Structural Change, Land Use and Urban Expansion

Nicolas Coeurdacier (SciencesPo & CEPR)

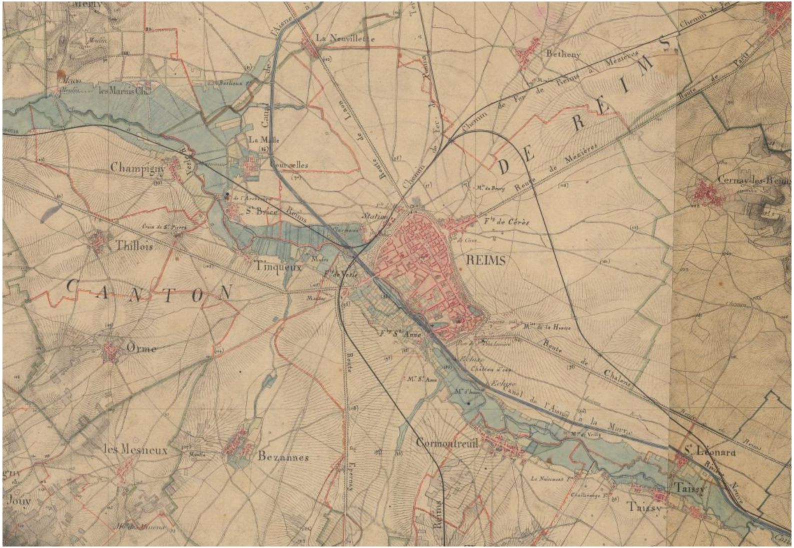
Florian Oswald (SciencesPo)

Marc Teignier (U. Barcelona)

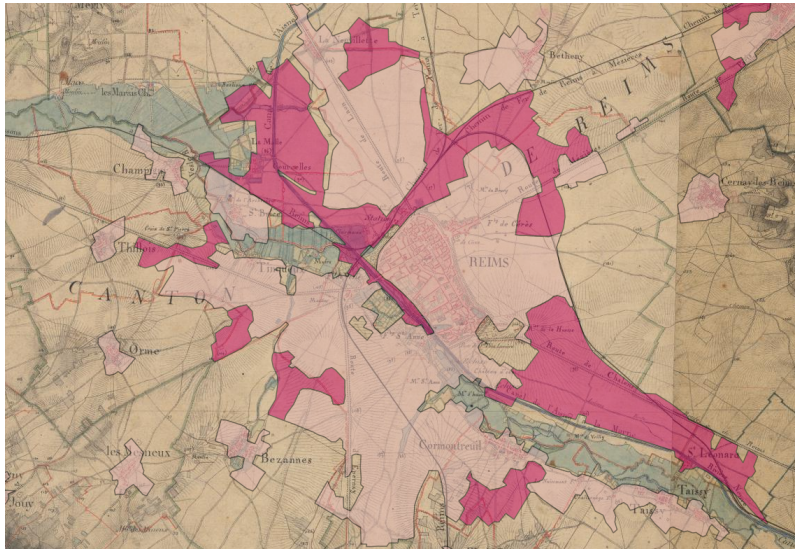
TM2 Conference April 2022

https://floswald.github.io/publication/landuse/

Motivation: Reims in 1866

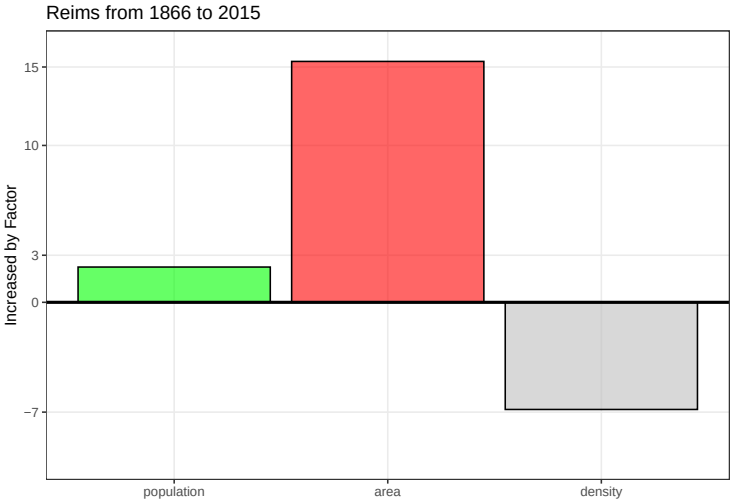


Motivation: Reims in 1866 vs IGN *Buildings* in 2017



Motivation: Reims in 1950 vs IGN *Buildings* in 2017

Motivation: Fall in Urban Density



- 50% work in Agriculture in 1866, 2% in 2015.
- Urban Surface increased about 15 fold.
- Density fell about 7 fold.
- Why?

Urban Expansion: Different Views

1. Urban Economics:
   - Decline in commuting cost over time allows residing further away from city centre.
   - New technologies (like train) enable suburbanisation.

Urban Expansion: Different Views

1. Urban Economics:
   - Decline in commuting cost over time allows residing further away from city centre.
   - New technologies (like train) enable suburbanisation.
2. Structural Change:
   - Food subsistence constraint is binding pre industrial revolution. High land values. No income left for bigger houses. (No need to commute to large suburban houses.)
   - Agricultural productivity growth solves food problem, and puts downward pressure on land values. City can expand easily to accomodate greater housing demand. Urban Density falls.

Urban Expansion: Different Views

1. Urban Economics:
   - Decline in commuting cost over time allows residing further away from city centre.
   - New technologies (like train) enable suburbanisation.
2. Structural Change:
   - Food subsistence constraint is binding pre industrial revolution. High land values. No income left for bigger houses. (No need to commute to large suburban houses.)
   - Agricultural productivity growth solves food problem, and puts downward pressure on land values. City can expand easily to accomodate greater housing demand. Urban Density falls.

This paper: Try to reconcile both views in a unified framework.

Related literature

(Traditional) Macro and Land Values

- Ricardo (1817), Nichols (1970), Grossman and Steger (2016). Measurement. Morris and Heathcote (2007), Piketty and Zucman (2014), Knoll, Schularick and Steger (2017), Miles and Sefton (2020)

(Macro) Structural Change

- Survey: Herrendorf, Rogerson and Valentinyi (2014). Theory: Kongsamut et al. (2001), Gollin et al. (2002), Boppart (2014), Acemoglu and Guerrieri (2008), Ngai and Pissarides (2007)... Structural change and urbanization. Lewis (1954), Michaels et al. (2012). Eckert and Peters (2018).
- Agricultural Productivity Gap. Gollin et al. (2014), Lagakos and Waugh (2013), Young (2013), Restuccia et al. (2008).

Urban — Size and Expansion of Cities

- Theory. Alonso-Mills-Muth. Surveys by Duranton and Puga (2014, 2015). Brueckner (1990), Brueckner and Lall (2014), ...
  Quantitative Spatial Economics. Redding and Rossi-Hansberg (2017). Sprawl/Density. Glaeser et al., Ahlfeldt et al. (2015), Angel et al. (2010)
- Land Prices and Rents. Combes et al. (2021), Combes et al. (mimeo 2021), Albouy (et al.) (2016, 2018), Glaeser et al. (2005).

