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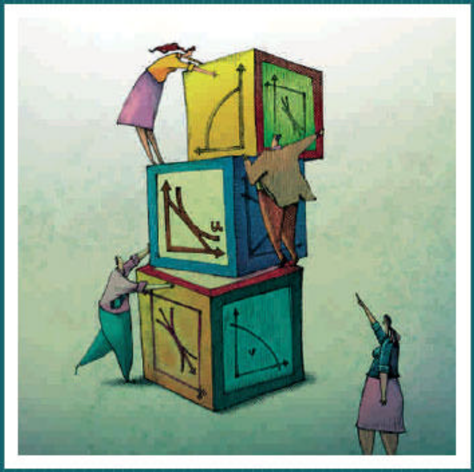

Nº 292 NEUTRAL MERGERS BETWEEN BILATERAL MARKETS

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Neutral mergers between bilateral markets

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Abstract

We study the consequences of bilateral market mergers. We first characterize the relationship between the M-optimal stable matching in the original markets with the M-optimal stable matching in the new market formed after the merger of the original markets. Then, we characterize the conditions under which the Cartesian product of the set of stable matching in each of the original markets remain stable in the new market.

Keywords: Two-sided Matching, Stable Matching Mergers, Comparative Statics.

Journal of Economic Literature Classification Numbers: C78, D78.

1 Introduction

The marriage problem studies the allocation of agents from two disjoint sets, males and females. Gale and Shapley (1962) solved the problem showing that, for any type of preference of males over females and vice versa; a stable matching exists.

We study the consequences of the merger of two disjoint marriage markets. We first analyze the relationship between the M-optimal stable matching in each of the original markets and the M-optimal stable matching in the new market formed after the merger. We provide an example which shows that the stability of the union of the original M-optimal stable matching is not guarantee to be M-optimal in the new market. Then, we provide intuitive necessary and sufficient conditions for the original M-optimal stable matching not to be affected by the merger. Finally, we characterize the conditions under which the set of stable matching in the new market includes the Cartesian product of the set of stable matching in each of the original markets. We refer to this situation as neutral mergers.

The welfare effects of one-sided entry have been previously analyzed in the literature. The first contributions are due to Gale and Sotomayor (1985), and they were later collected and completed by Roth and Sotomayor (1990). They show that if a group of women join the market, all men are weakly better off and all women are weakly worse off. These results are both clear-cut and preference independent and they were extended by Mo (1988) and Crawford (1991) to the many-to-one case (see also Klaus, 2011).

In our paper, we adopt a more general approach. We allow for bilateral entry or mergers. It turns out that, in general, the effects of market mergers are ambiguous and depend on agents' preferences. Nonetheless, we can think of markets, as the school allocation problem or university admission problem, where the agents' preferences or priorities are either predictable or designed as part of the model. In these cases, our results provide information on the effects of mergers or segmentation of school or university districts and establish preference patterns that make mergers neutral.

The paper is organized as follows: Section 2 introduces the formal model. In Section 3, we analyze how entry affects M-optimal stable matching. In Section 4, we characterize neutral markets and Section 5 concludes.

2 The model

A bilateral matching market is a triple (M,W,P). M and W are two finite sets of men and women, respectively. Each $m \in M$ is endowed with a strict complete, transitive preference relation P_m on $W \cup \{m\}$. For every $w, w' \in W, wP_mw'$ means that m prefers woman w to woman w' ; $mP_m w$ means that m prefers to stay single rather than being married to w. In such a case, w will be said to be not acceptable to m. For our purposes, it suffices to represent m's preferences by an ordered list of his acceptable women. We use similar notation to describe women's preferences.

Definition 1 *Let (M,W,P) be a matching market. A* **matching** *is a function μ : $M \cup W \rightarrow M \cup W$, such that, for every $m \in M$ and $w \in W$*
(1) if $\mu(m) \notin W$ then $\mu(m) = m$, and if $\mu(w) \notin M$ then $\mu(w) = w$, and
(2) $\mu(m) = w$ if and only if $\mu(w) = m$.

