Topic 10
RRH (2017): Counterfactuals

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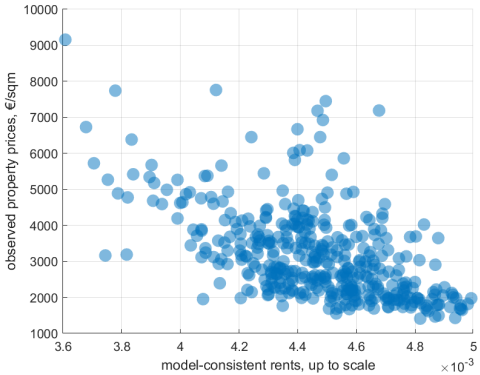
Acknowledgements

- This slide deck uses material from the following lectures
  - Quantitative Spatial Economics lecture in Princeton University course EC552—by Esteban Rossi-Hansberg

Observed house prices vs inverted rents (from RRH2017 model)



What's going on?

Assume Rosen-Roback is DGP

$$\ln r^{obsered} = c + \beta \ln r^{model} + \epsilon$$

$$\ln r^{\text{observed}} = c + \beta \underbrace{\left(\frac{1}{1-\alpha} \ln w - \frac{\alpha}{1-\alpha} \ln P \right)}_{\text{rent in RRH2017}} + \left[\frac{\beta}{1-\alpha} B + \epsilon \right]$$

What does Rosen-Roback predict?

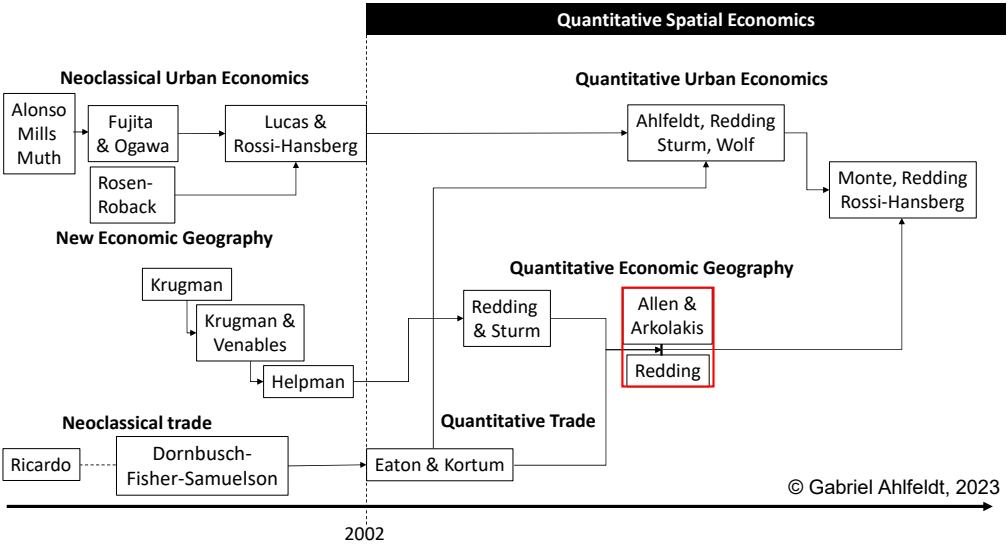
Introduction

Quantitative Spatial Models of Economic Geography

- Quantitative spatial models of economic geography emphasize **trade of goods**
  - Low trade costs to other locations ⇒ Greater market access
  - Greater market access ⇒ lower price index (and higher import/export shares)
  - Lower tradable prices ⇒ attract larger population
  - Larger population ⇒ higher non-tradable goods prices in **spatial equilibrium**
    - Inelastic supply of land generates dispersion force
    - Higher non-tradable prices compensate for lower tradable goods prices

Q: How will the economic geography change if we reduce trade frictions?

