Evaluating the Efficiency of Regulation in Matching Markets with Distributional Disparities

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introduction

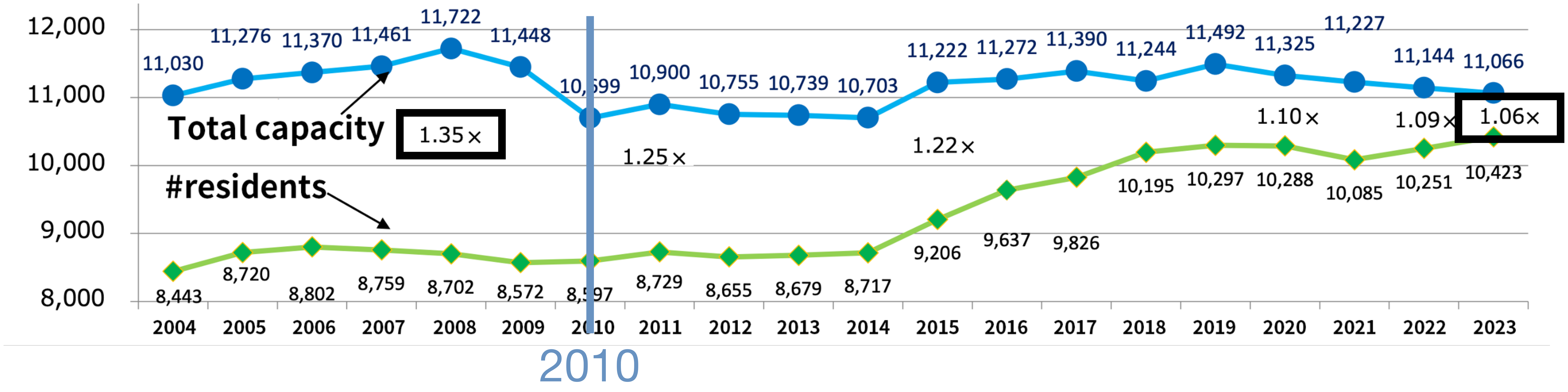
- outcomes in matching markets often diverge from socially desirable outcomes
- policymakers often intervene in the market
  - e.g., affirmative action in school choice, gender quotas in elections
- a common intervention is cap-based regulation
  - restricts the number of matches for certain categories

Japan Residency Matching Program (JRMP)

- students and hospitals are matched for a two-year residency program
  - **10,000** students from 80 schools
  - 11,000 positions from 1,000 hospitals
- without intervention, rural areas remain underserved
  - in 2009, **48.6%** of residents were matched with one of the **6** (out of **47**) prefectures
- policymakers want to ensure adequate coverage of residents in all areas

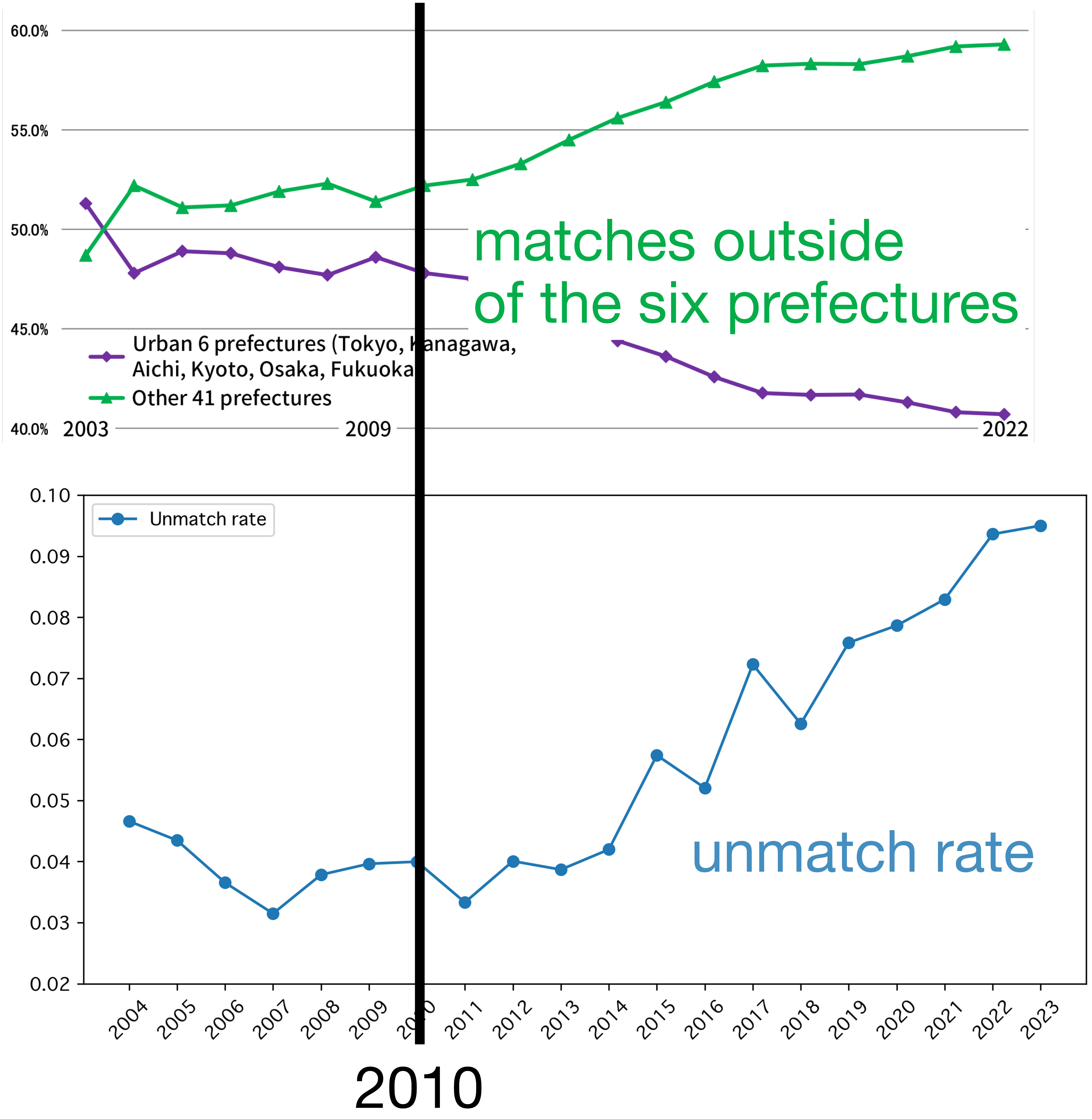
cap-based regulation in JRMP

- government has enforced a cap-based regulation **since 2010.**



- **ratio of positions to residents** is decreasing over time. (**1.35** in 2008 to **1.06** in 2023)
- **positions in urban areas** have been reduced significantly

results of the regulation



- matches in rural areas have increased (+)
- significant geographic disparity still remains (-)
- unmatch rate has been increasing (-)

