The Economic Geography of Innovation

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Introduction

- Technology and productivity are key drivers of production potential, attractiveness for mobile factors to locate, and for well-being.
- Technological capabilities influenced by local innovations and innovations generated elsewhere (spillovers).
- Many countries have introduced R&D investment incentive policies.
- What is the economic value and the spatial impact of innovations in general and of such incentive schemes?

This Paper

In a first step

- Formulate and calibrate a multi-region general equilibrium model of international trade.
- The model builds on Allen and Arkolakis '14 and Desmet et al. '17[1] and considers – beyond usual productivity shifters for the production of output – a productivity shifter for workers employed in innovation.

In a second step

- Structurally estimate this productivity shifter (and other model parameters) using region-specific patent registrations and country-specific R&D- investment incentives.

In a third step

- Conduct counterfactual experiments in order to quantify the steady-state effects of innovation and specific innovation incentives for the spatial distribution of economic activity and well-being.

[1] Henceforth: AA '14 and DNRH '17

The Model

Setup

- Consider a world of S regions r on a two-dimensional surface, so $r = 1, ..., S$.
- Region r has land density $G_r > 0$, and G_r is normalized by $\frac{1}{S}\sum_{r=1}^{S} G_r$.
- Each region r is unique in terms of: amenities, productivity, and geography.
- In each location, firms produce product varieties ω, innovate, and trade subject to iceberg transport costs.
- Firms have an incentive to innovate as it improves their productivity and allows them to post a higher bid for land (land competition).
- Innovation is less costly in locations with innovation incentive schemes.
- Benefits from innovation last only for one period, then technology diffuses completely.
- The world economy is populated by $\bar{L}$ agents, who are endowed with one unit of labor each and are fully mobile across regions.

- **Static part** of the model follows AA '14 and Eaton and Kortum '02 (EK '02).
- **Dynamic part** of the model follows Desmet and Rossi-Hansberg '14.

The Role of Innovation for Production (1)

- A firm's production of variety ω per unit of land in intensive form is defined as

$$q_{rt}(\omega) = \phi_{rt}(\omega)^{\gamma_1} \; z_{rt}(\omega) \; L_{rt}(\omega)^{\mu} \quad \gamma_1, \mu \in (0, 1]. \tag{1}$$

- A firm's productivity is determined by its decision to innovate, $\phi_{rt}(\omega)$, and an exogenous, good-specific productivity shifter, $z_{rt}(\omega)$.
- For each variety ω, z_{rt} is the realization of a random variable Z_{rt} that is drawn form a Fréchet distribution.

$$F(z, r) = e^{-T_{rt} z^{-\theta}}$$

  - $T_{rt} = \tau_{rt} \bar{L}_{rt}^{\alpha}$, $\alpha \geq 0$ and $\theta > 0$
  - τ_{it} is evolving according to

$$\tau_{rt} = \phi_{rt-1}^{\gamma_1 \theta} \frac{1}{S} \left[\int_S \tau_{st-1} ds \right]^{1-\gamma_2} \tau_{rt-1}^{\gamma_2}. \tag{2}$$

  - Note: If $\gamma_2 < 1$ then the model implies global diffusion of technology.
- Productivity draws are *i.i.d* across time and goods, but correlated across regions.

The Role of Innovation for Production (2)

- All products are produced under perfect local competition.
- Competition for land implies that firms bid until they break even.
- Firms have an incentive to invest in innovation as it increases their productivity in (1) and eventually increases their bid for land.

- Innovation is produced under Cobb-Douglas technology and constant returns to scale: $\phi_{rt}(\omega) = (\frac{1}{\nu} L_{rt}^{inno}(\omega) h_{rt})^{1/\xi}$, with $h_{rt} \geq 1$.
- Hence, to innovate, a firm has to employ additional units of labor

$$L_{rt}^{inno}(\omega) = \nu \phi_{rt}(\omega)^{\xi} h_{rt}^{-1}. \tag{3}$$

  - where h_{rt} is an innovation-worker-specific productivity shifter.

The Role of Innovation for Production (3)

- Firms enjoy the benefit of their innovation for only one period, in the next period all entrants to the market have the same access to technology.
- This simplifies the dynamic profit maximization to a sequence of static problems:

$$\max_{L_{rt}(\omega),\phi_{rt}(\omega)} \quad p_{rt}(\omega)\ \phi_{rt}(\omega)^{\gamma_1}\ z_{rt}(\omega)\ L_{rt}(\omega)^{\mu} - w_{rt}[L_{rt}(\omega) + \phi_{rt}(\omega)^{\xi} h_{rt}^{-1}] - b_{rt}$$

- Prices of a good produced in r and sold in r are: $p_{rt}(\omega) = o_{rt}/z_{rt}(\omega)$.
  - An individual firm takes the input costs (o_{rt}) as given.
  - Productivity draws affect prices without changing input costs.
- Unit costs o_{rt} are defined as follows

$$o_{rt} \propto b_{rt}^{(1-\mu)-\frac{\gamma_1}{\xi}}\, h_{rt}^{-\frac{\gamma_1}{\xi}}\, w_{rt}^{(\mu+\frac{\gamma_1}{\xi})}. \tag{4}$$

- b_{rt} is the firm's bid rent for land, which increases with the level of innovation

$$b_{rt} = \left[\frac{\xi(1-\mu)}{\gamma_1} - 1\right] w_{rt} \nu \phi_{rt}(\omega)^{\xi} h_{rt}^{-1}. \tag{5}$$

The Role of Innovation for Total Employment

- Total employment in region r at period t is the sum of production workers, $L_{rt}(\omega)$, and innovation workers, $\nu\phi_{rt}(\omega)^{\xi} h_{rt}^{-1}$, so

$$\bar{L}_{rt}(\omega) = L_{rt}(\omega) + \nu\phi_{rt}(\omega)^{\xi} h_{rt}^{-1} = L_{rt}(\omega)\left[1 + \frac{\gamma_1}{\mu\xi}\right]. \tag{6}$$

- The last equality follows from the first-order-condition ratio between production labor and innovation labor

$$\nu\phi_{rt}(\omega)^{\xi} h_{rt}^{-1} = \frac{\gamma_1}{\xi\mu} L_{rt}(\omega) = \frac{\gamma_1}{\mu\xi + \gamma_1}\bar{L}_{rt}(\omega). \tag{7}$$

- Production labor is proportional to total employment in all regions r.

