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

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April 2015
Motivation and objectives

Motivation

- US cities, counties, and states spend substantial resources on subsidies trying to attract firms from other locations.

- The annual costs of such subsidies range from $33.4m in Nevada to $19.1bn in Texas and total $80.4bn nationwide.

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.
Approach and findings

Approach

- I pursue these objectives in the context of a quantitative economic geography model which I calibrate to US states
- I calculate optimal subsides, 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
Key model features

- In my model, the location of economic activity is determined by a combination of first and second advantages.

- It emphasizes agglomeration forces in the New Economic Geography tradition but is isomorphic to one with external IRS.

- It can be calibrated to the US economy using data on internal trade flows, subsidies, and the distribution of workers alone.

- I make many simplifications in the interest of transparency so that my numbers have to be interpreted with a grain of salt.
Contribution

- 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 whereas I connect to data.

- Quantitative work such as Gaubert (2014) and Serrato and Zidar (2014) takes policy as given whereas I endogenize it.

- Methodologically most similar are the recent contributions by Ossa (2014), Redding (2014), and Caliendo et al (2014).

Outline

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

\[ U_{j^v} = U_j \exp(a_{j^v}) \]

\[ U_j = A_j \frac{C_j^F}{L_j} \]

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

\[ a_{j^v} \sim \text{Gumbel}(0, \sigma) \]
Firms use labor, capital, and intermediate goods:

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

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

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

\[ 1 = \theta^L + \theta^K \]
I adopt a simple formulation of subsidy policy to allow for a transparent analysis.

Governments are assumed to maximize the common component of worker utility.

Subsidies are given to all local firms to pay for a fraction of their overall costs.

These local cost subsidies are financed with local lump-sum taxes on consumers.

\[
E_i^F = w_i L_i + \lambda_i r K - s_i \left( w_i L_i + r K_i + E_i^I \right) - \Omega_i
\]
For given subsidies, consumers maximize utility, firms maximize profits, firms make zero profits, and markets clear.

The solution of the model can be expressed as a system of 3R equilibrium conditions in the 3R unknowns $\lambda^L_i, \lambda^K_i, P_i$.

However, this system depends on a large number of parameters which are hard to estimate including $\tau_{ij}, \varphi_i, f_i, A_i$.

I circumvent this difficulty by expressing the equilibrium conditions in changes using "exact hat algebra" techniques.

I only need $T_{ij}, \lambda^L_i, s_i$ and $\theta^L, \theta^K, \eta, \varepsilon, \sigma$ and compute counterfactuals from a benchmark which matches $T_{ij}, \lambda^L_i, s_i$. 

[Conditions]
Proof.

\[ P_j = \left( \sum_i M_i (p_i \tau_{ij})^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} \]

\[ \frac{P_j'}{P_j} = \left( \sum_i \frac{M_i (p_i \tau_{ij})^{1-\varepsilon} (P_j)^{\varepsilon-1} E_j}{\sum_m M_m (p_m \tau_{mj})^{1-\varepsilon} (P_j)^{\varepsilon-1} E_j} \frac{M_i'}{M_i} \left( \frac{p_i'}{p_i} \right)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} \]

\[ T_{ij} = M_i (p_i \tau_{ij})^{1-\varepsilon} (P_j)^{\varepsilon-1} E_j \]

\[ \hat{P}_j = \left( \sum_i \frac{T_{ij}}{\sum_m T_{mj}} \hat{M}_i (\hat{p}_i)^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} \]
Agglomeration forces: Consumers want to be close to firms and firms want to be close to firms to take advantage of lower prices

Dispersion forces: Consumers have heterogeneous preferences over locations but there are no local fixed factors such as housing

The model is isomorphic to an Armington model with external IRS technology up to the scale of $\phi_i$ if $\phi = \frac{1}{\varepsilon - 1}$ and technology is

$$q_i = \phi_i (l_i)^{1+\phi}$$

$$l_i = \left( \frac{1}{\eta} \left( \frac{L_i}{\theta^L} \right)^{\theta^L} \left( \frac{K_i}{\theta^K} \right)^{\theta^K} \right)^{\eta} \left( \frac{C_i}{1-\eta} \right)^{1-\eta}$$
Data - Sources

- 2007 Commodity Flow Survey
  \( T_{ij} \)

- New York Times Business Incentives Database
  \( \bar{s}_i = 0.7\%, \; s_{i}^{\text{min}} = 0.0\% \; (\text{NV}), \; s_{i}^{\text{max}} = 5.4\% \; (\text{VT}) \)

- 2007 Bureau of Economic Analysis Input-Output Table
  \( \theta^L = 0.57, \; \theta^K = 0.43, \; \eta = 0.58 \)

- 2007 Annual Survey of Manufacturing
  \( \lambda^L_i \)

- Oberfield and Raval (2014)
  \( \varepsilon = 4 \)

- Equilibrium conditions
  \( \lambda^K_i, \; \Omega_i \)
I purge the trade data of the net exports due to transfers in order to avoid having to take a stance on the units in which they are held fixed.