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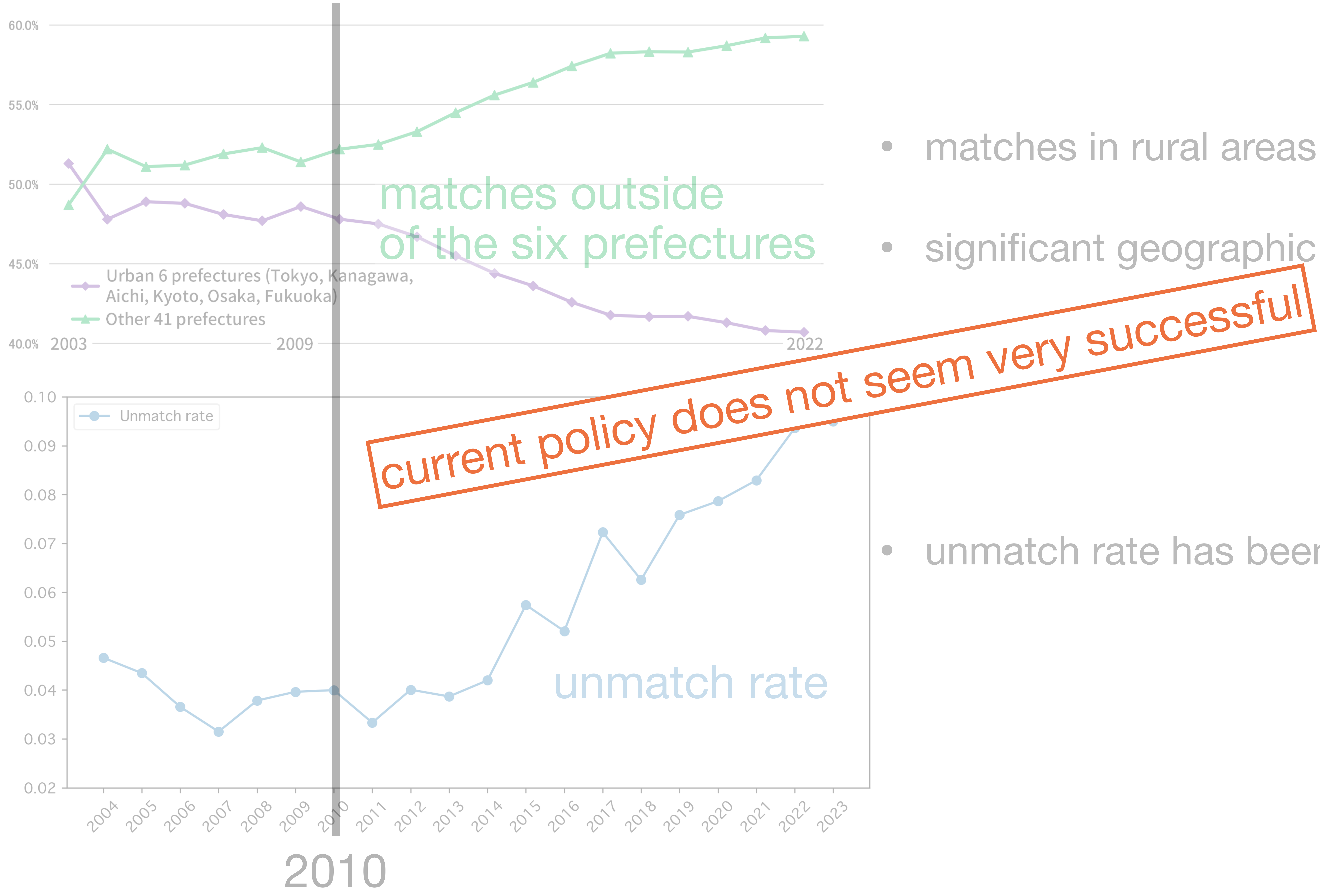

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questions

- how effective is cap-based regulation?
- how do alternative policies, such as monetary interventions, compare?
- can we quantify their performance?

contribution

this paper:

- develops a framework to evaluate policies in matching mkt with distributional constraints
  - transferable utility matching model with **regional constraints**
  - optimal taxation policy outperforms any cap-based policy
  - optimal taxation policy can be computed using data
- applies the framework to a novel dataset from the Japan Residency Matching Program:
  - status quo cap-based regulation generates a significant welfare loss
  - modest subsidy can achieve the same distributional goal, improving welfare

some relevant literature

- **matching with distributional constraints**
  - **Kamada and Kojima (2015)**, Abdulkadiroglu and Sonmez (2003), Ehlers, Hafalir, Yenmez, and Yildirim (2014), Kojima (2012), Hafalir, Yenmez, and Yildirim (2013), Fragiadakis and Troyan (2017) …
  - uses the non-transferable utility (NTU) matching model
  - primarily focuses on how to **set caps**, adjusting the deferred acceptance algorithm
- **our paper**: uses the transferable utility (TU) matching model
  - accommodates **a broader class of policies,** including monetary interventions
  - accounts for **endogenous transfer** (e.g., salary adjustment in response to intervention)

model

theoretical results

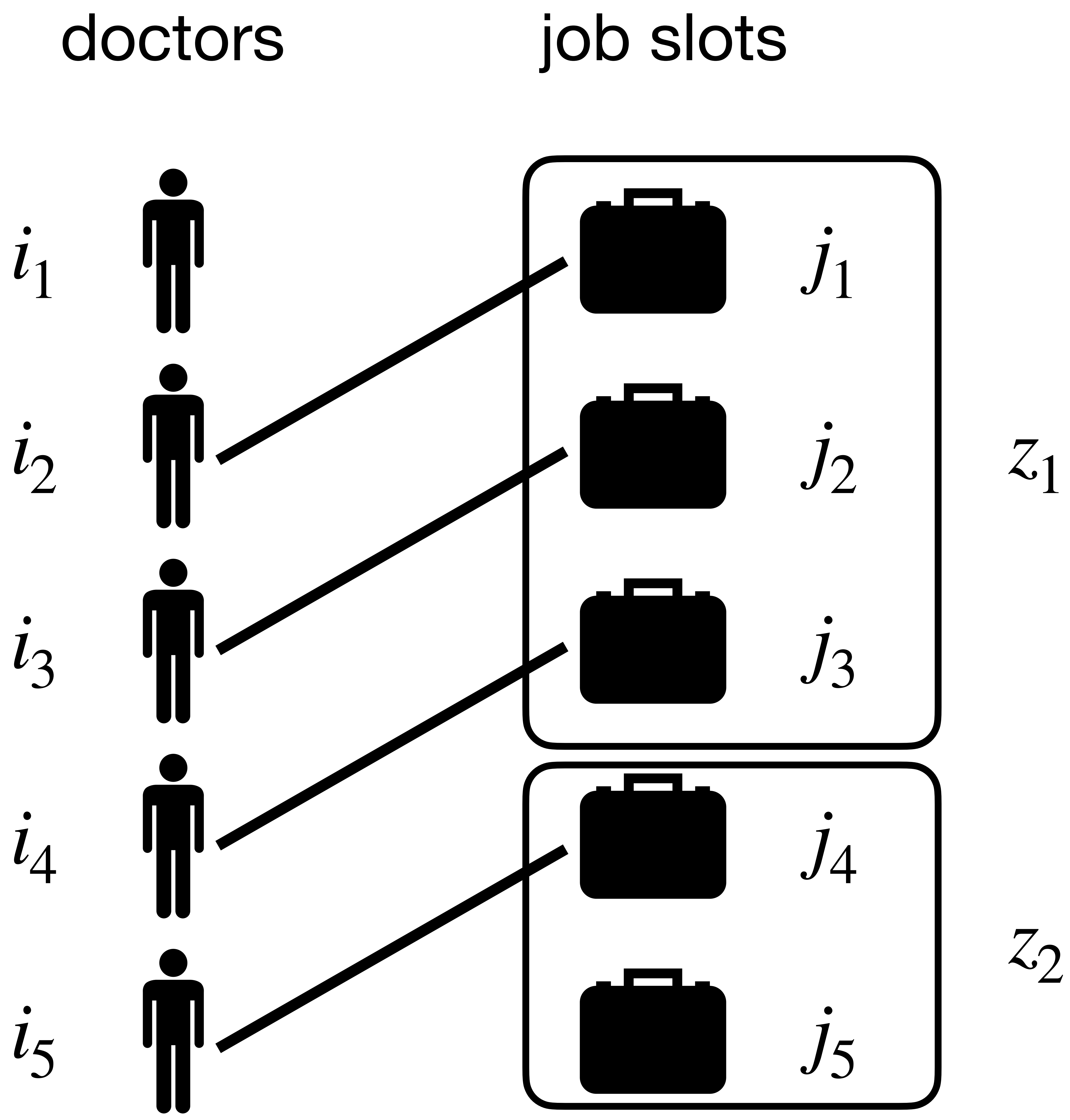
estimation

simulation

setup

- **doctors** $i \in I$ and **job slots** $j \in J$
- each slot belongs to a region $z \in Z$
- if i and j are matched, the pair generates a **joint surplus** $\Phi_{ij} \in \mathbb{R}$ and splits it
- agents know $(\Phi_{ij})_{i,j}$ and form the **matching**, achieving a **"stable outcome"**

