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Policy Analysis in Matching Markets†

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Government policies intended to affect assignments are prevalent in labor, education, and other matching markets. Common interventions influence prices and/or quantities through direct subsidies (e.g., financial aid), price regulations (e.g., tuition caps, pay scale revisions), quotas, or supply interventions (e.g., establishing or closing public schools, funding for new positions). To capture the re-sorting caused by these policies, an empirical approach that accounts for their effects on equilibrium assignments is necessary.

This article presents the key components of such an empirical framework and uses the estimates from Agarwal (2015) to compare financial incentives and supply interventions intended to encourage training of medical residents in rural America. The two key components of the framework are (i) a random utility model for the preferences of the agents and (ii) pairwise stability as a description of the equilibrium matches. The above-mentioned interventions influence either preferences or available positions. Using an estimated preference model, counterfactual simulations of an equilibrium assignment under various interventions can be conducted to analyze and predict the effects of a proposed policy. The article also briefly reviews the recent methodological literature that studies the problem of estimating preference models.

The illustrative empirical application we examine is motivated by the perceived under-supply of medical labor in the rural United States (Rosenblatt and Hart 2000). A fifth of the US population lives in rural areas, but less than a tenth of physicians practice in rural communities. Specialized rural residency training and physician retention is seen by practitioners as a key part of the solution to this disparity. The Affordable Care Act addresses the shortage of rural physicians by funding an increase in the number of residency programs in rural areas, redistributing unused Medicare funds originally allocated for residency training in urban hospitals and increasing funding for loan forgiveness programs that recruit physicians to shortage areas. Such regulations are not unique to the United States. Recently, Japan reduced capacities in urban residency programs for similar reasons (Kamada and Kojima 2015).

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I. Model

Consider a two-sided matching market and, for ease of reference, refer to one side as workers and the other as firms. The model can also be used to study other markets, such as the matching of students to colleges or schools. The two key components of the model are the preferences of each side of the market and an equilibrium concept describing the final matches.

A. *Preferences*

Let the (indirect) utility of worker $i \in \mathcal{I}$ for firm $j \in \mathcal{J}$ be given by

$$u_{ij} = U(z_{ij}, \xi_j, \eta_i), \tag{1}$$

where z_{ij} are observed worker-firm specific characteristics (that may include a wage), ξ_j is a firm-specific unobserved characteristic, and η_i is a vector that captures idiosyncratic tastes of the worker for various programs or program characteristics. Symmetrically, let the (indirect) utility of firm j for worker i be denoted

$$h_{ji} = H(x_{ji}, \varepsilon_i, \nu_j), \tag{2}$$

where x_{ji} are a set of observables that may or may not overlap with z_{ij}, and ε_i and ν_j are firm and worker specific unobservables, respectively.

The utilities for the worker and the firm for remaining unmatched are denoted u_{i0} and h_{j0}, respectively.

These utilities represent the (ordinal) preferences of the workers and the firms for agents on the other side of the market. This representation assumes that each agent's preferences depend only on the particular partner in consideration, and therefore rules out complementarities or externalities across matches such as peer effects. As is standard in the discrete choice literature, a scale and a location normalization is needed on each side of the market.

For estimation, it is typically necessary to make parametric assumptions on $U(\cdot)$ and $H(\cdot)$, and on the distributions of unobserved terms. In many applications, a (predetermined) tuition or a salary is one of the observable characteristics included in the preferences. If price regulations are the focus of the study, it can be important to instrument for this transfer to avoid bias in the estimates. Agarwal (2015) uses a control function approach to address this issue.

B. *Pairwise Stability*

A central concept in the empirical analysis of matching markets is that of a *pairwise stable* match. It is a match that is not blocked either by an individual or by a pair. Formally, a match is a function $\mu : \mathcal{I} \rightarrow \mathcal{J} \cup \{0\}$ with $|\mu^{-1}(j)| \leq c_j$, where 0 denotes being unmatched and c_j is the capacity of firm j. We say that μ is blocked by an individual if for any i, $u_{i\mu(i)} < u_{i0}$ or for any j and $i' \in \mu^{-1}(j)$, $h_{ji'} < h_{j0}$. Further, μ is blocked by the pair (i,j) if $u_{ij} > u_{i\mu(i)}$ and $h_{ji} > h_{ji'}$ for some $i' \in \mu^{-1}(j)$.[1]

Existence of a pairwise stable match is guaranteed because agents are substitutable in this preference model, and while there may be multiple stable matches, the structure of the equilibrium set is well known (Roth and Sotomayor 1992).[2] The equilibrium concept can be used either for estimation or for counter-factual predictions when estimation through other means is possible. Directly using this concept for analysis circumvents the need for observing and modeling an application or interview process. However, the model may be mis-specified if these stages introduce large meaningful frictions in a particular market. Although it may be applied to and be useful in decentralized matching markets, the assumption is most attractive for analysis in the growing number of education and entry-level labor markets worldwide that use stable matching algorithms for assignments.