For this calculation, I work with a version of the model without labor mobility so that all adjustments come from wage changes and capital flows.

I also introduce a federal subsidy on intermediate purchases in order to be able to focus on the beggar-thy-neighbor aspects of state subsidies.

\[ p_{ij} = \frac{\varepsilon}{\varepsilon - 1} \left( (w_i)^{\theta_L} (r)^{\theta_K} \right)^{\eta} \left( \rho^l P_i \right)^{1-\eta} \rho_i \tau_{ij} \]
Structure of equilibria for different sigmas in the special case $i=E,W$
I choose $\sigma \geq 1.5$ to make sure that the factual equilibrium is unique and stable.

I determine this threshold by trying out a large number of random guesses and subsidy shocks.

The lower $\sigma$, the more equilibria appear, involving extreme agglomeration in reasonable states.

I do not attempt to estimate $\sigma$ but consider various values capturing different time horizons.

Serrato and Zidar (2014) estimate $\sigma = 0.7$ but also include housing as another dispersion force.
Welfare effects of subsidy - Example

Effects of subsidy imposed by IL (\(\sigma=1.5\))

- IL welfare change (left scale)
- Other welfare change (right scale)

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

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

\[
\frac{dU_j}{U_j} = \frac{1}{\eta} \frac{1}{\varepsilon - 1} \sum_i T_{ij} \frac{dM_i}{M_i} + \frac{1}{\eta} \sum_i T_{ij} \left( \frac{dp_j}{p_j} - \frac{dp_i}{p_i} \right)
\]

\[
\text{home market effect} + \text{terms-of-trade effect}
\]

Moreover, price changes depend on subsidy changes, wage changes, and price index changes so that:

\[
\frac{dT_{OT_j}}{T_{OT_j}} = \theta^L \sum_{i=1}^{R} \frac{T_{ij}}{E_j} \left( \frac{dw_j}{w_j} - \frac{dw_i}{w_i} \right) + \frac{1}{\eta} \sum_{i=1}^{R} T_{ij} \left( \frac{d\rho_j}{\rho_j} - \frac{d\rho_i}{\rho_i} \right) + \frac{1 - \eta}{\eta} \sum_{i=1}^{R} T_{ij} \left( \frac{dP_j}{P_j} - \frac{dP_i}{P_i} \right)
\]

\[
\text{relative wage effect} + \text{direct subsidy effect} + \text{intermediate cost effect}
\]

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

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<tr>
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<th>U</th>
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<th>TOT_w</th>
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<td>IL</td>
<td>4.7%</td>
<td>3.1%</td>
<td>1.6%</td>
<td>6.8%</td>
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Optimal subsidies (sigma=1.5)

Own trade share in % vs. Optimal subsidy in %

Details

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Maximizing employment instead of welfare

Employment-maximizing subsidy in %

Optimal subsidy in %
Optimal subsidies - Welfare effects

Welfare effects relative to factual subsidies (sigma=1.5)
Welfare effects resulting from optimal subsidy imposed by IL

% change

-2 0 2 4 6 8

Factor ‡ows

Subsidy Competition

April 2015 22 / 32
Optimal subsidies - Sensitivity

### Sensitivity wrt $\varepsilon$

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Nash subsidies vs. optimal subsidies (sigma=1.5)

Nash subsidy in %
Optimal subsidy in %

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

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Determinants of welfare change (sigma=1.5)
Nash subsidies - Geography of welfare effects

Welfare effects of Nash subsidies

% change
-8 -6 -4 -2 0 2 4 6 8 10 12

Factor flows

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## Nash subsidies - Sensitivity

### Sensitivity wrt $\varepsilon$

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Cooperative subsidies

- Governments follow a bargaining process resembling symmetric Nash bargaining: \( \max_{\{s, \Omega\}} \hat{U}_1 \) s.t. 
  \[ \hat{U}_1 = \hat{U}_i \quad \forall \ i \text{ and } \sum_i \Omega_i = 0 \]

- Cooperative subsidies are always zero while cooperative transfers vary depending on the starting point to ensure \( \hat{U}_1 = \hat{U}_i \quad \forall \ i \)

- Welfare increases by 3.9 percent starting at Nash subsidies and by 0.04 percent starting at factual subsidies in all states

- Cooperative subsidies would be \( 1/\varepsilon \) if the federal government did not subsidize intermediate consumption at a rate \( 1/\varepsilon \)
### Cooperative subsidies - Sensitivity

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Starting at Nash eq.