no blocking pair + IR



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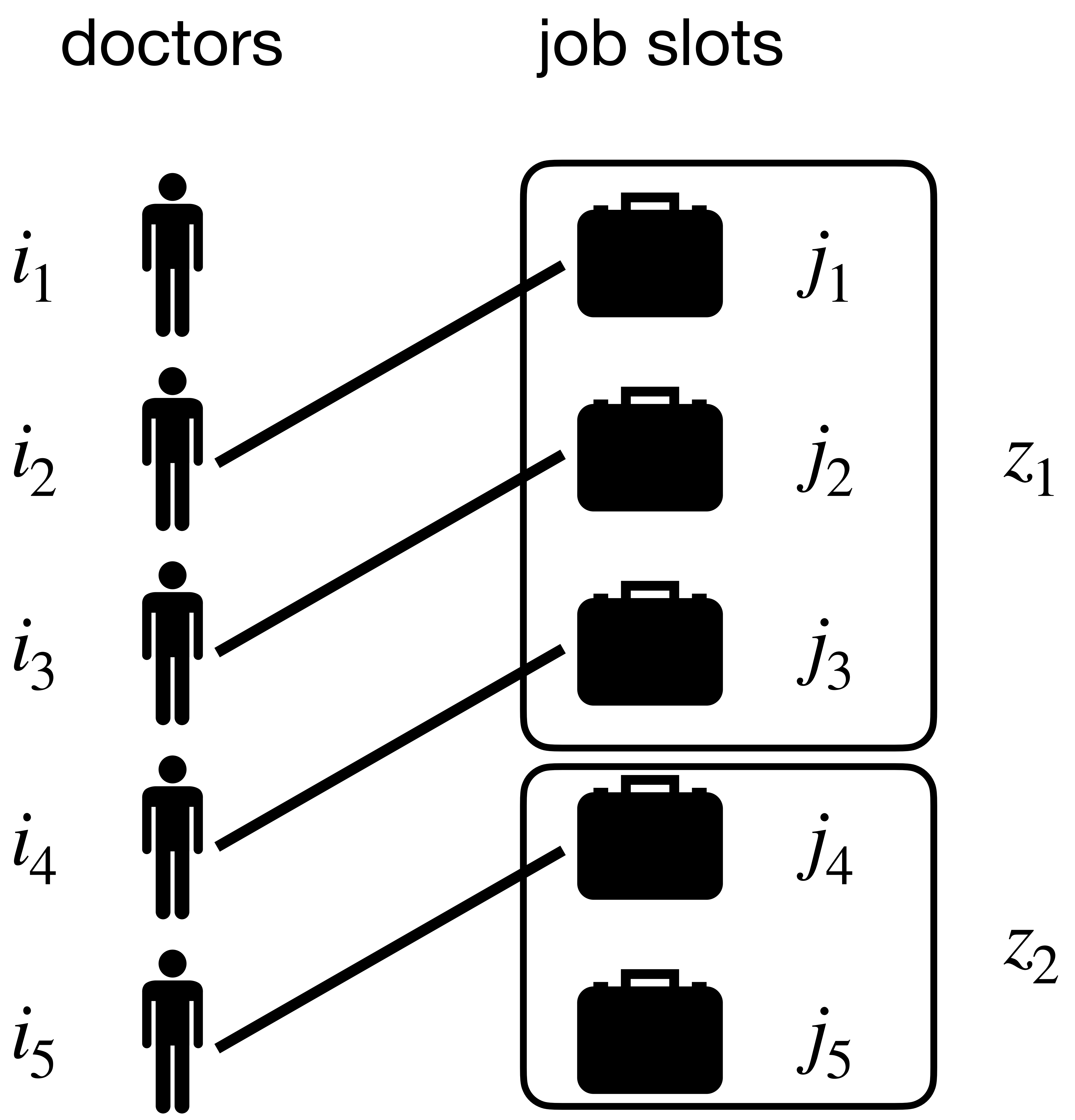
doctor i and slot j **block** the matching if

$$u_i + v_j < \Phi_{ij}$$

i's current payoff $\quad$ j's current payoff



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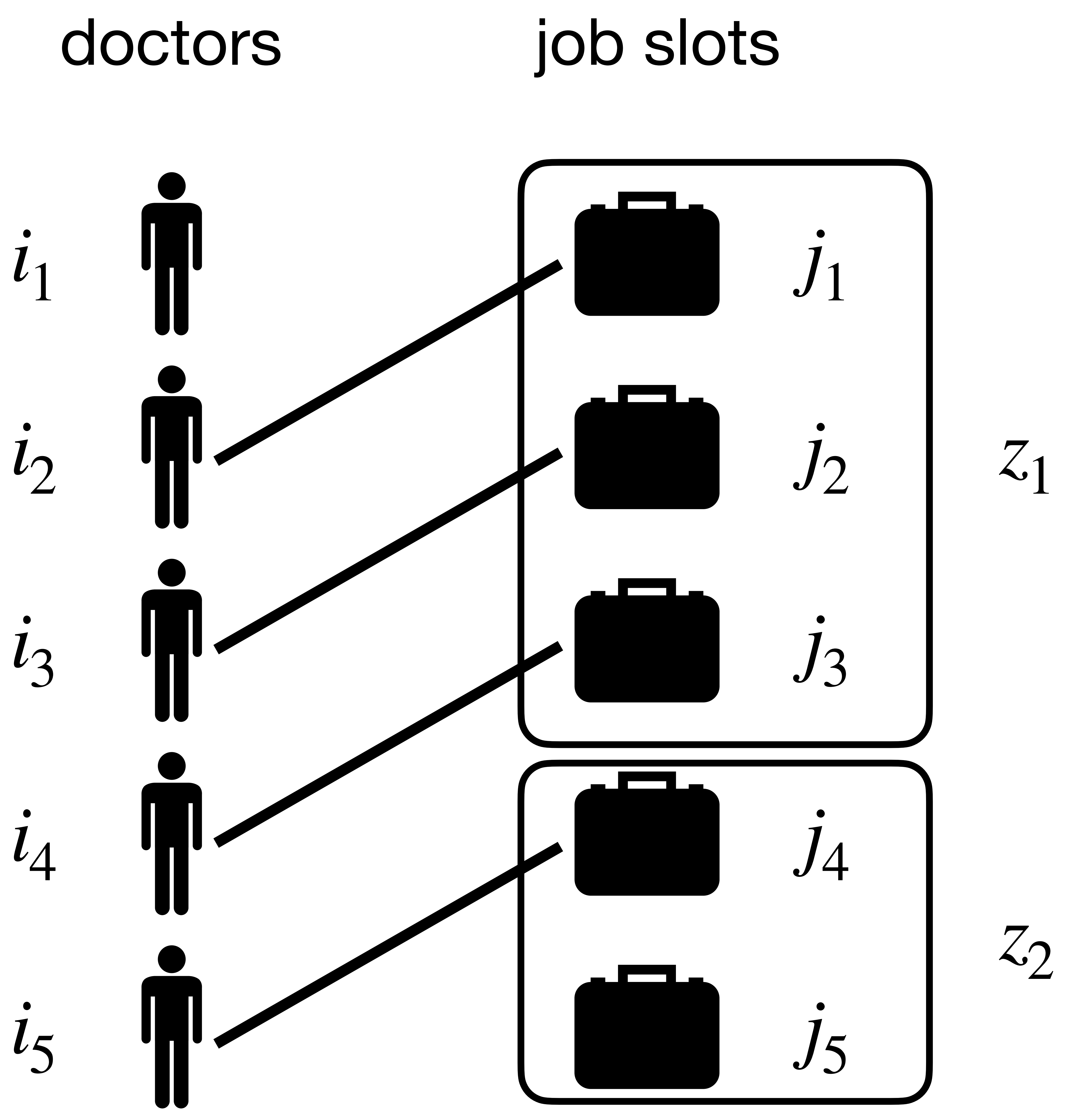