Let μ be a matching in the market (M,W,P).

Definition 2 *The matching μ is* **individually rational** *if each agent is acceptable to his or her mate. That is, a matching is individually rational if it is not blocked by any (individual) agent.*

Definition 3 *The matching μ is* **blocked** by a pair $(m,w) \in M \times W$ *if and only if $wP_m\mu(m)$ and $mP_w\mu(w)$.*

Definition 4 *The matching μ is* **stable** *in the market (M,W,P) if and only if it is individually rational and it is not blocked by any pair in $M \times W$.*

When preferences are strict, the set of stable matching of (M,W,P), denoted by $\Gamma(M,W,P)$, is not empty. The proof of its no-emptiness, due to Gale and Shapley (1962), uses the *Deferred Acceptance Algorithm (DAA)*. We call the matching produced by the deferred acceptance algorithm when men (women) propose M-optimal (W-optimal) matching, and we denote it by μ_M (μ_W). $\Gamma(M,W,P)$ has the structure of a complete distributive lattice induced by the following order, $\succ_M$

$$\mu' \succ_M \mu \text{ if and only if } \mu'(m) R_m \mu(m) \text{ for all } m \in M,$$

where R_m denotes weak preference. An analogous order $\succ_W$ can be built using women's preferences. The two orders are dual: $\mu' \succ_M \mu$ if and only if $\mu \succ_W \mu'$. An important consequence of this result is that the set of the unmatched agents or singles is the same for all the stable matching in $\Gamma(M,W,P)$. Therefore, it makes sense to speak of the singles of (M,W,P).

Let (M^i,W^i,P^i) $i = 1,2$ be the two *original matching markets*. When the two markets are merged, each agent complete her or his preferences to include the agents of the other market preserving the order on the agents of the market where she or he belongs. We denote the resulting *new matching market* by (M,W,P), where $M = M^1 \cup M^2$ and $W = W^1 \cup W^2$. Formally, for $i = 1,2$, for every $w,w' \in W^i$ and for each $m,m' \in M^i$ then: $wP_m w'$ if and only if $wP^i_m w'$ and $mP_w m'$ if and only if $mP^i_w m'$.

Finally, we focus on the cases in which $M^1 \cap M^2 = \emptyset$ and $W^1 \cap W^2 = \emptyset$.

Definition 5 *Let μ_1 be a matching in (M^1, W^1, P^1) and let μ_2 be a matching in (M^2, W^2, P^2). Let the* union of μ_1 and μ_2*, denoted by $\mu_1 \cup \mu_2$ be the matching in the market (M, W, P) defined as follows:*

$$[\mu_1 \cup \mu_2](x) = \mu_1(x) \text{ if } x \in M^1 \cup W^1,$$
$$[\mu_1 \cup \mu_2](x) = \mu_2(x) \text{ if } x \in M^2 \cup W^2.$$

3 M-optimal stable matching

Any relation between the set of stable matching in the original and the new markets is possible. In general, the new M-optimal stable matching (the M-optimal stable matching of the new market (M, W, P)) is different from the union of the two original M-optimal stable matching (the M-optimal stable matching of the original markets (M^1, W^1, P^1) and (M^2, W^2, P^2)). Also, there is no reason why the union of the M-optimal stable matchings of the original markets ($\mu_{M^1} \cup \mu_{M^2}$) remains stable. It is easy to provide an example in which a man m in M^1 and a woman w in W^2 are correspondingly best mates in the new market. Therefore, (m, w) blocks $\mu_{M^1} \cup \mu_{M^2}$ and any stable matching of the new market.

Let us characterize the conditions under which $\mu_{M^1} \cup \mu_{M^2}$, remains stable. Let $i, j = 1, 2$, $i \neq j$.

