# Topic 0
# Introduction

**Gabriel M Ahlfeldt**

Quantitative Spatial Economics

Humboldt University & Berlin School of Economics
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# Course convener

- CV
  - 2002-2006: Studies (Diplomvolkswirt), *Uni Freiburg, Carlos III Madrid, FU Berlin*
  - 2006-2009: PhD (Dr. rer. pol) an der *Universität Hamburg*
  - 2009-2024: Professor (Urban Economics), *London School of Economics*
  - Since 2024: Professor (Econometrics), *HU Berlin*
- Research focus: Urban/spatial economics
- Editor *Regional Science and Urban Economics*
- Winner of 2018 Frisch Medal (Mit Steve Redding, Daniel Sturm, Niko Wolf)
- Commissioned research for *Aldar Properties, Bundesamt für Kultur* (Schweiz), *IHK Darmstadt, Europäischer Rechnungshof, OECD, WRI*, DfT etc.

Are you a BSoE, HU, RoB, visiting student? Any QSE work done?

# Introduction

# Quantitative Spatial Economics

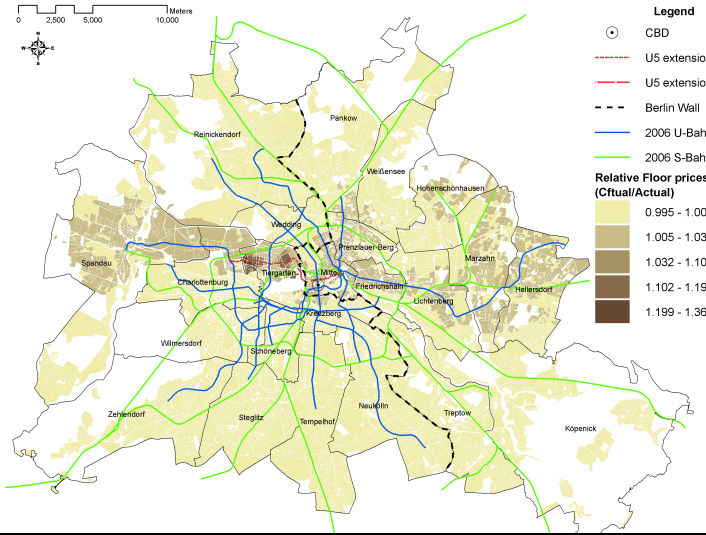
- What is it about?
  - **Economy consists of locations connected** through trade/migration/commuting
    - Understand what determines **how economic activities are distributed across space**
    - Understand how distribution will change in **response to shocks and policies**
  - Combines **theoretical** models, **empirical** data, and quantitative methods
  - **General equilibrium**—Integrates land, labour, and goods markets
- Why is it relevant?
  - General-purpose policy tool to **simulate** general equilibrium **effects of policies**
  - *white-box* approach complements *black-box* appraoches (*Machine Learning*)
    - with particular strengths in **out-of-sample prediction**
  - Penetrating development, environment, labour, trade, urban economics

# Learning objectives

- This is an ***applied* course**!
  - Assumes proficiency in microeconomics and econometrics
  - Assumes experience in coding (in languages such as Stata, Matlab, Python, etc.)
- Learn how to simulate counterfactuals within quantitative spatial models (QSMs)
  - Process data in GIS
  - Quantify the model's primitives (estimate parameters, invert fundamentals)
  - Solve the model for different values of its primitives
- **Emphasis on coding**!
  - Need to write numerical solution algorithms
  - Use iterative procedures to solve systems of equations where there is no analytical solution

# Counterfactual simulation of U-Bahn extension

- **Estimation** of parameters and **inversion** of fundamentals
- **Update primitives** (bilateral travel times) and re-solve the model for the counterfactual equilibrium
- Compare observed values of endogenous variables to counterfactual model solutions
- New U-Bahn **shifts demand** towards better connected places



# Target audience

- **Ambitious students** with a **genuine interest** in applying QSMs
  - Current or prospective **PhD students** who want to impress on academic job market
  - Students interested in **quantitative policy work** (World Bank, OECD, etc.)
    - Ongoing project with *UK department for transport*
  - QSMs may soon reach consultancies...
- **No 'cheap' ECTS credits**
  - Course teachers put a lot of work in preparing teaching materials
  - And it will be a lot of work going through them
  - Part of the learning experience...

