

Structural Change, Land Use and Urban Expansion

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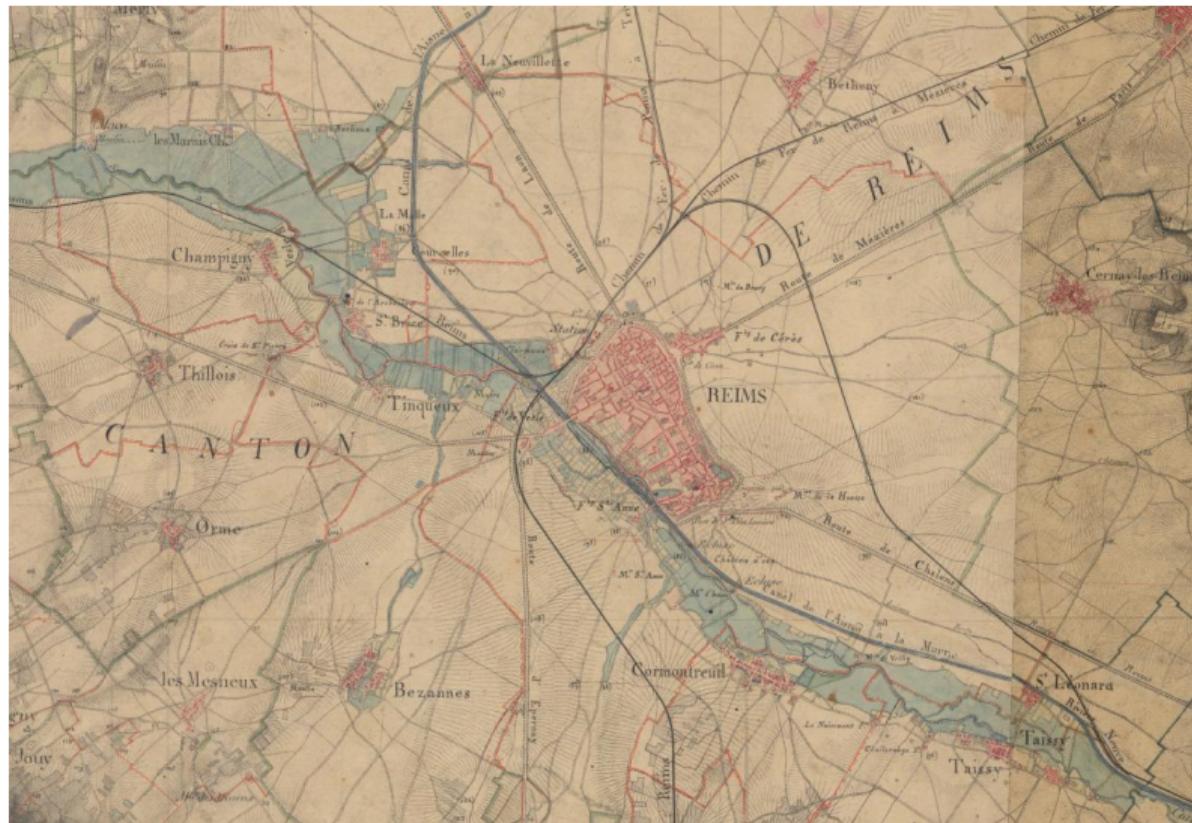
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Marc Teignier (U. Barcelona)

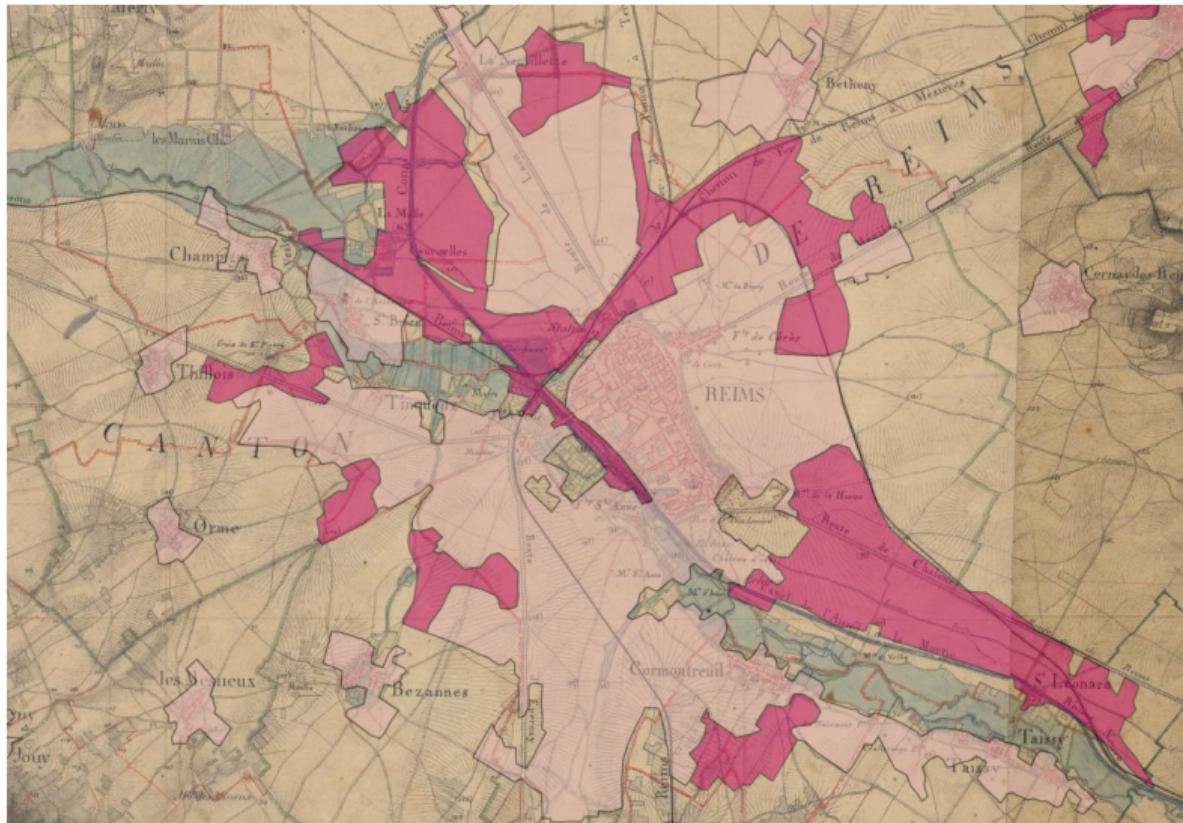
January 2022

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

Motivation: Reims in 1866



Motivation: Reims in 1866 vs IGN Buildings in 2017

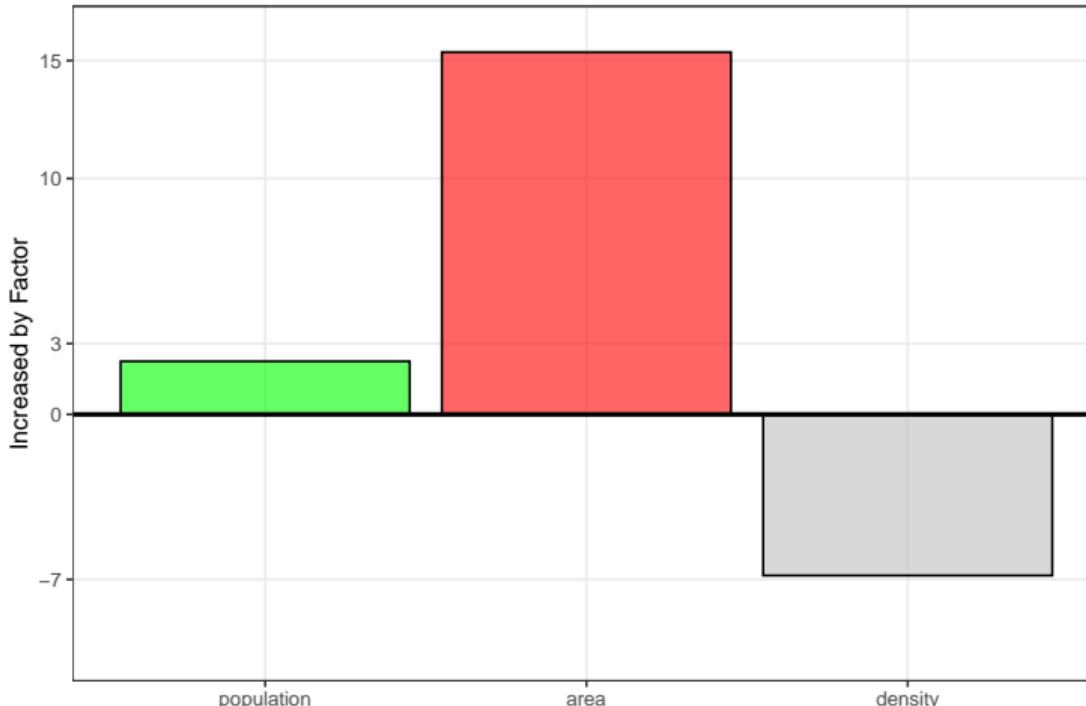


Motivation: Reims in 1950 vs IGN *Buildings* in 2017



Motivation: Fall in Urban Density

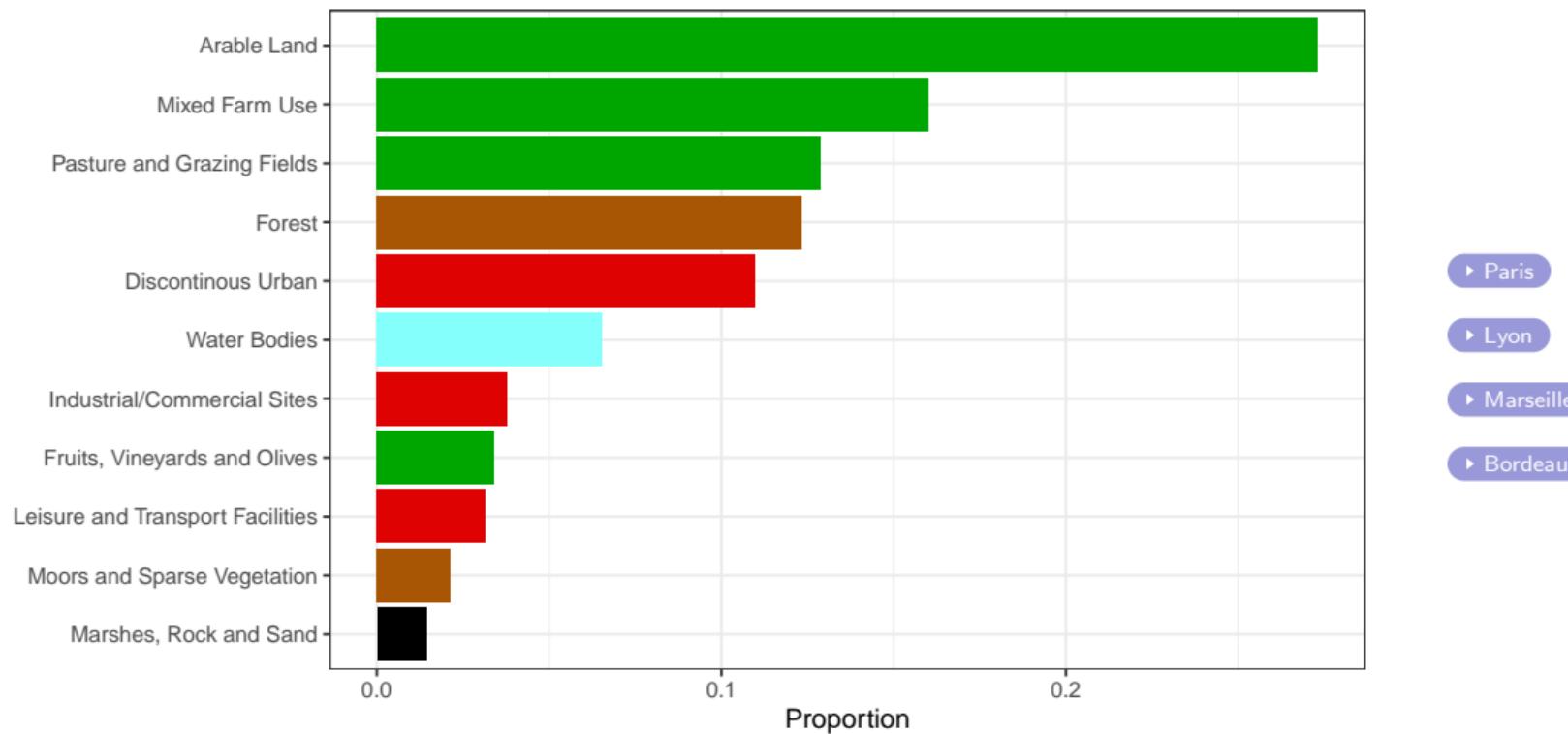
Reims from 1866 to 2015



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

Land Use Outside Top 100 French Cities Today

Average Land Use Outside top 100 Cities



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.

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- ▶ 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 accommodate greater housing demand. Urban Density falls.

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

Preview of Main Mechanisms

Transitory Dynamics with Rising Productivity and Falling Commuting Costs

- ▶ **Before Ind. Revolution:** Land is scarce. High values of farmland with respect to income due to low productivity ('food problem'). Small homes, low opportunity cost of time. Very small and dense, *walkable* cities.

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- ▶ **Nowadays:** Reallocation of factors/land use slows down. Cities expand less and land prices increase more with rising productivity.

Why Do We Care?

A general equilibrium spatial model of land use

- ▶ Understanding land/housing prices across space and time in the long-run.
 - ▶ Housing Affordability crisis.
- ▶ Understanding sprawling and soil artificialization.
 - ▶ Environmental impact (IPCC (2019)).
- ▶ Implications for welfare and aggregate productivity of land use restrictions. [not there yet]
 - ▶ Is sprawling 'excessive'? Benefits of compact cities?
 - ▶ General equilibrium implications of lowering commuting costs.

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).

Outline

1. Facts about Land use and Urban Expansion in France since 1840.
2. Theory
 - ▶ A general equilibrium model of structural change and land use
3. Quantitative analysis
 - ▶ Simple Version to generate intuition
 - ▶ Extended Quantitative Model to Match French data since 1840

Urban Expansion in France: Facts

Data Sources: France 1840–2016

- ▶ Land use and employment in agriculture across French regions
 - ▶ Historical: mostly from Toutain (1993) based on Recensement Agricole. Post-1950, Ministry of Agriculture.
- ▶ Employment and spending across sectors
 - ▶ Insee, Toutain (1993), Villa (1996), Herrendorf et al. (2014).
- ▶ The expansion of cities
 - ▶ Carte Etat-Major (1866), IGN (1950), Satellite Data post-1975 (GHSI data). Census for Population.
- ▶ Housing and Land Prices
 - ▶ Aggregate Historical: Piketty et al. (2014), Knoll et al. (2017). Farmland across regions: Ministère de l'Agriculture since 1950. Housing/Farmland Transactions: Base des Notaires.

Land and labor reallocation: Aggregate France

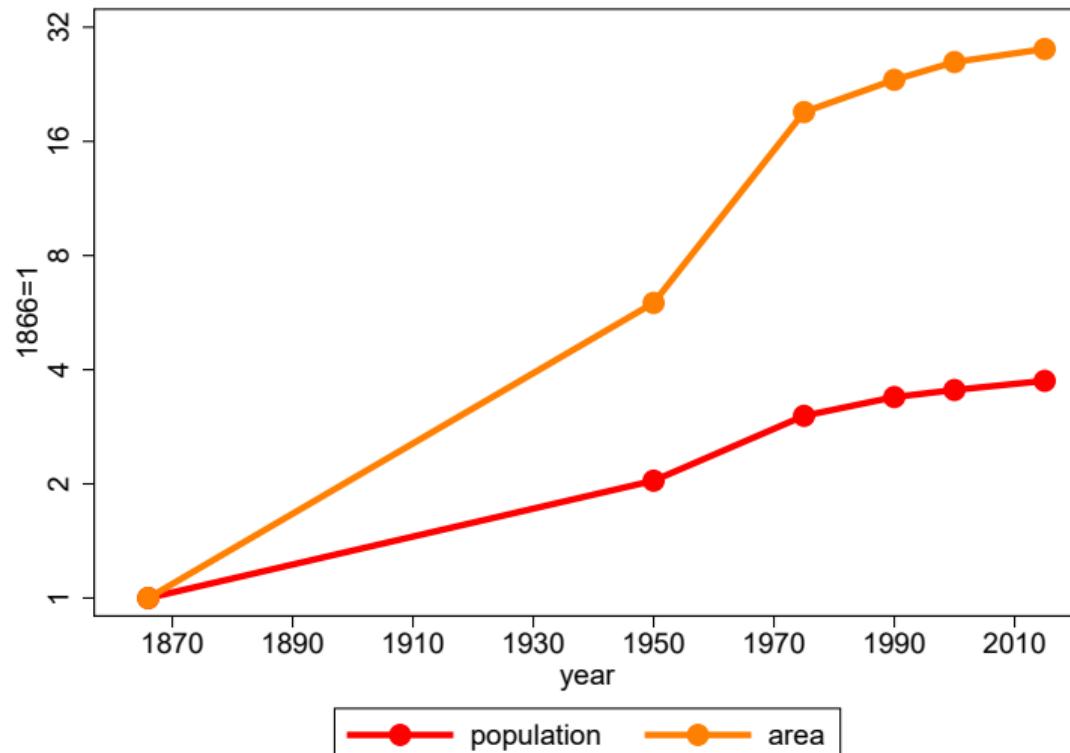


Sources:

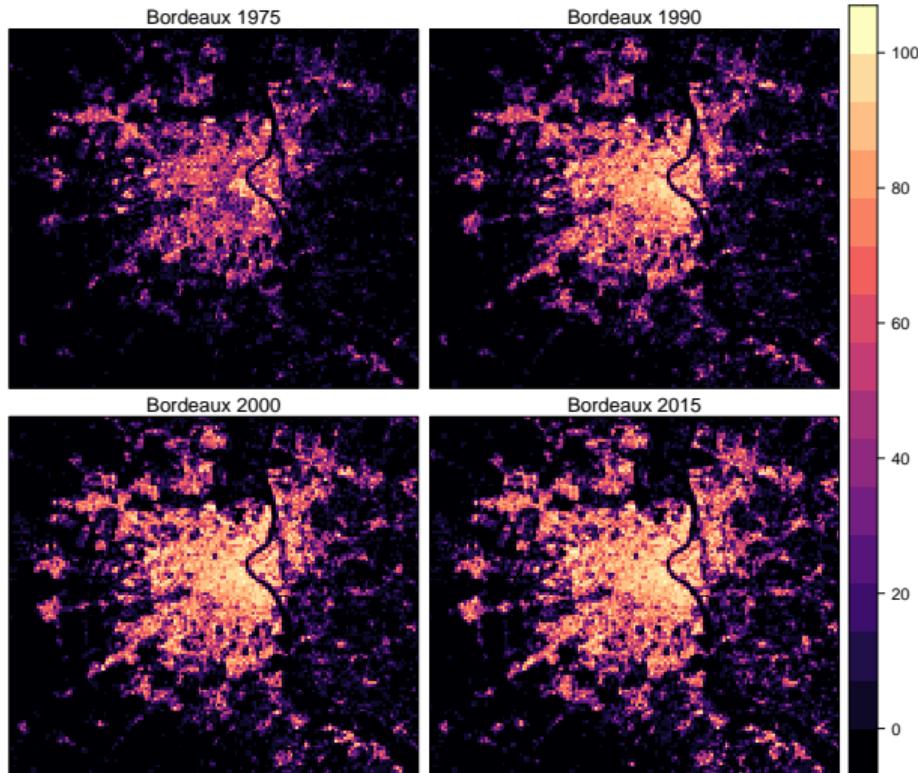
1. Toutain (1993)
2. Recensement Agricole (Ministry of Agriculture)
3. INSEE
4. Villa (1996)

Urban Expansion

Top 100 Cities in France



City Area and Population Measurement

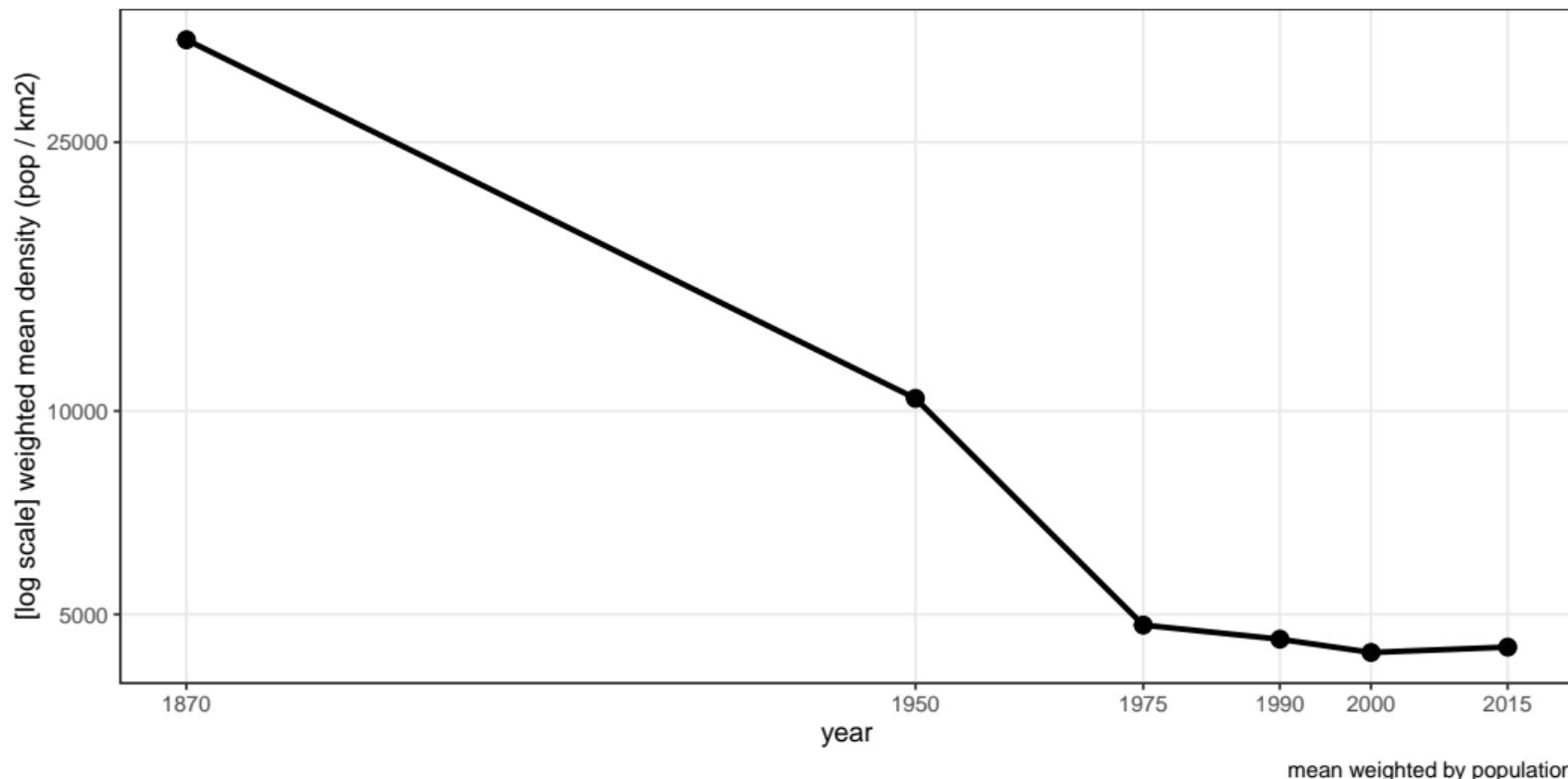


- ▶ 1866: Manual + Census
- ▶ 1950: Manual + Census
- ▶ 1975, 1990, 2000, 2015: GHSL
- ▶ More details please!

The Historical Fall in Urban Density

Mean Urban Density in France fell by Factor 8

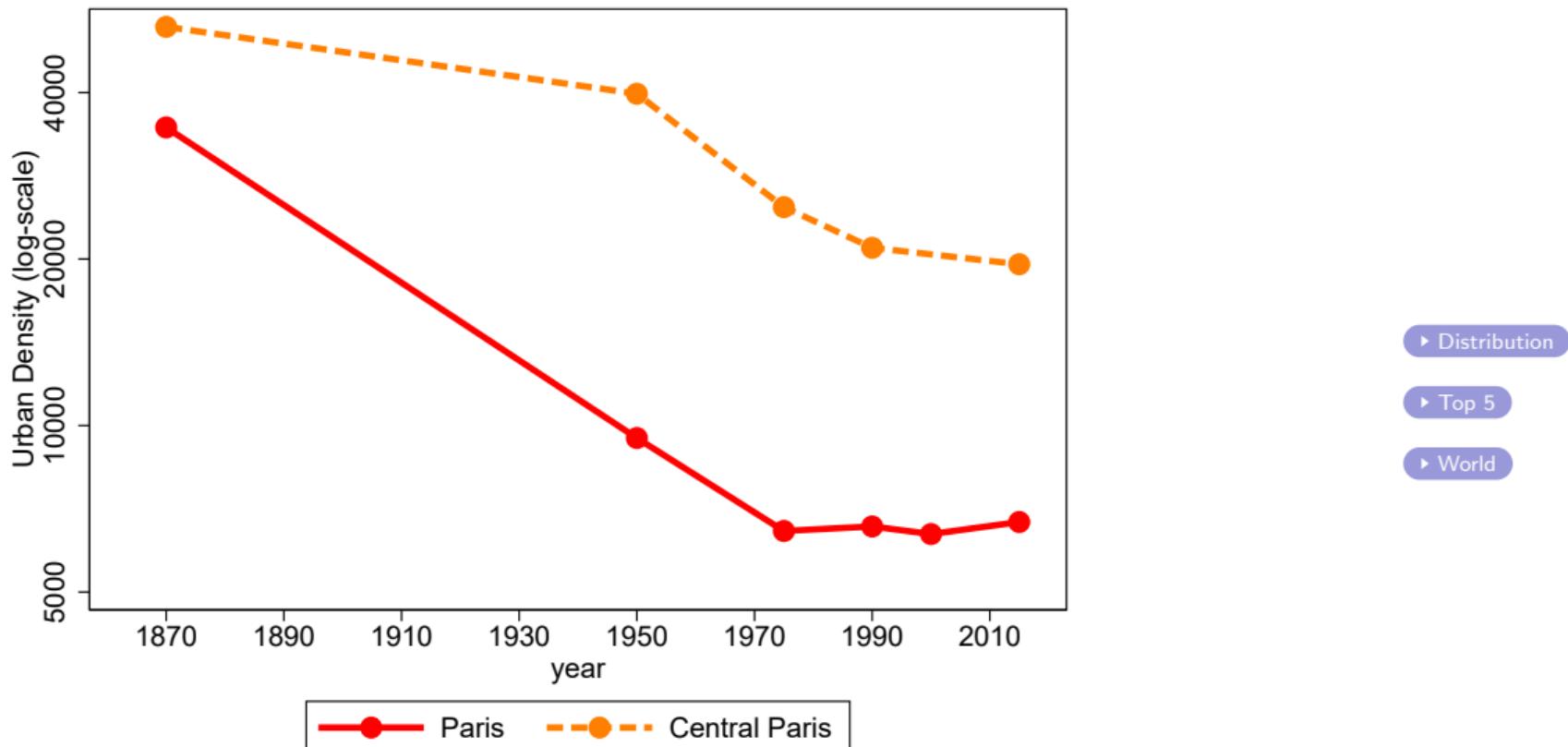
Top 100 French cities



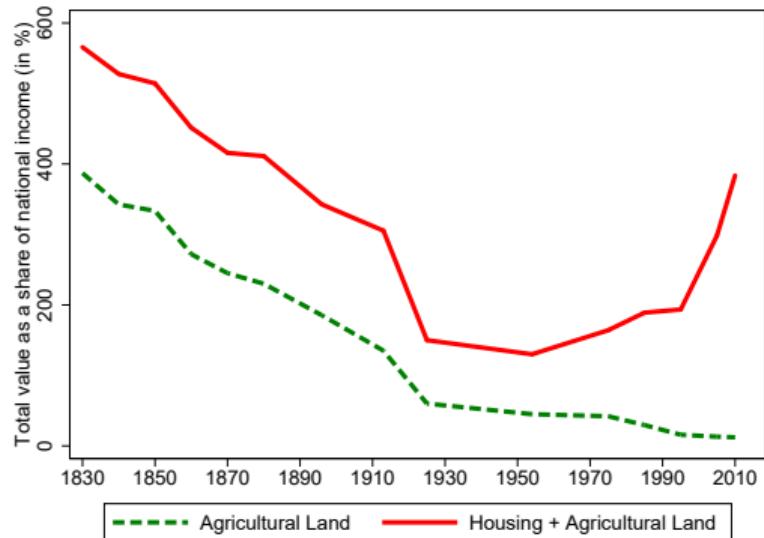
mean weighted by population



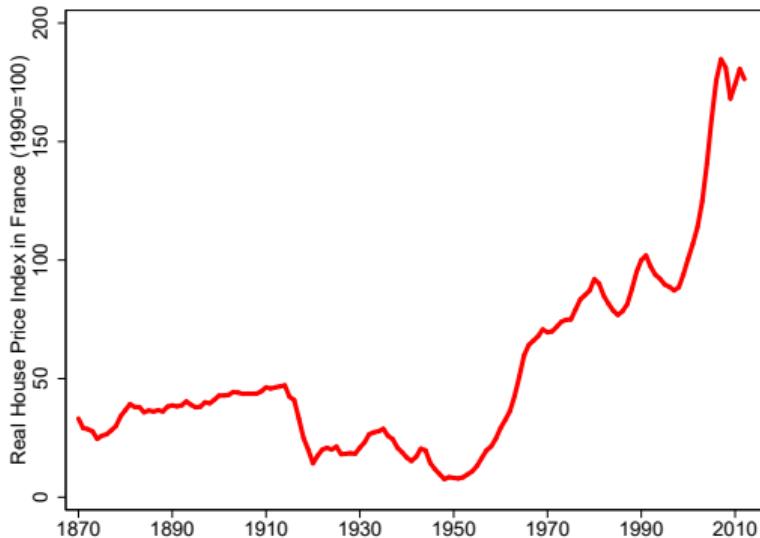
The Historical Fall in Urban Density: Within Paris



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,

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

- ▶ 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).

Factor Payments

Urban wage,

$$w_u = \theta_u,$$

with (u) good numeraire.

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Rural wage w_r and rental price of rural land ρ_r ,

$$w_r = \alpha p \theta_r \left(\frac{S_r}{L_r} \right)^{1-\alpha},$$

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

where p the relative price of the rural good.

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 $h(\ell)$.

c, 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 $w(\ell)$

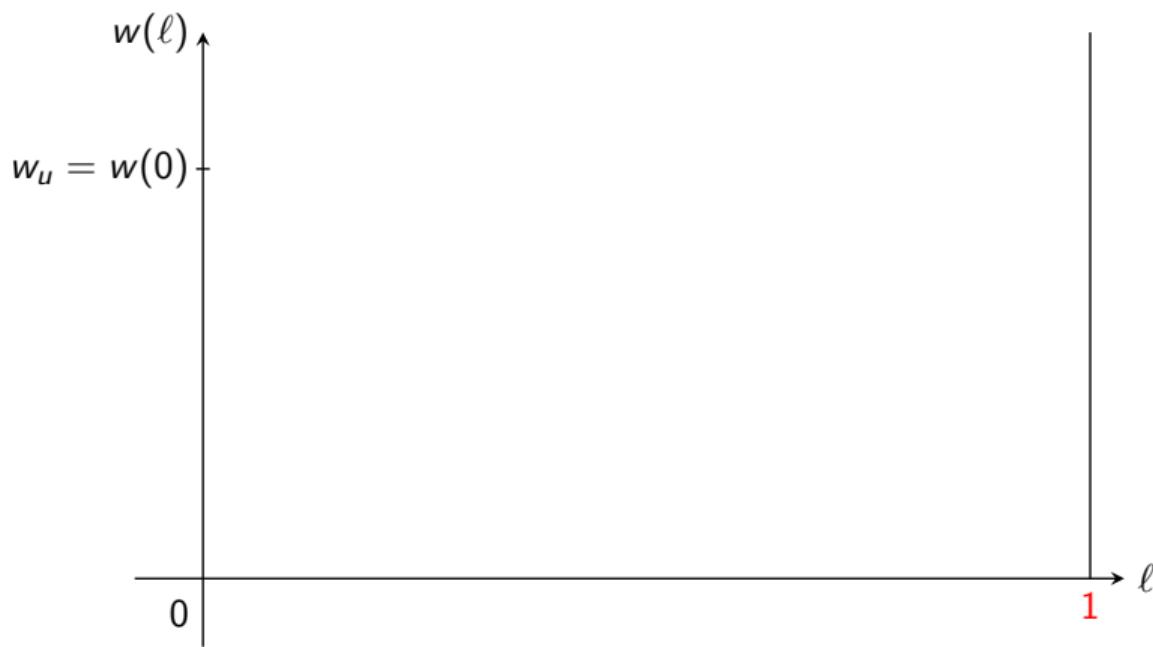
Wages Net Of Commuting Costs in Spatial Equilibrium: $C(\ell) = \bar{U}$

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



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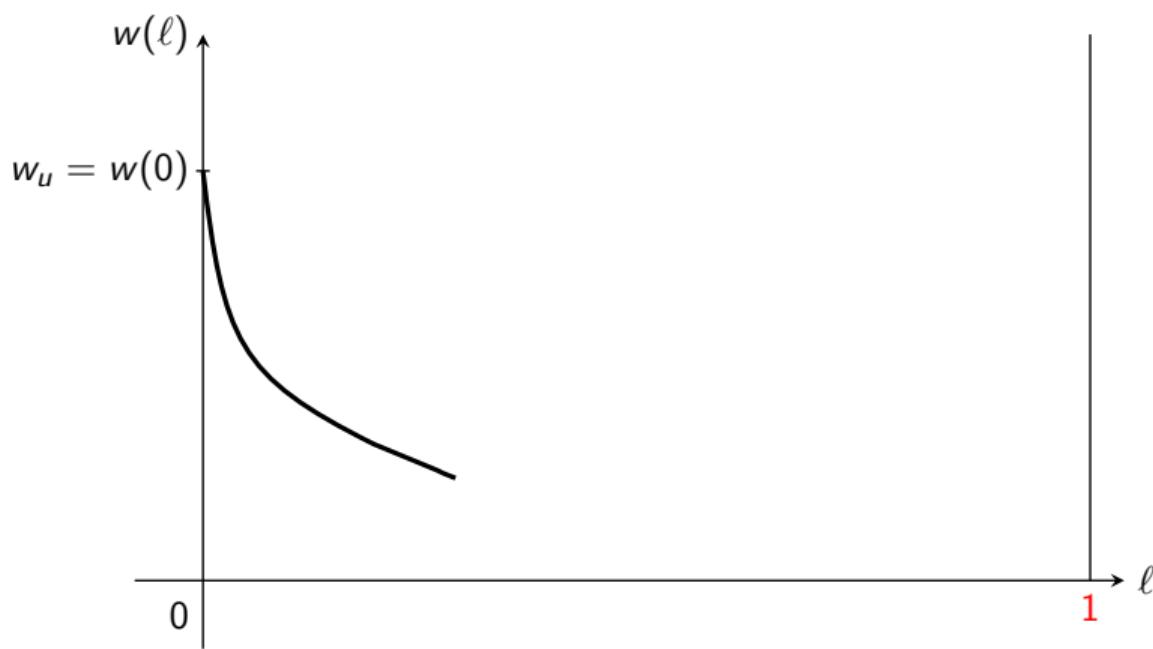
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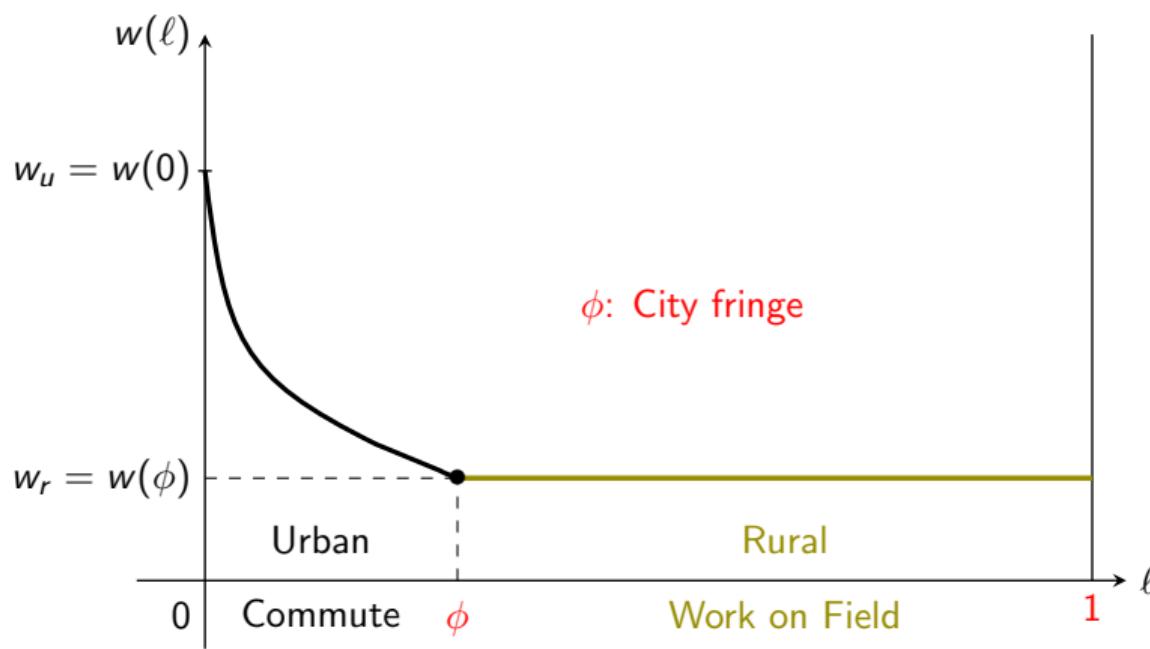
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4. $\tau(\ell)$: commuting cost from ℓ
5. $w_u - \tau(\ell)$ urban wage

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6. ϕ denotes urban fringe.