History of thought



Roadmap

- **Redding-Rossihansberg (2017) model**
  - A canonical QSM of Economic Geography
  - Multi-region version of the Helpman (1998) model
    - Also used in Redding & Sturm (2008)
- **Topic 9**
  - Model
  - Equilibrium
  - Quantification
- **Topic 10** (today)
  - Counterfactuals

Equilibrium solver

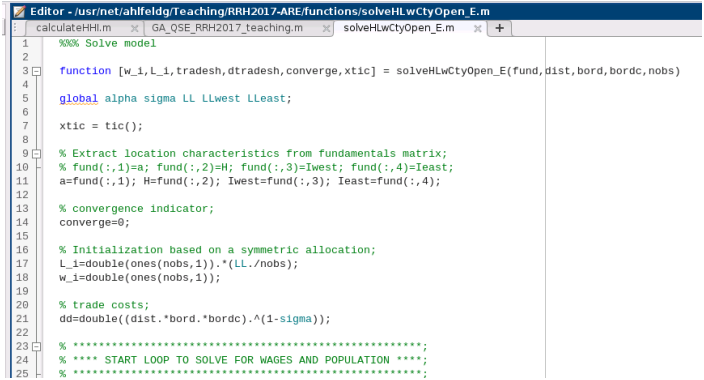
Recall

- The equilibrium condition uses
  - the following equations: Trade share (9), price index (8), population mobility (13)
  - the assumption that trade costs are symmetric ($d_{ni} = d_{in}$)
- **The equilibrium is referenced solely by L_n**
  - Can solve for L_n from Eq. (16) for given values of exogenous objects
    - structural parameters $\{\alpha, \sigma\}$, fundamentals $\{A_n, H_n\}$, trade costs d_{ni}, fixed cost, F
  - We do not need to solve for any other endogenous variable simultaneously
    - there is a **recursive structure** to solve for the other endogenous objects
- Can treat L_n as our sole target variable and then solve for the rest

Sounds good in theory, in practice...

In practice...

- ...MMH treat $\{L_n, w_n\}$ as target variables
  - Guess them
  - Solve simultaneously
- Lesson for us:
  - Nice to show that the equilibrium can be referenced by one variable
  - If the solver is easier to write with two target variables, we may still do it...



What seems noteworthy...

- Since MMH are targeting $\{L_n, w_n\}$, they need update rules for both
  - L_n is relatively straightforward
    - predict own trade shares π_{nn} for guesses of L_i (and w_i) using Eq. (9)
    - get $\lambda \bar{L}$ for π_{nn} using population share Eq. (15)
    - Can use that to update guess of L_n until we converge
  - As for w_n, RRH mention:
    - Zero profits $\Rightarrow$ wage bill equal to revenues
    - Redistribute rents to locals so that wage equals worker income
    - *income equals expenditure*

But how does this help with updating w_n?

Income equals expenditure

- Goods market clearing implies:
  - **Income** of workers producing goods at i must equal
  - **expenditure** of workers on goods produced at i in all $n \in N$
- RRH compute expenditure using trade shares in `solveHLwCtyOpen_E.m`
  - `income=double(w_i.*L_i)`
    - Simply the worker **income** corresponding to value of goods produced
  - `expend=double(tradesh*income)`
    - Sum of consumption of goods at at all n, weighted by trade share π_{ni}
    - π_{ni} is the share of location n's expenditure on goods produced in location i (in the MATLAB tradeshare matrix, n are columns, i are rows
- If expenditure $>$ ($<$) income, we need to increase (reduce) the wage
  - `w_e=double(w_i.*(expend./income).^(1./(sigma-1)))`
    - w up $\Rightarrow$ income up, expenditure down (share in consumption of other regions will fall)
    - Higher prices $\Rightarrow$ lower demand

Exact hat algebra

Conducting counterfactuals

- The standard approach to counterfactuals (for given parameters) in QSMs is
  - **Invert** unobserved **exogenous objects** using observed data
    - e.g. location fundamentals, transport costs
  - **Change** values of selected **primitives**
    - e.g. productivity in some regions, transport cost on some routes
  - **Solve** for the equilibrium
    - Under the new primitives
  - Compare new equilibrium values to initial values and **compute relative changes**

Can we skip inversion? We are using observed data for inversion anyway...