Definition 6 *An agent $a \in M^j \cup W^j$ is* **loyal** to his original mate *if for any $b \in M^i \cup W^j$: $aP_b\mu_{M^i}(b) \Rightarrow \mu_{M^j}(a)P_a b$.*

The loyalty to original mates of all men and all women is a necessary and sufficient condition for the union of the two original M-optimal stable matching to be stable.

Lemma 1 *$\mu_{M^1} \cup \mu_{M^2}$ is stable if and only if all women are* loyal *to their original mates, or, equivalently, if and only if all men are* loyal *to their original mates.*

Proof. The union matching $\mu_{M^1} \cup \mu_{M^2}$ can be blocked only by pairs constituted by a woman from one market and a man from the other one as $P = P^1$ on $M^1 \cup W^1$ and $P = P^2$ on $M^2 \cup W^2$. But such a blocking pair exists if and only if some woman prefers a man from the new market to his original mate and such a man prefers the former woman to his original optimal mate. This happens if and only if both are not *loyal* to their original mates. ■

Stability is not sufficient for $\mu_{M^1} \cup \mu_{M^2}$ to be the optimal stable matching as the following example shows.

Example 1 *Let* $M^1 = \{m_1\}$, $M^2 = \{m_2\}$, $W^1 = \{w_1\}$, $W^2 = \{w_2\}$. $P^1_{m_1} = w_1$, $P^2_{m_2} = w_2$, $P^2_{w_2} = m_2$.
The M-optimal and W-optimal stable matching in each market are:

$$\mu_{M^1}(m_1) = \mu_{W^1}(m_1) = w_{1,}\ \mu_{M^2}(m_2) = \mu_{W^2}(m_2) = w_2.$$

When the two markets are merged, the preferences evolve in the following way:
$P_{m_1} = w_2 w_1$, $P_{w_1} = m_1 m_2$, $P_{m_2} = w_1 w_2$, $P_{w_2} = m_2 m_1$.
The matching $\mu_{M^1} \cup \mu_{M^2}$ *is stable in the new market, but it does not coincide with* μ_M*, the M-optimal stable matching of* (M, W, P)*. Indeed, applying the deferred acceptance algorithm, we obtain:*

$$\mu_M(m_1) = w_2,\ \mu_M(m_2) = w_1,$$
$$\mu_W(m_1) = w_1,\ \mu_W(m_2) = w_2.$$

Thus, $\mu_M \neq \mu_{M^1} \cup \mu_{M^2}$ *although* $\mu_W = \mu_{W^1} \cup \mu_{W^2}$.

This example shows that merging two M-optimal stable matching may result in stable matching, which may (or may not) be M-optimal. Note that if we had extended preferences such that $P_{m_1} = w_2 w_1$, $P_{w_1} = m_2 m_1$,$P_{m_2} = w_1 w_2$, $P_{w_2} = m_2 m_1$, $\mu_{M^1} \cup \mu_{M^2} = \mu_{W^1} \cup \mu_{W^2}$ would not even be a stable matching.

Let us now introduce some additional properties. Let $i, j = 1, 2$, $i \neq j$.

Definition 7 *A woman* $w \in W^i$ *will be said to be* **in love** *if for each* $m \in M^j$ *we have* $\mu_{W^i}(w) P_w m$.

Analogous definition can be given for a man m. In general, an agent is *in love* if she/he prefers her/his original optimal mate to any agent of the opposite sex coming from the other market.

Definition 8 *A woman* $w \in W^i$ *is a* **lucky-loser** *if for some* $w' \in W_j$ $w' P_m w$*, where* $m = \mu_{M^i}(w)$*, then there exists* $m' \in M^i, w' P_{m'} \mu_{M^i}(m')$ *such that* $m' P_{w'} m$.

Let $w \in W^i$ and assume that her mate under μ_{M^i} prefers a woman from the other market to her. If w is a *lucky-loser* then there exists a man in M^i who would prefer to be matched with her, rather than remain with his original match.

