

# Structural Change, Land Use and Urban Expansion

Nicolas Coeurdacier (SciencesPo & CEPR)



Florian Oswald (Collegio Carlo Alberto)

Marc Teignier (U. Barcelona)

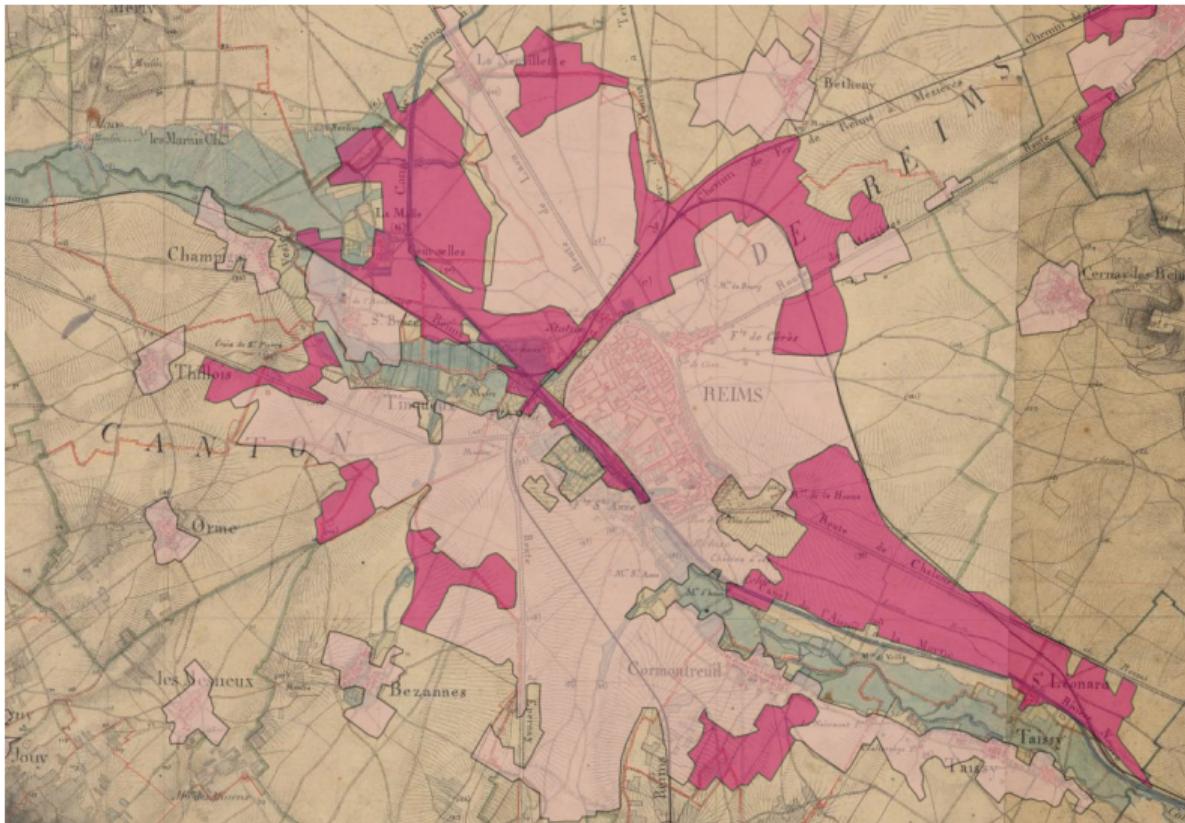


Spring 2025

## Motivation: Reims in 1866



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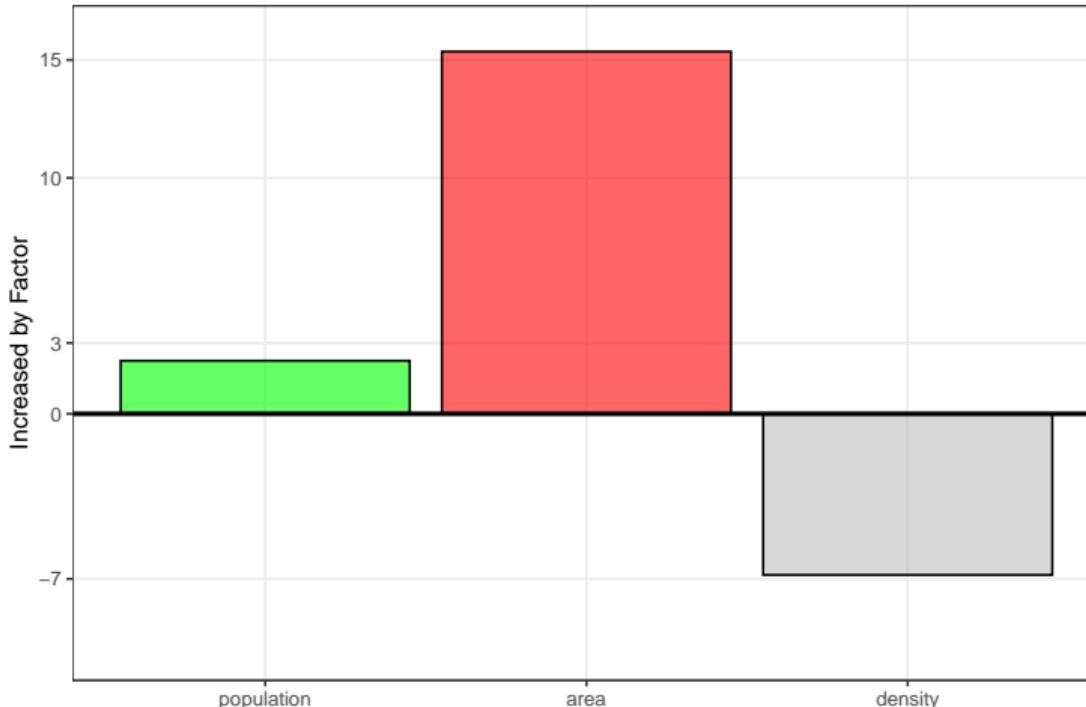


## Motivation: Reims in 1950 vs IGN Buildings in 2017



# 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?

# Urban Expansion: Different Views

## 1. Urban Economics:

- ▶ Decline in commuting cost over time allows residing further away from city centre.
- ▶ New technologies (🚗 🚛 🚅) enable suburbanisation. 🏠

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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

- ▶ **Early Period:** 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.
  - ▶ 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

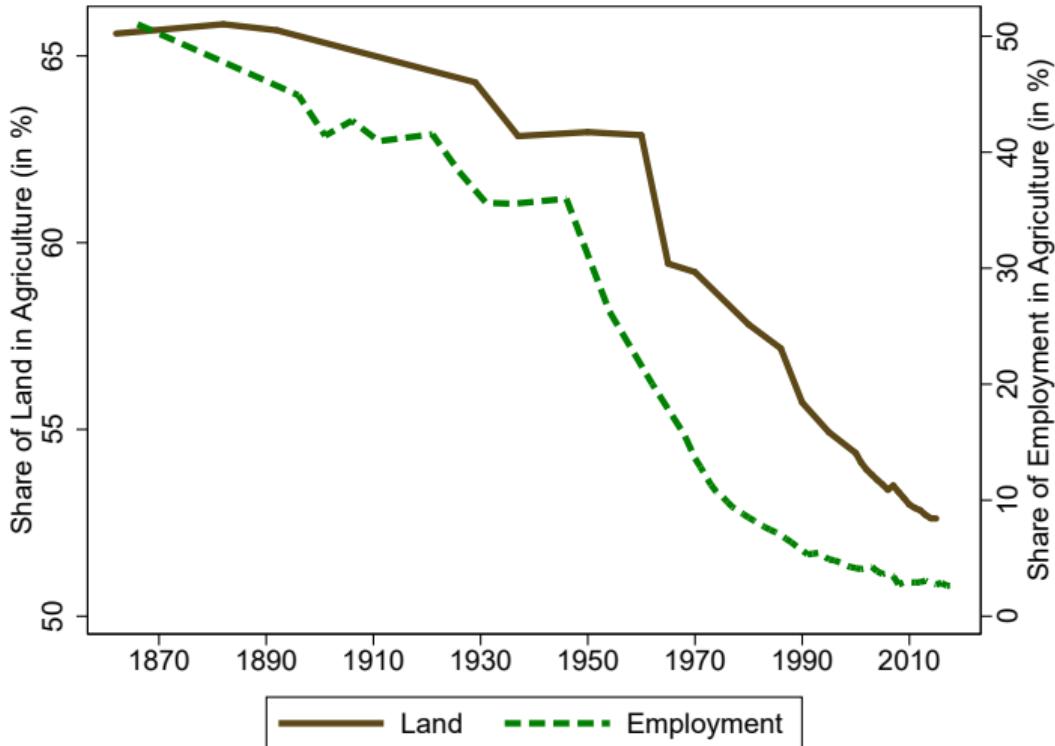
1. Facts about Land use and Urban Expansion in France since 1840.
2. Theory
  - ▶ A general equilibrium model of structural change and land use
3. Quantitative analysis
  - ▶ Simple Version to generate intuition
  - ▶ Extended Quantitative Model to Match French data since 1840

# **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

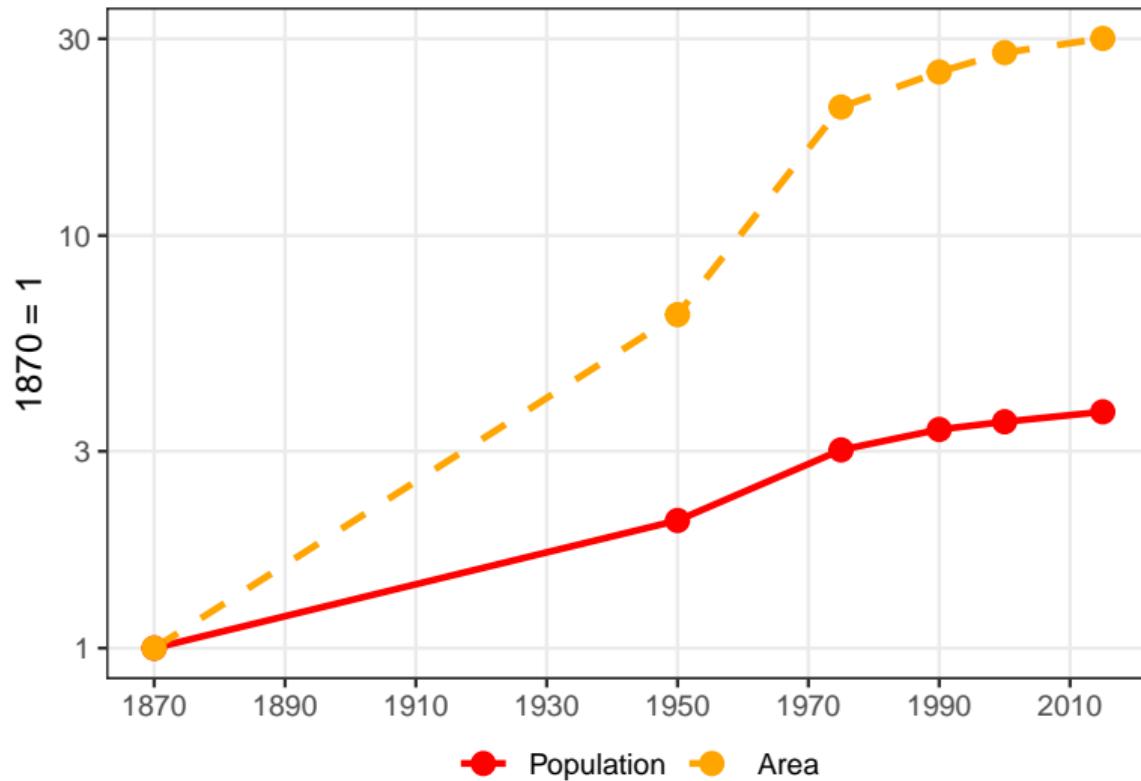


Sources:

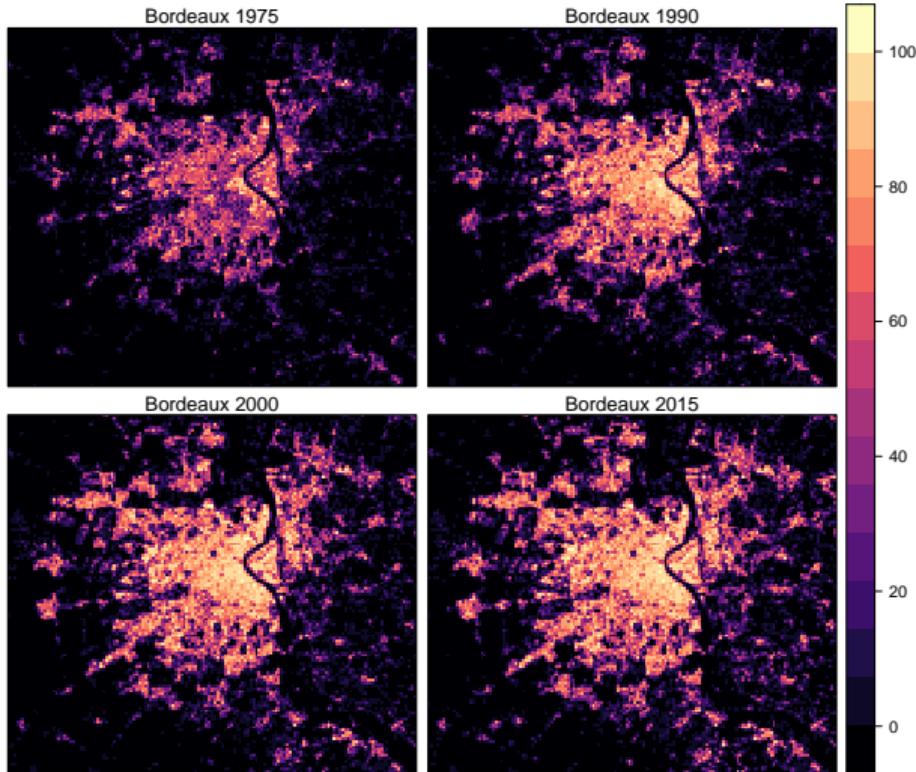
1. Toutain (1993)
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3. INSEE
4. Villa (1996)