Utility and Consumption (1)

- When choosing residence in region r, a representative worker in period t derives utility from local amenities, a_{rt}, and from consuming a set of differentiated product varieties ω with CES preferences according to

$$u_{rt} = a_{rt} C_{rt} = a_{rt} \left[\int_0^1 c_{rt}(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}} \quad \text{with} \quad a_{rt} = \bar{a}_r \ \bar{L}_{rt}^{-\lambda} \tag{8}$$

  - $\bar{a}_r$: time-invariant amenity attribute.
  - $\lambda \geq 0$: congestion externalities parameter.
  - C_{rt}: real consumption bundle.
  - $\sigma \in (1, \infty)$: elasticity of substitution between varieties ω.

Utility and Consumption (2)

- Agents earn income from work and from local ownership of land.
- Rents are assumed to be uniformly distributed across agents.
- Workers cannot write debt contracts with each other.
- Perfect local competition implies that each worker consumes all her income.
- Indirect utility:

$$u_{rt} = a_{rt} y_{rt} = a_{rt} \frac{w_{rt} + b_{rt}/\bar{L}_{rt}}{P_{rt}} \tag{9}$$

  - Price index, P_{rt}, is defined as $P_{rt} = \Gamma\left(\frac{1-\sigma}{\theta} + 1\right)^{\frac{1}{1-\sigma}} \left[\int_S T_{kt}[o_{kt}\zeta_{ks}]^{-\theta} dk\right]^{-\frac{1}{\theta}}$

- As in EK '02 the share of consumption in region r of varieties produced in region s is determined by

$$\pi_{rst} = \frac{T_{rt}[o_{rt}\zeta_{rs}]^{-\theta}}{\int_S T_{kt}[o_{kt}\zeta_{ks}]^{-\theta} dk}, \; \forall r, s \in S. \tag{10}$$

  - $\zeta_{rs} > 1$: iceberg costs of transporting a product from r to s.

Equilibrium

Equilibrium in Each Period

Equilibrium in each period only depends on current profits, as each period is self-contained and firms are not forward-looking.

1. **Population density** is determined by the location-specific utility derived

$$\frac{G_r \bar{L}_{rt}}{\bar{L}} = \frac{{u_{rt}}^{1/\Omega}}{\int_S u_{kt}^{1/\Omega} dk}, \quad \text{with} \int_S G_r L_{rt} dr = \bar{L} \tag{11}$$

   - Ω: Fréchet parameter of a location-specific preference shock.
   - No other migration costs than ones captured by $\bar{a}_r$.

2. **Wages** through product-market clearing that requires total revenues in region r to be equal to total expenditures on products of its customers:

$$w_{rt} G_r \bar{L}_{rt} = \int_S \pi_{rst} w_{st} G_s \bar{L}_{st} \; ds \quad \forall r, s \in S \tag{12}$$

Existence and Uniqueness

- An equilibrium exists and is unique if congestion forces are not smaller than agglomeration forces:

$$\frac{\alpha}{\theta} + \frac{\gamma_1}{\xi} \leq \lambda + 1 - \mu + \Omega.$$

Balanced Growth Path (BGP)

- If a BGP exists then all locations grow at the same rate and the spatial distribution of employment is constant.
- The investment decision will be constant but different across locations.
- There exists a unique growth path if

$$\frac{\alpha}{\theta}+\frac{\gamma_1}{\xi}+\underbrace{\frac{\gamma_1}{[1-\gamma_2]\xi}}_{\text{Dynamic agglomeration effect}}\leq\lambda+1-\mu+\Omega$$

- In a BGP aggregate welfare and real consumption depend on population size, the **productivity shifter** h_{rt} and their distribution in space

$$\frac{u_{rt+1}}{u_{rt}}=\frac{C_{rt+1}}{C_{rt}}\propto\left(\int_S(\bar{L}_s h_s)^{\frac{\theta\gamma_1}{[1-\gamma_2]\xi}}\;ds\right)^{\frac{1-\gamma_2}{\theta}} \tag{13}$$

Calibration of the Model

Calibration: Overview

1. Preferences	
$\sigma = 4$	Elasticity of substitution.
$\lambda = 0.65$	Relation between amenities and population.
$\Omega = 0.5$	Elasticity of migration flows w.r.t. income.
2. Technology	
$\alpha = 0.06$	Elasticity of productivity w.r.t. population density.
$\theta = 6.5$	Trade elasticity.
$\mu = 0.8$	Labor share in production (non-land share).
$\gamma_1 = 0.1130$	Elasticity of tomorrow's productivity w.r.t. today's innovation.
3. Evolution of productivity	
$\gamma_2 = 0.9898$	Elasticity of tomorrow's productivity w.r.t. today's productivity.
$\xi = 125$	Elasticity of innovation costs w.r.t. innovation.
$\nu = 0.15$	Intercept parameter in innovation cost function.
4. Transport Costs	
	Based on AA '14 and Fast Marching Algorithm.
4. Other Trade Costs	
$\theta = 6.5$	Elasticity of trade w.r.t. tariffs (tariffs from WDI).
$\kappa = 0.078$	Elasticity of trade w.r.t linguistic proximity (Melitz and Toubal, 2014).
	Trade costs