# Course structure

- Covering selection of 'core' papers
  - No textbook
- Weekly **lectures** (Thursdays 10-12)
  - Slides will be made available on Moodle
- Weekly **student-led** tutorials (Fridays 14-16)
  - Weekly problem sets must be prepared in advance
    - Essential for learning experience
  - Presentations by selected students, group work strongly encouraged
    - Solutions can be discussed with the tutor
- **B**erlin **Q**uantitative **S**patial **E**conomics Research Seminar (Fridays 16-18)
  - Fantastic opportunity to see leading spatial economists present their work
    - See `www.bqse.de` for seminar schedule

# Moodle

- Course material will be made available on Moodle
  - https://moodle.hu-berlin.de/course/view.php?id=125226
  - **Subscribe or unsubscribe asap** (if necessary, create an Moodle account for externals)
    - Subscription key (Einschreibeschlüssel, potentially no longer needed): QSE2025
- Moodle page provides
  - Lecture slides, problem sets for tutorials
  - Data directory
    - Useful for solving problem sets
  - Replication directories
    - prepared by authors of seminal papers
  - Toolkits and codebooks
    - Prepared for selected papers for this course
    - Simplified and commented code
    - 'Pseudo-code' outlining the structure of programmes

# Course structured by topics

- Each week maps into one topic
  - Week 1 (now) $\Rightarrow$ Topic 0
  - Week 2 $\Rightarrow$ Topic 1, etc. (may have to skip some weeks in case of bank holidays)
    - Check out **term schedule** on Moodle!
- Each topic contains one lecture and one tutorial

> Check tutorial handout for tomorrow after the lecture. Get system ready!

- **Revise** lecture and tutorial **soon after tutorial**. Then move on to next topic!

> **Start working on problem set early in the week of the tutorial**

# Information technology I

- Anaconda distribution to install **Python** and manage packages
  - Plus Jupyter Notebook to write codes
- **QGIS**, a free geographic information system
  - Available here: https://www.qgis.org/en/site/forusers/download.html
- Stata and Matlab
  - Powerful applications for data analysis and numerical simulation
  - Commercial products ⇒ **need licence**
  - BSoE institutions offer access either via campus licenses or on servers
    - Suggestions for HU students follow, others pls contact your IT department
  - Stata offers 6-months licence for students for just under €50
    - Notice that Stata BE does not handle large data sets
    - https://dpc-onlineshop.de/c/stata/stata-student

# Information technology II

- Humboldt Lab for Empirical and Quantitative Research (LEQR)
  - Offers remote desktop servers with **Stata and Matlab** installed
    - Hosted by the School of Business and Economics
  - Can apply here: https://leqr.wiwi.hu-berlin.de/
  - How to use: https://leqr.wiwi.hu-berlin.de/content/computeserver.php
    - Connect via VPN: https://www.cms.hu-berlin.de/de/dl/netze/vpn/standardseite
    - Map network drive: https://leqr.wiwi.hu-berlin.de/content/howto/3.pdf
    - Copy relevant directory to network drive
    - Connect to remote desktop server
    - Open main do file, adjust root directory to relevant folder on network drive

# Information technology III

- HU Desktop
  - Offers powerful remote desktop servers with **Stata and Matlab** installed
    - Hosted centrally by the Computer and Media Service (CMS)
  - Details: https://www.cms.hu-berlin.de/de/dl/hu-desktop
  - Available to students and not staff
    - Cannot check, but assume it works similar to LEQR
- Attention:
  - During the first weeks, the **HU desktop will likely be unavailable**. Please use the Remote Desktop Server pandia.wiwi.hu-berlin.de (from within the HU network or via VPN).

# Team

- Lectures
  - Gabriel Ahlfeldt
- Tutorials
  - Max Marczinek, WiMi at HU and PhD student at Oxford
- Administrative matters
  - Miriam Kaboub, econome@wiwi.hu-berlin.de

# Assessment

- Extensive margin (required to pass)
  - A compulsory **requirement for the successful completion** of the course is a contribution (multimedia presentations) to the tutorials of sufficient quality
  - Must present at least once their solutions to at least (part of) one problem set
  - Individual presentation and assessment, but collaboration on quantitative work is fine
- Intensive margin (decisive for grade)—**Submission by August 31!**
  - MSc students
    - Essay of 25,000 ZoL (about 5,000 words) describing a counterfactual analysis
    - Can be **based on simulations conducted during the tutorials**
    - Needs to be motivated, presented, and **written like an academic research paper**
  - PhD (BSoE) students
    - Same as MSc students, but longer: 35,000 ZoL (about 7,000 words). Must include a **comparison** of simulation results **to before-after changes observed in data** (75%)
    - **Academic poster** summarizing motivation and key findings (25%)
  - Appendix (including code) counts against word count