# Urban Expansion

Top 100 Cities in France

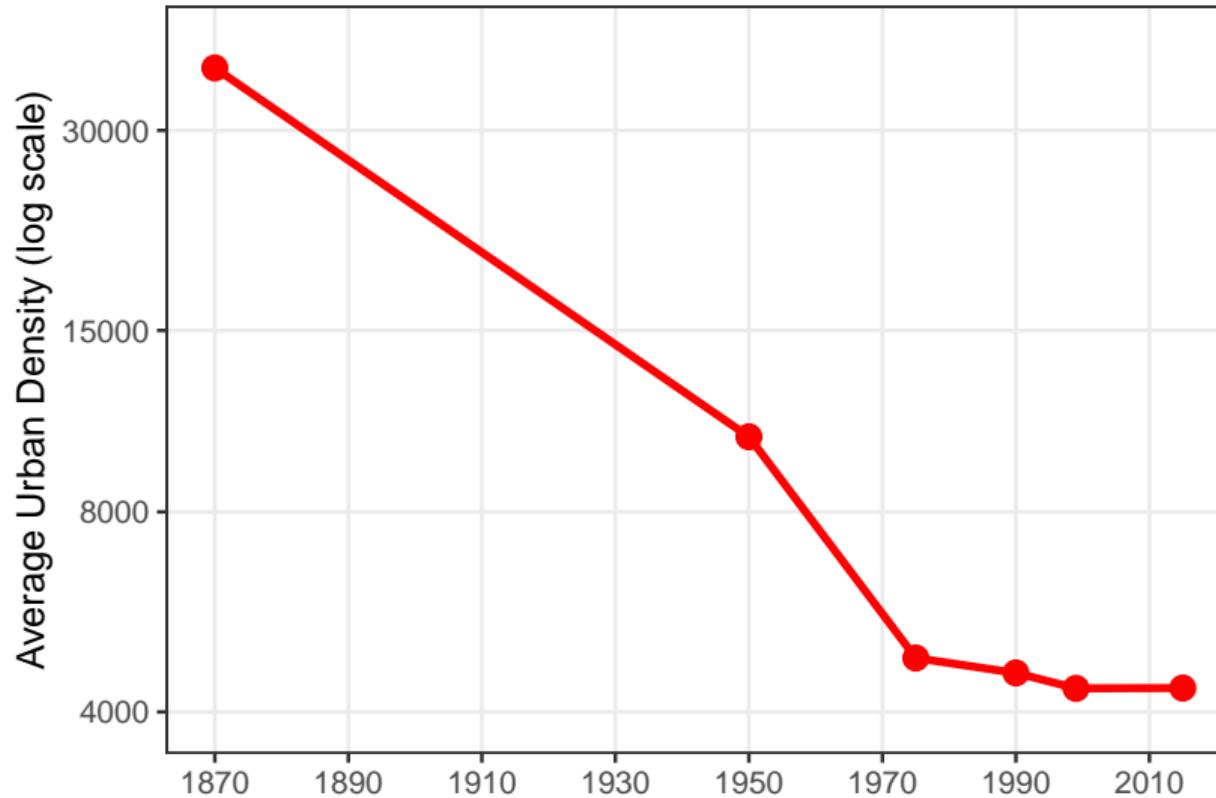


# City Area and Population Measurement

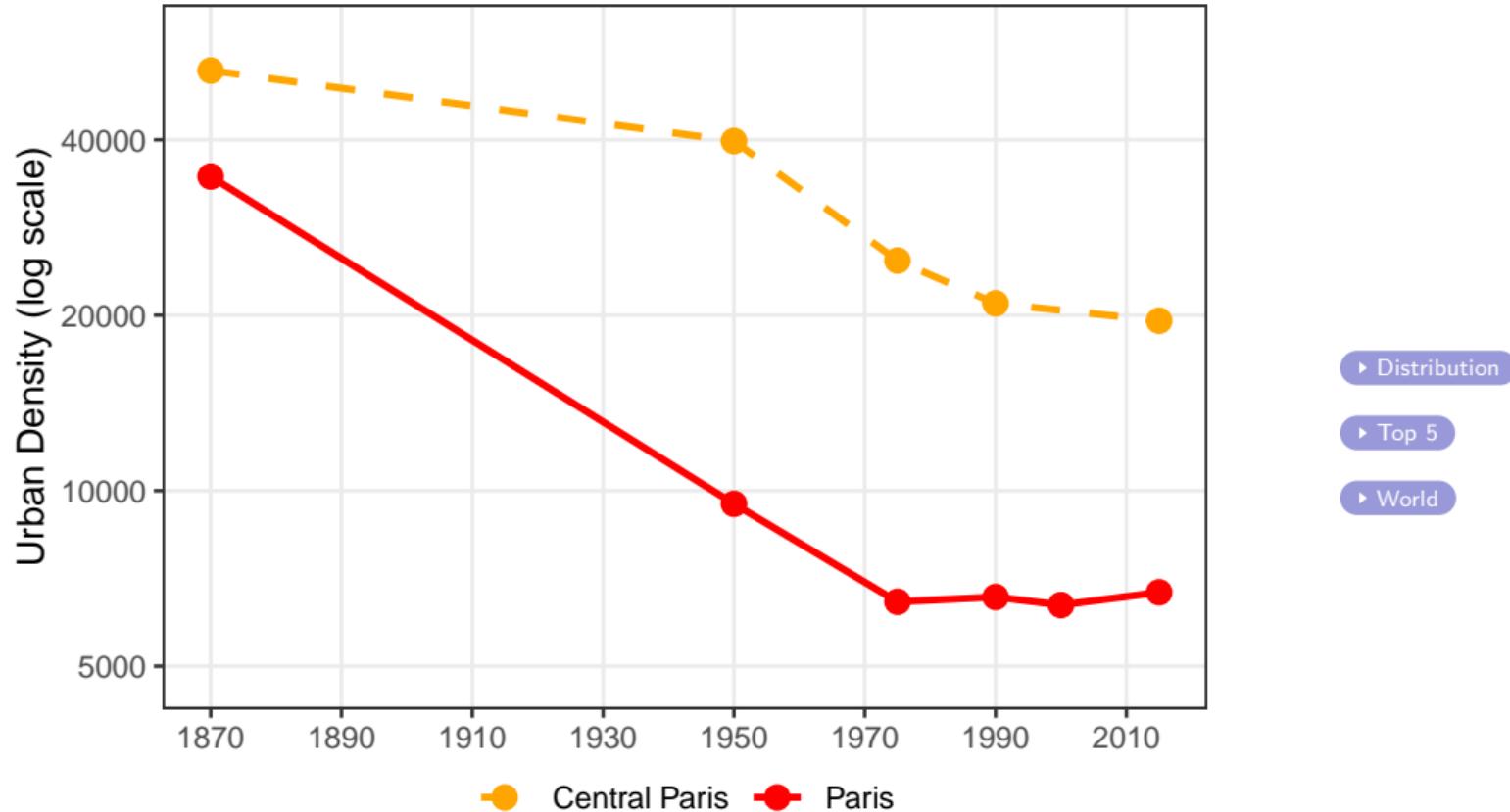


- ▶ 1866: Manual + Census
- ▶ 1950: Manual + Census
- ▶ 1975, 1990, 2000, 2015: GHSL
- ▶ More details please!

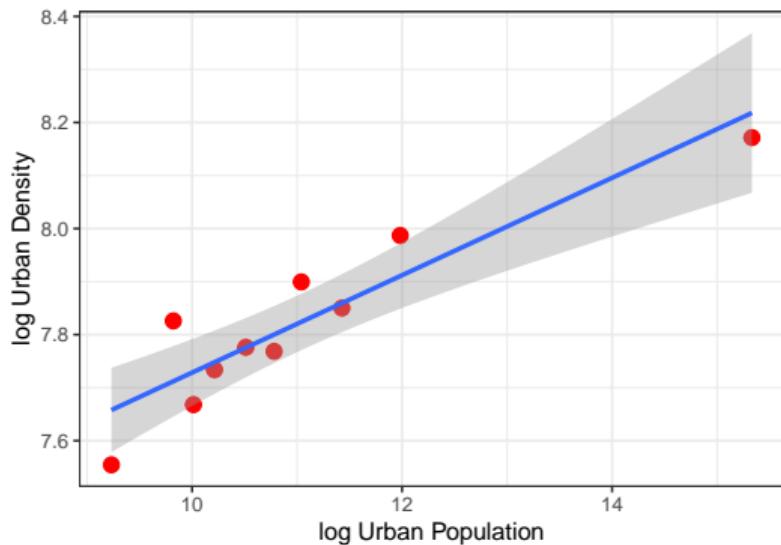
# The Historical Fall in French Urban Density



# The Historical Fall in Urban Density: Within Paris

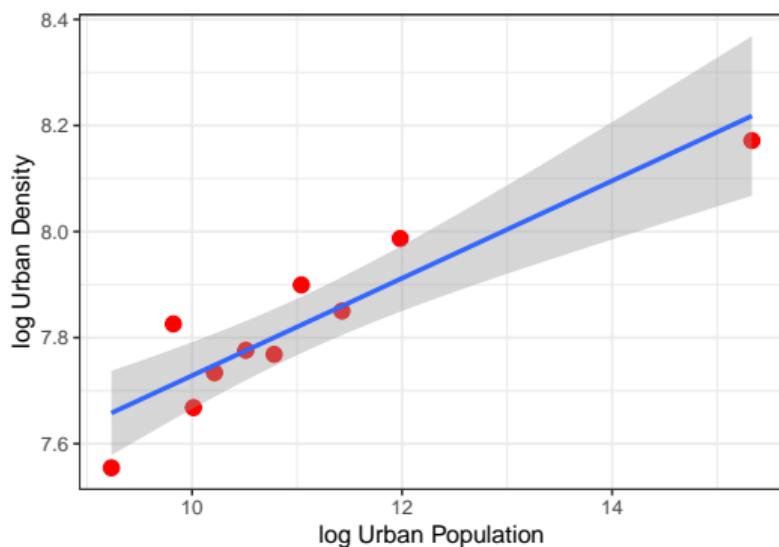


# Urban Density vs Farmland Price and Population (year 2000)

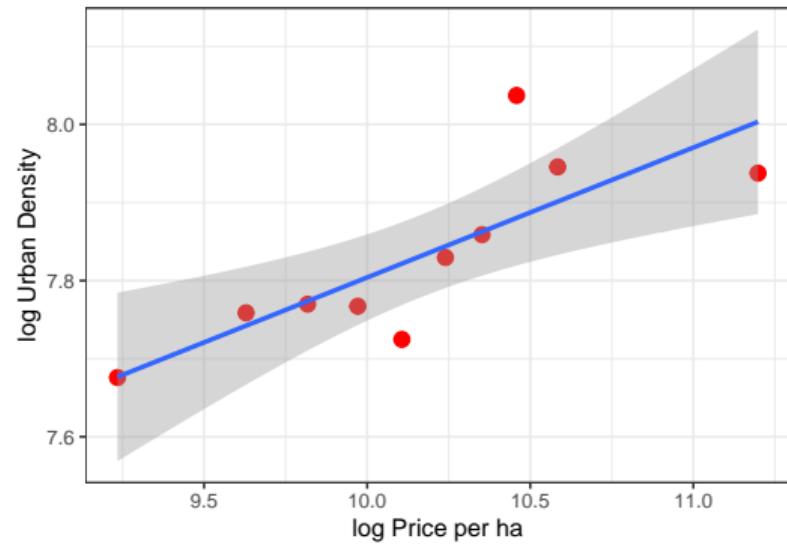


Well known: More populated cities are denser on average.

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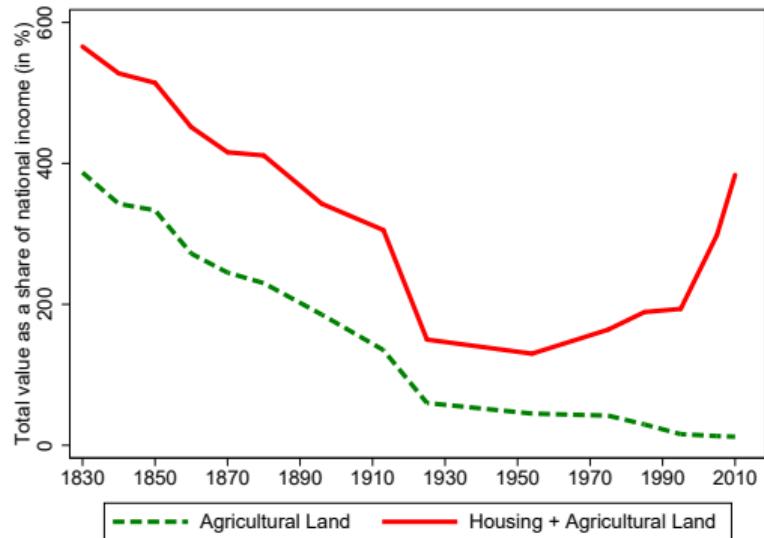
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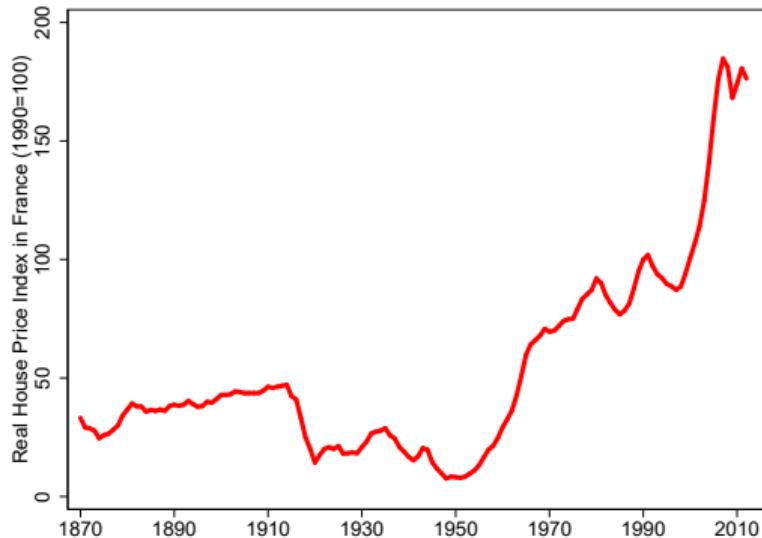
Less known: surrounding farmland and density are positively correlated.

▶ Fringe Land Use?

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



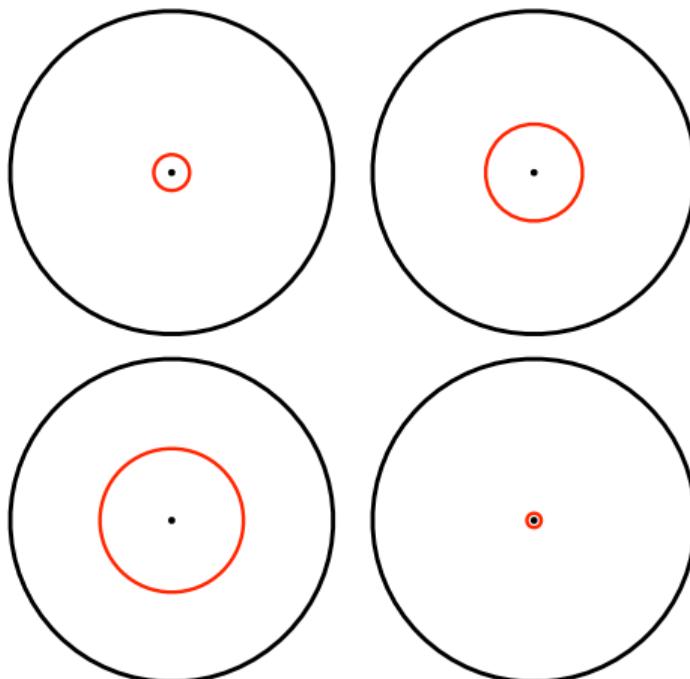
(a) Picketty and Zucman (2014)



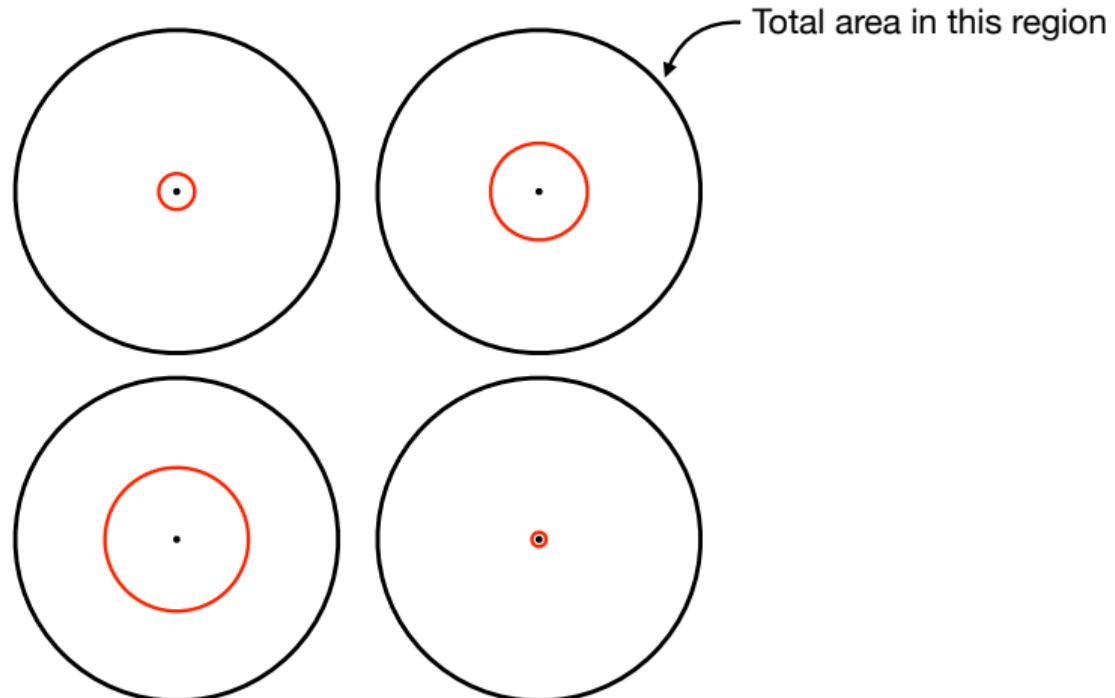
(b) Hockey Stick: Knoll et al. (2017)

