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

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June 2017

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 and findings

- Strategy
  - 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

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

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 and does not connect to data
- Quantitative work such as Gaubert (2014), Serrato and Zidar (2015), and Fajgelbaum et al (2015) takes policy as given
- My modeling of agglomeration forces builds on Krugman (1991), Krugman and Venables (1995), and Allen and Arkolakis (2014)
- Methodologically most similar are the recent contributions by Ossa (2014), Redding (2014), and Caliendo et al (2014)

Outline

- Model
- Calibration
- Analysis

Model - Setup - Preferences

- Preferences are common over goods and heterogeneous over amenities:

$$
\begin{aligned}
U_{jv} &= U_j u_{jv} \\
U_j &= \frac{A_j}{L_j} \left(\frac{T_j^R}{\mu} \right)^{\mu} \left(\frac{C_j^F}{1-\mu} \right)^{1-\mu} \\
C_j^F &= \left(\sum_i \int_0^{M_i} c_{ij}^F \left(\omega_i \right)^{\frac{\varepsilon-1}{\varepsilon}} d\omega_i \right)^{\frac{\varepsilon}{\varepsilon-1}} \\
u_{jv} &\sim Frechet \left(1, \sigma \right)
\end{aligned}
$$

NB: Heterogeneity is necessary to allow for a meaningful sense in which states can benefit at the expense of one another

Model - Setup - Technology

- Firms produce differentiated products using labor, capital, land, and intermediates:

$$
\begin{aligned}
q_j &= \varphi_j \left(z_j - f_j\right) \\
z_j &= \frac{1}{M_j} \left(\frac{1}{\eta} \left(\frac{L_j}{\theta^L} \right)^{\theta^L} \left(\frac{K_j}{\theta^K} \right)^{\theta^K} \left(\frac{T_j^C}{\theta^T} \right)^{\theta^T} \right)^{\eta} \left(\frac{C_j^I}{1-\eta} \right)^{1-\eta} \\
C_j^I &= \left(\sum_i \int_0^{M_i} c_{ij}^I \left(\omega_i\right)^{\frac{\varepsilon-1}{\varepsilon}} d\omega_i \right)^{\frac{\varepsilon}{\varepsilon-1}} \\
1 &= \theta^L + \theta^K + \theta^T
\end{aligned}
$$

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

Model - Setup - Government

- Government objective
  - In the non-cooperative regime, local governments maximize local expected utility, $E\left(U_{jv} | \text{living in } j\right)$, which amounts to maximizing U_j
  - In the cooperative regime, the federal government maximizes national expected utility, $E\left(\max_j \left\{U_{jv}\right\}\right)$, 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:

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

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

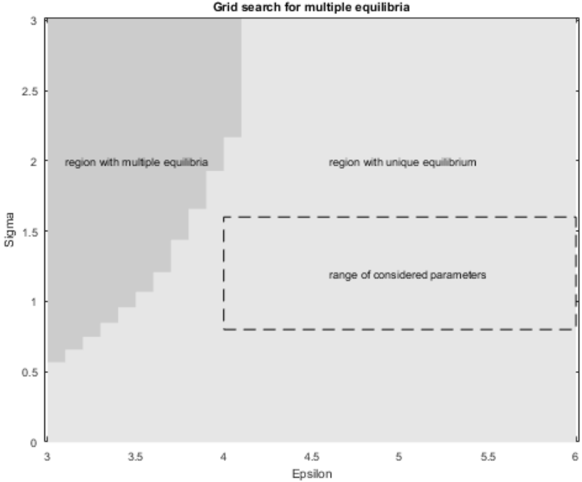
- Business incentives databases of Bartik (2017) and Story et al (2012)
  - $\bar{s}_i = 0.5\%$, $s_i^{\min} = 0.0\%$ (CO), $s_i^{\max} = 3.8\%$ (NM) Map
- 2007 Commodity Flow Survey
  - T_{ij}
- 2007 Annual Survey of Manufacturing
  - λ_i^L
- 2007 BEA Input-Output Table and BLS Capital Income Table
  - $\theta^L = 0.57$, $\theta^K = 0.33$, $\theta^T = 0.10$, $\eta = 0.58$
- Earlier work including Serrato and Zidar (2015) and Redding (2015)
  - $\sigma = 1.2$, $\mu = 0.25$, $\varepsilon = 5$

Calibration - Adjustments

- 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 to preserve the original distribution of employment ▸ Details
- I also introduce a federal subsidy on differentiated goods purchases in order to isolate the beggar-thy-neighbor aspects of state subsidies ▸ Details

$$p_{ij} = \frac{\varepsilon}{\varepsilon - 1} \frac{\left((w_i)^{\theta^L} (i)^{\theta^K} (r)^{\theta^T} \right)^{\eta} \left(\rho^F P_i \right)^{1-\eta} \rho_i \tau_{ij}}{\varphi_i}$$

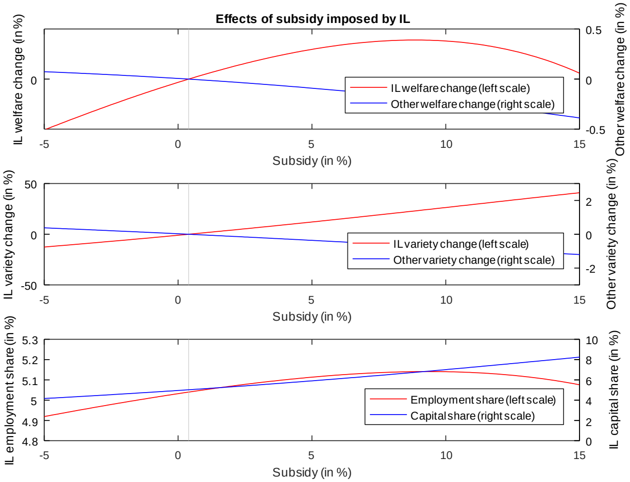
Calibration - Multiplicity of equilibria