Estimation

Amenity Parameter

- Amenities are defined as: $a_{rt} = \bar{a}_r \bar{L}_{rt}^{-\lambda}$
- We estimate the region-specific amenity shock $\bar{a}_r$ and the amenity parameter λ for the baseline year 2005 as follows

$$\log(a_r) = E(\log(\bar{a}_r)) - \lambda \log \bar{L}_r + \varepsilon_r^a \tag{14}$$

  - a_r: Amenity distribution (2005) is derived through an iterative process using the structure of the model. Amenities
  - $\bar{L}_r$: Gridded population data (2005) from SEDAC. Assignment
  - $\bar{L}_r$ is instrumented with a region-specific remoteness index, $R_r = weight_r^{area} \left(\frac{1}{S} \sum_s \zeta_{rs} \right)$

First Stage Dep. Var. $\log(\bar{L}_r)$		**Second Stage** Dep. Var. $\log(a_r)$	
$log(R_r)$	-0.581*** (0.014)	$\widehat{\log(\bar{L}_r)}$	-0.650*** (0.034)
cons	16.113*** (0.060)	cons	9.604*** (0.473)
#obs	5633	#obs	5633

  - $\bar{a}_r \equiv exp(E(\log(\bar{a}_r)) + \varepsilon_r^a)$

Technology Parameters

- The BGP implies (13). Taking logs and discretizing (13) gives

$$\begin{aligned}\log(u_{rt+1}) - \log(u_{rt}) &= \log(y_{rt+1}) - \log(y_{rt}) \\ &= \frac{(1-\gamma_2)}{\theta}\log(\eta) + \frac{\gamma_1}{\xi}\log(\Psi) + \frac{\gamma_1}{\xi}\log(SL_n) + \frac{1-\gamma_2}{\theta}\log(\sum_r \bar{L}^*_{rt})\end{aligned} \tag{15}$$

  - $\Psi = \frac{\gamma_1/\nu}{\gamma_1+\mu\xi}$, $L_n = 1000$, and $\bar{L}^*_{rt} = \left[\frac{\bar{L}_{rt}}{L_n} h_r\right]^{\frac{\theta\gamma_1}{(1-\gamma_2)\xi}}$.
  - y_{rt}, $\bar{L}_{rt}$: Gridded GDP p/c and population data from G-Econ Project. Assignment
  - t: 1990(5)2005

- We do a grid search for the minimum sum of squared residuals.
- We use the corresponding h_r for each value of γ_1 as the estimation of h_r itself depends on γ_1.
- Optimal parameter values: $\gamma_1 = 0.1130$, $\gamma_2 = 0.9898$ (DNRH: $\gamma_1 = 0.319$, $\gamma_2 = 0.99246$)

Estimation of h_r

- We estimate h_{rt} using (7) and assume

$$\phi_{rt}^{\xi} = Patents_{rt}^{\tilde{\xi}} = \frac{\gamma_1}{\xi\nu[\mu + \gamma_1/\xi]} \bar{L}_{rt} h_{rt} \tag{16}$$

  - $Patents_{rt}$: registered patents per unit of land in region r at year t (PATSTAT).
  - $\bar{L}_{rt}$: population density in region r at year t (SEDAC).
- We parametrize h_{rt} by country-specific binary tax instruments (Boesenberg and Egger, 2016), such that:

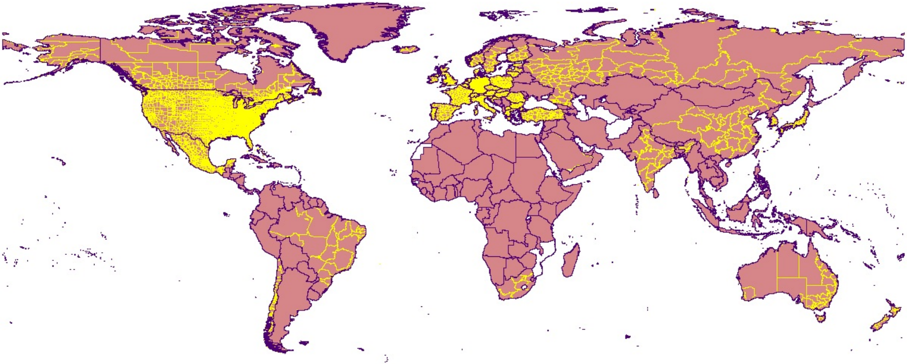
$$h_{rt} = \exp(\mathbf{D}_{ct}\beta + |lat_{rt}|\mathbf{D}_{ct}\gamma) \tag{17}$$

  - $\mathbf{D}_{ct}$ includes binary variables on R&D policy instruments: $Dpatentbox_{ct}$, $Dgrants_{ct}$, $Dtaxcredit_{ct}$, $Dtaxholiday_{ct}$, $Dsuperd_{ct}$, $Ddeduc_{ct}$, $Deatrrd_{ct}$.

- We estimate (16) as a cross section by negative binomial regression (year=2005)

$$Patents_r = \exp(\beta_0 + \frac{1}{\tilde{\xi}} \log \tilde{\bar{L}}_r + \frac{1}{\tilde{\xi}} \log h_r + \varepsilon_r) \tag{18}$$

where $\tilde{\bar{L}}_r = \xi\nu[\mu + \gamma_1/\xi]\bar{L}_r$ and ε_r is the error term.



Data: 5633 PATSTAT regions in 213 countries, benchmark year: 2005.

PATSTAT Classification of Regions

- Countries with a few patents do not have a regional classification.