# Model

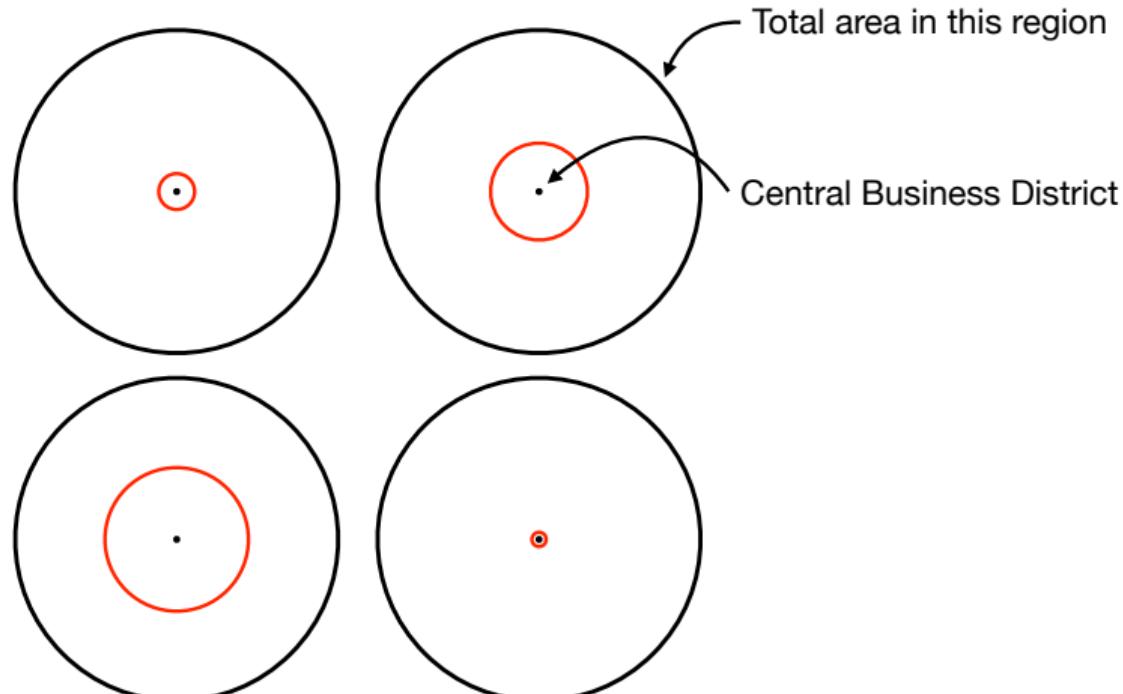
## Model: Spatial Setup



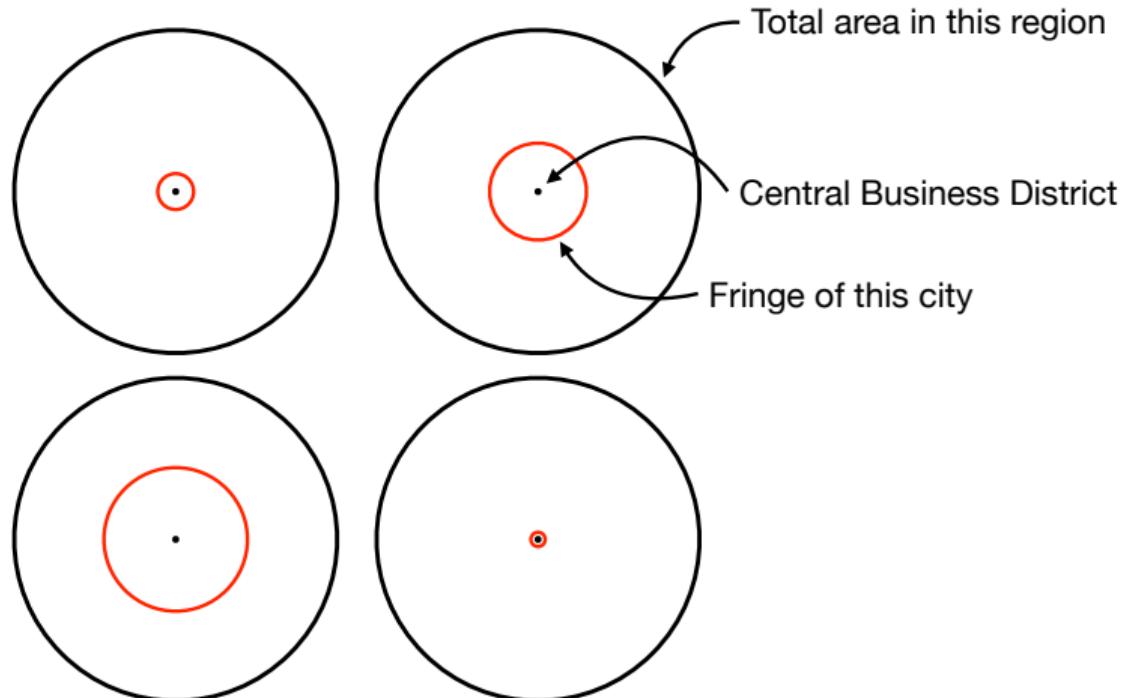
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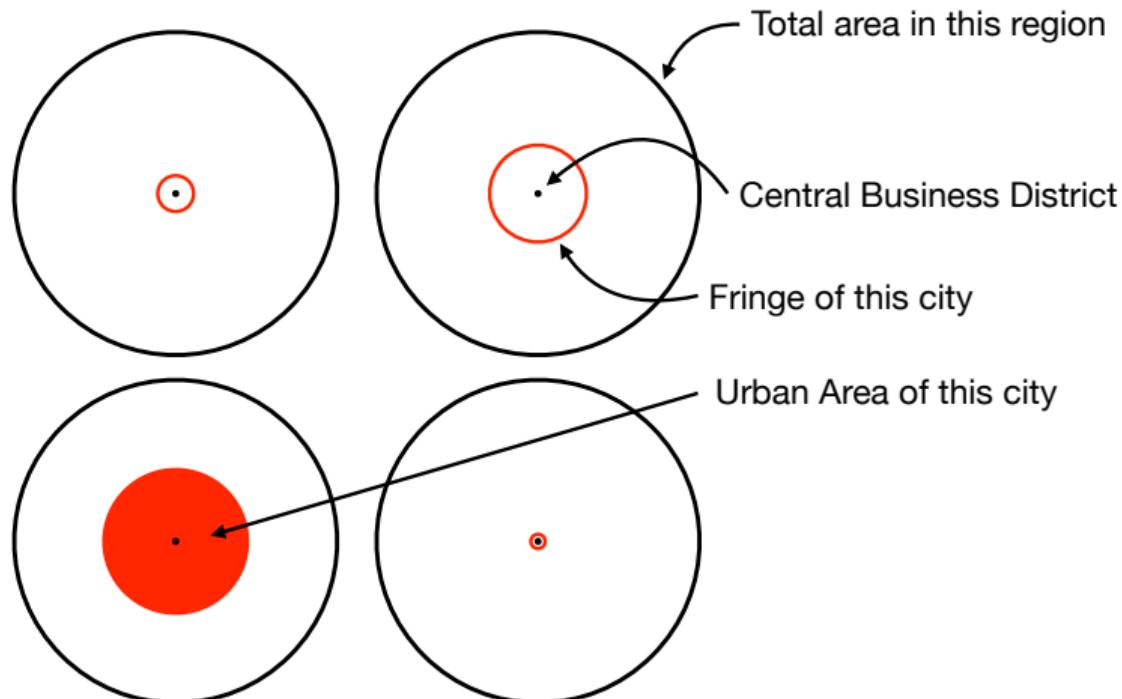
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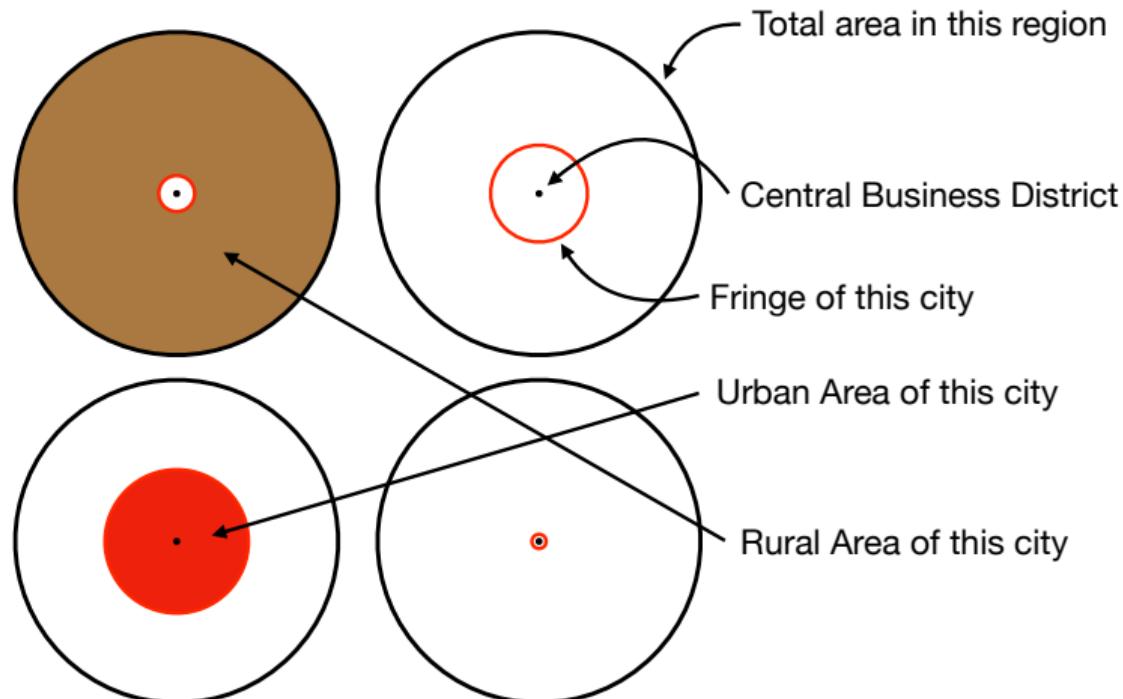
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- ▶ Economy consists of  $K$  regions of identical circular shape, but different productivities in their rural ( $r$ ) and urban ( $u$ ) sectors. At the center of each region  $k$  lies a single city.

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- ▶ 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, Rural goods and Housing Production

- ▶ For the urban good, only labor for simplicity,

$$Y_{u,k} = \theta_{u,k} L_{u,k}.$$

- ▶ For the rural good,

$$Y_{r,k} = \theta_{r,k} \left( L_{r,k}^\alpha \cdot S_{r,k}^{1-\alpha} \right).$$

- ▶  $\theta_{i,k}$  = TFP in sector  $i$ ,  $L_{i,k}$  = labor used in  $i$ ,  $S_{r,k}$  = land used in  $r$  in region  $k$ .
- ▶ Rural good more intensive in land, stronger decreasing returns to labor in ( $r$ ).
- ▶ Land developers produce  $H(\ell_k)$  units of housing space per unit of land.

## Preferences and budget constraint

- ▶ Preferences for an individual in location  $\ell$  are

$$C(\ell_k) = \mathcal{C}(c_r(\ell), c_u(\ell))^{1-\gamma} h(\ell_k)^\gamma$$

where non-homotheticity between rural and urban good is in  $\mathcal{C}$ :

$$\mathcal{C}(c_r(\ell), c_u(\ell)) = \left[ \nu^{1/\sigma} (c_r(\ell) - \underline{c})^{\frac{\sigma-1}{\sigma}} + (1-\nu)^{1/\sigma} (c_u(\ell) + \underline{s})^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

- ▶ Budget constraint,

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

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

# Factor Payments

Urban wage,

$$w_{u,k} = \theta_{u,k},$$

with ( $u$ ) good numeraire.

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Rural wage  $w_{r,k}$  and rental price of rural land  $\rho_{r,k}$ ,

$$w_{r,k} = \alpha p \theta_{r,k} \left( \frac{S_{r,k}}{L_{r,k}} \right)^{1-\alpha},$$

$$\rho_{r,k} = (1 - \alpha) p \theta_{r,k} \left( \frac{L_{r,k}}{S_{r,k}} \right)^{1-\alpha}$$

where  $p$  the relative price of the rural good.

# Spatial Structure: Spatial Equilibrium! $C(\ell_k) = \bar{U}$

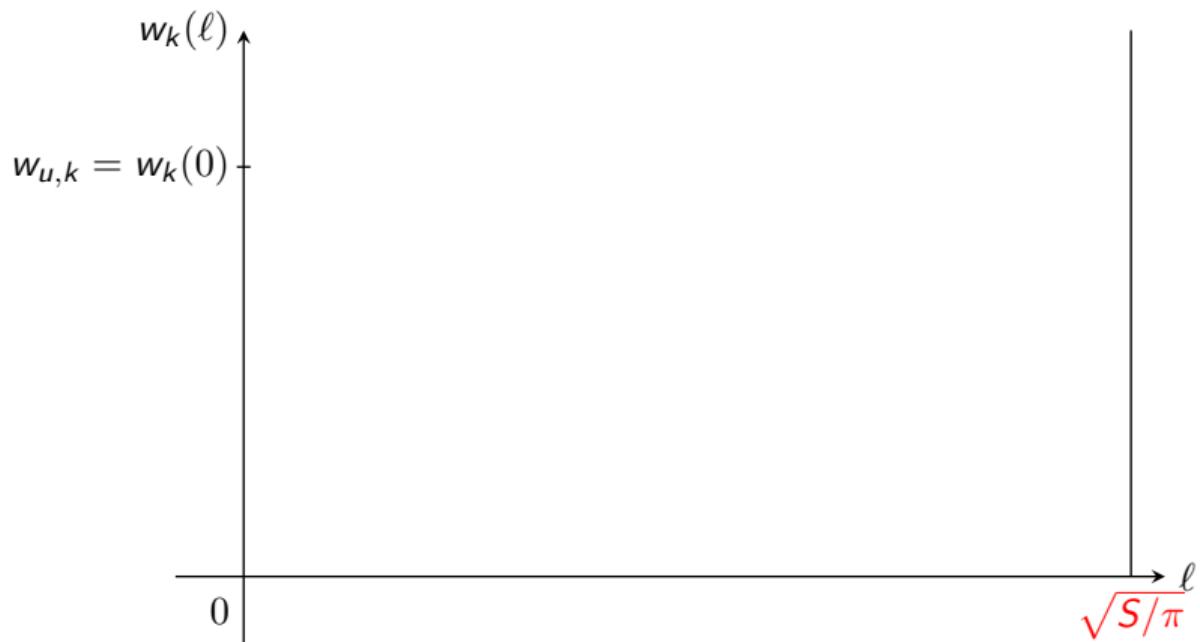
Illustrating net wages along a single radius

1. Space  $\ell \in [0, \sqrt{S/\pi}]$



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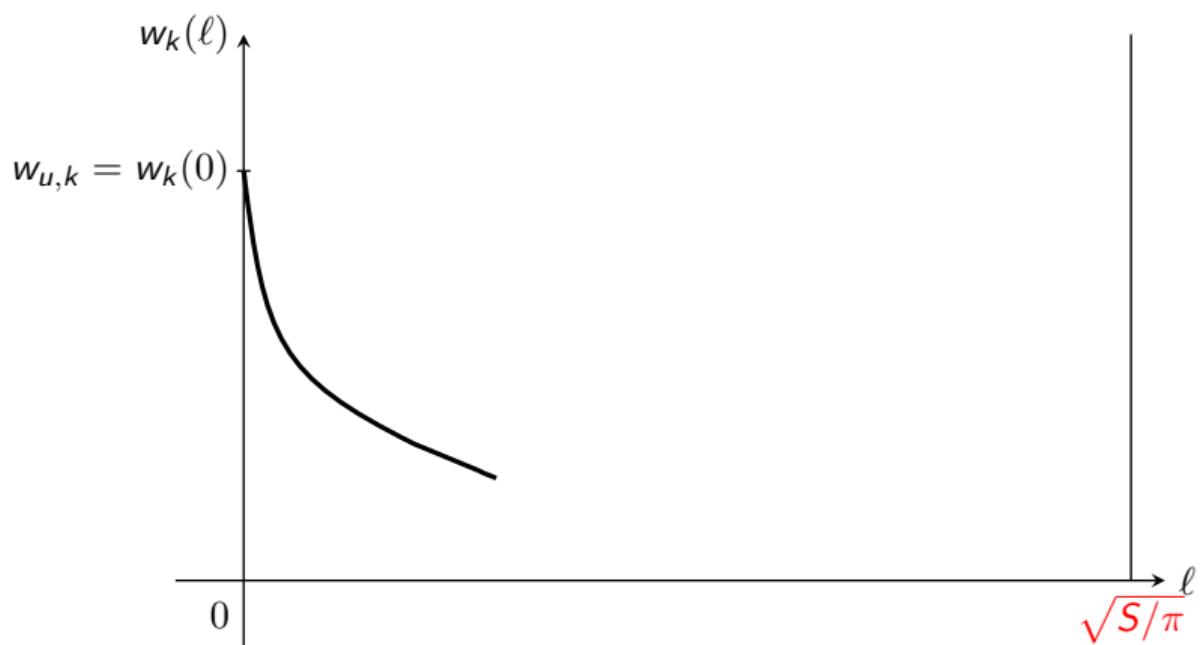
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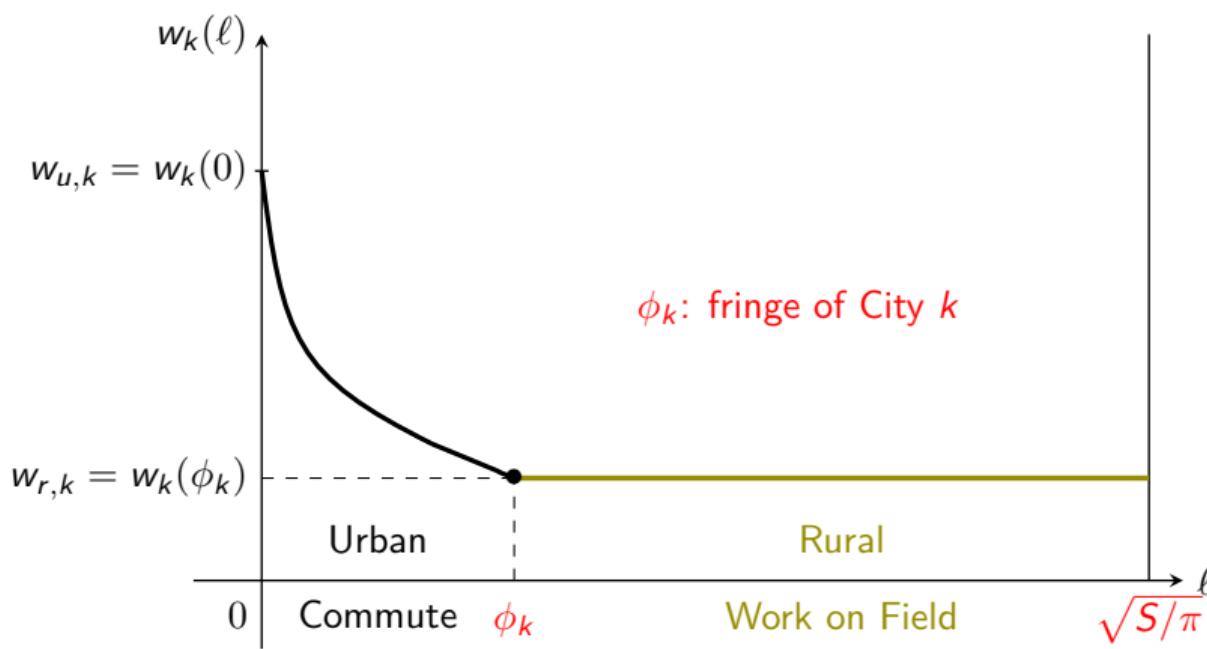
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4.  $\tau(\ell)$ : commuting cost from  $\ell$
5.  $w_u - \tau(\ell)$  urban wage

# Spatial Structure: Spatial Equilibrium! $C(\ell_k) = \bar{U}$

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5.  $w_u - \tau(\ell)$  urban wage
6.  $\phi_k$  denotes urban fringe of city  $k$ .

# 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.



# Commuting Costs in units of Numeraire Good

Based on DeSalvo and Huq (JUE 1996)

Our commuting cost function is:

$$\tau(\ell_k) = a \cdot (w_{u,k})^{\xi_w} (\ell_k)^{\xi_\ell}$$

- ▶ We have a micro-foundation for this model.
- ▶ Substantive points:  $\tau$  must decrease over time, and costs concave:  $\xi_w, \xi_\ell \in (0, 1)$ .
- ▶  $\xi_w < 1$  is key: commuting costs rise less than proportional with increasing wages.

# Location Sorting

## Spatial Equilibrium

- ▶ Location indifference within region  $k$ ,

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

and across regions

$$\bar{C} = \bar{C}_k = \kappa \frac{w_{r,k} + r + \underline{s} - p\underline{c}}{(q_{r,k})^\gamma}$$

- ▶ Same house price  $q_{r,k}$  at  $\phi_k$  and in the rural area,  $q(\ell \geq \phi_k) = q_{r,k}$ .

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- ▶ Same house price  $q_{r,k}$  at  $\phi_k$  and in the rural area,  $q(\ell \geq \phi_k) = q_{r,k}$ .

