A Quantitative Analysis of Subsidy Competition in the U.S.

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Motivation and objectives

- **Motivation**
  - US cities, counties, and states spend substantial resources on subsidies trying to attract firms from other locations.
  - Such subsidies had an annual cost of $45 billion in 2015, equivalent to 30% of average state and local business taxes.

- **Objectives**
  - Understand what motivates regional governments to subsidize firm relocations and quantify how strong their incentives are.
  - Characterize fully non-cooperative and cooperative subsidy choices and assess how far away we are from these extremes.
Strategy

- I pursue these objectives in the context of a quantitative economic geography model which I calibrate to US states.
- I calculate optimal subsidies, Nash subsidies, and cooperative subsidies and compare them to observed subsidies.

Findings

- I show that states have strong incentives to subsidize firm relocations in order to gain at the expense of other states.
- Observed subsidies are closer to cooperative than non-cooperative subsidies but the potential losses from an escalation of subsidy competition are large.
Mechanism and approach

Mechanism

- My model features agglomeration externalities in the New Economic Geography tradition which policymakers try to exploit

- Consumers want to be close to firms and firms want to be close to firms to have better access to final and intermediate goods

Approach

- I try to strike a balance between transparency and realism to be able to clearly illustrate the main mechanism and yet obtain broadly credible quantitative results

- Analytical results are notoriously hard to derive in economic geography models and the standard practice has been to resort to simple numerical examples instead
I am not aware of any comparable analysis of noncooperative and cooperative policy in a spatial environment.

Theoretical work such as Baldwin et al (2005) restricts attention to highly stylized models and does not connect to data.

Quantitative work such as Gaubert (2014), Suarez Serrato and Zidar (2016), and Fajgelbaum et al (2016) takes policy as given.


Methodologically most similar are the recent contributions by Ossa (2014), Fajgelbaum et al (2016), and Redding (2016).
Outline

- Model
- Calibration
- Analysis
Preferences are common over goods and heterogeneous over amenities:

\[ U_{jv} = U_j u_{jv} \]

\[ U_j = \frac{A_j}{L_j} \left( \frac{T_j^R}{\mu} \right)^\mu \left( \frac{C_j^F}{1 - \mu} \right)^{1 - \mu} \]

\[ C_j^F = \left( \sum_i \int_0^{M_i} c_{ij}^F (\omega_i)^{\frac{\epsilon-1}{\epsilon}} d\omega_i \right) \frac{\epsilon}{\epsilon - 1} \]

\[ u_{jv} \sim \text{Frechet} \left( 1, \sigma \right) \]

NB: Heterogeneity is necessary to allow for a meaningful sense in which states can benefit at the expense of one another.
Firms produce differentiated products using labor, capital, land, and intermediates:

\[ q_j = \varphi_j (z_j - f_j) \]

\[ z_j = \frac{1}{M_j} \left( \frac{1}{\eta} \left( \frac{L_j}{\theta^L} \right)^{\theta^L} \left( \frac{K_j}{\theta^K} \right)^{\theta^K} \left( \frac{T_j}{\theta^T} \right)^{\theta^T} \right)^{\eta} \left( \frac{C_j}{1 - \eta} \right)^{1-\eta} \]

\[ C_j = \left( \sum_i \int_0^{M_i} c_{ij}^l (\omega_i) \frac{\epsilon - 1}{\epsilon} d\omega_i \right)^{\frac{\epsilon}{\epsilon - 1}} \]

\[ 1 = \theta^L + \theta^K + \theta^T \]

NB: Tax-financed cost subsidies would not work if there was only labor because then workers would essentially subsidize themselves.
Government objective

- In the non-cooperative regime, local governments maximize local expected utility, $E (U_{jv} | \text{living in } j)$, which amounts to maximizing $U_j$.

- In the cooperative regime, the federal government maximizes national expected utility, $E (\max_j \{U_{jv}\})$, which amounts to maximizing $\left(\sum_{i=1}^{R} U_i^\sigma\right)^\frac{1}{\sigma}$.