Urban Expansion in France: Facts

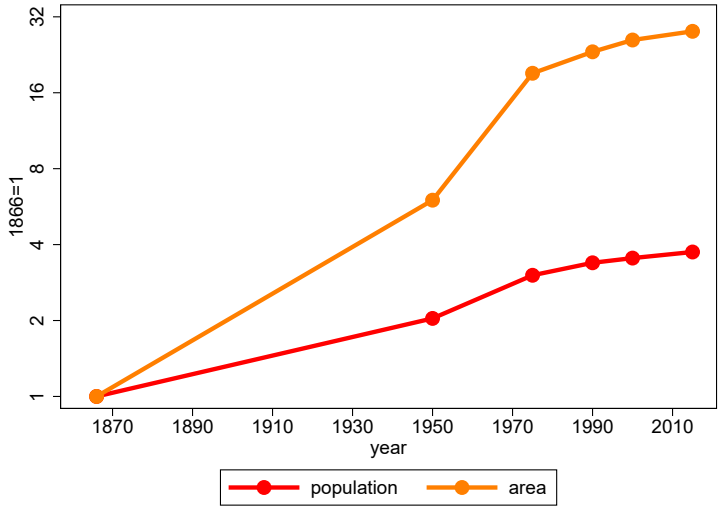
Land *and* labor reallocation: Aggregate France

Sources:

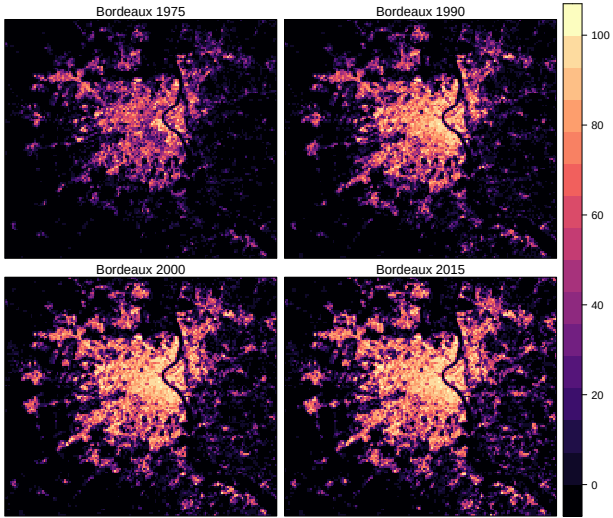
1. Toutain (1993)
2. Recensement Agricole (Ministry of Agriculture)
3. INSEE
4. Villa (1996)

Urban Expansion

Top 100 Cities in France

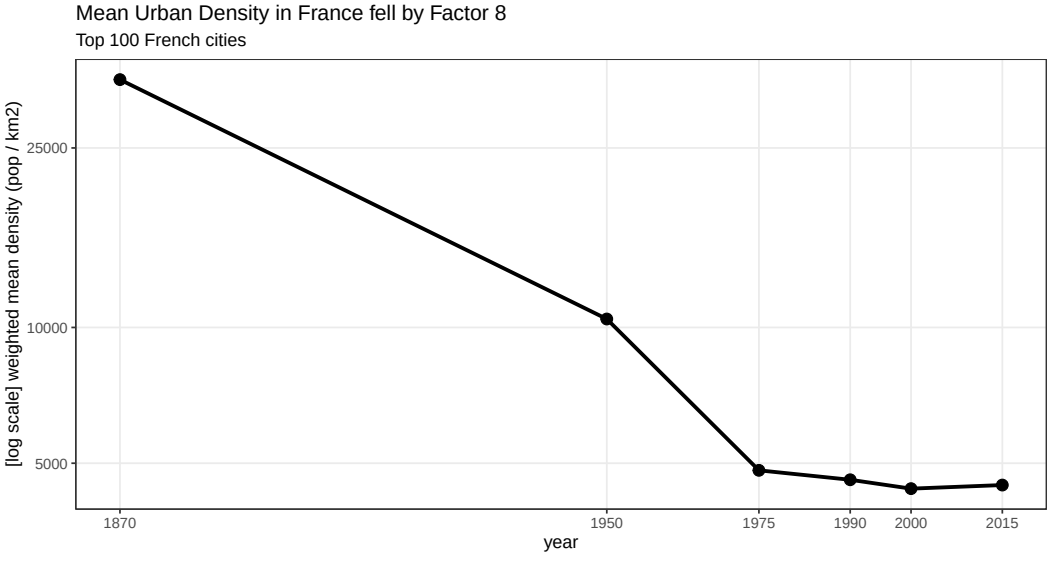


City Area and Population Measurement

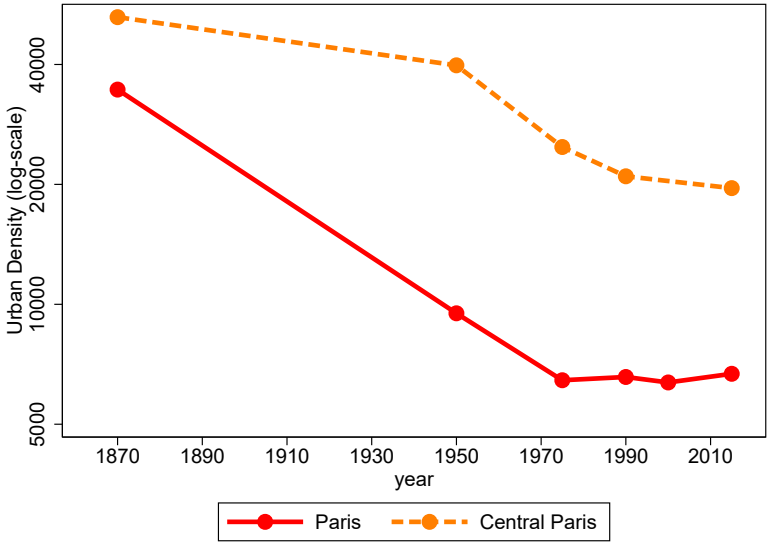


- 1866: Manual + Census
- 1950: Manual + Census
- 1975, 1990, 2000, 2015: GHSL
- ▸ More details please!

The Historical Fall in Urban Density

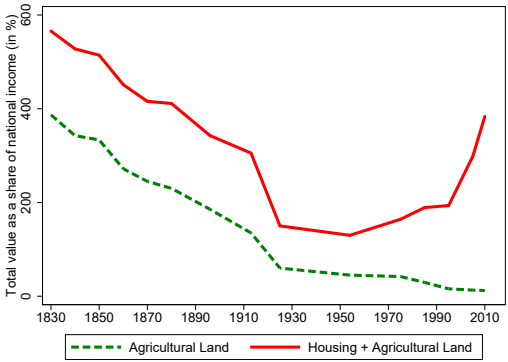


The Historical Fall in Urban Density: Within Paris

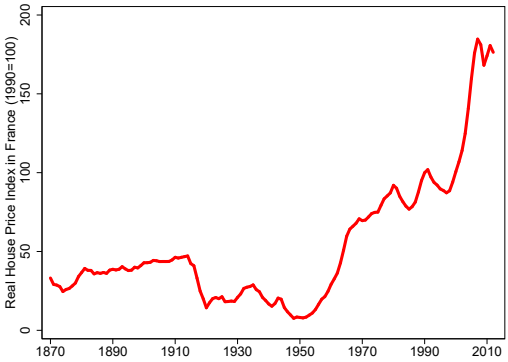


Distribution
Top 5
World

Fall in Agricultural Value Share and *Hockey-stick* in Housing Prices



(a) Picketty and Zucman (2014)



(b) Hockey Stick: Knoll et al. (2017)

Model

A general equilibrium model of land use

Set-up

- Three sectors and goods: rural (r), urban (u) and housing (h).
  - Different intensity in the use of land as input
  - Rival Land Use: Agriculture *or* Housing
  - Fixed Supply of Land
- Urban versus Rural Land: (Endogenous) commuting costs for urban workers.
- Drivers of Structural Change
  - Non-homothetic preferences for the rural good.
  - Increases in productivity during transition.

Technology

Urban and Rural goods Production

- For the urban good, only labor for simplicity,

$$Y_u = \theta_u L_u.$$

- For the rural good,

$$Y_r = \theta_r \left(L_r^{\alpha} \cdot S_r^{1-\alpha} \right).$$

- θ_i = TFP in sector i, L_i = labor used in i, S_r = land used in r.
- Rural good more intensive in land.
- Stronger decreasing returns to labor in (r).