Definition 9 *A woman* $w \in W^i$ *is a* **lucky-winner** *if for all* $w' \in W^j$ *such that* $w' P_m w$ *where* $m = \mu_{M^i}(w)$*, we have* $\mu_{M^j}(w') P_{w'} m$.

Let us assume that w is matched to m under μ_{M^i} and m prefers the new entry w'. If w is a *lucky winner* then w' would prefer to stay with his original mate rather than to marry m. A woman who is either a *lucky loser* or a *lucky winner* will be called ***lucky***.

Definition 10 *Let $m \in M^i$ and let $x = \mu_{M^i}(m)$. We say that m is a* **potential loser** *if for all individually rational matching μ such that $\mu(m) = w' \in W_j$, $w' P_m \mu_{M^i}(m)$ then there exists $m' \in M^i$ such that such that w is unachievable for $m'$and (m', w') blocks μ.*

Let us assume that $m \in M^i$ *is matched with w under μ_{M^i} and m prefers an entrant w'. If m is a potential loser* then (m, w') will be blocked by a man $m' \in M^i$ not matched with w in any matching of $\Gamma(M^i, W^i, P^i)$.

Definition 11 *Let $m \in M^i$ and let $x = \mu_{M^i}(m)$. We say that m* **does not alter** μ_{M^j} *if for all individually rational matching μ such that $\mu(m) = w' \in W^j$ and $w' P_m x$ then μ is blocked by $(w', \mu_{M^j}(w'))$.*

The first step in the characterization result is to show that a combination of the previously defined properties is sufficient to guarantee the stability of the original M-optimal stable matching in the newly form market.

Theorem 1 *The following statements are equivalent:*
i) $\mu_{M^1} \cup \mu_{M^2} = \mu_M$.
ii) All women are loyal *to their original mates and each of them either has a mate who is* in love *or she is lucky.*
iii) For each $i = 1, 2$, any man $m \in M^i$ who is not in love *nor is a* potential loser *has a mate under μ_{M^i} who* does not alter μ_{M^j}*, for $i \neq j$.*

Proof. $i) \Rightarrow ii)$ If $\mu_{M^1} \cup \mu_{M^2} = \mu_M$ then $\mu_{M^1} \cup \mu_{M^2}$ is stable. Then Lemma 1 implies that all women are *loyal* to their original mates.
Consider the preferences P' such that from each man's list the women of the same market preceding his mate in $\mu_{M^1} \cup \mu_{M^2}$ are deleted. The stable lattice is not altered by this operation if $\mu_{M^1} \cup \mu_{M^2} = \mu_M$. Now consider the deferred acceptance algorithm that uses such preferences P'. Under P' no man proposes to a woman in his market before having proposed to his match. Let w be a woman definitively matched at the earliest stage using the deferred acceptance procedure (which yields $\mu_{M^1} \cup \mu_{M^2} = \mu_M$). Without loss of generality assume $w \in W^1$. Assume that w mate m in the original market is not *in love*. If in a previous stage m proposed to a woman in $w' \in W^2$. Such a woman w' must have rejected him, m, in favor of a man in M^1. Otherwise w' would be definitively matched before w (by how P' is defined). Then,

w either have a mate who is *in love* or she is a *lucky-loser*.
Now consider a woman whose mate is not *in love* nor she is a *lucky-loser* Then it must be the case she has not been matched in the original market. So his mate has been rejected in favor of the definitive mate of the last woman he was matched too, then she is a *lucky-winner*. *ii*) $\Rightarrow$ *iii*) It is immediate given that loyalty implies stability. *iii*) $\Longrightarrow$ *i*) First of all we show that $\mu_{M^1} \cup \mu_{M^2}$ is stable. By contradiction assume it is not the case. Then, there exists no stable matching in which at least one man is matched to a woman on the other market whom he strictly prefers to his mate under $\mu_{M^1} \cup \mu_{M^2}$, in particular at μ_M. But being $\mu_{M^1} \cup \mu_{M^2}$ individually rational and not stable by strong stability property (Theorem 3.4 on Roth and Sotomayor, 1990) there exists a stable matching μ stable in the market (M,W,P), and a blocking pair (m,w) such that $\mu(m)P'(m)[\mu_{M^1} \cup \mu_{M^2}](m)$ and $\mu(w)P'(w)[\mu_{M^1} \cup \mu_{M^2}](w)$, but it is in contradiction with the hypothesis. Now let μ be an individually rational matching. If $\mu(m)P_m[\mu_{M^1} \cup \mu_{M^2}](m)$ for some $m \in M^i$ then, by hypothesis, either he is *in love* or he is a *potential loser* or he *does not alter* μ_{M^j}. In any case μ is not stable. ■

