbf{r}, r)) > \underline{\theta}(p_i^\alpha)$ for all $r = (a, t) \in \mathbf{r}(S : p^\alpha)$. By Corollary 2, $r_i = (1, \underline{\theta}(p_i^\alpha(\mathbf{r}, r)))$ for all such r. Again, by IC $\mathbf{r}(\cdot : p^\alpha) = \mathbf{1}_{r^\alpha}(p^\alpha) = \mathbf{r}^\alpha(\cdot : p^\alpha)$, a contradiction.

Now, construct mechanism $\mathbf{r}^\lambda$ as follows: for any p and $\lambda \in \mathbb{R}$ construct function

$$t_k^\lambda(p) = \inf\{\theta_k : \theta_k \in S(p_k), \theta_k \geq \lambda\},$$

and define the mechanism, for $k \in N$, by supposing that $\lambda > \overline{\theta}(p_j)$ for all $j \neq i$ for some $i \in N$

$$\mathbf{r}_k^\lambda(\theta) = (a_k^\lambda(\theta), t_k^\lambda(\theta)) = \begin{cases} (1, t_k^\lambda(p)), & \text{if } \theta_k \geq \lambda, \theta \in S(p), \\ (0, 0), & \text{otherwise.} \end{cases} \tag{4}$$

Step 3: By Step 1 and 2, there is $r \in \mathbf{r}(S : p^{\alpha})$ and λ such that $\overline{\theta}(p_i^{\alpha}(\mathbf{r}, r)) \geq \lambda > \underline{\theta}(p_i^{\alpha}(\mathbf{r}, r)) = \underline{\theta}(p_i^{\alpha}) = \overline{\theta}(p_j^{\alpha})$. Now $\mathbf{r}^{\lambda}(p^{\alpha}(\mathbf{r}, r))$ upsets $r(p^{\alpha}(\mathbf{r}, r))$. Thus, by internal stability, $\mathbf{r}^{\lambda}(p^{\alpha}(\mathbf{r}, r)) \notin \mathbf{G}$ implying, by Remark 2, that $\mathbf{1}_{r^{\lambda}}(p^{\alpha}(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})) \notin \mathbf{G}$ for some r^{λ} such that $r_i^{\lambda} \in \{(0,0), (1, t_i^{\lambda}(p^{\alpha}(\mathbf{r}, r))\}$. If $r_i^{\lambda} = (1, t_i^{\lambda}(p^{\alpha}(\mathbf{r}, r))$, then $\mathbf{1}_{r^{\lambda}}(\underline{\theta}(p_i(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})) > \overline{\theta}(p_j^{\alpha}(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda}))$ for $j \neq i$. Thus, by Corollary 2, $\mathbf{1}_{r^{\lambda}}(\underline{\theta}(p_i^{\alpha}(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda}))) \in \mathbf{G}$, a contradiction. Therefore, $r_i^{\lambda} = (0,0)$ and $\underline{\theta}(p_i^{\alpha}(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})) = \underline{\theta}(p_i^{\alpha}(\mathbf{r}, r)) = \overline{\theta}(p_j^{\alpha})$. By external stability, there is $\mathbf{r}'\left(\cdot : p^{\alpha}(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})\right) \in \mathbf{G}$ which upsets $\mathbf{1}_{r^{\lambda}}(p^{\alpha}(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda}))$.

Step 4: Define

$$\mathbf{R}' = \{\mathbf{1}_{r'} : r' \in \mathbf{r}'(S : p^{\alpha}(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})), \underline{\theta}(p_i(\mathbf{r}, r)) = \underline{\theta}(p_i(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})(\mathbf{r}', r'))\}.$$

Since $\mathbf{G}$ is strongly stationary it follows that $\mathbf{1}_{r'} = \mathbf{1}_{r} = \mathbf{1}_{r^{\lambda}}$ for all $\mathbf{1}_{r'} \in \mathbf{R}'$, thus $\mathbf{R}' = \{\mathbf{1}_{r^{\lambda}}\}$. Moreover, since $\mathbf{r}' \neq \mathbf{1}_{r^{\lambda}}$, it must be that $\overline{\theta}(p_i(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})) > \overline{\theta}(p_i(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})(\mathbf{r}', r^{\lambda})) \equiv \kappa$. Construct $\mathbf{r}^{\kappa}$ as in (4). Note that $p^{\alpha}(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})(\mathbf{r}', r^{\lambda}) = p^{\alpha}(\mathbf{r}, r')(\mathbf{r}^{\kappa}, r^{\lambda})$. Thus, $\mathbf{1}_{r^{\lambda}}(p^{\alpha}(\mathbf{r}, r)(\mathbf{r}^{\kappa}, r^{\lambda})) \in \mathbf{G}$ and, by applying Corollary 2 to the recommendations submitted in cases $\theta_i > \overline{\theta}(p_i(\mathbf{r}, r)(\mathbf{r}^{\lambda}, r^{\lambda})(\mathbf{r}', r^{\lambda}))$, it follows that $\mathbf{r}^{\kappa}(p^{\alpha}(\mathbf{r}, r)) \in \mathbf{G}$. However, $v(\mathbf{r}^{\kappa}, p(\mathbf{r}, r)) \geq v(r) = \underline{\theta}(p_i(\mathbf{r}, r))$ and $\mathbf{r}^{\kappa}(\cdot : p^{\alpha}(\mathbf{r}, r)) \neq \mathbf{1}_r(p^{\alpha}(\mathbf{r}, r))$. Thus $\mathbf{r}^{\kappa}(\cdot : p^{\alpha}(\mathbf{r}, r))$ upsets $\mathbf{r}(\cdot : p^{\alpha}) \in \mathbf{G}$. But this violates internal consistency. ■

Any recommendation generated by $\mathbf{r}^{\alpha}$ reveals the buyer with the highest valuation and the greatest lower bound of his possible valuations which is higher than the least upper bound of any other buyer's valuation. Therefore, the above theorem is analogous to Theorem 2 in that all that needs to be shown is that if there is a good agreeable mechanism which upsets $\mathbf{r}^{\alpha}(\cdot : p)$, then the stationarity restriction is necessarily violated. One can think the situation as the one where seller's valuation is upgraded to match the least upper bound of nonwinners' valuations. In such case, by Lemma 2 we can safely disregard all the other buyers but the winner. But then the problem of the seller is identical with the one buyer case, and one can use the same argument as in Theorem 2 to show that $\mathbf{1}_r(p)$ is the only agreeable mechanism satisfying the stationarity restriction, for any $r \in \mathbf{r}^{\alpha}(S : p)$..

The following Corollary follows immediately from the previous therem. It highlights the "Coasian" flavor of the solution in the multiple buyer case.

Corollary 3 *Let* $\mathbf{G}$ *be strongly stationary stable set. Then* $\mathbf{r}(\cdot : p) \in \mathbf{G}$ *only if (i)* $\mathbf{r}$ *is efficient, and (ii)* $v(\mathbf{r}(\theta : p)) \geq \underline{\theta}(S(p_{(1)}(\theta_{-(1)}))) \geq \theta_{(2)}$ *for all* $\theta \in \Theta$.

To see why $(\mathbf{r}, r) \in \mathbf{G}$ implies $\mathbf{r}$ is efficient, note that otherwise there would be agreeable mechanism $(\mathbf{r}^{\alpha}, p(\mathbf{r}, r))$ which would upset any inefficient $(r, p(\mathbf{r}, r))$ such that $r \in \mathbf{r}(S : p)$. Since $(\mathbf{r}^{\alpha}, p)$ is good for some α, an inefficient agreeable mechanism could never satisfy external stability. For the same reason, since buyer can always safely use mechanism $\mathbf{r}^{\alpha}$, it must be true that her payoff in each state is at least as high as the second highest valuation. The above result strengthens the Coase conjecture in that commitment inability leads to the efficient allocation of the object. To my knowledge, this result is new in a multi-buyer incomplete information environment.[33] Therefore, the analysis provides stronger motivation for the Coase conjecture than has been proposed in the literature.

Furthermore, given (i) and (ii) of the previous corollary, it follows immediately from the *Revenue Equivalence Theorem* that in the independent values case the English auction is (essentially) the *only* feasible auction mechanism. However, we can say more. The next theorem says that if the type space *finite* (or an infinite set is approximated by a discretizated), then the English auction is the *only* feasible mechanism for *all* priors. (Alternatively, we could assume the existence of a smallest monetary unit.).

