

Lahiri, Somdeb

Working Paper

The Cooperative Theory of Two Sided Matching Problems: A Re-examination of Some Results

Nota di Lavoro, No. 109.2004

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Suggested Citation: Lahiri, Somdeb (2004) : The Cooperative Theory of Two Sided Matching Problems: A Re-examination of Some Results, Nota di Lavoro, No. 109.2004, Fondazione Eni Enrico Mattei (FEEM), Milano

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**The Cooperative Theory of Two
Sided Matching Problems:
A Re-examination of Some Results**

Somdeb Lahiri

NOTA DI LAVORO 109.2004

JULY 2004

CTN – Coalition Theory Network

Somdeb Lahiri, *School of Economic and Business Sciences, University of Witwatersrand*

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The Cooperative Theory of Two Sided Matching Problems: A Re-examination of Some Results

Summary

We show that, given two matchings of which say the second is stable, if (a) no firm prefers the first matching to the second, and (b) no firm and the worker it is paired with under the second matching prefer each other to their respective assignments in the first matching, then no worker prefers the second matching to the first. This result is a strengthening of a result originally due to Knuth (1976). A theorem due to Roth and Sotomayor (1990), says that if the number of workers increases, then there is a non-empty subset of firms and the set of workers they are assigned to under the F – optimal stable matching, such that given any stable matching for the old two-sided matching problem and any stable matching for the new one, every firm in the set prefers the new matching to the old one and every worker in the set prefers the old matching to the new one. We provide a new proof of this result using mathematical induction. This result requires the use of a theorem due to Gale and Sotomayor (1985 a,b), which says that with more workers around, firms prefer the new optimal stable matchings to the corresponding ones of the old two-sided matching problem, while the opposite is true for workers. We provide an alternative proof of the Gale and Sotomayor theorem, based directly on the deferred acceptance procedure.

Keywords: Two-sided matching, Stable

JEL Classification: C 71

I would like to thank Tamas Fleiner and Tali Diamant for comments and discussion. An earlier version of this paper was presented at the IBM-Taj International Conference on Game Theory held at Mumbai, from January 8-10, 2003. I would like to thank all those who attended the talk for their participation.

Address for correspondence:

Somdeb Lahiri
School of Economic and Business Sciences
University of Witwatersrand
Private Bag 3
WITS 2050
South Africa
E-mail: lahiris@sebs.wits.ac.za

1. Introduction : A salient feature of many markets is to match one kind of agent with another. This is particularly true, in the case of assigning workers to firms. Such markets are usually studied with the help of “two sided matching models” introduced by Gale and Shapley (1962). The emphasis in that work was on college admissions and marriage. None the less, the model is general enough to accommodate several other types of assignment problems.

The solution concept proposed by Gale and Shapley (1962), called a stable matching, requires that there should not exist two agents, each on a different side of the market, who prefer each other, to the individual they have been paired with. Gale and Shapley (1962) proved, that given any such two sided matching model, with one set consisting of firms and the other set consisting of workers, there was always a stable matching which no firm thought was inferior to any other stable matching, and there was always a stable matching that no worker thought was inferior to any other stable matching. The first was called an F – optimal stable matching (i.e. stable matching optimal for firms) and the second one a W – optimal stable matching (i.e. stable matching optimal for workers). An overview of the considerable literature that has evolved out of the work of Gale and Shapley (1962), is available in Roth and Sotomayor (1990).

The first significant result that we present here is a strengthening of a result originally due to Knuth (1976). The original result said that given any two stable matchings for a two-sided matching problem, if no firm prefers the first matching to the second, then no worker prefers the second matching to the first. In this paper we show that, given two matchings of which say the second is stable, if (a) no firm prefers the first matching to the second, and (b) no firm and the worker it is paired with under the second matching prefer each other to their respective assignments in the first matching, then no worker prefers the second matching to the first.