Commuting Costs in units of Numeraire Good

Based on DeSalvo and Huq (JUE 1996)

- ▶ Commuters choose best mode of transport.
- ▶ Opportunity cost of time (i.e. wage) and location matter.
- ▶ High urban wage → demand faster commute.



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- ▶ Balance marginal cost/benefit of faster mode:

$$\tau(\ell) = a \times (w_u \ell)^\xi$$

1. Faster commutes for people further away.
2. Speed increases with wage (opp. cost of time).
3. Elasticity of $\tau(\ell)$ wrt wage is strictly less than unity

Location Sorting

Spatial Equilibrium

- ▶ Indifference conditions across locations,

$$\bar{C} = C(\ell) = \kappa \frac{w(\ell) + r + s - p\underline{c}}{q(\ell)^\gamma}.$$

- ▶ Same house price q_r at ϕ and in the rural area, $q(\ell \geq \phi) = q_r$.
- ▶ Indifference at the fringe,

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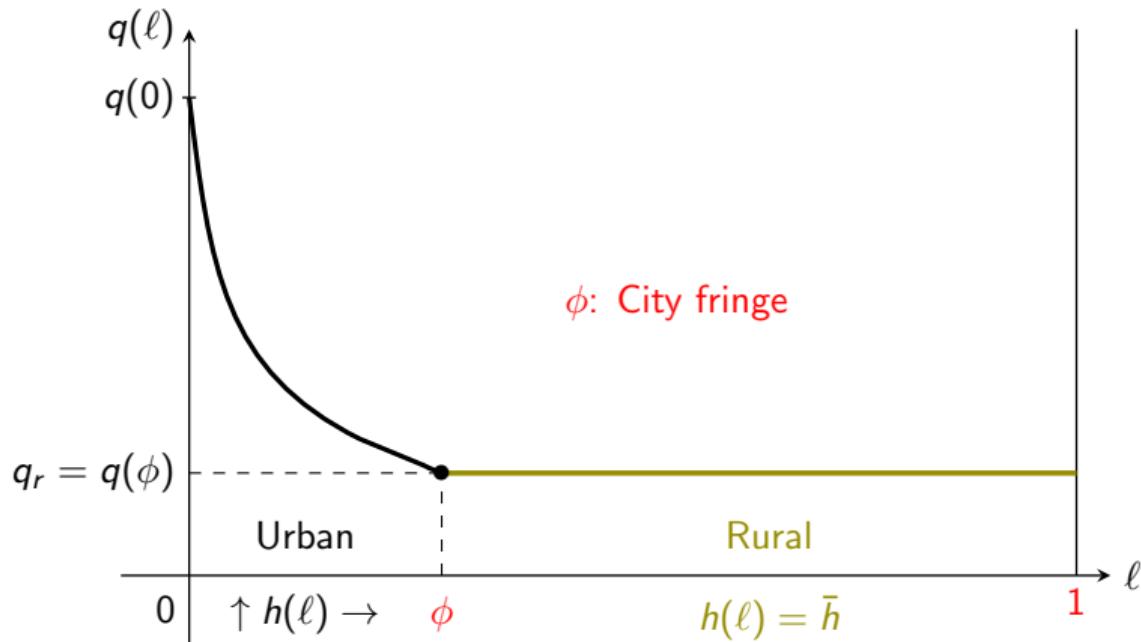
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- ▶ The last urban worker has same net wage as rural worker.
- ▶ Higher commuting costs deter rural workers to move into urban sector.

Housing Rental Price Gradient

Piecewise Constant Housing Price, Demand, and Population Density



Closed forms for:

- ▶ House price $q(\ell)$
- ▶ Housing demand $h(\ell)$
- ▶ Population Density: $D(\ell)$

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.

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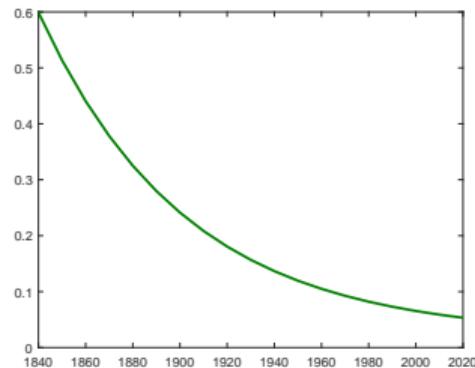
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- ▶ **Recent Times:** Reallocation of factors/land use slows down. Cities expand less and land prices increase more with rising productivity. Land particularly scarce in some locations.

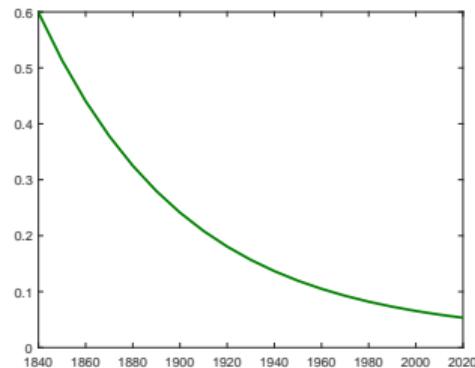
Results

Numerical Illustration: Identical Growth (1.25%) in Both Sectors

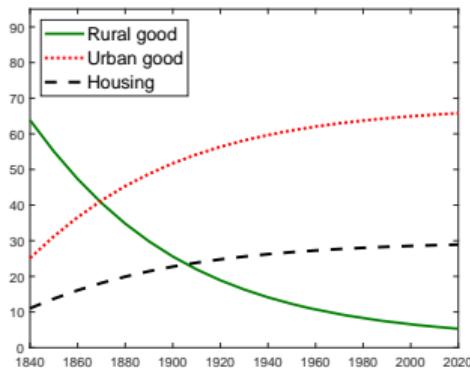


(a) Rural Employment share.

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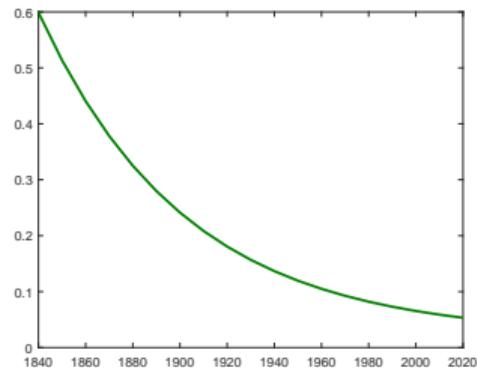


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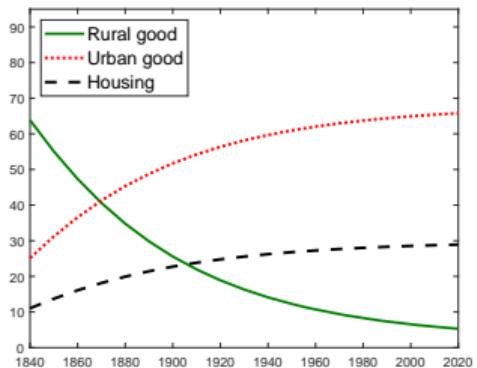


(b) Expenditure Shares.

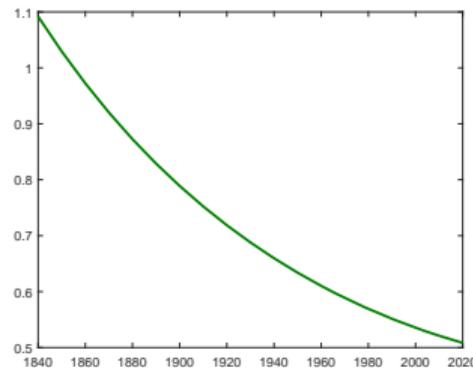
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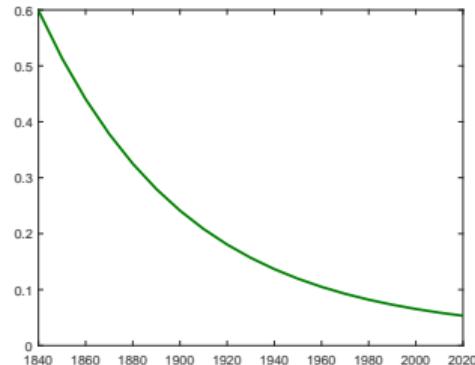


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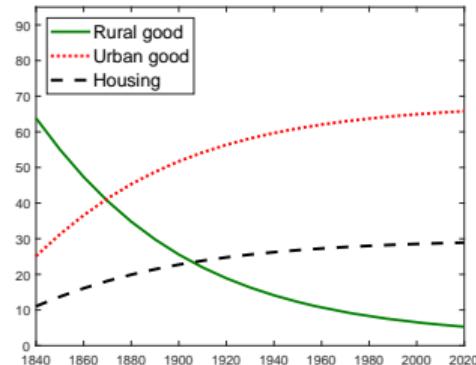


(c) r -price

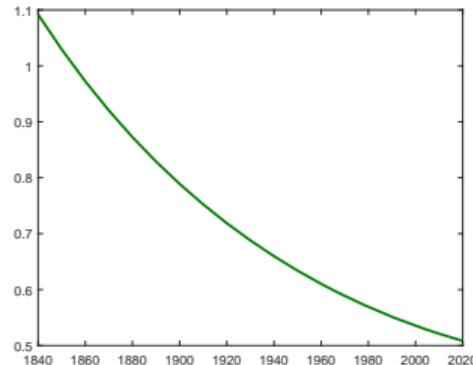
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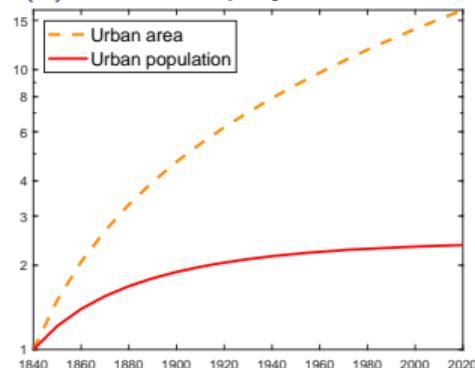
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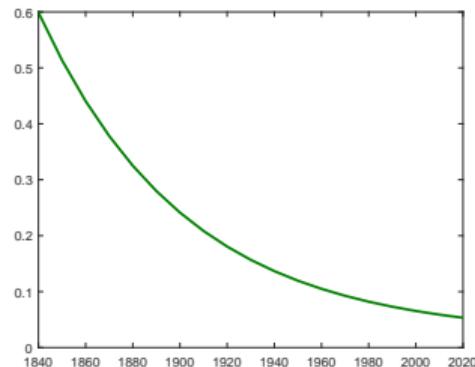


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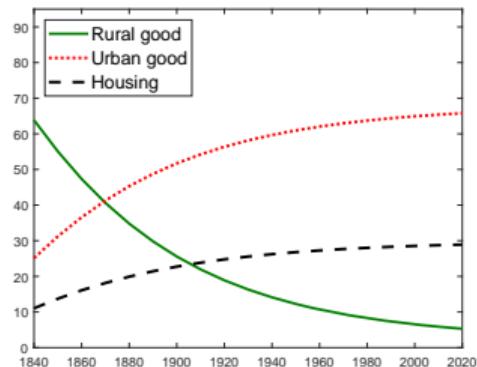


(d) City size (Index, 1840=1)

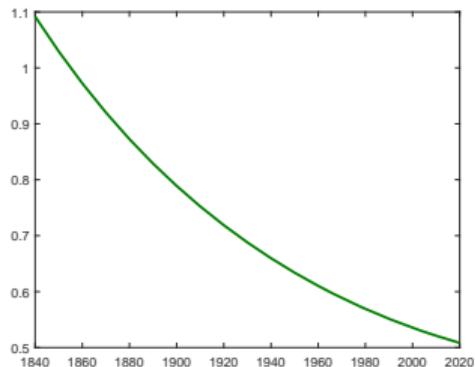
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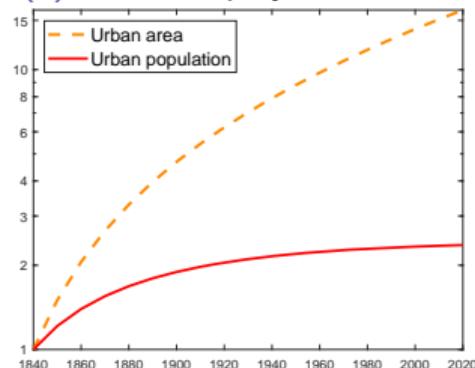
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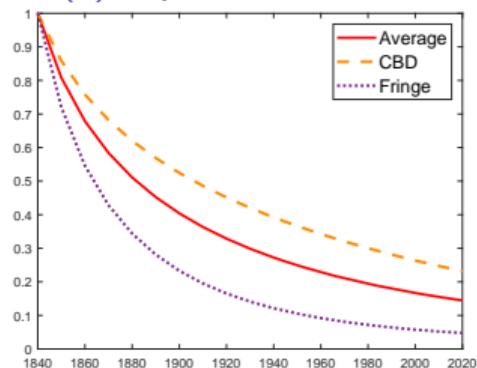
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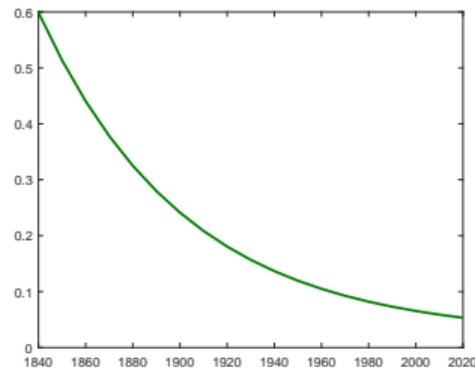


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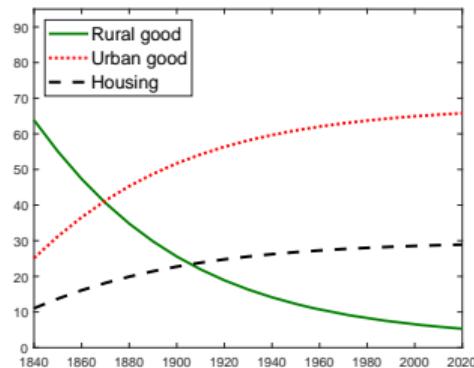


(e) Densities (Index, 1840=1)

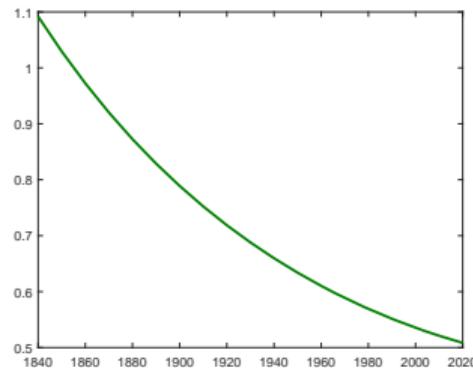
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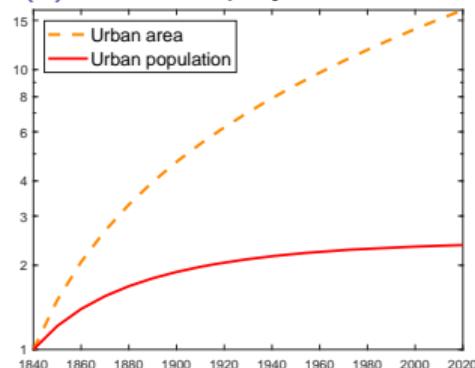
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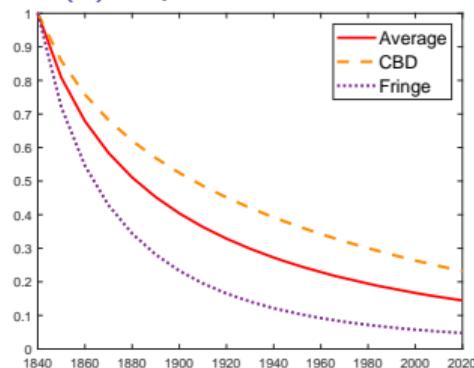
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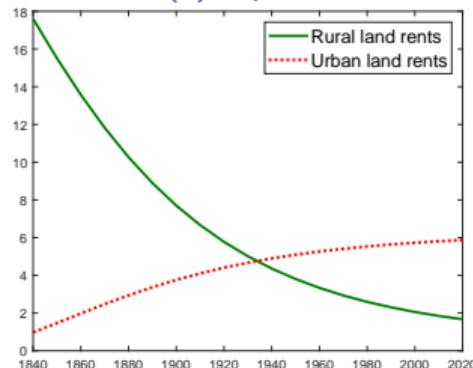
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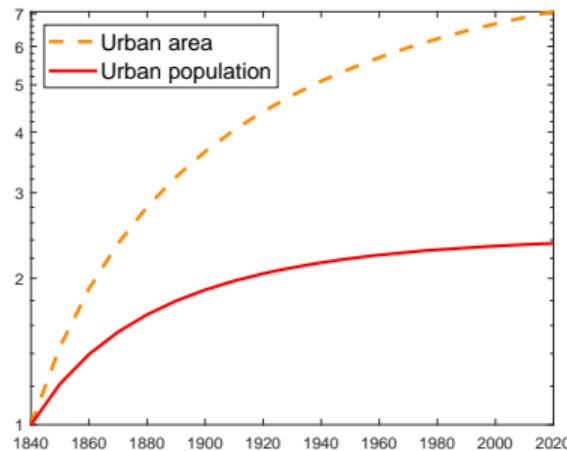


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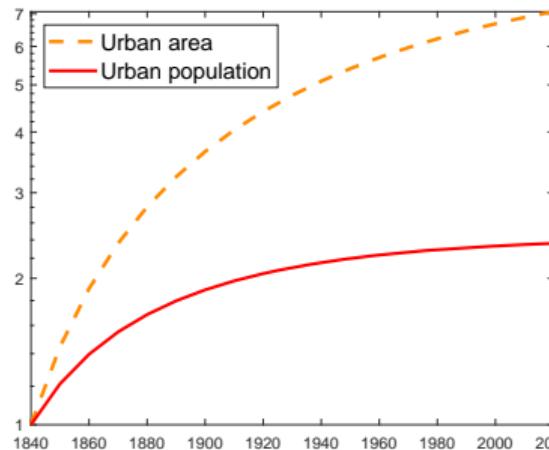
(f) Land rents (%).

