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 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), Suarez Serrato and Zidar (2016), and Fajgelbaum et al (2016) 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), Fajgelbaum et al (2016), and Redding (2016)

Outline

- Model
- Calibration
- Analysis

- 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

Model - Equilibrium - Properties

- 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:

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

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

Calibration - Data

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

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

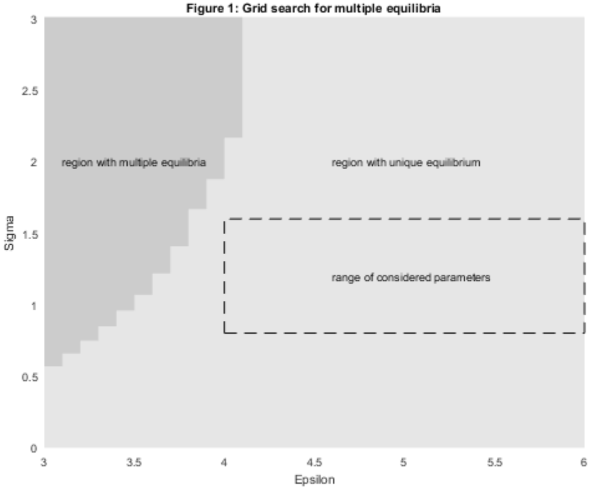
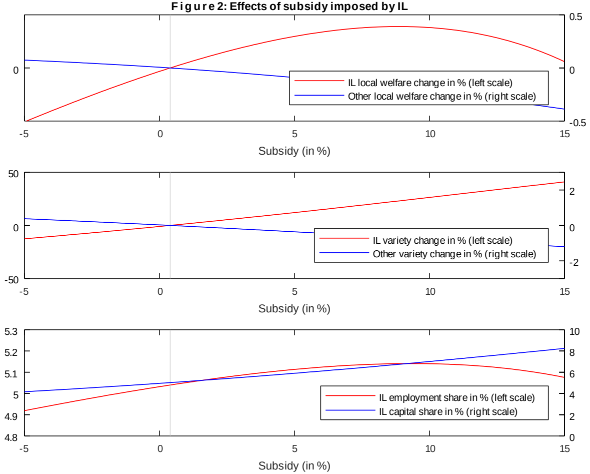


Figure 1: Grid search for multiple equilibria
3
2.5
2
1.5
1
0.5
0
Sigma
region with multiple equilibria
region with unique equilibrium
range of considered parameters
3
3.5
4
4.5
5
5.5
6
Epsilon

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:

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

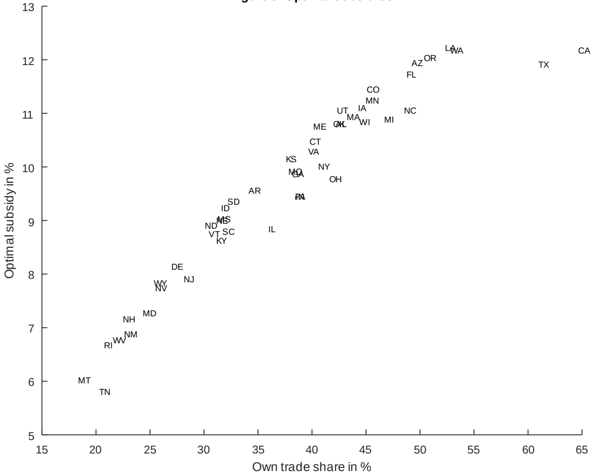
- The terms-of-trade effect can be further decomposed into:

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

- 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%

Figure 3: Optimal subsidies

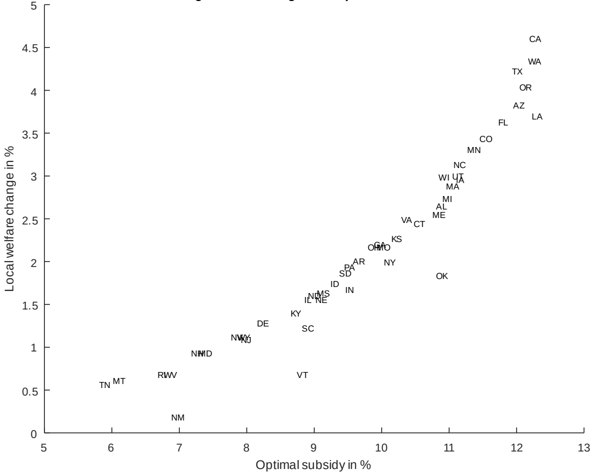


NB: Optimal subsidies average 9.6% or $14.9 billion

▸ Own trade share

Optimal subsidies - Welfare effects

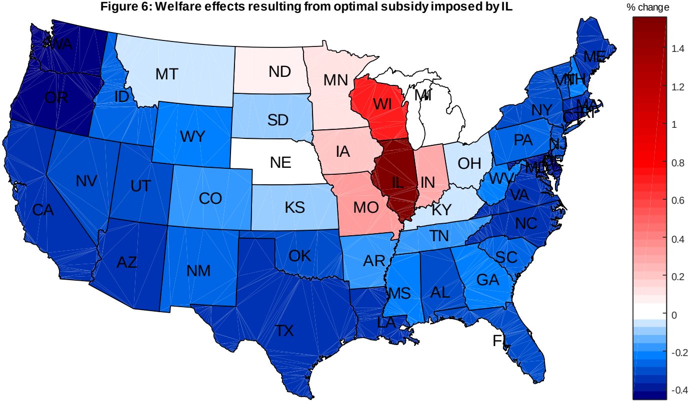
Figure 4: Welfare gains of optimal subsidies



NB: Local welfare rises by 2.2% or $1.2 billion on average in the subsidy imposing state

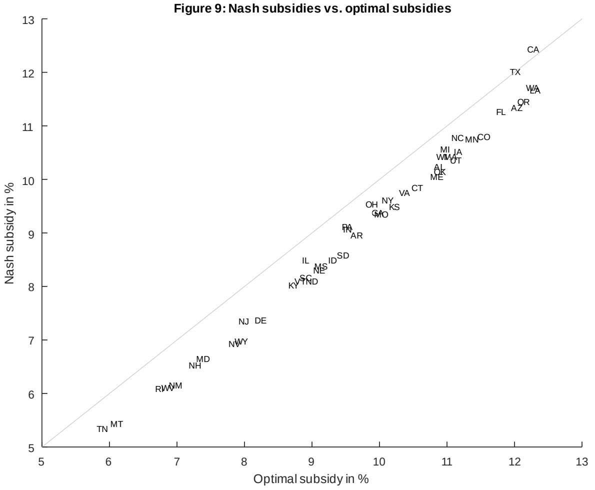
Employment max

Optimal subsidies IL - Geography of welfare effects



▸ Sensitivity

Nash subsidies



Nash subsidies - Welfare effects

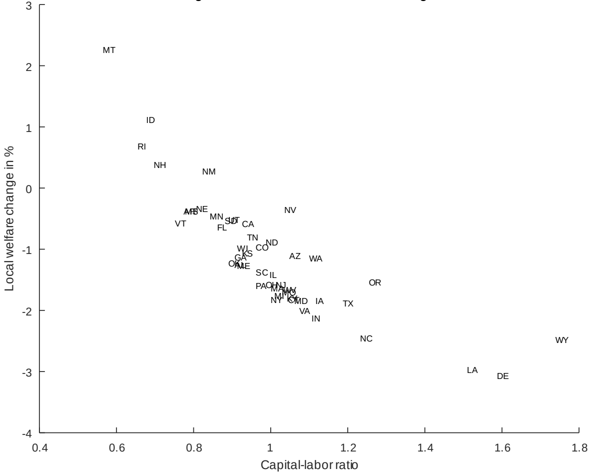
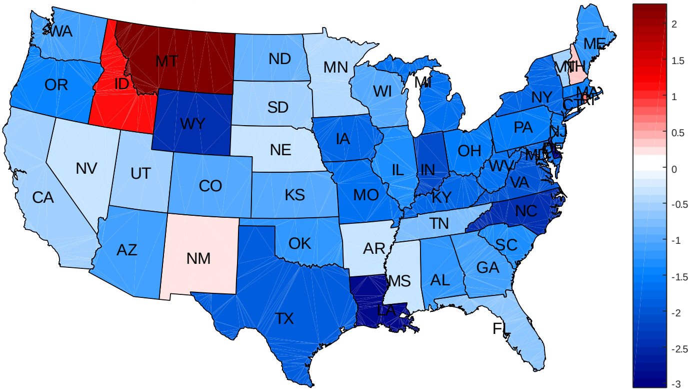