Preferences and budget constraint

- Non-homothetic preferences for an individual in location ℓ

$$C(\ell) = (c_r(\ell) - \underline{c})^{\nu(1-\gamma)} (c_u(\ell) + \underline{s})^{(1-\nu)(1-\gamma)} h(\ell)^{\gamma},$$

$c_i(\ell)$ = consumption of $i = \{r, u\}$, housing consumption $h(\ell)$.
$\underline{c}, \underline{s}$ subsistence consumption and initial endowment of urban good.

- Budget constraint,

$$pc_r(\ell) + c_u(\ell) + q(\ell)h(\ell) = w(\ell) + \mathbf{r},$$

$q(\ell)$ the (rental) price of one unit of housing in location ℓ.
$\mathbf{r}$ rental income per capita, equally distributed.

Spatial Structure: Wage Function $w(\ell)$

Wages Net Of Commuting Costs in Spatial Equilibrium: $C(\ell) = \bar{U}$

1. Space $\ell \in [0, 1]$

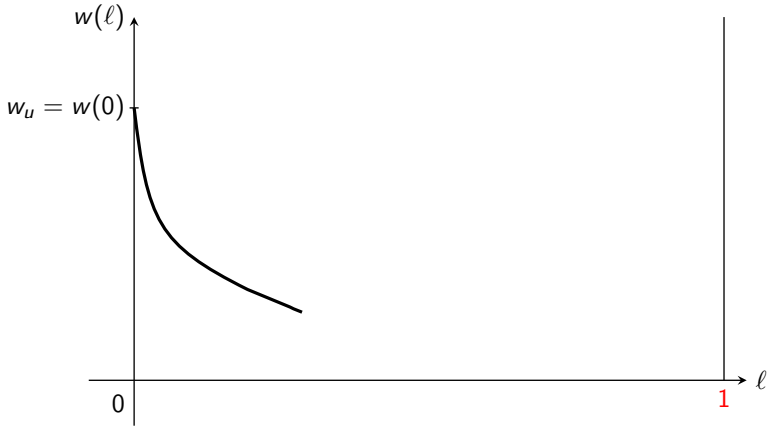
Spatial Structure: Wage Function $w(\ell)$

Wages Net Of Commuting Costs in Spatial Equilibrium: $C(\ell) = \bar{U}$

1. Space $\ell \in [0, 1]$
2. Urban production at $\ell = 0$
3. Residence at any $\ell \in [0, 1]$

Spatial Structure: Wage Function $w(\ell)$

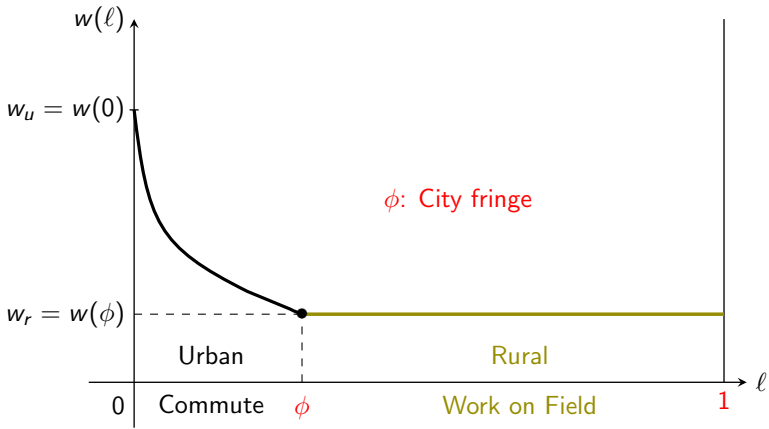
Wages Net Of Commuting Costs in Spatial Equilibrium: $C(\ell) = \bar{U}$



1. Space $\ell \in [0, 1]$
2. Urban production at $\ell = 0$
3. Residence at any $\ell \in [0, 1]$
4. $\tau(\ell)$: commuting cost from ℓ
5. $w_u - \tau(\ell)$ urban wage

Spatial Structure: Wage Function $w(\ell)$

Wages Net Of Commuting Costs in Spatial Equilibrium: $C(\ell) = \bar{U}$



1. Space $\ell \in [0, 1]$
2. Urban production at $\ell = 0$
3. Residence at any $\ell \in [0, 1]$
4. $\tau(\ell)$: commuting cost from ℓ
5. $w_u - \tau(\ell)$ urban wage
6. ϕ denotes urban fringe.

Equilibrium

- Land developers buy land and numeraire good to provide residential floorspace.
  Details!
- Arbitrage across land use at the fringe pins down land values and house prices:

$$\rho_r = \frac{q_r^{1+\epsilon}}{1+\epsilon} = (1-\alpha)p\theta_r \left(\frac{L_r}{S_r}\right)^{\alpha}$$

- Land Market Clearing.
- Labour Market Clearing.
- Land Rents consistently defined.

Summary of Main Mechanisms

Transitory Dynamics with Rising Productivity and Falling Commuting Costs

- **Old Times:** Land is scarce. High values of farmland with respect to income due to low productivity ('food problem'). Very small and dense, *walkable* cities.

Summary of Main Mechanisms

Transitory Dynamics with Rising Productivity and Falling Commuting Costs

- **Old Times:** Land is scarce. High values of farmland with respect to income due to low productivity ('food problem'). Very small and dense, *walkable* cities.

- **Transition:** Agricultural productivity growth frees up labor and land for cities to expand. Urban workers use faster commuting modes. Cities getting large (in area) and much less dense *without* a large increase in land values.

Summary of Main Mechanisms

Transitory Dynamics with Rising Productivity and Falling Commuting Costs

- **Old Times:** Land is scarce. High values of farmland with respect to income due to low productivity ('food problem'). Very small and dense, *walkable* cities.

- **Transition:** Agricultural productivity growth frees up labor and land for cities to expand. Urban workers use faster commuting modes. Cities getting large (in area) and much less dense *without* a large increase in land values.

- **Recent Times:** Reallocation of factors/land use slows down. Cities expand less and land prices increase more with rising productivity. Land particularly scarse in some locations.

