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INITIAL ALLOCATION OF EMISSIONS PERMITS IN THE TWO-SIDED MATCHING FRAMEWORK

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Abstract

For the initial allocation of emissions permits, auctioning has been theoretically the most preferred allocation mechanism; but to attract the participation of polluting industries these permits have been generally grandfathered. Following two-sided matching literature, we model an auction market for emissions permits as a two-sided matching procedure and based on the objectives of all the players, characterize a set of stable matching rules that lead to the core allocation. We show that matching based allocation mechanism retains the essence of grandfathering by keeping the reservation price for permits at zero, by giving firms more maneuvering space in auctioning and also by rewarding more environmentally efficient firms and are thus more suitable for the emissions markets.

Keywords: Emissions Permits, Grandfathering, Initial Allocation, Matching

JEL Classifications: C78, D44, Q58

1. Introduction

A host of decisions must be made to translate the concept of emissions market into a workable program. The general issues have been described in the literature on the emissions trading. The initial allocation of allowances is one of the important elements of any emissions trading program, in large part because major sums of money are at stake, apart from other equally important welfare considerations. The total value of the emissions covered under an EU programme for the relevant sectors has been estimated to be nearly Euro 30 billion per year, substantially greater than the estimated control costs of Euro 3.7 to 7.5 billion (Harrison and Radov 2002).

Moreover, Stavins (1995) argues that in the presence of transactions costs, the equilibrium allocation and hence aggregate abatement costs of a tradable permit system are very much dependent on the initial allocations. Hence the way permits are allocated initially is crucial (Related arguments are in Stavins 1998, 2001, 2002). Most of the existing emissions trading

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programs grandfather the emissions permits (For a comprehensive list of major emissions trading programs see Harrison and Radov 2002, Dubey 2007); i.e. distribute them freely. But in the literature, grandfathering of permits is severely criticized. It is argued that grandfathering the permits is a lump sum payment to the polluting firms. It is an entitlement of property right on a resource for free besides granting an implicit subsidy to the polluting industries (Dijkstra 1999).

Oates and Schwab (1988), Poterba (1993) and Repetto et al. (1992) note that emissions permits that are grandfathered do not bring in revenue and cannot finance cuts in pre-existing taxes unlike emissions taxes and auctions. Further, numerical investigations by Terkla (1992) and Shackleton et al. (1996) indicate that such "revenue recycling" can substantially lower the aggregate social cost of environmental regulations. Similarly, Goulder, Parry and Butraw (1997), in a different context, using analytical and numerical general equilibrium models show that preexisting factor taxes produce a tax interaction effect that substantially increases the costs of pollution taxes and quotas. Under policies that raise revenue and recycle it through cuts in marginal factor tax rates, this effect is partially offset by a revenue recycling effect. Grandfathered pollution quotas do not benefit from this offset. Parry (2004) concludes that grandfathered permits redistribute income to wealthy households by creating firm rents that ultimately accrue to shareholders. Consequently they can be highly regressive, even if the poor do not have large budget shares for polluting goods.

The alternative to grandfathering as envisaged in the existing literature is auctioning. Jensen and Rasmussen (2000) suggest that auctioning the permits and using the revenue to reduce distorting taxes is by far the most cost effective method while grandfathering and output based allocation both imply extra costs as the opportunity to reduce distortionary taxes is forgone. It suggests that both these cases imply tax base erosion, and if we use a distortionary tax to replace government revenue, costs increase significantly. Cramton and Kerr (1999, 2002) argue that an auction of carbon permits is the best way to achieve carbon caps set by international negotiation to limit global climate change. An auction is preferred to grandfathering, because it allows reduced tax distortions, provides more flexibility in distribution of costs, provides greater incentives for innovation, and reduces the need for politically contentious arguments over the allocation of rents.

But, with existing mechanisms of auctioning there is an issue of acceptability amongst the firms (Pezzey and Park 1998). Any mechanism that auctions the emissions permits is not easy to implement because of resistance from the regulated firms. Polluting industries will be opposed to auctioning of emissions permits if it threatens an economic rent or if they fear that they would not be able to pass the additional cost of pollution abatement immediately to consumers; hence they often lobby to get the permits for free. For example Hanoteau (2003) shows using campaign contributions as a rent seeking effort, that the lobbies of the US regional power sector lobbied non-cooperatively for the permits grandfathered under the US acid rain program. Besides this, auctioning mechanisms invariably don't differentiate amongst the firms, which have heavily invested in the pollution abatement from those, which have not.