Calibration - Model fit

- 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 Details

Welfare effects of subsidy - Example



- Under certain restrictions, the welfare effects resulting from small subsidy changes can be decomposed into:

$$\frac{dU_j}{U_j} = \underbrace{\frac{1}{\eta}\sum_i \frac{X_{ij}}{E_j}\frac{1}{\varepsilon - 1}\frac{dM_i}{M_i}}_{\text{home market effect}} + \underbrace{\frac{1}{\eta}\sum_i \frac{X_{ij}}{E_j}\left(\frac{dp_j}{p_j} - \frac{dp_i}{p_i}\right)}_{\text{terms-of-trade effect}} - \underbrace{\mu\left(\frac{dr_j}{r_j} - \frac{dP_j}{P_j}\right)}_{\text{residential congestion}} - \underbrace{\theta^T\left(\frac{d\lambda_j^L}{\lambda_j^L} - \frac{d\lambda_j^C}{\lambda_j^C}\right)}_{\text{commercial congestion}}$$

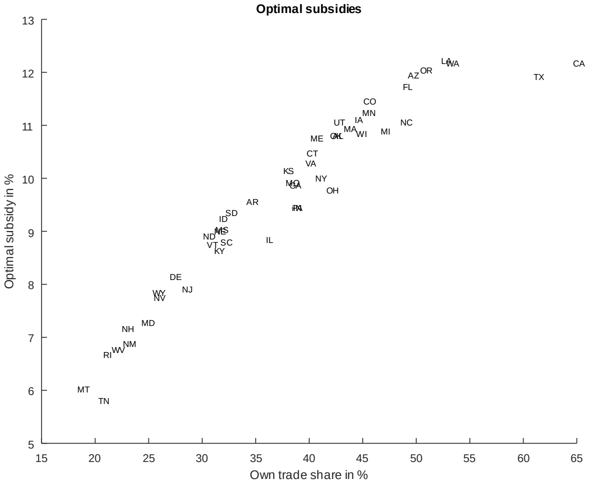
- The terms-of-trade effect can be further decomposed into:

$$\underbrace{\theta^L \sum_i \frac{X_{ij}}{E_j}\left(\frac{dw_j}{w_j} - \frac{dw_i}{w_i}\right)}_{\text{relative wage effect}} + \underbrace{\theta^T \sum_i \frac{X_{ij}}{E_j}\left(\frac{dr_j}{r_j} - \frac{dr_i}{r_i}\right)}_{\text{relative rent effect}} + \underbrace{\frac{1}{\eta}\sum_i \frac{X_{ij}}{E_j}\left(\frac{d\rho_j}{\rho_j} - \frac{d\rho_i}{\rho_i}\right)}_{\text{direct subsidy effect}} + \underbrace{\frac{1\text{-}\eta}{\eta}\sum_i \frac{X_{ij}}{E_j}\left(\frac{dP_j}{P_j} - \frac{dP_i}{P_i}\right)}_{\text{intermediate cost effect}}$$

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

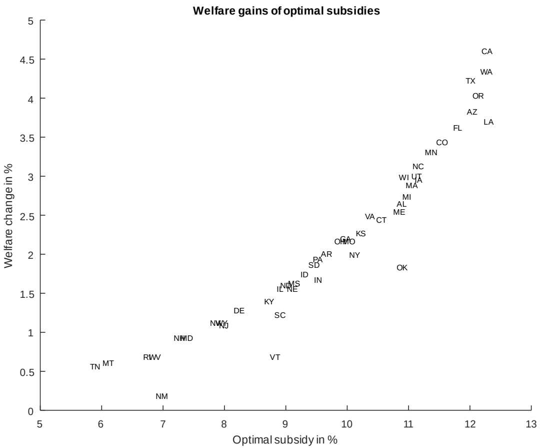
	U	HME	TOT	CON	TOT_w	TOT_r	TOT_s	TOT_{int}	CON_{res}	CON_{com}
IL	1.2%	1.6%	1.0%	-1.4%	5.4%	0.5%	-4.5%	-0.3%	-2.1%	0.7%

Optimal subsidies



▸ Own trade share

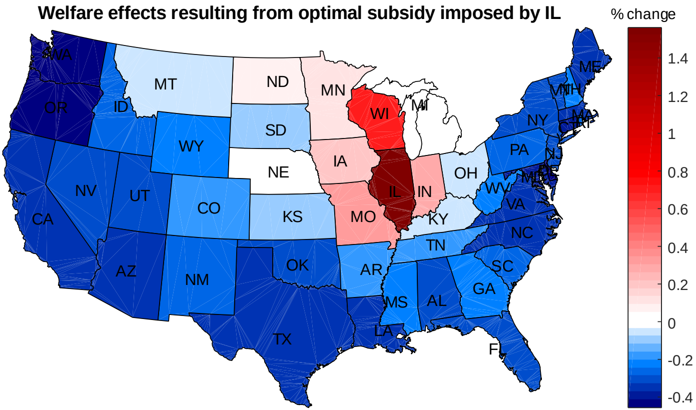
Optimal subsidies - Welfare effects



NB: Expected welfare falls by 0.07% on average which amounts to a loss worth $1.6 billion for the entire country