Exact hat algebra

- Dekle et al. (2007) denote the
  - known value of a variable in the initial equilibrium by x
  - unknown value of a variable in the counterfactual equilibrium by x' (with a prime)
  - relative change in the variable by $\hat{x} = \frac{x'}{x}$ (with a hat)
- We can compute the counterfactual value $x' = \hat{x}x$
  - We only need the relative changes and initial levels of a variable
- Aim of **exact hat algebra** is
  - express **relative changes in endogenous variables** as functions of
    - **relative changes in primitives**
    - **initial values of endogenous variables**

We can derive system of equations that avoid levels of fundamentals altogether

Example

- RRH asssume that researcher
  - observes $\{L_n, w_n, \pi_{ni}\}$
  - obtained estimates of the values of structural parameters α, σ
  - have computed a measure of relative change in bilateral trade costs $\hat{d}_{ni}$
- They derive a system of equations to evaluate the effects of changes in trade cost
  - combining Eqs. (9), (10), (11), (12), (13)
- System of Eqs. (18), (19), (20) has **three equations and three unkonwns** ✓
  - Can use it to solve for $\{\hat{w}_n, \hat{\lambda}_n, \hat{\pi}_{ni}\}$ using only $\{\lambda_n, w_n, \pi_{ni}, \hat{d}_{ni}\}$
  - Counterfactual values in levels are $w'_n = w_n \hat{w}_n, \lambda'_n = \lambda_n \hat{\lambda}_n, \pi_{ni} = \pi_{ni} \hat{\pi}_{ni}$
  - Recall that $L_n = \lambda_n \bar{L}$

Exact hat system of equations

- $\hat{w}_i \hat{\lambda}_i (w_i \lambda_i) = \sum_{n \in N} \hat{\pi}_{ni} \hat{w}_n \hat{\lambda}_n \pi_{ni} (w_n \lambda_n)$
  - 'hat' variant of **income equals expenditure** $w_i L_i = \sum_n \pi_{ni} w_n L_n$
    - where $L_n = \lambda_n \bar{L}$ and $\bar{L}$ drops out in ratios
- $\hat{\pi}_{ni} \pi_{ni} = \frac{(\hat{d}_{ni} \hat{w}_i)^{1-\sigma} \hat{L}_i \pi_{ni}}{\sum_{k \in N} (\hat{d}_{nk} \hat{w}_k)^{1-\sigma} \hat{L}_k \pi_{nk}}$
  - 'hat' variant of **trade shares**
    - Notice that $\hat{L}_i$ could be written as $\hat{\lambda}_i$ and A_i drops out in ratios
- $\hat{\lambda}_n \lambda_n = \frac{\hat{\pi}_{nn}^{-\frac{\alpha}{\sigma(1-\alpha)-1}} \lambda_n}{\sum_{k \in N} \hat{\pi}_{kk}^{-\frac{\alpha}{\sigma(1-\alpha)-1}} \lambda_k}$
  - 'hat' variant of of residential choice probability equation
    - Notice that $\{A_n, H_n\}$ drop out in ratios

Welfare

- Welfare is given by the population mobility condition: $V_n = \frac{v_n}{P_n^{\alpha} r_n^{1-\alpha}} = \bar{V}$ (Eq. 13)
  - $v_n = w_n/\alpha$ (Eq. 11)
  - $P_n = \frac{\sigma}{\sigma-1} \left(\frac{L_n}{\sigma F \pi_{nn}} \right)^{\frac{1}{1-\sigma}} \frac{w_n}{A_n}$ (Eq. 10)
  - $r_n = \frac{1-\alpha}{\alpha} \frac{w_n L_n}{H_n}$ (Eq. 12)
- Plug into Eq. (13) and observe the magic of 'exact hat algebra'
  - $\widehat{\bar{V}} = \frac{\bar{V}'}{\bar{V}} = \left(\frac{1}{\hat{\pi}_{nn}} \right)^{\frac{\alpha}{\sigma-1}} \left(\frac{1}{\hat{\lambda}_n} \right)^{\frac{\sigma(1-\alpha)-1}{\sigma-1}}$ (Eq. 21)
    - Various primitives A_n, H_n, F and multiplicative constants cancel out in ratios