Therefore, in the next section, we examine the objectives of both government and firms for participating in any emissions trading program. Subsequently, following two-sided matching literature we try to model an auction market for emissions permits as a two-sided matching procedure.

2. Emissions Permit Market and Two-Sided Matching

In any emissions trading program initial allocation can be analyzed as a two-sided matching procedure. On one side we have government with handful of permits and on the other side there are firms demanding those permits. Therefore, any initial allocation of permits is a two sided matching between permits and firms. The term "two-sided" refers to the fact that agents in such market belong, from the outset, to one of the two disjoint sets- for example firms and workers. This contrasts with the commodity market where the market price may determine whether an agent is buyer or seller. The term "matching" refers to the bilateral nature of exchange in these markets.

In the next paragraphs of this sub-section, for the sake of completeness, we briefly review the two-sided matching literature mostly following Roth and Sotomayor (1990).

The game-theoretic analysis of the two-sided matching begun with the study of the marriage market by David Gale and Lloyd Shapley in their 1962 paper in which it was proved that a stable matching[2] exists for every marriage market. Furthermore, they also proved that when men and women have strict preferences, there always exists a Man-optimal[3], and a Women-optimal stable matching. Closely related work appeared until the 1972 paper of Shapley and Shubik, which studied the class of related games called the assignment games. Further work in this direction came in Demange, Gale, and Sotomayor (1987) and Demange (1987).

Gale and Shapley (1962) also discussed the many to one matching as the "college admission problem". Further, Roth (1984) observed that the 1951 National Intern Matching Program (NIMP) algorithm for matching in the hospital-intern market in the United States is, in fact an example of this type of many to one matching. Roth (1985) introduced the notion of responsive preferences and observed that certain theorems that were thought to; do not carry over from the case of one-to-one matching to many- to-one matching. Further work in this direction appeared in Roth (1999, 2002). Models with money and more complex preferences were dealt in Kelso and Crawford (1982), which expanded on a paper by Crawford and Knoer (1981).

Further examples of market design are auction markets for radio spectrum licenses and spot markets for electric power (Chao and Wilson 1999, Cramton 1997, Mcafee and McMillan 1996, McMillan 1994, 1995, Milgrom 1998a, 1998b, 1998c, 2004, Wilson, 1998, 1999). Primary design issues have been different in each of these markets.

In the next sub-sections we try to model emissions permit markets as a two sided matching procedure.

2.1 Players in Emissions Permit Market and their Objectives

As has been envisaged in the emissions trading literature, the basic goal in any emissions trading scheme is to limit the overall level of emissions. For this, suppose the Government sets the cap on the emissions by m kilotons and then it creates m permits of 1

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2 A matching is stable if it is not blocked by any individual or any pair of agents.

3 A stable matching is Man-optimal stable matching if every man likes it at least as well as any other stable matching.

kiloton each. Furthermore, after the initialization of the emissions trading program government will be having three goals in mind. The first goal will be acceptance of the program by the polluting industries. Second goal will be that participation in the program rewards the "environmentally efficient" firms and encourages the other firms to improve environmental efficiency and the third goal should be as suggested by the literature, that by the program some revenue is generated so that there is "revenue recycling" effect in the economy. We list the objectives of the government as the following:

Objective G_1 : Acceptability by the firms

Objective G_2 : Environmentally efficient firms are rewarded and other firms are encouraged to improve environmental efficiency.

Objective G_3 : Revenue is generated so that there is some kind of "revenue-recycling" effect.

So we model the government as follows. Given the objective G_2 , First, Government ranks the firms on the basis of some criteria of environmental efficiency which can be

(a) Emissions per unit of value added or

(b) The pollution abatement technology used by the firms or

(c) Emissions per laborer or

(d) Emissions per created job.

We suppose that the utility (after fixing the emissions cap) to the Government in allocating permit i to firm j at price p_i is given by $u_{ij}(p_i)$. Then given the objective G_3 we have $u_{ij}'(p_i) > 0$.