A theorem due to Roth and Sotomayor (1990), says that if the number of workers increases, then there is a non-empty subset of firms and the set of workers they are assigned to under the F – optimal stable matching, such that given any stable matching for the old two-sided matching problem and any stable matching for the new one, every firm in the set prefers the new matching to the old one and every worker in the set prefers the old matching to the new one. We provide a proof of this result using mathematical induction. Whereas the original proof used graph theory, our proof does not. In fact, the original proof was non-inductive. This result requires the use of a theorem due to Gale and Sotomayor (1985 a,b), which says that with more workers around, firms prefer the new optimal stable matchings to the corresponding ones of the old two-sided matching problem, while the opposite is true for workers. This result was originally proved in Gale and Sotomayor (1985 a,b), by using the lattice structure of stable matchings. Following recent approaches by Roth (2001), to arrive at new proofs of several existing results by directly appealing to the deferred acceptance procedure used by Gale and Shapley (1962), as for instance the Weak Pareto Optimality Property of F - optimal stable matchings and the Blocking Lemma of Demange, Gale and Sotomayor (1987), we provide an alternative proof of the Gale and Sotomayor theorem discussed above, based directly on the deferred acceptance procedure. Our proof does not rely on the lattice structure of stable matchings. Wolfstetter (1999) has a lucid discussion of such problems, where every matching is required to map the set of firms, bijectively onto the set of workers. In the traditional literature on matching theory, such models are known as marriage models. Moulin (1995) also contains an easily accessible discussion of the marriage model.

2. The Model : There are two non empty finite and disjoint sets: F of firms and W of workers. Each firm $f \in F$ has preferences over $W \cup \{f\}$ represented by a linear order R_f (: a binary relation R on a non empty subset of $F \cup W$ is said to be a linear order if it is reflexive, complete, anti- symmetric and transitive) and each worker $w \in W$ has preferences over $F \cup \{w\}$ represented by a linear order R_w . Given a binary relation R on $F \cup W$ and a non-empty subset S of $F \cup W$, let $R \upharpoonright S = R \cap (S \times S)$ and let $P(R) = \{ (x,y) \in R / (y,x) \notin R \}$ denote the asymmetric part of R . A two-sided matching problem G is an array $\langle F, W, (R_x)_{x \in F \cup W} \rangle$. Given a two-sided matching problem G , $f \in F$ and $w \in W$, the acceptable set for f , denoted $A(f) = \{w \in W / (w,f) \in R_f\}$ and acceptable set for w , denoted $A(w) = \{f \in F / (f,w) \in R_w\}$. A pair $(f,w) \in F \times W$, is said to be mutually acceptable if $w \in A(f)$ and $f \in A(w)$. Given, $x,y,z \in F \cup W$, we denote $(y,z) \in R_x$ by $y \geq_x z$ and $(y,z) \in P(R_x)$ by $y >_x z$. Given a two-sided matching problem G , a matching for G is a bijection μ from $F \cup W$ to itself such that :
- (i) for all $x \in F \cup W$: $\mu(x) \in A(x) \cup \{x\}$;
 - (ii) for all $x \in F \cup W$: $\mu(\mu(x)) = x$.
- Since the identity function on $F \cup W$ is a matching every two-sided matching problem admits at least one matching.

Given a matching μ for a two-sided matching problem G , a pair $(f,w) \in F \times W$ is said to block μ , if $f \succ_w \mu(w)$ and $w \succ_f \mu(f)$. The matching μ is said to be stable if it does not admit any blocking pair.

Given two matchings μ, μ' for G and a non-empty subset S of $F \cup W$, we write:

- (i) $\mu \succeq_S \mu'$ if $\mu(x) \succeq_x \mu'(x)$ for all $x \in S$;
- (ii) $\mu \succ_S \mu'$ if $\mu \succeq_S \mu'$ but $\mu \neq \mu'$.

In the case where S is a singleton, $S = \{x\}$, we write $\mu \succeq_x \mu'$ to denote $\mu \succeq_{\{x\}} \mu'$ and $\mu \succ_x \mu'$ to denote $\mu \succ_{\{x\}} \mu'$.