- ▶ Indifference at the fringe:

$$w(\phi_k) = w_{r,k} = w_{u,k} - \tau(\phi_k)$$

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

## 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:

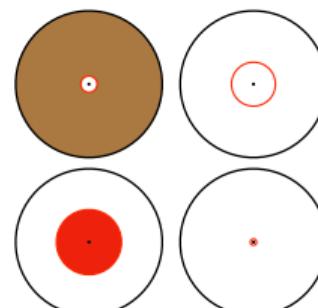
$$\rho_{r,k} = \frac{q_{r,k}^{1+\epsilon}}{1+\epsilon} = (1-\alpha)p\theta_{r,k} \left(\frac{L_{r,k}}{S_{r,k}}\right)^\alpha$$

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- ▶ Land Market Clearing: each city  $k$  is big enough to host  $L_{r,k}$  workers, enough  $S_{r,k}$  land left to produce food.
- ▶ Labour Market Clearing.
- ▶ Land Rents consistently defined.



## **Results:**

- 1. Intuition: Artificial Economy with  $K = 4$**
- 2. Full Quantitative Model**

## Sectoral and Regional Productivities

For the productivity processes, we posit that

$$\theta_{s,k,t} = \theta_{s,t} \cdot \theta_{s,t}^k$$

We denote for sector  $s$  in period  $t$ :

- ▶ an aggregate component:  $\theta_{s,t}$ ,
  - ▶ a shifter for region  $k$ :  $\theta_{s,t}^k$  with weighted mean equal to 1.
- 👉 Aggregating over all  $K$  cities recovers the *average city* (i.e the one following  $\theta_{s,t}$  only)

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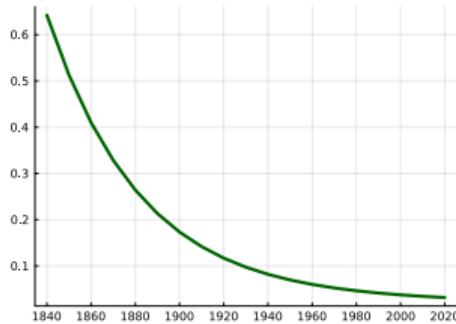
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In Artificial setting ( $K = 4$ ): fix constant growth of  $\theta_{s,t}$ , and pick  $\theta_{s,t}^k$  *high/low*. Full model: estimate  $\theta_{s,t}^k$  to match size and land price distributions.

Artificial Model.  $K = 4$ , constant agg. growth and shifters  $\theta_{s,t}^k$

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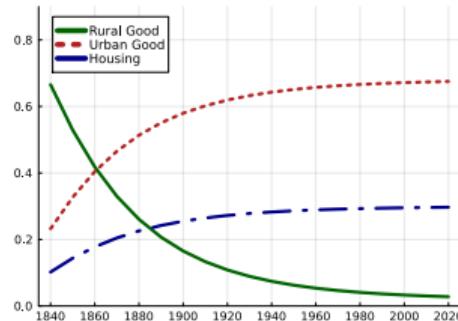


(a) Rural Labor Share.

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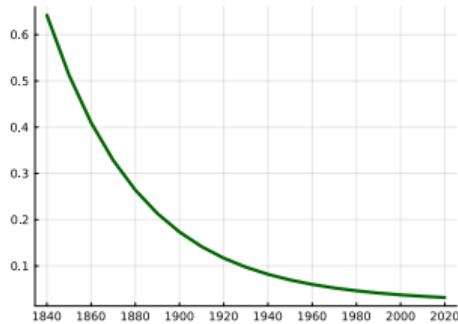


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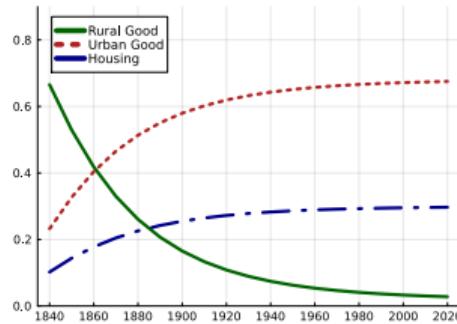


(b) Spending Shares.

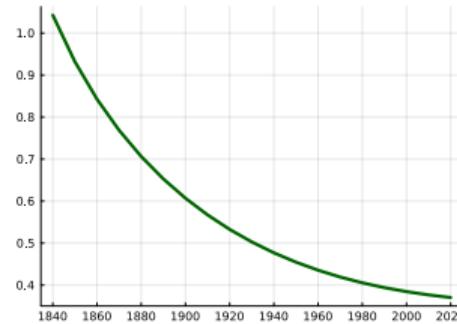
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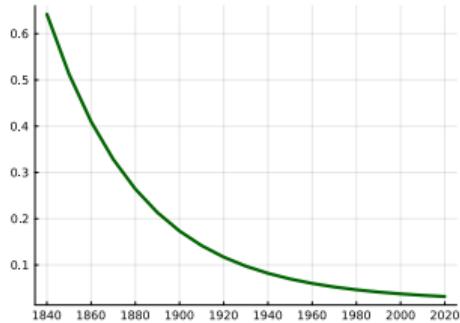


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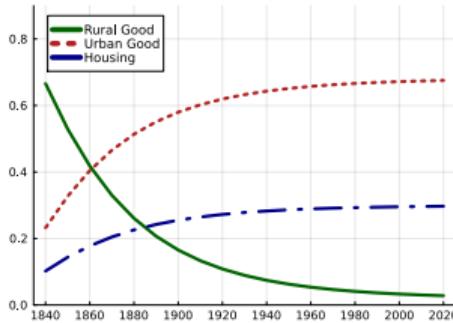


(c) Relative price  $p$ .

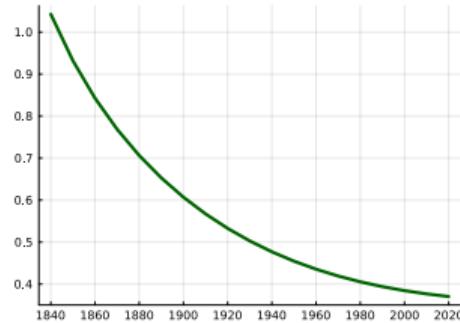
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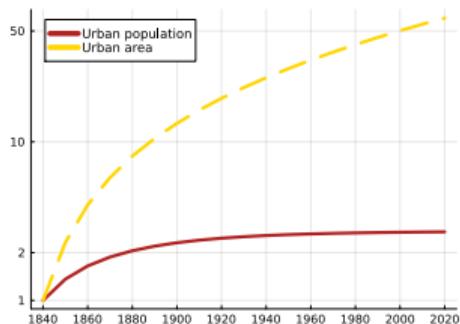
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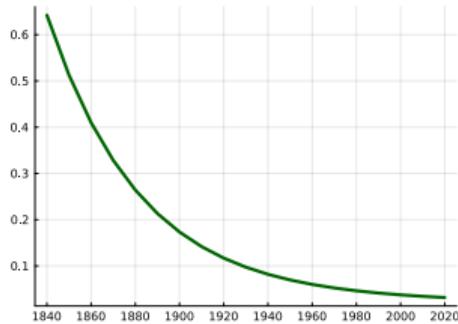


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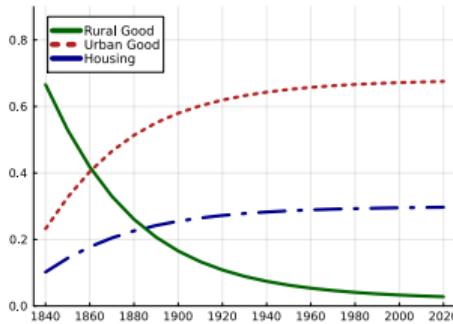


(d) Area and Population.

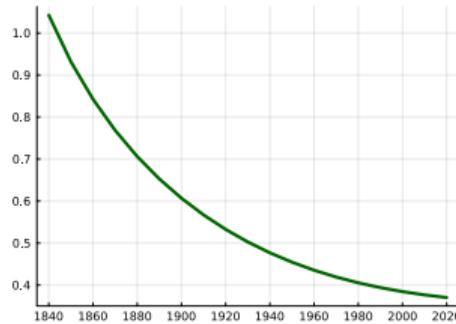
# Artificial Model. $K = 4$ , constant agg. growth and shifters $\theta_{s,t}^k$



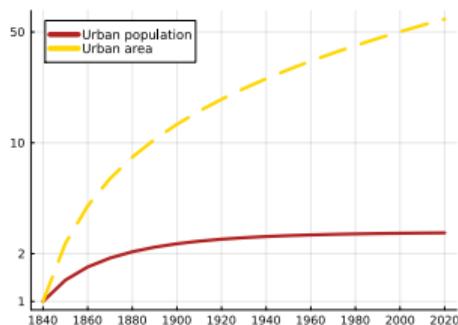
(a) Rural Labor Share.



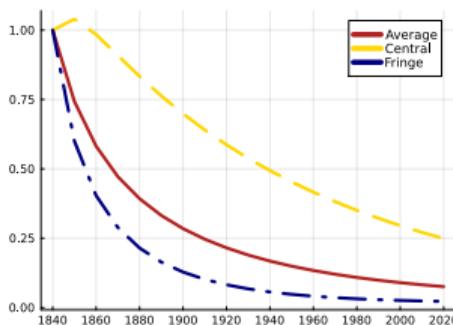
(b) Spending Shares.



(c) Relative price  $p$ .

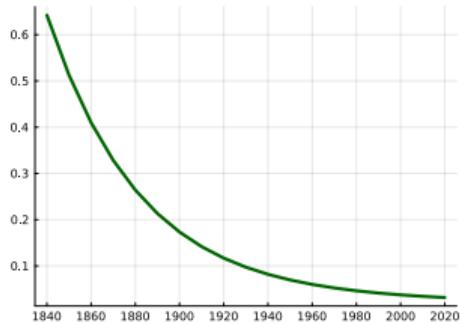


(d) Area and Population.

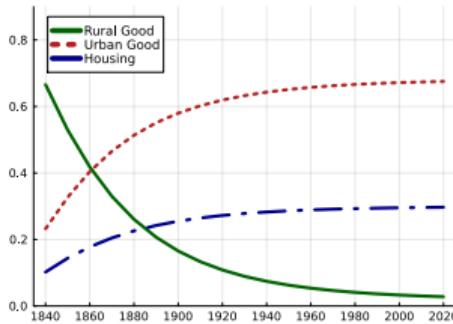


(e) Average Urban Densities.

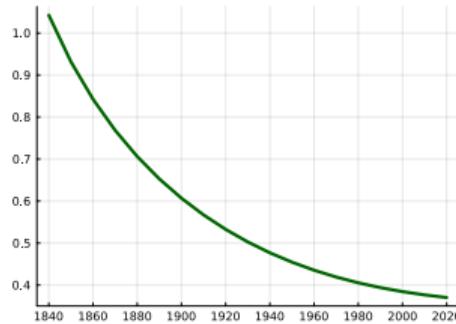
# Artificial Model. $K = 4$ , constant agg. growth and shifters $\theta_{s,t}^k$



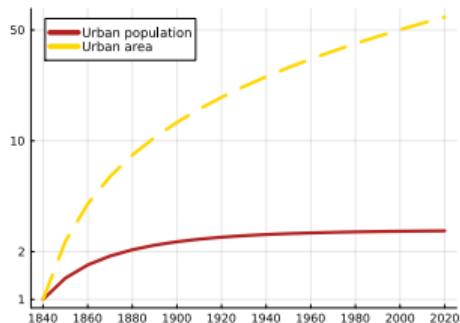
(a) Rural Labor Share.



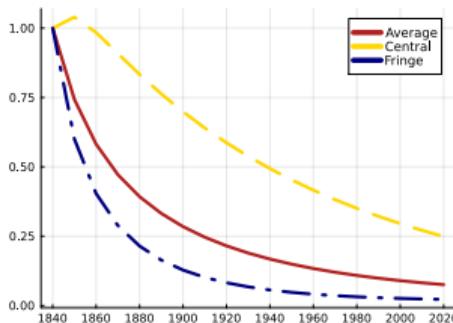
(b) Spending Shares.



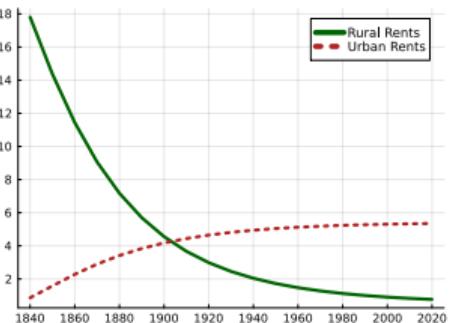
(c) Relative price  $p$ .



(d) Area and Population.



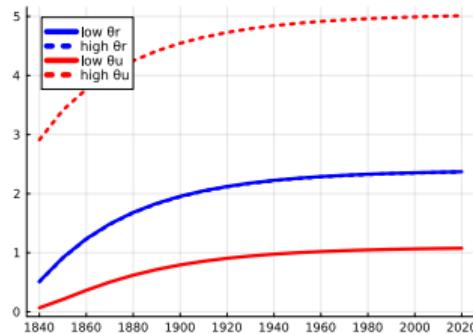
(e) Average Urban Densities.



(f) Average land rents.

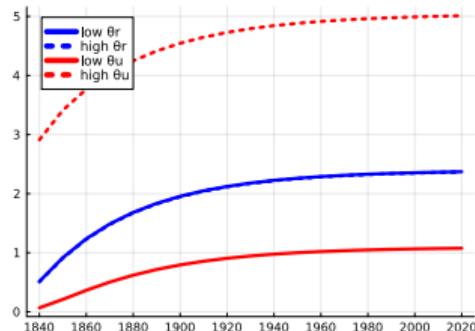
Artificial Model.  $K = 4$ : Identifying Cross sectional differences via  $\{\theta_{s,t}^k\}$

# Artificial Model. $K = 4$ : Identifying Cross sectional differences via $\{\theta_{s,t}^k\}$

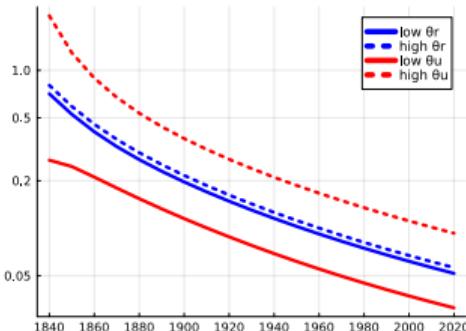


(a) Urban population.

# Artificial Model. $K = 4$ : Identifying Cross sectional differences via $\{\theta_{s,t}^k\}$

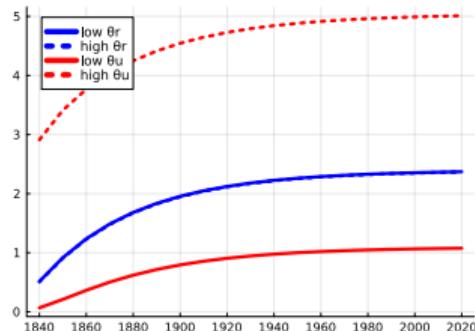


(a) Urban population.

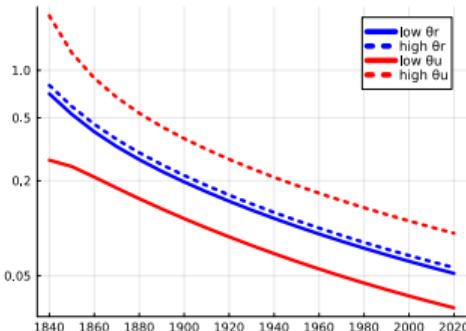


(b) Average urban Densities.

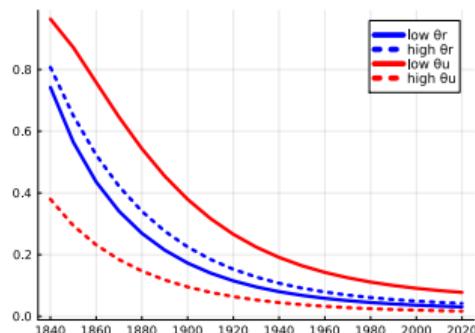
# Artificial Model. $K = 4$ : Identifying Cross sectional differences via $\{\theta_{s,t}^k\}$



(a) Urban population.

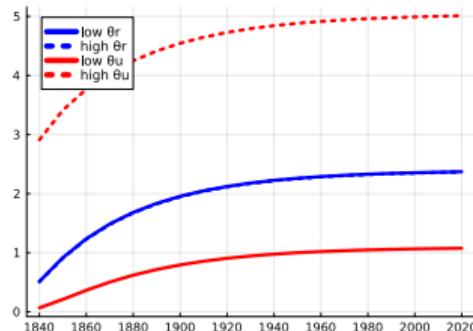


(b) Average urban Densities.

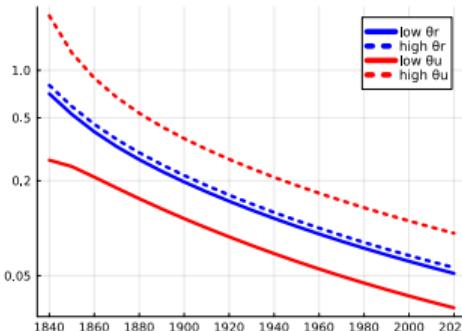


(c) Rural employment share.

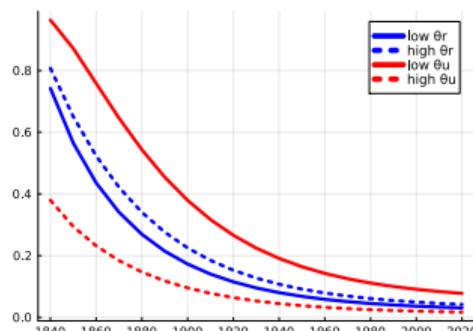
# Artificial Model. $K = 4$ : Identifying Cross sectional differences via $\{\theta_{s,t}^k\}$



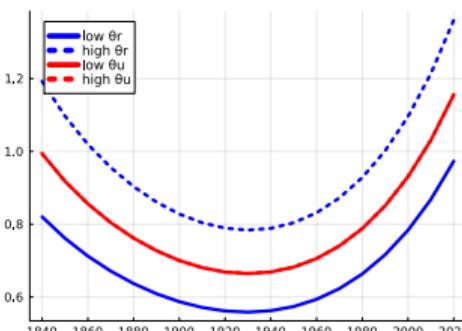
(a) Urban population.