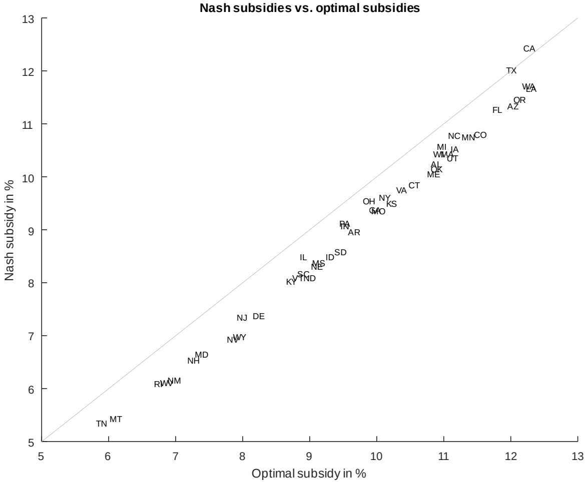
Employment max

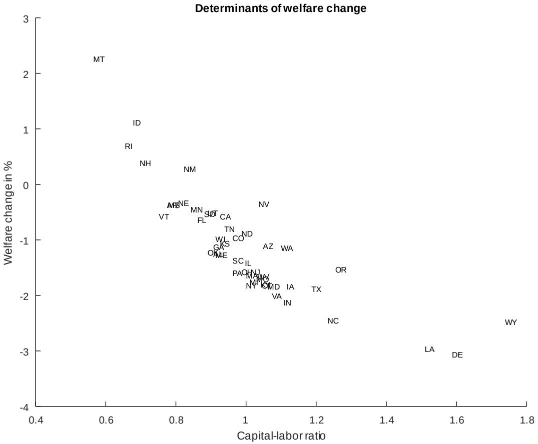
Optimal subsidies IL - Geography of welfare effects



Sensitivity

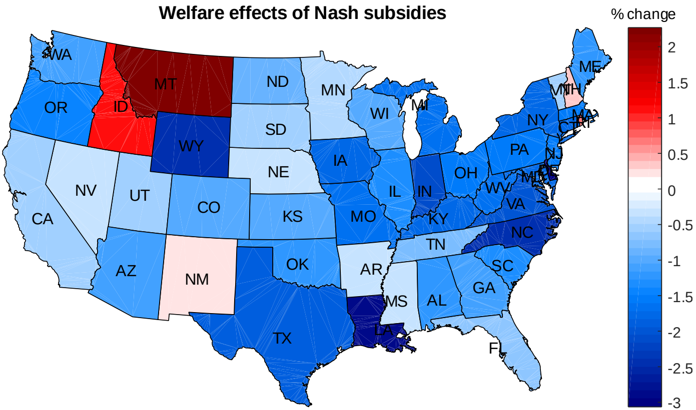
Nash subsidies





NB: Expected welfare falls by 1.3% which amounts to a loss of $29.4 billion for the entire country

Nash subsidies - Geography of welfare effects

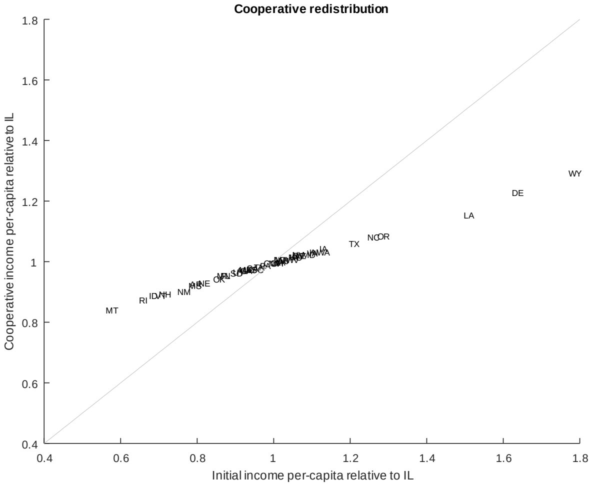


Sensitivity

Cooperative subsidies

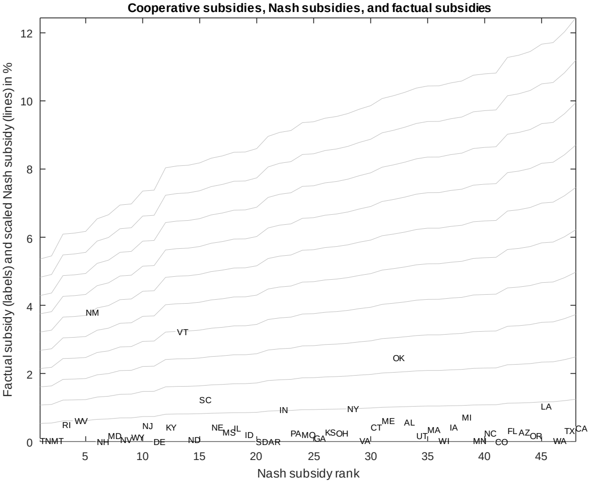
- If the federal government maximizes expected welfare, it sets all subsidies equal to zero and uses transfers to reduce inequality
- Starting at factual subsidies, this increases expected welfare by 0.5% which amounts to a gain of $11.4 billion for the entire country
- Almost the entire effect is due 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

