Structural Change, Land Use and Urban Expansion

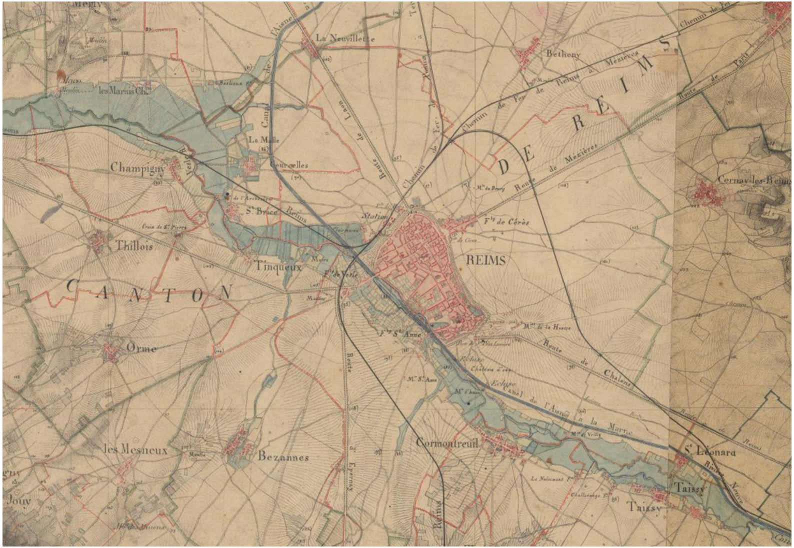
Nicolas Coeurdacier (SciencesPo & CEPR)

Florian Oswald (U. Turin)

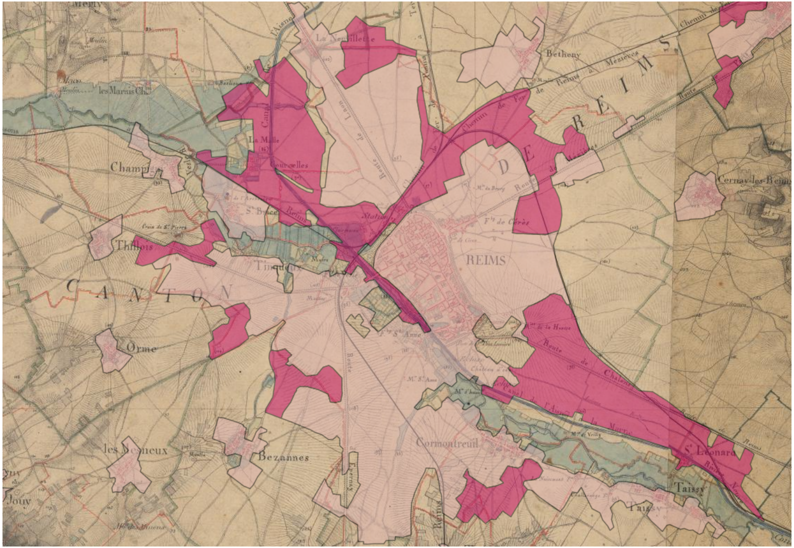
Marc Teignier (U. Barcelona)

STEG Oxford Jan 2025

Motivation: Reims in 1866

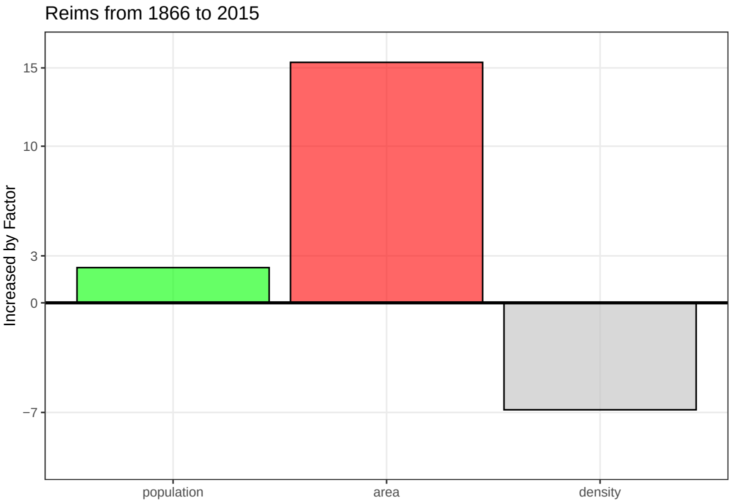


Motivation: Reims in 1866 vs IGN *Buildings* in 2017



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 (🚗 🚎 🚊) enable suburbanisation. 🏠

Urban Expansion: Different Views

1. Urban Economics:
   - Decline in commuting cost over time allows residing further away from city centre.
   - New technologies (🚗 🚎 🚊) enable suburbanisation. 🏠
2. Structural Change:
   - Food subsistence constraint 🍖 is binding initially. Land values ⬆️. No income left for bigger houses. (No need to commute to large suburban houses.)
   - Agricultural productivity growth solves food problem, 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 (🚗 🚎 🚊) enable suburbanisation. 🏠
2. Structural Change:
   - Food subsistence constraint 🍖 is binding initially. Land values ⬆️. No income left for bigger houses. (No need to commute to large suburban houses.)
   - Agricultural productivity growth solves food problem, 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.

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.

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.

- **Transition:** Productivity and income increases, subsistence problems diminish. Workers move to cities. Farmland getting more abundant. Free up land for cities to expand, accommodating rising demand for housing. Opp. cost of time is increasing, people have faster commutes. Cities getting large (in area) and much less dense *without* a large increase in land values.

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.

- **Transition:** Productivity and income increases, subsistence problems diminish. Workers move to cities. Farmland getting more abundant. Free up land for cities to expand, accommodating rising demand for housing. Opp. cost of time is increasing, people have faster commutes. Cities getting large (in area) and much less dense *without* a large increase in land values.

- **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 (GHSL 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.

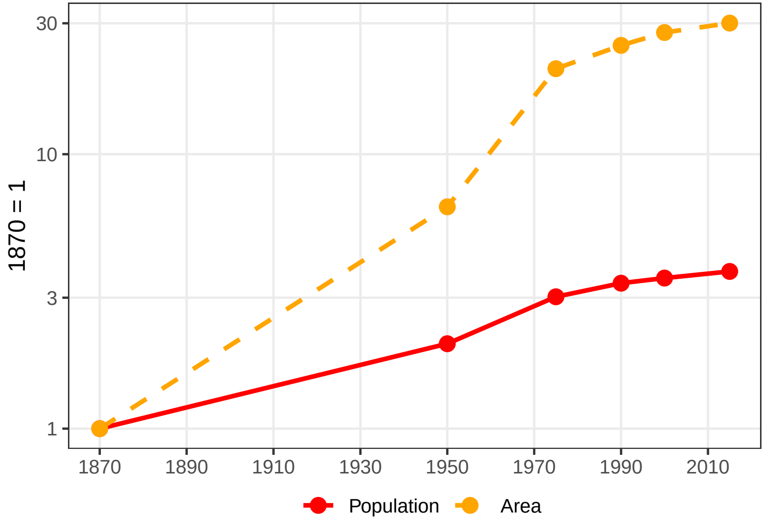
Land *and* labor reallocation: Aggregate France

Sources:

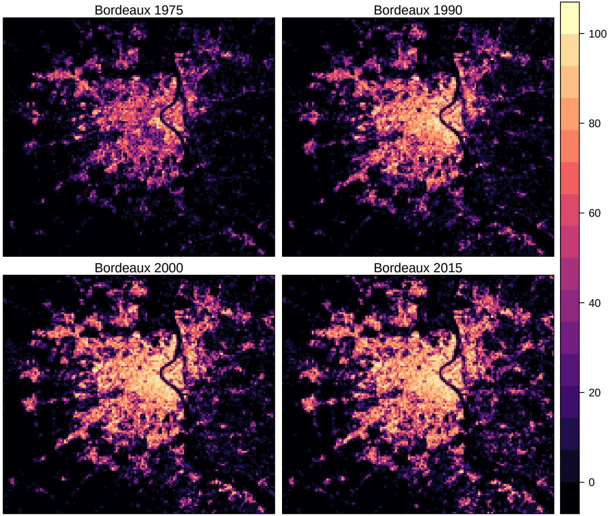
1. Toutain (1993)
2. Recensement Agricole (Ministry of Agriculture)
3. INSEE
4. Villa (1996)