Figure 10: Determinants of welfare change

NB: Local welfare falls by -1.1% on average which adds up to a nationwide loss of -$30.9 billion

Nash subsidies - Geography of welfare effects

Figure 11: Welfare effects of Nash subsidies

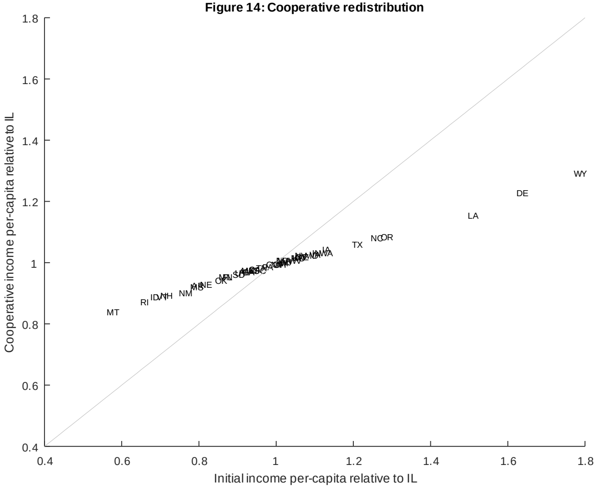


Sensitivity

Cooperative subsidies

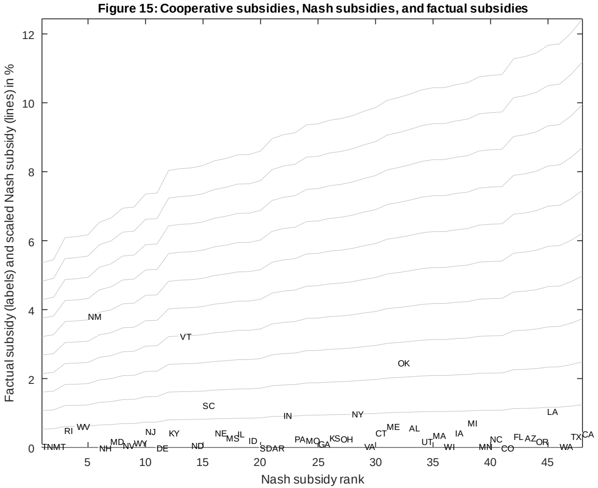
- If the federal government maximizes expected welfare, it sets all subsidies equal to zero and uses transfers to reduce inequality
- Starting at factual subsidies, this increases expected welfare by 0.5% which amounts to a gain of $11.4 billion for the entire country
- Almost the entire effect is due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