During the proof of the main result we obtain the following characterization.

Corollary 1 *If $\mu_{M^1} \cup \mu_{M^2} = \mu_M$, then, there exists at least a woman with a mate who is* in love *or a woman who is a* lucky-loser *and there exists at least a woman whose mate is in love or a man $m \in M^i$ who* does not alter μ_{M^j}.

Proof. It has been shown for all the women matched at the earliest stage ■
Analogous results can be obtained for W-optimal stable matching.

4 Neutral mergers

In this section we provide conditions under which the stability of the original matching is preserved after two previously independent matching markets are merged. Let us denote $\Pi(M,W,P)$ the set of the unions of stable matching from the two original markets. Notice that $\Pi(M,W,P)$ is isomorphic to the Cartesian product of $\Gamma(M^1,W^1,P^1)$ and $\Gamma(M^2,W^2,P^2)$ and with the abuse of language we will call it the *Cartesian product* of $\Gamma(M^1,W^1,P^1)$ and $\Gamma(M^2,W^2,P^2)$, when no ambiguity is possible. So we characterize the cases in which $\Gamma(M,W,P) = \Pi(M,W,P)$.

Condition 1 *$\mu_1 \cup \mu_2$ satisfies* women's loyalty *if $i, j = 1,2$ $i \neq j$ and for all $m \in M^i$ and for all $w \in W^j$ such that $wP_m\mu^i(m)$ then $\mu^j P_w m$.*

Informally if m in M^1 prefers a woman from W^2 to his mate under μ_1 then such a woman prefers her mate under μ_2 to m.

The Lemma 2 follows from the observation that μ_1 and μ_2 are stable in their respective markets so we need to check stability of $\mu_1 \cup \mu_2$ focusing on *mixed pairs*, that are pairs in which a man from the market M^1 (resp. M^2) marries a woman from W^2 (resp. W^1).

Lemma 2 *Let μ_1 be a stable matching in the market (M^1, W^1, P^1) and let μ_2 be a stable matching in the market (M^2, W^2, P^2). Then $\mu_1 \cup \mu_2$ is stable if and only if it satisfies women's loyalty.*

An immediate consequence of the lemma is the following:

Proposition 1 *The Cartesian product of the original set of stable matchings is stable after entry, formally $\Pi(M,W,P) \subset \Gamma(M,W,P)$, if and only if $\mu_1 \cup \mu_2$ satisfies women's loyalty for all μ_1, μ_2 stable in their respective original markets.*

5 Conclusions

In this paper we provide intuitive necessary and sufficient conditions for the original M-optimal stable matching not to be affected by a merger, in terms both of stability and optimality. The conditions, loosely speaking, mean that for the original M-optimal stable matching to remain stable, it is necessary that either each agent does not like any new agent who prefers him or her better than his or her mate better than his or her original mate, or if it is not the case, any superior matching with an agent of the new market would be blocked by another agent from the new market.

We also analyze the impact of merging on the set of stable matching. We characterize the conditions under which stability of original matchings is preserved after two markets are merged.

The effects of merging or splinting markets are not clear in general and depend on the agents' preferences. However, our characterizations have implications for market design when entry is involved as long as we have information about the structure of preferences of both markets. This information and can be used to anticipate entry-related instabilities.

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