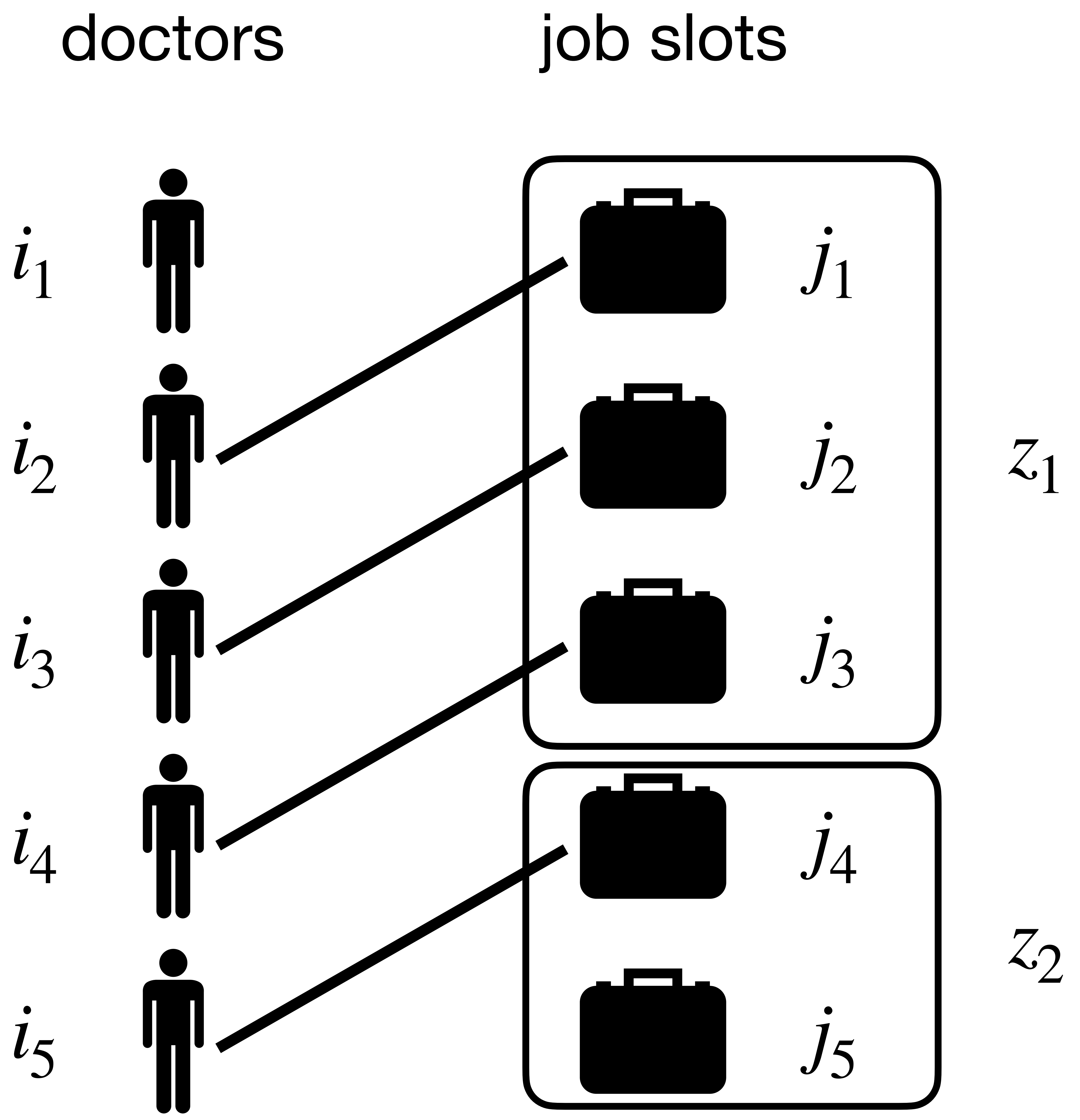
doctor i and slot j **block** the matching if

$$u_i + v_j < \Phi_{ij}$$

they can be better off by forming a new match and splitting the surplus

setup

- policymaker (PM) faces exogenous regional constraints
  - **lower and upper bounds** on # of matches in each region
  - without intervention, the matching formed by the agents may not satisfy regional constraints
  - PM's goal: ensure # of matches in every region stays within the bounds

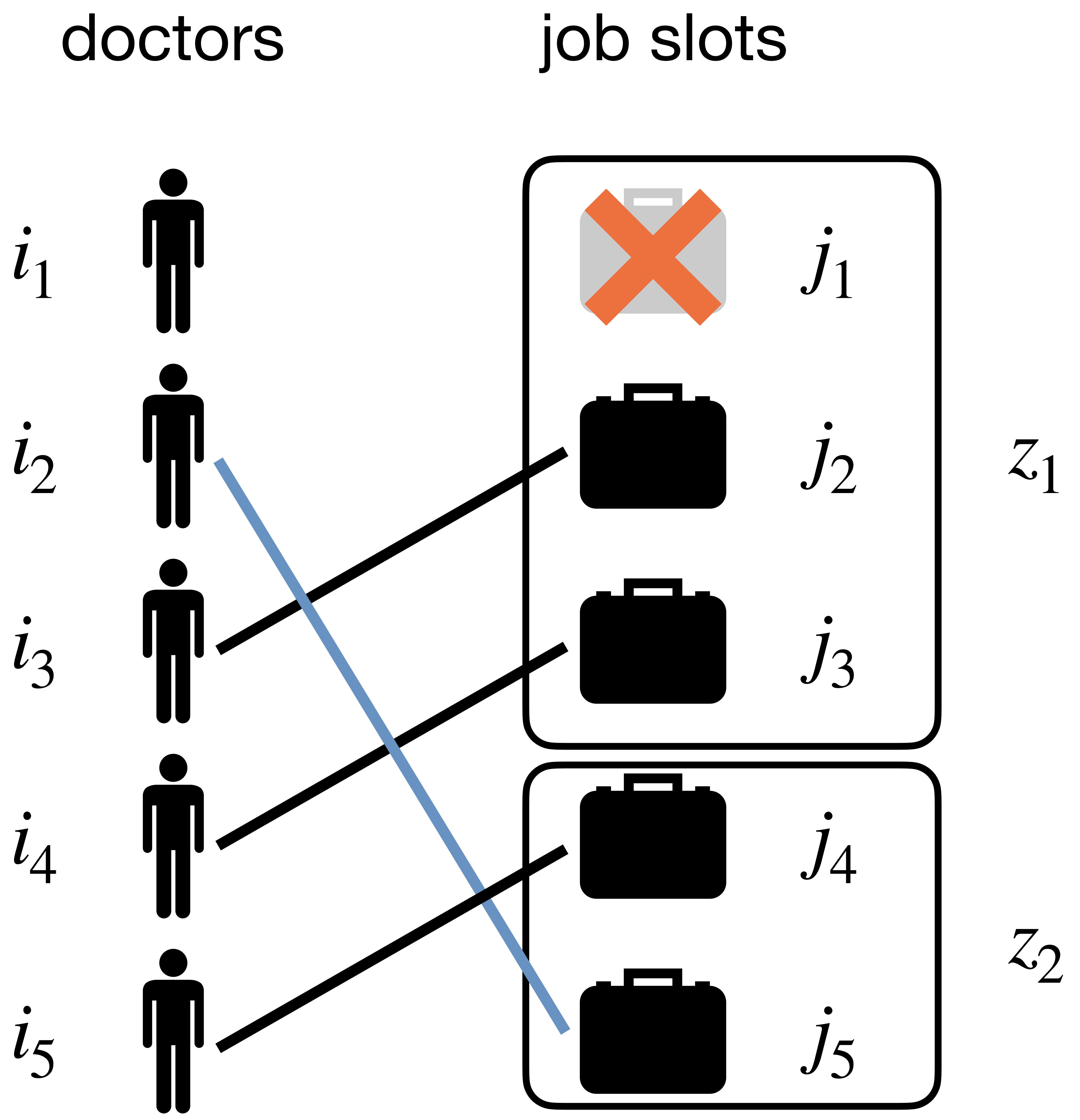


# of matches in z_2 ≥ 2

cap-based policy

- cap-based policy removes positions in high-demand regions to encourage inflow into low-demand regions