Urban Expansion

Top 100 Cities in France

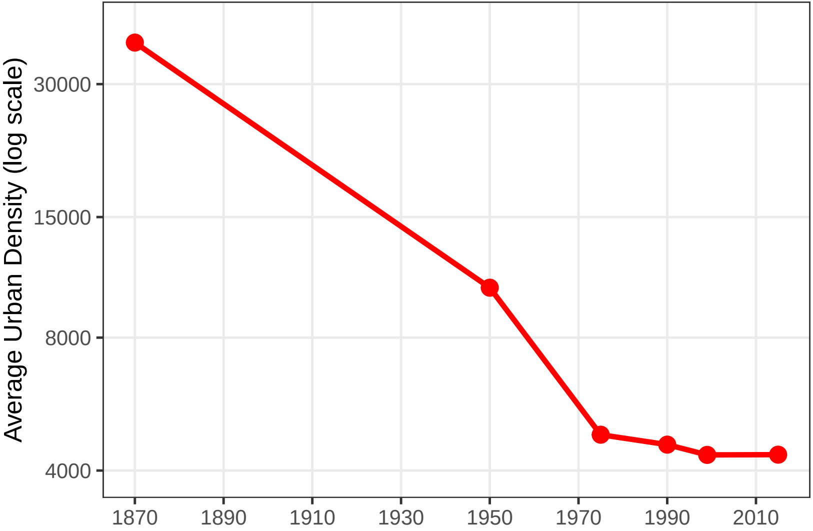


City Area and Population Measurement

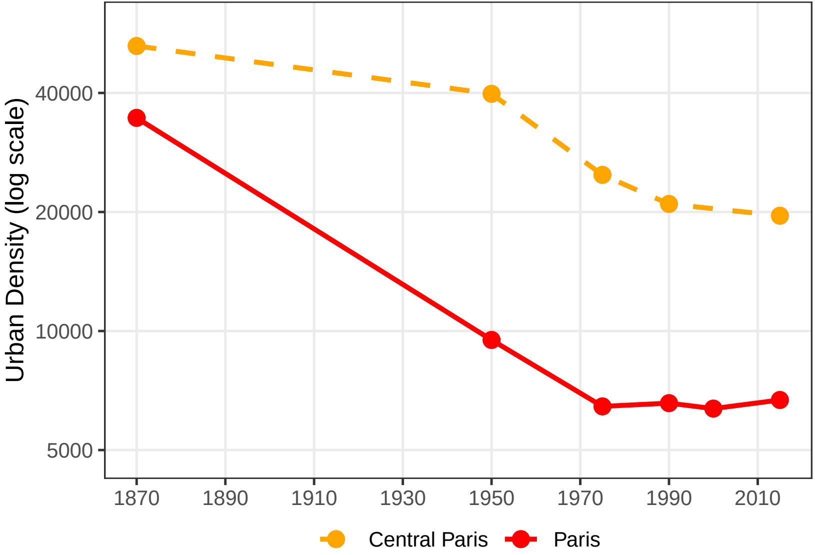


- 1866: Manual + Census
- 1950: Manual + Census
- 1975, 1990, 2000, 2015: GHSL
- More details please!

The Historical Fall in French Urban Density



The Historical Fall in Urban Density: Within Paris

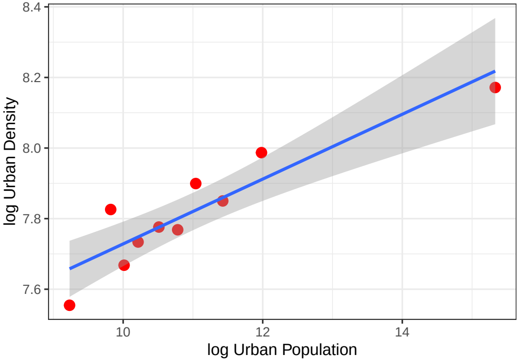


Distribution

Top 5

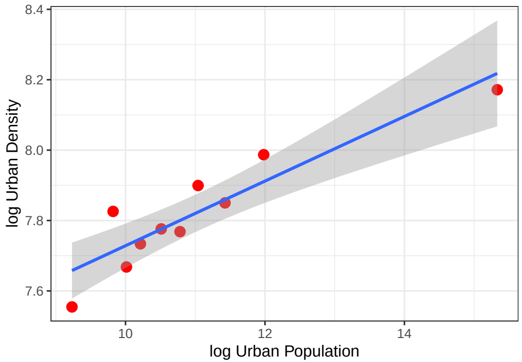
World

Urban Density vs Farmland Price and Population (year 2000)

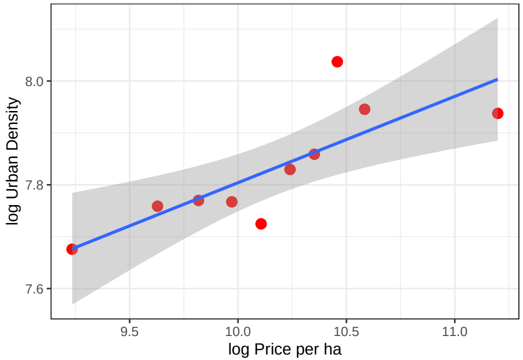


Well known: More populated cities are denser on average.

Urban Density vs Farmland Price and Population (year 2000)



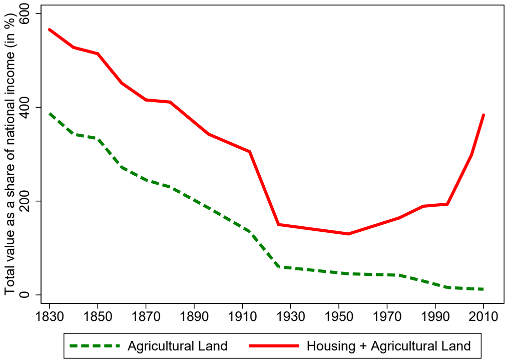
Well known: More populated cities are denser on average.



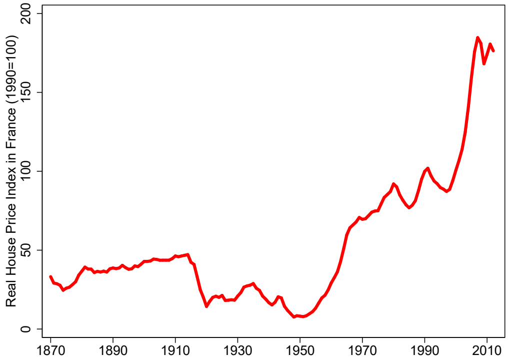
Less known: surrounding farmland and density are positively correlated.

▸ Fringe Land Use?

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



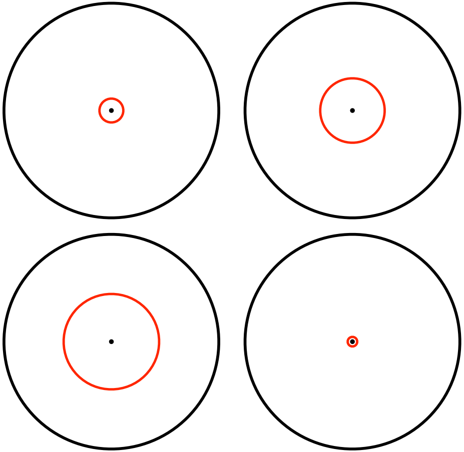
(a) Picketty and Zucman (2014)



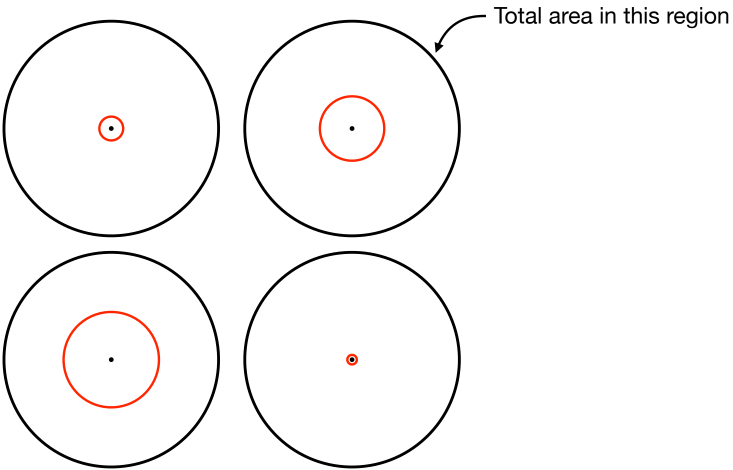
(b) Hockey Stick: Knoll et al. (2017)