Merits of exact hat algebra

- Exact hat algebra allows expressing counterfactual values with **fewer primitives**
  - **Simplifies notations**
    - Can drop exogenous objects ⇒ leaner equations
  - **Counterfactuals more transparent**
    - Link between forcing variable and outcome variables in relative differences
  - Can **save a space** in the paper as we can skip inversion
    - QSE papers tend to be too large ⇒ Issue in publication process

Q: How do RRH use exact hat algebra in their code?

Counterfactuals

Replication directory

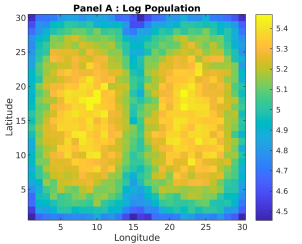
You can replicate the following counterfactuals using the RRH replication directory with GA edits available from Moodle

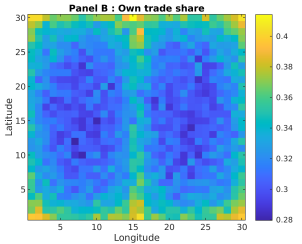
Follow the `GA_QSE_RRH2017_teaching.m` script

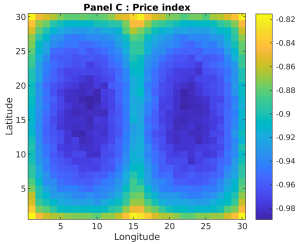
Recall

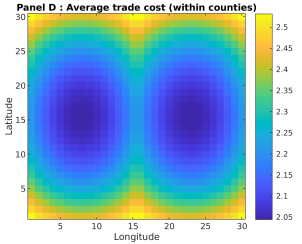
- RRH model with GA's parameterization of A_n
- Central locations have lower average trade costs (within countries)
- Results in more trade (lower own share) and a lower price index
- And, indeed, a greater population

Q: What will happen if we increase productivity in the north of the western country?



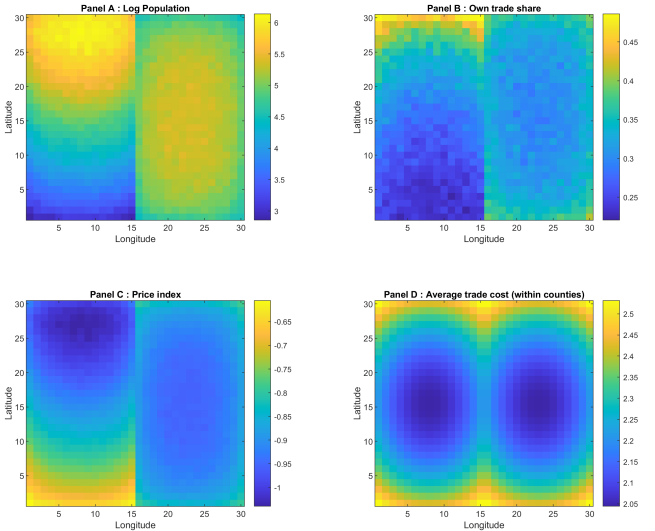






With productivity gradient

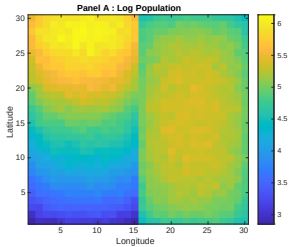
- Higher productivity in the north of west, shifts labour demand outwards
- Larger population in the north of west
- Own trade share increases in the north of west
  - not because places are more remote
  - they are larger and sell more to themselves $\Rightarrow$ 'home market effect'