Results

Numerical Model Results: Structural Change

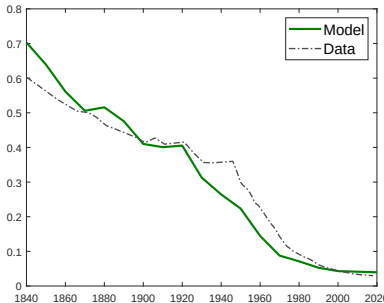


Figure: Rural Employment

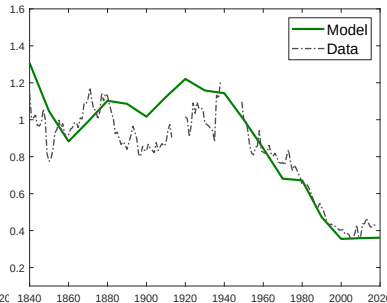


Figure: r-good price

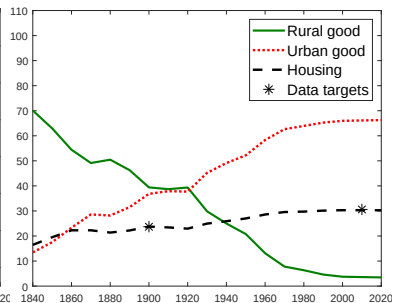


Figure: Spending Shares

Numerical Model Results: Urban Expansion

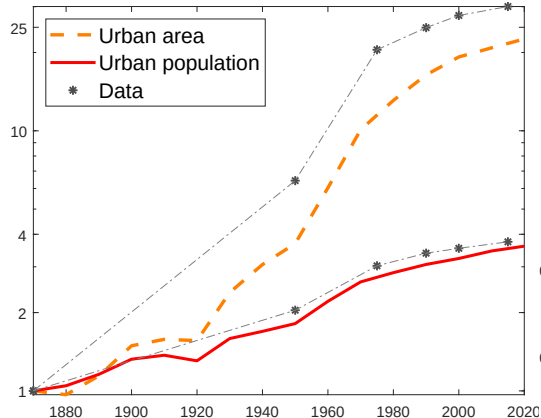


Figure: City Size

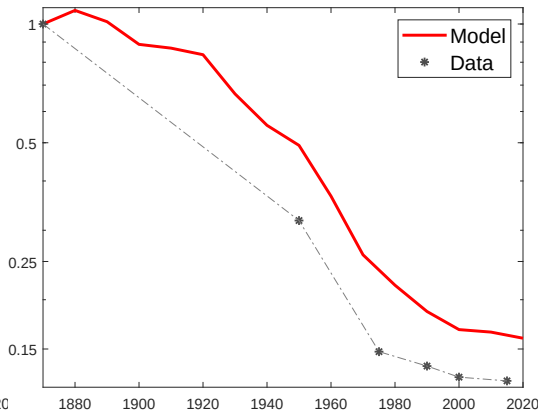


Figure: Avg. urban density

Numerical Model Results: Urban Structure

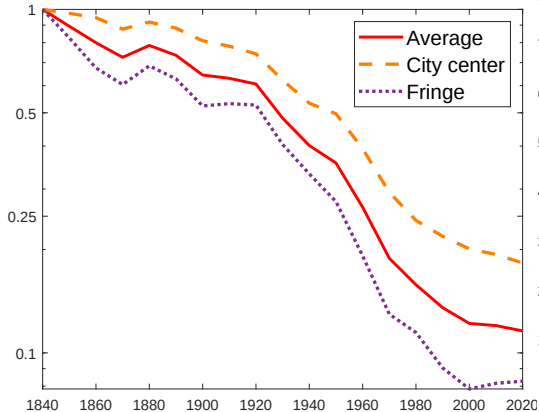


Figure: Urban Density

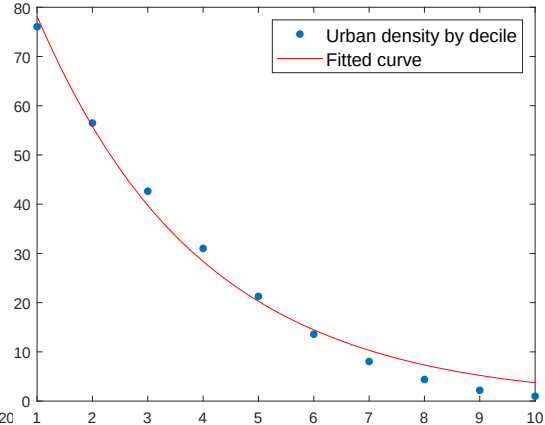
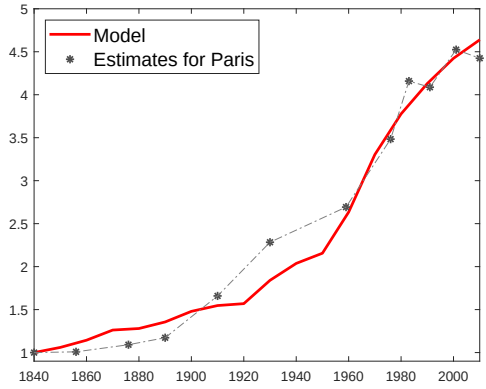
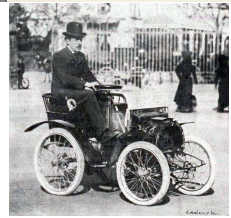


Figure: Density Gradient (2015)

Numerical Model Results: Commuting Speed





Numerical Model Results: Wealth Distribution and House Price

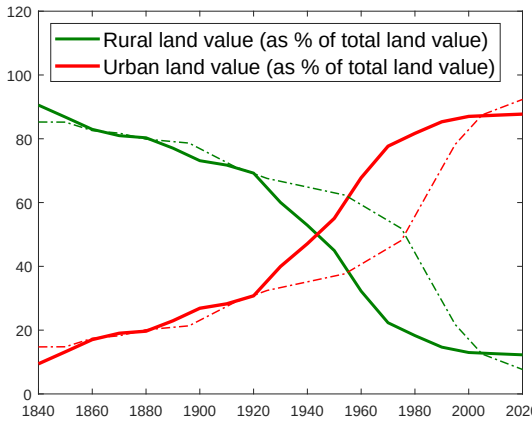


Figure: Urban and Rural Wealth

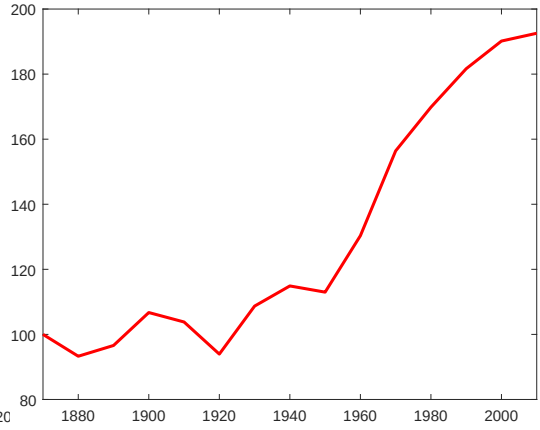


Figure: Real House Price Index

▸ Agricultural Productivity Gap

Sensitivity Analysis

Counterfactuals enlightening the mechanisms

- The role of rural productivity growth. ▸ lower rural growth
- The role of faster commuting modes. ▸ $\xi_w = 1$
- The elasticity of substitution between land and labor in the rural sector. ▸ σ
- Constant housing elasticity $\epsilon = 3$. ▸ $\epsilon = 3$

Extensions

1. Agglomeration. Go
2. Multiple Cities. Go
3. Relaxing Monocentricity. Go

Conclusion

We introduced a spatial general equilibrium model of land use to explain

1. Evolution of sectoral allocation across space.
2. Evolution of Urban Density.
3. Evolution of the land value distribution.

We found:

- Rural Productivity growth is crucial to understand urban expansion.
- Quantitatively, both rural and urban productivity growth as well as falling commuting costs are needed to explain data.

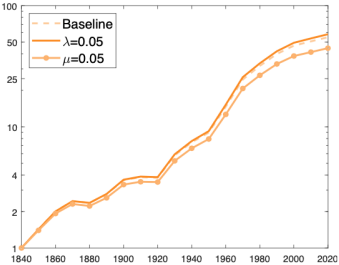
THANK YOU!

Agglomeration and Congestion Effects

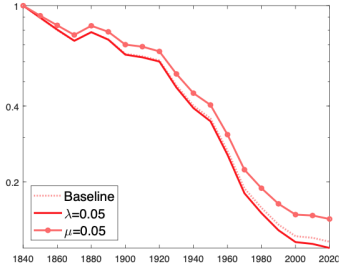
- Agglomeration effects are thought to be important enablers of modern city growth.
- Congestion costs act as significant inhibitors to city growth.
- How will those effects play out in general equilibrium?

Agglomeration and Congestion

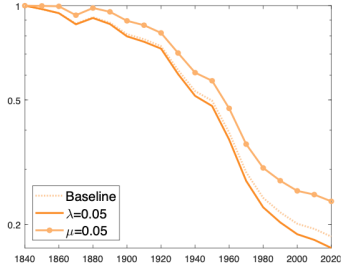
back



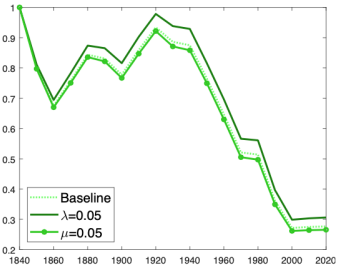
(a) City area (1840=1).



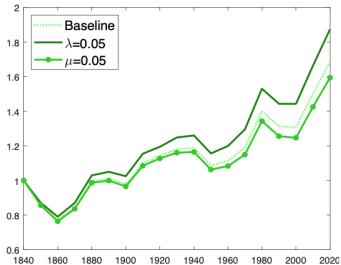
(b) Average urban density (1840=1).