For firms, we make the assumption that the firms under consideration are the profit maximizing firms. In a mandatory emissions trading program, each firm must have enough number of permits for their levels of emissions. But a profit maximizing firm will like to acquire the first permit i.e. will participate in the program, only if the income after acquiring that permit is more than the price it pays to acquire that particular permit and if the firm is already having a set of permits then it will go for the next permit only if the marginal income from that permit is more than the price it pays to acquire that permit.

Now if we suppose that for each firm j and for each subset C of permits, there is a non-negative number $Y^J(C)$ representing the amount of income that will accrue to the firm which acquires set C of permits then the above assumptions can be written in the form of incentive structure of the firms as following:

F_1: $Y^J(\{i\}) - Y^J(\varphi) \geq p_i$ where ϕ represents the null set.

F_2 : $Y^J(C \cup \{i\}) - Y^J(C) \geq p_i$

F_3 : Choose C to Maximize $\pi_j = Y^J(C) - \sum_{i \in C} p_i$.

Let $p = (p_1, \dots, p_m)$ be a vector of prices and $M^J(p)$ denotes the set of solutions to the incentive F_3 . Considering another vector of prices $\bar{p} = (\bar{p}_1, \dots, \bar{p}_m)$ and also $T^J(C) = \{i / i \in C, \bar{p}_i = p_i\}$. Then for every firm J , if $C \in M^J(p)$ and $\bar{p} \geq p$, then there exists $\bar{C} \in M^J(\bar{p})$ such that $T^J(C) \in \bar{C}$ following the gross substitutability assumption.

2.2 Two-sided Matching Procedure[4]

A *matching* μ can be taken to be a set of disjoint alignments of form $\{J, C\}$ or $\{J\}$, where $\{J, C\}$ denotes that firm J acquires the set C of permits, and $\{J\}$ denotes that the firm J acquires no permits. An *outcome* for this model consists of a matching μ and, for each partnership $\{J, C\}$ in μ , an allocation of income $Y^J(C)$ into π_j (profit) and $\{p_i, i = C\}$, such that $Y^J(C) = \pi_j + \sum_{i \in C} P_i$.

We will denote an outcome by a triple (μ, π, p) where π is the vector of profits for each firm J , and p is the vector of price paid for each permit i by firm $\mu(i)$.

An outcome (μ, π, p) is *individually rational* for the Government if $p_i \geq 0$ for each permit i and for firm J if $\pi_j \geq 0$. A matching μ is *blocked* by the firm-permit pair (J, i) if $\mu(i) \neq J$ and if $J \succ_i \mu(i)$ and $i \succ_J \sigma$ for some σ in $\mu(J)$. A matching μ is *stable* if it is not blocked by any individual agent or any firm-permit pair. A *group stable matching* is one that is not block by any coalition.

An outcome (μ, π, p) will be called a *core allocation* unless there is a firm J , a subset of permits C and a vector r of prices r_i , for all permits in C such that $\pi_j < Y^J(C) - \sum_{i \in C} r_i$ and $u_{i\mu(i)}(p_i) < u_{ij}(r_i)$ for all permits i in C .

2.3 Rules of the Matching and the Existence of Core

In this section, given the objectives G_1, G_2, G_3 and, F_1, F_2, F_3 , we adopt a variant of the deferred acceptance algorithm (Gale and Shapley, 1962) developed by Kelso and Crawford (1982) to frame rules of the matching.

[4] For concepts and definitions see Roth and Sotomayor (1990).

Rule 1: We start with government's intent of grandfathering the permits. In the first round, the Government will offer the permits for free. By offering the permits for free in the first round, the government will express its willingness to distribute the permits freely if the firms so desire. This also satisfies the objective G_1 . So in the first round each firm will make offers for all the permits as it is costless to do.

Rule 2: On any round t firm J makes offer to the member of C where C maximizes $\pi_j = Y^J(C) - \sum_{i \in C} p_i$ which is according to the objective F_3 .

Rule 3: Each permit which receives more than one offer rejects all but its most favored one, taking price offered into account (objective G_3), which is tentatively accepted. If the two firms offer price within a pre specified range then the tie is broken on the basis of the criteria listed in objective G_2 .

Rule 4: Offers not rejected in the previous rounds remain in force. If permit i rejected an offer from firm J in round t then $p_{ij}(t+1) = p_{ij}(t) + \in$; otherwise $p_{ij}(t+1) = p_{ij}(t)$.

Rule 5: The algorithm stops when no rejections are issued in the previous round. Permits then accept the offers that remain in force from the firm they have not rejected.