Model

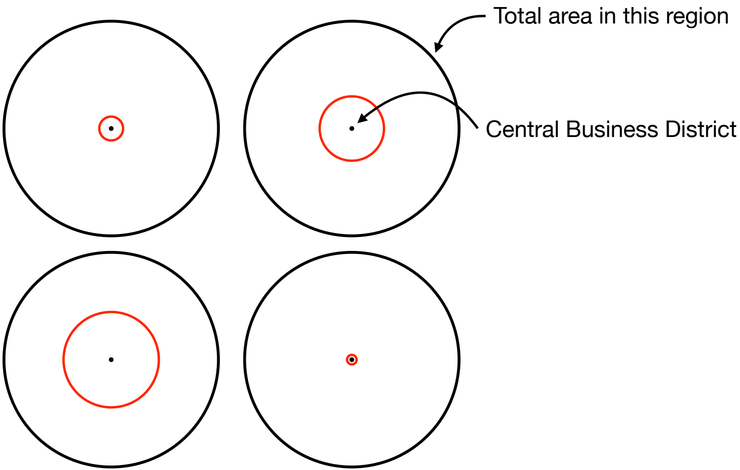
Model: Spatial Setup



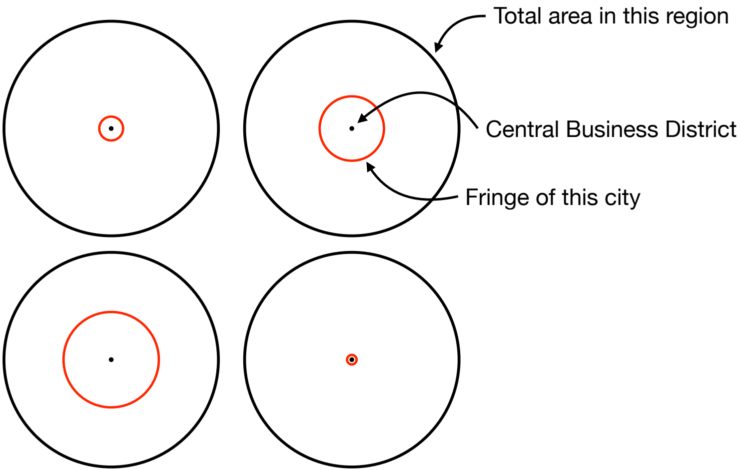
Model: Spatial Setup



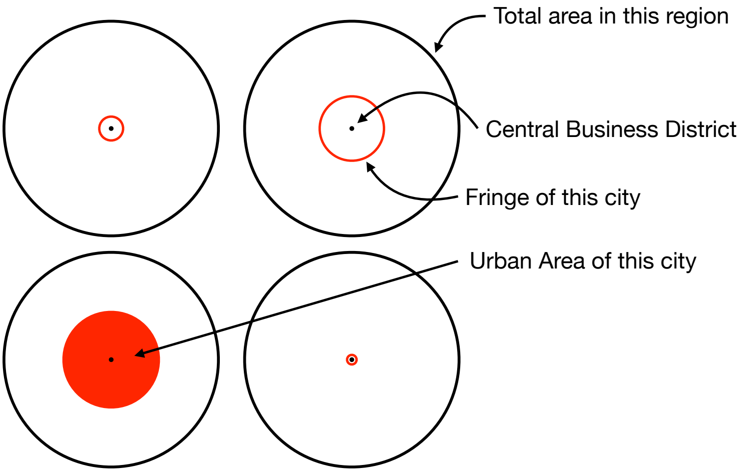
Model: Spatial Setup



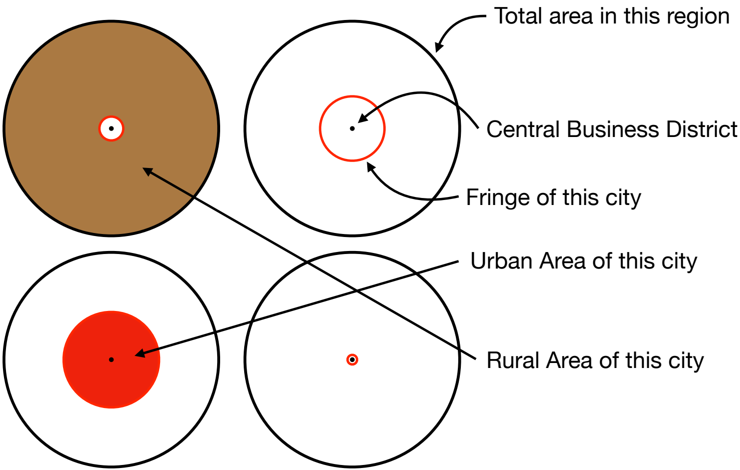
Model: Spatial Setup



Model: Spatial Setup



Model: Spatial Setup



Model: Environment

- 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.

Model: Environment

- 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.
  - Different intensity in the use of land as input
  - Rival Land Use: Agriculture *or* Housing
  - Fixed Supply of Land

Model: Environment

- 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.
  - 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.

Model: Environment

- 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.
    - 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, 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 ℓ are

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

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

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

- 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 ℓ.
  r rental income per capita, equally distributed.

Factor Payments

Urban wage,

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

with (u) good numeraire.

Factor Payments

Urban wage,

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

with (u) good numeraire.

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

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

where p the relative price of the rural good.

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

Illustrating net wages along a single radius

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

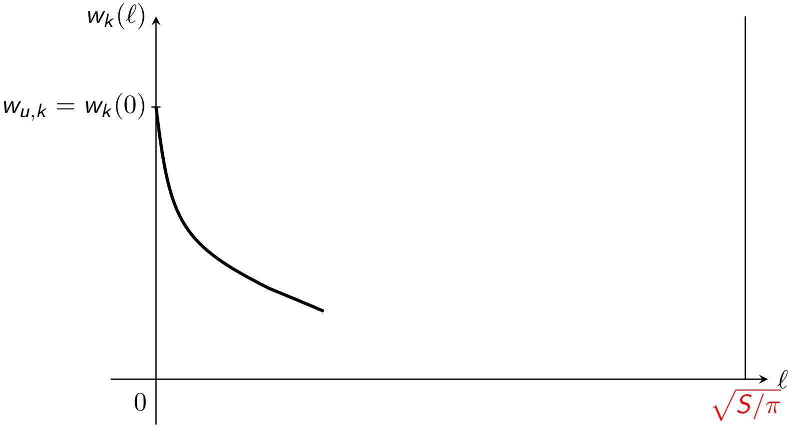
Spatial Structure: Spatial Equilibrium! $C(\ell_k) = \overline{U}$

Illustrating net wages along a single radius

1. Space $\ell \in [0, \sqrt{S/\pi}]$
2. Urban production at $\ell = 0$
3. Residence at any $\ell \in [0, \sqrt{S/\pi}]$

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

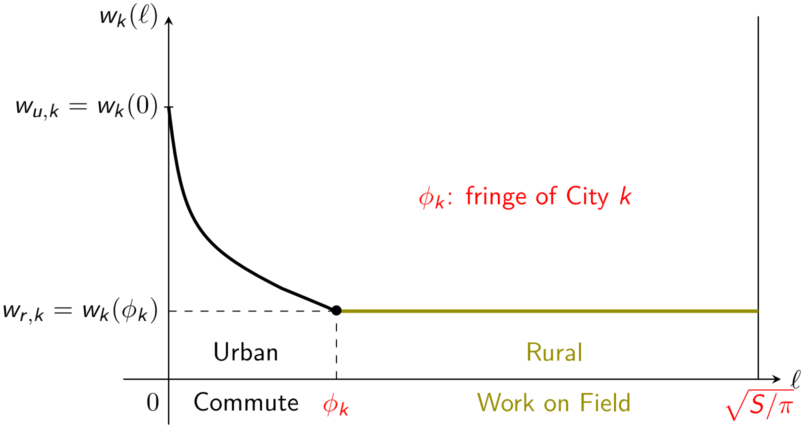
Illustrating net wages along a single radius



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

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

Illustrating net wages along a single radius

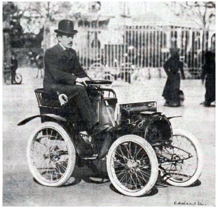


1. Space $\ell \in [0, \sqrt{S/\pi}]$
2. Urban production at $\ell = 0$
3. Residence at any $\ell \in [0, \sqrt{S/\pi}]$
4. $\tau(\ell)$: commuting cost from ℓ
5. $w_u - \tau(\ell)$ urban wage
6. ϕ_k denotes urban fringe of city k.