(b) Average urban Densities.

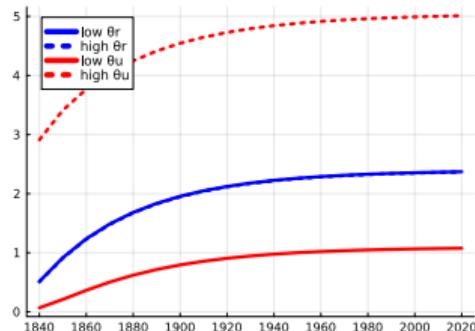


(c) Rural employment share.

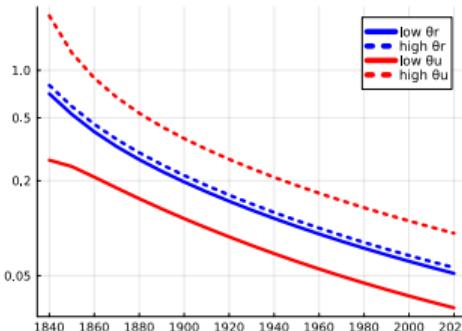


(d) Rural Land Rents.

# Artificial Model. $K = 4$ : Identifying Cross sectional differences via $\{\theta_{s,t}^k\}$



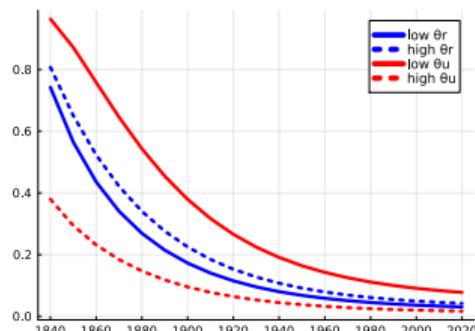
(a) Urban population.



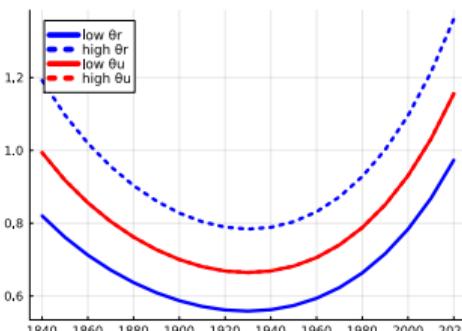
(b) Average urban Densities.



Local vs Global Shocks!



(c) Rural employment share.

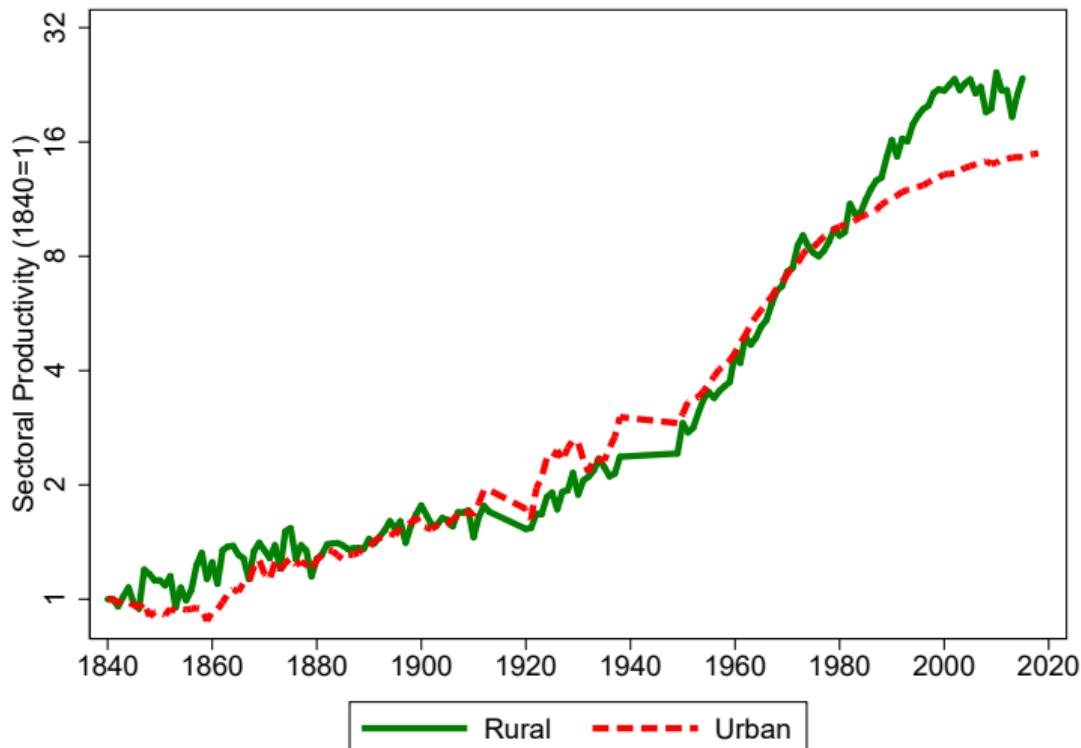


(d) Rural Land Rents.

## Full Quantitative Model and Parameterization

1. We estimate the *aggregate*  $\theta$  series from data.
2. We use observed population growth.
3. We use individual commuting data to directly calibrate the  $\tau$  parameters. ▶ How?
4. Jointly estimate preference parameters to match set of moments.  
and Fit Population distribution and land value distributions across regions.

# (Aggregate) Productivities Estimated From Data



- ▶  $\theta_{s,k,t} = \theta_{s,t} \cdot \theta_{s,t}^k$
- 👉 Aggregate Processes:  $\theta_{s,t}$
- ▶ Regional shifters:  $\theta_{s,t}^k$

# Estimation and Identification

We target the following moments:

## Aggregate:

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

## Regional:

- ▶  $L_{ukt}/L_{u1t}$ : Urban pop in city  $k$  rel. to city 1 (Paris)  $\Rightarrow \{\theta_{u,t}^k\}$
- ▶  $\rho_{kt}/\rho_{1t}$ : Farmland value outside city  $k$  rel. to city 1.  $\Rightarrow \{\theta_{r,t}^k\}$

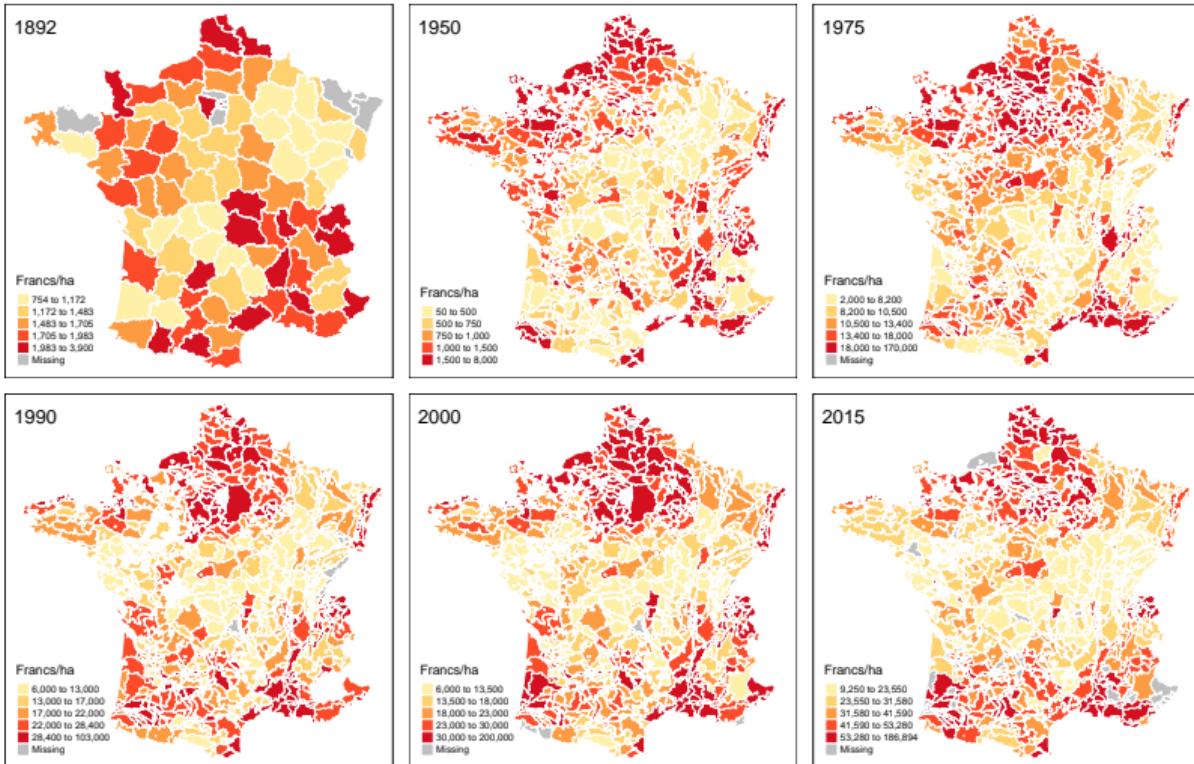
Internal city structure, density fall, commuting speed, house price: not targeted!

TABLEAU A-1 (suite)  
EVOLUTION DU PRIX DES TERRES LABOURABLES DE 1950 A 1968 PAR REGION AGRICOLE

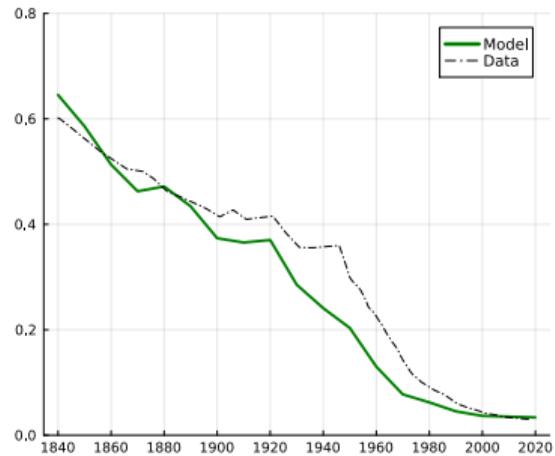
(Francs à l'hectare)

		1950	1953	1958	1960	1962	1963	1964	1965	1966	1967	1968	
26 463-RJ BARONNIES		DOM MINI MAXI	900 800 1000	900 800 1000	2200* 700 3000	2200* 700 4500	4500 1000 5000	4500 1000 5000	5000 2000 6000	5000 2000 6000	5000 1500 7000	5500 1000 11000	
26 464-KI TRICASTIN		DOM MINI MAXI	2000 1000 4000	2000 700 4000	2500* 700 3000	2500* 2500 4500	6700* 2500 8000	6700* 2500 8000	6800 2000 8000	7500 2000 10000	7500 1500 11000	8000 1500 16000	
ENSEMBLE DROME		MOYENNE INDICE	2500 39	2500 39	4100 63	4100 63	5900 93	6100 95	6100 95	6700 105	7000 109	7300 113	
ISERE													
38 199-EI BAS DAUPHINE		DOM MINI MAXI	1000* 700* 3000*	1300 1000 4000	2750 1600 4000	2750 1600 4000	3000 2200 3500	5000 3500 5000	7000 4000 7000	8000 5000 13000	8500 6000 13000	9000 7000 15000	
38 217-AI GRESIVAUDAN		DOM MINI MAXI	1500 1000* 4000*	2000 1200 5000	3000 2000 4500	3200 2000 5500	4000 3500 5000	7000 4500 9000	10000 5000 15000	11000 6000 15000	12000 7000 16000	12000 6000 17000	
38 453-PI PREALPES		DOM MINI MAXI	500* 200* 2000*	600 250 2000	2500 1500 3500	2500 1500 3500	3500 1500 3000	3500 1500 4500	3600 1000 4000	4000 1000 4000	4000 1000 7000	5000 2000 8000	
38 457-JI REGION HAUTE ALPINE		DOM MINI MAXI	300* 100* 800*	400 100 1000	2500 1500 3500	2500 1500 3500	2500 1500 3000	3500 1500 4500	3600 1000 4000	4000 1000 4000	4000 1000 7000	5000 2000 8000	
38 465-SI VALLEE DU RHONE		DOM MINI MAXI	2000* 1000* 4000*	2500 1500 5000	3000 2000 4500	3200 2000 5500	4000 3500 5000	7000 4500 9000	10000 5000 15000	11000 6000 15000	12000 7000 16000	12000 6000 17000	
ENSEMBLE ISERE		MOYENNE INDICE	1000 14	1300 18	2800 37	2800 37	3100 42	5200 69	7100 94	7900 106	8500 114	8800 118	
LOIRE													
42 168-AI MT DU JAREZ ET BASSIN HOUILLER ST EPHANOIS		DOM MINI MAXI	750 400 1100	800 250 1300	1750* 700* 3000*	2400* 1000* 4000*	3300* 1500* 5500*	3300* 2000* 6000*	3500* 2500* 6000*	3500* 3000* 6000*	4100* 2000* 7000*	4500 3500 8000	5000 3500 10000
42 170-BI MTS DU PILAT		DOM MINI MAXI	550 400 900	600 250 1100	1300* 500* 3000*	1800* 500* 3500*	2400* 1200* 4000*	2400* 1200* 4000*	2600* 1500* 4000*	2650* 1500* 4500*	3000* 1500* 5000*	3200 1700 6000	3800 1700 6500
42 189-BI PLATEAUX DE NEULISSE		DOM MINI MAXI	500 300 850	500 250 1100	1400* 700* 2500*	1800* 1000* 3000*	2550* 1500* 4500*	2550* 1500* 5000*	2750* 1500* 5000*	2800* 1500* 5000*	3200* 1500* 7000*	3500 1800 7500	4000 1800 4000

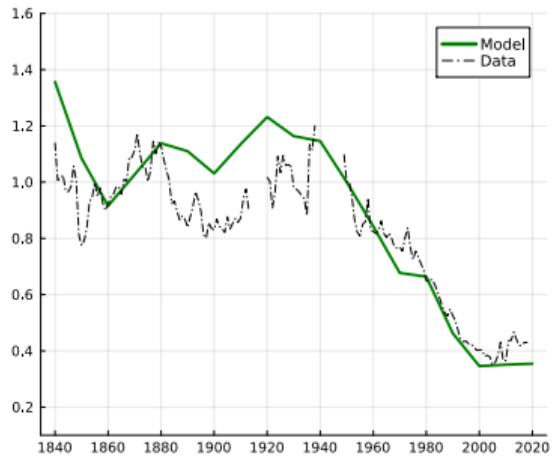
# Novel Data on Land Values!



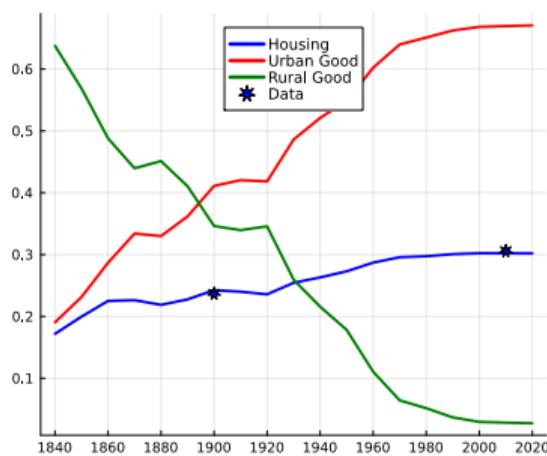
# Aggregate Results: Structural Change



(a) Rural employment share.



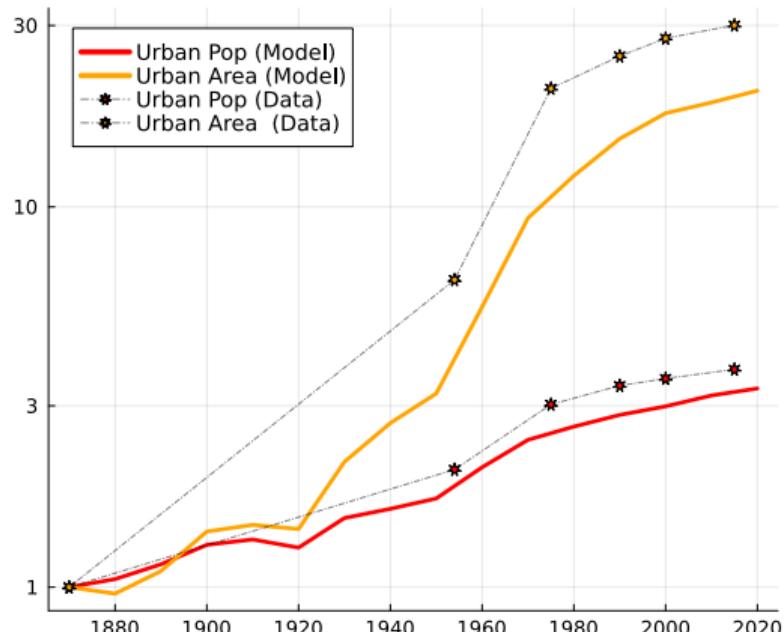
(b) Relative price of rural good.