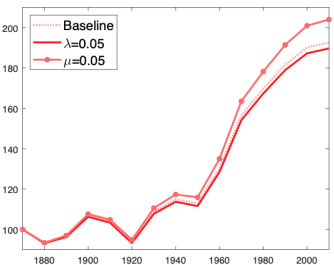
(c) Central density (1840=1).



(d) Relative price of rural good (1840=1).



(e) Rental price of farmland (1840=1).



(f) Real Housing Price Index (1870=100).

Multiple Cities

A *Country* with *K Regions*

- Split total area into $K = 20$ equal parts. (arbitrary)
- Assume that rural productivity $\theta_{r,k} = \theta_r, \forall k$.
- Initial level and growth of urban productivity $\theta_{u,k}$ determines city sizes.

Multiple Cities

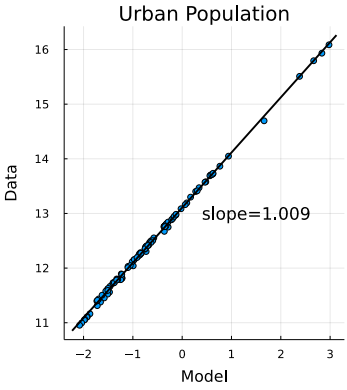
A *Country* with *K Regions*

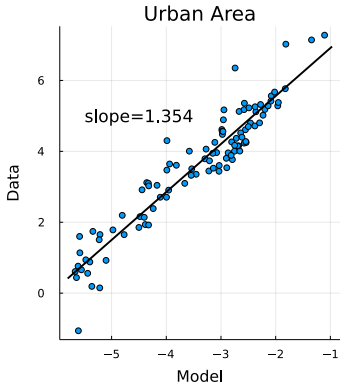
- Split total area into $K = 20$ equal parts. (arbitrary)
- Assume that rural productivity $\theta_{r,k} = \theta_r, \forall k$.
- Initial level and growth of urban productivity $\theta_{u,k}$ determines city sizes.

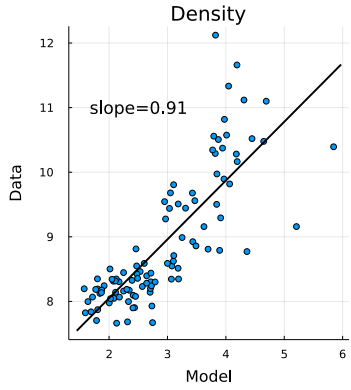
We impose 2 constraints:

1. The average over $\theta_{u,k}$ needs to be equal to our single city θ_u
2. The population distribution in the data must be reproduced.

Multiple Cities: Cross Section Model vs Data







back

Multiple Cities with Relaxed Monocentricity

- The biggest cities are not big enough in the model (in terms of space).
- Bigger cities in data may have multiple employment centers.
- We relax monocentricity via

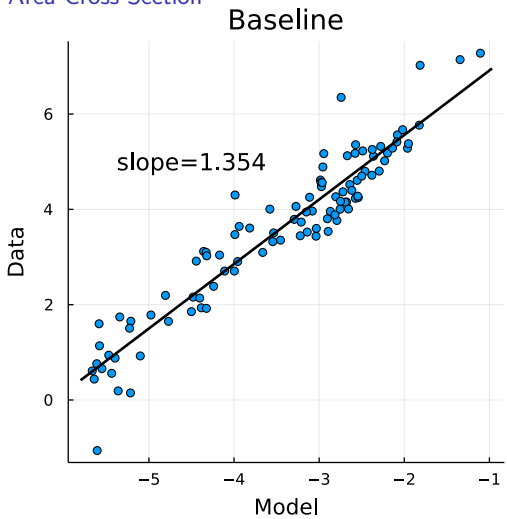
$$d(\ell) = d_0(\phi) + d_1(\phi)\ell$$

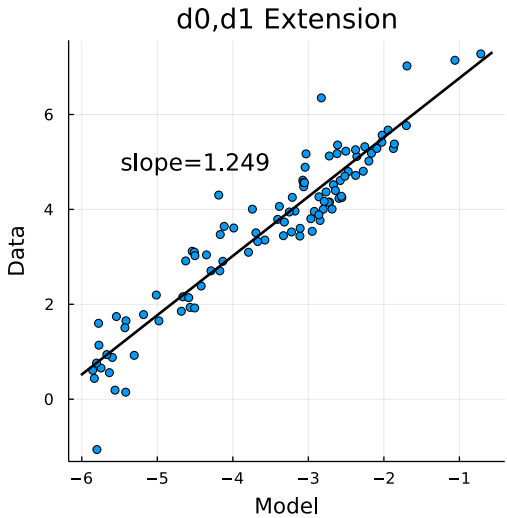
  where commuting distance d increases *less than one-for-one* with residential distance ℓ.

- We choose simple forms for $d_i(\phi)$'s and parameterize with individual commuting data.