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 $\rightarrow$ 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: τ 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,

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

  and across regions

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

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

Location Sorting

Spatial Equilibrium

- Location indifference within region k,

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

  and across regions

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

- Same house price $q_{r,k}$ at ϕ_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:

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

Equilibrium

- Land developers buy land and numeraire good to provide residential floorspace.

  ▸ Details!

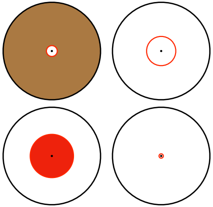
- Arbitrage across land use at the fringe pins down land values and house prices:

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

- Land Market Clearing: each city k is big enough to host $L_{u,k}$ 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

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

We denote for sector s in period t:

- an aggregate component: $\theta_{s,t}$,
- a shifter for region k: $\theta^k_{s,t}$ with weighted mean equal to 1.

👉 Aggregating over all K cities recovers the *average* city (i.e the one following $\theta_{s,t}$ only)

Sectoral and Regional Productivities

For the productivity processes, we posit that

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

We denote for sector s in period t:

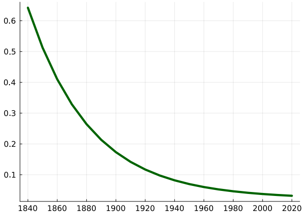
- an aggregate component: $\theta_{s,t}$,
- a shifter for region k: $\theta^k_{s,t}$ with weighted mean equal to 1.

👉 Aggregating over all K cities recovers the *average* city (i.e the one following $\theta_{s,t}$ only)

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

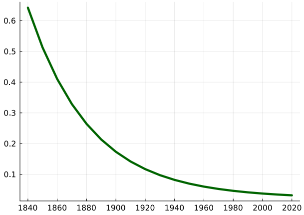
Artificial Model. $K = 4$, constant agg. growth and shifters $\theta^k_{s,t}$

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

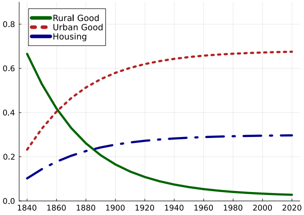


(a) Rural Labor Share.

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

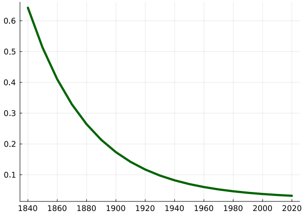


(a) Rural Labor Share.

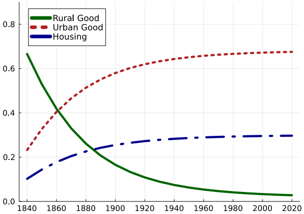


(b) Spending Shares.

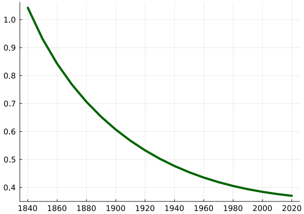
Artificial Model. $K = 4$, constant agg. growth and shifters $\theta^k_{s,t}$



(a) Rural Labor Share.

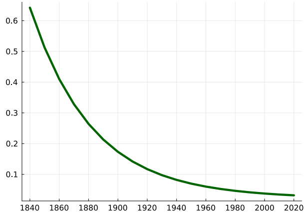


(b) Spending Shares.

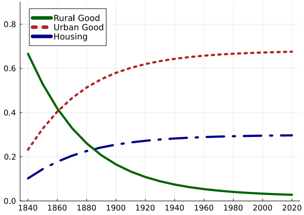


(c) Relative price p.

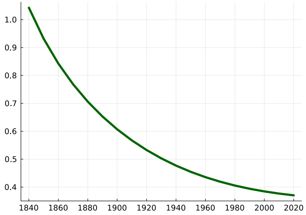
Artificial Model. $K = 4$, constant agg. growth and shifters $\theta^k_{s,t}$



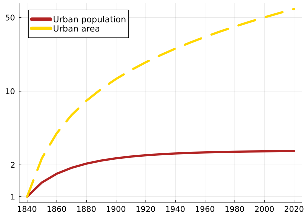
(a) Rural Labor Share.



(b) Spending Shares.

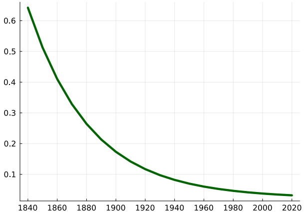


(c) Relative price p.

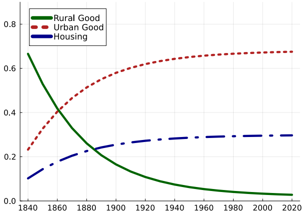


(d) Area and Population.

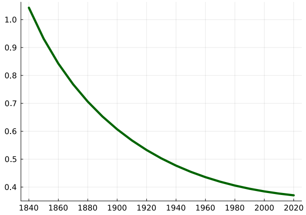
Artificial Model. $K = 4$, constant agg. growth and shifters $\theta^k_{s,t}$



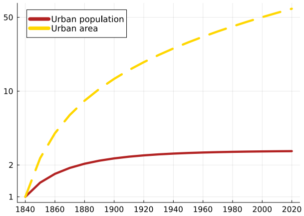
(a) Rural Labor Share.



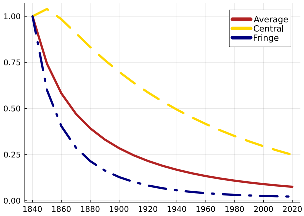
(b) Spending Shares.



(c) Relative price p.

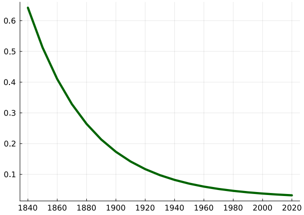


(d) Area and Population.

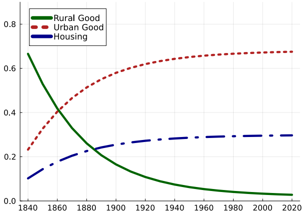


(e) Average Urban Densities.

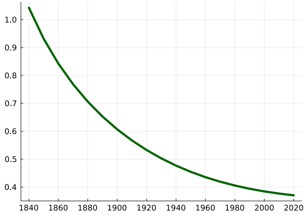
Artificial Model. $K = 4$, constant agg. growth and shifters $\theta^{k}_{s,t}$



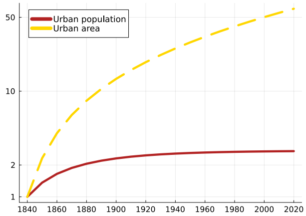
(a) Rural Labor Share.



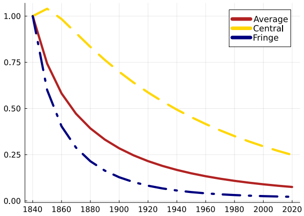
(b) Spending Shares.



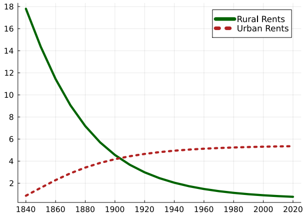
(c) Relative price p.



(d) Area and Population.



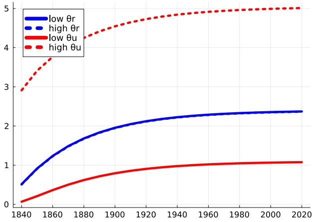
(e) Average Urban Densities.



(f) Average land rents.

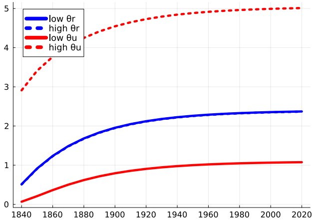
Artificial Model. $K = 4$: Identifying Cross sectional differences via $\left\{\theta^{k}_{s,t}\right\}$

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

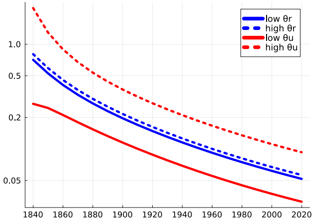


(a) Urban population.

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

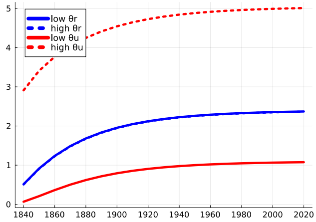


(a) Urban population.