A stable matching μ_F for G is said to be F - optimal (i.e. optimal for firms) if $\mu_F \succeq_F \mu$, whenever μ is any stable matching for G .

A stable matching μ_W for G is said to be W - optimal (i.e. optimal for workers) if $\mu_W \succeq_W \mu$, whenever μ is any stable matching for G .

3. Some Preliminary Lemmas:

Lemma 1: Let μ and $\bar{\mu}$ be stable matchings for a two-sided matching problem G .

Let $f \in F$ and $\mu(f) = w \in W$. If, $\mu(f) \succ_f \bar{\mu}(f)$, then $\bar{\mu}(w) \succ_w \mu(w)$. Conversely, if $\bar{\mu}(w) = \bar{f}$ and $\bar{\mu}(w) \succ_w \mu(w)$, then $\mu(\bar{f}) \succ_{\bar{f}} \bar{\mu}(\bar{f})$.

Proof: Suppose $\mu, \bar{\mu}, f$ and w are as above. If $w = \mu(f) \succ_f \bar{\mu}(f)$, then $\bar{\mu}(w) \neq f$. Thus stability of $\bar{\mu}$ requires, $\bar{\mu}(w) \succ_w f = \mu(w)$. Conversely, if $\bar{f} = \bar{\mu}(w) \succ_w \mu(w)$, then since $\mu(\bar{f}) \neq w$, stability of μ requires that $\mu(\bar{f}) \succ_{\bar{f}} w = \bar{\mu}(\bar{f})$. Q.E.D.

The following lemma extends one due to Knuth (1976):

Lemma 2: Let G be a two-sided matching problem, for which $\bar{\mu}$ is a stable matching. Suppose that μ is a matching such that $\bar{\mu} \succeq_F \mu$. If there does not exist $f \in F$, such that $(f, \bar{\mu}(f))$ block μ , then $\mu \succeq_W \bar{\mu}$.

Proof: Towards a contradiction suppose that $f = \bar{\mu}(w) \succ_w \mu(w)$, for some $w \in W$. Since $(f, \bar{\mu}(f)) = (f, w)$ does not block μ , and since $\mu(f) \neq w$, it must be the case that $\mu(f) \succ_f w = \bar{\mu}(f)$. This contradicts the hypothesis $\bar{\mu} \succeq_F \mu$, and proves the lemma. Q.E.D.

Hence, if in Lemma 2, μ is a stable matching, then, $\bar{\mu} \succeq_F \mu$ if and only if

$\mu \geq_W \bar{\mu}$. This is precisely the result in Knuth (1976), which Lemma 2 extends.

4. The Gale-Shapley Theorem and its consequences:

We begin this section by presenting the seminal theorem due to Gale and Shapley (1962). In an appendix to this paper we provide the procedure (Deferred Acceptance Procedure With Firms Making Offers) used to prove the theorem, since the same argument is required in the proofs of several theorems that follow.

Theorem 1 (Gale and Shapley (1962)) : Every two-sided matching problem admits an F-optimal and a W-optimal stable matching.

As a consequence of Lemma 2 and Theorem 1 we obtain the following result:

Corollary of Lemma 2 : Let G be a two-sided matching problem and suppose μ is an unstable matching, such that $\mu_F >_F \mu$. If there does not exist a pair $(f, \mu_F(f))$ which blocks μ , then there exists $f \in F$ and $w \in W$, such that $\mu_F(f) >_f \mu(f)$ and $f >_w \mu(w)$.