Theorem 8 *Let* $\mathbf{G}$ *be a strongly stationary stable set and* Θ *finite. Then* $\mathbf{r}(\cdot : p) \in \mathbf{G}$ *if and only if* $\mathbf{r}(\theta : p) = \mathbf{r}^{\alpha}(\theta : p)$ *for all* p.

Proof. We know that $\mathbf{r}^{\alpha}(\cdot : p) \in \mathbf{G}$, for all p. Now we show the converse: given p, if $\mathbf{r}(\cdot : p) \in \mathbf{G}$ then $\mathbf{r}(\cdot : p) = \mathbf{r}^{\alpha}(\cdot : p)$. Take $\mathbf{r}(\cdot : p) = (a(\cdot), t(\cdot)) \in \mathbf{G}$. Write $\underline{\theta}_i = \underline{\theta}(p_i)$ and denote $Y_{-i}(\theta_i, p) = \{\theta_{-i} \in S(p_{-i}(\theta_i)) : \theta_i = \max_{j \in N} \theta_j\}$. By Corollary 3 and EXP-IR we have, for $\theta_{-i} \in Y_{-i}(\theta_i, p)$, that

$$a_i(\theta_{-i}, \theta_i) > 0 \text{ and } \theta_i \geq t_i(\theta_{-i}, \theta_i) \geq \underline{\theta}(p_{(1)}(\theta_{-(1)})). \tag{5}$$

By the efficiency of $\mathbf{r}$, it suffices to show that $t_i(\theta_{-i}, \theta_i) = \underline{\theta}(p_{(1)}(\theta_{-(1)}))$, for all $\theta_i \in Y_{-i}(\theta_i, p)$.

By (5),

$$\begin{aligned} \mathbb{E}_p\left[u\left(\mathbf{r}\left(\theta_{-i}, \theta_i' : p\right), \theta_i\right)\right] &= \sum_{\theta_{-i} \in \Theta_{-i}} \left[a_i(\theta_{-i}, \theta_i')\theta_i - t_i(\theta_{-i}, \theta_i')\right] p_{-i}\left(\theta_{-i} : \theta_i\right) \\ &= \sum_{\theta_{-i} \in Y_{-i}(\theta_i', p)} \left[\theta_i - t_i(\theta_{-i}, \theta_i')\right] p_{-i}\left(\theta_{-i} : \theta_i\right). \end{aligned}$$

Let $\theta_i^+ = \min\{\theta_i' \in S(p_i) : \theta_i' > \theta_i\}$. Note that $Y_{-i}(\theta_i, p) \cap S(p_{-i}(\theta^+)) \subseteq Y_{-i}(\theta_i^+, p)$. By construction, $\underline{\theta}(p_{(1)}(\theta_{-(1)})) = \theta_i^+$ for all $\theta_{-i} \in Y_{-i}(\theta_i^+, p) \setminus [Y_{-i}(\theta_i, p) \cap S(p_{-i}(\theta^+))]$ and, by (5), for these θ_{-i},

$$t_i(\theta_{-i}, \theta_i^+) = \theta_i^+. \tag{6}$$

By IC, we have

$$\begin{aligned} &\sum_{\theta_{-i} \in Y_{-i}(\theta_i^+, p)} \left[\theta_i^+ - t_i(\theta_{-i}, \theta_i^+)\right] p_{-i}\left(\theta_{-i} : \theta_i^+\right) \\ \geq &\sum_{\theta_{-i} \in Y_{-i}(\theta_i^+, p)} \left[\theta_i^+ - t_i(\theta_{-i}, \theta_i)\right] p_{-i}\left(\theta_{-i} : \theta_i^+\right) \end{aligned}$$

[33] Milgom (1987) analyzes a *deterministic* auction situation, where all the players know each others' valuations. He shows that any *core* outcome in such scenario leads to the effcient allocation of resources. Of course, his analysis does not imply that efficiency is reached also in the incomplete information framework.

or

$$\sum_{\theta_{-i}\in Y_{-i}(\theta_i^+,p)\setminus Y_{-i}(\theta_i,p)} \left[\theta_i^+ - t_i(\theta_{-i},\theta_i^+)\right] p_{-i}\left(\theta_{-i}:\theta_i^+\right)$$
$$\geq \sum_{\theta_{-i}\in Y_{-i}(\theta_i^+,p)\setminus Y_{-i}(\theta_i,p)} \left[\theta_i^+ - t_i(\theta_{-i},\theta_i)\right] p_{-i}\left(\theta_{-i}:\theta_i^+\right)$$
$$+ \sum_{\theta_{-i}\in Y_{-i}(\theta_i,p)} \left[t_i(\theta_{-i},\theta_i^+) - t_i(\theta_{-i},\theta_i)\right] p_{-i}\left(\theta_{-i}:\theta_i^+\right).$$

By (5), $\theta_i^+ > \theta_i \geq t_i(\theta_{-i},\theta_i)$. By this and (6) we have (note that θ_{-i} has positive probability only in $S(p_{-i}(\theta^+))$)

$$\sum_{\theta_{-i}\in Y_{-i}(\theta_i,p)\cap S(p_{-i}(\theta^+))} \left[t_i(\theta_{-i},\theta_i^+) - t_i(\theta_{-i},\theta_i)\right] p_{-i}\left(\theta_{-i}:\theta_i^+\right) \leq 0. \qquad (7)$$

Now, *suppose* that θ_i satisfies

$$t_i(\theta_{-i},\theta_i) = \underline{\theta}(p_{(1)}(\theta_{-(1)})), \text{ for all } \theta_{-i}\in Y_{-i}(\theta_i,p). \qquad (8)$$

That is, the i^{th} component of $\mathbf{r}$ agrees with $\mathbf{r}^\alpha$ at θ_i. As $Y_{-i}(\theta_i,p)\cap S(p_{-i}(\theta^+)) \subseteq Y_{-i}(\theta_i^+,p)$, we have by (5),

$$\underline{\theta}(p_{(1)}(\theta_{-(1)})) \leq t_i(\theta_{-i},\theta_i^+), \text{ for all } \theta_{-i}\in Y_{-i}(\theta_i,p)\cap S(p_{-i}(\theta^+)). \qquad (9)$$

Thus, by (7), the weak inequality in (9) must hold as equality for all $\theta_{-i} \in Y_{-i}(\theta_i^+,p)$. Therefore, (8) implies

$$t_i(\theta_{-i},\theta_i^+) = \underline{\theta}(p_{(1)}(\theta_{-(1)})), \text{ for all } \theta_{-i}\in Y_{-i}(\theta_i,p)\cap S(p_{-i}(\theta^+)).$$

This together with (6) implies

$$t_i(\theta_{-i},\theta_i^+) = \underline{\theta}(p_{(1)}(\theta_{-(1)})), \text{ for all } \theta_{-i}\in Y_{-i}(\theta_i^+,p).$$

Finally, order the elements of $S(p_i)$ by $\theta_i^0 < ... < \theta_i^K$ for some finite K. The initial step $\theta_i^0 = \underline{\theta}_i$ obviously satisfies property (8). Replace $\theta_i = \theta_i^k$ and $\theta_i^+ = \theta^{k+1}$ for $k = 0,...,K-1$. By the argument above, use induction to get

$$t_i(\theta_{-i},\theta_i^k) = \underline{\theta}(p_{(1)}(\theta_{-(1)})), \text{ for all } \theta_{-i}\in Y_{-i}(\theta_i^k,p) \text{ for all } k = 0,...,K-1,$$

which was to be shown. ■

To get the intuition, le $\Theta_i = \{1,2\}$ for all i, and suppose p has full support, $S(p) = \{1,2\}^n$. If $\theta_i = 1$, then i cannot ever gain any surplus. only be winner if $\theta_j = 1$ for all $j \neq 1$ and then

3.3 Summary and Interpretation

In the light of stable sets, the main problem for the seller is to construct a mechanism which is not destabilized by any good agreeable mechanism. In the standard case, the simplest way to do this is, first, to elicit information regarding who has the highest valuation for the object, say i, and, second, elicit information of the exact valuation of the other buyers'. Call mechanism that performs this task by $\mathbf{r}^{\alpha}$. When this information is public the seller *can* commit to selling the object to the player i since anything else would require her to make an incredible threat of selling the object to some other buyer with a lower price. By the same argument as in the one buyer case, such agreeable mechanism would be upset by a good agreeable mechanism within any stable set meeting the stationarity property. Knowing this, i would not reveal information regarding his valuation since he can always buy the object with the price of his lowest possible valuation. Hence, agreeable mechanism employing $\mathbf{r}^{\alpha}$ is indeed good. Moreover, unless an agreeable mechanism is robust against upsetting by an agreeable mechanism employing $\mathbf{r}^{\alpha}$, then the agreeable mechanism is bad. This restriction in turn implies that any good agreeable mechanism is efficient. In the case of independent absolutely continuous valuations, this result is very forceful, and by the Revenue Equivalence Theorem together with the observation that in each state the price is at least the second highest valuation, it follows that any stable mechanism must be generically equivalent with $\mathbf{r}^{\alpha}$.