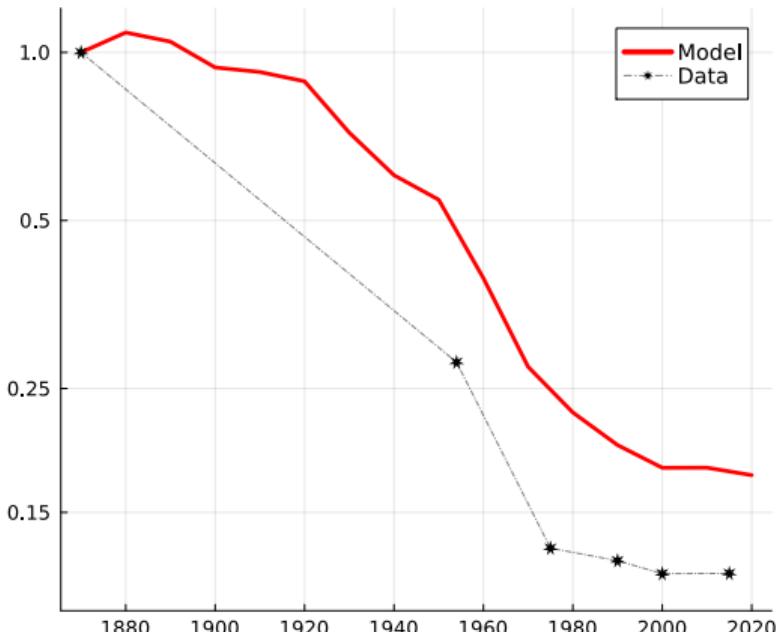
(c) Spending shares.

Figure: Structural change aggregated over  $K$  cities.

# Aggregate Results: Urban Expansion



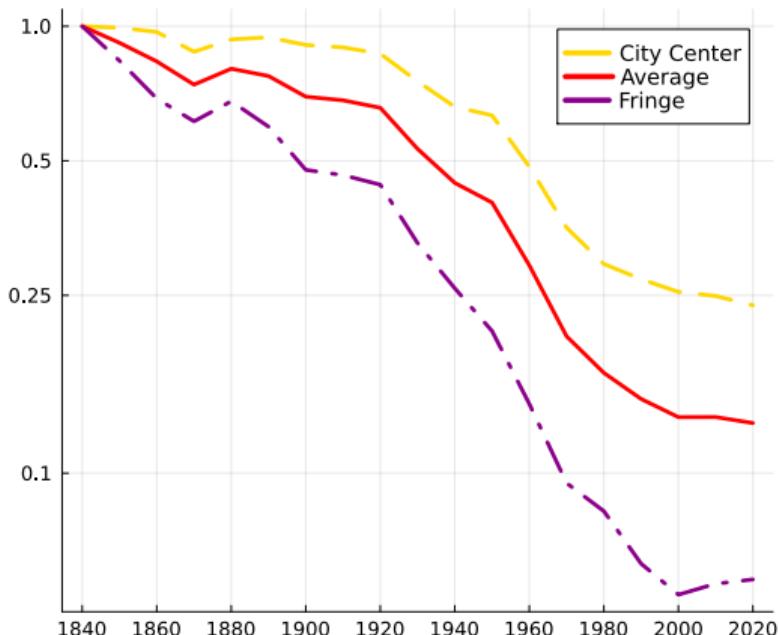
(a) Urban Area and Population (1870=1)



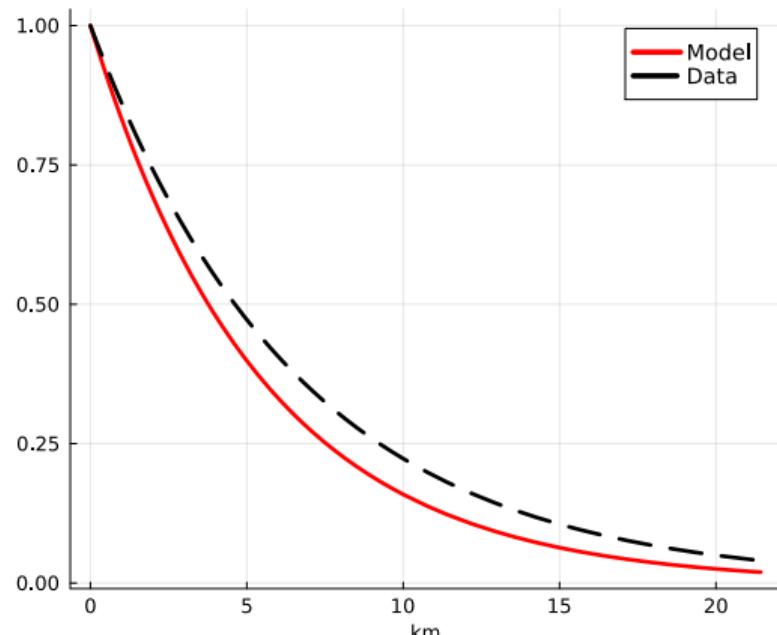
(b) Average urban density (1870=1)

Figure: Urban expansion aggregated over  $K$  cities.

# Aggregate Results: Urban Structure



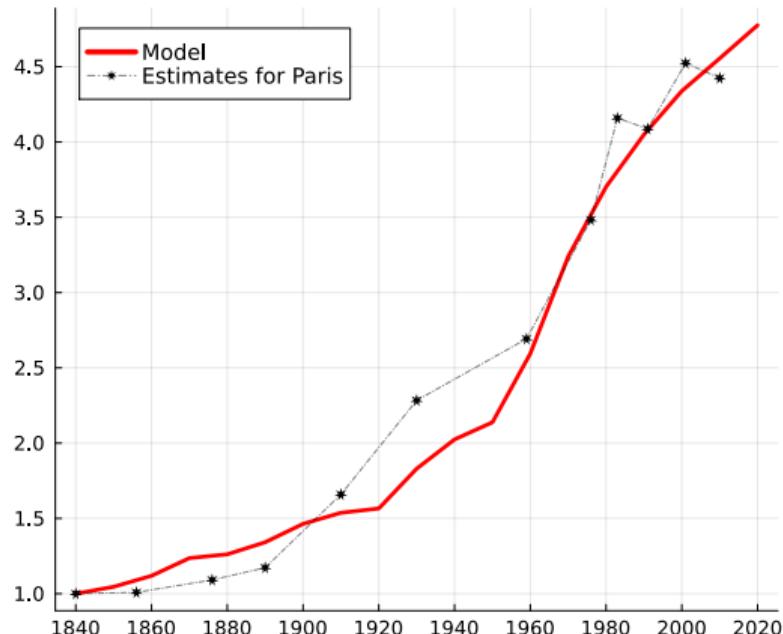
(a) Urban density (1840=1).



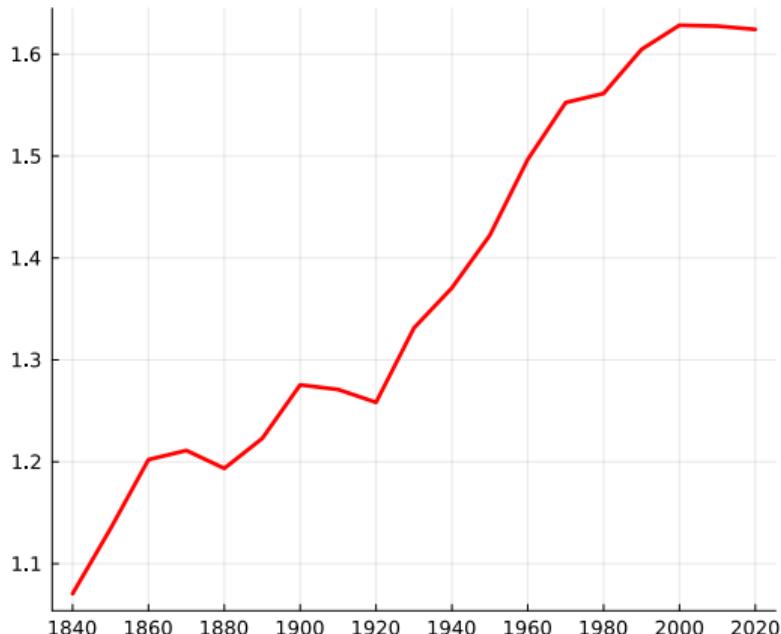
(b) Density gradient (2020).

Figure: Density across space.

# Aggregate Results: Commuting Speed and APG



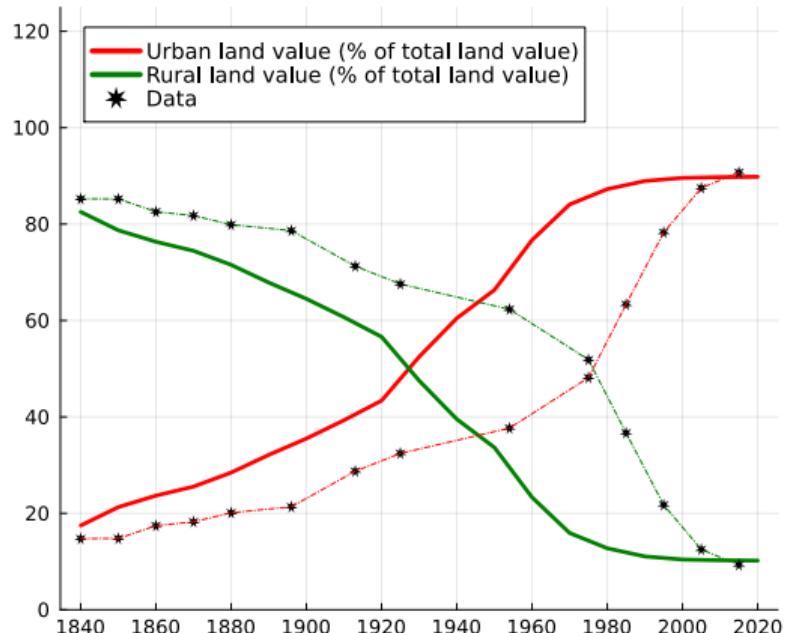
(a) Average urban commuting speed (1840=1).



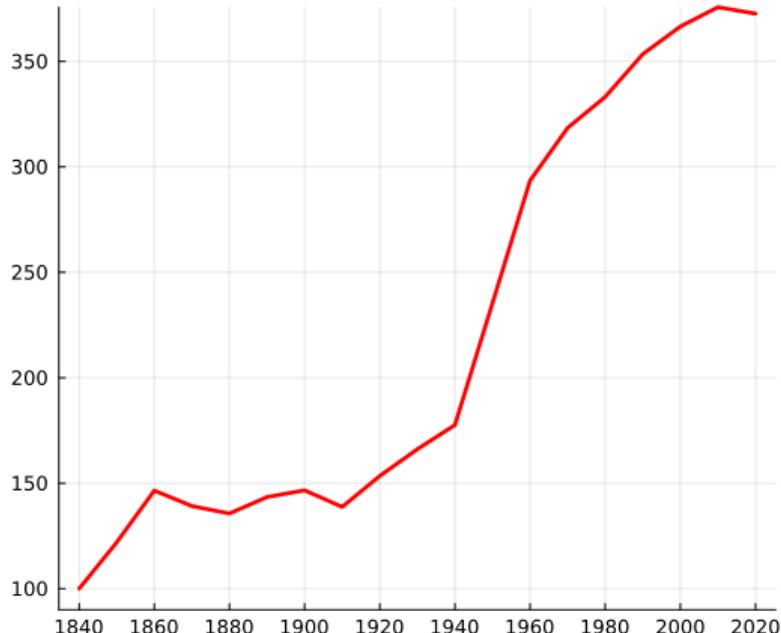
(b) Agricultural productivity gap.

Figure: Commuting speed and the 'agricultural productivity gap'

# Aggregate Results: Wealth Distribution and House Price



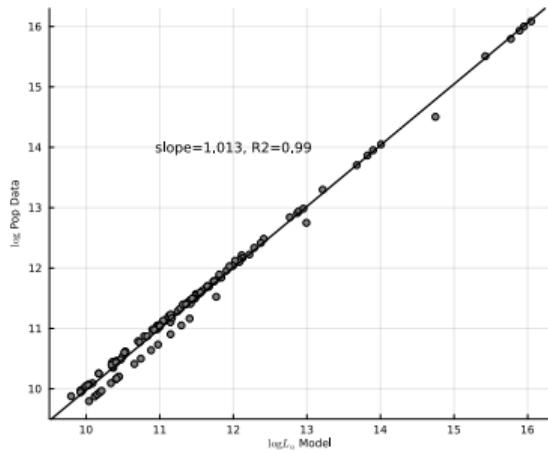
(a) Urban versus rural land wealth.



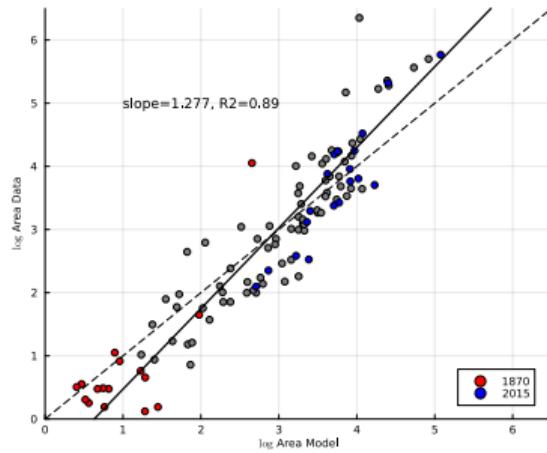
(b) Real Housing Price Index (1840=100).

Figure: Land values and housing price

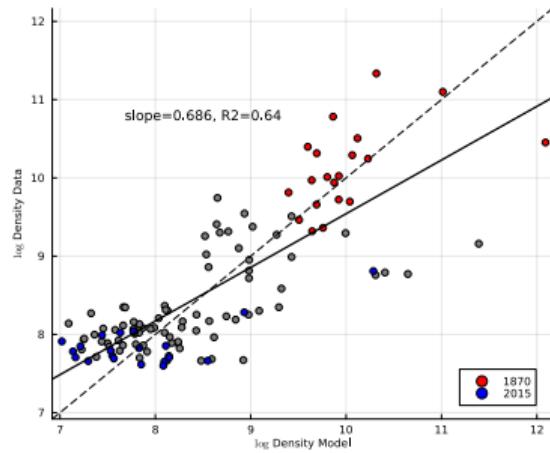
# Regional Results: Outcomes Across Regions



(a) Urban Population.



(b) Urban Area.



(c) Urban Density.

Figure: Regional Urban Moments

## Regional Results: Urban Density and Land Values

	log Urban Density		
	Model	Data (OLS)	Data (IV)
$\log \bar{\rho}_{r,k,t}$	0.371*** (0.018)	0.126*** (0.026)	0.346*** (0.098)
Controls	$\log w_{u,k,t}$	$\log w_{u,k,t}$	$\log w_{u,k,t}$
Num.Obs.	80	766	314
R2	0.994	0.253	0.272
FE: year	X	X	X

Table: Urban density and rural land values in model and data.

# 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. (Section B.3.1. in [Appendix B](#))
- ▶ Constant housing elasticity  $\epsilon = 3$ . ((Section B.3.2. in [Appendix B](#)))

## Extensions

1. Agglomeration. (Section B.3.3. in Appendix B)
2. Relaxing Monocentricity. (Section B.3.4. in Appendix B)

# 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.

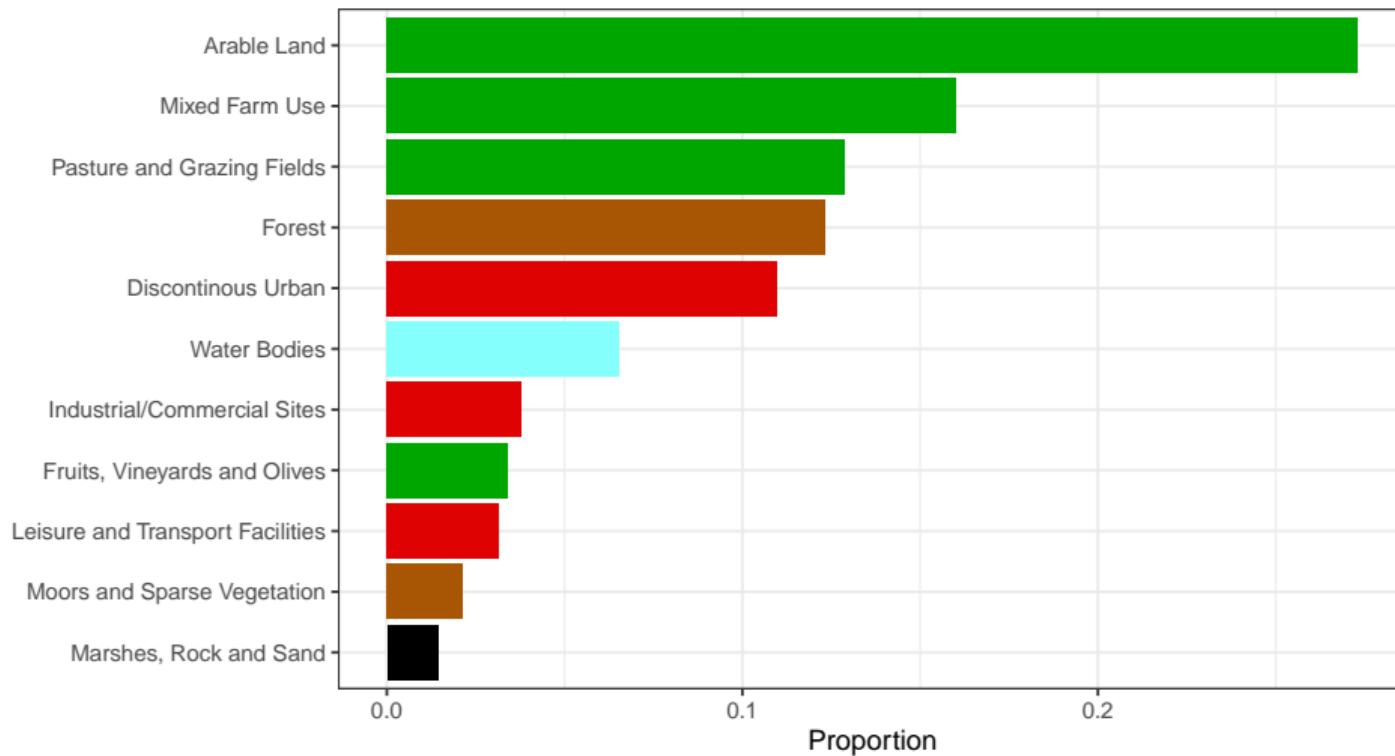
We found:

- ▶ 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!