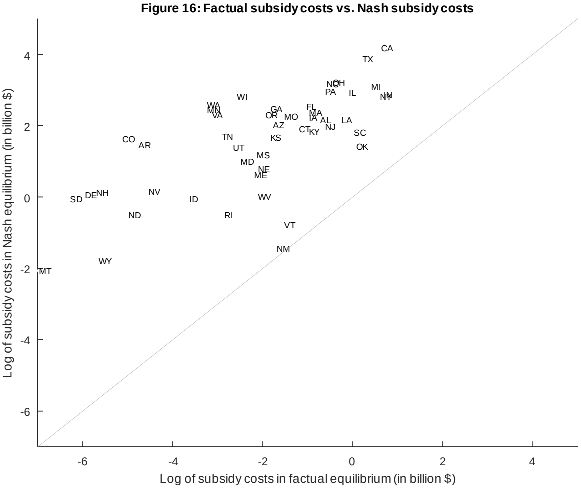


Sensitivity

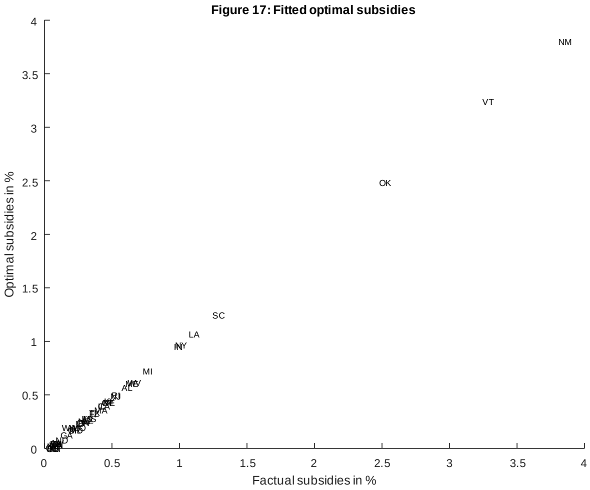
Observed vs. counterfactual subsidies



Observed vs. counterfactual subsidy costs



Fitted subsidies



▸ Nash

Fitted subsidies - Own welfare weights

Own welfare weights

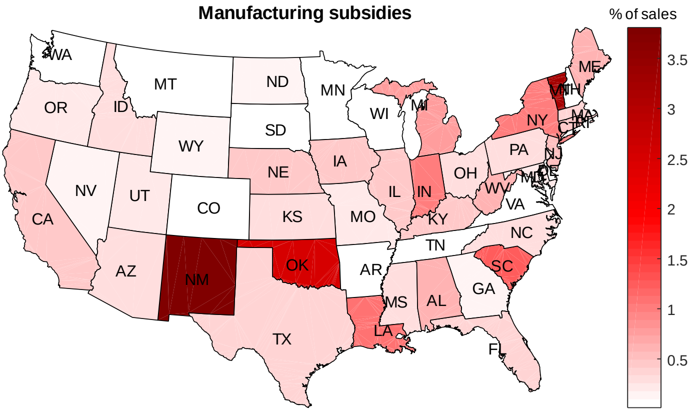
State	Weight (%)	State	Weight (%)
IN	0.54	MS	0.05
NY	0.52	GA	0.05
CA	0.41	KS	0.05
OK	0.40	RI	0.04
SC	0.38	AZ	0.04
MI	0.37	ME	0.03
IL	0.29	MD	0.03
TX	0.20	TN	0.03
NJ	0.20	OR	0.02
NM	0.19	WI	0.02
OH	0.17	UT	0.02
PA	0.16	ID	0.01
VT	0.15	MN	0.01
AL	0.14	VA	0.01
KY	0.12	WA	0.01
LA	0.11	NV	0.00
NC	0.10	AR	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