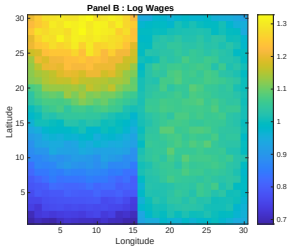


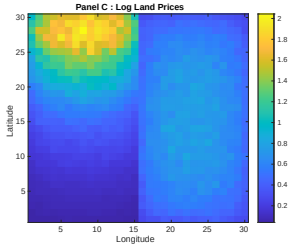
Initial equilibrium

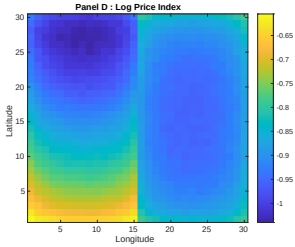
- Higher productivity in the north of west:
  - higher wages
  - higher rents
- West has **more unequal** distribution of productivity
  - Also a **more unequal** distribution of pop.
    - HHI West: 34.7%
    - HHI East: 23%

Q: What happens when removing border frictions **within** countries?



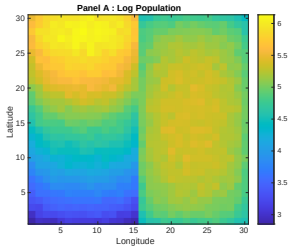


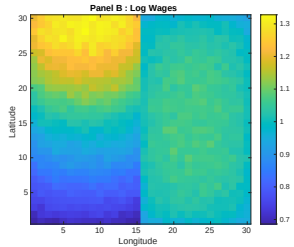


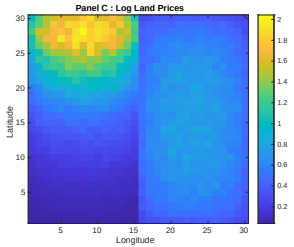


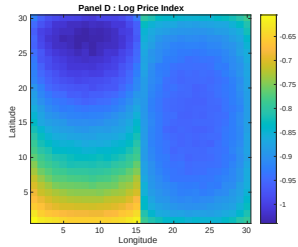
No domestic borders

- Iceberg border friction between grid points now 1 instead of 2
  - Within East and West
    - Friction between East and West persists
- Agglomeration force weaker $\Rightarrow$ less inequality in West
  - HHI West: 31.1% (-3.6pp)
- Hardly any change in East
  - HHI East: 23.4% (+0.4pp)