Policy instruments

- Governments provide cost subsidies to local firms which they finance with lump-sum taxes on local residents.

- These subsidies capture deviations from a benefit tax benchmark which includes statutory corporate tax rates.
The solution to the model can be expressed as a system of $4N$ equilibrium conditions in the $4N$ unknows $\hat{\lambda}_i^L$, $\hat{\lambda}_i^K$, $\hat{\lambda}_i^C$, and $\hat{P}_i$.

It can be calibrated with minimal data requirements using the "exact hat algebra" approach of Dekle et al (2008).

Following Allen and Arkolakis (2014), the model is isomorphic to an Armington model with external IRS technology if $\phi = \frac{1}{\varepsilon-1}$ and the technology is:

$$Q_i = \varphi_i (Z_i)^{1+\phi}$$

$$Z_i = \left( \frac{1}{\eta} \left( \frac{L_i}{\theta^L} \right)^{\theta^L} \left( \frac{K_i}{\theta^K} \right)^{\theta^K} \left( \frac{T_i^C}{\theta^T} \right)^{\theta^T} \right)^{\eta} \left( \frac{C_i}{1-\eta} \right)^{1-\eta}$$
Calibration - Data

  - $\bar{s}_i = 0.5\%$, $s_i^{\text{min}} = 0.0\% \text{ (CO)}$, $s_i^{\text{max}} = 3.8\% \text{ (NM)}$

- 2007 Commodity Flow Survey
  - $T_{ij}$

- 2007 Annual Survey of Manufacturing
  - $\lambda^L_i$

- 2007 BEA Input-Output Table and BLS Capital Income Table
  - $\theta^L = 0.57$, $\theta^K = 0.33$, $\theta^T = 0.10$, $\eta = 0.58$

- Earlier work including Suarez Serrato and Zidar (2015) and Redding (2015)
  - $\sigma = 1.2$, $\mu = 0.25$, $\epsilon = 5$
I purge the trade data of the net exports due to nominal transfers so that subsidies cannot affect the real values of nominal transfers.

For this calculation, I work with a version of the model without labor mobility to preserve the original distribution of employment.

I also allow for a federal subsidy on differentiated goods purchases in order to isolate the beggar-thy-neighbor aspects of state subsidies.

\[
p_{ij} = \frac{\varepsilon}{\varepsilon - 1} \left( (w_i)^{\theta_L} (i)^{\theta_K} (r)^{\theta_T} \right)^{\eta} \left( \rho F P_i \right)^{1-\eta} \rho_i \tau_{ij} \phi_i
\]
Figure 1: Grid search for multiple equilibria

region with multiple equilibria

region with unique equilibrium

range of considered parameters
The calibration procedure essentially pins down trade costs, amenities, and productivities such that manufacturing trade and employment are exactly matched.

Assuming $\tau_{ij} = \tau_{ji}$ and $\tau_{ii} = 1$, the model can be inverted and relative trade costs, amenities, and productivities can be backed out (as well as many other variables).

It turns out that the variation in trade flows and manufacturing employment is mainly attributed to variation in trade costs and amenities, respectively.
Welfare effects of subsidy - Example

Figure 2: Effects of subsidy imposed by IL

- IL local welfare change in % (left scale)
- Other local welfare change in % (right scale)

- IL variety change in % (left scale)
- Other variety change in % (right scale)

- IL employment share in % (left scale)
- IL capital share in % (right scale)
Under certain restrictions, the welfare effects resulting from small subsidy changes can be decomposed into:

\[
\frac{dU_j}{U_j} = \frac{1}{\eta} \sum_i X_{ij} \frac{1}{E_j} \frac{dM_i}{\epsilon - 1} \frac{dM_i}{M_i} + \frac{1}{\eta} \sum_i X_{ij} \left( \frac{dp_j}{p_j} - \frac{dp_i}{p_i} \right) - \mu \left( \frac{dr_j}{r_j} - \frac{dP_j}{P_j} \right) - \theta_T \left( \frac{d\lambda_j^L}{\lambda_j^L} - \frac{d\lambda_j^C}{\lambda_j^C} \right)
\]