What is the interpretation of mechanism $\mathbf{r}^{\alpha}$ which was used as a workhorse in the previous analysis? Interestingly, the informational properties of mechanism $\mathbf{r}^{\alpha}$ *cannot* be associated to any other standard auction form than the *English auction*: the English auction reveals the magnitude of the second highest valuation and the player with the highest valuation. For example, in the Dutch or in the First Price auctions bidding strategies in the efficient equilibrium are strictly increasing in buyers' types.[34] Such strategies necessarily reveal too much information to have desirable stability properties. The Second Price (Vickrey) auction requires that there is an impartial mediator which converts buyers' bids to recommendations and, in particular, does not reveal players' announcements to the seller. In the absence of such mediation, the Second Price auction is not applicable. Thus, the English auction is the only standard auction form which has required informational properties and, conversely, any stable auction mechanism must have informational and allocational properties which closely resemble those of the English auction (the only variation can only concern the extent that valuations below the second highest valuation are revealed).

4 Robustness of the Model

Risk aversion. If buyers are *risk averse* things become more complex in the standard auction design scenario.[35] For example, revenue equivalence breaks

[34] In the Dutch or first price sealed bid auctions, there typically exist also inefficient equilibria. Obviously, they cannot be associated with $\widehat{\pi}$

[35] For analysis, see e.g. Maskin-Riley (1984) or Matthews (1987).

down and the English auction is not the optimal auction form even in the symmetric case. However, or results are fairly insensitive to risk aversion. To see why, observe that Lemma 1, which was fundamental for the analysis, holds true whenever utility for money is *strictly increasing*. Also, as the take-it-or-leave-it offers and the English auction meet the VETO-IC with any such utility specification, our arguments should be extendable to cover this case as well. It is also interesting that some inconvenient structures of optimal auctions under risk aversion (elaborated entry fee and penalty systems) cannot be entertained by any stable mechanism.

Other motivations for stationarity The stationarity restriction is rather demanding: the seller cannot even weakly commit to the imposed mechanism. In a more complete model with repeated interaction this assumption may not be natural. Are there ways recover the results even without the stationarity restriction? There are several slight modifications of the model that allow us to do that. An obvious restriction is to assume that $\Theta \subset \mathbb{R}^n_{++}$ is a discrete set where ties never materialize. In such case the Gap Case is always valid, and stationarity restriction never needed. Another option is to modify seller's payoff function. By letting the seller be slightly concerned about the general welfare, redefine the seller's utility as follows: $v(r, \theta, \lambda) = v(r) + \lambda(u_1(r, \theta_1) + ... + u_n(r, \theta_n))$, for any small $\lambda > 0$. Defining the upsetting relation with respect to this utility specification would imply that (i) the no-trade agreeable mechanism, (ii) the agreeable mechanism which sells the object to the second highest bidder is always upset by a constant agreeable mechanism. Therefore, such agreeable mechanisms cannot ever be good. Consequently, the stationarity restriction is not needed.

5 Concluding Remarks

In this study, we have focused on auction mechanisms under the hypothesis that no player can commit to the completion of a mechanism. Buyers' inability to make commitments manifests itself as an assumption that they can choose their outside option at any stage of the mechanism. Seller's commitment inability in turn gives her the option to reformulate the rules of the auction mechanism at any stage of the mechanism. The first problem is taken care of by appropriately reformulating the incentive and participation constraints. To cope with the latter problem, we have developed a solution concept.

Our solution concept is based on the notion of stable sets, introduced by von-Neumann and Morgenstern (1944) and further developed by Greenberg (1990). Our main findings strengthens the famous Coase conjecture: given the inability to make binding commitments, any acceptable, or stable, mechanism must be *efficient*. Intuitively, the reason for this is that with any inefficient mechanism the seller cannot commit not to exploit further trading opportunities. Therefore, inefficient mechanism are subject to renegotiation at the ex post stage. However, any efficient mechanism which sells the object to a buyer with the highest valuation by price at least as high as the second highest valuation cannot be credibly instabilized since any profitable deviation from such mechanism at the ex post stage would entail that the object is allocated inefficiently under some states. By the previous argument, such mechanism cannot be stable and therefore the deviation is not credible.

By this argument, it follows also that in the independent valuations case the only stable auction mechanism is a version of the *English auction*. In particular, no other commonly used auction mechanism have similar stability properties. Thus, our result can be viewed as an explanation of why the English auction is one of the most commonly used auction forms.

Hence, the stable set apparatus seems to be very fruitful tool in analyzing commitment problems in mechanism design scenario. Even though the approach is motivated by noncooperative reasoning, it abstracts us from involved analysis of perfect Bayesian equilibria of any dynamic noncooperative model where the seller cannot make binding commitments. Also, our approach is advantageous relative standard noncooperative approach in that it allows one to focus on the general class of feasible auction mechanisms. Therefore we do not need to specify a priori the actual form of the bidding game that is used.[36] It is not obvious why a particular bidding game would be more natural than another.

[36] Which would be necessary if one would merely replicate the approach of the durable good monopoly literature to this multi-buyer situation.

A Appendix

A.1 Machine

Consider a scenario where the seller in her mind uses a machine (or automaton) to implement a strategy. A machine for the seller consists of the following components:

Definition 5 *A machine is a 6-tuple* $(Q, \mathbf{R}, \Theta, \mathbf{r}, \rho, c)$ *where*

- Q *is a set of states containing* q^p *for each* $p \in \Delta^\Theta$*,*
- $\mathbf{R}$ *is a set of functions from* Θ *to* $\Delta^n \times \mathbb{R}^n$*,*
- $\mathbf{r} : Q \to \mathbf{R}$ *such that* $\mathbf{r}(\cdot : q) \in \mathbf{R}(p(\cdot : q))$*,*
- $\rho : \mathbf{R} \times \Theta \to \Delta^n \times \mathbb{R}^n$ *such that* $\rho(\mathbf{r}, \theta) = \mathbf{r}(\theta : q)$*,*
- $c : Q \times \mathbf{R} \times (\Delta^n \times \mathbb{R}^n) \to (\Delta^n \times \mathbb{R}^n) \cup Q$ *such that* $c(q, \mathbf{r}(q), \rho(\mathbf{r}(q), \theta)) \in \{\rho(\mathbf{r}, \theta)\} \cup Q$*.*

Since the game is indexed by the prior distribution, the initial state q^p needs to be indexed by p. Function $\mathbf{r}$ determines the chosen mechanisms, given state Q. Function $\mathbf{r}$ then gives the recommendation of the mechanism, given the true state in Θ and the chosen mechanism, function c finally decides either to implement the recommendation, in which case the machine halts, or to preceed to another state. Note that $\mathbf{r} \circ r \circ c : Q \times \Theta \to (\Delta^n \times \mathbb{R}^n) \cup Q$.

It is clear that with Q unrestricted, any strategy of the seller can be implemented by a machine. Thus by focusing on machines we do not artificially restrict seller's strategic options. Nevertheless, the machine-framework endows us with tools to discuss about complexity issues in more detail. Think of the seller choosing the machine before the prior probability distribution is determined. *We assume that (i) the seller can replace the machine at any stage of the game if a replacement is (strictly) profitable, (ii) if two machines are equally profitable, she prefers the less complex machine.*

In the literature on complexity of games played by automata, the following naïve but simple and intuitive approach is often adopted: the number of states is used as a measure of complexity. The set of states of the machine defines a partition on the set of histories of the game, and complexity is then measured by the size of the partition.