Starting at factual eq.
Cooperative subsidies, Nash subsidies, and factual subsidies (sigma=1.5)

Factual subsidy (labels) and scaled Nash subsidy (lines) in %

MT TN NM WY WV MD RI NV NH DE NJ ND VT KY NE SC ID IL SD AR GA MO PA IN VA NY KS OH ME CO MI IA MA WI MN FL NC AZ LA OR WA TX CA
Observed vs. counterfactual subsidy costs

Factual subsidy costs vs. Nash subsidy costs (sigma=1.5)

Log of subsidy costs in Nash equilibrium (in billion $)
Log of subsidy costs in factual equilibrium (in billion $)
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.

By using "exact hat algebra" techniques I move beyond the illustrative numerical examples typical of the literature.

My results still have to be interpreted with caution since I make many simplifications in the interest of transparency.
Solution - Equilibrium conditions in levels

\[ E_i^F = w_i L_i + \lambda_i^L rK - s_i \left( w_i L_i + rK_i + \rho_i^l E_i^l \right) - \lambda_i^l s_i^l \sum_{m=1}^{R} E_m^l - \Omega_i \]

\[ \lambda_i^l = \frac{U_i^{\frac{1}{\sigma}}}{\sum_{j=1}^{R} U_j^{\frac{1}{\sigma}}} \]

\[ U_i = A_i E_i^F / (L_i P_i) \]

\[ w_i L_i = \left( \theta^L / \theta^K \right) rK_i \]

\[ E_i^l = \left( (1 - \eta) / \rho_i^l \eta \theta^K \right) rK_i \]

\[ \rho_i = \frac{\varepsilon}{\varepsilon - 1} \left( (w_i)^{\theta^L (r)^{\theta^K}} \right)^{\eta} (\rho_i^l P_i)^{1-\eta} \rho_i \]

\[ \frac{1}{\varepsilon} \sum_{j=1}^{R} (p_i \tau_{ij})^{1-\varepsilon} (P_j)^{\varepsilon-1} \left( E_j^F + E_j^l \right) = \left( (w_i)^{\theta^L (r)^{\theta^K}} \right)^{\eta} (\rho_i^l P_i)^{1-\eta} \rho_i f_i \]

\[ M_i = \frac{L_i}{\varepsilon f_i \eta \theta^L} \frac{w_i}{\left( (w_i)^{\theta^L (r)^{\theta^K}} \right)^{\eta} (\rho_i^l P_i)^{1-\eta}} \]

\[ P_j = \left( \sum_{i=1}^{R} M_i (p_i \tau_{ij})^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}} \]
\[
\hat{E}_i^F = \frac{w_i L_i}{E_i^F} \hat{w}_i \hat{\lambda}_i^L + \frac{\lambda_i^L r K}{E_i^F} \hat{\lambda}_i^L - \frac{S_i}{E_i^F} s_i' \left( \frac{w_i L_i}{S_i} \hat{w}_i \hat{\lambda}_i^L + \frac{r K_i}{S_i} \hat{\lambda}_i^K + \frac{\rho}{S_i} E_i' E_i \right) - \frac{S_i}{E_i^F} \hat{\lambda}_i^L \sum_{m=1}^{R} \lambda_m^K E_m - \frac{\Omega_i^l}{E_i^F}
\]

\[
\hat{\lambda}_i^L = (\hat{U}_i)^{\frac{1}{\sigma}} / \sum_{j=1}^{R} \lambda_j^L (\hat{U}_j)^{\frac{1}{\sigma}}
\]

\[
\hat{U}_i = \hat{E}_i^F / (\hat{\lambda}_i^L \hat{P}_i)
\]

\[
\hat{\lambda}_i^K = \hat{\lambda}_i^K
\]

\[
\hat{\lambda}_i^F = \hat{\lambda}_i^K
\]

\[
\hat{\lambda}_i = (\hat{w}_i)^{\theta \eta \eta} (\hat{P}_i)^{1-\eta} \hat{\rho}_i
\]