Variable	Mean	Std.Dev.	Min.	Max.	N
Patents per norm. unit of land (avg. 2000-2010)					
Total	1,201	8,058	0	375,281	5,470
One-region countries	988	9,044	0	113,542	163
One-region countries islands	4,233	18,549	0	113,542	38
One-region countries non-islands	1.511	3.475	0	18.025	125
Patents per km^2 (avg. 2000-2010)					
Total	0.026	0.172	0	8.012	5,470
One-region countries	0.021	0.193	0	2.424	163
One-region countries islands	0.09	0.396	0	2.424	38
One-region countries non-islands	0	0	0	0	125

Summary Statistics

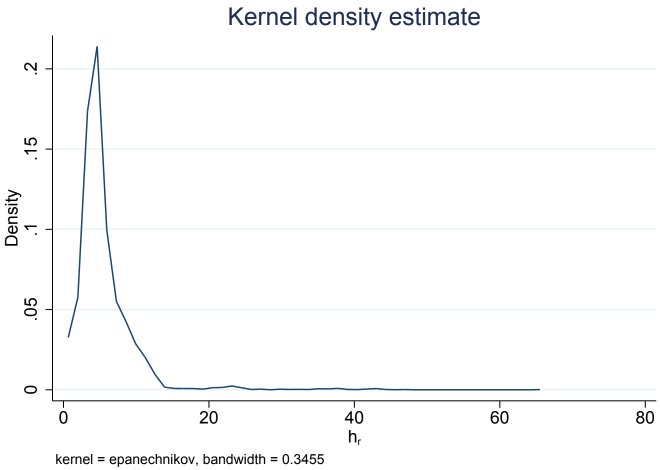
Variable	Mean	Std. Dev.	Min.	Max.
Patents per norm. unit of land				
$patents_r$ (inv) avg 2000-2010	1,195	8,087	0	375,281
$patents_r$ (inv) 2005	1,218	8,337	0	392,807
$patents_r$ (app) avg 2000-2010	1,795	24,303	0	1,165,570
$patents_r$ (app) 2005	1,814	24,282	0	1,178,841
$\log(\tilde{\bar{L}}_r)$	8.955	2.172	-1.585	15.811
$Dtaxcredit_c$	0.715	0.452	0	1
$Dsuperd_c$	0.053	0.224	0	1
$Dtaxholiday_c$	0.023	0.151	0	1
$Dgrants_c$	0.081	0.273	0	1
$Dpatentbox_c$	0.022	0.147	0	1
$Ddeduc_c$	0.029	0.169	0	1
$Deatrrd_c$	0.982	0.131	0	1
$\|lat_r\|$	40.205	9.583	0.2	74.728

S= 5633

Estimation Results: Marginal Effects

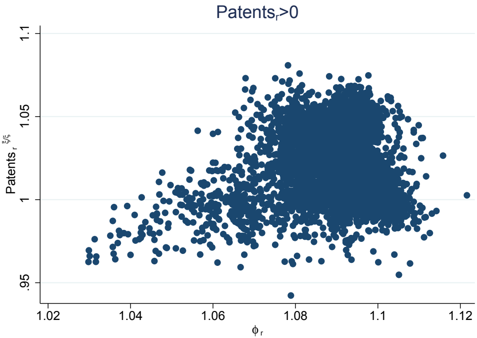
	(1) patents$_r$ (inv) avg 2000-2010	(2) patents$_r$ (inv) 2005	(3) patents$_r$ (inv) avg 2000-2010	(4) patents$_r$ (inv) 2005	(5) patents$_r$ (app) avg 2000-2010	(6) patents$_r$ (app) 2005	(7) patents$_r$ (app) avg 2000-2010	(8) patents$_r$ (app) 2005
$\log(\tilde{\tilde{L}}_r)$	1.260***	1.287***	1.321***	1.315***	1.098***	1.160***	1.153***	1.186***
	(0.070)	(0.038)	(0.062)	(0.043)	(0.036)	(0.058)	(0.034)	(0.038)
Dtaxcredit$_c$	0.069	0.223	0.146	0.272	0.206	0.427	0.170	0.516
	(0.438)	(0.426)	(0.501)	(0.476)	(0.391)	(0.372)	(0.415)	(0.427)
Dsuperd$_c$	0.160	-0.416	0.193	-1.609***	0.226	-0.306	-1.301*	-1.298**
	(0.697)	(0.541)	(0.663)	(0.537)	(0.514)	(0.490)	(0.775)	(0.544)
Dtaxholiday$_c$	2.451**	2.234***	1.394**	2.410***	3.317***	3.032***	2.853***	3.108***
	(1.024)	(0.732)	(0.669)	(0.489)	(0.542)	(0.395)	(0.560)	(0.457)
Dgrants$_c$	1.277***	1.297***	2.055	2.307	1.522***	1.498***	2.576	2.951
	(0.430)	(0.396)	(2.008)	(2.100)	(0.375)	(0.361)	(2.187)	(2.387)
Dpatentbox$_c$	-2.199**	-2.077***	-1.813***	-2.638***	-3.190***	-3.114***	-3.476***	-3.668***
	(1.059)	(0.769)	(0.656)	(0.502)	(0.565)	(0.400)	(0.604)	(0.515)
Ddeduc$_c$	0.102	0.272	0.130	1.134**	1.558*	0.178	1.582*	1.007**
	(0.324)	(0.266)	(0.349)	(0.471)	(0.908)	(0.290)	(0.933)	(0.437)
Deatrrd$_c$	1.775**	2.004***	1.962**	2.093***	-0.106	-0.093	0.093	-0.108
	(0.775)	(0.720)	(0.784)	(0.751)	(0.574)	(0.549)	(0.581)	(0.571)
cons	-9.498***	-10.023***	-10.251***	-10.375***	-6.243***	-6.955***	-6.874***	-7.245***
	(1.051)	(0.745)	(0.935)	(0.771)	(0.607)	(0.788)	(0.589)	(0.601)
lnalpha	0.946***	1.509***	0.858***	1.438***	1.570***	2.177***	1.463***	2.103***
	(0.188)	(0.176)	(0.177)	(0.170)	(0.170)	(0.323)	(0.175)	(0.331)
# obs	5633	5633	5633	5633	5633	5633	5633	5633
$\|lat_r\|\mathbf{D}_c$	NO	NO	YES	YES	NO	NO	YES	YES
overall fit	0.6434	0.7758	0.6471	0.5787	0.4732	0.6332	0.3922	0.3108
tax instruments fit	0.2091	0.2090	0.1057	0.1171	0.1259	0.1417	0.0431	0.0310

Kernel Density: Productivity Shifter h_r



Note: In the comparative statics we keep h_r constant over all years.