Multiple Cities with Relaxed Monocentricity

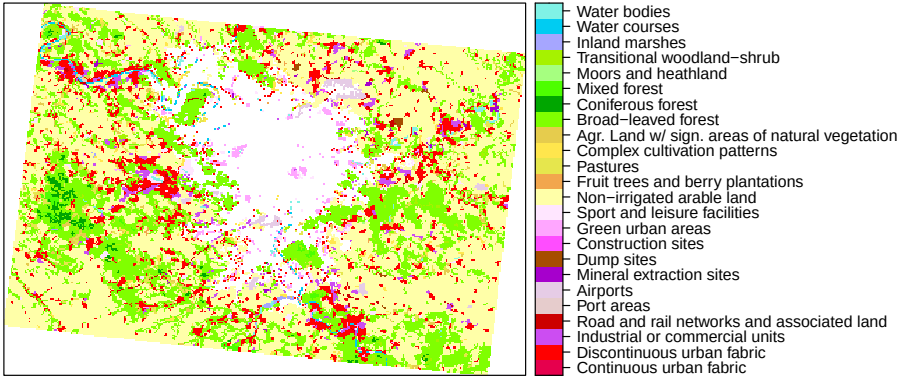
Urban Area Cross Section



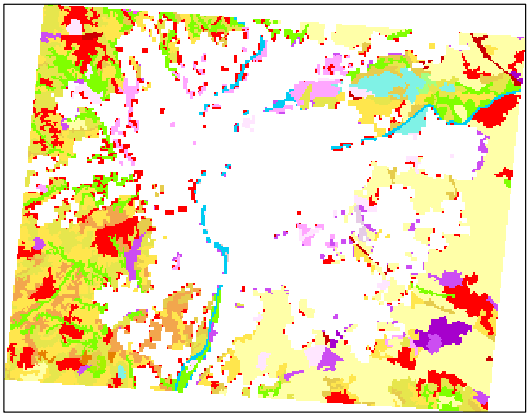


back

Land Use outside Paris 2020

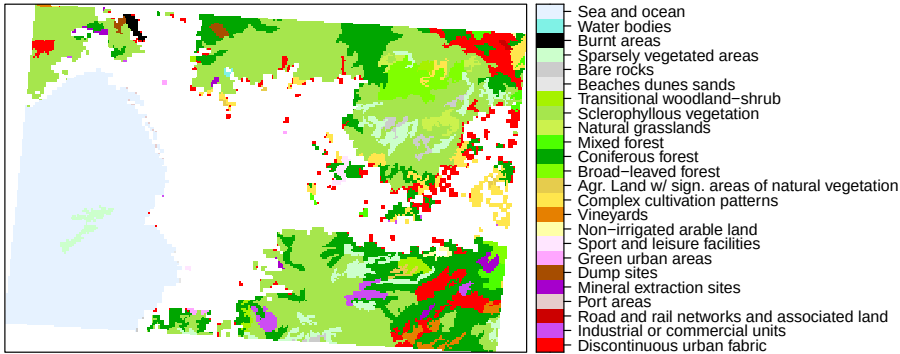


Land Use outside Lyon 2020

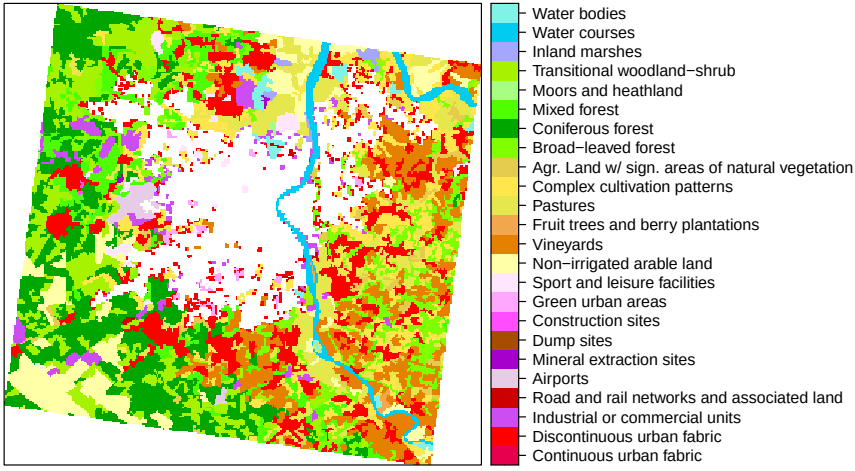


- Water bodies
- Water courses
- Transitional woodland−shrub
- Moors and heathland
- Broad−leaved forest
- Agr. Land w/ sign. areas of natural vegetation
- Complex cultivation patterns
- Pastures
- Fruit trees and berry plantations
- Vineyards
- Non−irrigated arable land
- Sport and leisure facilities
- Green urban areas
- Construction sites
- Mineral extraction sites
- Airports
- Port areas
- Road and rail networks and associated land
- Industrial or commercial units
- Discontinuous urban fabric
- Continuous urban fabric