# Questions?

Photocredit: Photo by Camylla Battani on Unsplash

# Course content

# Related fields

- **Spatial Economics**
  - analysis of the spatial **aspects of economics broadly defined**
  - Related to development, labour, environment, economic history, trade, urban
- **Urban Economics**
  - subset of spatial economics with a **focus on urban areas**
  - covers—not exclusively—the analysis of internal city structure
- **Economic geography**
  - **interdisciplinary field** that seeks to understand the spatial distribution and characteristics of economic activities
- **New Economic Geography**
  - subfield within **economics** with a focus on explaining the spatial distribution of economic activity **across different regions and cities**

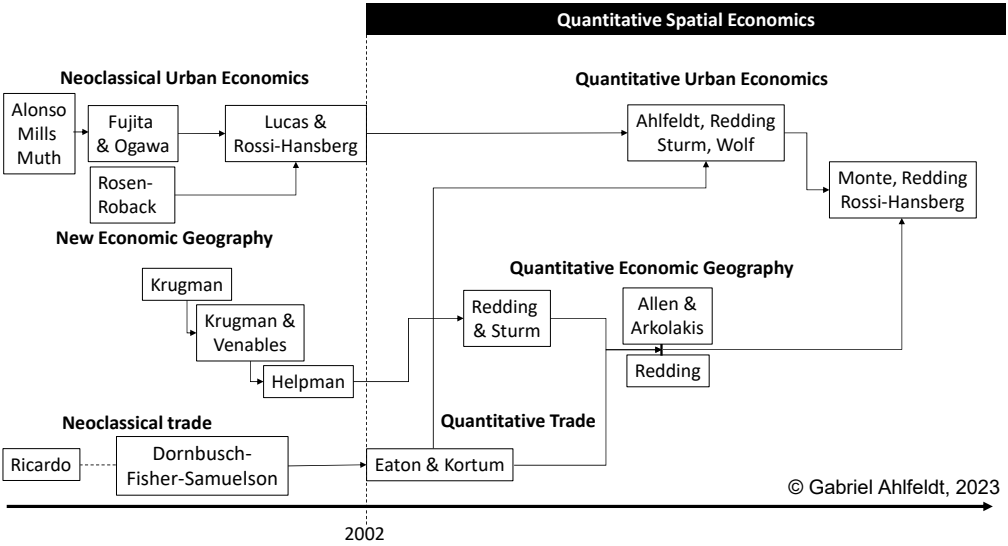
# Distinguishing fields

- **Urban** and **spatial** economics sometimes used **interchangeably**
  - *Urban economics association* covers most areas of spatial economics
  - *JUE* and *RSUE* publish papers in most areas of spatial economics
- **Urban economics** addresses analyses variation **within and between** cities
  - Urban economics not just about within-city analysis
  - But any within-city analysis is (also) urban economics
- Within **quantitative spatial economics**, typically distinguish between
  - **Quantitative urban models**
    - concerned with distribution **within cities**
  - **Quantitative economic geography models**
    - concerned with distribution **between cities**

# Features of quantitative spatial models

- **Realistic geography**
  - Discrete set of $i \in J$ locations corresponding to actual units in data
  - For example, county, municipality, postcode
- **Rationalize spatial distributions** observed in data (prices and quantities)
  - Variation not explained by endogenous forces is captured by structural residuals
  - Fundamental amenity explains why more people live in a block than predicted
- **Heterogeneity in tastes** or productivity at worker or firm level (often)
  - Ensures well-behaved location choices (responses at finite elasticity)
- **General equilibrium**
  - Accounting for interactions between factor and goods markets
  - Important feature of QSM, but, of course, not exclusive to QSMs

# History of thought



# From neoclassical to quantitative spatial economics


| Neoclassical SE | Quantitative SE |
|---|---|
| **Often general functional forms** | **Fully parametric** |
| **Analytical solutions** | **Numerical solutions** |
| **Stylized representation of economic geography** | **Rationalizes observed distributions in data** |
| **Numerically a nightmare (quoting Kris Behrens)** | **Numerically tractable, nice counterfactuals** |

# Topics

1. Rosen-Roback
   Compensating differentials
2. Alonso-Mills-Muth
   Monocentric city model
3. Ahlfeldt & Barr, 2022 I
   From stylized to quantitative models
4. Ahlfeldt & Barr, 2022 II
   Numerical solution algorithms
5. Discrete choice
   Preference heterogeneity ($\epsilon$)
6. Ahlfeldt, Redding, Sturm & Wolf I
   The model
7. Ahlfeldt, Redding, Sturm & Wolf II
   Quantification
8. Ahlfeldt, Redding, Sturm & Wolf III
   Counterfactuals
9. Redding & Rossi-Hansberg (2017)
   Quantitative economic geography I
10. Redding & Rossi-Hansberg (2017)
    Quantitative economic geography II
11. Monte, Redding & Rossi-Hansberg I
    quantification
12. Monte, Redding & Rossi-Hansberg II
    counterfactuals