- given the caps, agents form a stable outcome over the available slots



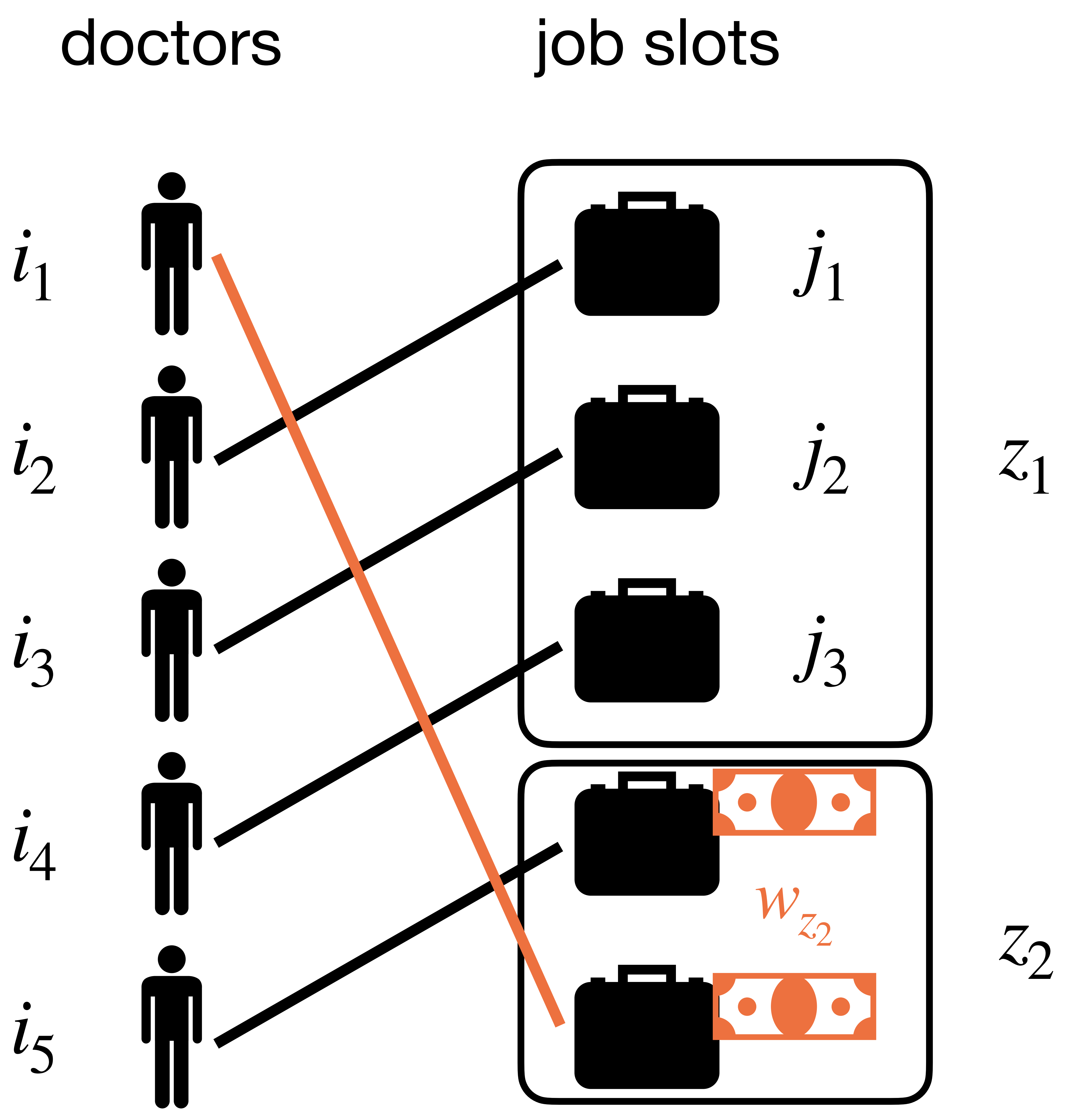
# of matches in $z_2 \geq 2$

taxation policy

- alternative: taxation policy
  - tax $w_z \in \mathbb{R}$ is applied uniformly to all the matches in region z

    negative tax = subsidy

  - Given $(w_z)_z$, agents form a stable outcome as if net joint surplus $\Phi_{ij} - w_z$ were the joint surplus
  - by choosing taxes properly, PM may induce socially desirable matchings



# of matches in z_2 ≥ 2

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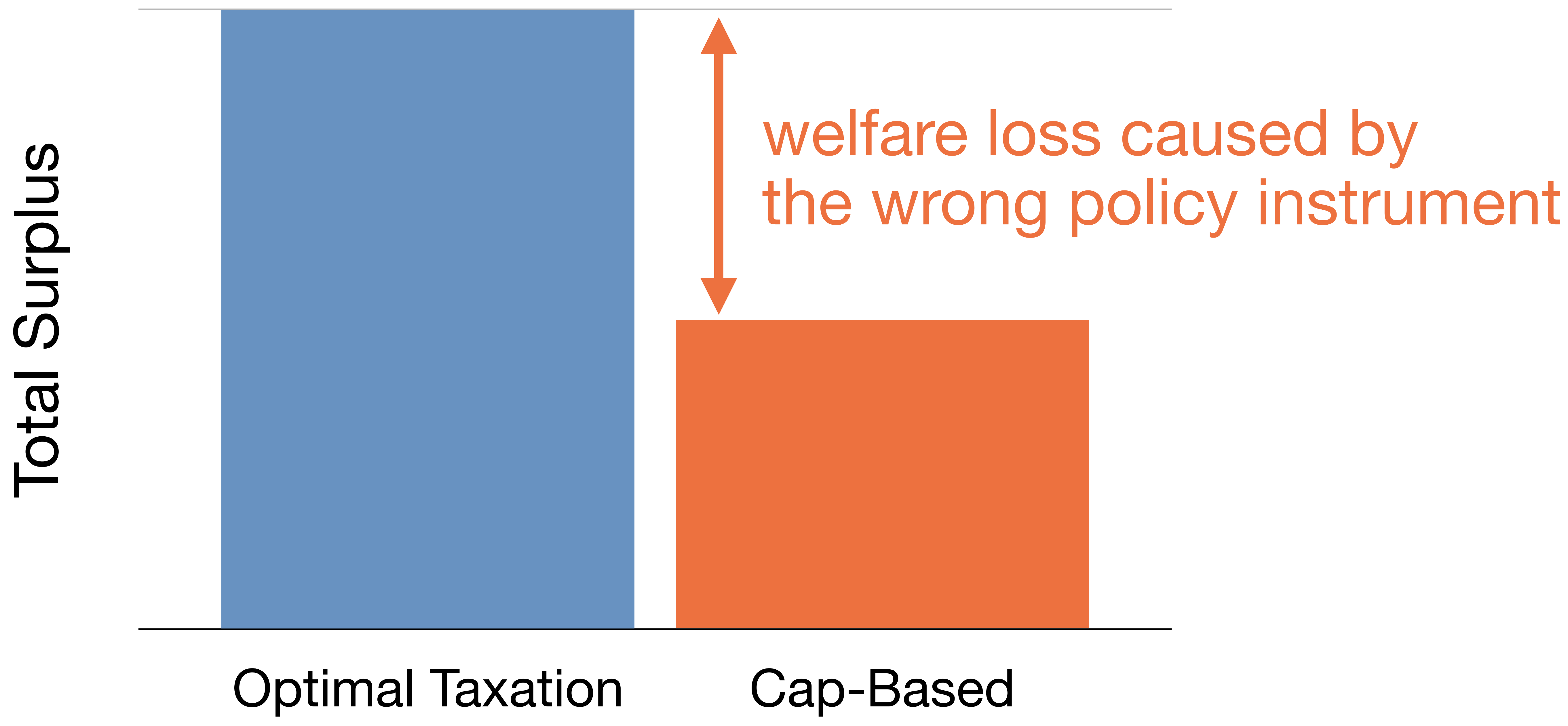
optimal taxation policy

Theorem 1 (informal): optimal taxation policy generates a higher social surplus than any other cap-based policy that satisfies the same regional constraints.