Of course, in the current set-up this counting-states approach is problematic since we need to allow infinitely many of states. Thus, to compare the sizes of the state sets, we need to use other arguments. To proceed to this direction, identify the set of indexed states $Q^P \subseteq Q$ where $Q^P = \{Q^p : p \in \Delta\}$. Any machine necassarily contains states Q^P. When evaluating when a the size of a set is bigger that anopther set, we confine our attention to set Q^P. Assume that players wish to avoid needlessly many states in their machine. If there are two machines such that in the first one the set of states consists only of those in Q^P, and the other some extra states as well, then the implementation of first one requires less complex reasoning.

We say that machine $t = (Q, \mathbf{R}, \Theta, \mathbf{r}, r, c)$ is *minimal* if $Q^P = Q$. However, we can identify a condition which captures situations where one of minimal machines is more complex than another. Let $\bar{Q}$ be a partition of Q^P such that $\mathbf{R} \in \bar{Q}$ iff $q^p = q^{p'}$ for all $q^p, q^{p'} \in \mathbf{R}$. Thus if Q^P consists of distinguished elements, then the partition $\bar{Q}$ consists of singleton sets. We say that partition $\bar{Q}$ is *at least as coarse as* $\bar{Q}'$ if $\mathbf{R} \subseteq \mathbf{R}'$ for all $\mathbf{R}' \in \bar{Q}'$, for some $\mathbf{R} \in \bar{Q}$. When the set inclusion is strict in some case, then $\bar{Q}$ is *coarser than* $\bar{Q}'$..Moreover, t is *equally coarse* with $t' = (Q', \mathbf{R}, \Theta, \mathbf{r}', r', c')$ if $\bar{Q}$ is as coarse as $\bar{Q}'$, and t is *coarser* than t' if $\bar{Q}$ coarser than $\bar{Q}'$.

Definition 6

1. *Machine t is more complex than machine t' if t is minimal and at least as coarse as t',*
2. *Machine t is weakly more complex than machine t' if t is minimal and coarser than t'*

Now, consider the game situation: first the seller chooses a machine to implement a strategy. As she cannot commit not to replace the machine at any later stage, the corresponding strategy must be Perfect Bayesian Equilibrium of the game. Thus, we focus on strategies that form an equilibrium and have the property that there is no other strategy whose machine is less complex while generates the same payoff.

Definition 7 *Strategy of the seller is said to be stationary if it can be implemented by a minimal machine.*

A truthtelling PBE strategy $\mathbf{r}$ is defined for each history by the following properties,

1. the game ends in the first stage,
2. the conditional ditribution $p(\cdot : q)$ is derived via Bayes rule.

Definition 8 *A PBE strategy is (strongly) robust against complexity considerations if there exist no other PBE strategy which is (i) equally profitable and (ii) can be implemented by a (weakly) less complex machine.*

The following simple consequence follows from the this complexity argument.

Proposition 1 *A PBE strategy is robust against complexity considerations only if it is stationary.*

Proof. Suppose that t, which implements PBE strategy $\mathbf{r}$, is robust against complexity considerations, but $\mathbf{r}$ is not stationary. By the revelation principle, any PBE strategy terminates at the end of the first stage. Thus only states in Q^P are reached with positive probability. Replace any state $q \in Q \setminus Q^P$ with state q^p iff $p(\cdot : q) = p$. Clearly, this operation reduces the complexity of the machine without affecting the payoffs. Thus $\mathbf{r}$ is not robust against complexity considerations. ■

Thus, any nonstationary strategy uses a nonminimal machine, and any such machine can be replaced by a less complex machine which implements an equally profitable strategy (however, such strategy need not be a PBE).

By applying the stronger complexity criterion we obtain the following strenghtening of our criterion.

Proposition 2 *A PBE strategy is strongly robust against complexity considerations if it is strongly stationary.*

Proof. Suppose that t, which implements PBE strategy $\mathbf{r}$, is robust against complexity considerations, but $\mathbf{r}$ is not strongly stationary: there are $\mathbf{r}\left(\cdot : p\right), (\mathbf{r}'\left(\cdot : p'\right) \in \mathbf{G}$ such that $\mathbf{r}, \mathbf{r}' \in \mathbf{R}(p)$ and $v(\mathbf{r}\left(\cdot : p\right))$=$v(\mathbf{r}'$,$p)$ but $\mathbf{r} \neq \mathbf{r}'$. Necessarily $q^p \neq q^{p'}$. Replace state $q^{p'}$ with state q^p. This operation weakly reduces the complexity of the machine without affecting the payoffs. Thus $\mathbf{r}$ is not strongly robust against complexity considerations. ■

This far, we have argued that different kinds of complexity considerations imply different degrees of stationarity from PBE strategies. As a consequence, if one wants to implement a mechanism without commitment ability in a PBE which is robust against complexity considerations, then one arrves to stable mechanisms. However, this leaves open the question whether the converse is also true, i.e. whether stable mechanisms are robust against complexity considerations. Luckily, it is easy to verify that stable mechanisms are robust against strong complexity considerations (and, hence, against complexity considerations).

A.2 Proof of Lemma 3

We want to show that, for all $i \in N$,for all $\theta_i, \theta_i' \in \Theta_i$,

$$E_{p_{-i}} u_i(\mathbf{r}^\alpha(\theta), \theta_i) - E_{p_{-i}} \max\{u_i(\mathbf{r}^\alpha(\theta_{-i}, \theta_i'), \theta_i), 0\} \geq 0. \tag{10}$$

Recall that mechanism does not depend on the valuations if the winner, as long as it is publicly known who the winner is: $\mathbf{r}(\theta) = \alpha(\theta)(1, \underline{p_{(1)}}(\theta))$ is constant for all $\theta_i \geq \theta_{(2)}$ in $S(p_{(1)}\left(\cdot : \theta_{-(1)}\right))$.

Suppose that $\theta_i' < \theta_i$. Then $\theta_i < \theta_{(2)}$ implies $\theta_i' < \theta_{(2)}$ and $u_i(\mathbf{r}^\alpha(\theta), \theta_i) = u_i(\mathbf{r}^\alpha(\theta), \theta_i) = 0$. However, if $\theta_i' < \theta_{(2)} \leq \theta_i$, then $u_i(\mathbf{r}^\alpha(\theta), \theta_i) = \alpha_i(\theta)(\theta_i - \underline{p_{(1)}}(\theta)) \geq 0 = u_i(\mathbf{r}^\alpha(\theta_{-i}, \theta_i'), \theta_i)$. Then (10) yields

$$\begin{aligned} &E_{p_{-i}}\left[\alpha_i(\theta)(\theta_i - \underline{p_{(1)}}(\theta)) : \theta_i' < \theta_{(2)} \leq \theta_i\right] - E_{p_{-i}}\left[0 : \theta_i' < \theta_{(2)} \leq \theta_i\right] \\ &= E_{p_{-i}}\left[\alpha_i(\theta)(\theta_i - \underline{p_{(1)}}(\theta)) : \theta_i' < \theta_{(2)} \leq \theta_i\right] - 0 \geq 0. \end{aligned}$$

Thus, underreporting does not pay: i would only loose the object exactly in the cases where he would gain by having it without changing the price in those cases when he obtains the object.

Suppose that $\theta_i' > \theta_i$. Then $\theta_i \geq \theta_{(2)}$ implies $\theta_i' \geq \theta_{(2)}$. Thus in those cases $\mathbf{r}^\alpha(\theta) = \mathbf{r}^\alpha(\theta_i', \theta_{-i})$. However, if $\theta_i' \geq \theta_{(2)} > \theta_i$, then $u_i(\mathbf{r}^\alpha(\theta), \theta_i) = \alpha_i(\theta_{-(1)})(\theta_i - \underline{p_{(1)}}(\theta_{-(1)})) = 0$. On the other hand, since $\underline{p_{(1)}}(\theta_i', \theta_{-i}) \geq \theta_{(2)}$, we have $\alpha_i(\theta_i', \theta_{-i})(\theta_i - \underline{p_{(1)}}(\theta_i', \theta_{-i})) \leq 0$. Thus, (10) yields

$$E_{p_{-i}}\left[0 : \theta_i' \geq \theta_{(2)} > \theta_i\right] - E_{p_{-i}}\left[\max\{\alpha_i(\theta_i', \theta_{-i})(\theta_i - \underline{p_{(1)}}(\theta_i', \theta_{-i})), 0\} : \theta_i' \geq \theta_{(2)} > \theta_i\right]$$
$$= 0 - 0 = 0$$

Consequently, relative to truthful reporting, overreporting would induce recommendations that would suggest i to receive the object in cases where he would need to pay more than his own valuation. This induces he to employ the veto right resulting the 0 payoff. Thus overreporting cannot be profitable. Hence $\mathbf{r}^\alpha$ satisfies VETO-IC given any prior information structure $p \in \Delta^\Theta$.