Proof : Suppose that there does not exist a pair $(f, \mu_F(f))$ which blocks μ . Thus, there does not exist a pair $(\mu_F(w), w)$ which blocks μ . Thus, $f = \mu_F(w) >_w \mu(w)$ implies $\mu(f) >_f w = \mu_F(f)$. This contradicts $\mu_F >_F \mu$. Thus, $\mu \geq_W \mu_F$. Since μ is unstable there exists a pair (f, w) which blocks μ . Thus, $w >_f \mu(f)$ and $f >_w \mu(w)$. If $\mu_F(f) \geq_f w$, then we are done. Hence suppose $w >_f \mu_F(f)$. Since μ_F is stable, $\mu_F(w) >_w f$. Thus $\mu_F(w) >_w \mu(w)$. This contradicts, $\mu \geq_W \mu_F$. Thus there exists $f \in F$ and $w \in W$, such that $\mu_F(f) >_f \mu(f)$ and $f >_w \mu(w)$. Q.E.D.

Another direct consequence of a combination of Lemma 2 and the deferred acceptance procedure with firms making offers is the following theorem due to Gale and Sotomayor (1985 a,b).

Theorem 2 (Gale and Sotomayor (1985 a,b)) : Let $G = \langle F, W, (R_x)_{x \in F \cup W} \rangle$ and $G' = \langle F, W', (R'_x)_{x \in X} \rangle$, where $W \subset W'$, $X = F \cup W'$ and $R_x = R'_x \upharpoonright F \cup W$ for all $x \in F \cup W$.

Let μ_F and μ_W be the F – optimal and W – optimal stable matchings for G . Let μ'_F and μ'_W be the F – optimal and W – optimal stable matchings for G' . Then,
(i) $\mu_F \geq_W \mu'_F$, $\mu_W \geq_W \mu'_W$; (ii) $\mu'_W \geq_F \mu_W$, $\mu'_F \geq_F \mu_F$.

Proof : By the symmetry of the F- optimal stable matching and the W- optimal stable matchings and Lemma 2 it is enough to prove the following:

(a) Let $G = \langle F, W, (R_x)_{x \in F \cup W} \rangle$ and $G' = \langle F, W', (R'_x)_{x \in X} \rangle$, where $W \subset W'$, $X = F \cup W'$ and $R_x = R'_x \upharpoonright F \cup W$ for all $x \in F \cup W$. Let μ_F be the F – optimal for G and let μ'_F be the F – optimal stable matchings for G' . Then, $\mu'_F \geq_F \mu_F$.

(b) Let $G = \langle F, W, (R_x)_{x \in F \cup W} \rangle$ and $G' = \langle F', W, (R'_x)_{x \in X} \rangle$, where $F \subset F'$, $X = F' \cup W$ and $R_x = R'_x \upharpoonright F \cup W$ for all $x \in F \cup W$. Let μ_F be the F -optimal for G and let μ'_F be the F' -optimal stable matchings for G' . Then, $\mu_F \geq_F \mu'_F$.

Let us first prove (a). Suppose that at the first step of the deferred acceptance procedure for G' , a firm f is rejected by a worker $w = \mu_F(f)$. Since, worker w , proceeds up his ranking during the procedure, w rejects f in favor of some other firm f' . This follows from the fact that the set of firms acceptable to w is non-empty. Since, f' made the offer to w at the very first step, f' ranks w first and hence above, $\mu_F(f')$. This contradicts the stability of μ_F .

Suppose that up to a certain stage in the deferred acceptance procedure for G' , no firm f is rejected by a worker $w = \mu_F(f)$. Suppose that at the next stage of the procedure for G' , a firm f is rejected by a worker $w = \mu_F(f)$ in favor of another firm f' . Thus, w prefers f' to f . By the induction hypothesis, f' has not been rejected by $\mu_F(f')$ up to the stage, where it makes the offer to w in the deferred acceptance procedure for G' . Since, f' moves one rank down at a time in the procedure, $w \geq_{f'} \mu_F(f')$. Since $w \neq \mu_F(f')$, $w >_{f'} \mu_F(f')$, contradicting the stability of μ_F . Thus, even at this stage of the deferred acceptance procedure for G' , no firm f is rejected by a worker $w = \mu_F(f)$. Since the procedure terminates in a finite number of steps, it must be the case that $\mu'_F \geq_F \mu_F$.