- "taxation policy is better"
- the outcome under the optimal taxation policy serves as a benchmark:



optimal taxation policy

$$
(\mathrm{P}_0) \quad
\begin{aligned}
\underset{d \in \{0,1\}^{I \times J}}{\text{maximize}} \quad & \sum_{(i,j) \in I} \Phi_{ij} d_{ij} + \sum_{i \in I} \left(1 - \sum_{j \in J} d_{ij}\right) \Phi_{i,j_0} + \sum_{j \in I} \left(1 - \sum_{i \in I} d_{ij}\right) \Phi_{i_0,j} \\
\text{subject to} \quad & \sum_{j \in J} d_{ij} \le 1 && \forall i \in I, \\
& \sum_{i \in I} d_{ij} \le 1 && \forall j \in J, \\
& \underline{o}_z \le \sum_{j \in z} \sum_{i \in I} d_{ij} \le \bar{o}_z && \forall z \in Z,
\end{aligned}
$$

total surplus generated under d

regional constraints

- optimal taxation policy w^*: **Lagrange multipliers (shadow prices)** for the regional constraints
  - can be computed by LP (we can relax the integrality constraint)
- w^* induces a stable outcome with matching d^* that solves (P_0)

optimal taxation policy

$$
(\mathrm{P}_0) \quad \begin{aligned} \underset{d \in \{0,1\}^{I \times J}}{\text{maximize}} \quad & \sum_{(i,j) \in I} \Phi_{ij} d_{ij} + \sum_{i \in I} \left(1 - \sum_{j \in J} d_{ij}\right) \Phi_{i,j_0} + \sum_{j \in I} \left(1 - \sum_{i \in I} d_{ij}\right) \Phi_{i_0,j} \\ \text{subject to} \quad & \sum_{j \in J} d_{ij} \leq 1 && \forall i \in I, \\ & \sum_{i \in I} d_{ij} \leq 1 && \forall j \in J, \\ & \underline{o}_z \leq \sum_{j \in z} \sum_{i \in I} d_{ij} \leq \bar{o}_z && \forall z \in Z, \end{aligned}
$$

total surplus generated under d

regional constraints

Theorem 1 (formal): if PM knows $(\Phi_{ij})_{i,j}$, then for any regional constraints, PM can compute a taxation policy $(w_z^*)_z$ that induces the matching d^* that maximizes the total surplus subject to the regional constraints

unobs. heterogeneity and aggregate-level data

- in practice, the joint surplus Φ_{ij} is unknown to PM and often hard to identify
- suppose that PM has access to past aggregate-level matching data:
  - doctors' observable characteristics $s \in S$ (school)
  - job slots' observable characteristics $h \in H$ (hospital)
  - # of matches μ_{sh} between school s and hospital h

$$\mu = (\mu_{s,h})_{s,h} = \begin{array}{c c} & \begin{array}{ccc} h_1 & h_2 & h_3 \end{array} \\ \begin{array}{c} s_1 \\ s_2 \end{array} & \begin{bmatrix} 2 & 0 & 0 \\ 0 & 1 & 1 \end{bmatrix} \end{array}$$

taxation policy with aggregate-level data

- key assumption: **additive separability** (Galichon and Salanié, 2021):

$$\Phi_{ij} = \Phi_{sh} + \varepsilon_{ih} + \eta_{sj}$$

indep. error terms

aggregate-level joint surplus

Theorem 2 (informal): Assume additive separability and error distributions. Under certain regularity conditions, we can compute the optimal taxation policy using aggregate-level matching data μ.

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available data

from 2016 to 2019

- **JRMP matching outcomes**
  - # of matches between all schools and hospitals
  - # of positions offered in each hospital
- **Salary**
  - monthly salary paid to residents by each program
- **Characteristics of hospitals and schools**
  - **hospital:** # of beds, # of emergency transport cases — hospital size
  - **school:** private or public, T-scores (difficulty of entrance exam) — students' quality
  - locations

two-step procedure

- we want to estimate agents' preferences to perform counterfactual simulations

$$u_i = U_{ij}^{\text{base}} + \tau_i$$

equilibrium payoff (actual payoff) | base utility | transfer

utility that an agent derives from the match without transfer

two-step procedure

- we want to estimate agents' preferences to perform counterfactual simulations

$$u_i = U_{ij}^{\text{base}} + \tau_i$$

equilibrium payoff (actual payoff) | base utility | transfer

- we estimate these objects in two steps:
  1. estimate equilibrium payoff ← apply GS2021's method
  2. estimate the parameters in the base utilities and transfers
- (see the paper for details of estimation methods and results)

Step 2: more details

$$u_i = U_{ij}^{\text{base}} + \tau_i$$

- "transfer" in our application consists of many different components:
  - salary, workload, experience, risk of medical accidents, etc.

unobservable

- we assume that agents' utilities are **quasi-linear** in monetary transfers
- we regress equilibrium payoffs on agents' characteristics and salary (+IV) to estimate agents' base utility and marginal value of salary
  - we can evaluate the agents' utilities and social welfare in terms of money