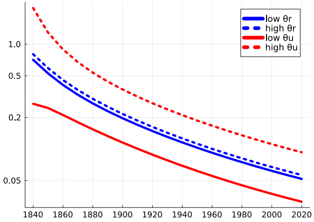


(b) Average urban Densities.

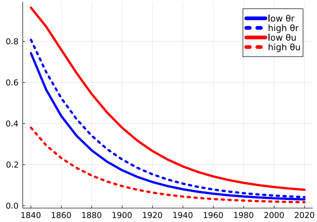
Artificial Model. $K = 4$: Identifying Cross sectional differences via $\{\theta^k_{s,t}\}$



(a) Urban population.

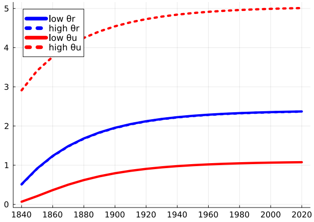


(b) Average urban Densities.

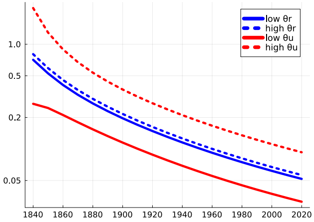


(c) Rural employment share.

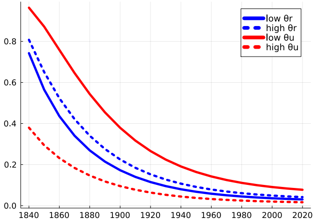
Artificial Model. $K = 4$: Identifying Cross sectional differences via $\{\theta^k_{s,t}\}$



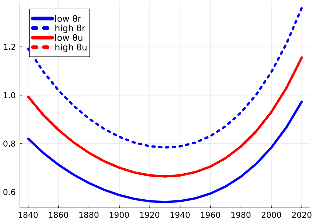
(a) Urban population.



(b) Average urban Densities.

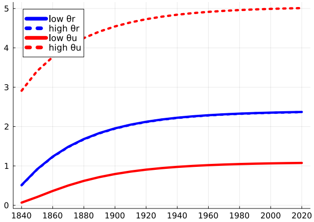


(c) Rural employment share.

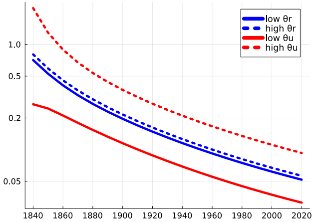


(d) Rural Land Rents.

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

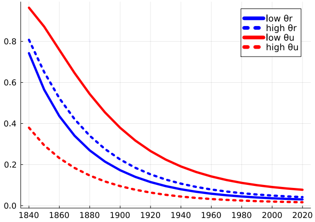


(a) Urban population.

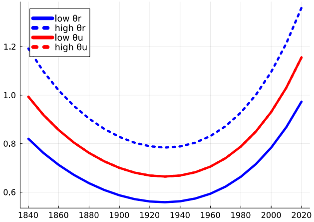


(b) Average urban Densities.

🚨 Local vs Global Shocks!



(c) Rural employment share.



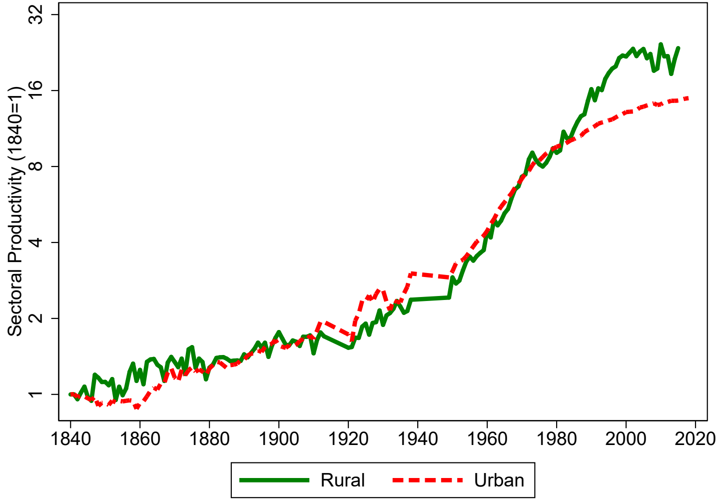
(d) Rural Land Rents.

Full Quantitative Model and Parameterization

1. We estimate the *aggregate* θ series from data.
2. We use observed population growth.
3. We use individual commuting data to directly calibrate the τ 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



- $\theta_{s,k,t} = \theta_{s,t} \cdot \theta^{k}_{s,t}$
- 👈 Aggregate Processes: $\theta_{s,t}$
- Regional shifters: $\theta^{k}_{s,t}$

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) $\Rightarrow \{\theta^k_{u,t}\}$
- ρ_{kt}/ρ_{1t}: Farmland value outside city k rel. to city 1. $\Rightarrow \{\theta^k_{r,t}\}$

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

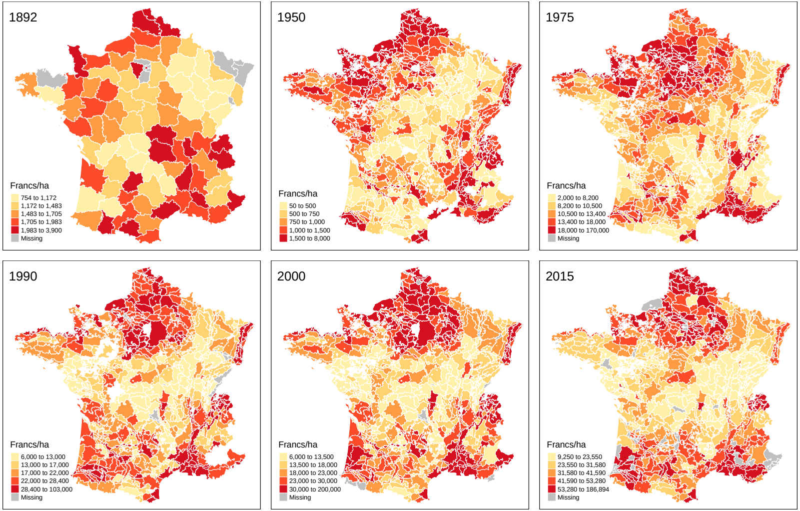
TABLEAU A-1 (suite)

EVOLUTION DU PRIX DES TERRES LABOURABLES DE 1950 A 1968 PAR REGION AGRICOLE

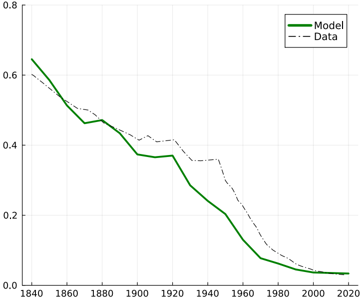
(Francs à l'bectare)