Now let us prove (b). For a stage k of the deferred acceptance procedure for G and $w \in W$, let $F^k(w) = \{f \in F / f \text{ makes an offer to } w\}$. For a stage k of the deferred acceptance procedure for G' and $w \in W$, let $H^k(w) = \{f \in F' / f \text{ makes an offer to } w\}$. Clearly, $F^k(w) \subset H^k(w)$ for all $w \in W$. Further, for all $w \in W$, any firm who is rejected from $F^k(w)$ is also rejected from $H^k(w)$. Suppose that up to a stage K of the two procedures: $[\bigcup_{k=1}^K F^k(w) \subset \bigcup_{k=1}^K H^k(w) \text{ for all } w \in W]$ and $[\text{for all } w \in W,$

any firm who is rejected from $\bigcup_{k=1}^K F^k(w)$ by w at a stage $k \leq K$, is also rejected

from $\bigcup_{k=1}^K H^k(w)$ by w at the same stage or earlier]. Suppose firm f makes an offer to worker w at stage $K+1$ in the deferred acceptance procedure for G . In that case there must have been a worker w' , such that $f \in F^k(w')$ for some $k < K+1$ and f was rejected by w' from $\bigcup_{k=1}^K F^k(w')$ at stage K . Thus, $f \in \bigcup_{k=1}^K F^k(w')$, and f was rejected

by w' from $\bigcup_{k=1}^K F^k(w')$ at stage K . By the induction hypothesis, $f \in \bigcup_{k=1}^K H^k(w')$,

and f was rejected by w' from $\bigcup_{k=1}^K H^k(w')$ at stage K or earlier. Since each firm

moves down its list of acceptable workers one rank at a time in the deferred acceptance procedure, the fact that f makes an offer to w after being rejected by w' in the procedure for G , implies that it would be doing the same in the procedure

for G' . Thus, $\bigcup_{k=1}^{K+1} F^k(w) \subset \bigcup_{k=1}^{K+1} H^k(w)$. Further, any firm who is rejected from $\bigcup_{k=1}^{K+1} F^k(w)$ at stage $K+1$, will also be rejected from $\bigcup_{k=1}^{K+1} H^k(w)$ at stage $K+1$, unless it has already been rejected at an earlier stage. Thus, even up to stage $K+1$ of the two procedures, $[\bigcup_{k=1}^{K+1} F^k(w) \subset \bigcup_{k=1}^{K+1} H^k(w)$ for all $w \in W]$ and [for all $w \in W$, any firm who is rejected from $\bigcup_{k=1}^{K+1} F^k(w)$ by w at a stage $k \leq K+1$, is also rejected from $\bigcup_{k=1}^{K+1} H^k(w)$ by w at the same stage or earlier]. Since each firm moves down its list of acceptable workers one rank at a time in the deferred acceptance procedure, it follows that $\mu_F \geq_F \mu'_F$. Q.E.D.

5. The Roth and Sotomayor theorem:

Theorem 3 (Roth and Sotomayor (1990)): Let $G = \langle F, W, (R_x)_{x \in F \cup W} \rangle$ and $G' = \langle F, W', (R'_x)_{x \in X} \rangle$, where $W' = W \cup \{w_0\}$, $w_0 \notin W$, $X = F \cup W'$ and $R_x = R'_x \upharpoonright F \cup W$ for all $x \in F \cup W$. Let μ^* be the F - optimal stable matching for G and let μ^{**} the W - optimal stable matching for G' . If w_0 is not single under μ^{**} , then given any stable matching μ for G and μ' for G' there exists a non-empty subset S of firms, such that $\mu' >_S \mu$ and $\mu >_{W^*} \mu'$, where $W^* = W \cap \mu^*(S)$.

Proof: We prove by induction on the cardinality of W that there exists a non-empty subset S of firms, such that $\mu^{**} >_S \mu^*$ and $\mu^* >_{W^*} \mu^{**}$, where $W^* = W \cap \mu^*(S)$.