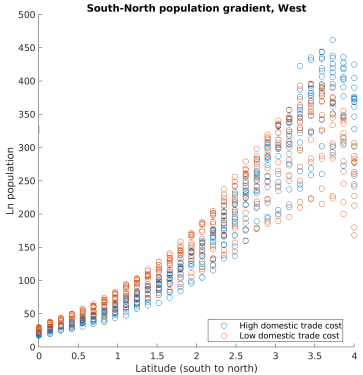




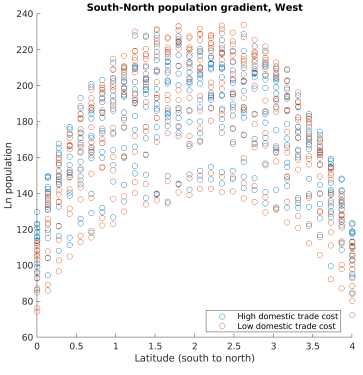




Gradients with and without domestic borders



Agglomerated north loses pop. in **west**
Weaker agglo force ⇒ less inequality



No big changes in the **east**
Perhaps a bit more dispersion

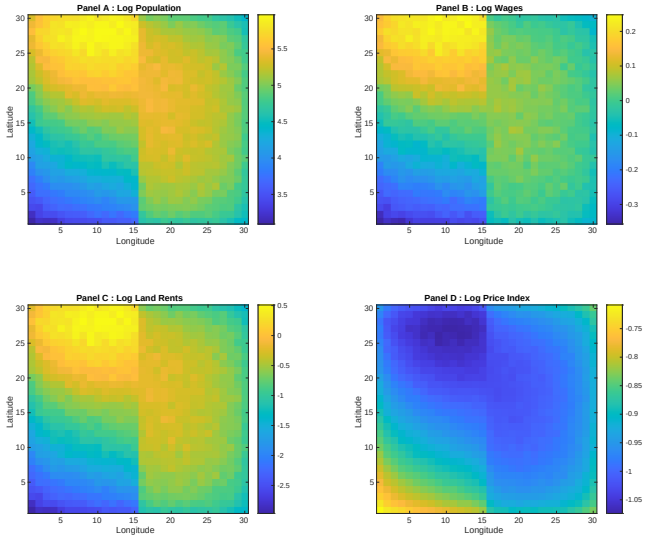
Trade costs and agglomeration

- **High trade costs reinforce fundamental productivity advantages**
  - Market access generates an agglomeration force
  - Consumers benefit from access to products
  - Firms benefit from access to consumers
  - With higher trade costs, stronger agglomeration effect

Q: What happens when we remove border frictions **between** countries?

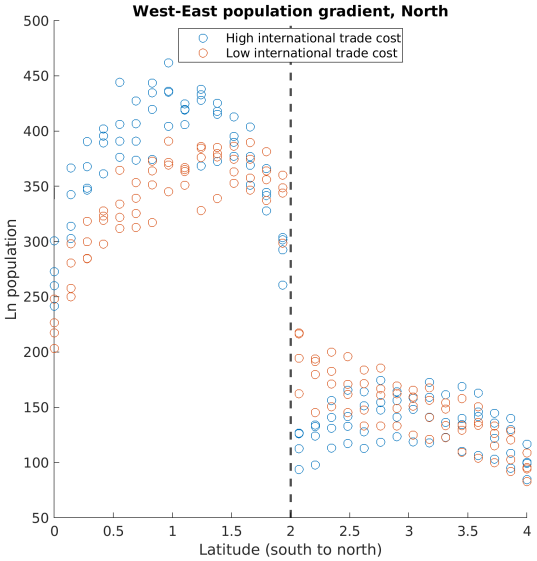
No international borders

- **Economic activity shifts towards the international border**
  - Formerly remote areas now have the greatest market access
- Positive welfare effect: 3.4%
  - All regions benefit from **greater market access**
  - Great market access $\Rightarrow$ smaller own trade share $\pi_{nn} \Rightarrow$ greater $\bar{V}$ (see Eq. 21)



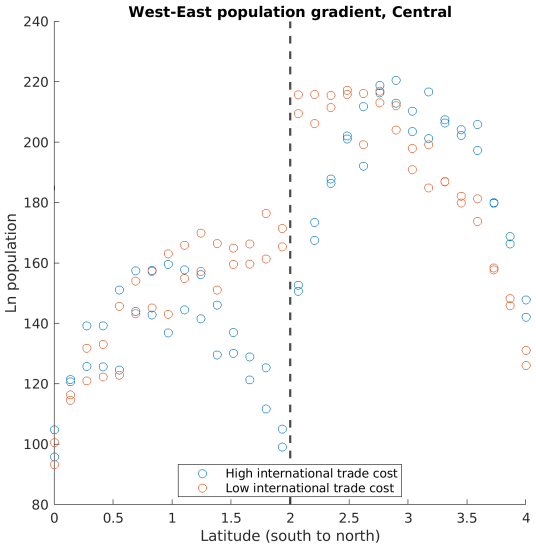
No international borders: North

- Economic activity shifts towards the international border
- **'Dip' disappears** on both sides o the border
- In the less productive east, population density increases close to the border
  - Locations in the north-east benefit from market access to the productive north-west