References

[1] ANDERLINI, L. AND SABOURIAN. H. (1999), Cooperation and Complexity in N player Games, manuscript.

[2] ASHEIM. G. (1991), Extending Renegoatiation Proofness to Infinite Horizon Games, *Games and Economic Behavior* **3,** 278-94.

[3] ASHEIM. G. (1992), A Unique Solution to the $n-$person Bargaining Game, *Games and Economic Behavior* **4,** 161-81.

[4] AUSUBEL, L. AND DENECKERE, R. (1989), Reputation in Bargaining and Durable Goods Monopoly, *Econometrica* **57,** 511-32.

[5] AUSUBEL, L. AND DENECKERE, R. (1989), A Direct Mechanism Characterization of Sequential Bargaining with One-Sided Incomplete Information, *Journal of Economic Theory* **48,** 18-46.

[6] BESTER, H. AND STRAUSZ, R. (1998), Imperfect Commitment and the Revelation Principle, forthcoming in *Econometrica*.

[7] BLUME, A. AND SOBEL, J. (1997), Communication-Proof Equilibria in Cheap-Talk Games, *Journal of Economic Theory* **65**, 359-82.

[8] CHATTERJEE, K. AND SABOURIAN. H. (2000), Multiperson Bargaing and Strategic Complexity, *Econometrica* **68,** 1491-511.

[9] COASE. R. (1972), Durability and Monopoly, *Journal of Law and Economics* **15**, 143-9.

[10] FORGES, F. (1993), Some Thoughts on Efficiency and Information, in Binmore, Kirman and Tani (eds.), *Frontiers of Game Theory,* 133-53, New York: MIT Press.

[11] FORGES, F. (1994), Posterior Efficiency, *Games and Economic Behavior* **6**, 238-61.

[12] FORGES, F. (1998), Ex Post Individually Rational Trading Mechanisms, manuscript, THEMA, Universite of Cergy-Pontoise.

[13] FREIXAS, X., GUESNERIE, R., AND TIROLE, J. (1985), Planning under Incomplete Information ans the Ratchet Effect, *Rewiev of Economic Studies* **52,** 173-92.

[14] FUDENBERG, D., LEVINE, D., AND TIROLE, J. (1985), Infinite-horizon models of bargaining with one-sided incomplete information, in A. Roth (ed.) *Game theoretic models of Bargaining*, 73-98, Cambridge UK, Cambridge University Press.

[15] GREENBERG, J. (1990), *The theory of Social Situations, an Alternative Game-Theoretic Approach,* Cambridge, UK: Cambridge University Press.

[16] Gresik, T. (1991), Ex Ante Efficient, Ex Post Individually Rational Trade, *Journal of Economic Theory* **53,** 131-45.

[17] Gresik, T. (1996), Incentive Efficient Equilibria of Two-Party Sealed-Bid Bargaining Games, *Journal of Economic Theory* **68,** 26-48.

[18] Gul, F., Sonnenshein, H., and Wilson, R. (1986), Foundations of Dynamic Monopoly and The Coase Conjecture, *Journal of Economic Theory* **39,** 155-90.

[19] Hart, O. and Tirole, J. (1988), Contract Renegotiation and Coasian Dynamics, *Review of Economic Studies* **55,** 509-40.

[20] Kahn, A. and Mookherjee, D. (1992), The Good, the Bad, and the Ugly: Coalition Proof Equilibrium in Games with Infinite Strategy Spaces, *Games and Economic Behavior* **4**, 101-21.

[21] Kahn, A. and Mookherjee, D. (1995), Coalition Proof Equilibrium in Adverse Selection Insurance Economy, *Journal of Economic Theory* **66,** 113-38.

[22] Klemperer, P. (1999), Auction Theory: a Guide to the Literature, *Journal of Economic Surveys* **13,** 237-86.

[23] Krasa, S. (1999), Unimprovable Allocations in Economies with Incomplete Information, *Journal of Economic Theory* **87,** 144-68.

[24] Laffont, J.-J. and Tirole, J. (1990), Adverse Selection and Renegotiation in Procurement , *Review of Economic Studies* **57,** 597-625.

[25] Lopomo, G. (1998), The English Auction is Optimal Among Simple Sequential Auctions, *Journal of Economic Theory* **82,** 144-66.

[26] Maskin, E. and Riley, J. (1984), Optimal Auction with Risk Averse Buyers, *Econometrica* **52,** 1473-518.

[27] Matthews, S. and Postlewaite, A. (1989), Pre-play Communication in Two-Person Sealed-Bid Double Auctions, *Journal of Economic Theory* **89,** 238-63.

[28] Matthews, S. (1987), Comparing Auctions for Risk Averse Buyers: a Buyer's Point of View, *Econometrica* **89,** 633-46.

[29] Matthews, S. (1995), A Technical Primer on Auction Theory I, Independent Private Values, MEDS Discussion Paper 1096, Northwestern University.

[30] Milgrom, P. (1987), Auction Theory, in T.Bewley (ed.), *Advances in Economic Theory: Fifth World Congress*, 1-32, Cambridge UK, Cambridge University Press.

[31] Milgrom, P. and Weber, R. (1982), A Theory of Auctions and Competitive Bidding, *Econometrica* **50,** 1089-122.

[32] McAfee, P. and Vincent, D. (1997), Sequentially Optimal Auctions, *Games and Economic Behavior* **18,** 246-76.

[33] McAfee, P. and McMillan, J. (1987), Auctions and Bidding, *Journal of Economic Literature* **XXV,** 699-738.

[34] Myerson, R. (1981), Optimal Auction Design, *Mathematics of Operation Research* **6,** 58-73.

[35] Myerson, R. (1982), Optimal Coordination Mechanisms in Generalized Principle-Agent Problems, *Journal of Mathematical Economics* **28,** 67–81.

[36] Riley, J. (1988), Ex Post Information in Auctions, *Review of Economic Studies* **57,** 409-430.

[37] Riley, J. and Samuelson, W. (1981), Optimal Auctions, *American Economic Review* **71,** 381-92.

[38] Tadelis, S. (1996), Pareto Optimality and Optimistic Stability in Repeated Extensive Form Games, *Journal of Economic Theory* **69,** 470-89.

[39] Vartiainen, H. (1999), Studies in Mechanism Design and Game Theory, Ph.D thesis, Department of Economics Research reports No 83, University of Helsinki.

[40] Vickrey, W. (1961), Counterspeculation, Auctions and Competitive Sealed Tenders, *Journal of Finance* **16,** 8-37.

[41] vonNeumann, J. and Morgenstern, O. (1944), *Theory of Games and Economic Behavior*, Princeton, N.J.: Princeton University Press.