\[
\sum_{j=1}^{R} \frac{T_{ij}}{T_{in}} (\hat{P}_j)^{\epsilon-1} \left( \frac{E_i^F}{E_j} \hat{E}_j^F + \frac{E_j^F}{E_j} \hat{E}_j^F \right) = (\hat{\rho}_i)^{\epsilon}
\]

\[
M_i = \frac{L_i}{\varepsilon f_i \eta \theta L} \frac{w_i}{(\hat{w}_i)^{\theta L} (r)^{\theta_K}} \frac{\eta (\rho \hat{P}_i)^{1-\eta}}{\eta (\rho \hat{P}_i)^{1-\eta}}
\]

\[
\hat{P}_j = \left( \sum_{i=1}^{R} \frac{T_{ij}}{T_{mj}} \hat{M}_i (\hat{\rho}_i)^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}}
\]
Self-reliance as measured by own trade share

% of imports

15 20 25 30 35 40 45 50 55 60

States

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

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The model links observed trade flows and unobserved capital incomes and capital shares through the following equilibrium conditions:

\[
\begin{align*}
    rK_i &= \frac{\theta^K \eta}{\rho_i} \sum_n T_{in} \\
    \lambda^K_i &= \frac{rK_i}{\sum_m rK_m}
\end{align*}
\]

The model also allows me to decompose net exports into an endogenous component and a residual \( \Omega_j \) which I interpret as transfers:

\[
\sum_n (T_{jn} - T_{nj}) = \left( \lambda^K_j - \lambda^L_j \right) rK + \Omega_j
\]
Adjustment I - Transfers

Effects on net exports (w/o labor mobility)

Adjusted EXP/IMP vs. Original EXP/IMP for various states.

- States: MT, TX, UT, VT, WA, WY, LA, AL, AZ, CA, CO, CT, DE, FL, GA, ID, IL, IN, IA, KS, KY, LA, ME, MI, MN, MS, MO, NC, ND, NY, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VT, VA, WY, WI, WV

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Adjustment I - Transfers

Effects on trade flows (w/o labor mobility)

Original log trade flows (in billion $)

Adjusted log trade flows (in billion $)
Adjustment I - Transfers

Effects on market access (w/o labor mobility)

Original own trade shares

Adjusted own trade shares

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

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Role of wage adjustments and capital flows

Wage change in % = Capital stock change in %

EXP/IMP change in %
Adjustment I - Transfers

Effects on predicted capital-labor ratios

Original capital-labor ratio vs. Adjusted capital-labor ratio for various states. The graph shows a positive correlation between the two measures for most states, indicating that transfers have a significant impact on capital-labor ratios.
Adjustment II - Federal subsidy

Optimal state subsidy with and without federal subsidy in special case N=1

State subsidy in %
Welfare change in %
Federal subsidy = 1/epsilon
Federal subsidy = 0
Stability of equilibria in the special case $i=E,W$ (sigma=0.5)

Stability of equilibria in the special case $i=E,W$ (sigma=1.5)
Multiplicity of equilibria - Agglomeration on West Coast

Alternative equilibrium share of national manufacturing employment (sigma=1)

% of total

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Multiplicity of equilibria - Agglomeration on East Coast

Alternative equilibrium share of national manufacturing employment (sigma=1)

% of total

Altamaha
Subsidy Competition
April 2015 32 / 32
Multiplicity of equilibria - Agglomeration on East Coast

Associated employment change

% change
-8 -7 -6 -5 -4 -3 -2 -1 0 1

Back
Optimal subsidies - Determinants of own trade share

Productivity and self-reliance

Manufacturing productivity index in %
Own trade share in %

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Importance of HMEs for overall welfare effects (sigma=1.5)
Worker flows resulting from optimal subsidy imposed by IL

% change
-2  -1  0  1  2  3  4  5

Optimal subsidies IL - Geography of labor reallocation

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Capital flows resulting from optimal subsidy imposed by IL
Worker flows resulting from Nash subsidies

% change
-4  -2  0  2  4  6  8  10

Ralph Ossa (U of C) Subsidy Competition April 2015 32 / 32
Capital flows resulting from Nash subsidies

% change
-20 -15 -10 -5 0 5 10 15 20 25 30
From Nash subsidies to zero subsidies with transfers (\(\sigma=1.5\))

Transfer payments as a fraction of output in %

Welfare change without transfers in %
From factual subsidies to zero subsidies with transfers (sigma=1.5)

Welfare change without transfers in %

Transfer payments as a fraction of output in %
Cooperative subsidies - Geography of capital reallocation

Capital flows resulting from cooperation starting at factual subsidies

% change
-16 -14 -12 -10 -8 -6 -4 -2 0 2

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