Let $\mu^{**}(w_0) = f_0$. Suppose $\#W = 1$. Let $W = \{w\}$.

- (a) If w is single under μ^* , then $\mu^*(f) = f$ for all $f \in F$. Let $S = \{f_0\}$. Thus, $\mu^{**} >_S \mu^*$. Since, $W^* = \emptyset$, $\mu >_{W^*} \mu^{**}$ holds vacuously.
- (b) If $\mu^*(w) = f \neq f_0$, then $\mu^*(f_0) = f_0$. Let $S = \{f_0\}$. Thus, $\mu^{**} >_S \mu^*$. Since, $W^* = \emptyset$, $\mu^* >_{W^*} \mu^{**}$ holds vacuously.
- (c) If $\mu^*(w) = f_0$, then for all $f \in F \setminus \{f_0\}$, $w >_f$ implies $f_0 >_w f$ by the stability of μ^* and the fact that $W = \{w\}$. Further $f_0 >_w w$. If f_0 prefers w to w_0 then the pair (f_0, w_0) would block μ^{**} contradicting its stability. Thus, f_0 prefers w_0 to w . Let $S = \{f_0\}$. Thus, $\mu^{**} >_S \mu^*$ and $\mu^* >_{W^*} \mu^{**}$, where $W^* = \{w\}$.

Hence the required assertion is true for $\#W = 1$.

Suppose the required assertion is true for $\#W = 1, \dots, k$ and now let $\#W = k+1$. If $\mu^*(f_0) = f_0$, then by letting $S = \{f_0\}$, the required assertion is easily seen to hold.

Hence suppose $\mu^*(f_0) = w_1 \in W$. Thus, w_1 prefers f_0 to remaining single.

Case 1: $\mu^{**}(w_1) = w_1$.

If f_0 prefers w_1 to w_0 , then the pair (f_0, w_1) would block μ^{**} , contradicting its stability. Thus f_0 prefers w_0 to w_1 . Let $S = \{f_0\}$. Thus, $\mu^{**} >_S \mu^*$ and $\mu^* >_{W^*} \mu^{**}$, where $W^* = \{w_1\}$.

Case 2: $\mu^{**}(w_1) = f_1 \in F$.

Let $Z' = X \setminus \{w_1\}$ and $Z = Z' \setminus \{w_0\}$. Let $G_1 = \langle F, W \setminus \{w_1\}, (Q'_x)_{x \in Z'} \rangle$, $G_2 = \langle F, W \setminus \{w_0, w_1\}, (Q_x)_{x \in Z} \rangle$, where for all $x \in Z'$, $Q'_x = R'_x|Z'$ and for all $x \in Z$, $Q_x = R_x|Z$. Let μ be the F-optimal stable matching for G_2 and μ' be the W-optimal stable matching for G_1 .

By the induction hypothesis there exists a non-empty subset S of F , such that $\mu' >_S \mu$ and $\mu(w) >_w \mu'(w)$ for all $w \in (W \setminus \{w_1\}) \cap \mu(S)$.

By Theorem 2, $\mu^{**} \geq_F \mu'$, $\mu \geq_F \mu^*$.

Now, $\mu^{**} \geq_F \mu'$, $\mu' >_S \mu$ and $\mu \geq_F \mu^*$ implies $\mu^{**} >_S \mu^*$.

By Lemma 2, $\mu^* >_{W^*} \mu^{**}$.

It now follows by a standard induction argument that for all cardinalities of W , there exists a non-empty subset S of firms, such that $\mu^{**} >_S \mu^*$ and $\mu^* >_{W^*} \mu^{**}$, where $W^* = W \cap \mu^*(S)$.

Further $\mu^* \geq_F \mu$ and $\mu^{**} \geq_{W'} \mu'$.