Rule 6: After the end of the algorithm the auctioneer ranks all the firms on the basis of these accepted offers irrespective of for which permit that offer has been made. The firm which offers the highest price is permitted to take as many permits as it wishes subject to an upper limit; similarly for the other firms subject to the supply of permits.

Following Kelso and Crawford (1982) we now prove that there is a core allocation reached through the above algorithm. The core can be thought of as generalizing the set of competitive allocations (Shubik 1959, Debreu and Scarf 1963, Aumann 1964).[5]

Theorem: The *core allocation* obtained through above algorithm is non-empty.

Proof: If $p = (p_1, \ldots, p_m)$ is the set of prices finally accepted by the permits and μ is the matching when the process stops, the set $\pi = \{\pi_1, \ldots \pi_n\}$ of profits for the firms is given by $\pi_j = Y^j(C) - \sum_{i \in C} p_i$, if $\{C, j\}$ belongs to the matching μ .

It is obvious from the rule 1 and rule 4 that $p_i \geq 0$, for all $i = 1, \ldots m$ if i and j are matched by μ . It is also immediate from rule 2 and the fact that the firm is not required to buy permits that $\pi_j \geq 0$ for all $j = 1, \ldots, n$.

5 The idea of core goes back at least to "contract curve" in Edgeworth (1881) and is one of the most important solution concepts in game theory. The idea was discussed by von Neumann and Morgenstern (1944) in the context of a general solution for games, and studied as a distinct solution concept for games by Gilles (1953a, 1953b) and Shapley (1953).

When the algorithm stops, for every permit there is exactly one offer. Furthermore, the set of permits C assigned by μ to j gives j the maximum net profit it could get among all possible set of permits at prices $p_{ij}(t^*)$ where t^* is the round, at which the algorithm stopped. That is,

$$\pi_j \geq Y^j(C) - \sum_{i \in C} p_{ij}(t^*), \text{ for all subsets of permits C} \qquad \dots (1)$$

Then if (j, C, r) blocked (μ, π, p), we should have

$$u_{ij}(r) > u_{i\mu(i)}(p) \text{ ,for all } i \text{ in } C \qquad \dots (2)$$

And $Y^j(C) - \sum_{i \in C} r_i > \pi_j$ … (3)

By (2) and rule 3, permit i must never have received an offer from firm j at price r_i or greater, for all i in C. But then $\pi_j < Y^j(C) - \sum_{i \in C} r_i \leq Y^j(C) - \sum_{i \in C} p_{ij}(t^*)$ which contradicts (1). Thus it proves that the outcome produced by above algorithm is in core.

QED.

3. Advantages of the Matching Mechanism

The matching mechanism modifies the simultaneous ascending auction mechanism and allows the individual permits to evaluate offers by considering both the identity of the firm and the price offered. Thus it gives an opportunity to reward the firms which are “environmentally efficient”. It requires that a firm’s bid to a permit beats its own best previous bid to the same permit rather than the best bid from any other firm. Thus it gives more maneuvering space to the firms. In matching mechanism no bidder would be forced to guess about which permits to bid on and each bidder could be assured that if it wins at all it will win the number of permits anticipated by its business plan at the bid price it chose. It also ensures that firms have no incentive to keep the price of the permits low thus signaling a representative price for the secondary market.

The simultaneous nature of the auctioning provides opportunity to the bidders to place bids on any of the permits and track bids on all the permits. The openness of the process would eliminate the guesswork, allowing the bidders to switch among permits which are essentially substitutes and promote equal prices.

To make sure that auction doesn’t drag infinitely a form of Wilson-Milgrom activity rule (Milgrom, 2004) can be applied. An activity rule limits a bidder’s ability to increase its activity late in the auction. For example, a bidder that has been actively bidding for ten permits may not, late in the auction, begin bidding for eleven permits.

4. Conclusion

Auctioning has been theoretically most preferred initial allocation mechanism for emissions permits; but to attract the participation of the polluting industries these permits have been generally grandfathered. Based on the two-sided matching literature we analyzed the initial allocation of emissions permits as a procedure which incorporates incentives of both government and firms for participating in such a market. Firstly we identified the incentives of both government and firms for participating in such a market and then defined a set of rules for matching which led to the core allocation. We showed that for the emissions permit market, matching based allocation mechanism retains the incentives of both government and firms and thus provides an improvement over standard grandfathering and auction based allocation mechanisms.