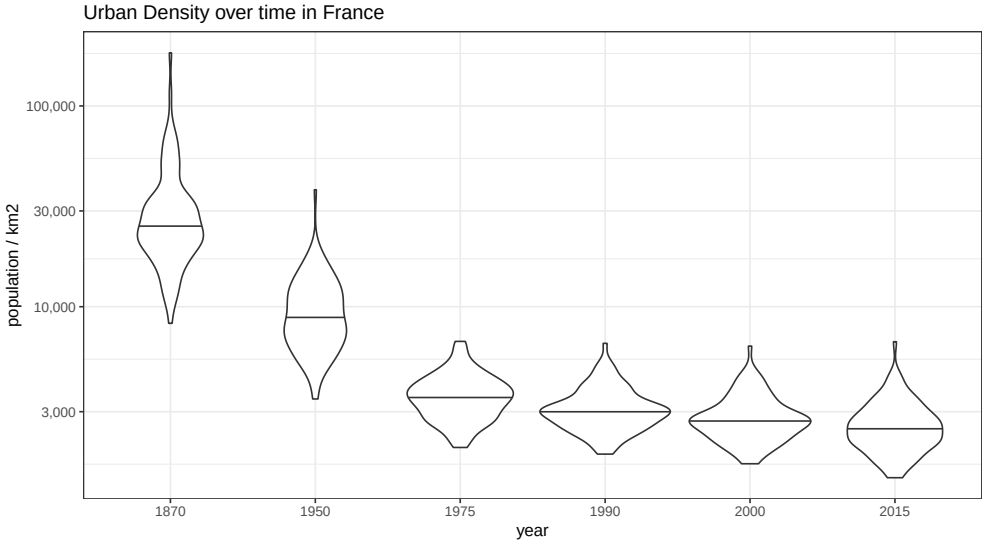
Land Use outside Marseille 2020



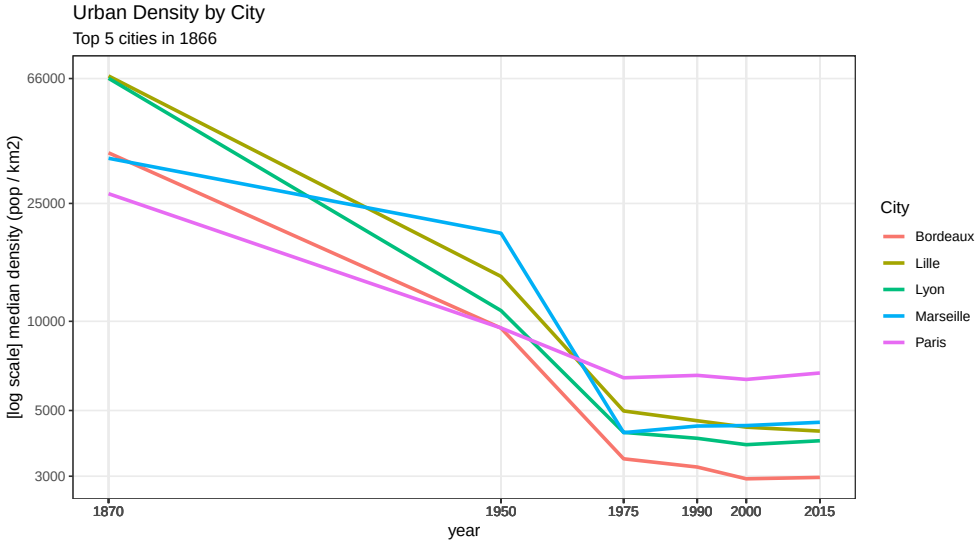
Land Use outside Bordeaux 2020



The historical fall in urban density

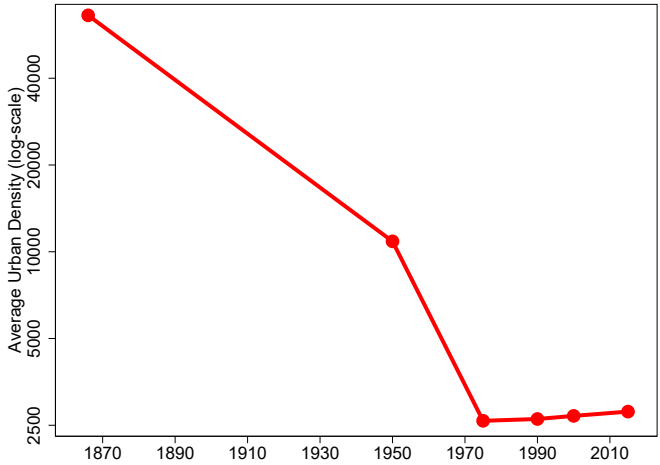


The historical fall in urban density



The historical fall in urban density

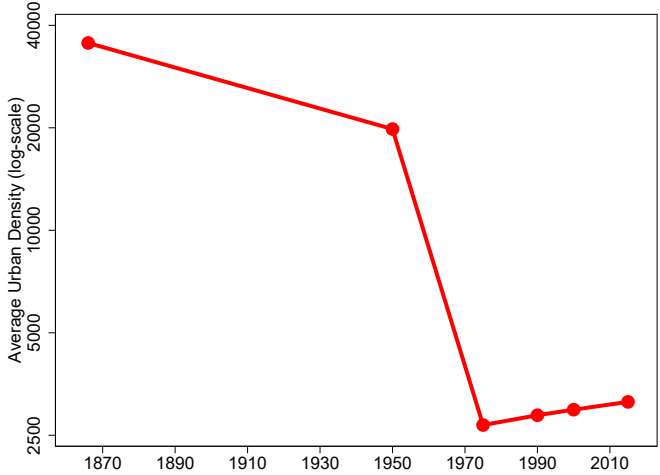
Lyon



back

The historical fall in urban density

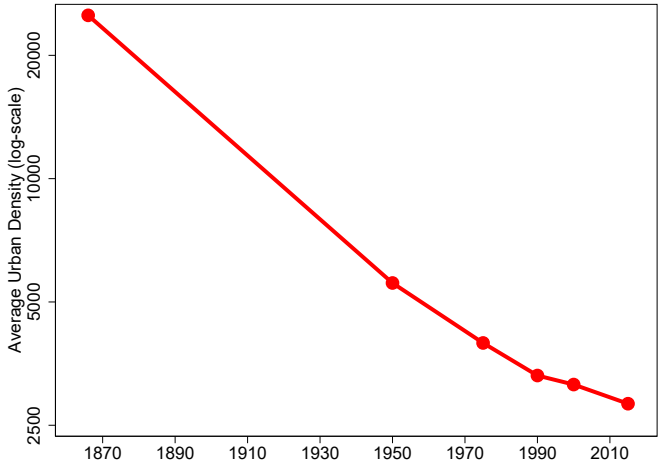
Marseille



back

The historical fall in urban density

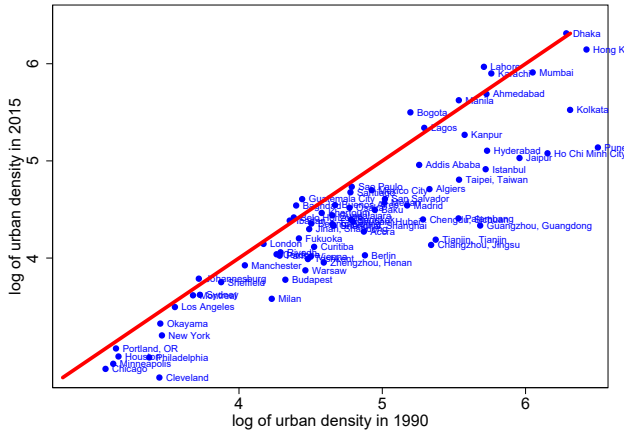
Reims



back

The fall in urban density across the globe, 1990-2015

World sample of large cities

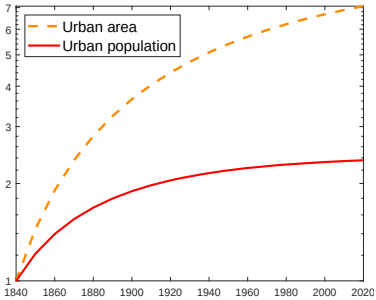


Source: Atlas of Urban Expansion. Sample of 73 cities above 1 000 000 people. Details in Angel et al. (2010).

back

Numerical Illustrations

Rural Productivity Growth Only

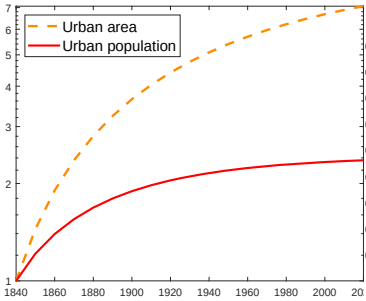


(a) City Size

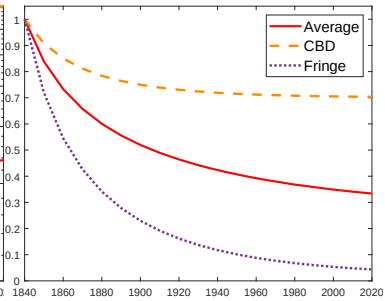
back

Numerical Illustrations

Rural Productivity Growth Only



(a) City Size

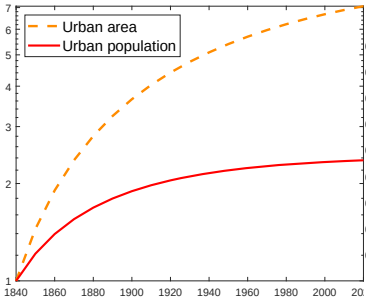


(b) Urban Densities

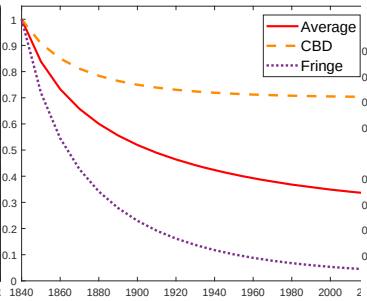
back

Numerical Illustrations

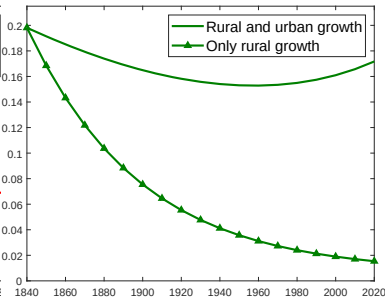
Rural Productivity Growth Only



(a) City Size



(b) Urban Densities



(c) Farmland Price

back

Housing Market Equilibrium

Land developers

- Housing supply provided by land developers.
- Use more or less intensively the land for residential purposes.
- Technology

  In each location, developers supply housing space $H(\ell)$ per unit of land with a convex cost,

  $$\frac{H(\ell)^{1+1/\epsilon}}{1+1/\epsilon},$$

  in units of the numeraire.

  $\epsilon =$ cost parameter, possibly dependent on the location.

Housing Market Equilibrium

Housing supply

- Profits per unit of land at ℓ,

$$\pi(\ell) = q(\ell)H(\ell) - \frac{H(\ell)^{1+1/\epsilon_\ell}}{1+1/\epsilon_\ell} - \rho(\ell),$$

  $\rho(\ell)$ the price of a unit of **land** in ℓ.

- Housing supply from profit maximization,

$$H(\ell) = q(\ell)^{\epsilon_\ell},$$

  with housing supply elasticity $\epsilon_\ell \geq 0$, $\partial\epsilon_\ell/\partial\ell \geq 0$.
  see Baum-Snow and Huan (2019).

Housing Market Equilibrium: Supply

Land Prices and Land Use

- Profit maximization and free entry of developers pins down land prices in ℓ,

$$\rho(\ell) = \frac{q(\ell)^{1+\epsilon_\ell}}{1+\epsilon_\ell},$$

- Land use with the highest rental value (Rivalry)
- Indifference conditions across uses at the fringe,

$$\rho_r = \frac{(q_r)^{1+\epsilon_r}}{1+\epsilon_r} = (1-\alpha)p\theta_r \left(\frac{L_r}{S_r}\right)^{\alpha}.$$

back

Agricultural Productivity Gap

- Gollin et al (2013) show that sizeable productivity gap between agricultural and other sectors: Value added is higher in non-agricultural sectors, particularly in developing countries.
- Proposed mechanisms in literature: migration costs, selection of migrants.
- Here spatial frictions together with ℓ-specific housing:

$$w(\phi) = w_u - \tau(\phi) = w_r$$

back

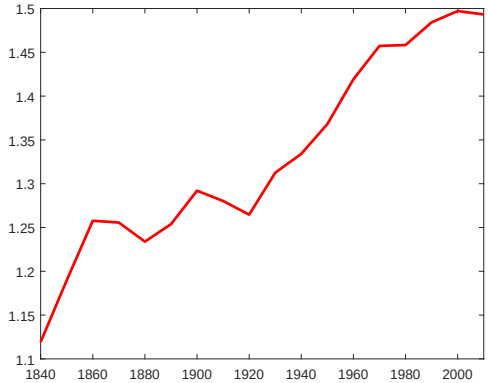
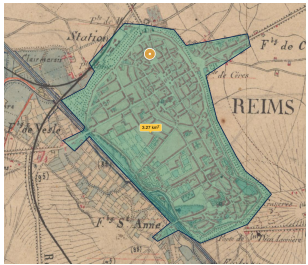
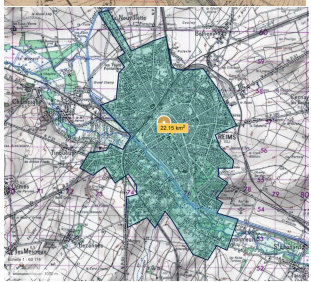