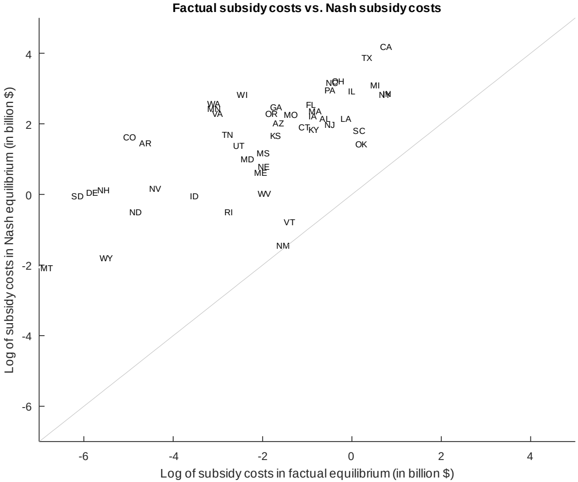


Sensitivity

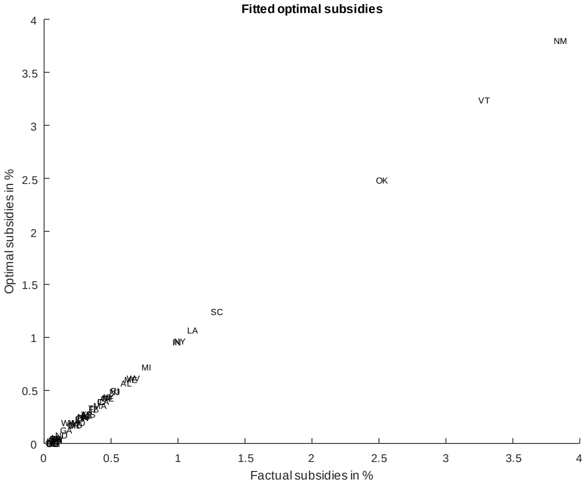
Observed vs. counterfactual subsidies



Observed vs. counterfactual subsidy costs



Fitted subsidies



Nash

Fitted subsidies - Own welfare weights

Own welfare weights

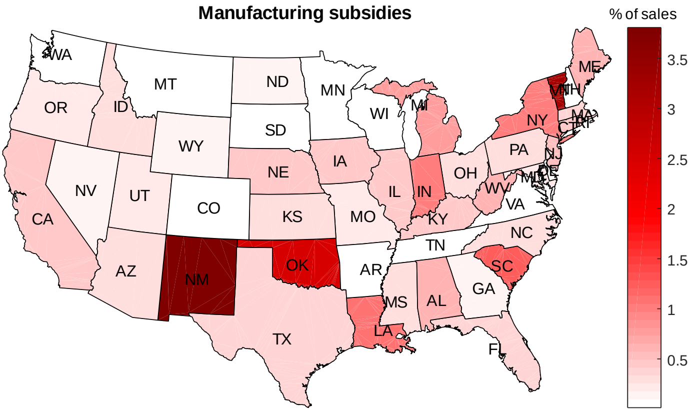
State	Weight (%)	State	Weight (%)
IN	0.54	MS	0.05
NY	0.52	GA	0.05
CA	0.41	KS	0.05
OK	0.40	RI	0.04
SC	0.38	AZ	0.04
MI	0.37	ME	0.03
IL	0.29	MD	0.03
TX	0.20	TN	0.03
NJ	0.20	OR	0.02
NM	0.19	WI	0.02
OH	0.17	UT	0.02
PA	0.16	ID	0.01
VT	0.15	MN	0.01
AL	0.14	VA	0.01
KY	0.12	WA	0.01
LA	0.11	NV	0.00
NC	0.10	AR	0.00
FL	0.10	MT	0.00
MA	0.09	NH	0.00
IA	0.08	ND	0.00
CT	0.08	CO	0.00
MO	0.06	SD	0.00
WV	0.05	DE	0.00
NE	0.05	WY	0.00