Numerical Illustration: Only Rural Growth

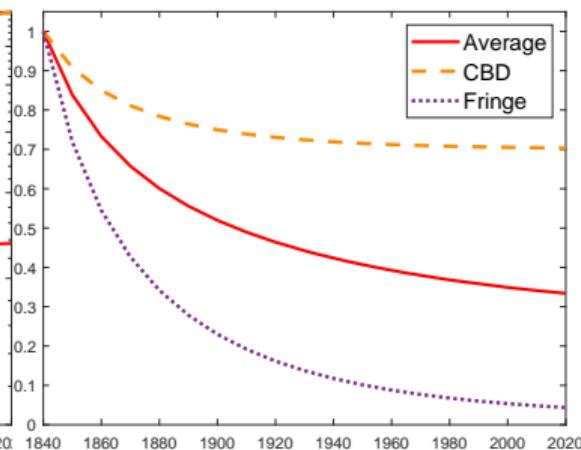


(a) Urban Population and Area

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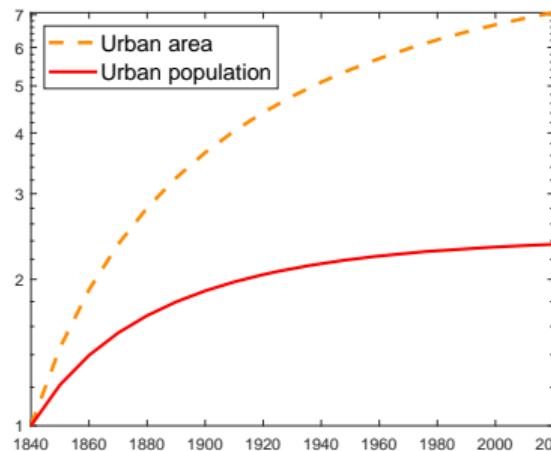


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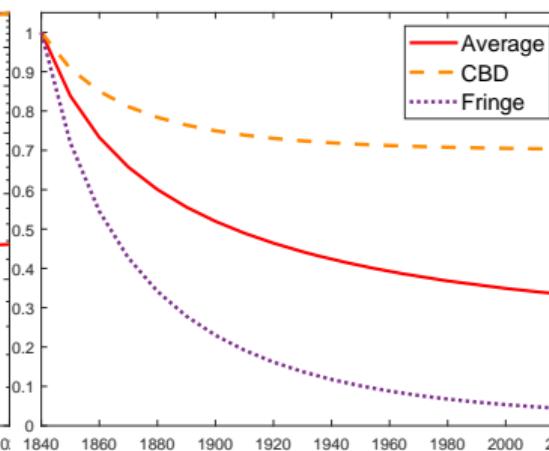


(b) Urban Densities

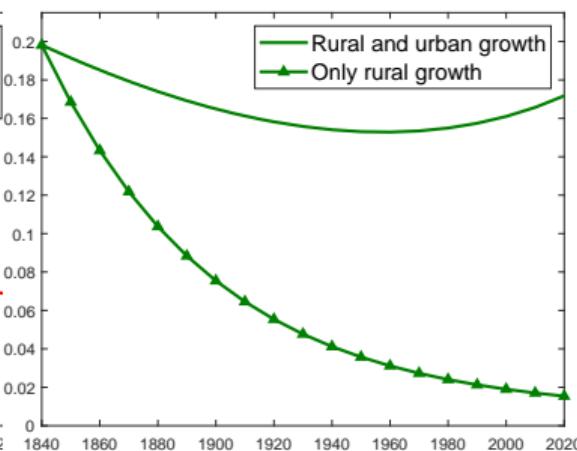
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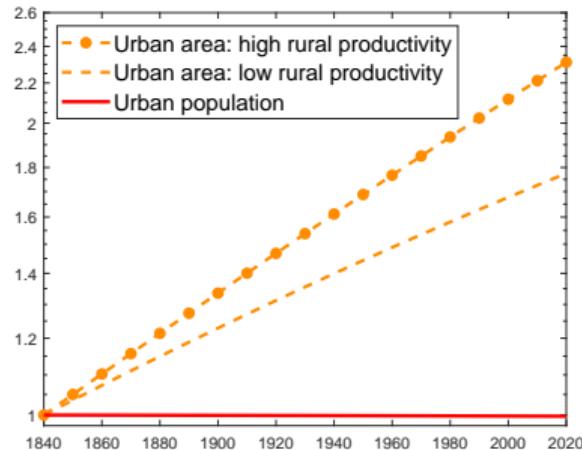


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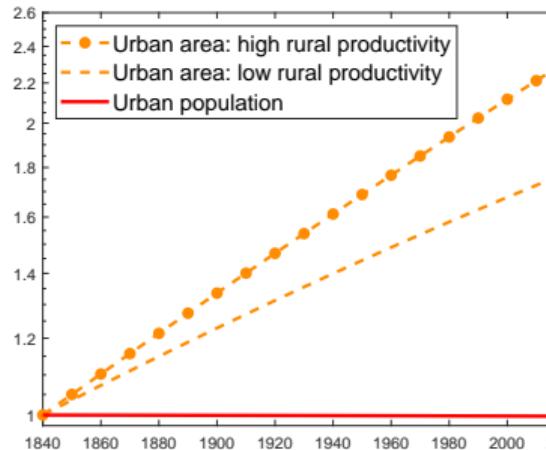
(c) Farmland Price

Numerical Illustration: Only Urban Growth

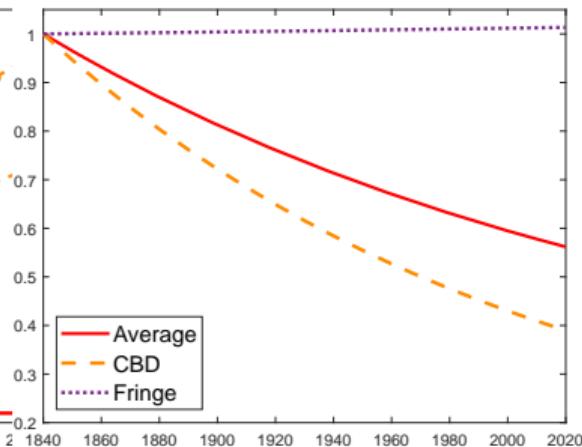


(a) Urban Population and Area

Numerical Illustration: Only Urban Growth

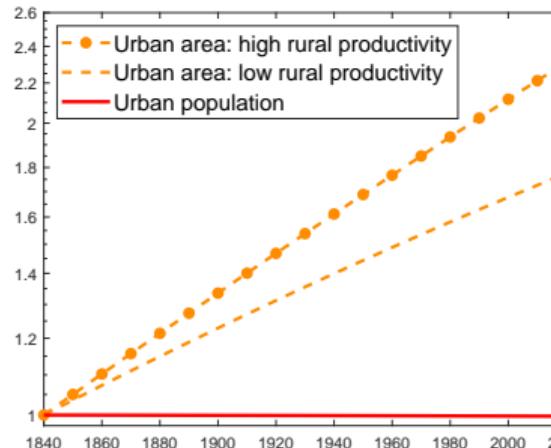


(a) Urban Population and Area

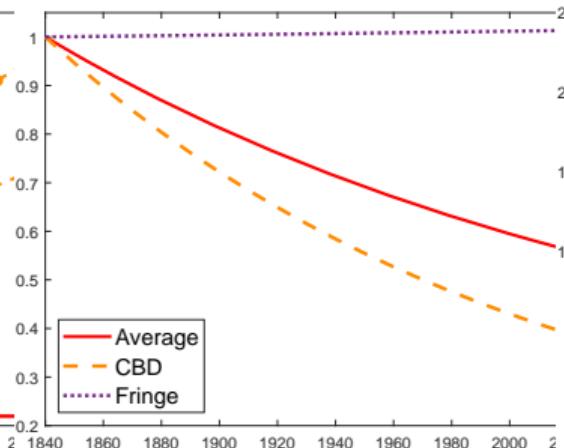


(b) Urban Densities

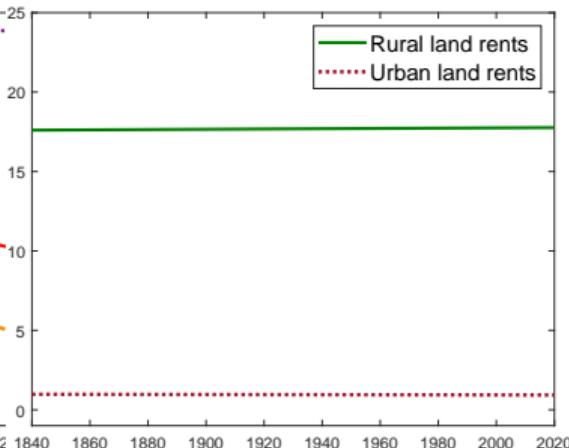
Numerical Illustration: Only Urban Growth



(a) Urban Population and Area



(b) Urban Densities

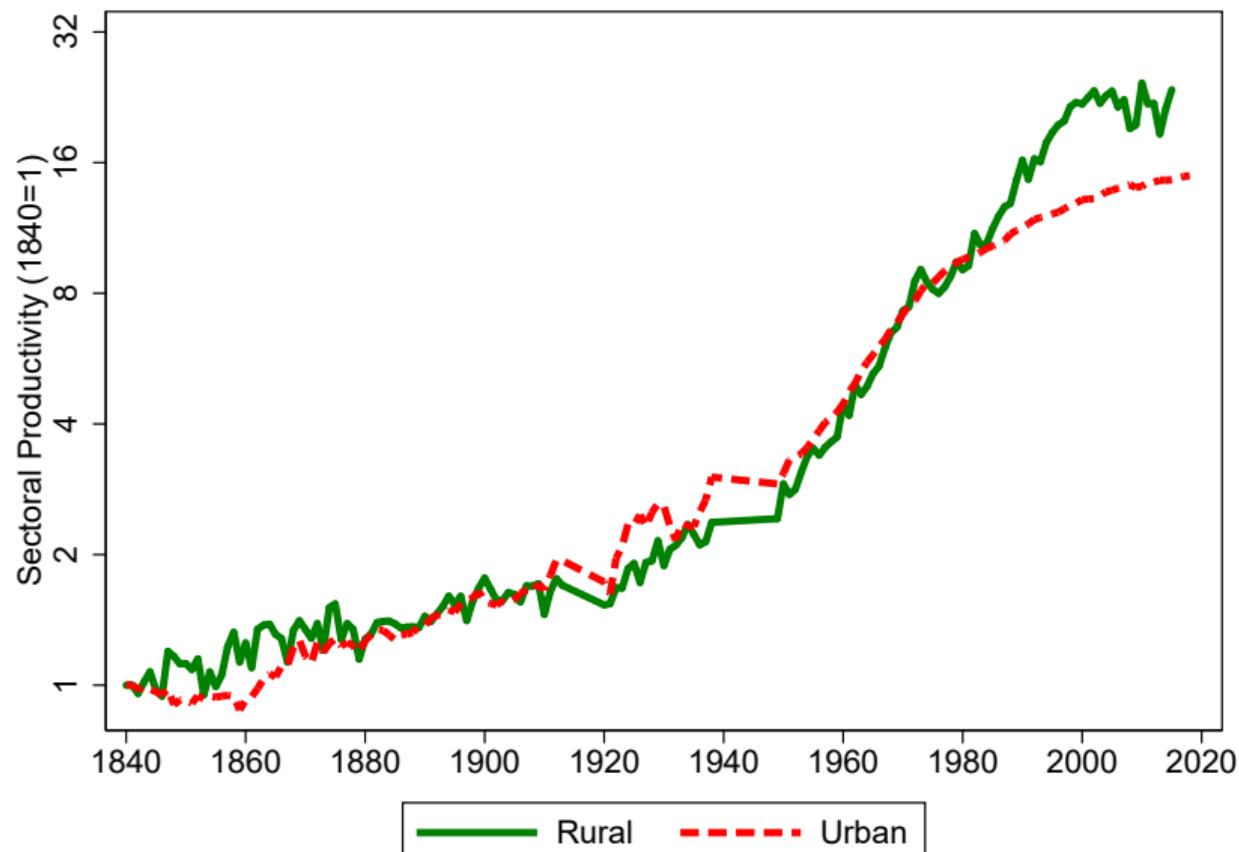


(c) Land rents over income

Full Quantitative Model and Parameterization

1. Extend the model to bring closer to the data.
2. We estimate the θ series from data.
3. Observed Population Growth.
4. We use individual commuting data to directly calibrate the τ parameters. ▶ How?
5. Jointly estimate preference parameters to match set of moments.

Estimated θ 's



Estimation and Identification

We target the following moments:

- ▶ L_{rt}/L_t : employment share in each period.
- ▶ City is 18% of rural area in 2015.
- ▶ Spending share on housing 1900 and 2010.

Internal city structure, density fall, commuting speed, house price: not targeted!