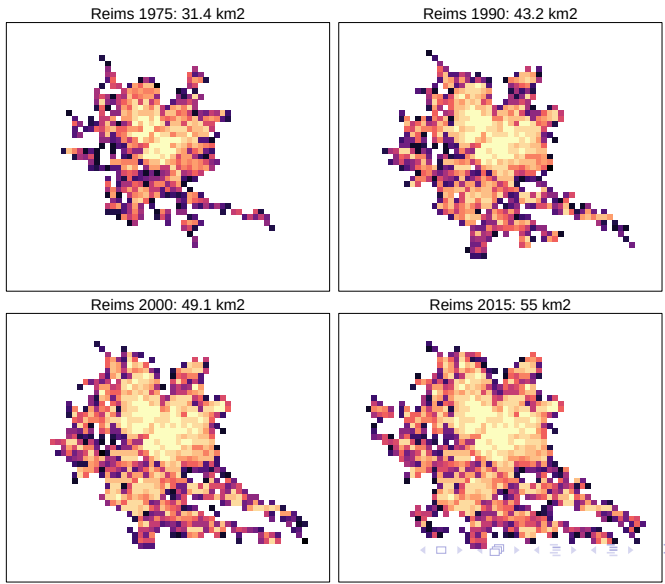
Figure: Agricultural Productivity Gap

GHSL Measurement - Reims

back

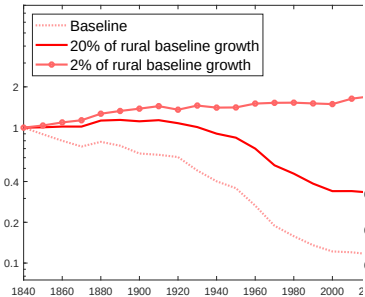




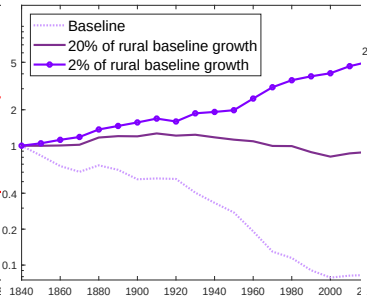


Sensitivity Analysis

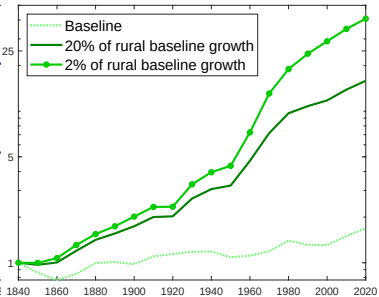
The role of rural productivity growth



(a) Urban Density



(b) Fringe Density



(c) Farmland Price

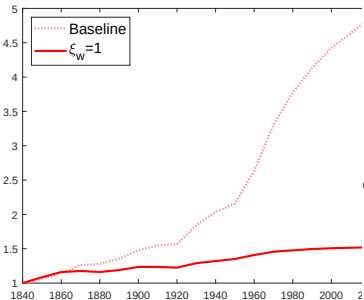
back

Sensitivity Analysis

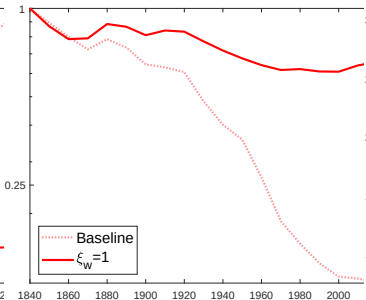
The role of increasing commuting speed

Commuting costs: $\xi_w = 1$

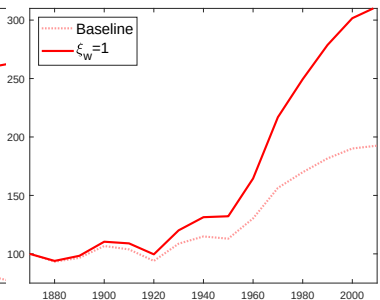
$$\tau(\ell) = a \cdot w_u^{\xi_w} \cdot \ell^{\xi_\ell}$$



(a) Commuting speed



(b) Urban Density



(c) Housing Price Index

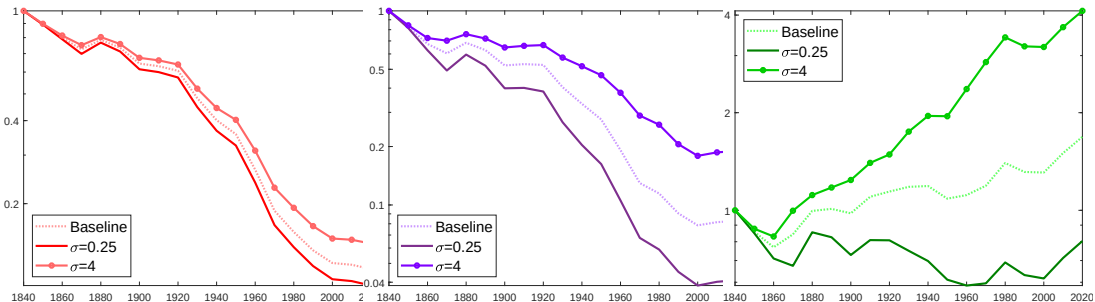
back

Sensitivity Analysis

The elasticity of substitution between land and labor in the rural sector

Rural good production function:

$$Y_r = \theta_r \left(\alpha (L_r)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)(S_r)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

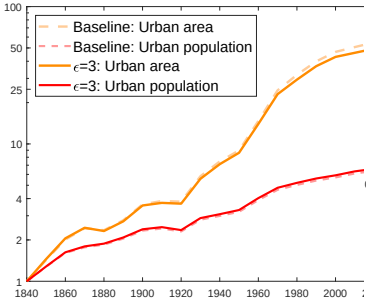


(a) Urban Density (b) Fringe Density (c) Farmland rental price

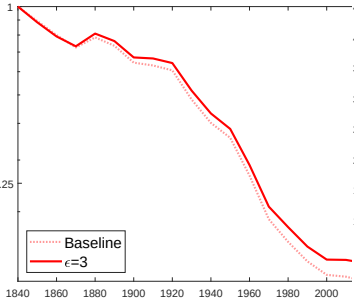
back

Sensitivity Analysis

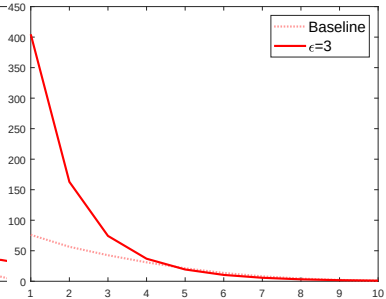
Constant housing elasticity $\epsilon = 3$



(a) City Size



(b) Urban Density



(c) Density by decile (2010)

back

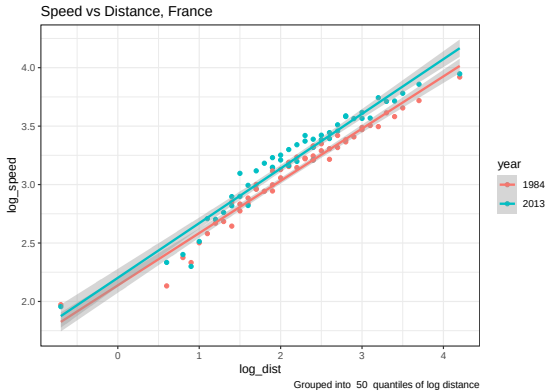
Calibration of τ

- Micro foundation yields:

$$\tau(\ell) = a \cdot w_u^{\xi_w} \cdot \ell^{\xi_\ell}$$

- The elasticites of commuting speed m with respect to income and speed are defined and measured in individual commuting data as:

  1. Income: $1 - \xi_w$. Given distance, increase in speed over increase in income (across years (see plot).
  2. Distance: $1 - \xi_\ell$. Given income, elasticity of speed to distance (in a given year - see table III in appendix).



back