More

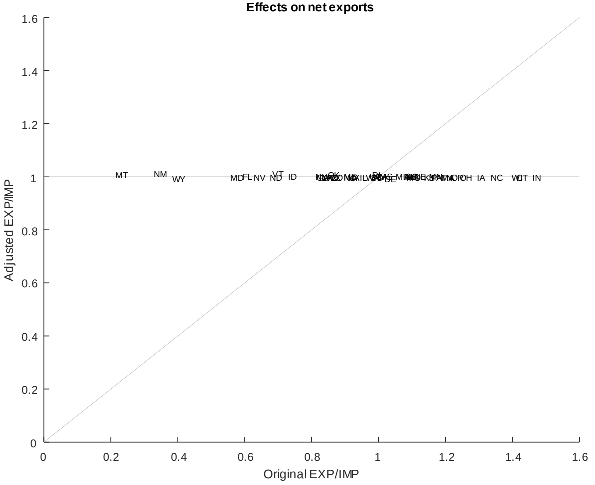
Conclusion

- 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

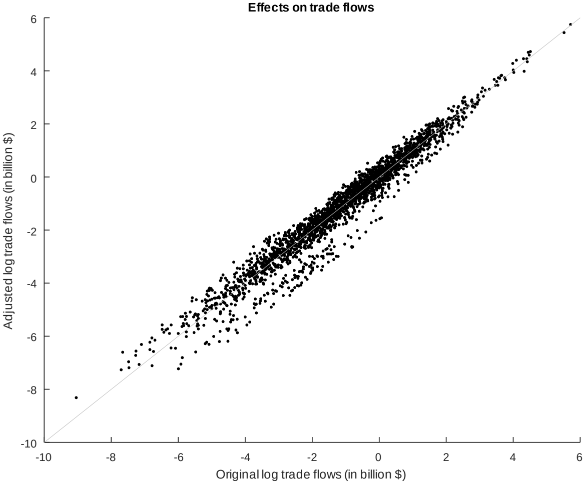
Data - Distribution of subsidies



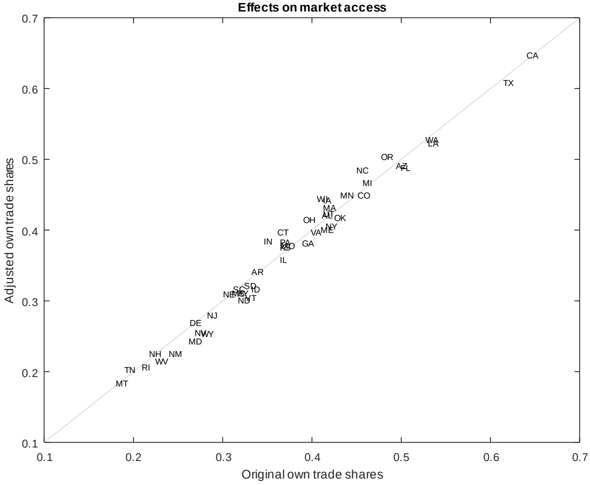
Back


Effects on net exports
Adjusted EXP/IMP
Original EXP/IMP
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
MT
NM
WY
MD
FL
NV
VT
ND
ID
DE
IA
NC
IN