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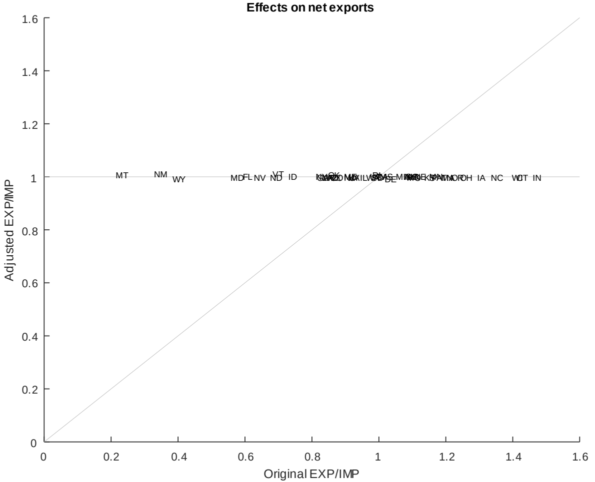
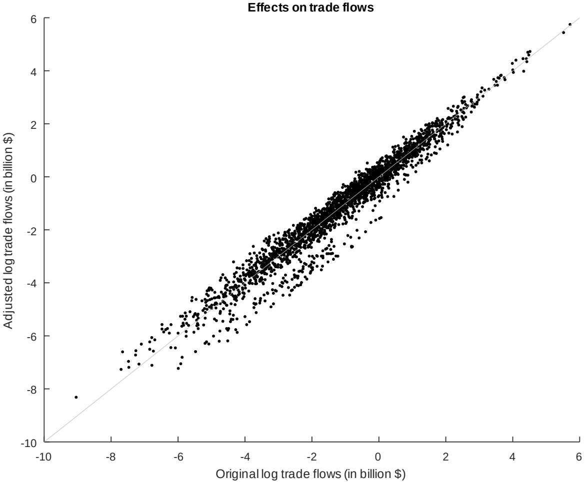
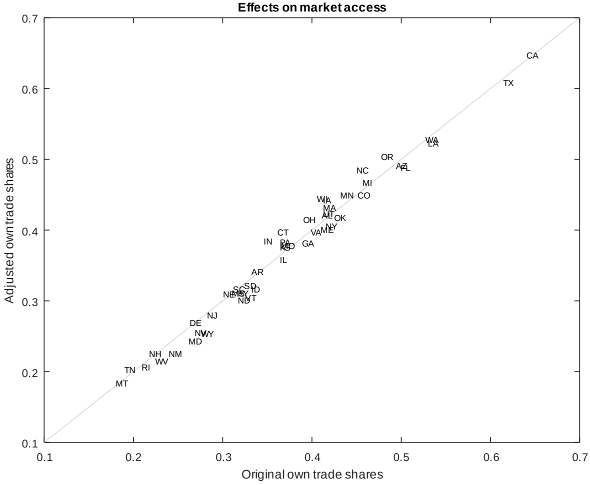
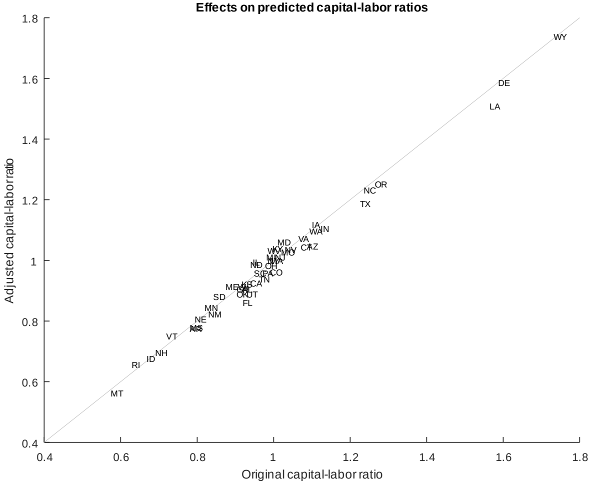

Effects on net exports
Adjusted EXP/IMP
Original EXP/IMP
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
MT
NM
WY
MD
FL
NV
ND
VT
ID
OH
IA
NC
IN


Effects on trade flows
6
4
2
0
-2
-4
-6
-8
-10
Adjusted log trade flows (in billion $)
-10
-8
-6
-4
-2
0
2
4
6
Original log trade flows (in billion $)