References

Aumann, R. J. (1964), "Markets with a Continuum of Traders", *Econometrica,* **32**, 39-50.

Chao, H. and Wilson, R. (1999), "Design of Wholesale Electricity Markets", Draft 990101, Electric Power Research Institute.

Cramton, P. (1997), "The FCC Auctions: An Early Assessment", *Journal of Economics and Management Strategy,* **6**(3), 431-497.

Cramton, P. and Kerr S. (1999), "The Distributional Effects of Carbon Regulation: Why Auctioned Carbon Permits are Attractive and Feasible", The Market and the Environment (ed. Thomas Sterner in *International Studies in Environmental Policy Making Series*), Edward Elgar Publication.

Cramton P. and Kerr S. (2002); "Tradable Carbon Permit Auctions: How and why to Auction not Grandfather", *Energy Policy,* **30**, 333-345.

Crawford V. P. and Knoer, E. M.(1981), "Job Matching with Heterogeneous Firms and Workers", *Econometrica,* **53**, 345-361.

Debreu, G. and Scarf H. (1963), "A Limit Theorem on the Core of an Economy", *International Economic Review*, **4**, 235-246.

Demange, G. (1987), "Nonmanipulable Cores", *Econometrica,* **55**, 1057-1074.

Demange, G., Gale, D, and Sotomayor M. (1986), "Multi-item Auctions", *The Journal of Political Economy,* **94**(4), 863-872.

Demange, G., Gale, D, and Sotomayor M. (1987), "A Further Note on the Stable Matching Problem," *Discrete Applied mathematics,* **16**, 217-222.

Dijkstra B. R. (1999), *The Political Economy of Environmental Policy: A Public Choice Approach to Market Instruments,* Edward Elgar Publication.

Dubey, A. K. (2007), "Emissions Permit Markets: The Case of Initial Allocation Mechanisms", Unpublished M. Phil. Dissertation, Indira Gandhi Institute of Development Research (IGIDR), Mumbai, India

Edgeworth, F. Y. (1881), *Mathematical Psychics: An Essay on the Application of Mathematics to the Moral Sciences,* London: Kegan Paul.

Gale and Shapley (1962), "College Admissions and the Stability of Marriage", *The American Mathematical Monthly,* **69**(1), 9-15.

Gillies, D. B. (1953a), *Some Theorems on N-Person Games,* PhD Dissertation, Princeton University.

Gillies, D. B. (1953b), "Location of Solutions", in *Report of an Informal Conference on the Theory of N-Person Games*, Princeton University.

Goulder, Lawrence H., Ian W. H. Parry, and Dallas Burtraw (1997); "Revenue Raising vs. Other Apporaches to Environmental Protection: The Critical Significance of Pre-Existing Tax Distortions", *RAND Journal of Economics (winter),* **28**(4), 708-731.

Hanoteau, J. (2003), "Lobbying for Emissions Allowances: A New Perspective on the Political Economy of the US Acid Rain Program", *Rivista di Politica Economica,* **Jan-Feb**, 289-31.

Harrison, D. and Radov D.B., (2002), *"Evaluation of alternative initial allocation mechanisms in a European Union Greenhouse gas emissions allowances trading scheme",* Brussels, NERA for the European Commission.

Jensen J. and Rasmussen T. N. (2000), "Allocation of CO2 Emissions Permits: A General Equilibrium Analysis of Policy Instruments", *Journal of Environmental Economics and Management,* **40**, 111-136.

Kelso, A. and Crawford, V. P. (1982); "Job Matching Coalition Formation and Gross Substitutes", *Econometrica*, **50**(6), 1483-504.

McAfee, R. P. and McMillan J. (1996), "Analyzing the Airwaves Auction", *Journal of Economic Perspectives,* **10**, 159-176.

McMillan, J. (1994), "Selling Spectrum Rights", *Journal of Economic Perspectives,* **8**, 771-778.

McMillan, J. (1995), "Why Auction the Spectrum?," *Telecommunication Policy,* **19**, 191-199.

Milgrom, P. (1998a), "Putting Auction Theory to Work: The simultaneous Ascending Auction", Policy Research Working Paper 1986, The World Bank.