		1950	1953	1958	1960	1962	1963	1964	1965	1966	1967	1968
26 463-R: BARONNIES	DOM	900	900	2200*	2200*	4500	4500	4500	5000	5000	5000	5500
	MINI	800	800	700	700	1000	1000	1000	2000	2000	1500	1000
	MAXI	1000	1000	3000	4500	5000	5000	5000	6000	7000	11000	11000
26 464-K: TRICASTIN	DOM	2000	2000	2500*	2500*	6700*	6700*	6800	7500	7500	8000	9000
	MINI	1000	1000	700	700	2500	2500	2500	2000	2000	1500	1500
	MAXI	4000	4000	3000	4500	8000	8000	8000	10000	11000	13000	16000
ENSEMBLE DROME	MOYENNE	2500	2500	4100	4100	5900	6100	6100	6700	7000	7300	7900
	INDICE	39	39	63	63	93	95	95	105	109	113	123
ISERE												
38 199-E: BAS DAUPHINE	DOM	1000*	1300	2750	2750	3000	5000	7000	8000	8500	9000	10000
	MINI	700*	1000	1600	1600	2200	3500	3500	4000	5000	6000	7000
	MAXI	3000*	4000	4000	4000	3500	7000	12000	13000	13000	13000	15000
38 217-A: GRESIVAUDAN	DOM	1500	2000	3000	3200	4000	7000	10000	11000	12000	12000	12500
	MINI	1000*	1200	2000	2000	3500	4500	5000	6000	7000	6000	8000
	MAXI	4000*	5000	4500	5500	5000	9000	15000	15000	16000	17000	18000
38 453-P: PREALPES	DOM	500*	600	2500	2500	2500	3500	3500	3600	4000	4000	5000
	MINI	200*	250	1500	1500	1500	1500	1000	1000	1000	1500	2000
	MAXI	2000*	2000	3500	3500	3000	4500	4000	4000	7000	7000	8000
38 457-J: REGION HAUTE ALPINE	DOM	300*	400	2500	2500	2500	3500	3500	3600	4000	4000	5000
	MINI	100*	100	1500	1500	1500	1500	1000	1000	1000	1500	2000
	MAXI	800*	1000	3500	3500	3000	4500	4000	4000	7000	7000	8000
38 465-S: VALLEE DU RHONE	DOM	2000*	2500	3000	3200	4000	7000	10000	11000	12000	12000	12500
	MINI	1000*	1500	2000	2000	3500	4500	5000	6000	7000	6000	8000
	MAXI	4000*	5000	4500	5500	5000	9000	15000	15000	16000	17000	18000
ENSEMBLE ISERE	MOYENNE	1000	1300	2800	2800	3100	5200	7100	7900	8500	8800	9700
	INDICE	14	18	37	37	42	69	94	106	114	118	130
LOIRE												
42 168-A: MT DU JAREZ ET BASSIN HOUILLER ST EPHANOIS	DOM	750	800	1750*	2400*	3300*	3300*	3500*	3500*	4100*	4500	5000
	MINI	400	250	700*	1000*	1500*	2000*	2000*	2500*	3000*	3500	3500
	MAXI	1100	1300	3000*	4000*	5500*	6000*	6000*	6000*	7000*	8000	10000
42 170-G: MTS DU PILAT	DOM	550	600	1300*	1800*	2400*	2400*	2600*	2650*	3000*	3200	3800
	MINI	400	250	500*	500*	1000*	1200*	1200*	1500*	1500*	1700	1700
	MAXI	900	1100	3000*	3500*	4000*	4000*	4000*	4500*	5000*	6000	6500
42 189-B: PLATEAUX DE NEULISSE	DOM	500	500	1400*	1800*	2550*	2550*	2750*	2800*	3200*	3500	4000
	MINI	300	250	700*	1000*	1500*	1500*	1500*	1500*	1500*	1700	1800
	MAXI	850	1100	2500*	3000*	4500*	5000*	5000*	5000*	7000*	7000	7500

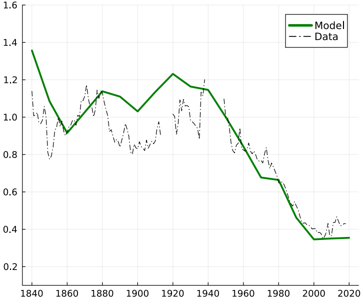
Novel Data on Land Values!



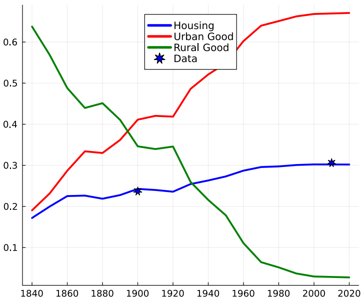
Aggregate Results: Structural Change



(a) Rural employment share.



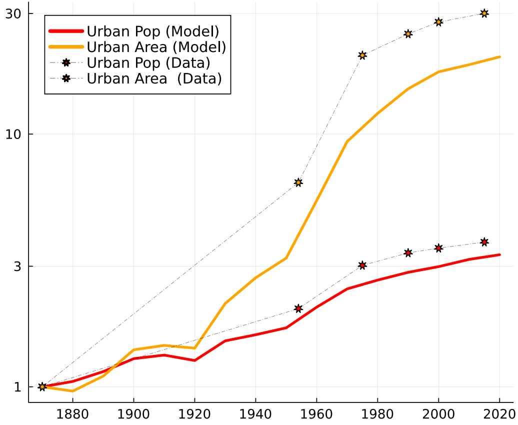
(b) Relative price of rural good.



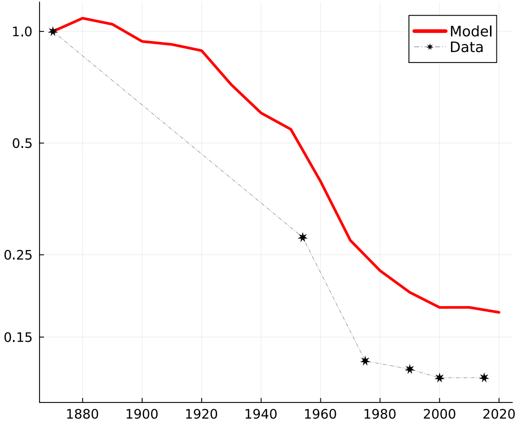
(c) Spending shares.

Figure: Structural change aggregated over K cities.

Aggregate Results: Urban Expansion



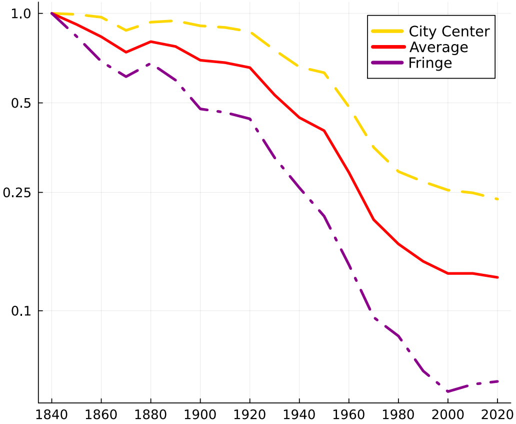
(a) Urban Area and Population (1870=1)



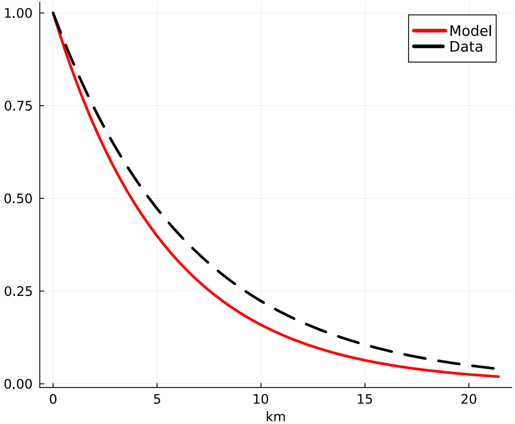
(b) Average urban density (1870=1)

Figure: Urban expansion aggregated over K cities.

Aggregate Results: Urban Structure



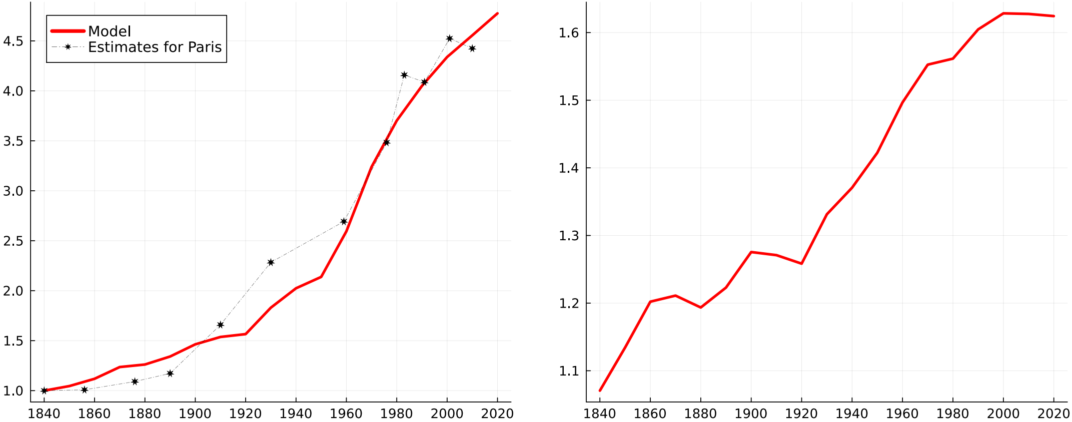
(a) Urban density (1840=1).



(b) Density gradient (2020).

Figure: Density across space.

Aggregate Results: Commuting Speed and APG

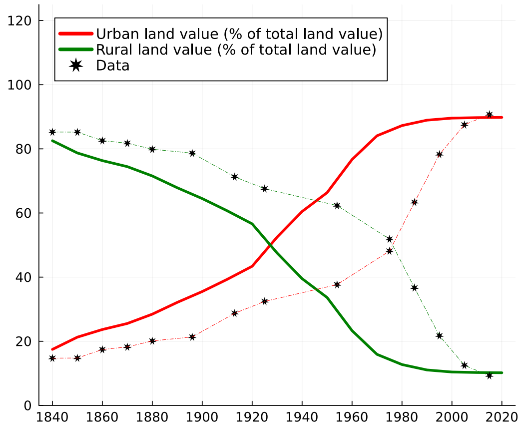


(a) Average urban commuting speed (1840=1).