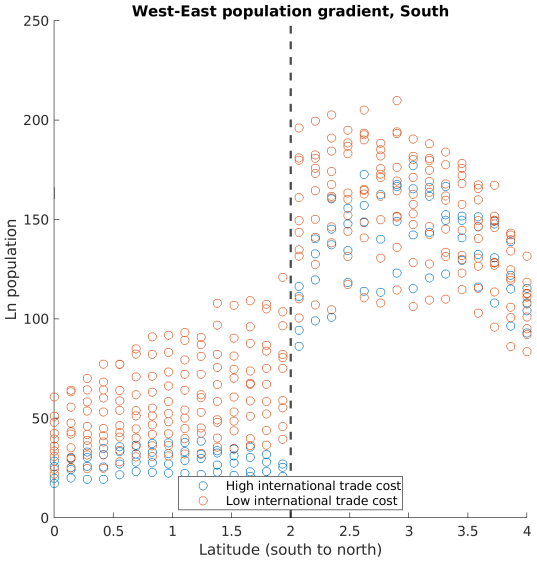
No international borders: Central

- Productivity is larger in the west, but central parts of east are more populated
  - In the west, fundamental productivity advantage attracts workers to north
  - In the east, market access advantage attracts workers to central parts
- Without border friction, **border dip disappears**



No international borders: South

- Productivity is similar on both sides of the border
- But east has a greater market access since much of the population in the west is in the north)
- Without border friction
  - **border dip disappears**
  - Population **density gradient emerges in the west** since areas close to east benefit from market access



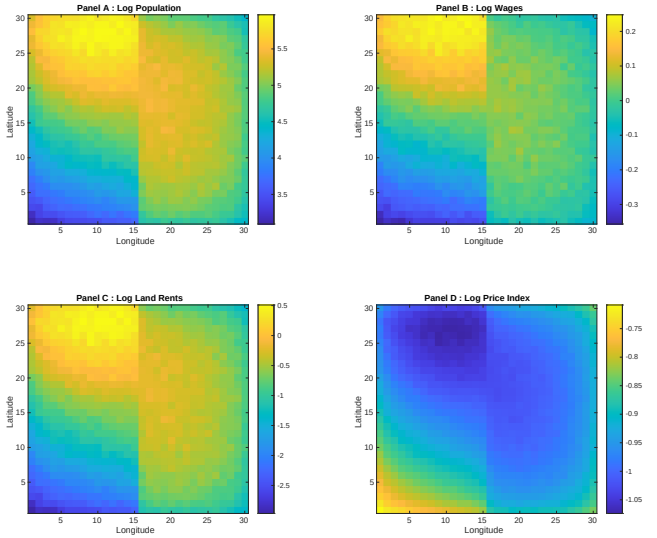
Market access and border effects

- **Removal of border frictions turns remote areas into central areas**
  - Increase in market access on both sides of the border $\Rightarrow$ Local economic development
  - Effect particularly large on the side of the border with initially lower market access
- **Compelling evidence** supports the role of market access
  - Evidence from German Division and Reunification: Redding & Sturm (2008)
  - Evidence from EU integration: Caliendo et al. (2021)

Q: What's the international border effect under lower domestic trade frictions?

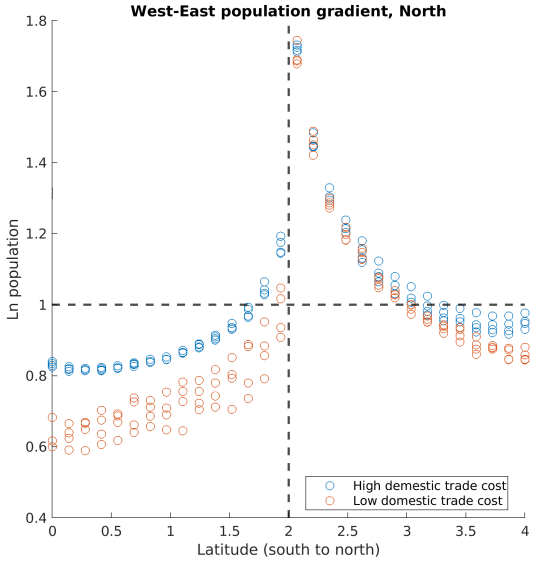
No international borders

- Same experiment as before, but **without border frictions between grid cells**
  - domestic border friction in initial equilibrium and counterfactual
  - Only international border friction changes
- Similar spatial adjustments
  - Economic activity shifts towards the international border
- **Larger positive welfare effect**: 5% (instead of 3.4%)