NOTE DI LAVORO DELLA FONDAZIONE ENI ENRICO MATTEI
Fondazione Eni Enrico Mattei Working Paper Series
Our working papers are available on the Internet at the following addresses:
http://www.feem.it/web/activ/_wp.html
http://papers.ssrn.com

SUST	1.2002	*K. TANO, M.D. FAMINOW, M. KAMUANGA and B. SWALLOW*: Using Conjoint Analysis to Estimate Farmers' Preferences for Cattle Traits in West Africa
ETA	2.2002	*Efrem CASTELNUOVO and Paolo SURICO*: What Does Monetary Policy Reveal about Central Bank's Preferences?
WAT	3.2002	*Duncan KNOWLER and Edward BARBIER*: The Economics of a "Mixed Blessing" Effect: A Case Study of the Black Sea
CLIM	4.2002	*Andreas LÖSCHEL*: Technological Change in Economic Models of Environmental Policy: A Survey
VOL	5.2002	*Carlo CARRARO and Carmen MARCHIORI*: Stable Coalitions
CLIM	6.2002	*Marzio GALEOTTI, Alessandro LANZA and Matteo MANERA*: Rockets and Feathers Revisited: An International Comparison on European Gasoline Markets
ETA	7.2002	*Effrosyni DIAMANTOUDI and Eftichios S. SARTZETAKIS*: Stable International Environmental Agreements: An Analytical Approach
KNOW	8.2002	*Alain DESDOIGTS*: Neoclassical Convergence Versus Technological Catch-up: A Contribution for Reaching a Consensus
NRM	9.2002	*Giuseppe DI VITA:* Renewable Resources and Waste Recycling
KNOW	10.2002	*Giorgio BRUNELLO*: Is Training More Frequent when Wage Compression is Higher? Evidence from 11 European Countries
ETA	11.2002	*Mordecai KURZ, Hehui JIN and Maurizio MOTOLESE*: Endogenous Fluctuations and the Role of Monetary Policy
KNOW	12.2002	*Reyer GERLAGH and Marjan W. HOFKES:* Escaping Lock-in: The Scope for a Transition towards Sustainable Growth?
NRM	13.2002	*Michele MORETTO and Paolo ROSATO*: The Use of Common Property Resources: A Dynamic Model
CLIM	14.2002	*Philippe QUIRION*: Macroeconomic Effects of an Energy Saving Policy in the Public Sector
CLIM	15.2002	*Roberto ROSON*: Dynamic and Distributional Effects of Environmental Revenue Recycling Schemes: Simulations with a General Equilibrium Model of the Italian Economy
CLIM	16.2002	*Francesco RICCI* (l): Environmental Policy Growth when Inputs are Differentiated in Pollution Intensity
ETA	17.2002	*Alberto PETRUCCI*: Devaluation (Levels versus Rates) and Balance of Payments in a Cash-in-Advance Economy
Coalition Theory Network	18.2002	*László Á. KÓCZY* (liv*):* The Core in the Presence of Externalities
Coalition Theory Network	19.2002	*Steven J. BRAMS, Michael A. JONES and D. Marc KILGOUR* (liv): Single-Peakedness and Disconnected Coalitions
Coalition Theory Network	20.2002	*Guillaume HAERINGER* (liv): On the Stability of Cooperation Structures
NRM	21.2002	*Fausto CAVALLARO and Luigi CIRAOLO:* Economic and Environmental Sustainability: A Dynamic Approach in Insular Systems
CLIM	22.2002	*Barbara BUCHNER, Carlo CARRARO, Igor CERSOSIMO and Carmen MARCHIORI*: Back to Kyoto? US Participation and the Linkage between R&D and Climate Cooperation
CLIM	23.2002	*Andreas LÖSCHEL and ZhongXIANG ZHANG:* The Economic and Environmental Implications of the US Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrakech
ETA	24.2002	*Marzio GALEOTTI, Louis J. MACCINI and Fabio SCHIANTARELLI*: Inventories, Employment and Hours
CLIM	25.2002	*Hannes EGLI:* Are Cross-Country Studies of the Environmental Kuznets Curve Misleading? New Evidence from Time Series Data for Germany
ETA	26.2002	*Adam B. JAFFE, Richard G. NEWELL and Robert N. STAVINS*: Environmental Policy and Technological Change
SUST	27.2002	*Joseph C. COOPER and Giovanni SIGNORELLO*: Farmer Premiums for the Voluntary Adoption of Conservation Plans
SUST	28.2002	*The ANSEA Network*: Towards An Analytical Strategic Environmental Assessment
KNOW	29.2002	*Paolo SURICO*: Geographic Concentration and Increasing Returns: a Survey of Evidence
ETA	30.2002	*Robert N. STAVINS:* Lessons from the American Experiment with Market-Based Environmental Policies

NRM	31.2002	*Carlo GIUPPONI and Paolo ROSATO:* Multi-Criteria Analysis and Decision-Support for Water Management at the Catchment Scale: An Application to Diffuse Pollution Control in the Venice Lagoon
NRM	32.2002	*Robert N. STAVINS*: National Environmental Policy During the Clinton Years
KNOW	33.2002	*A. SOUBEYRAN and H. STAHN* : Do Investments in Specialized Knowledge Lead to Composite Good Industries?
KNOW	34.2002	*G. BRUNELLO, M.L. PARISI and Daniela SONEDDA:* Labor Taxes, Wage Setting and the Relative Wage Effect
CLIM	35.2002	*C. BOEMARE and P. QUIRION* (lv): Implementing Greenhouse Gas Trading in Europe: Lessons from Economic Theory and International Experiences
CLIM	36.2002	*T.TIETENBERG* (lv): The Tradable Permits Approach to Protecting the Commons: What Have We Learned?
CLIM	37.2002	*K. REHDANZ and R.J.S. TOL* (lv): On National and International Trade in Greenhouse Gas Emission Permits
CLIM	38.2002	*C. FISCHER* (lv): Multinational Taxation and International Emissions Trading
SUST	39.2002	*G. SIGNORELLO and G. PAPPALARDO:* Farm Animal Biodiversity Conservation Activities in Europe under the Framework of Agenda 2000
NRM	40.2002	*S .M. CAVANAGH, W. M. HANEMANN and R. N. STAVINS:* Muffled Price Signals: Household Water Demand under Increasing-Block Prices
NRM	41.2002	*A. J. PLANTINGA, R. N. LUBOWSKI and R. N. STAVINS:* The Effects of Potential Land Development on Agricultural Land Prices
CLIM	42.2002	*C. OHL* (lvi): Inducing Environmental Co-operation by the Design of Emission Permits
CLIM	43.2002	*J. EYCKMANS, D. VAN REGEMORTER and V. VAN STEENBERGHE* (lvi): Is Kyoto Fatally Flawed? An Analysis with MacGEM
CLIM	44.2002	*A. ANTOCI and S. BORGHESI* (lvi): Working Too Much in a Polluted World: A North-South Evolutionary Model
ETA	45.2002	*P. G. FREDRIKSSON, Johan A. LIST and Daniel MILLIMET* (lvi): Chasing the Smokestack: Strategic Policymaking with Multiple Instruments
ETA	46.2002	*Z. YU* (lvi): A Theory of Strategic Vertical DFI and the Missing Pollution-Haven Effect
SUST	47.2002	*Y. H. FARZIN*: Can an Exhaustible Resource Economy Be Sustainable?
SUST	48.2002	*Y. H. FARZIN*: Sustainability and Hamiltonian Value
KNOW	49.2002	*C. PIGA and M. VIVARELLI*: Cooperation in R&D and Sample Selection
Coalition Theory Network	50.2002	*M. SERTEL and A. SLINKO* (liv): Ranking Committees, Words or Multisets
Coalition Theory Network	51.2002	*Sergio CURRARINI* (liv): Stable Organizations with Externalities
ETA	52.2002	*Robert N. STAVINS*: Experience with Market-Based Policy Instruments
ETA	53.2002	*C.C. JAEGER, M. LEIMBACH, C. CARRARO, K. HASSELMANN, J.C. HOURCADE, A. KEELER and R. KLEIN* (liii): Integrated Assessment Modeling: Modules for Cooperation
CLIM	54.2002	*Scott BARRETT* (liii)*:* Towards a Better Climate Treaty
ETA	55.2002	*Richard G. NEWELL and Robert N. STAVINS*: Cost Heterogeneity and the Potential Savings from Market-Based Policies
SUST	56.2002	*Paolo ROSATO and Edi DEFRANCESCO*: Individual Travel Cost Method and Flow Fixed Costs
SUST	57.2002	*Vladimir KOTOV and Elena NIKITINA* (lvii): Reorganisation of Environmental Policy in Russia: The Decade of Success and Failures in Implementation of Perspective Quests
SUST	58.2002	*Vladimir KOTOV* (lvii): Policy in Transition: New Framework for Russia's Climate Policy
SUST	59.2002	*Fanny MISSFELDT and Arturo VILLAVICENCO* (lvii): How Can Economies in Transition Pursue Emissions Trading or Joint Implementation?
VOL	60.2002	*Giovanni DI BARTOLOMEO, Jacob ENGWERDA, Joseph PLASMANS and Bas VAN AARLE:* Staying Together or Breaking Apart: Policy-Makers' Endogenous Coalitions Formation in the European Economic and Monetary Union
ETA	61.2002	*Robert N. STAVINS, Alexander F.WAGNER and Gernot WAGNER*: Interpreting Sustainability in Economic Terms: Dynamic Efficiency Plus Intergenerational Equity
PRIV	62.2002	*Carlo CAPUANO*: Demand Growth, Entry and Collusion Sustainability
PRIV	63.2002	*Federico MUNARI and Raffaele ORIANI*: Privatization and R&D Performance: An Empirical Analysis Based on Tobin's Q
PRIV	64.2002	*Federico MUNARI and Maurizio SOBRERO*: The Effects of Privatization on R&D Investments and Patent Productivity
SUST	65.2002	*Orley ASHENFELTER and Michael GREENSTONE*: Using Mandated Speed Limits to Measure the Value of a Statistical Life
ETA	66.2002	*Paolo SURICO:* US Monetary Policy Rules: the Case for Asymmetric Preferences
PRIV	67.2002	*Rinaldo BRAU and Massimo FLORIO*: Privatisations as Price Reforms: Evaluating Consumers' Welfare Changes in the U.K.
CLIM	68.2002	*Barbara K. BUCHNER and Roberto ROSON*: Conflicting Perspectives in Trade and Environmental Negotiations
CLIM	69.2002	*Philippe QUIRION*: Complying with the Kyoto Protocol under Uncertainty: Taxes or Tradable Permits?
SUST	70.2002	*Anna ALBERINI, Patrizia RIGANTI and Alberto LONGO*: Can People Value the Aesthetic and Use Services of Urban Sites? Evidence from a Survey of Belfast Residents
SUST	71.2002	*Marco PERCOCO:* Discounting Environmental Effects in Project Appraisal