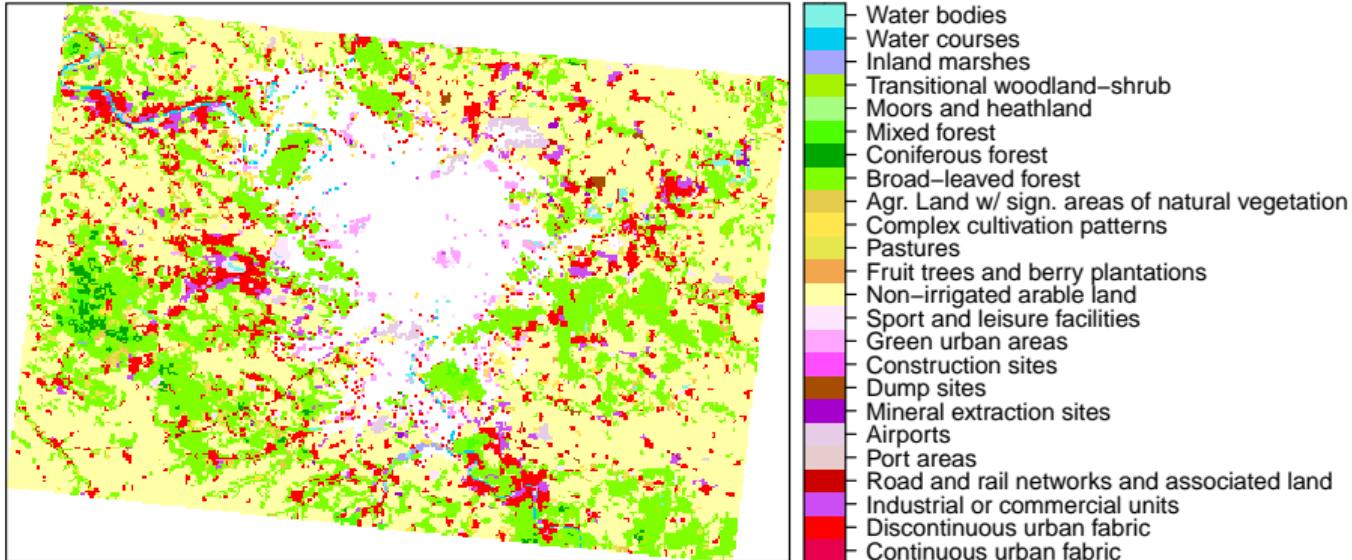
# Land Use Outside Top 100 French Cities Today