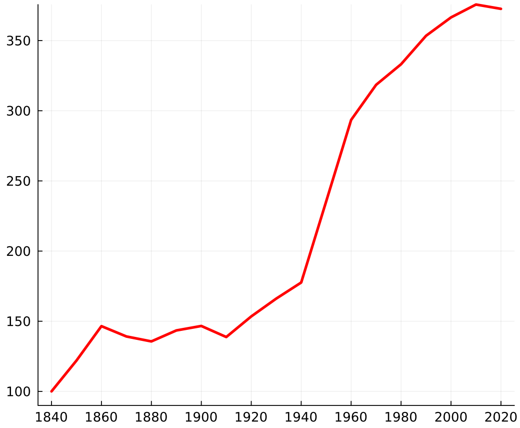
(b) Agricultural productivity gap.

Figure: Commuting speed and the 'agricultural productivity gap'

Aggregate Results: Wealth Distribution and House Price



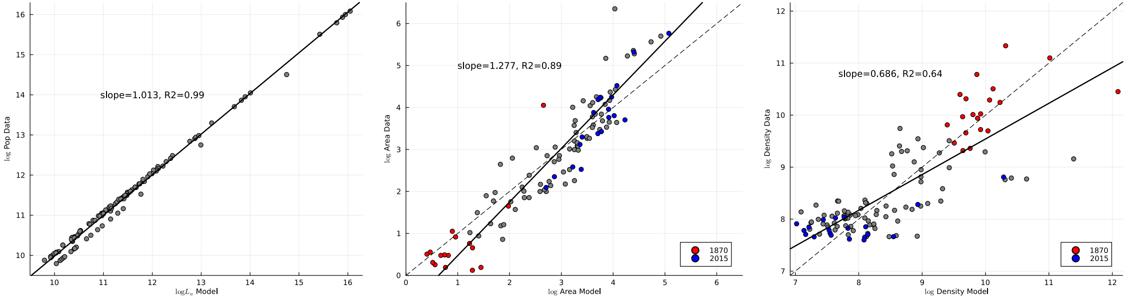
(a) Urban versus rural land wealth.



(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)
$\log \overline{\rho}_{r,k,t}$	0.371***	0.126***	0.346***
	(0.018)	(0.026)	(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

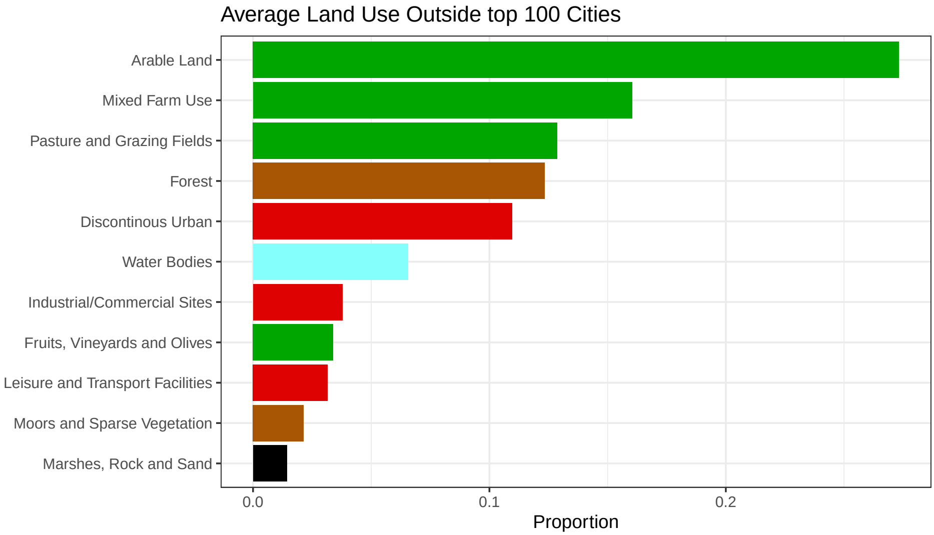
1. Evolution of sectoral allocation across space.
2. Evolution of Urban Density.
3. Evolution of the land value distribution.