Numerical Model Results: Structural Change

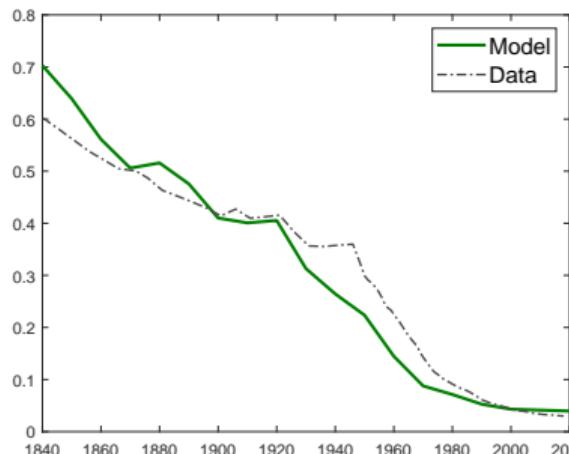


Figure: Rural Employment

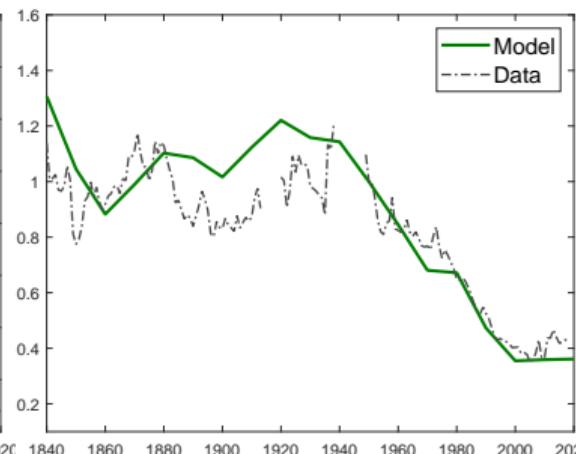


Figure: r -good price

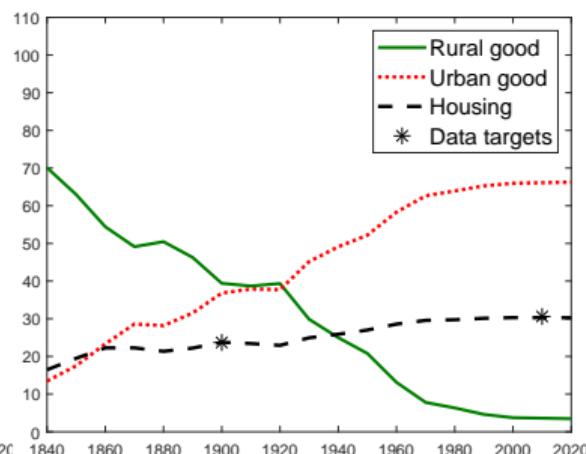


Figure: Spending Shares

Numerical Model Results: Urban Expansion

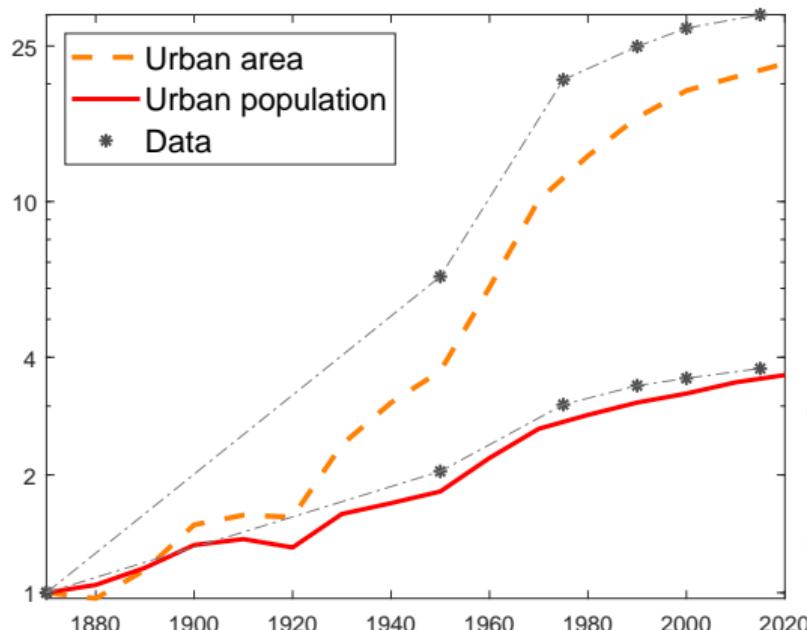


Figure: City Size

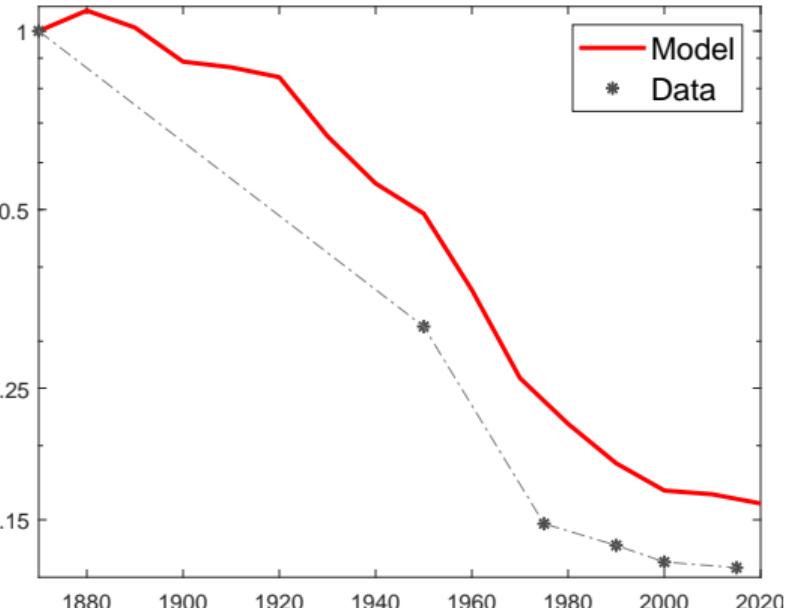


Figure: Avg. urban density

Numerical Model Results: Urban Structure

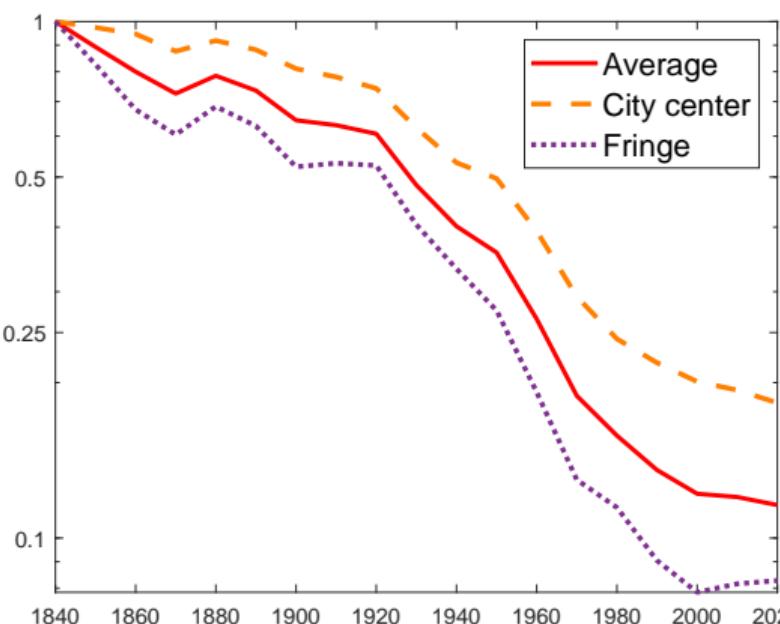


Figure: Urban Density

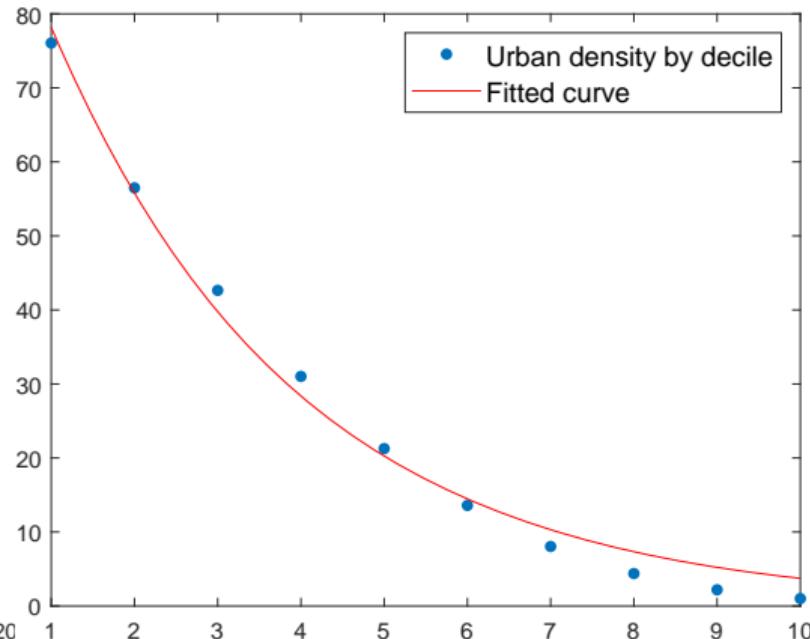
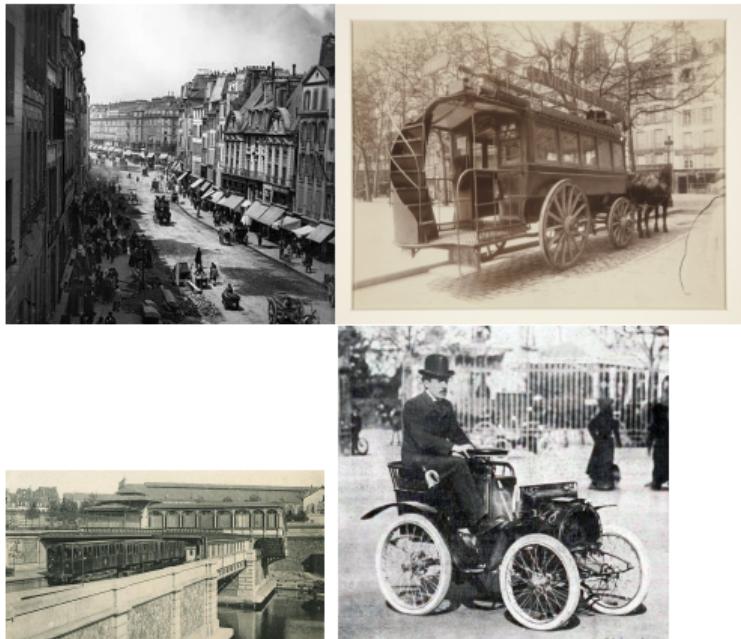
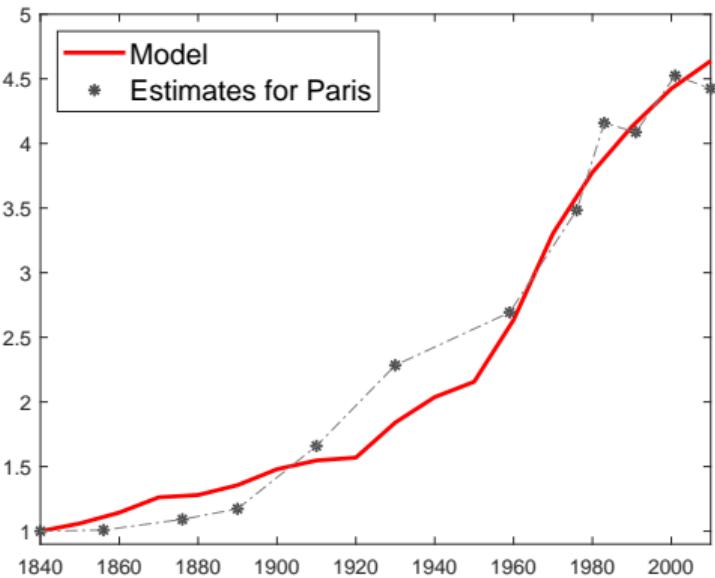


Figure: Density Gradient (2015)

Numerical Model Results: Commuting Speed



Numerical Model Results: Wealth Distribution and House Price

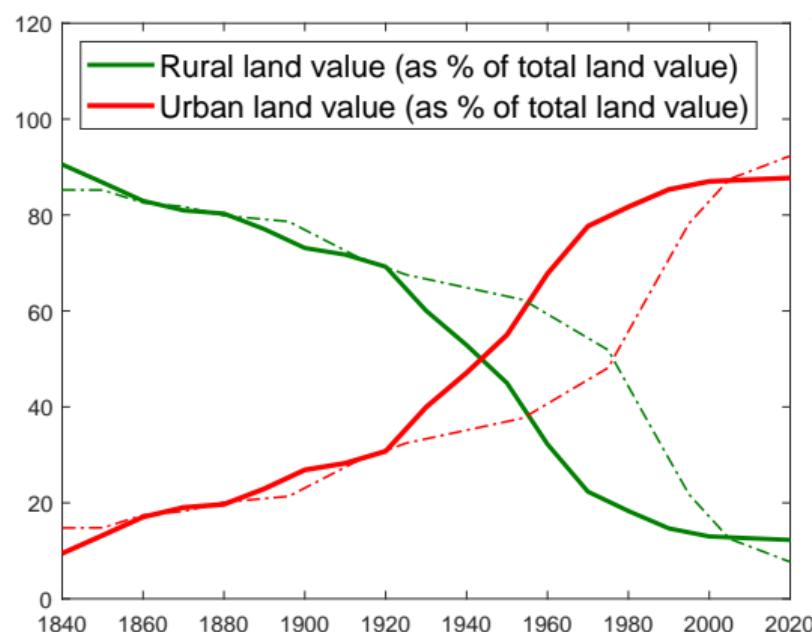


Figure: Urban and Rural Wealth

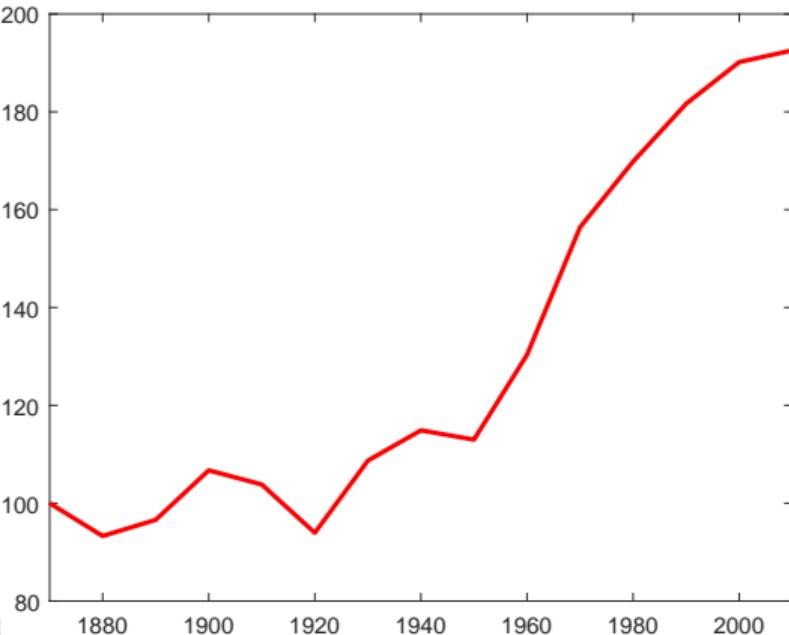


Figure: Real House Price Index

► 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 $\epsilon = 3$. ▶ $\epsilon = 3$

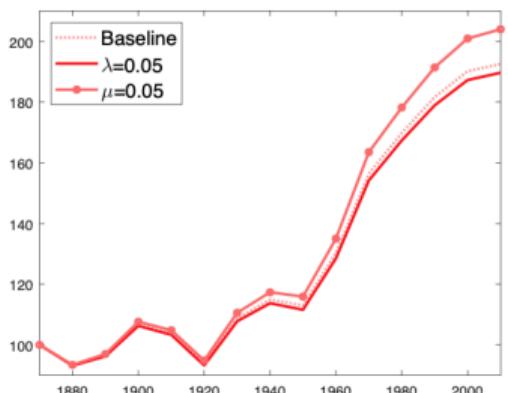
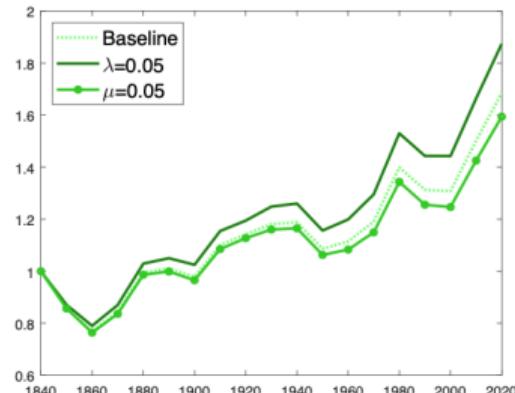
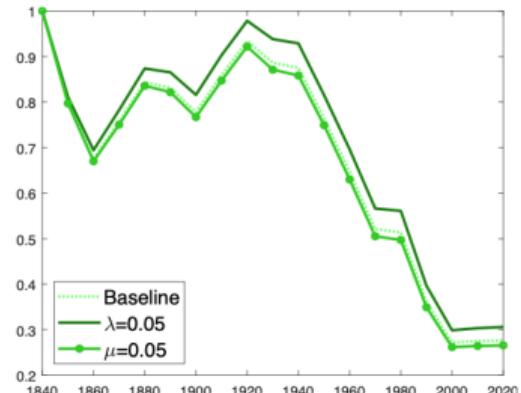
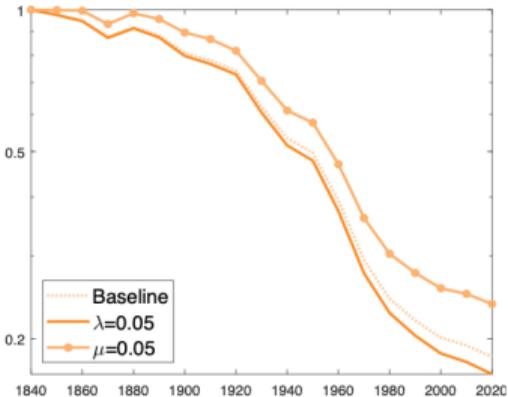
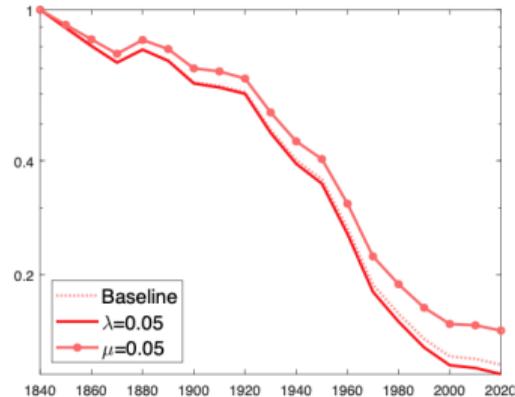
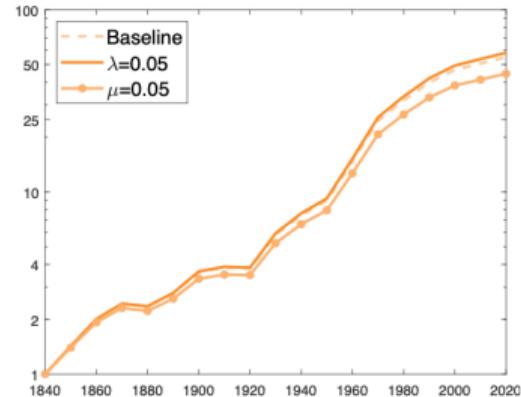
Extensions