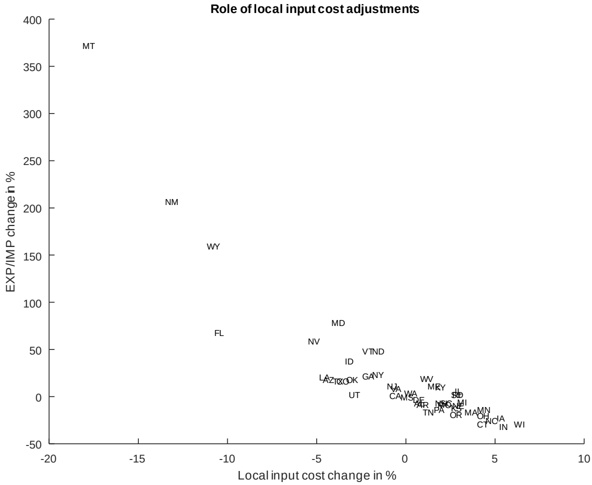
Adjustment I - Transfers



Adjustment I - Transfers

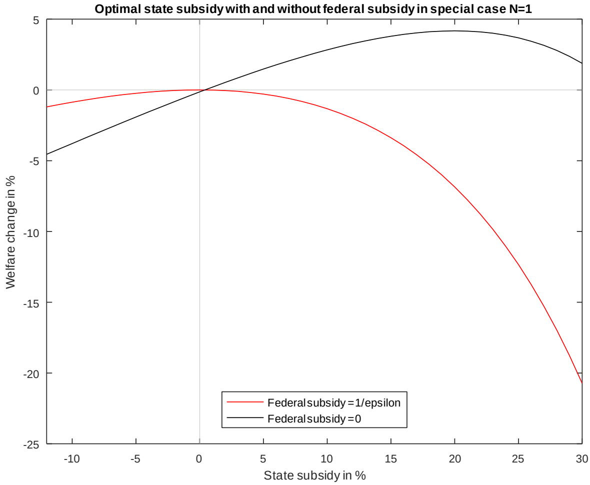


Adjustment I - Transfers



▸ Back

Adjustment II - Federal subsidy



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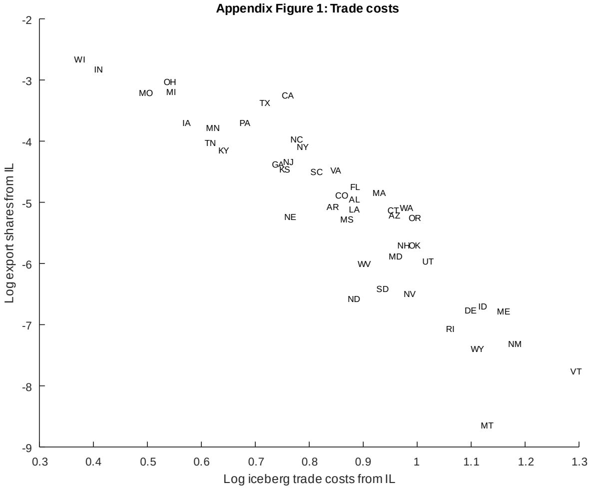
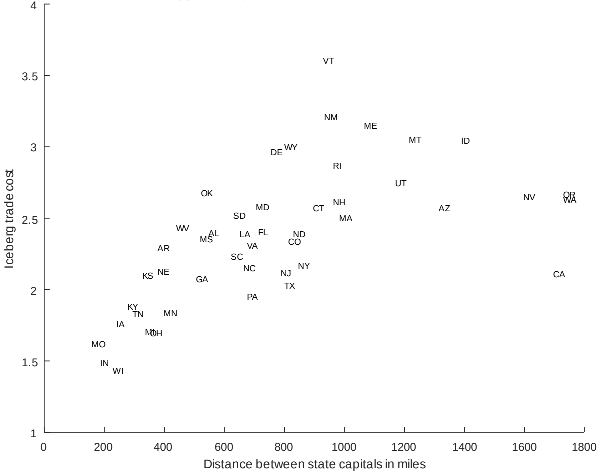
Data - Model fit

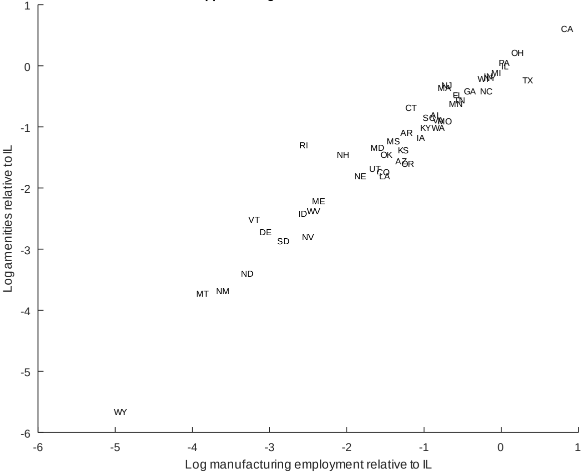


Data - Model fit

Appendix Figure 2: Predicted trade costs from IL



Appendix Figure 3: Relative amenities



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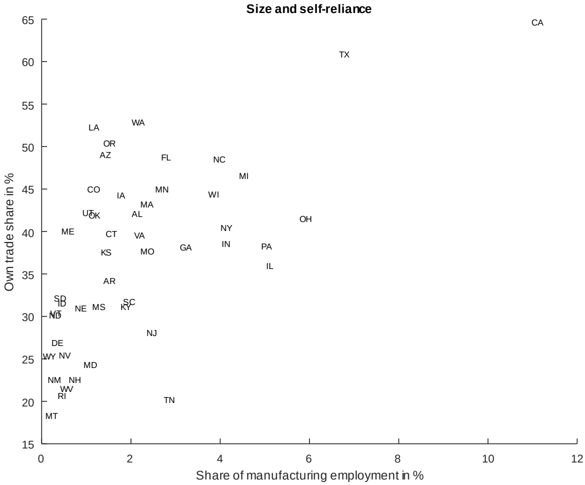
Optimal subsidies - Determinants of own trade share