Innovation and Patents in 2010: Data vs. Model ($\phi_r^{\xi} = Patents_r^{\tilde{\xi}}$)



Negative binominal regression	
Dep Var: $Patents_r^{\frac{\tilde{\xi}}{\xi}}$	$Patents_r > 0$
$\log(\phi_r)$	0.156*** (0.035)
cons	0.006* (0.003)
#obs	4642

Counterfactual Analysis

Counterfactual Experiments

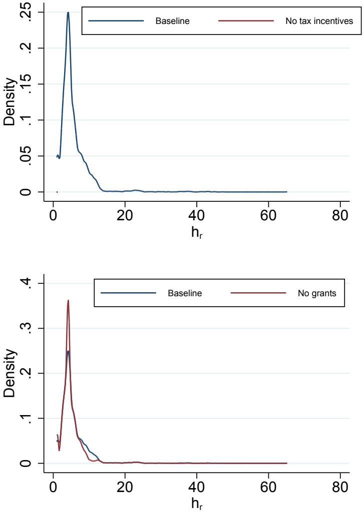
We analyze key parameters (employment, welfare, productivity, innovation) in three different scenarios:

1. No R&D tax incentives ($h_r = 1, \ \forall \ r$)
2. No R&D tax holidays
3. No R&D grants

Tax Policy Instrument	Description	Countries (in 2005)
Tax credits	Tax credits on R&D investments	Austria, Canada, China, France, Ireland, Japan, Mexico, Netherlands, Norway, Portugal, South Korea, Spain, Taiwan, US, Venezuela.
Tax holidays	Tax holidays for firms with R&D investments.	France, Malaysia, Singapore, Switzerland.
Grants	R&D investments can benefit from grants	Germany, Hungary, Ireland, Israel.
Patent boxes	(Partial) exemption of returns on R&D investments.	France, Hungary.
Deductions	Any form of deductions on R&D investments.	Australia, Belgium, Ireland, Japan, South Korea.
Super deductions	Super deductions of more than 100% for R&D investments.	Australia, China, Czech Republic, Hungary, India, Malaysia, Malta, Puerto Rico, Singapore, UK.
$EATR_{R\&D}$	Effective average tax rate is lower on returns on R&D investments than on other investments.	114 of 213 countries in the data.

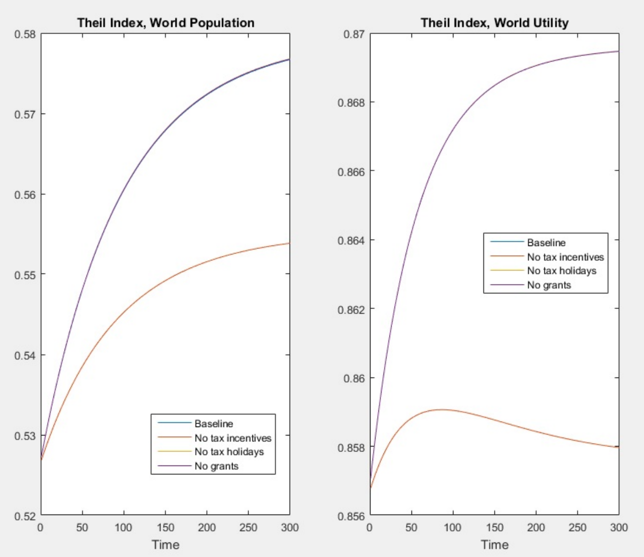
France incl. Guadeloupe, French Guiana, Martinique, Reunion; Netherlands incl. Bonaire; US incl. American Samoa, US Minor Outlying Islands; Australia incl. Cocos Islands; UK incl. Falkland Islands, Gibraltar, Montserrat, Pitcarn, St. Helena.

Kernel Densities of h_r in Different Scenarios

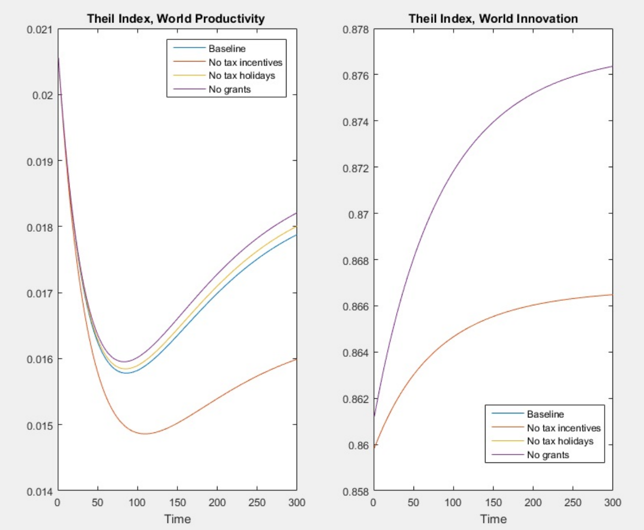


1. The Evolution of R&D Incentives and Inequality Across Regions

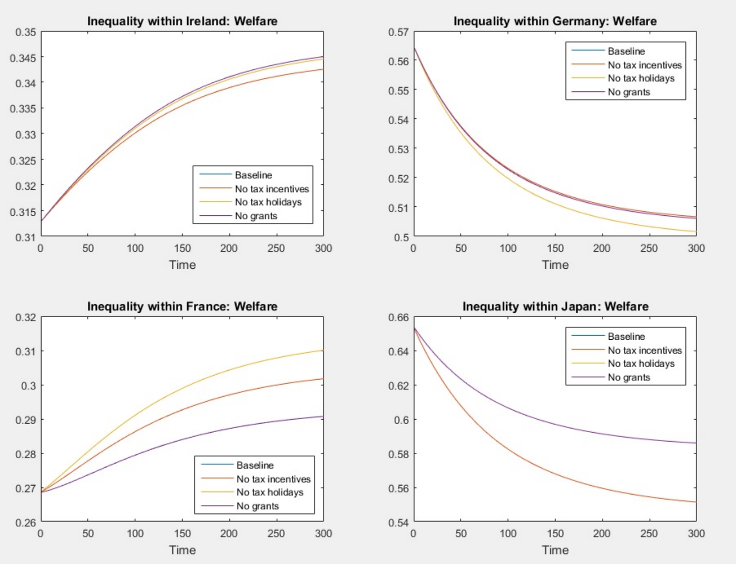
Evolution of World Inequality: Population Distribution & Welfare