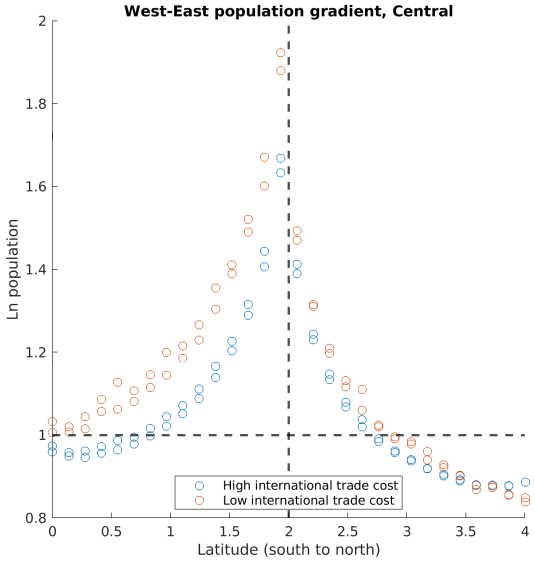
No international borders: North

- Economic activity shifts towards the international border
- **Stronger adjustments** under low domestic trade costs
  - Loss of economic activity in west is GE effect stronger gains in MA in central and southern parts of west



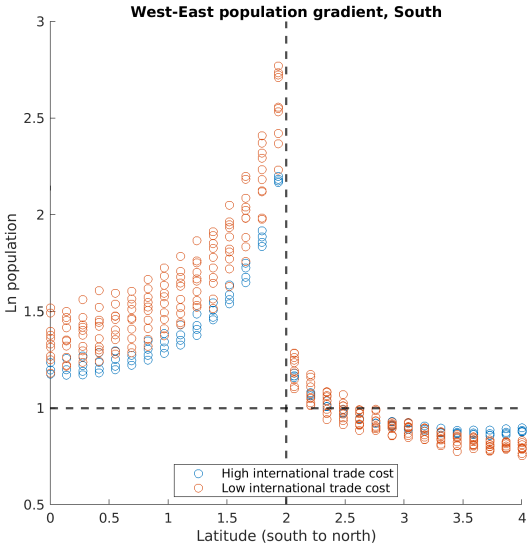
No international borders: Central

- Economic activity shifts towards the international border
- **Stronger adjustments** under low domestic trade costs



No international borders: South

- Economic activity shifts towards the international border
- **Stronger adjustments** under low domestic trade costs



Conclusion

Summary

- **QSMs of Economic Geography** emphasize the trade between regions
  - Market access (MA) plays a crucial role
    - Reduces tradable goods price index and attracts workers
  - Prediction that market access promotes economic development has empirical support
- In reduced-form, **trade MA works similar to commuting MA**
  - At a small geographic (within cities) commuting MA clearly more important
  - At a large geographic scale (between labour markets) trade MA more important
  - At intermediate geographic scale, both could matter...

Next week: **Commuting and trade in one model**

Literature I

Core readings

- **Redding, S., Rossi-Hansberg, E. (2017): Quantitative Spatial Economics. Annual Review of Economics, 9, 21–58.**

Other readings

- Caliendo, L., Opromolla L. D., Parro, F., Sforza, A. (2021): Goods and Factor Market Integration: A Quantitative Assessment of the EU Enlargement. Journal of Political Economy, 129(12)
- Dekle R., Eaton J., Kortum S. (2007): Unbalanced trade. American Economic Review, 97(2):351–55
- Redding, S., Sturm, D. (2008): The Costs of Remoteness: Evidence from German Division and Reunification. American Economic Review, 98(5), 1766-97