NRM	72.2002	*Philippe BONTEMS and Pascal FAVARD*: Input Use and Capacity Constraint under Uncertainty: The Case of Irrigation
PRIV	73.2002	*Mohammed OMRAN:* The Performance of State-Owned Enterprises and Newly Privatized Firms: Empirical Evidence from Egypt
PRIV	74.2002	*Mike BURKART, Fausto PANUNZI and Andrei SHLEIFER:* Family Firms
PRIV	75.2002	*Emmanuelle AURIOL, Pierre M. PICARD:* Privatizations in Developing Countries and the Government Budget Constraint
PRIV	76.2002	*Nichole M. CASTATER*: Privatization as a Means to Societal Transformation: An Empirical Study of Privatization in Central and Eastern Europe and the Former Soviet Union
PRIV	77.2002	*Christoph LÜLSFESMANN*: Benevolent Government, Managerial Incentives, and the Virtues of Privatization
PRIV	78.2002	*Kate BISHOP, Igor FILATOTCHEV and Tomasz MICKIEWICZ*: Endogenous Ownership Structure: Factors Affecting the Post-Privatisation Equity in Largest Hungarian Firms
PRIV	79.2002	*Theodora WELCH and Rick MOLZ*: How Does Trade Sale Privatization Work? Evidence from the Fixed-Line Telecommunications Sector in Developing Economies
PRIV	80.2002	*Alberto R. PETRUCCI*: Government Debt, Agent Heterogeneity and Wealth Displacement in a Small Open Economy
CLIM	81.2002	*Timothy SWANSON and Robin MASON* (lvi): The Impact of International Environmental Agreements: The Case of the Montreal Protocol
PRIV	82.2002	*George R.G. CLARKE and Lixin Colin XU:* Privatization, Competition and Corruption: How Characteristics of Bribe Takers and Payers Affect Bribe Payments to Utilities
PRIV	83.2002	*Massimo FLORIO and Katiuscia MANZONI*: The Abnormal Returns of UK Privatisations: From Underpricing to Outperformance
NRM	84.2002	*Nelson LOURENÇO, Carlos RUSSO MACHADO, Maria do ROSÁRIO JORGE and Luís RODRIGUES*: An Integrated Approach to Understand Territory Dynamics. The Coastal Alentejo (Portugal)
CLIM	85.2002	*Peter ZAPFEL and Matti VAINIO* (lv): Pathways to European Greenhouse Gas Emissions Trading History and Misconceptions
CLIM	86.2002	*Pierre COURTOIS*: Influence Processes in Climate Change Negotiations: Modelling the Rounds
ETA	87.2002	*Vito FRAGNELLI and Maria Erminia MARINA* (lviii): Environmental Pollution Risk and Insurance
ETA	88.2002	*Laurent FRANCKX* (lviii): Environmental Enforcement with Endogenous Ambient Monitoring
ETA	89.2002	*Timo GOESCHL and Timothy M. SWANSON* (lviii): Lost Horizons. The noncooperative management of an evolutionary biological system.
ETA	90.2002	*Hans KEIDING* (lviii): Environmental Effects of Consumption: An Approach Using DEA and Cost Sharing
ETA	91.2002	*Wietze LISE* (lviii): A Game Model of People's Participation in Forest Management in Northern India
CLIM	92.2002	*Jens HORBACH*: Structural Change and Environmental Kuznets Curves
ETA	93.2002	*Martin P. GROSSKOPF:* Towards a More Appropriate Method for Determining the Optimal Scale of Production Units
VOL	94.2002	*Scott BARRETT and Robert STAVINS*: Increasing Participation and Compliance in International Climate Change Agreements
CLIM	95.2002	*Banu BAYRAMOGLU LISE and Wietze LISE:* Climate Change, Environmental NGOs and Public Awareness in the Netherlands: Perceptions and Reality
CLIM	96.2002	*Matthieu GLACHANT*: The Political Economy of Emission Tax Design in Environmental Policy
KNOW	97.2002	*Kenn ARIGA and Giorgio BRUNELLO*: Are the More Educated Receiving More Training? Evidence from Thailand
ETA	98.2002	*Gianfranco FORTE and Matteo MANERA*: Forecasting Volatility in European Stock Markets with Non-linear GARCH Models
ETA	99.2002	*Geoffrey HEAL*: Bundling Biodiversity
ETA	100.2002	*Geoffrey HEAL, Brian WALKER, Simon LEVIN, Kenneth ARROW, Partha DASGUPTA, Gretchen DAILY, Paul EHRLICH, Karl-Goran MALER, Nils KAUTSKY, Jane LUBCHENCO, Steve SCHNEIDER and David STARRETT*: Genetic Diversity and Interdependent Crop Choices in Agriculture
ETA	101.2002	*Geoffrey HEAL:* Biodiversity and Globalization
VOL	102.2002	*Andreas LANGE*: Heterogeneous International Agreements – If per capita emission levels matter
ETA	103.2002	*Pierre-André JOUVET and Walid OUESLATI*: Tax Reform and Public Spending Trade-offs in an Endogenous Growth Model with Environmental Externality
ETA	104.2002	*Anna BOTTASSO and Alessandro SEMBENELLI*: Does Ownership Affect Firms' Efficiency? Panel Data Evidence on Italy
PRIV	105.2002	*Bernardo BORTOLOTTI, Frank DE JONG, Giovanna NICODANO and Ibolya SCHINDELE*: Privatization and Stock Market Liquidity
ETA	106.2002	*Haruo IMAI and Mayumi HORIE* (lviii): Pre-Negotiation for an International Emission Reduction Game
PRIV	107.2002	*Sudeshna GHOSH BANERJEE and Michael C. MUNGER*: Move to Markets? An Empirical Analysis of Privatisation in Developing Countries
PRIV	108.2002	*Guillaume GIRMENS and Michel GUILLARD*: Privatization and Investment: Crowding-Out Effect vs Financial Diversification
PRIV	109.2002	*Alberto CHONG and Florencio LÓPEZ-DE-SILANES*: Privatization and Labor Force Restructuring Around the World
PRIV	110.2002	*Nandini GUPTA*: Partial Privatization and Firm Performance
PRIV	111.2002	*François DEGEORGE, Dirk JENTER, Alberto MOEL and Peter TUFANO*: Selling Company Shares to Reluctant Employees: France Telecom's Experience