1. Agglomeration and Congestion.
2. Multiple Cities.
3. Relaxing Monocentricity.

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



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

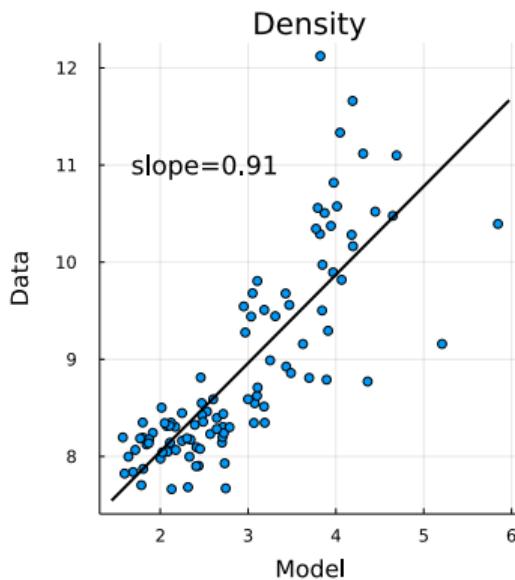
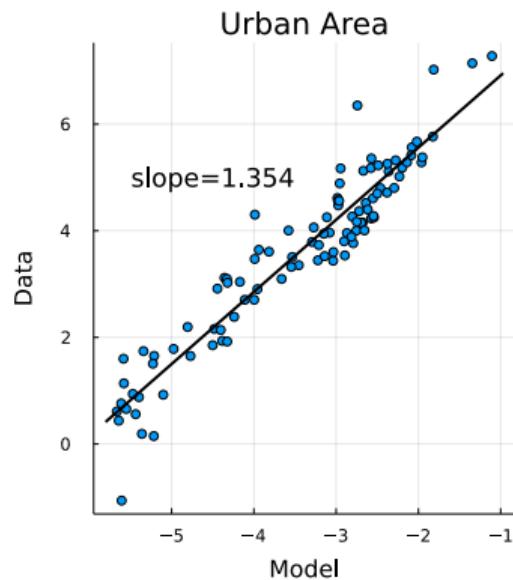
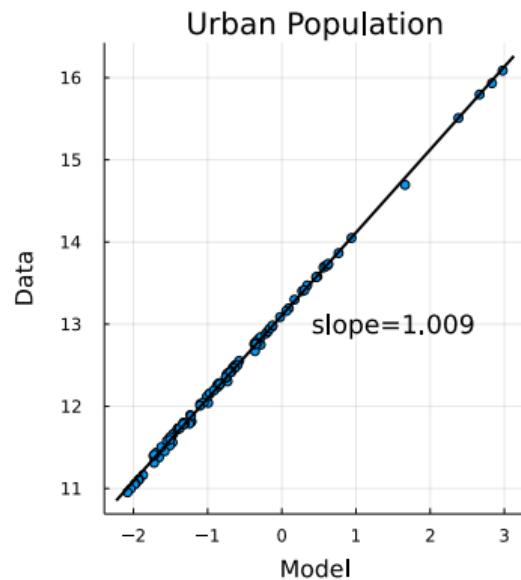
A Country with K Regions

- ▶ 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



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

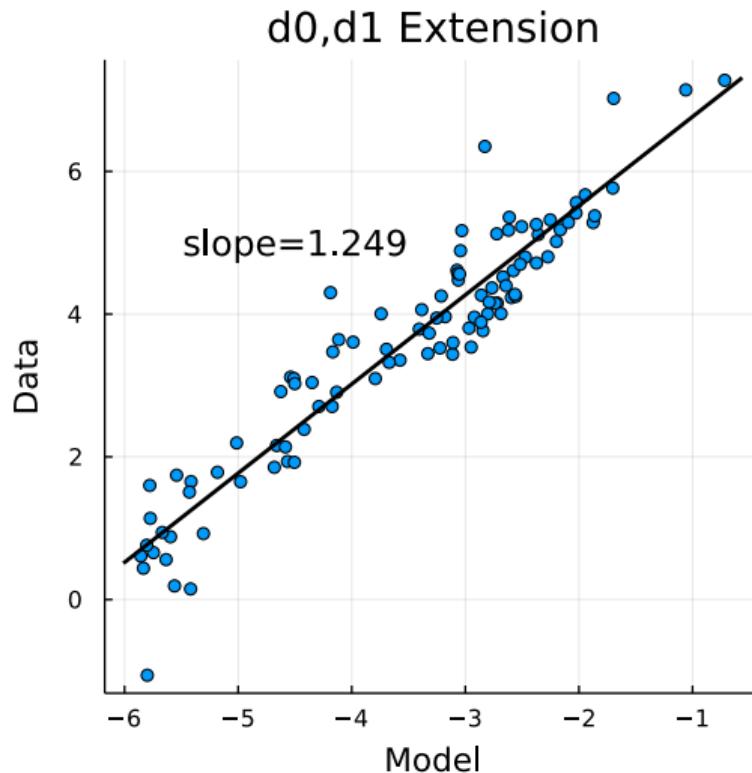
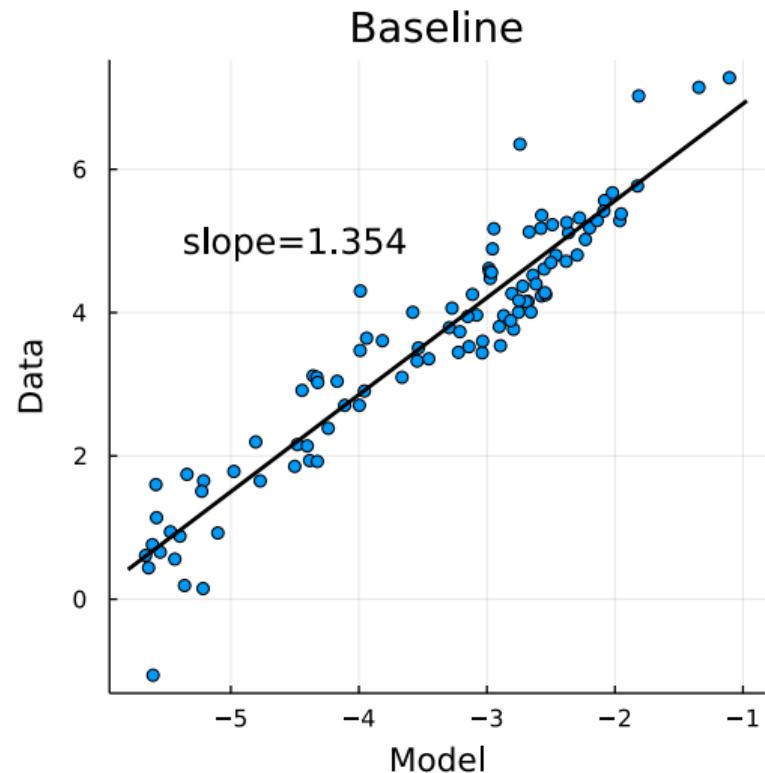
$$d(\ell) = d_0(\phi) + d_1(\phi)\ell$$

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



Conclusion

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

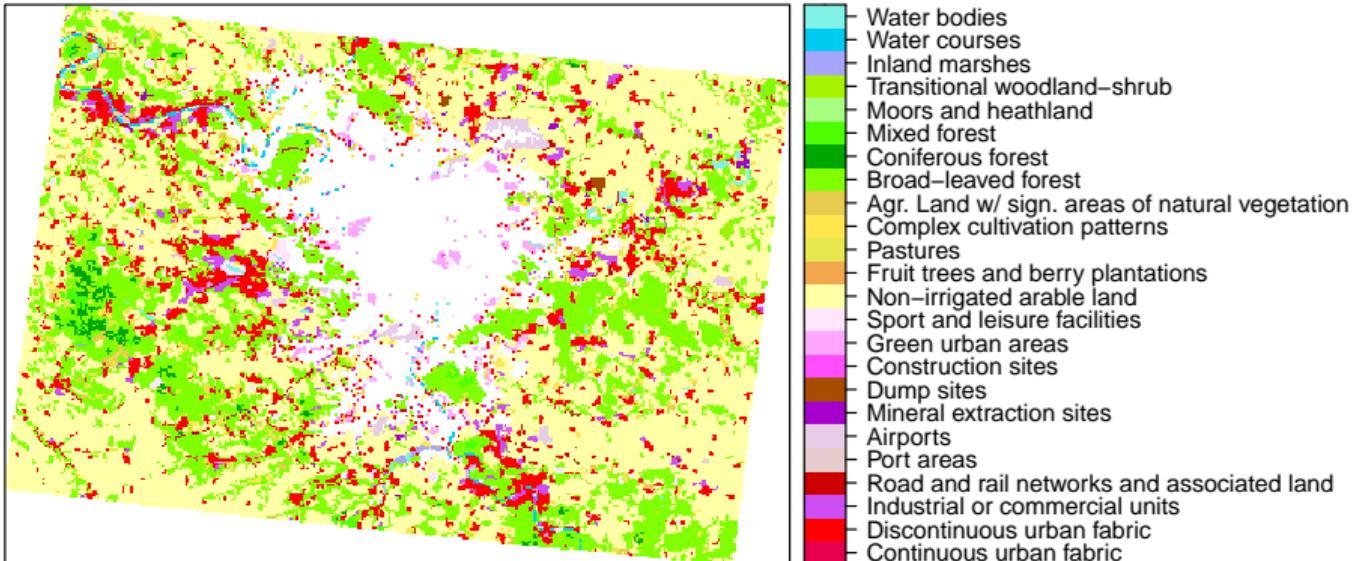
1. Evolution of sectoral allocation across space.
2. Evolution of Urban Density.
3. Evolution of the land value distribution.

We found:

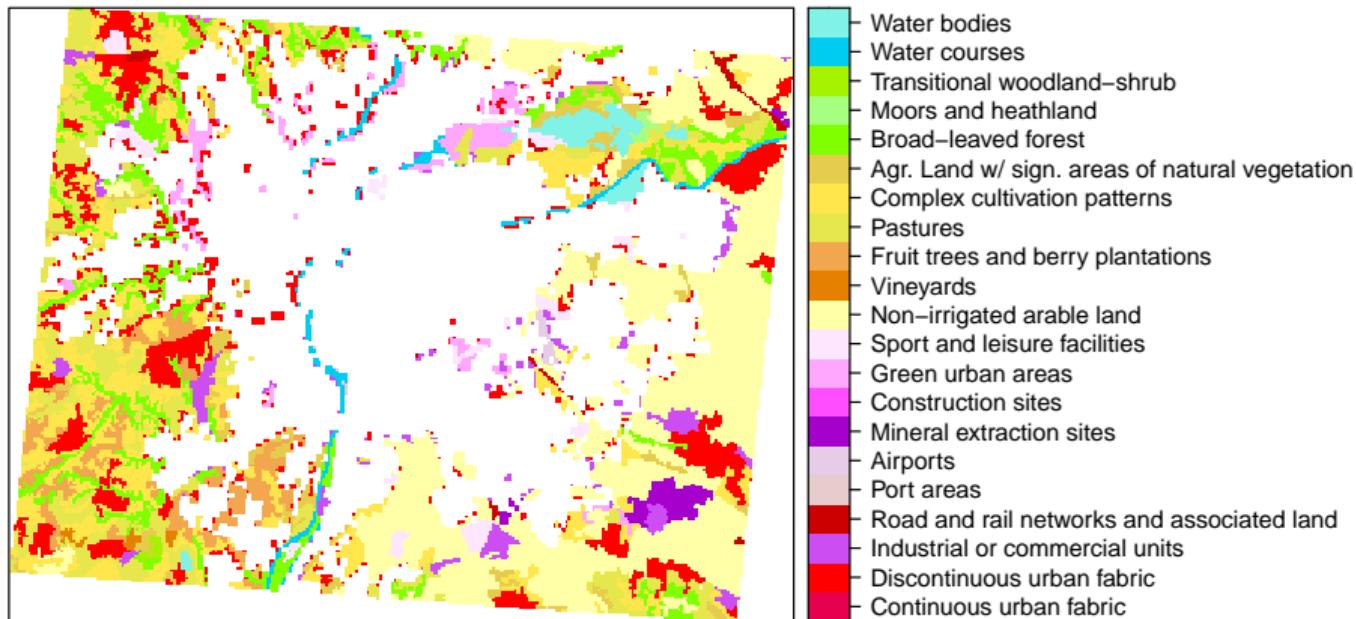
- ▶ Rural Productivity growth is crucial to understand urban expansion.
- ▶ Quantitatively, both rural and urban productivity growth as well as falling commuting costs are needed to explain data.

THANK YOU!