Average Land Use Outside top 100 Cities

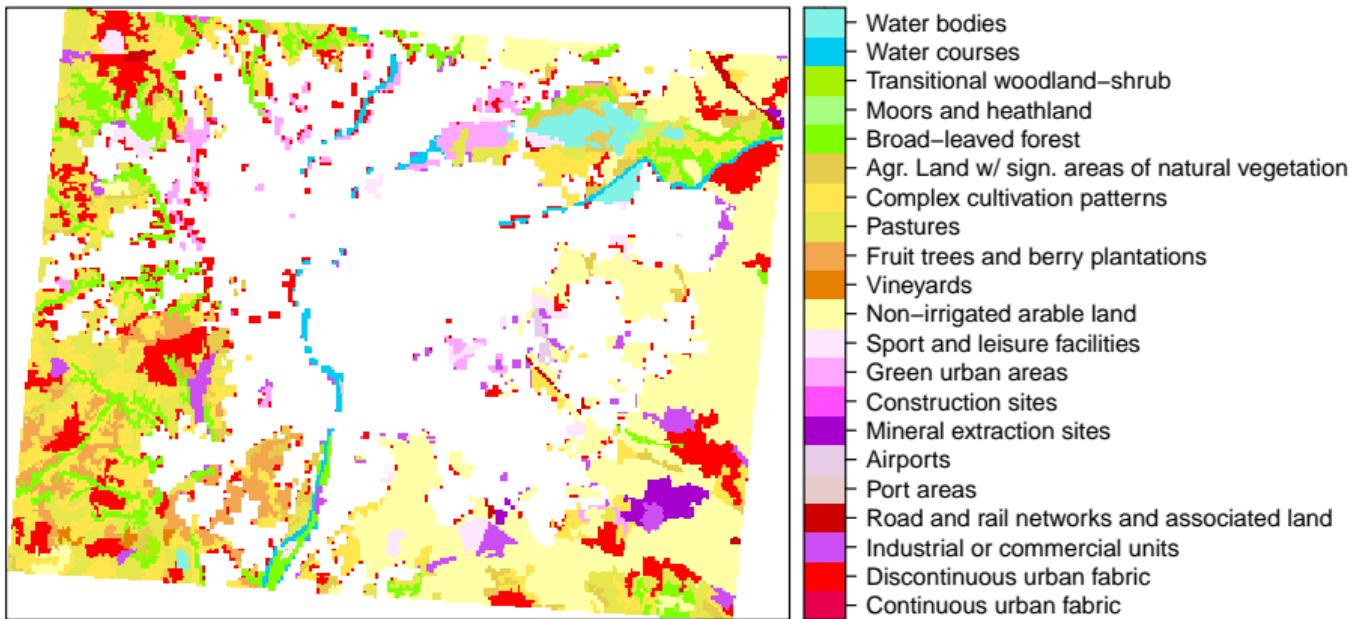


- ▶ Paris
- ▶ Lyon
- ▶ Marseille
- ▶ Bordeaux
- ▶ back

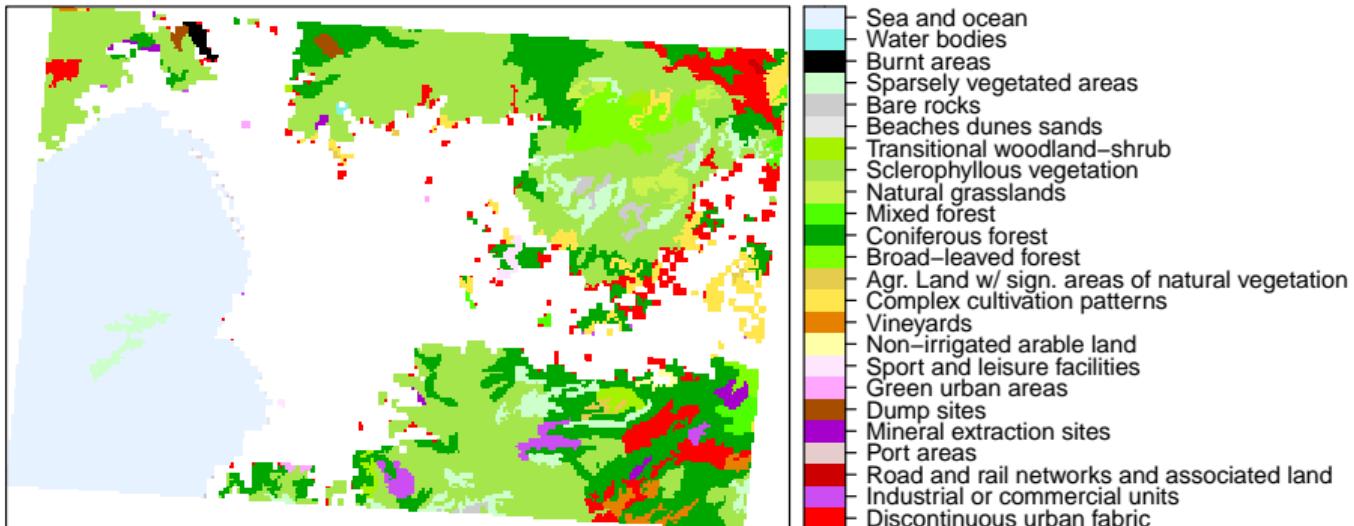
Land Use outside Paris 2020



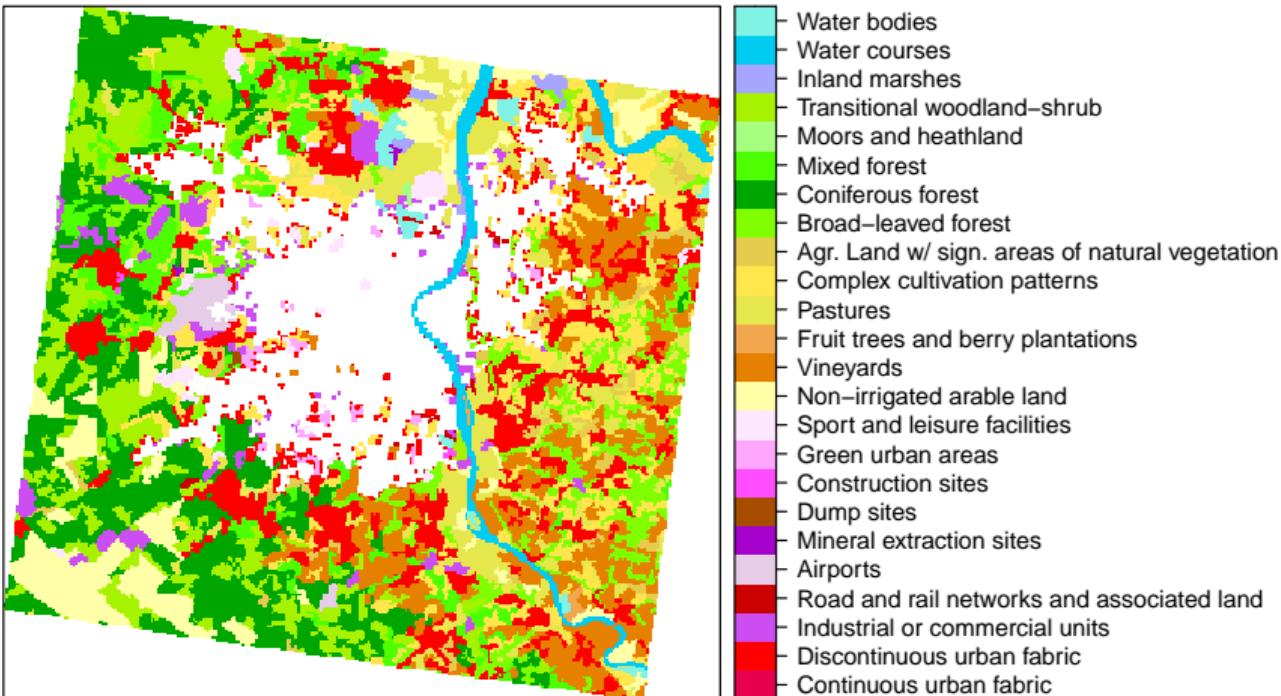
Land Use outside Lyon 2020



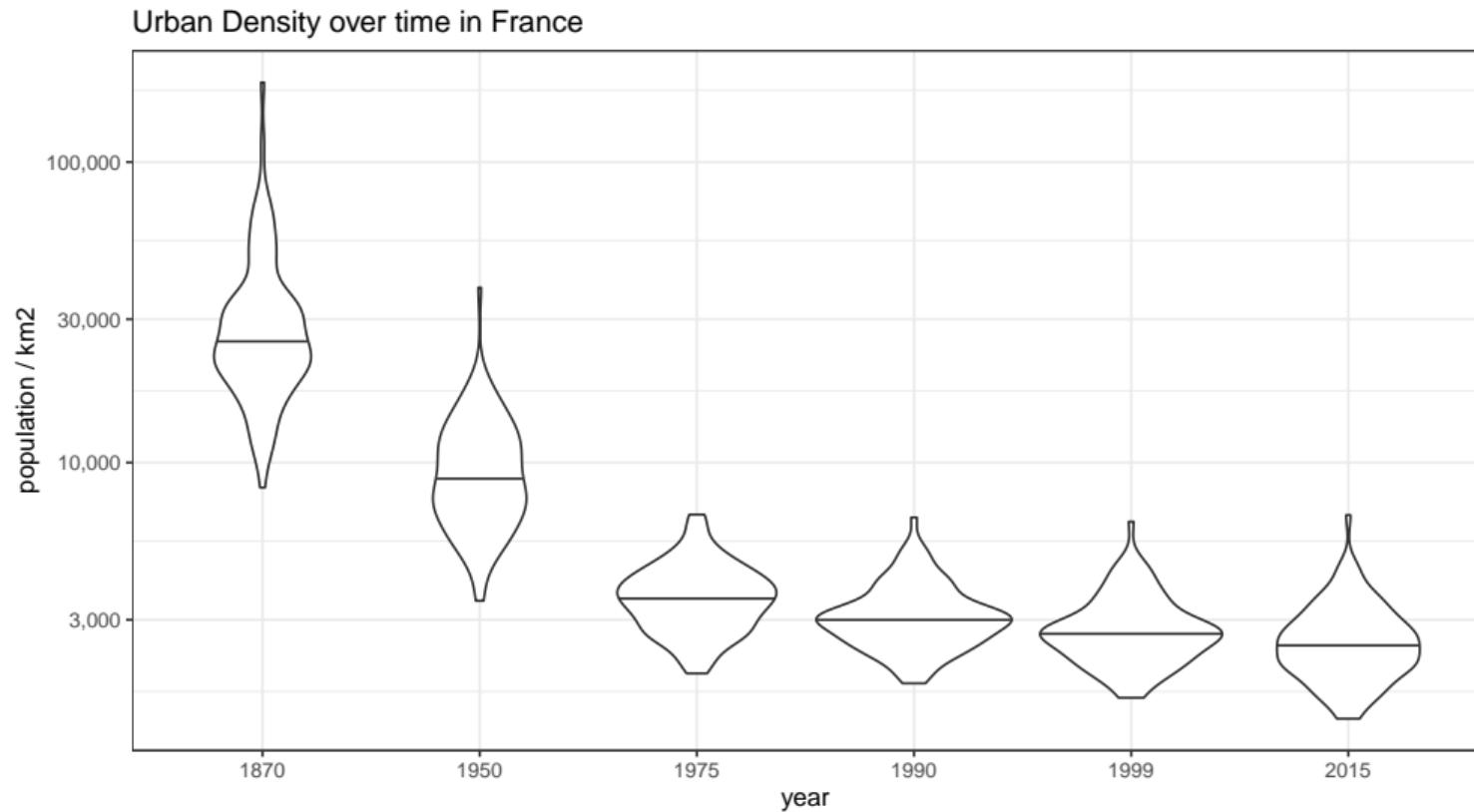
Land Use outside Marseille 2020



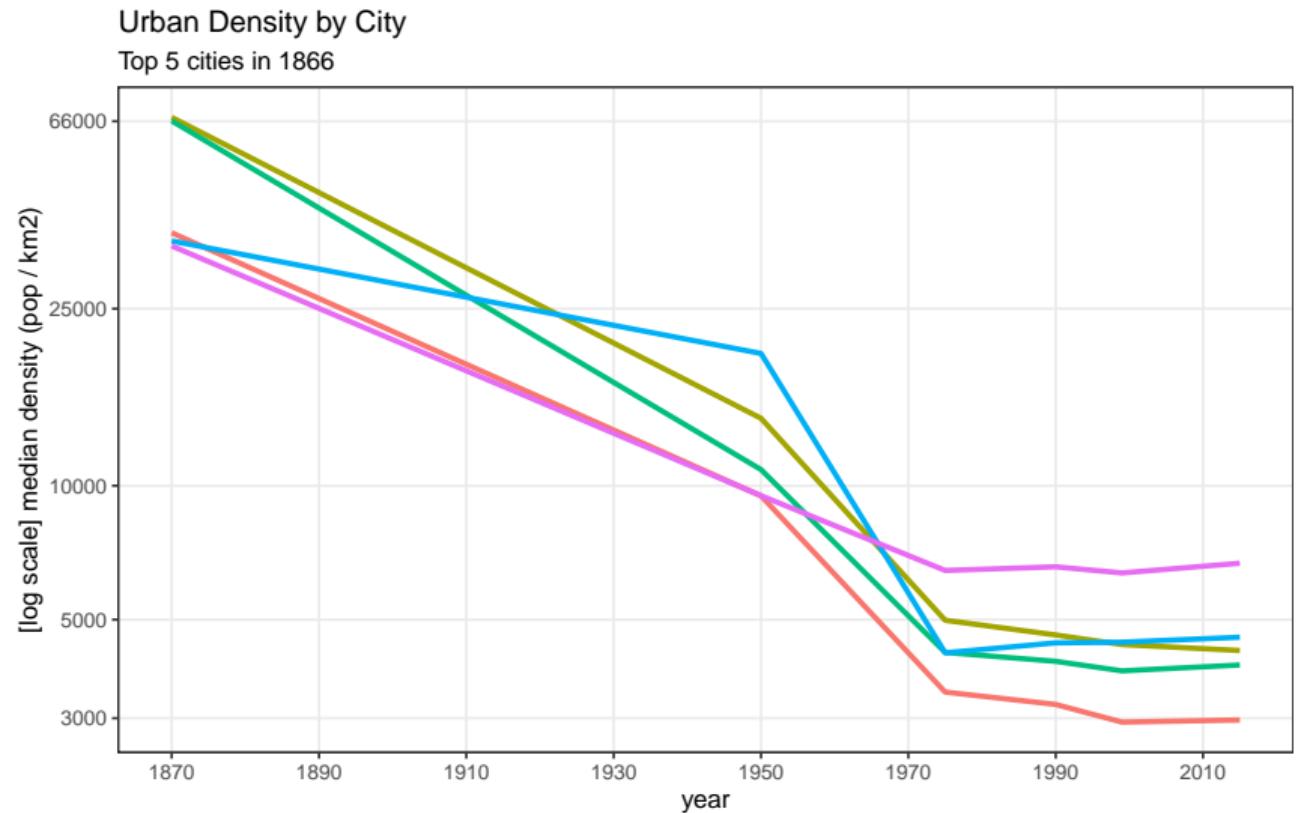
Land Use outside Bordeaux 2020



# The historical fall in urban density

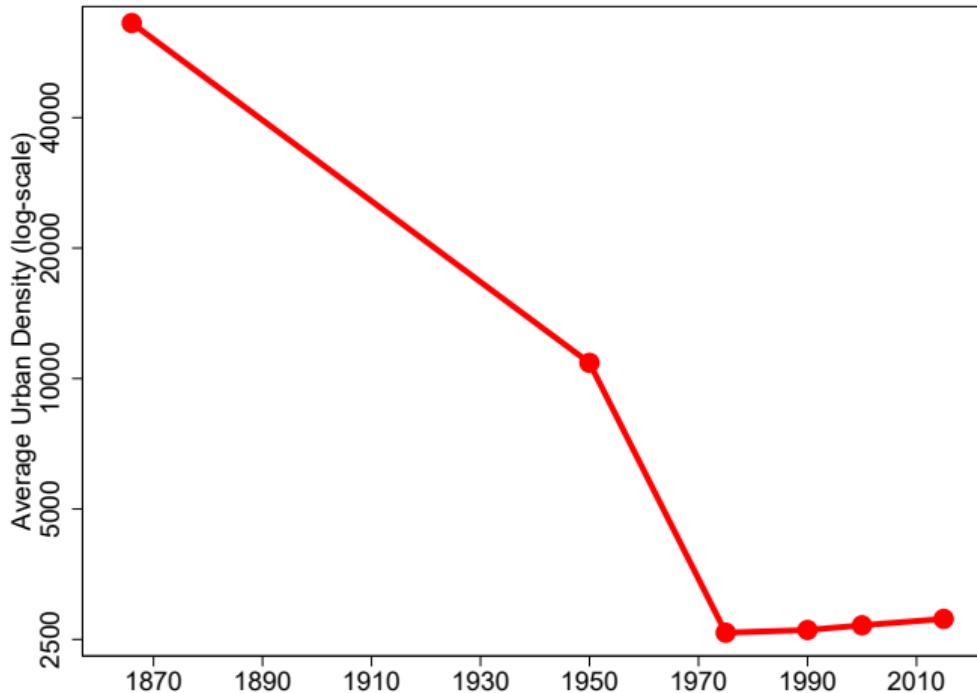


# The historical fall in urban density



# The historical fall in urban density

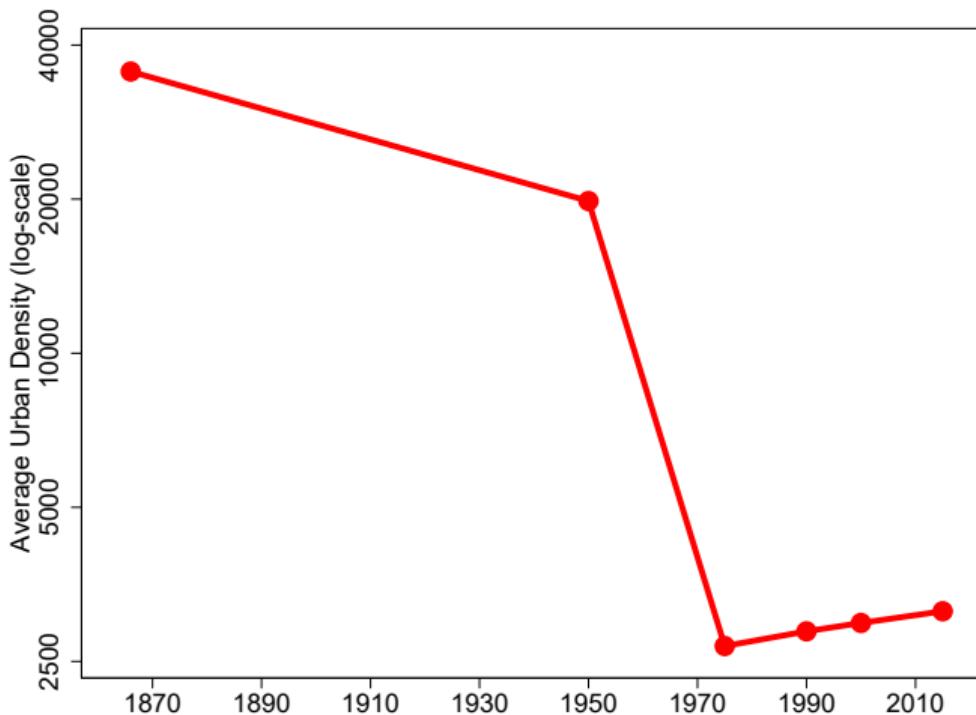
Lyon



▶ back

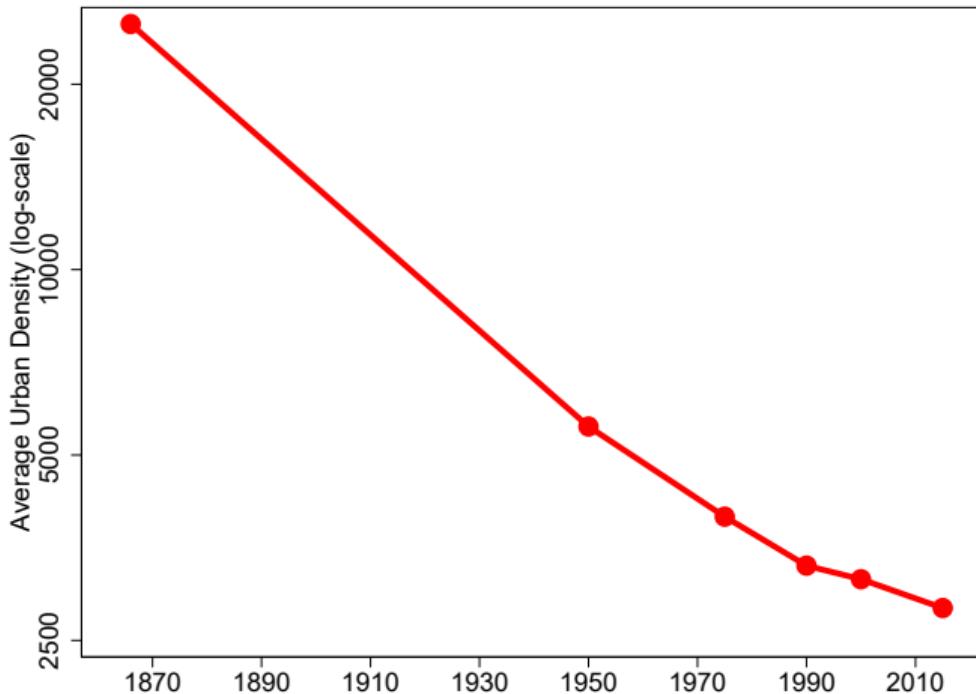
## The historical fall in urban density

## Marseille



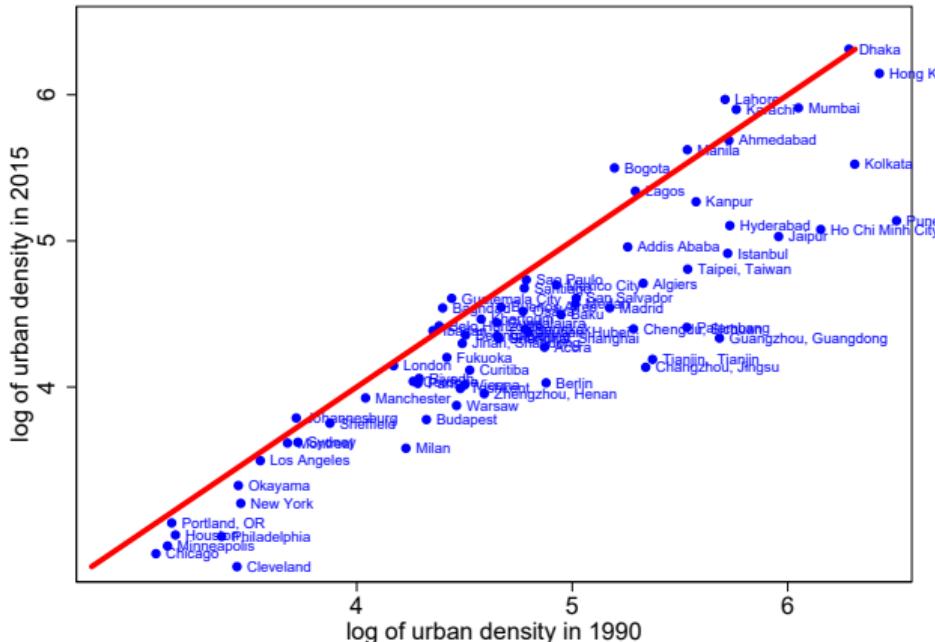
## The historical fall in urban density

Reims



## 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).

# 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  $\ell$ ,

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

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

- ▶ 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  $\ell$ ,

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

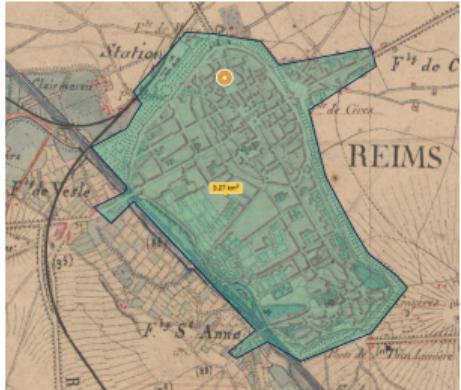
- ▶ Land use with the highest rental value (**Rivalry**)
- ▶ Indifference conditions across uses at the fringe,

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

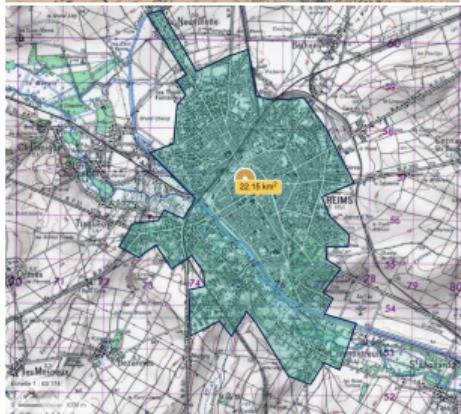
◀ back

# GHSI Measurement - Reims

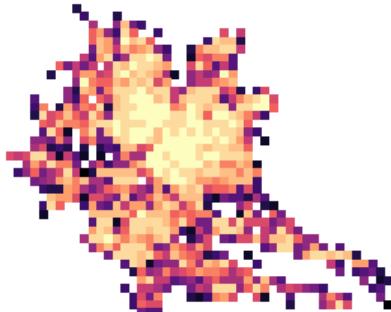
[back](#)



Reims 1975: 31.4 km<sup>2</sup>



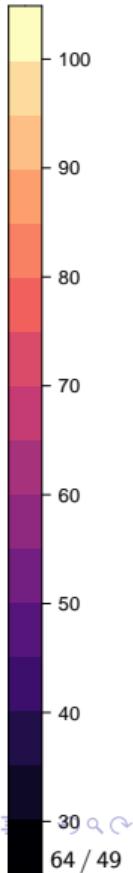
Reims 2000: 49.1 km<sup>2</sup>



Reims 1990: 43.2 km<sup>2</sup>

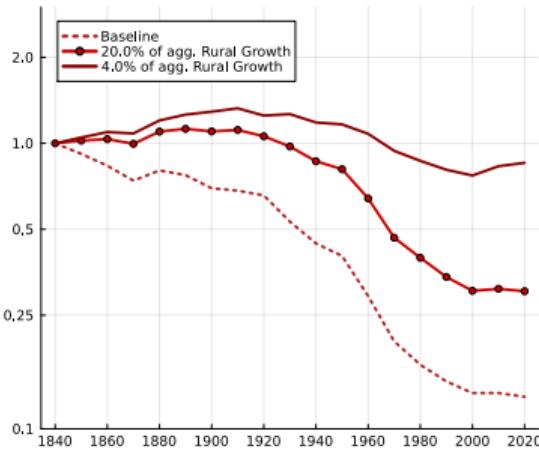


Reims 2015: 55 km<sup>2</sup>

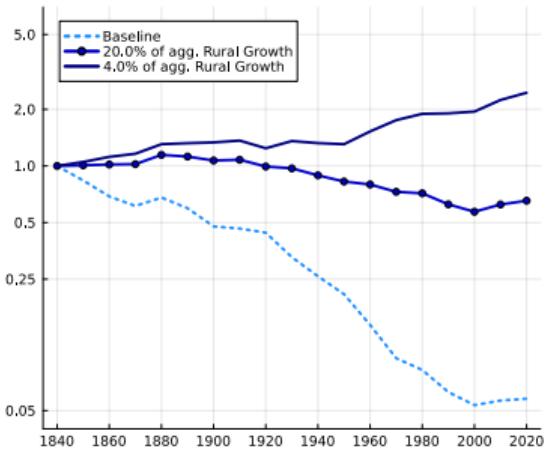


# Sensitivity Analysis

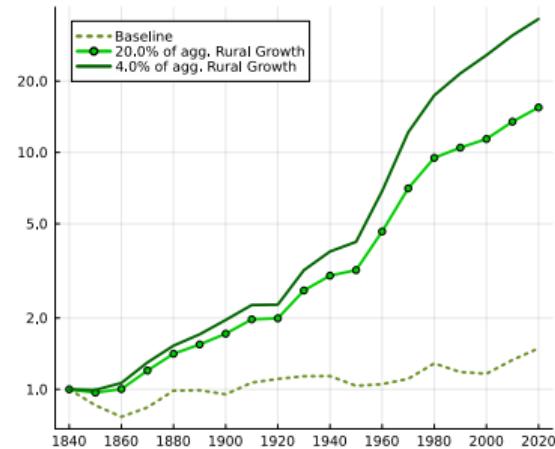
## The role of rural productivity growth



(a) Average density (1840=1).



(b) Density at the fringe (1840=1).



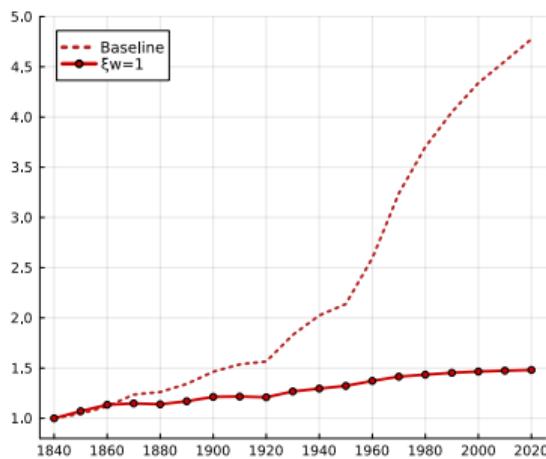
(c) Rental price of farmland.

▶ back

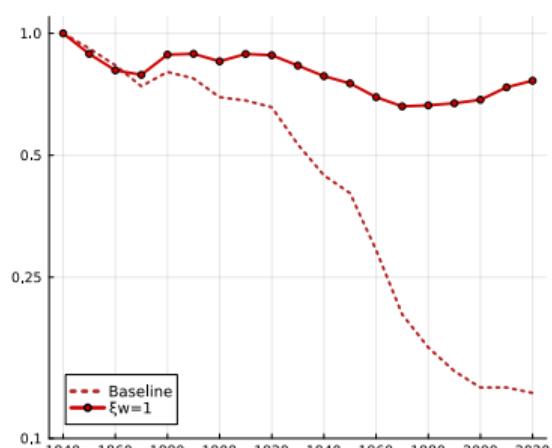
## Sensitivity Analysis

## The role of increasing commuting speed

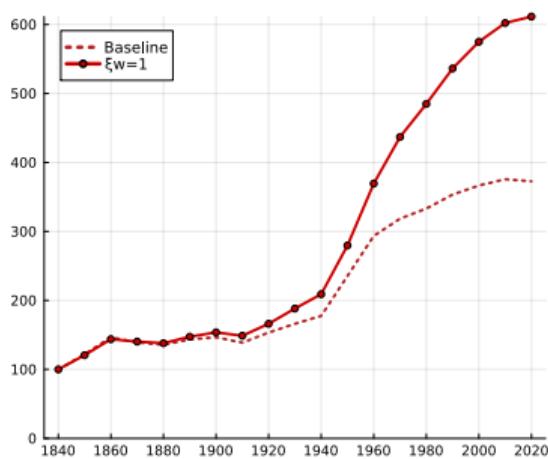
$$\tau(\ell) = a \cdot w_u^{\xi_w} \cdot \ell^{\xi_\ell}$$



(a) Commuting speed (1840=1).



(b) Average density (1840=1).



(c) House Price Index (1840=1).

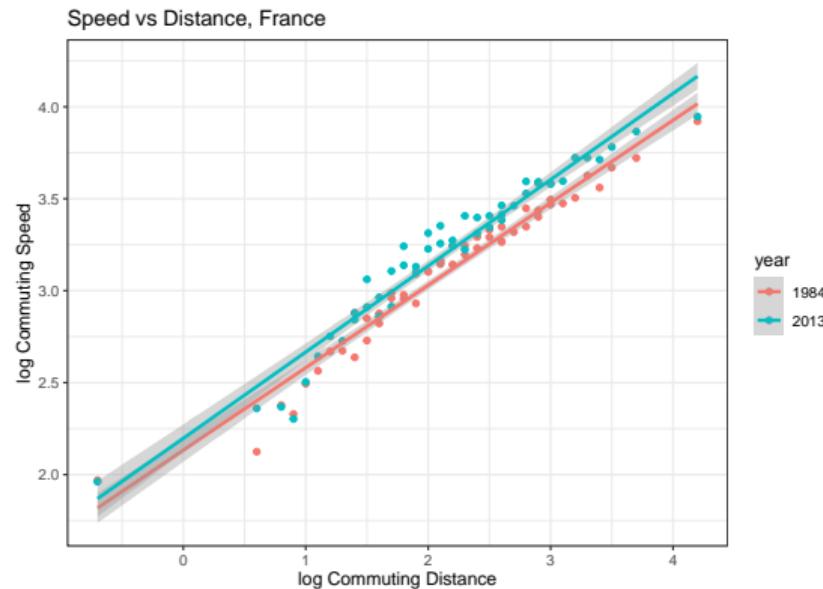
# Calibration of $\tau$

- ▶ 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).



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