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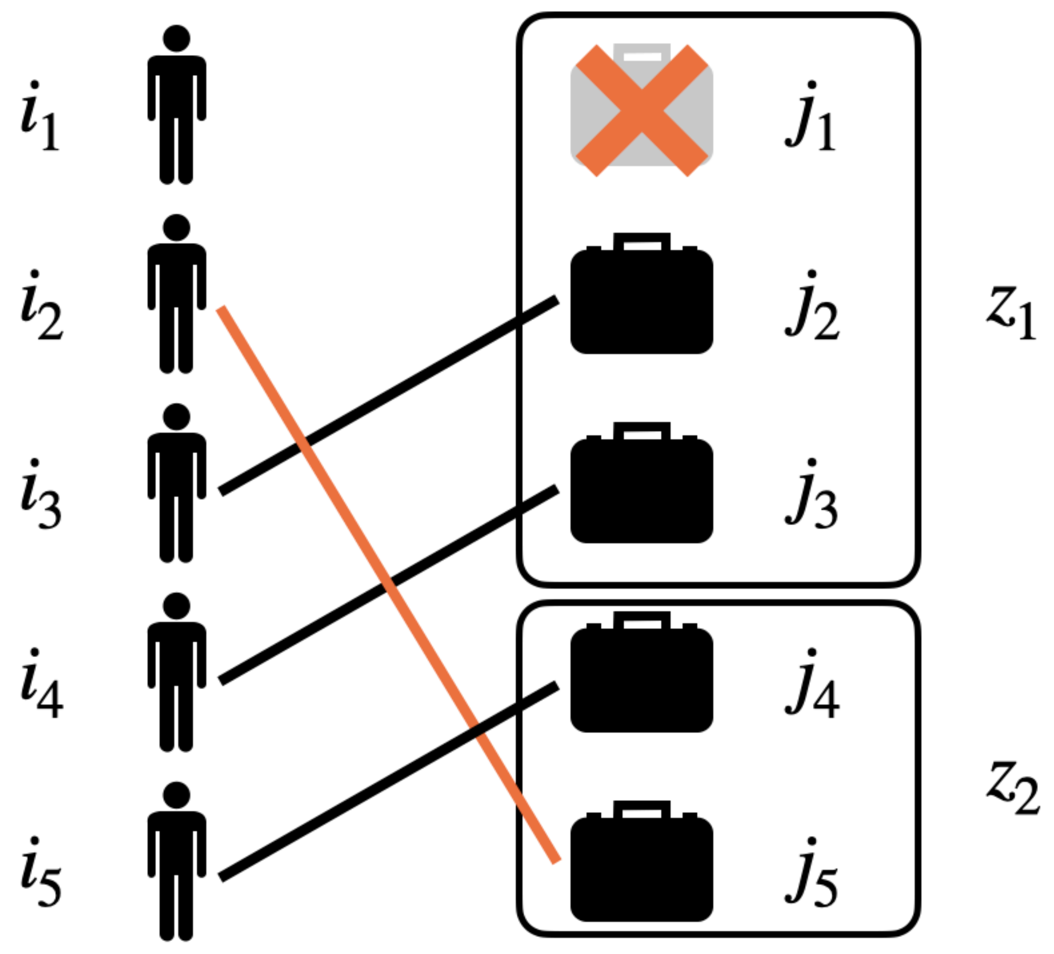
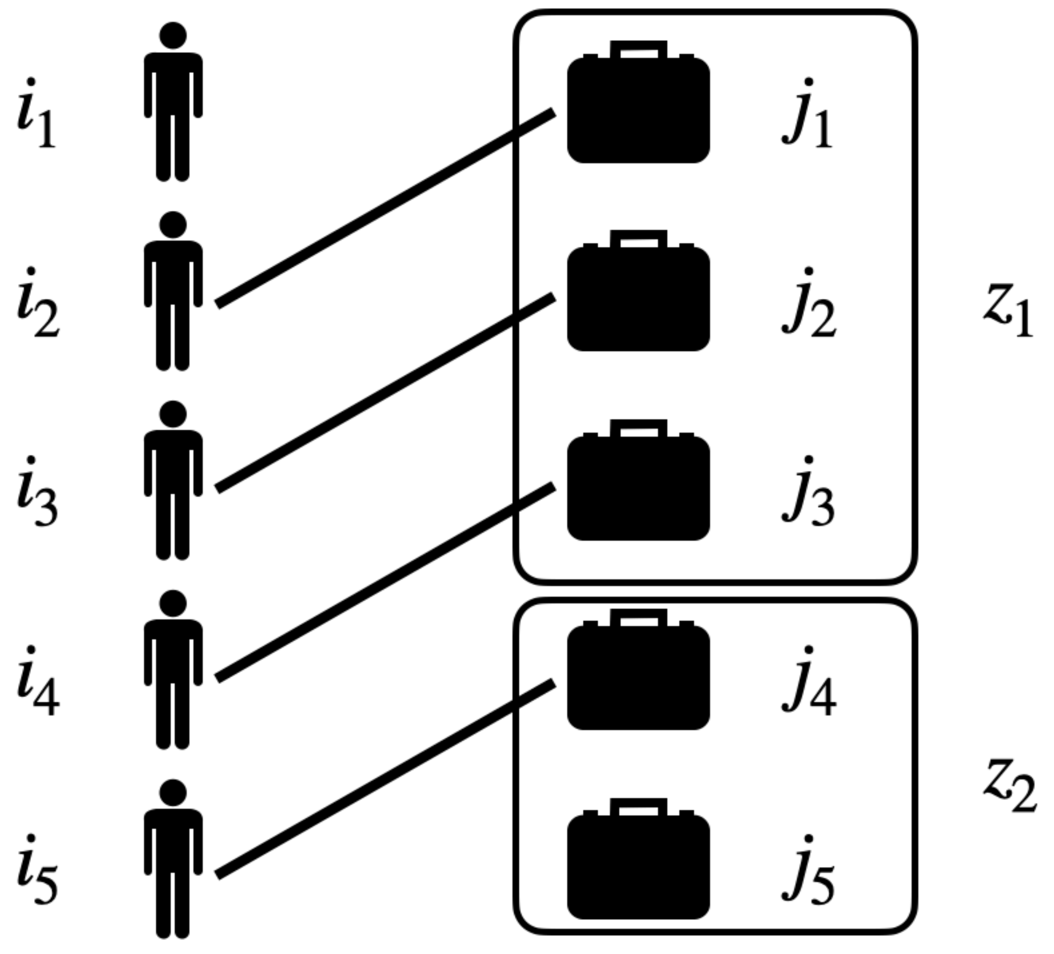
simulation setup

- we simulate the JRMP market in 2017 using estimated preferences
- compare three different policies:

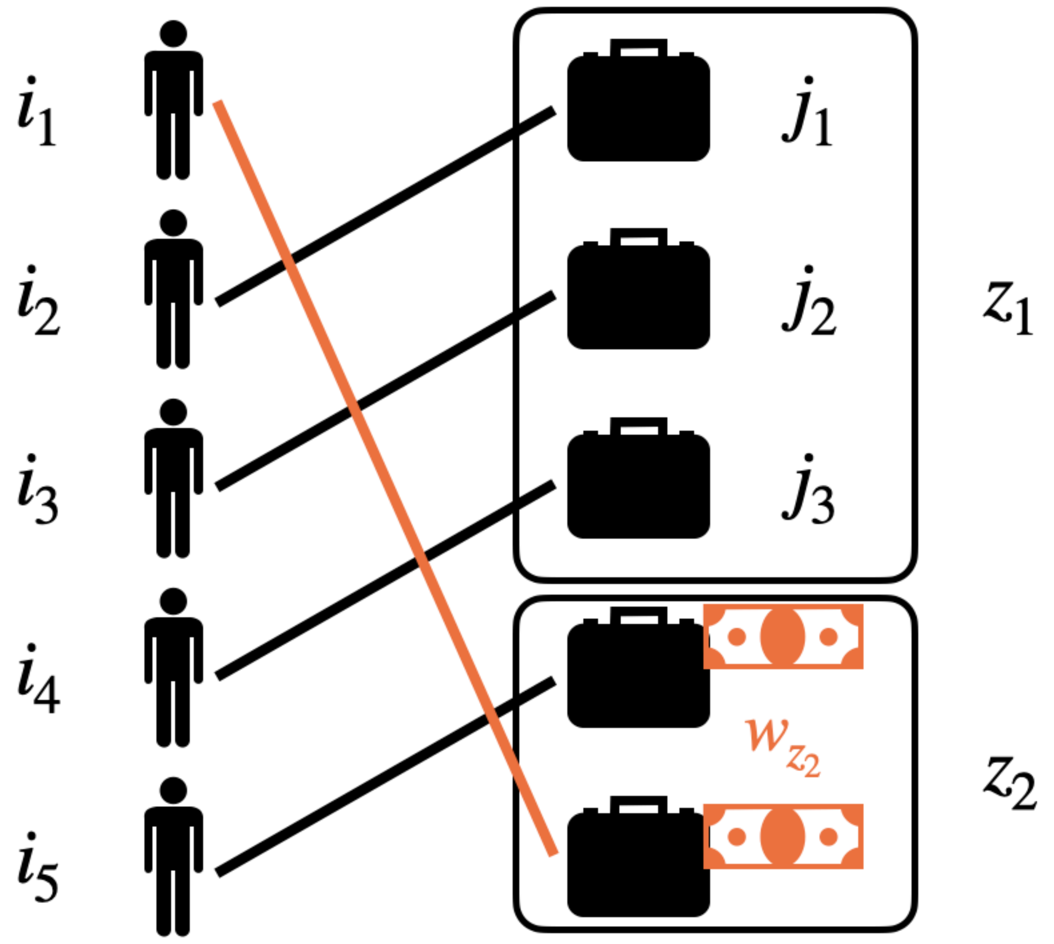
Artificial Caps (AC)
(cap on urban areas)



No Caps (NC)
(all slots available)



Optimal Subsidy (OS)
(all slots available + subsidy)



regional constraints: rural prefectures receive at least as many residents as they did under the AC