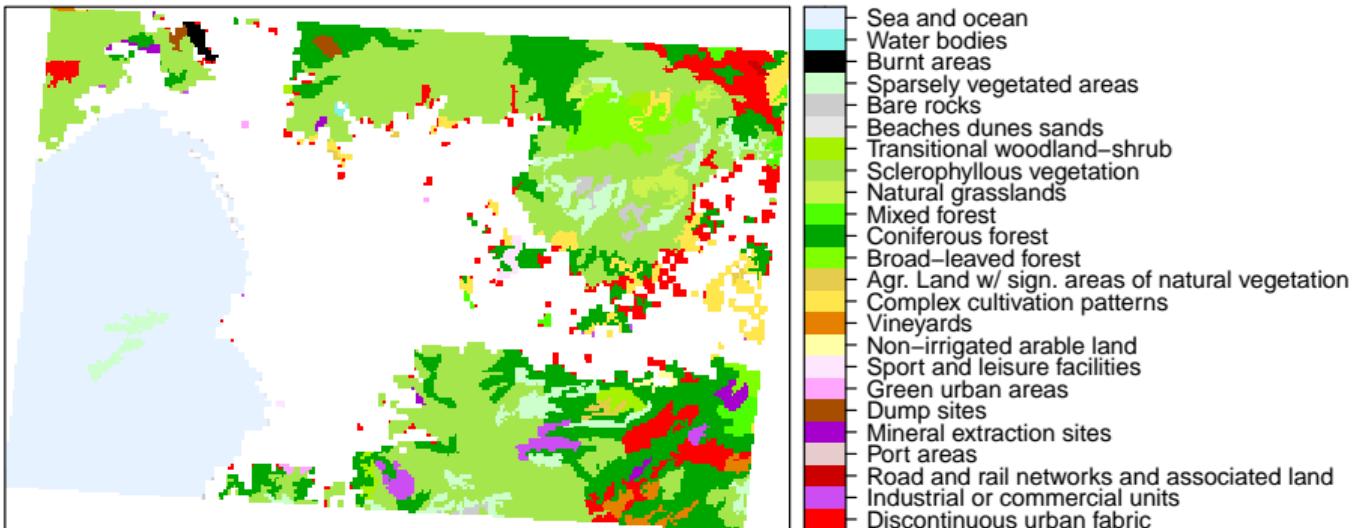
Land Use outside Paris 2020



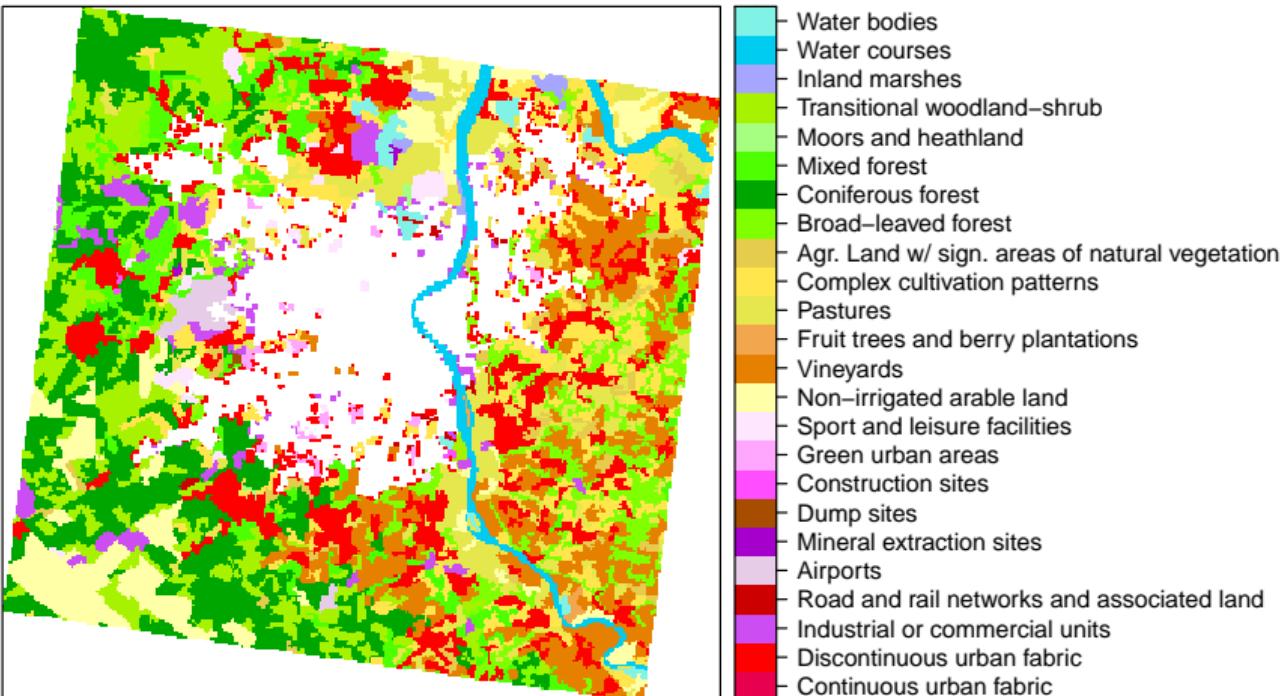
Land Use outside Lyon 2020



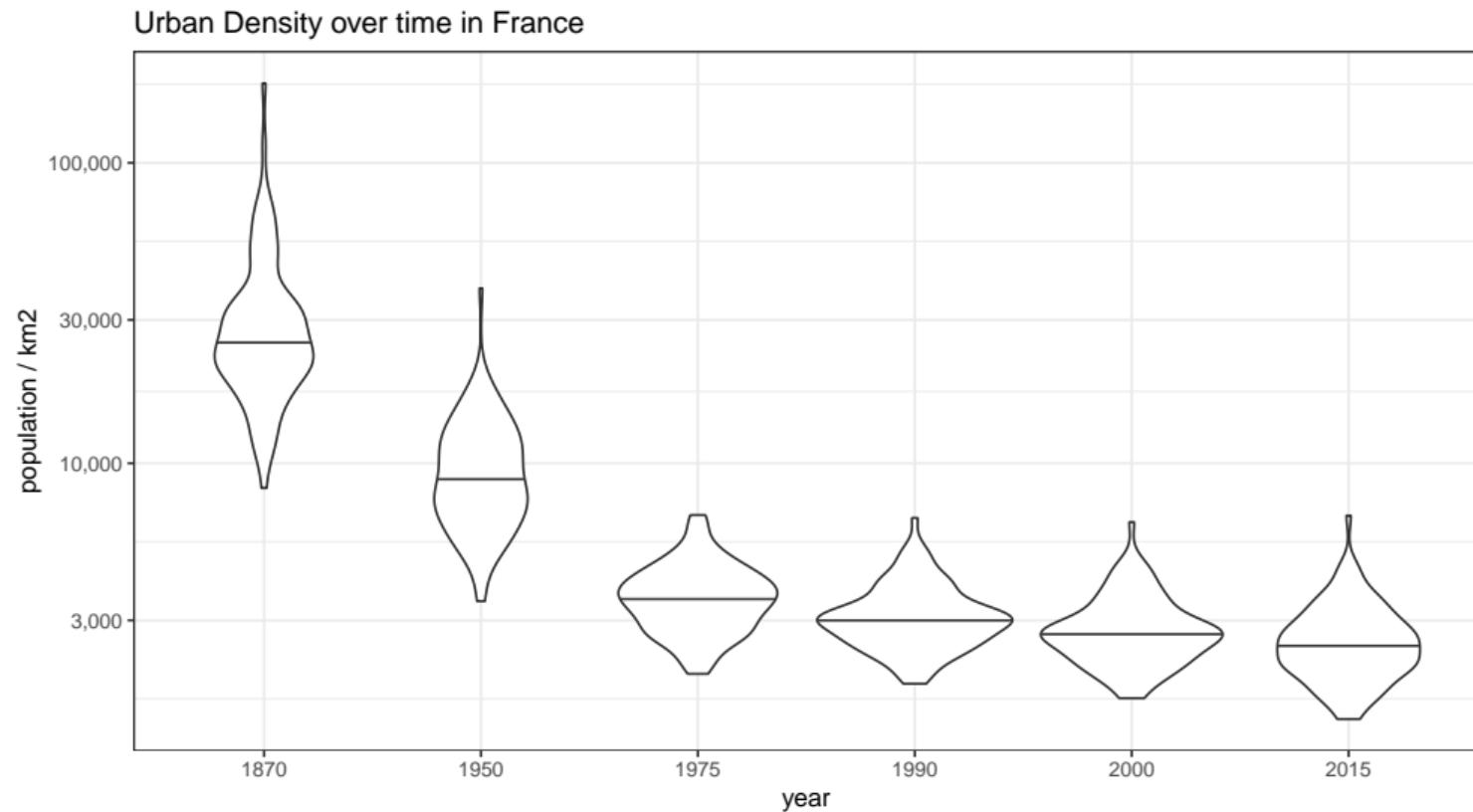
Land Use outside Marseille 2020



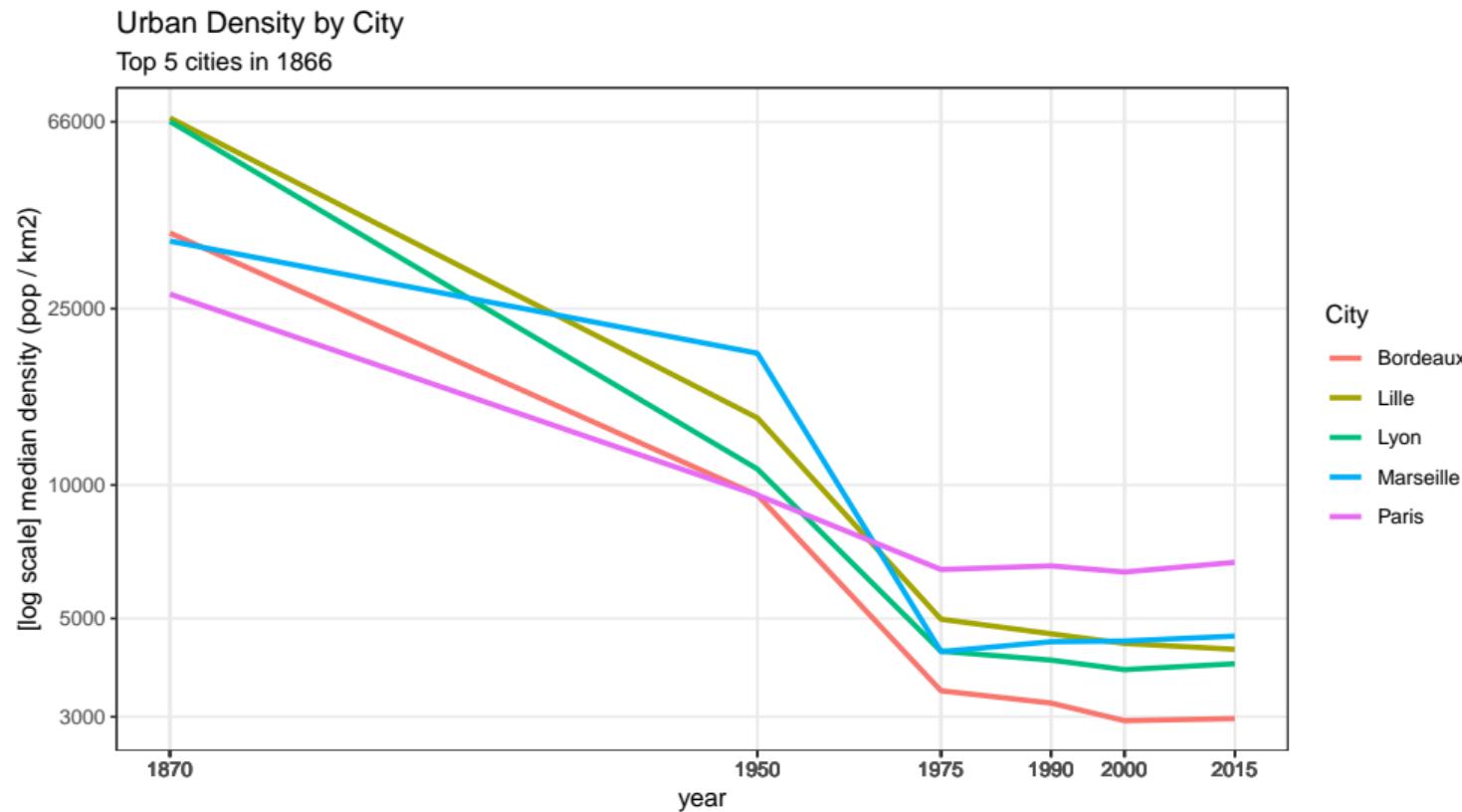
Land Use outside Bordeaux 2020



The historical fall in urban density

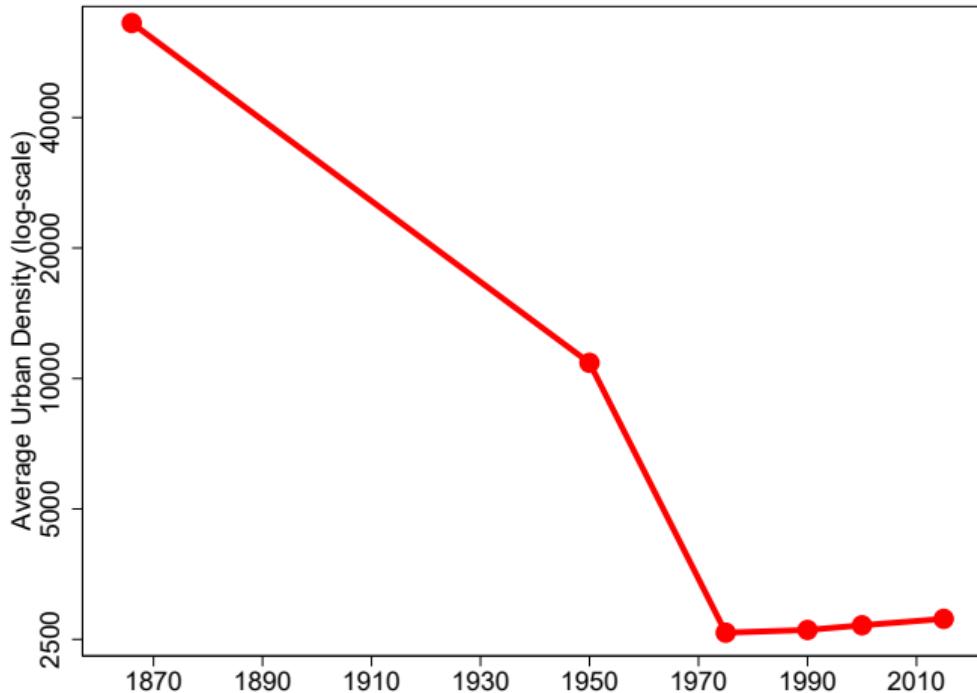


The historical fall in urban density



The historical fall in urban density

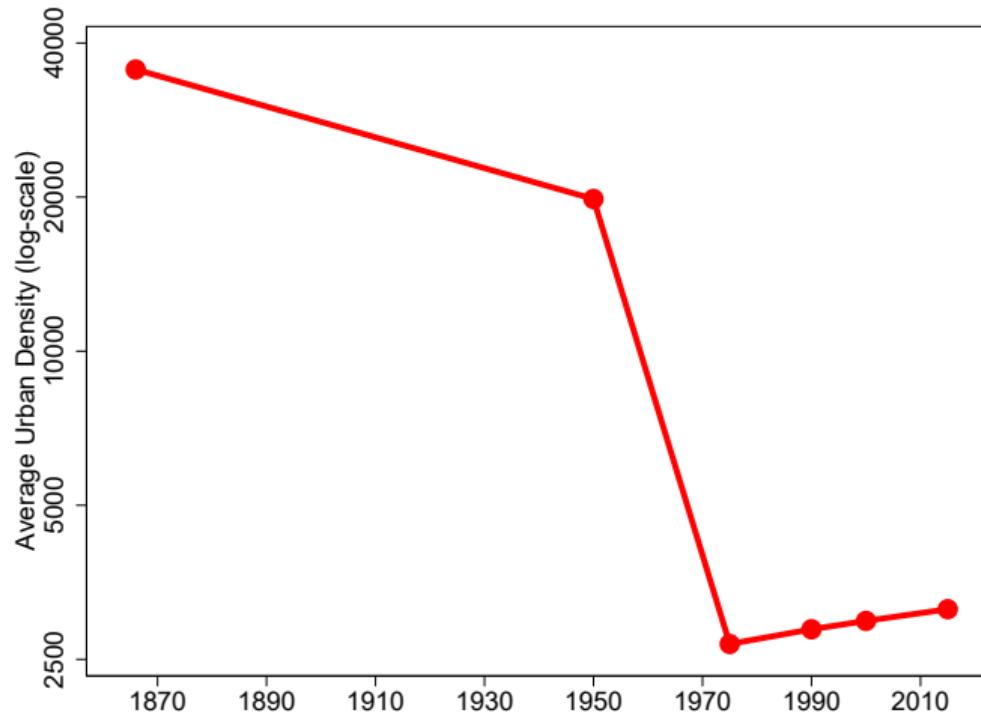
Lyon



▶ back

The historical fall in urban density

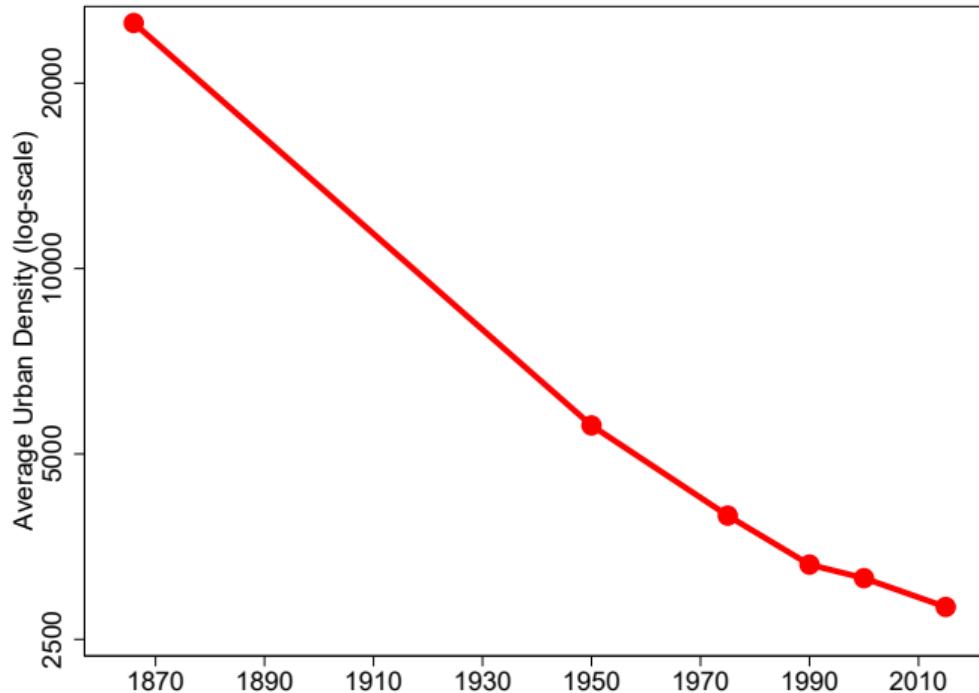
Marseille



▶ back

The historical fall in urban density

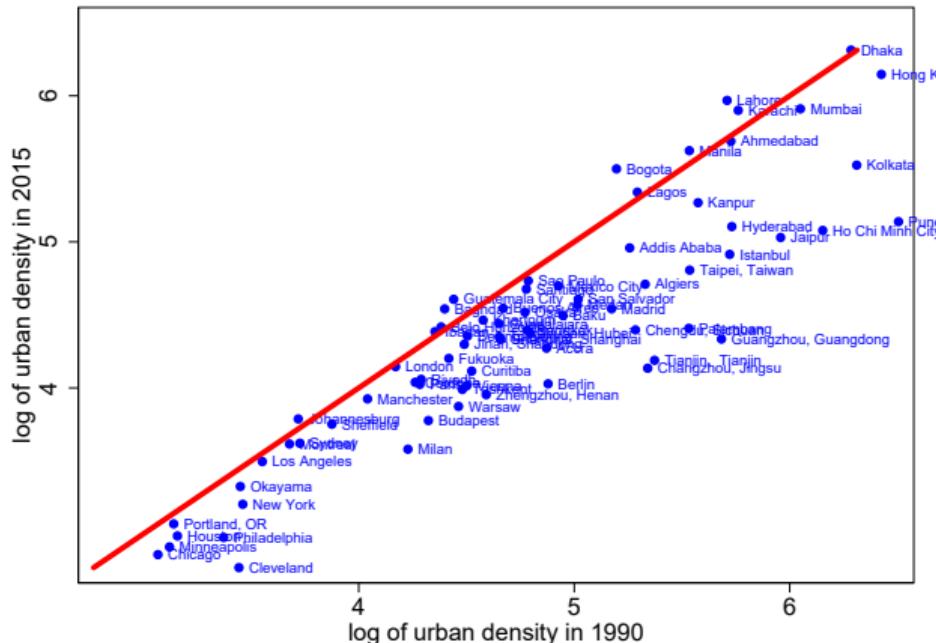
Reims



▶ back

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

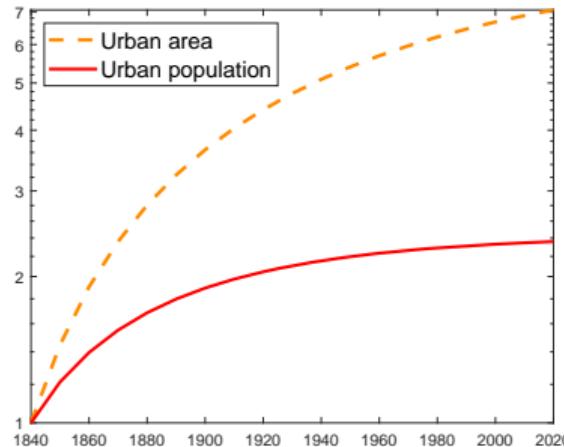
World sample of large cities



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

Numerical Illustrations

Rural Productivity Growth Only

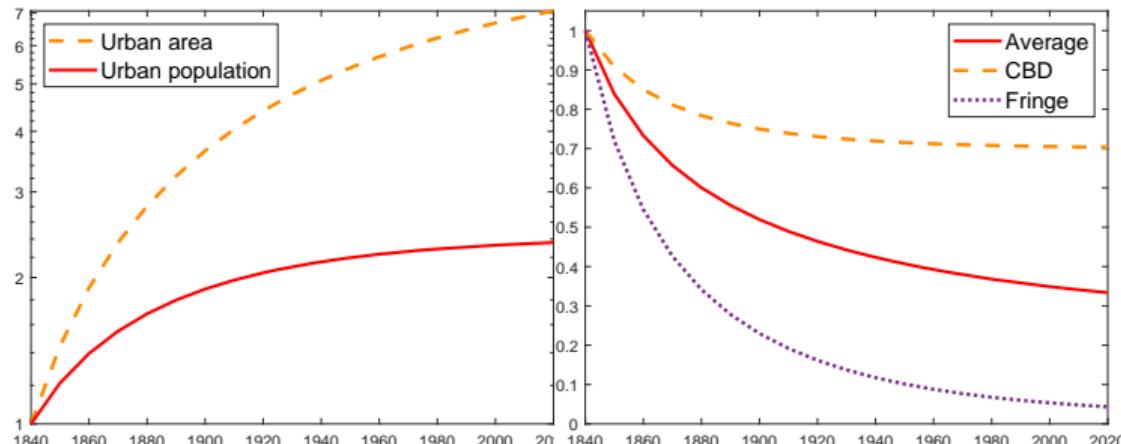


(a) City Size

▶ back

Numerical Illustrations

Rural Productivity Growth Only



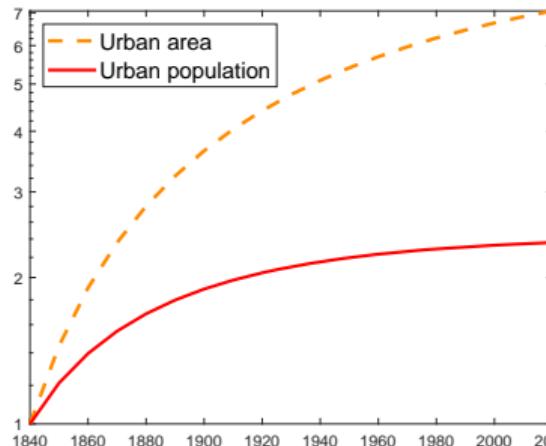
(a) City Size

(b) Urban Densities

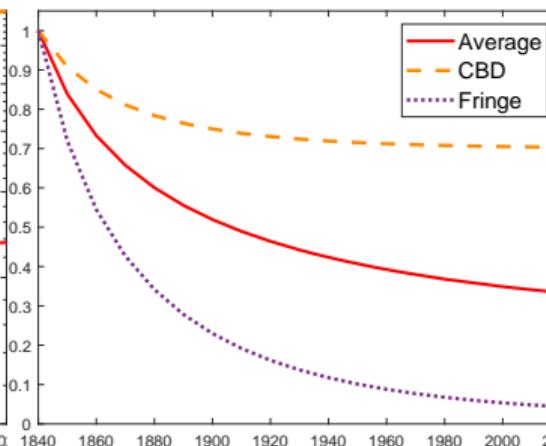
▶ back

Numerical Illustrations

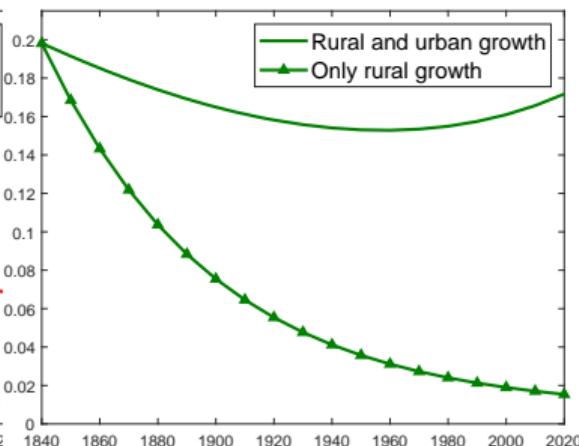
Rural Productivity Growth Only



(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.