PRIV	112.2002	*Isaac OTCHERE*: Intra-Industry Effects of Privatization Announcements: Evidence from Developed and Developing Countries
PRIV	113.2002	*Yannis KATSOULAKOS and Elissavet LIKOYANNI*: Fiscal and Other Macroeconomic Effects of Privatization
PRIV	114.2002	*Guillaume GIRMENS:* Privatization, International Asset Trade and Financial Markets
PRIV	115.2002	*D. Teja FLOTHO:* A Note on Consumption Correlations and European Financial Integration
PRIV	116.2002	*Ibolya SCHINDELE and Enrico C. PEROTTI*: Pricing Initial Public Offerings in Premature Capital Markets: The Case of Hungary
PRIV	1.2003	*Gabriella CHIESA and Giovanna NICODANO*: Privatization and Financial Market Development: Theoretical Issues
PRIV	2.2003	*Ibolya SCHINDELE*: Theory of Privatization in Eastern Europe: Literature Review
PRIV	3.2003	*Wietze LISE, Claudia KEMFERT and Richard S.J. TOL*: Strategic Action in the Liberalised German Electricity Market
CLIM	4.2003	*Laura MARSILIANI and Thomas I. RENSTRÖM*: Environmental Policy and Capital Movements: The Role of Government Commitment
KNOW	5.2003	*Reyer GERLAGH*: Induced Technological Change under Technological Competition
ETA	6.2003	*Efrem CASTELNUOVO*: Squeezing the Interest Rate Smoothing Weight with a Hybrid Expectations Model
SIEV	7.2003	*Anna ALBERINI, Alberto LONGO, Stefania TONIN, Francesco TROMBETTA and Margherita TURVANI:* The Role of Liability, Regulation and Economic Incentives in Brownfield Remediation and Redevelopment: Evidence from Surveys of Developers
NRM	8.2003	*Elissaios PAPYRAKIS and Reyer GERLAGH*: Natural Resources: A Blessing or a Curse?
CLIM	9.2003	*A. CAPARRÓS, J.-C. PEREAU and T. TAZDAÏT*: North-South Climate Change Negotiations: a Sequential Game with Asymmetric Information
KNOW	10.2003	*Giorgio BRUNELLO and Daniele CHECCHI*: School Quality and Family Background in Italy
CLIM	11.2003	*Efrem CASTELNUOVO and Marzio GALEOTTI*: Learning By Doing vs Learning By Researching in a Model of Climate Change Policy Analysis
KNOW	12.2003	*Carole MAIGNAN, Gianmarco OTTAVIANO and Dino PINELLI (eds.)*: Economic Growth, Innovation, Cultural Diversity: What are we all talking about? A critical survey of the state-of-the-art
KNOW	13.2003	*Carole MAIGNAN, Gianmarco OTTAVIANO, Dino PINELLI and Francesco RULLANI* (lvix): Bio-Ecological Diversity vs. Socio-Economic Diversity. A Comparison of Existing Measures
KNOW	14.2003	*Maddy JANSSENS and Chris STEYAERT* (lvix): Theories of Diversity within Organisation Studies: Debates and Future Trajectories
KNOW	15.2003	*Tuzin BAYCAN LEVENT, Enno MASUREL and Peter NIJKAMP* (lvix): Diversity in Entrepreneurship: Ethnic and Female Roles in Urban Economic Life
KNOW	16.2003	*Alexandra BITUSIKOVA* (lvix): Post-Communist City on its Way from Grey to Colourful: The Case Study from Slovakia
KNOW	17.2003	*Billy E. VAUGHN and Katarina MLEKOV* (lvix): A Stage Model of Developing an Inclusive Community
KNOW	18.2003	*Selma van LONDEN and Arie de RUIJTER* (lvix): Managing Diversity in a Glocalizing World
Coalition Theory Network	19.2003	*Sergio CURRARINI:* On the Stability of Hierarchies in Games with Externalities
PRIV	20.2003	*Giacomo CALZOLARI and Alessandro PAVAN* (lvx): Monopoly with Resale
PRIV	21.2003	*Claudio MEZZETTI* (lvx): Auction Design with Interdependent Valuations: The Generalized Revelation Principle, Efficiency, Full Surplus Extraction and Information Acquisition
PRIV	22.2003	*Marco LiCalzi and Alessandro PAVAN* (lvx): Tilting the Supply Schedule to Enhance Competition in Uniform-Price Auctions
PRIV	23.2003	*David ETTINGER* (lvx): Bidding among Friends and Enemies
PRIV	24.2003	*Hannu VARTIAINEN* (lvx): Auction Design without Commitment

(l) This paper was presented at the Workshop "Growth, Environmental Policies and Sustainability" organised by the Fondazione Eni Enrico Mattei, Venice, June 1, 2001

(li) This paper was presented at the Fourth Toulouse Conference on Environment and Resource Economics on "Property Rights, Institutions and Management of Environmental and Natural Resources", organised by Fondazione Eni Enrico Mattei, IDEI and INRA and sponsored by MATE, Toulouse, May 3-4, 2001

(lii) This paper was presented at the International Conference on "Economic Valuation of Environmental Goods", organised by Fondazione Eni Enrico Mattei in cooperation with CORILA, Venice, May 11, 2001

(liii) This paper was circulated at the International Conference on "Climate Policy – Do We Need a New Approach?", jointly organised by Fondazione Eni Enrico Mattei, Stanford University and Venice International University, Isola di San Servolo, Venice, September 6-8, 2001

(liv) This paper was presented at the Seventh Meeting of the Coalition Theory Network organised by the Fondazione Eni Enrico Mattei and the CORE, Université Catholique de Louvain, Venice, Italy, January 11-12, 2002

(lv) This paper was presented at the First Workshop of the Concerted Action on Tradable Emission Permits (CATEP) organised by the Fondazione Eni Enrico Mattei, Venice, Italy, December 3-4, 2001

(lvi) This paper was presented at the ESF EURESCO Conference on Environmental Policy in a Global Economy "The International Dimension of Environmental Policy", organised with the collaboration of the Fondazione Eni Enrico Mattei , Acquafredda di Maratea, October 6-11, 2001

(lvii) This paper was presented at the First Workshop of "CFEWE – Carbon Flows between Eastern and Western Europe", organised by the Fondazione Eni Enrico Mattei and Zentrum fur Europaische Integrationsforschung (ZEI), Milan, July 5-6, 2001

(lviii) This paper was presented at the Workshop on "Game Practice and the Environment", jointly organised by Università del Piemonte Orientale and Fondazione Eni Enrico Mattei, Alessandria, April 12-13, 2002

(lvix) This paper was presented at the ENGIME Workshop on "Mapping Diversity", Leuven, May 16-17, 2002

(lvx) This paper was presented at the EuroConference on "Auctions and Market Design: Theory, Evidence and Applications", organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002

2002 SERIES

CLIM	*Climate Change Modelling and Policy* (Editor: Marzio Galeotti)
VOL	*Voluntary and International Agreements* (Editor: Carlo Carraro)
SUST	*Sustainability Indicators and Environmental Valuation* (Editor: Carlo Carraro)
NRM	*Natural Resources Management* (Editor: Carlo Giupponi)
KNOW	*Knowledge, Technology, Human Capital* (Editor: Dino Pinelli)
MGMT	*Corporate Sustainable Management* (Editor: Andrea Marsanich)
PRIV	*Privatisation, Regulation, Antitrust* (Editor: Bernardo Bortolotti)
ETA	*Economic Theory and Applications* (Editor: Carlo Carraro)

2003 SERIES

CLIM	*Climate Change Modelling and Policy* (Editor: Marzio Galeotti)
GG	*Global Governance* (Editor: Carlo Carraro)
SIEV	*Sustainability Indicators and Environmental Valuation* (Editor: Anna Alberini)
NRM	*Natural Resources Management* (Editor: Carlo Giupponi)
KNOW	*Knowledge, Technology, Human Capital* (Editor: Gianmarco Ottaviano)
IEM	*International Energy Markets* (Editor: Anil Markandya)
CSRM	*Corporate Social Responsibility and Management* (Editor: Sabina Ratti)
PRIV	*Privatisation, Regulation, Antitrust* (Editor: Bernardo Bortolotti)
ETA	*Economic Theory and Applications* (Editor: Carlo Carraro)
CTN	*Coalition Theory Network*