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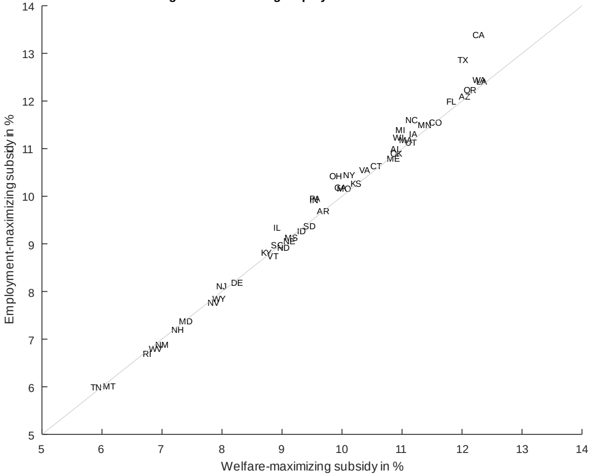
Optimal subsidies - Maximizing employment

Figure 5: Maximizing employment instead of welfare



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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

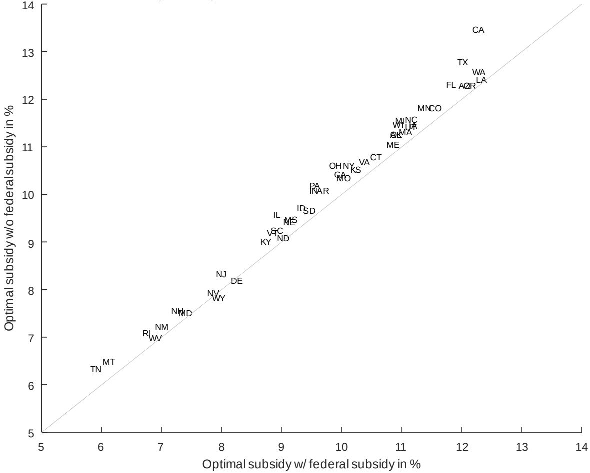
Optimal subsidies - Sensitivity

Sensitivity wrt. intial subsidies

state	subsidy		state	subsidy	
	min	max		min	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

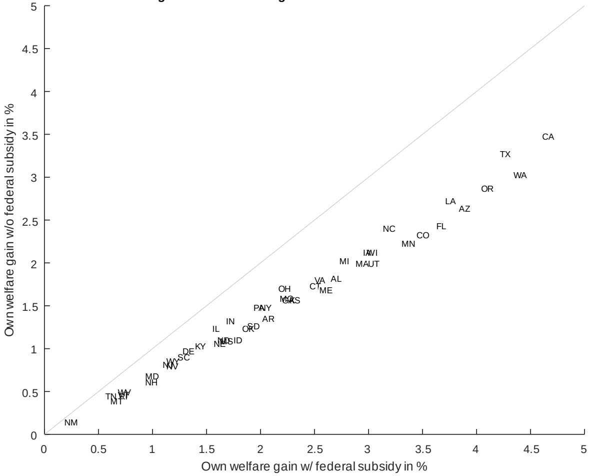
Optimal subsidies - Sensitivity

Figure 7: Optimal subsidies w/ and w/o federal subsidies



Optimal subsidies - Sensitivity

Figure 8: Own welfare gains w/ and w/o federal subsidies



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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