ϵ = 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:

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

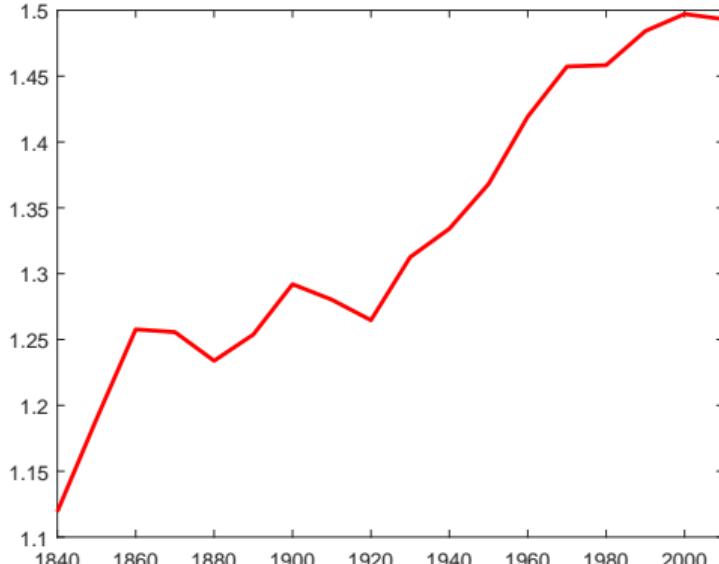
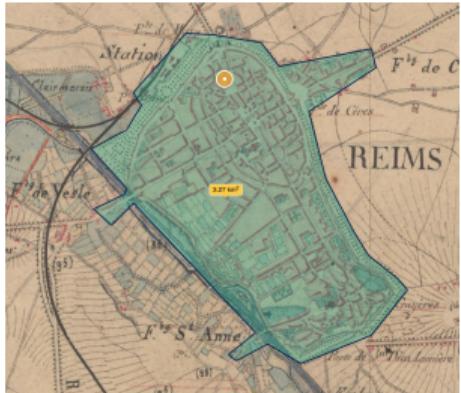


Figure: Agricultural Productivity Gap

▶ back

GHSI Measurement - Reims

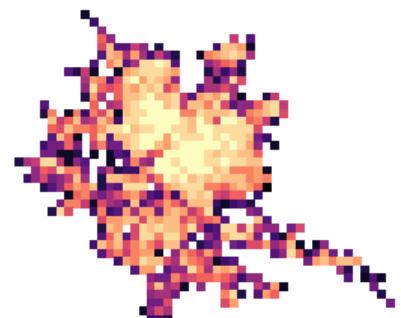
[back](#)



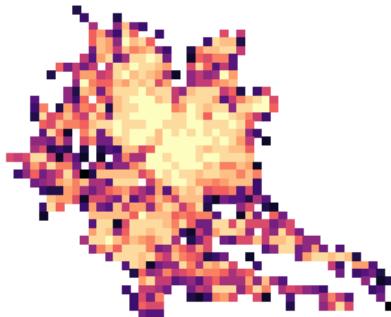
Reims 1975: 31.4 km²



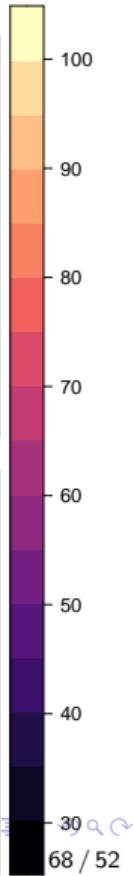
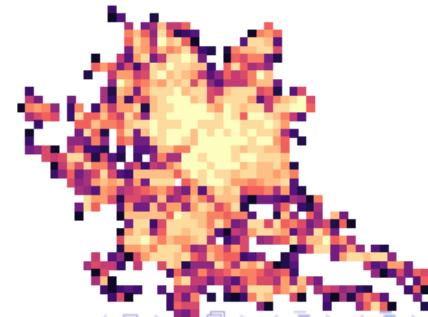
Reims 1990: 43.2 km²



Reims 2000: 49.1 km²

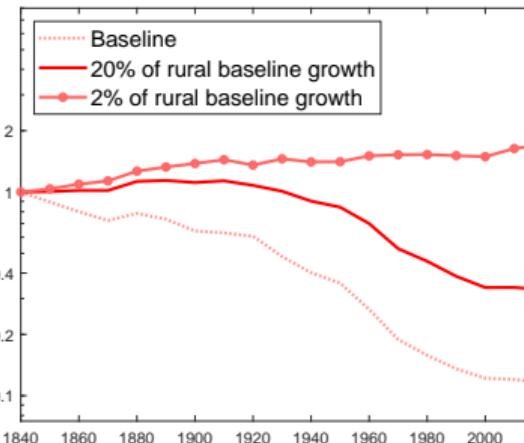


Reims 2015: 55 km²

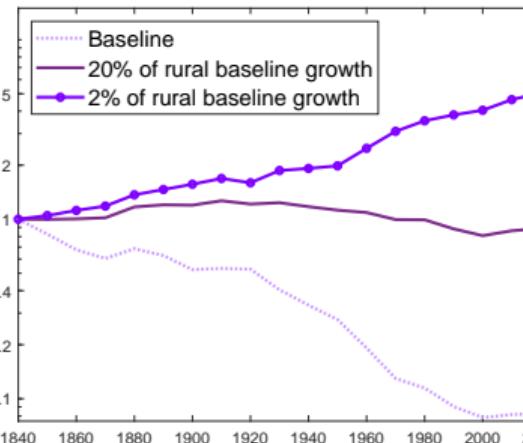


Sensitivity Analysis

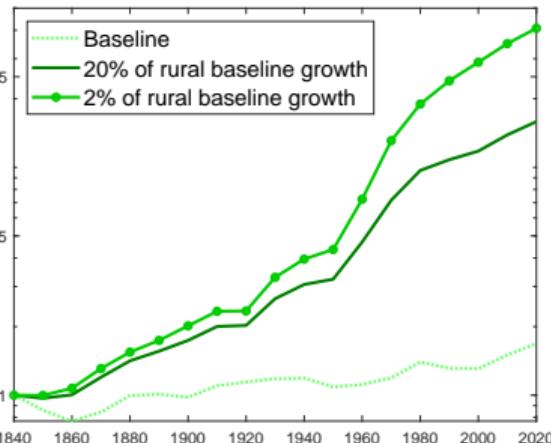
The role of rural productivity growth



(a) Urban Density



(b) Fringe Density



(c) Farmland Price

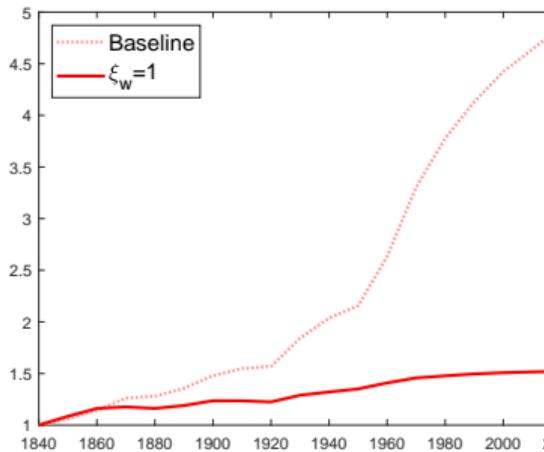
▶ back

Sensitivity Analysis

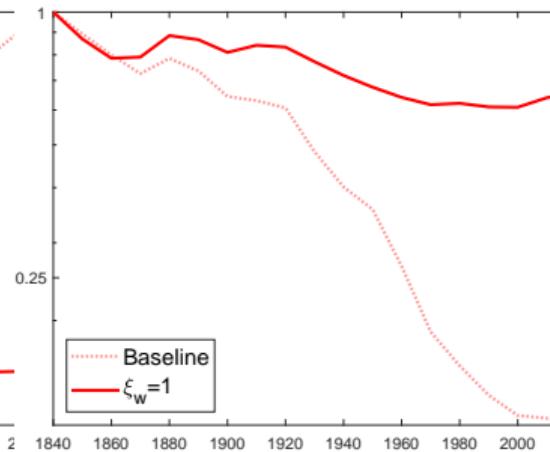
The role of increasing commuting speed

Commuting costs: $\xi_w = 1$

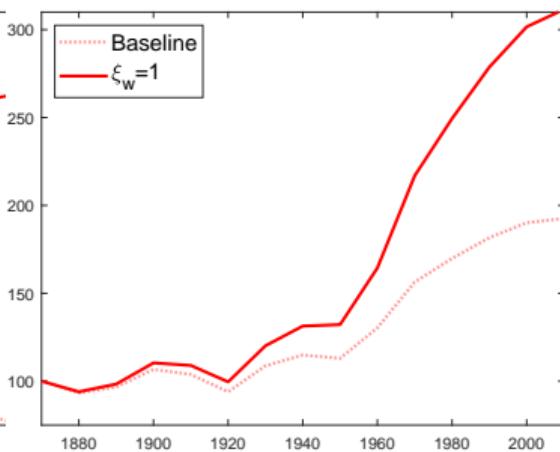
$$\tau(\ell) = a \cdot w_{II}^{\xi_w} \cdot \ell^{\xi_\ell}$$



(a) Commuting speed



(b) Urban Density



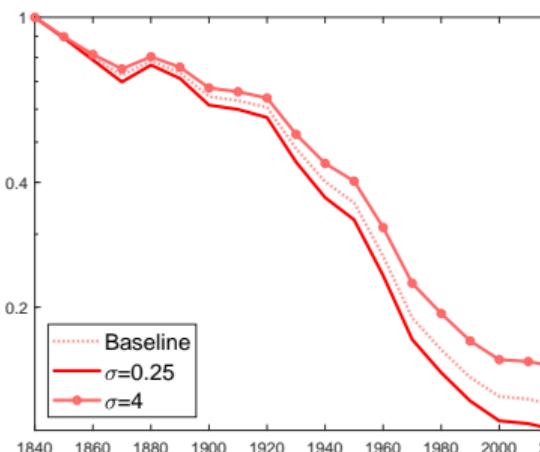
(c) Housing Price Index

Sensitivity Analysis

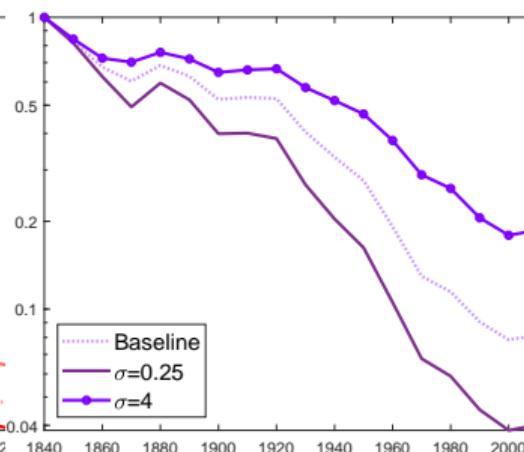
The elasticity of substitution between land and labor in the rural sector

Rural good production function:

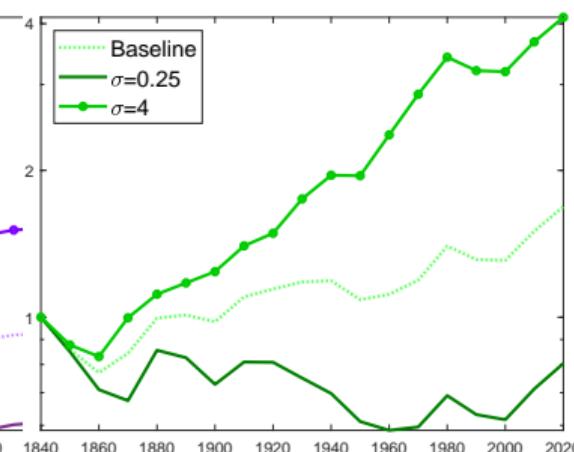
$$Y_r = \theta_r \left(\alpha(L_r)^{\frac{\sigma-1}{\sigma}} + (1-\alpha)(S_r)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$



(a) Urban Density



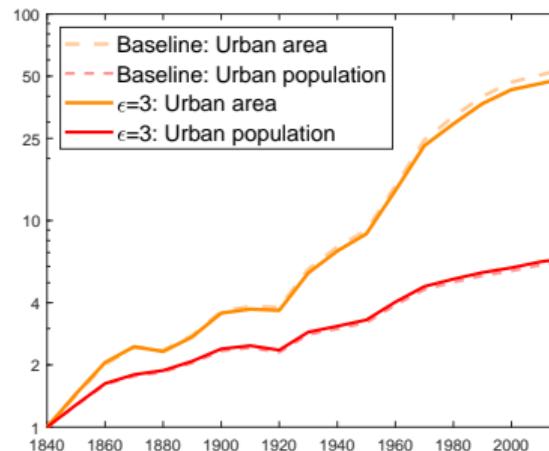
(b) Fringe Density



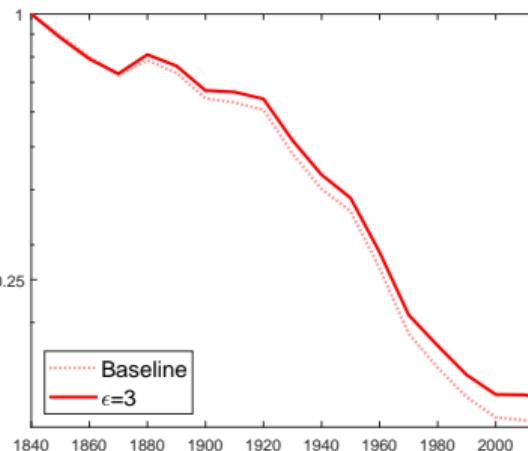
(c) Farmland rental price

Sensitivity Analysis

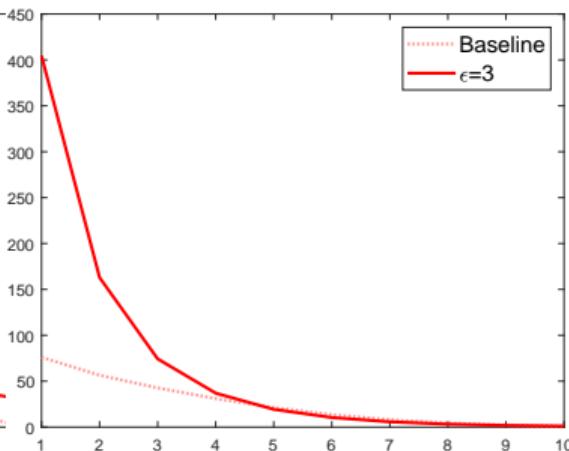
Constant housing elasticity $\epsilon = 3$



(a) City Size



(b) Urban Density



(c) Density by decile (2010)

▶ back

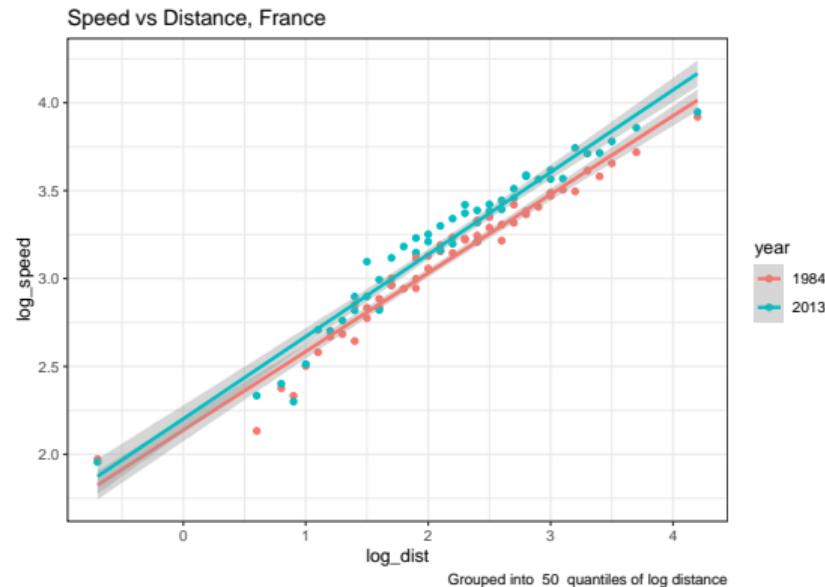
Calibration of τ

- ▶ Micro foundation yields:

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

- ▶ The elasticities 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