- home market effect
- terms-of-trade effect
- residential congestion
- commercial congestion

The terms-of-trade effect can be further decomposed into:

\[
\theta_L \sum_i X_{ij} \left( \frac{dw_j}{w_j} - \frac{dw_i}{w_i} \right) + \theta_T \sum_i X_{ij} \left( \frac{dr_j}{r_j} - \frac{dr_i}{r_i} \right) + \frac{1}{\eta} \sum_i X_{ij} \left( \frac{d\rho_j}{\rho_j} - \frac{d\rho_i}{\rho_i} \right) + \frac{1-\eta}{\eta} \sum_i X_{ij} \left( \frac{dP_j}{P_j} - \frac{dP_i}{P_i} \right)
\]

- relative wage effect
- relative rent effect
- direct subsidy effect
- intermediate cost effect

For example, if IL unilaterally imposes a 5 percent subsidy, the approximate welfare effects are:

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Figure 3: Optimal subsidies

NB: Optimal subsidies average 9.6% or $14.9 billion
NB: Local welfare rises by 2.2% or $1.2 billion on average in the subsidy imposing state
Optimal subsidies IL - Geography of welfare effects

Figure 6: Welfare effects resulting from optimal subsidy imposed by IL

% change

Figure 6: Welfare effects resulting from optimal subsidy imposed by IL

Sensitivity

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Nash subsidies

Figure 9: Nash subsidies vs. optimal subsidies

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NB: Local welfare falls by -1.1% on average which adds up to a nationwide loss of -$30.9 billion
Figure 11: Welfare effects of Nash subsidies

Sensitivity

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Cooperative subsidies

- If the federal government maximizes expected welfare, it sets all subsidies equal to zero and uses transfers to reduce inequality.

- Starting at factual subsidies, this increases expected welfare by 0.5% which amounts to a gain of $11.4 billion for the entire country.

- Almost the entire effect is due to the use of transfers, just setting subsidies to zero brings about a total gain of only $50.7 million.

- If the federal government was not allowed to make transfers, it would mimic them by cooperatively manipulating the terms-of-trade.
Cooperative redistribution

Figure 14: Cooperative redistribution
Figure 15: Cooperative subsidies, Nash subsidies, and factual subsidies
Figure 16: Factual subsidy costs vs. Nash subsidy costs
Figure 17: Fitted optimal subsidies
### Fitted subsidies - Own welfare weights

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I analyze subsidy wars and subsidy talks among US states using a quantitative economic geography model.

I believe this is the first quantitative analysis of noncooperative and cooperative policy in a spatial environment.

I show that states have strong incentives to subsidize firm relocations in order to gain at the expense of other states.

Observed subsidies are closer to cooperative than non-cooperative subsidies but the potential losses from an escalation of subsidy competition are large.
Data - Distribution of subsidies

Manufacturing subsidies

% of sales

0.5 1 1.5 2 2.5 3 3.5

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Adjustment I - Transfers

Effects on net exports

Adjusted EXP/IMP vs. Original EXP/IMP

MT  NM  WY  FL  NV  ID  OK  SD  MN  IA  NE  CO  WY  IN

0  0.2  0.4  0.6  0.8  1  1.2  1.4  1.6

Original EXP/IMP

Adjusted EXP/IMP

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Adjustment I - Transfers

Effects on trade flows

Original log trade flows (in billion $)

Adjusted log trade flows (in billion $)

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Adjustment I - Transfers

Effects on market access

Adjusted own trade shares vs. Original own trade shares

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Adjustment I - Transfers

Effects on predicted capital-labor ratios

Original capital-labor ratio

Adjusted capital-labor ratio
Role of local input cost adjustments

Local input cost change in %

EXP/IMP change in %

MT
NM
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Subsidy Competition
January 2019
Optimal state subsidy with and without federal subsidy in special case $N=1$