# Example

# Recovering transformed wages from commuting gravity

- Local wages are en endogenous object in Ahlfeldt, Redding, Sturm, Wolf (2015)
  - Adjust to clear the commuting market
  - All workers commuting from $i$ to $j$ must find a just at at $j$
- Commuting market clearing condition $H_{Mj} = \sum_{i=1}^{S} \frac{E_j (w_j / d_{ij})^{\epsilon}}{\sum_{s=1}^{S} E_s (w_s / d_{is})^{\epsilon}} H_{Ri}$, where
  - $H_{Mj}$ is workplace employment; workers working in $j$
  - $H_{Ri}$ is workplace employment; workers living in $i$
  - $E_j w_j^{\epsilon}$ is transformed wage at $j$
  - $d_{ij}^{\epsilon}$ is bilateral commuting cost
- **Our problem**
  - We observe workplace and residence employment $\{H_{Mj}, H_{Ri}\}$, but **not wages**, $w_j$
  - But we **need wages**

# Recovering transformed wages from commuting gravity

- We want to use the commuting market clearing condition to recover wages, $w_j$

$$H_{Mj} = \sum_{i=1}^{S} \frac{E_j \left(w_j / d_{ij}\right)^{\epsilon}}{\sum_{s=1}^{S} E_s \left(w_s / d_{is}\right)^{\epsilon}} H_{Ri}$$

- System of $J$ equations for $J$ unknowns
  - We cannot solve it analytically but should be able to solve it numerically
  - Up to a multiplicative constant that can be added to numerator and denominator
- Intuition
  - If we increase $\omega_j = E_j w_i^{\epsilon}$ at $j$, we'll predict more workplace employment at $j$
  - Just need to keep adjusting $\omega_j$ until we predict observed $H_{Mj}$
  - Simple programming problem...

# Recovering transformed wages from commuting gravity

- Let's think through the problem in 'pseudo code' (see codebook)

**Algorithm 1:** Solving for transformed wages ($\omega_j$): `comegaopt0.m` (used in estimation)

**Data:** Given values for structural parameters $\{\alpha, \beta, \kappa\varepsilon\}$, bilateral travel times $\tau_{ij}$, observed workplace employment $H_{Mj}$ and residence employment $H_{Ri}$, guesses of transformed wages $\tilde{\omega}_j^0$

1 **while** *Predicted workplace employment* $\hat{H}_{Mj} \neq H_{Mj}$ **do**
2 Use guessed values of transformed wages $\tilde{\omega}_j^0$ in Eq. (S.44) to predict $\hat{H}_{Mj}$
3 Generate new guesses $\tilde{\omega}_j^1 = \frac{H_{Mj}}{\hat{H}_{Mj}} \tilde{\omega}_j^0$
4 Update guesses to weighted combination of new and old guesses
5 Normalize guesses by geometric mean

**Result:** Transformed wages $\tilde{\omega}_j$

Line 3: We increase guesses when we underpredict $H_{iM}$
Line 4: Weighted combination ensures smoother convergence due to smaller changes
Line 5: Recall that we are only identified up to a constant...

**Let's enjoy the magic in MATLAB**

# Result

- Algorithm **converges quickly**
  - After about one minute, guesses do not change anymore
- We **predict workplace employment correctly**
  - Perfect correlation between predicted and observed employment
- Recovered **wages look sensible** on the map
  - Generally higher in more commercial areas
  - But not extremely high in central areas
    - workers pay for lower commuting cost via lower wages

**Example for how to work in this course:**
1. Understand model; 2. think about how to code; 3. code; 4. inspect output

# Conclusion

- This is an ***applied* course**!
  - Assumes proficiency in microeconomics and econometrics
  - Assumes experience in coding (in languages such as Stata, Matlab, Python, etc.)
- For those who want to **learn how to use QSMs**
  - We work with a small number of models
  - Once you understand how to use these, it will be easier learn others
- **Having fun coding clearly helps!!!**

Next week: **Rosen-Roback**

# Literature


- Ahlfeldt, G., Redding, S, Sturm, D, Wolf, N. (2015): The Economics of Density: Evidence from the Berlin Wall. Econometrica. 83: 2127-2189. https://doi.org/10.3982/ECTA1087 (ARSW)