Evolution of World Inequality: Productivity & Innovation



Decomposition of Theil Index: Within Subgroup Welfare Inequality



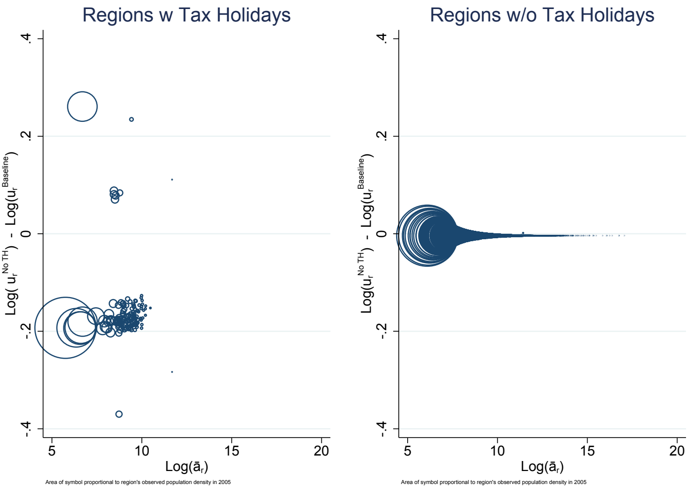
Discussion: Inequality Analysis

- Overall the different tax instruments have only little impact on considered inequality aspects.
- While the distribution of world population/utility/innovation is no more (un)equal if R&D grants or R&D tax holidays were abandoned, world population/utility/innovation would be more equally distributed if no tax instruments at all were in place.
- On the other hand, the different tax instruments have a more distinct impact on the distribution of world productivity. Both, R&D grants and R&D tax holidays, decrease the level of inequality in world productivity.

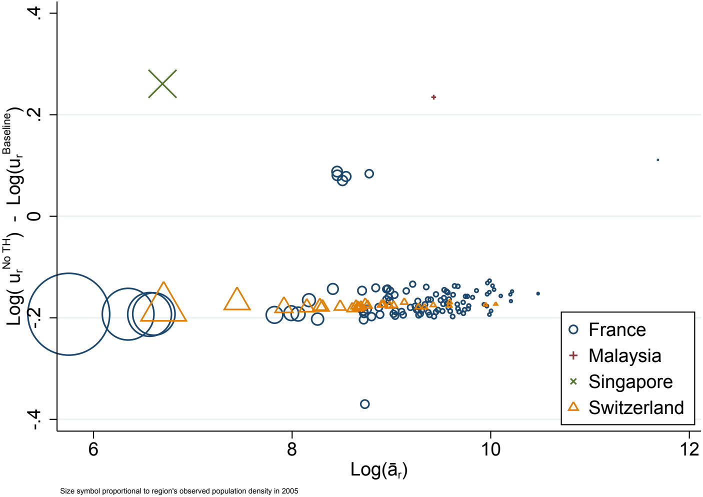
- The decomposition of the Theil index allows for within-country comparisons, i.e., comparison between regions of the same country.
- The results suggest that countries experience an increase in welfare inequality between regions, if a tax instrument was abolished that they had in place (France: R&D tax holidays and Ireland/Germany: R&D grants)
- There are **spillover effects** from abolishing R&D tax incentives in neighboring economies: Germany's welfare inequality would be lowest if R&D tax holidays were abandoned abroad.

2. R&D Tax Holidays, R&D Grants and Welfare Levels at T=300

Welfare Change: Baseline vs. No R&D Tax Holidays in T=300



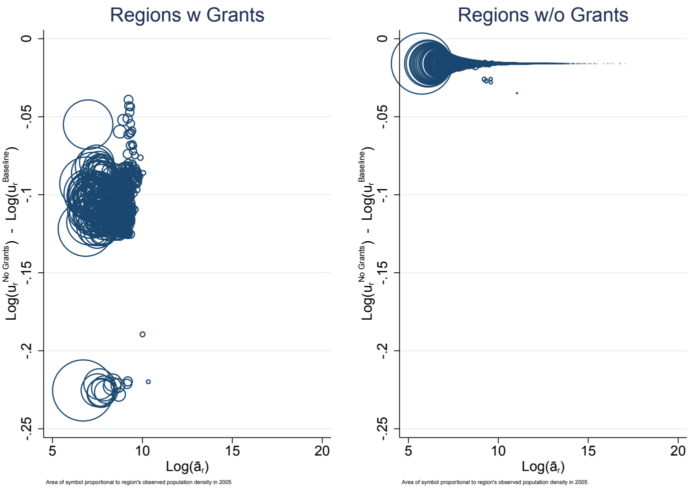
Welfare Change: Baseline vs. No R&D Tax Holidays, by Country with R&D Tax Holidays (T=300)