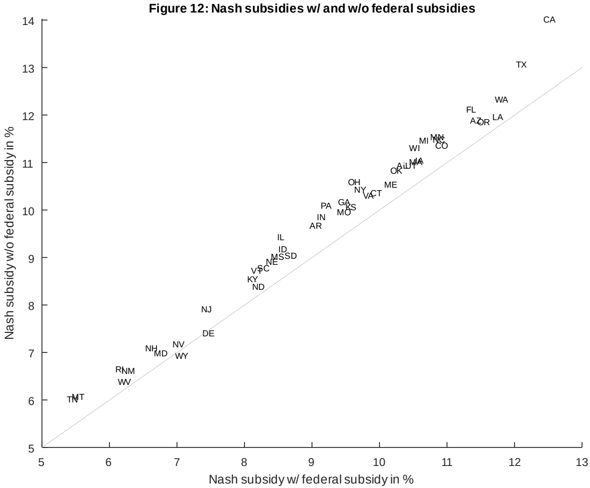
	subsidy	Δ welfare		$\Delta\lambda^L$
ϕ	avg.	incumbent	expected	avg.
0.33	14.9	-4.5	-4.9	0.5
0.25	9.1	-1.1	-1.3	0.3
0.20	5.3	-0.3	-0.4	0.2

Nash subsidies - Sensitivity

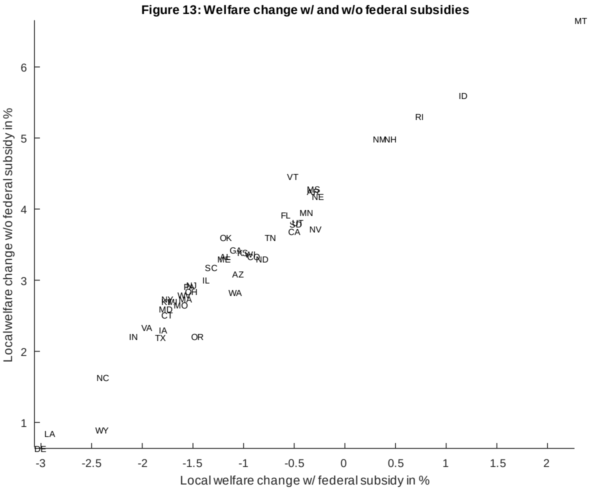
Sensitivity to intial subsidies

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



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Cooperative subsidies - Sensitivity

Sensitivity wrt. sigma

σ	subsidy	Δ welfare incumbent	Δ welfare expected	$\Delta\lambda^L$ 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

ε	subsidy	Δ welfare incumbent	Δ welfare expected	$\Delta\lambda^L$ 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

ϕ	subsidy	Δ welfare incumbent	Δ welfare expected	$\Delta\lambda^L$ 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

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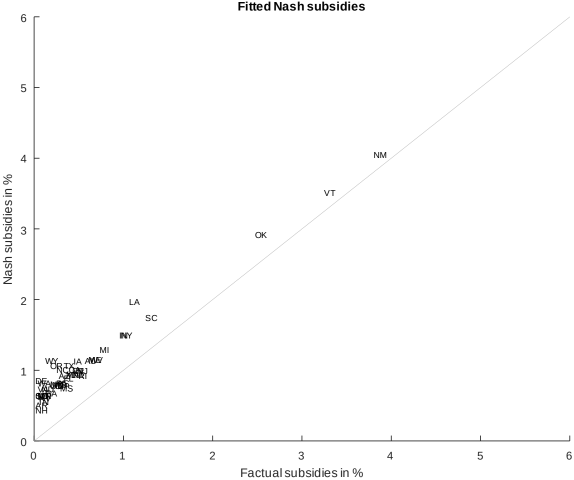
Fitted subsidies - Nash



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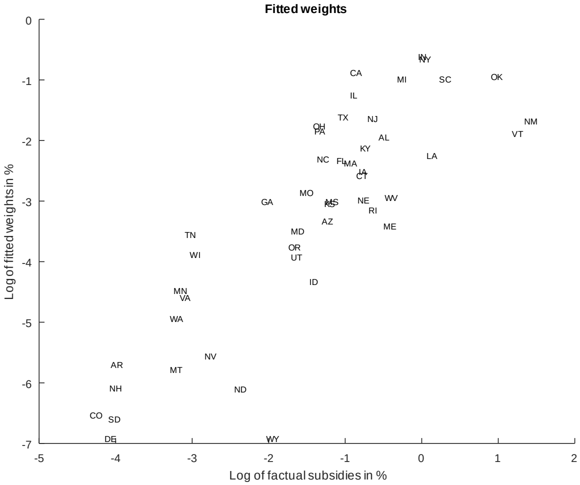
Fitted subsidies - Weights



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