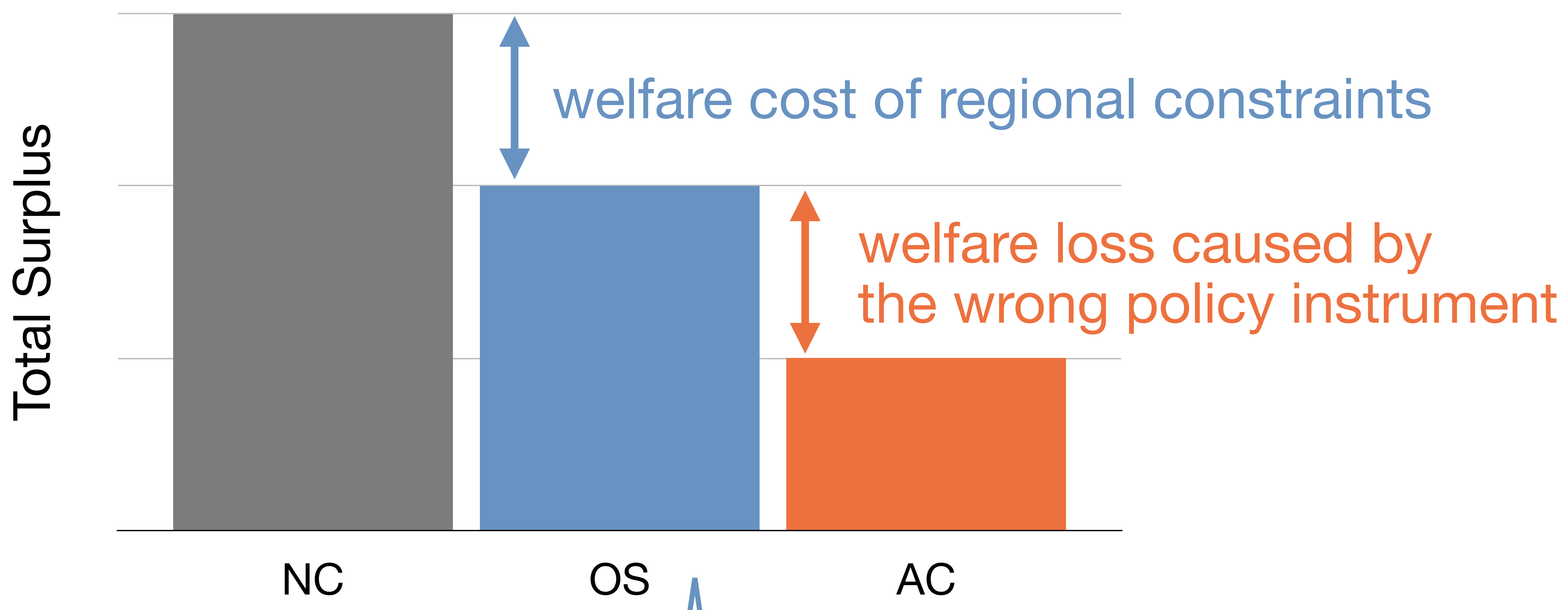
welfare ranking

Artificial Caps (AC)
(cap on urban areas)

No Caps (NC)
(all slots available)

Optimal Subsidy (OS)
(all slots available + subsidy)

Fact: NC maximizes total surplus (w/o regional constraints)



Thm 1: OS maximizes total surplus s.t. regional constraints

Artificial Caps (AC)
(cap on urban areas)

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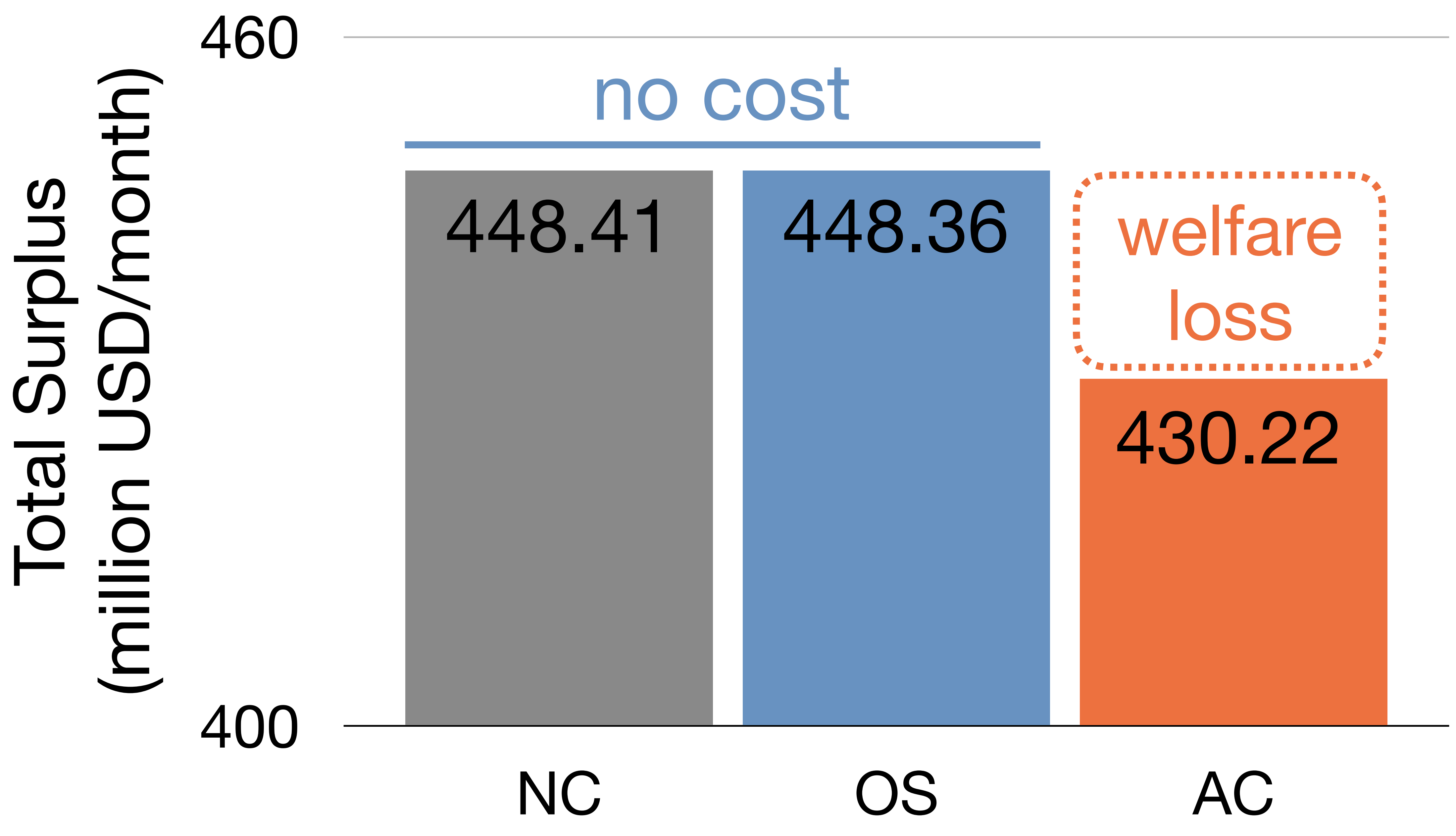
Optimal Subsidy (OS)
(all slots available + subsidy)

simulation results



- the status quo policy (AC) generates a significant welfare loss ($18M/month)
- the same distributional goal can be achieved by the optimal subsidy policy with almost no cost
- amount of required subsidy is modest
  - $400/month (10-20% of resident's salary) for each matched pair in rural prefectures
  - total national cost $100K/month
- caps are blunt instruments that do not account for the intensity of preferences

conclusion

- we develop a framework to evaluate the efficiency of policies in matching markets
  - optimal taxation policy outperforms any cap-based policy
- we apply the framework to JRMP data:
  - current cap-based policy generates a significant welfare loss
  - modest subsidy can address distributional imbalances, improving social welfare