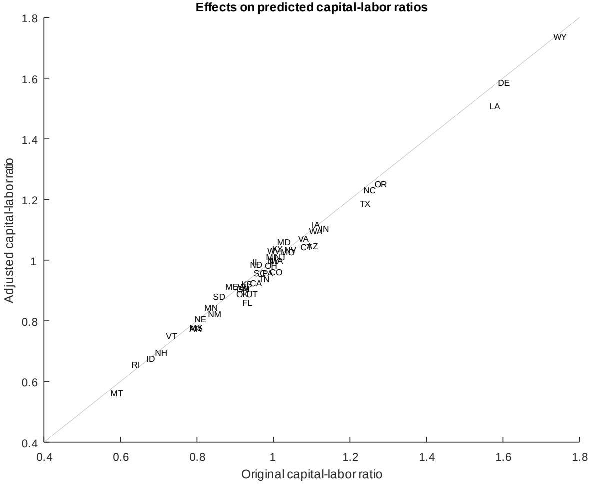
Adjustment I - Transfers



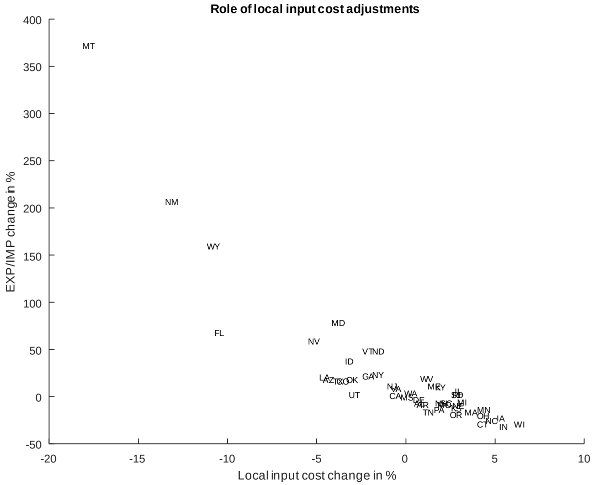
Adjustment I - Transfers



Adjustment I - Transfers

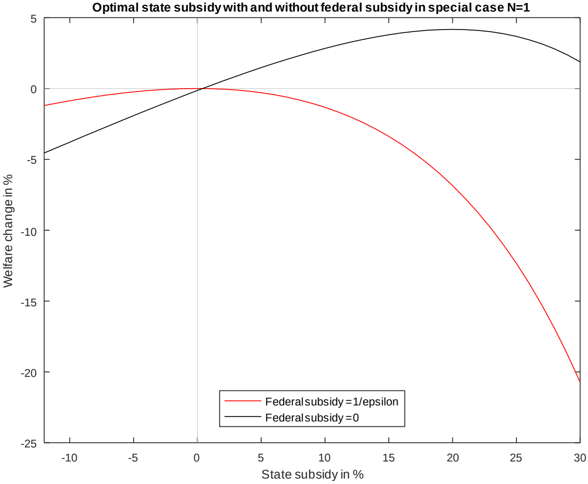


Adjustment I - Transfers



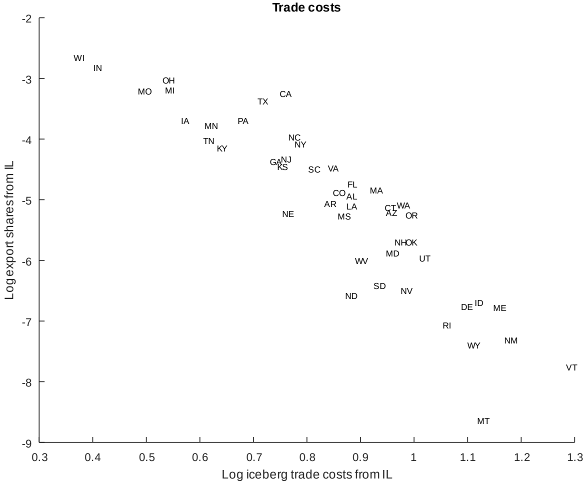
Back

Adjustment II - Federal subsidy

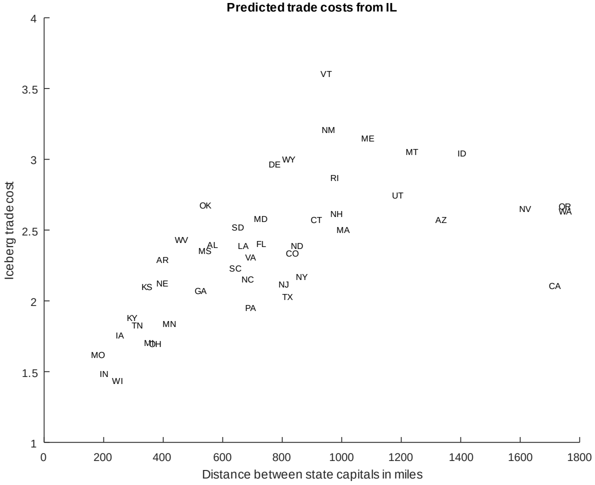


Back

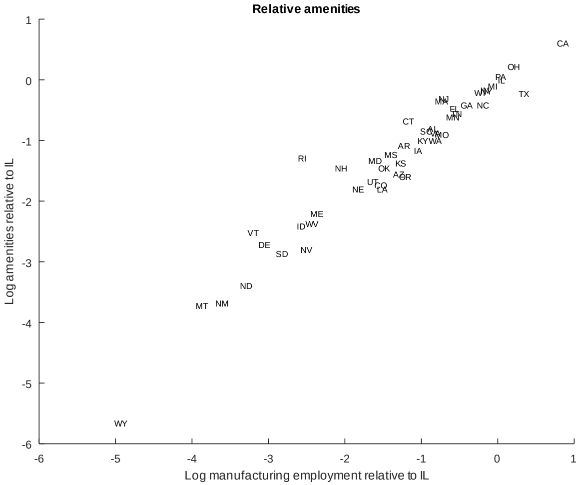
Data - Model fit



Data - Model fit

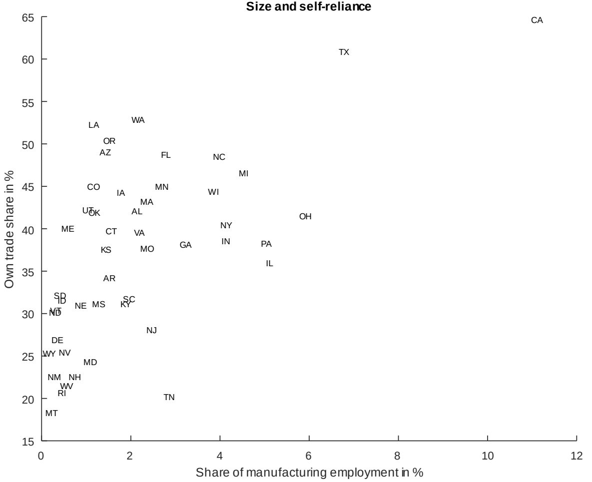


Data - Model fit



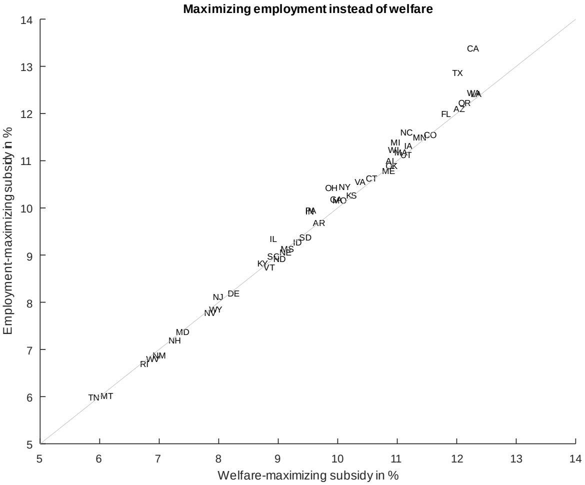
Back

Optimal subsidies - Determinants of own trade share



Back

Optimal subsidies - Maximizing employment



Back

Optimal subsidies - Sensitivity

Sensitivity wrt. sigma

	subsidy	Δ welfare			$\Delta\lambda^L$
σ	avg	own	other	expected	avg.
0.80	9.6	2.2	-0.2	-0.1	1.8
1.20	9.6	2.2	-0.2	-0.1	2.7
1.60	9.7	2.1	-0.2	-0.1	3.5

Sensitivity wrt. epsilon

	subsidy	Δ welfare			$\Delta\lambda^L$
ε	avg	own	other	expected	avg.
4.00	13.0	6.7	-0.7	-0.3	8.5
5.00	9.6	2.2	-0.2	-0.1	2.7
6.00	7.8	1.1	-0.1	0.0	1.3