Milgrom, P. (1998b), "Game Theory and Spectrum Auctions", *European Economic Review,* **42**, 771-778.

Milgrom, P. (1998c), *Auction Theory for Privatization,* Cambridge University Press.

Milgrom, P. (2004), *Putting Auction Theory to Work,* Cambridge University Press.

Oates W. and Schwab R. (1988), "Economic Competition among Jurisdictions: Efficiency Enhancing or Distortion Inducing?", *Journal of Public Economics,* **35**, 333-354.

Parry I. W. H. (2004), "Are Emissions Permits Regressive?", *Journal of Environmental Economics and Management,* **47**, 364-387.

Pezzey J. C. V. and Park A. (1998), "Reflections on the Double Dividend Debate: The Importance of Interest Groups and Information Costs", *Environmental and Resource Economics,* **11**(3-4), 539-555.

Poterba, J. M. (1993), "Global Warming Policy: A Public Finance Perspective", *Journal of Economic Perspective,* **7**, 47-63.

Repetto , R., Dower, R. C. and Jenkins, R. (1992), *Green Fees: How a Tax Shift Can Work for the Environment and Economy,* World Resources Institute.

Roth, A. E. (1984), "The Evolution of the Labor Market for Medical Interns and\ Residents: A Case Study in Game Theory", *Journal of Political Economy,* **92**, 991-1016.

Roth, A. E. (1985), "The College Admissions Problem Is Not Equivalent to the Marriage Problem", *Journal of Economic Theory,* **36**, 277-288.

Roth A. E. (1999), "Game Theory as a Tool for Market Design", *http://kuznets.fas.harvard.edu/~aroth/design.pdf*

Roth, A. E. (2002); “The Economist as Engineer: Game Theory, Experimentation, and Computation as Tools for Design Economics”, *Econometrica*, **70**(4), 1341-1378.

Roth, A. E. and Sotomayor, M. A. O. (1990); “Two Side Matching, A Study in Game-Theoretic Modeling and Analysis”, Econometric Society Monograph, 171-186.

Shackleton, R., Shelby, M., Cristfaro, A.,Brinner, R., Yanchar, J., Goulder, L., Jorgenson, D., Wilcoxen, P., and Pauly, P. (1996), “The Efficiency Value of Carbon Tax Revenues”, in D. Gaskins and J. Weyant, (eds.), *Reducing Global Carbon Dioxide Emissions: Costs and Policy Options*, Stanford Energy Modeling Forum.

Shapley L. S. (1953), “Open Questions”, in *Report of An Informal Conference On the Theory of N-Person Games*, Princeton University.

Shapley, Lloyd S., and Shubik M. (1972), “The Assignment Game I: The Core”, *International Journal of Game Theory,* **1**, 23-28.

Shubik M. (1959), “Edgeworth Market Games”, in *Contributions to the Theory of Games*,4, R. D. Luce and A. W. Tucker (eds.), Princeton: Princeton University Press.

Stavins, Robert N. (1995), “Transaction Costs and Tradable Permits”, *Journal of Environmental Economics and Management*, **995**(29), 133-148.

Stavins, Robert N. (1998), “What Can We Learn from the Grand Policy Experiment? Lessons from SO2 Allowance Trading” *Journal of Economic Perspective* **12**(3), 69-88. (Reprinted in Stavins, R. ed. (2000) *Economics of the Environment*. W. W. Norton & Company.)

Stavins, Robert N. (2001), *Environmental Economics and Public Policy,* Edward Elgar Publication.

Stavins, Robert N. (2002), *Emission Trading: Environmental Policy's New Approach*, edited by Kosobud et al , Chapter 2, John Wiley and Sons, Inc.

Terkla, D. (1984), “The Efficiency Value of Effluent Tax Revenues”, *Journal of Environmental Economics and Management,* **11**, 107-123.

Von Neumann, J. and Morgenstern (1994), *Theory of Games and Economic Behavior,* Princeton: Princeton University Press.

Wilson, R. (1998), “Design Principles” Chapter 11 in H. Chao and H. Huntington (eds.), *Design of Restructured Power Markets*, 1998, Norwell MA: Kluwer Academic Press.

Wilson R. (1999), “Activity Rules for an Iterative Double Auction” Chapter 10 in K. Chatterjee and W. Samuelson (eds.), *Business Application of Game Theory*, Norwell MA: Kluwer Academic Press.

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