Blocking pairs in this definition of pairwise stability is based only on predetermined match values with fixed transfers. Therefore, it is only appropriate to use this concept in settings where the terms of the partnership are inflexible or transfers are not used.[3]

II. Empirical Strategy

In some cases, direct data on agent choices is available and estimation of the preference models above can be accomplished using extensions of standard discrete choice approaches. This approach is most commonly applied when a centralized assignment authority uses reported preferences to determine assignments.[4]

More frequently, a researcher has data only on final assignments from sources such as matched employer-employee data or enrollment records. Even with such limited data, it may still be possible to estimate preference models if pairwise stability is a suitable assumption. Data limitations, however, necessitate additional restrictions on preferences. Menzel (2015) and Diamond and Agarwal (forthcoming) show that flexible preference models are under-identified in these cases because preferences on either side of the market can explain the observed matches. When many workers are matched to the same firm, some of the under-identification issues can be resolved (Diamond and Agarwal forthcoming). Intuitively, multiple hires at the same firm for the same job must be similarly qualified in a pairwise stable match. This can allow a researcher to learn more about preferences, particularly on the firm side. In addition, exclusion restrictions, whereby certain observables only

[1] We use the convention that $0 \in \mu^{-1}(j)$ if $|\mu^{-1}(j)| < c_j$.

[2] One may either place a restriction on preferences to guarantee a unique stable match, or select an equilibrium (e.g., the firm-optimal one) for analysis.

[3] See empirical approaches following Choo and Siow (2006) for notions with transferable utility.

[4] Hastings, Kane, and Staiger (2009) and Abdulkadiroglu, Agarwal, and Pathak (2015) estimate preferences assuming truthful reporting, while approaches by He (2014), Agarwal and Somaini (2014), and references within consider cases where truthful reporting may not be a reasonable assumption.

enter one side of the market, can be useful in learning about preferences.

Agarwal (2015) uses these two sources of information and the assumption that the firms have identical preferences for workers to estimate preferences using pairwise stability in the market for family medicine residents. Jiang (2016) uses a similar empirical framework, but one that relies on an observed proxy for the productivity of workers, to address the under-identification of preferences. Vissing (2016) extends the framework to allow for certain types of complementarities across matches to study the assignment of oil leases.

III. Price and Quantity Regulations in Matching Markets: Application to Rural Residency Training

This section uses data from the 2010–2011 academic year of the family medicine residency market and preference parameter estimates from Specification (1) of Agarwal (2015) to simulate the impact of various interventions for encouraging rural training. This market uses rank-order lists and the Roth and Peranson (1999) stable matching algorithm with predetermined salaries to assign residents to programs. The table below focuses on quantifying the impact of these policy interventions on the sorting and number of residents in rural programs.

A. *Price Regulations: Financial Incentives for Rural Training*

To simulate the impact of financial incentives, I exogenously increase the salaries at rural hospitals.[5] Panel A of Table 1 presents the impact of this intervention. The incentive affects residents on the margin between an urban and a rural program to rank the rural program higher. It results in only a small increase in the number of residents matched to programs in rural communities. An incentive of $20,000 increases the number of residents training in rural areas by about 20, from a base of 310. This incentive costs the government $325,000 per additional resident matched to a rural program because most of the incentive accrues to residents assigned to positions that would be occupied without the financial incentive. Instead of affecting numbers, the primary impact is an increase in the human capital of residents matched to rural areas. As compared to a baseline of about an even chance, under a small $5,000 incentive, a randomly chosen rural resident is about 9.4 percentage points more likely to have a higher human capital than an urban resident. This increase in the quality of residents is increasing with size of the incentives.

These results are driven by capacity constraints in desirable rural programs. With 310 out of rural 334 positions filled, there is little scope for a substantial increase total number of residents. Instead, there is an increase in the quality of residents matched at subsidized programs.

One may ask whether a simpler analysis based on partial equilibrium reasoning with unilateral salary increases by programs would lead to similar conclusions. With quasi-linear utility, a uniform increase in salaries of all residency programs would not impact assignments because the utility comparison between any two programs remains unchanged. A partial equilibrium analysis based on unilateral deviations would still find increases in numbers and quality at each hospital. We expect the importance of the general equilibrium effects to be less pronounced for smaller interventions.