Sensitivity wrt. phi

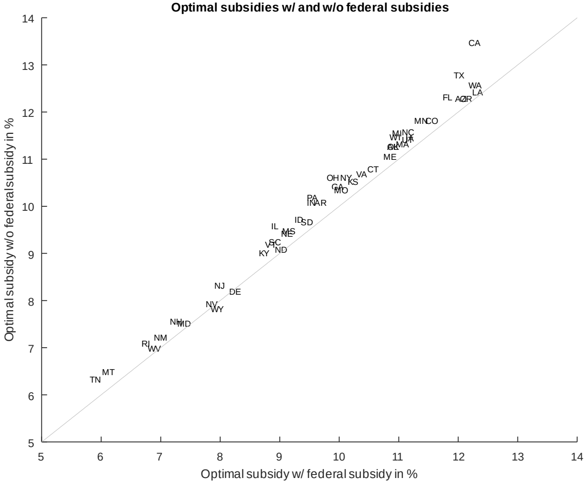
	subsidy	Δ welfare			$\Delta\lambda^L$
ϕ	avg	own	other	expected	avg.
0.33	16.4	15.7	-1.5	-0.6	20.2
0.25	9.6	2.2	-0.2	-0.1	2.7
0.20	5.6	0.5	0.0	0.0	0.7

Optimal subsidies - Sensitivity

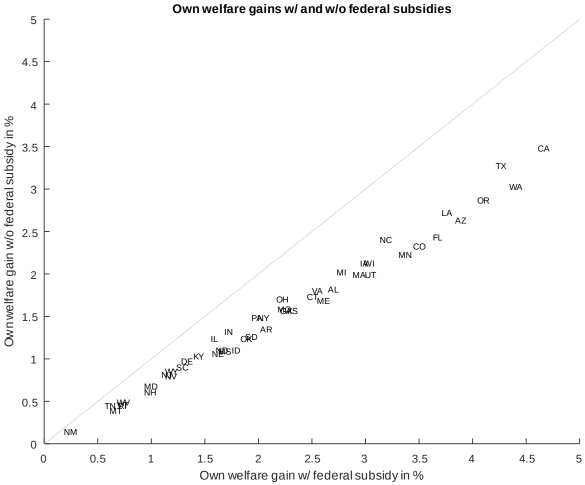
Sensitivity wrt. intial subsidies

state	subsidy min	subsidy max	state	subsidy min	subsidy max
AL	10.6	10.8	NE	8.7	9.1
AZ	11.7	12.0	NV	7.4	7.8
AR	9.3	9.6	NH	6.9	7.2
CA	12.2	12.3	NJ	7.7	8
CO	11.2	11.5	NM	6.9	7.2
CT	10.2	10.5	NY	9.9	10.1
DE	7.8	8.2	NC	10.9	11.1
FL	11.5	11.8	ND	8.6	8.9
GA	9.6	9.9	OH	9.6	9.8
ID	8.9	9.3	OK	10.7	11
IL	8.7	8.9	OR	11.8	12
IN	9.3	9.5	PA	9.3	9.5
IA	10.9	11.1	RI	6.4	6.7
KS	9.9	10.2	SC	8.6	8.9
KY	8.4	8.7	SD	9	9.4
LA	12.1	12.3	TN	5.6	5.8
ME	10.5	10.8	TX	11.9	12
MD	7.0	7.3	UT	10.8	11.1
MA	10.7	11.0	VT	8.7	9
MI	10.8	10.9	VA	10	10.3
MN	11.0	11.3	WA	12	12.2
MS	8.7	9.1	WV	6.5	6.8
MO	9.7	9.9	WI	10.6	10.9
MT	5.7	6.0	WY	7.5	7.9

Optimal subsidies - Sensitivity



Optimal subsidies - Sensitivity



Back

Nash subsidies - Sensitivity

Sensitivity wrt. sigma

	subsidy	Δ welfare		$\Delta\lambda^L$
σ	avg.	incumbent	expected	avg.
0.80	9.1	-1.1	-1.3	0.2
1.20	9.1	-1.1	-1.3	0.3
1.60	9.1	-1.1	-1.3	0.4

Sensitivity wrt. epsilon

	subsidy	Δ welfare		$\Delta\lambda^L$
ε	avg.	incumbent	expected	avg.
4.00	11.7	-2.8	-3.2	0.6
5.00	9.1	-1.1	-1.3	0.3
6.00	7.5	-0.6	-0.7	0.2

Sensitivity wrt. phi

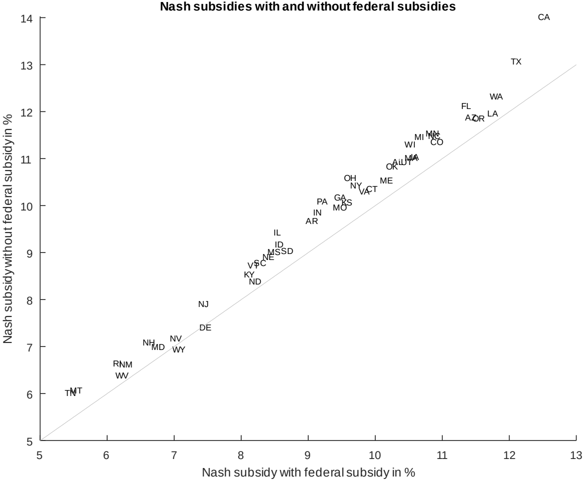
	subsidy	Δ welfare		$\Delta\lambda^L$
ϕ	avg.	incumbent	expected	avg.
0.33	14.9	-4.5	-4.9	0.5
0.25	9.1	-1.1	-1.3	0.3
0.20	5.3	-0.3	-0.4	0.2