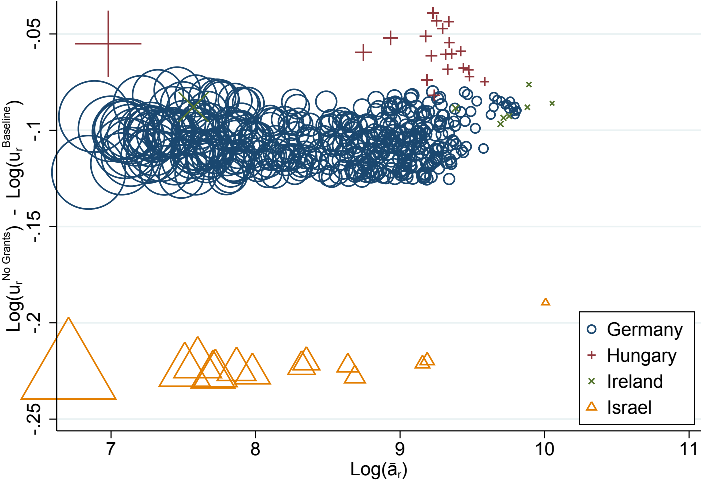
Discussion: R&D Tax Holidays

- Among those regions with R&D tax holidays, the majority experiences a drop in welfare from abandoning that instrument.
- There are regions which experience a welfare gain from abandoning R&D tax holidays.
- The country-specific analysis suggests that those regions are part of smaller economies, e.g., Singapore or Malaysia.
- There is only little correlation between amenities and the magnitude of the welfare change.

Welfare Change: Baseline vs. No R&D Grants in T=300



Welfare Change: Baseline vs. No R&D Grants, by Country with R&D Grants (T=300)



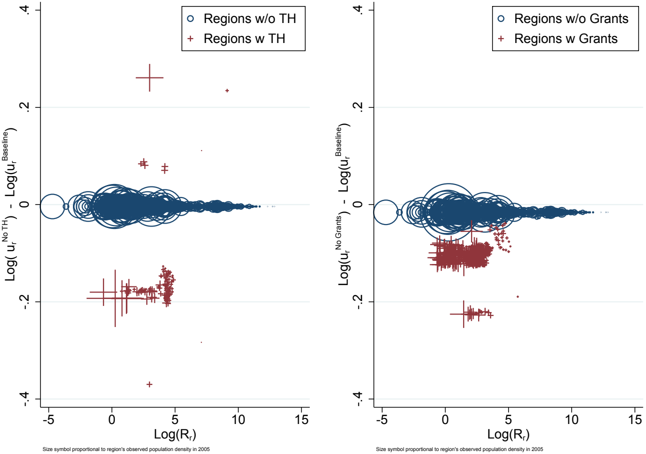
Size of symbol proportional to region's observed population density in 2005

Discussion: Grants

- In all regions, independent of whether a R&D grants policy was in place, welfare declines when abandoning R&D grants.
- As for tax holidays, the welfare loss is heterogeneous in regions where the policy instrument prevails.
- The differences are well explained by a country effect – however, no indication that the size of the economy plays a role.

3. Welfare Change and Remoteness : R&D Tax Holidays, R&D Grants at T=300

Welfare Change and Remoteness



- The welfare change of the treated regions correlates with the remoteness of those regions (Corr. Tax holidays: 0.17, Corr. Grants: 0.12)

Conclusions

- Innovation incentives are important policy instruments to attract mobile factors and enhance regional well-being.
- Results suggest that innovation incentives have only little impact on reducing welfare inequalities.
- However, there is evidence of spillover effects – Germany's welfare inequality would be comparatively lowest if R&D tax holidays were abandoned in the neighborhood (such policy exists in France and Switzerland, among others)
- Heterogeneous effects for different tax polices: R&D grants have a positive welfare effect on all regions, whereas R&D tax holidays only benefit those regions where the policy is in place.
- The welfare change due to innovation incentives seems only weakly correlated with the economic attractiveness of a region (amenities), while remoteness is important.

Thank you!

Amenity Distribution

- We substitute the indirect utility (9) into the first equilibrium condition (11) and solve for a_{rt} as follows

$$a_{rt} = \left(\frac{G_r \bar{L}_{rt}}{\bar{L}}\right)^{\Omega} \quad \frac{\left[\int_S (a_{kt} w_{kt})^{1/\Omega} \left(\int_S B_{jt} dj\right)^{(1/\Omega\theta)} dk\right]^{\Omega}}{w_{rt} \left(\int_S B_{kt} dk\right)^{(1/\theta)}} \tag{19}$$

  - $B_{(\cdot)t} = \tau_{(\cdot)t} \bar{L}^{\rho}_{(\cdot)t} w^{-\theta}_{(\cdot)t} h^{\theta\gamma_1/\xi}_{(\cdot)t} \zeta^{-\theta}_{(\cdot)s}$
  - $\rho = \alpha - ((1 - \mu - \gamma_1/\xi)\theta)$

Data

- $\bar{L}_{rt}$: Observed population density in 2005 (SEDAC).
- w_{rt}: Observed wages per capita in 2005 (G-Econ Project).
- τ_{rt}: Initial efficiency distribution obtained through iterative process using the model structure and data on observed wages and population densities in 2005.

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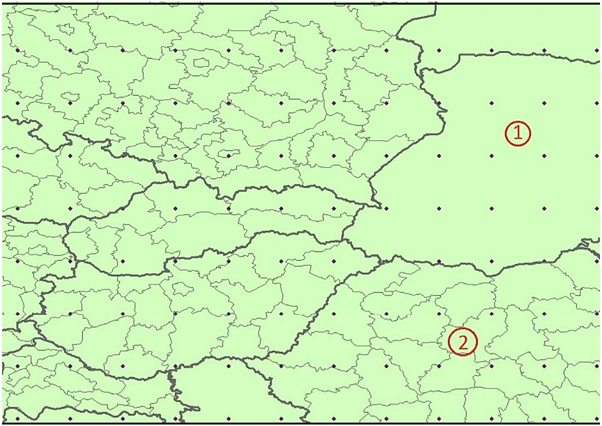
Assignment Strategy

- Some data that we use for estimation and simulation are on the $1^\circ \times 1^\circ$-cell level: trade costs, wages per capita, GDP per capita.
- Strategy to assign data to the regional level:
  1. $M:1$ assignment: simple average of all cells falling in region r.
  2. $1:M$ assignment: nearest cell within country border.