By Lemma 2, $\mu' \geq_F \mu^{**}$ and $\mu \geq_W \mu^*$. Hence, $\mu' \geq_F \mu^{**}$, $\mu^{**} >_S \mu^*$ and $\mu^* \geq_F \mu$ implies $\mu' >_S \mu$. Similarly, $\mu \geq_W \mu^*$, $\mu^* >_{W^*} \mu^{**}$ and $\mu^{**} \geq_{W'} \mu'$ implies $\mu >_{W^*} \mu'$. This proves the theorem. Q.E.D.

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Appendix

Deferred Acceptance Procedure With Firms Making Offers (Gale and Shapley (1962)): To start each firm makes an offer to its favorite worker, i.e. to its first worker on its list of acceptable workers. Each worker rejects the offer of any firm who is unacceptable to him, and each worker who receives one or more acceptable offers, rejects all but his most preferred of these. Any firm whose offer is not rejected at this point is kept “pending”.

At any step any firm whose offer was rejected at the previous step, makes an offer to its next choice (i.e., to its most preferred acceptable worker, among those who have not rejected its offer), so long as there remains an acceptable worker to whom it has not yet made an offer. If at any step of the procedure, a firm has already made offers to, and been rejected by all workers it finds acceptable, then it makes no further offers. Each worker receiving offers rejects any from unacceptable firms, and also rejects all but his most preferred among the group consisting of the new offers together with any firm that he may have kept pending from the previous step.

The algorithm stops after any step in which no firm is rejected. At this point, every firm is either kept pending by some worker or has been rejected by every worker on its list of acceptable workers. The matching that is defined now, associates to each firm the worker who has kept him pending, if there be any. Further, workers who did not receive any offers at all and firms who have been rejected by all the workers on their list of acceptable workers, remain single. In the above procedure, each firm, proceeds down its list of acceptable workers, and each worker proceeds up his list of acceptable firms.

Let us call this matching μ_F .

Note : It follows from the deferred acceptance procedure that a worker who is not employed, either has a empty set of admissible firms or is ranked below the F-optimal stable matching allocation of every firm. The latter, in particular implies that the concerned worker is unacceptable to any firm who in spite of being acceptable to the worker, does not employ any worker in the F-optimal stable matching.

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- (lix) This paper was presented at the ENGIME Workshop on “Mapping Diversity”, Leuven, May 16-17, 2002
- (lx) 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
- (lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003
- (lxii) This paper was presented at the ENGIME Workshop on “Communication across Cultures in Multicultural Cities”, The Hague, November 7-8, 2002
- (lxiii) This paper was presented at the ENGIME Workshop on “Social dynamics and conflicts in multicultural cities”, Milan, March 20-21, 2003
- (lxiv) This paper was presented at the International Conference on “Theoretical Topics in Ecological Economics”, organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003
- (lxv) This paper was 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 25-27, 2003
- (lxvi) This paper has been presented at the 4th BioEcon Workshop on “Economic Analysis of Policies for Biodiversity Conservation” organised on behalf of the BIOECON Network by Fondazione Eni Enrico Mattei, Venice International University (VIU) and University College London (UCL), Venice, August 28-29, 2003
- (lxvii) This paper has been presented at the international conference on “Tourism and Sustainable Economic Development – Macro and Micro Economic Issues” jointly organised by CRENoS (Università di Cagliari e Sassari, Italy) and Fondazione Eni Enrico Mattei, and supported by the World Bank, Sardinia, September 19-20, 2003
- (lxviii) This paper was presented at the ENGIME Workshop on “Governance and Policies in Multicultural Cities”, Rome, June 5-6, 2003
- (lxix) This paper was presented at the Fourth EEP Plenary Workshop and EEP Conference “The Future of Climate Policy”, Cagliari, Italy, 27-28 March 2003
- (lxx) This paper was presented at the 9th Coalition Theory Workshop on "Collective Decisions and Institutional Design" organised by the Universitat Autònoma de Barcelona and held in Barcelona, Spain, January 30-31, 2004

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