- Federal subsidy = $1/\epsilon$
- Federal subsidy = 0
Appendix Figure 1: Trade costs
Appendix Figure 2: Predicted trade costs from IL
Appendix Figure 3: Relative amenities

Data - Model fit
Figure 5: Maximizing employment instead of welfare

Employment-maximizing subsidy in %

Welfare-maximizing subsidy in %
## Optimal subsidies - Sensitivity

### Sensitivity wrt. sigma

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### Sensitivity wrt. epsilon

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### Sensitivity wrt. phi

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Figure 7: Optimal subsidies w/ and w/o federal subsidies
Figure 8: Own welfare gains w/ and w/o federal subsidies
## Nash subsidies - Sensitivity

### Sensitivity wrt. sigma

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<th>Δ welfare</th>
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<th>avg.</th>
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</thead>
<tbody>
<tr>
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<td>-1.3</td>
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<td>1.20</td>
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<td>-1.1</td>
<td>-1.3</td>
<td>0.4</td>
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### Sensitivity wrt. epsilon

<table>
<thead>
<tr>
<th>ε</th>
<th>avg.</th>
<th>Δ welfare</th>
<th>Δλ^L</th>
<th>avg.</th>
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<td>-0.7</td>
<td>0.2</td>
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### Sensitivity wrt. phi

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<tr>
<th>φ</th>
<th>avg.</th>
<th>Δ welfare</th>
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<th>avg.</th>
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### Nash subsidies - Sensitivity

#### Sensitivity to initial subsidies

<table>
<thead>
<tr>
<th>State</th>
<th>Min</th>
<th>Max</th>
<th>State</th>
<th>Min</th>
<th>Max</th>
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<td>9.0</td>
<td>NH</td>
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<td>6.6</td>
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<td>12.5</td>
<td>NJ</td>
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<td>PA</td>
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<td>VA</td>
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<td>5.5</td>
<td>WY</td>
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<td>7.1</td>
</tr>
</tbody>
</table>
Nash subsidies - Sensitivity

Figure 12: Nash subsidies w/ and w/o federal subsidies

Ralph Ossa (UZH)
Figure 13: Welfare change w/ and w/o federal subsidies
### Cooperative subsidies - Sensitivity

#### Sensitivity wrt. sigma

<table>
<thead>
<tr>
<th>σ</th>
<th>subsidy</th>
<th>Δ welfare</th>
<th>Δλ^L</th>
<th>avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.80</td>
<td>0.0</td>
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<td>0.5</td>
<td>1.6</td>
</tr>
<tr>
<td>1.20</td>
<td>0.0</td>
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<tr>
<td>1.60</td>
<td>0.0</td>
<td>2.0</td>
<td>0.5</td>
<td>2.7</td>
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#### Sensitivity wrt. epsilon

<table>
<thead>
<tr>
<th>ε</th>
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<tr>
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<td>1.8</td>
<td>0.4</td>
<td>1.7</td>
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#### Sensitivity wrt. phi

<table>
<thead>
<tr>
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<td>0.25</td>
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<td>0.20</td>
<td>0.9</td>
<td>2.4</td>
<td>0.4</td>
<td>2.5</td>
</tr>
</tbody>
</table>

**NB:** Without federal subsidies, the cooperative subsidy would be set to undo the markup distortion.
Fitted subsidies - Nash

Fitted Nash subsidies

Factual subsidies in %
0
1
2
3
4
5
6
Nash subsidies in %
Fitted Nash subsidies

AL
AZ
AR
CA
CO
CT
DE
FL
GA
ID
IL
IN
IA
KS
KY
LA
ME
MD
MA
MI
MN
MS
MO
MT
NE
NV
NH
NJ
NM
NY
NC
ND
OH
OK
OR
PA
RI
SC
SD
TN
TX
UT
VT
VA
WA
WV
WI
WY