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Assignment Strategy: Wages

- $1 : M$ assignment: wage levels are identical for regions that are assigned to the same 1° cell.
- We use night-light and population information (both 2005) to weight wages accordingly.
- Assumption:

$$\frac{\text{light p/c in region } r}{\text{avg(light p/c } \forall \text{ regions of same cell)}} = \frac{\text{wage p/c in region } r}{\text{avg(wage p/c } \forall \text{ regions of same cell)}}$$

- Night light data is censored ($0 \leq \text{light} \leq 63$). We deal with the sum of all light pixels in a given region. Hence, we only know the lower bound.
- We run a tobit regression to predict the *true* night light values per region, $sumlight_r$:

$$sumlight_r = \begin{cases} 0 & \text{if} \quad sumlight_r^* \leq 0 \\ sumlight_{rt}^* & \text{if} \quad sumlight_r^* > 0 \end{cases} .$$

- We specify the latent variable $sumlight_r^*$ in a linear fashion as a function of the parameters of interest through

$$\log(sumlight_r^*) = \alpha_1 \log(wage_r) + \alpha_2 \log(pop_r) + \alpha_3 \log(area_r) + V_r \iota + \varepsilon_r^{light}.$$

Note: We also included quadratic terms of all explanatory variables in V_r.

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Trade Costs (1)

- Contrary to DNRH '17, we allow for intra-regional trade.
- Transport costs within a region are obtained by two strategies
  - If many cells fall within a region: Simple average of transport costs.
  - If many regions get assigned to the same cell: We learn the exchange rate between fast marching transport costs ζ_{sk} and the great circle distance ($dist_{sk}$ in degrees).

$$\log(\zeta_{sk}) = \alpha_0 + \alpha_1 \log(dist_{sk}) + \varepsilon_{sk}^{\zeta} \tag{20}$$

	$0< dist_{sk} \leq 3$	$3< dist_{sk} \leq 20$	$20< dist_{sk} \leq \max(dist_{sk})$
$\log(dist_{sk})$	1.021***	0.832***	0.219***
	(0.003)	(0.000)	(0.000)
const	3.610***	3.886***	5.979***
	(0.002)	(0.001)	(0.000)
R^2	0.284	0.285	0.091
#obs	419,580	13,228,282	276,969,394

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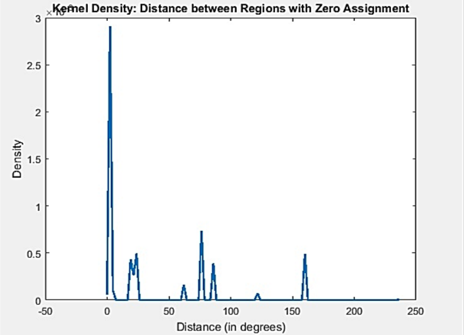
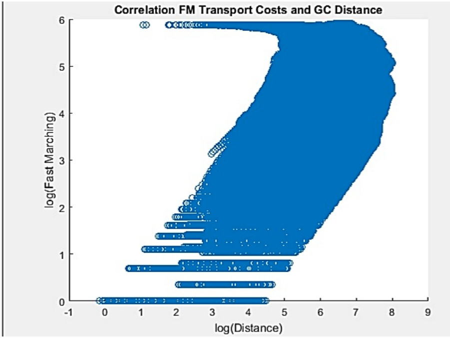

Kernel Density: Distance between Regions with Zero Assignment
×10
Density
Distance (in degrees)
3
2.5
2
1.5
1
0.5
0
-50
0
50
100
150
200
250


Correlation FM Transport Costs and GC Distance
log(Fast Marching)
log(Distance)
6
5
4
3
2
1
0
-1
0
1
2
3
4
5
6
7
8
9

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Trade Costs (2)

- Tariffs: We inflate the transport cost matrix by applied weighted tariffs for manufactured products according to WTO rules (WDI).
- Linguistic proximity (LP): We inflate the transport cost matrix by an indicator that measures LP (Melitz and Toubal, 2014).
- Impact on the results:

	Fast Marching	Fast Marching Tariffs & LP
1. Total country-to-country imports to total sales		
t=1	0.0312	0.0286
t=300	0.0762	0.0643
2. Total intra-regional trade to total sales		
t=1	0.6596	0.6620
t=300	0.7303	0.7413
3. Correlation btw. estimated and observed population density		
levels 2010	0.9993	0.9993
logs 2010	0.9996	0.9996
levels diff 2010-2005	0.5551	0.5551
logs diff 2010-2005	0.4446	0.4445

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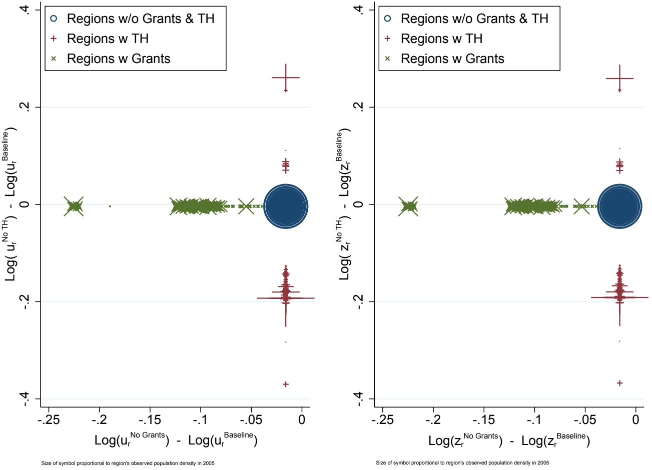
Welfare vs. Productivity Change: R&D Tax Holidays and R&D Grants, by Groups of Regions (T=300)



Note: Productivity in the model is defined as $z_{rt} = (\tau_{rt} \bar{L}_{rt}^{\alpha})^{1/\theta}$