Table 1 also shows that a $5,000 incentive results in a transfer of $1.6 million from the government to residents. However, the estimated increase in residents' private welfare is 13.5 percent more than this amount. This difference is due to the presence of heterogeneous preferences and the ability of financial incentives to target residents with the lowest distaste for rural programs. A small incentive for training in a rural program only induces a resident who is roughly indifferent between a rural and an urban program to choose rural training. This resident then opens up a position in an urban program that may be strongly preferred by another resident. Therefore, general equilibrium re-sorting effects of the financial incentive can result in an increase in the efficiency of assignments. Without preference heterogeneity, the impact on the private benefits to residents, net of the transfer, is only through the total number of positions filled at different programs.

[5] The average resident is willing to take a $8,000 salary cut for an urban instead of a rural program.

TABLE 1—EFFECTS OF POLICY INSTRUMENTS FOR ENCOURAGING RURAL TRAINING

Panel A. Salary incentives	$5,000	$10,000	$20,000
Δ Number of rural matches	10.23	17.3	20.63
Δ Probability rural residents > urban residents	9.38 %	17.70 %	31.28 %
Total cost of subsidy (mil.)	$1.62	$3.31	$6.68
Δ Private residents' welfare (mil.)	$1.84	$3.64	$7.05
Cost per additional resident	$158,143	$191,116	$323,762

Panel B. Quantity regulations	Reduce urban positions	Increase rural positions	Combined policy
Modified urban capacity	2,846	2,963 (baseline)	2,688
Modified rural capacity	334 (baseline)	460	460
Δ Number of rural matches	12.01	121.31	146.63
Δ Probability rural residents > urban residents	−0.56 %	7.02 %	−3.73 %
Δ Private residents' welfare (mil.)	−$3.76	$5.39	−$5.49

Notes: In the first and third columns of panel B, urban positions are reduced in proportion to program size, subject to integer constraints, until further reductions would yield a greater number of residents than programs. Two rural positions were added per program in the second and third columns.

B. *Quantity Regulations*

Panel B of Table 1 considers three types of quantity regulations. The first mimics the policy implemented in Japan and reduces the number of positions in urban programs proportional to the size of the program. The second increases the number of rural training positions at existing rural programs. The final intervention combines the two by first increasing the number of positions at existing rural programs followed by decreasing the number of positions in urban programs proportionally.

Because reducing the number of positions offered at urban programs displaces residents, it mechanically increases the number of residents matching at rural programs. However, the sorting effects of these changes are not a priori obvious. A naïve reasoning may lead to the conclusion that caps have a large adverse impact on the quality of residents training at rural programs because displaced residents are disproportionately less desired by the programs they were previously matched with. However, residents displaced from urban programs in turn displace others, resulting in overall re-sorting. According to the estimates, the distribution of resident quality matching at rural programs is similar to the distribution before the caps.

The decreased availability of positions in urban areas results in a similar number of additional residents in rural programs as a $5,000 financial incentive, but reduces the private welfare of residents. This suggests that quantity regulations are a blunt policy instrument that do not target residents with the least dislike for rural positions.

In contrast, increasing positions in rural programs raises both the number and quality of residents matched with these programs. The change in quality of residents in rural areas is due to increases in the number of residents matched at the highest quality rural programs but decreases in the number of residents matched at low quality residency programs in urban and rural areas.

Finally, the third policy combines the other two and, by construction, has a large effect on the number of residents placed in rural programs. As compared to a singular increase in positions offered in rural areas, this policy can adversely affect the quality of residents assigned to rural program by forcing residents into undesirable residency positions that were previously vacant.

IV. Conclusion

Two common features of two-sided matching markets are that agents are heterogeneous and that highly individualized prices are often not used. Both properties have important policy implications because assignments are determined by the mutual choices of agents rather than price-based market clearing. The framework presented in this article captures these two aspects of matching markets and is a natural tool for prospective analysis when sorting is an important consideration in policy decisions.

The empirical application studied here illustrates the importance of considering the sorting effects. The primary effect of financial incentives were to increase the quality, not numbers, of residents training in rural areas. In contrast, quantity regulations were effective at increasing the supply of residents in rural areas, but remarkably, this increase did not come at a detriment to the quality of residents due to the re-sorting of residents.

In future work and as the application demands, it may be useful to extend the model to incorporate other equally important factors such as entry into the market and salary setting.

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