Nash subsidies - Sensitivity

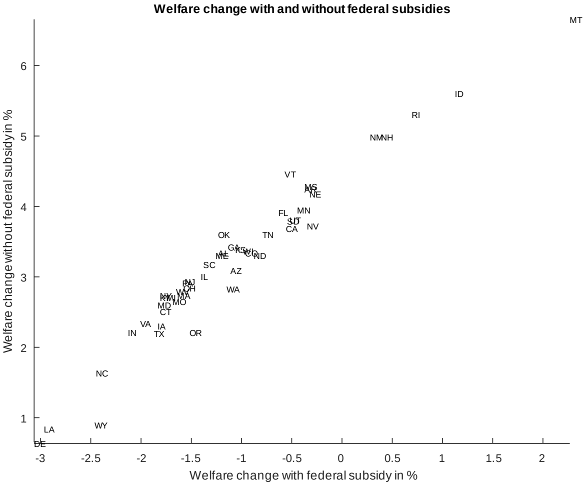
Sensitivity to intial subsidies

state	min	max	state	min	max
AL	10.0	10.4	NE	8.0	8.4
AZ	11.1	11.4	NV	6.6	7.1
AR	8.6	9.0	NH	6.2	6.6
CA	12.4	12.5	NJ	7.1	7.5
CO	10.5	10.9	NM	6.2	6.5
CT	9.6	10.0	NY	9.4	9.8
DE	7.1	7.5	NC	10.6	10.9
FL	11.1	11.3	ND	7.8	8.2
GA	9.1	9.5	OH	9.3	9.6
ID	8.2	8.6	OK	10.0	10.4
IL	8.3	8.6	OR	11.2	11.6
IN	8.9	9.2	PA	8.9	9.2
IA	10.3	10.6	RI	5.8	6.2
KS	9.2	9.6	SC	8.0	8.4
KY	7.8	8.1	SD	8.3	8.7
LA	11.5	11.8	TN	5.1	5.4
ME	9.8	10.2	TX	11.9	12.0
MD	6.4	6.8	UT	10.1	10.5
MA	10.2	10.5	VT	8.0	8.4
MI	10.4	10.7	VA	9.5	9.8
MN	10.5	10.8	WA	11.5	11.8
MS	8.1	8.5	WV	5.9	6.2
MO	9.1	9.4	WI	10.2	10.5
MT	5.2	5.5	WY	6.7	7.1

Nash subsidies - Sensitivity



Nash subsidies - Sensitivity



Back

Cooperative subsidies - Sensitivity

Sensitivity wrt. sigma

	subsidy	Δ welfare		$\Delta\lambda^L$
σ		incumbent	expected	avg.
0.80	0.0	2.7	0.5	1.6
1.20	0.0	2.3	0.5	2.2
1.60	0.0	2.0	0.5	2.7

Sensitivity wrt. epsilon

	subsidy	Δ welfare		$\Delta\lambda^L$
ε		incumbent	expected	avg.
4.00	0.0	3.6	0.8	3.5
5.00	0.0	2.3	0.5	2.2
6.00	0.0	1.8	0.4	1.7

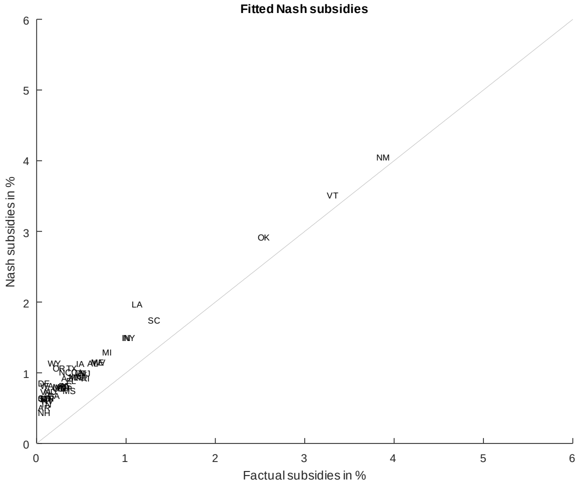
Sensitivity wrt. phi

	subsidy	Δ welfare		$\Delta\lambda^L$
ϕ		incumbent	expected	avg.
0.33	0.0	2.9	0.8	2.8
0.25	0.0	2.3	0.5	2.2
0.20	0.9	2.4	0.4	2.5

NB: Without federal subsidies, the cooperative subsidy would be set to undo the markup distortion

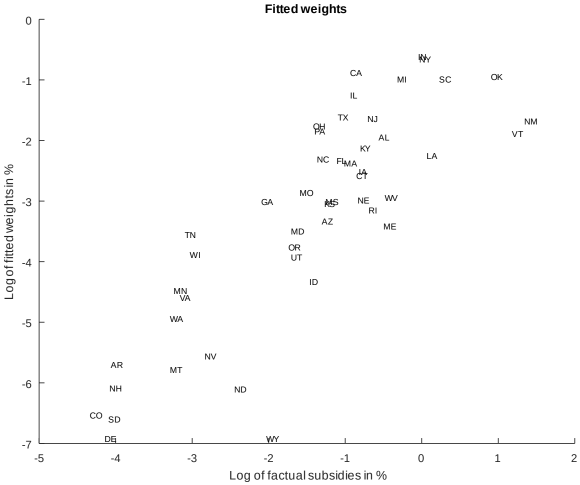
Back

Fitted subsidies - Nash



Back

Fitted subsidies - Weights



Back