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



Paris

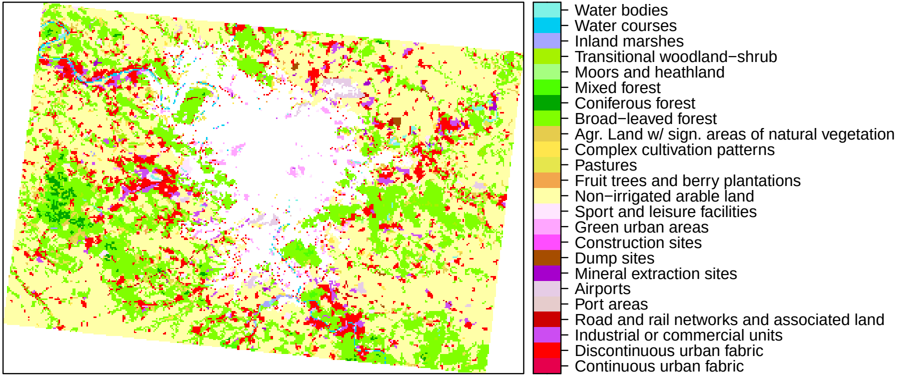
Lyon

Marseille

Bordeaux

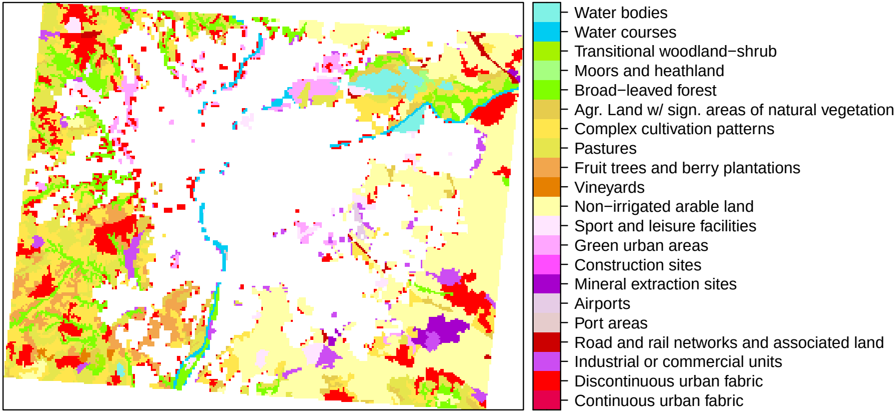
back

Land Use outside Paris 2020



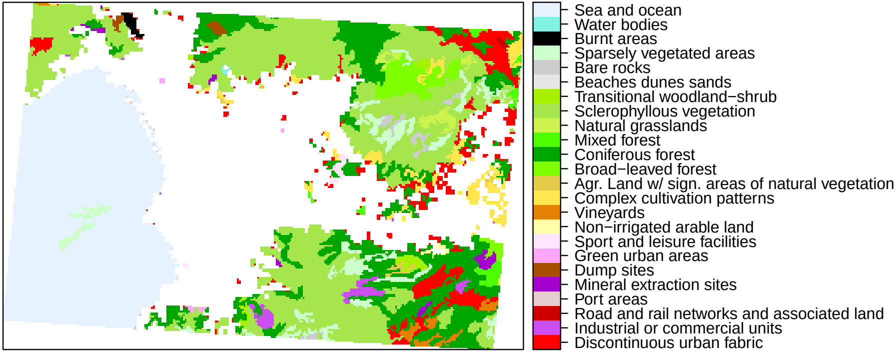
back

Land Use outside Lyon 2020



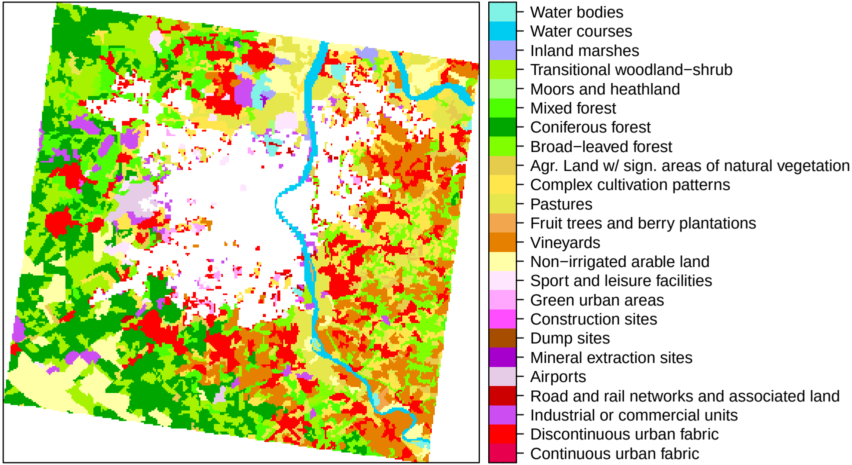
back

Land Use outside Marseille 2020



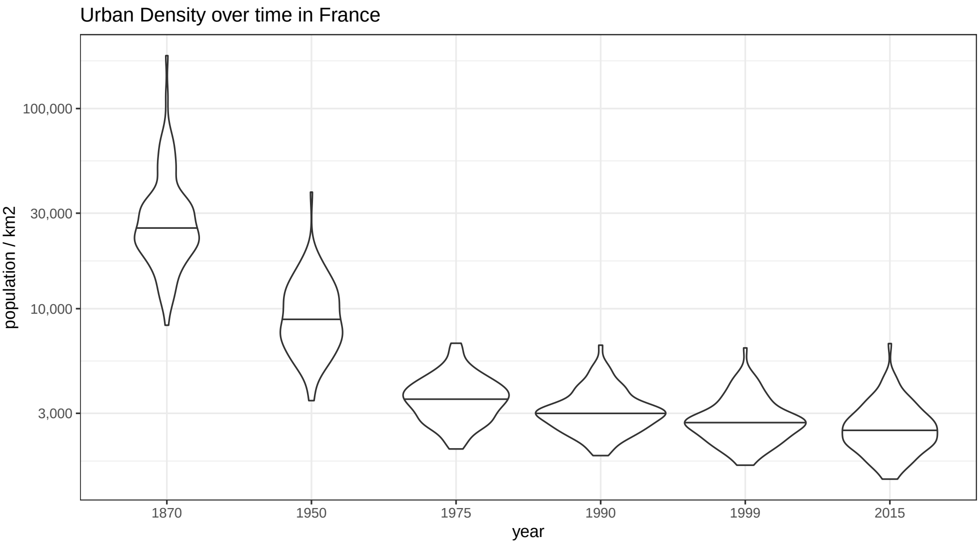
back

Land Use outside Bordeaux 2020



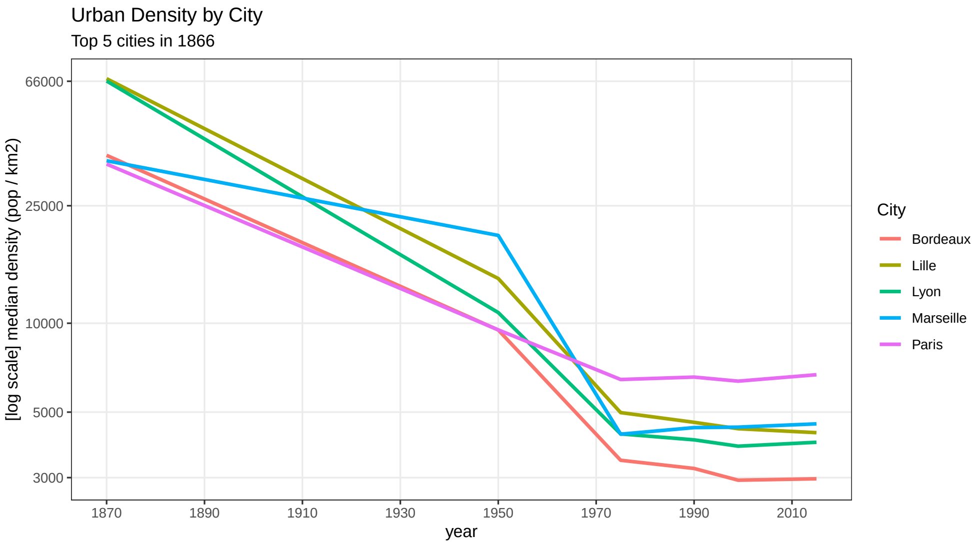
back

The historical fall in urban density



▸ back

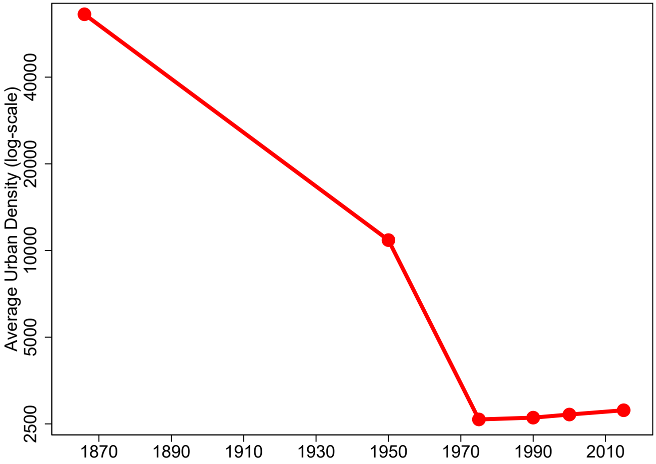
The historical fall in urban density



▸ back

The historical fall in urban density

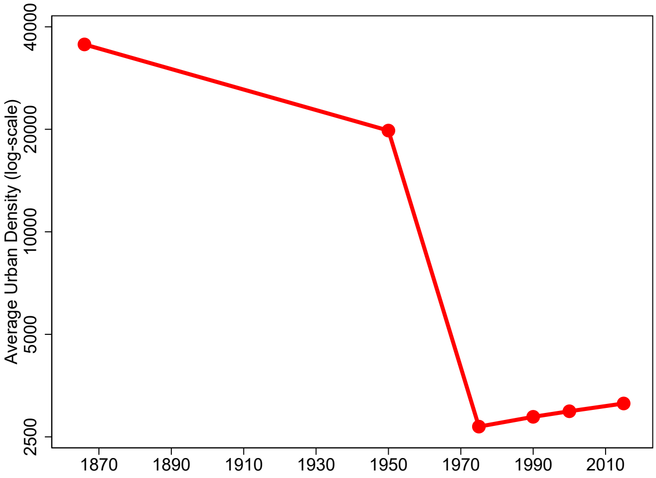
Lyon



back

The historical fall in urban density

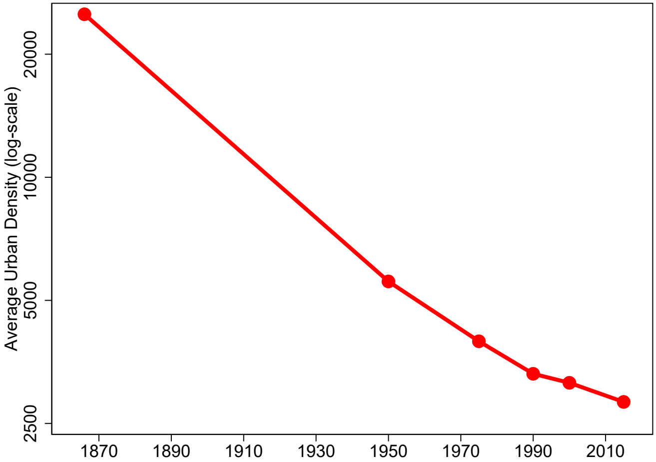
Marseille



back

The historical fall in urban density

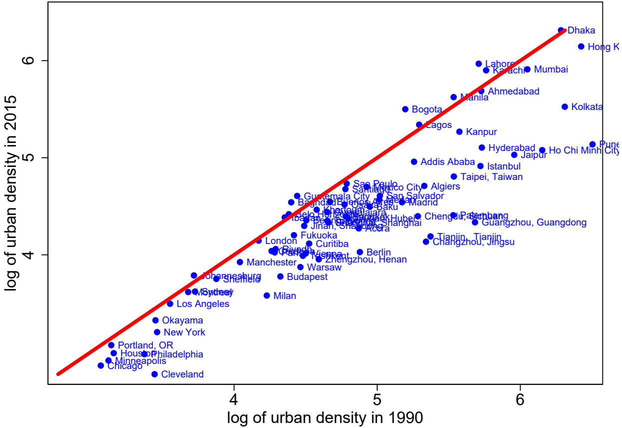
Reims



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

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,

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

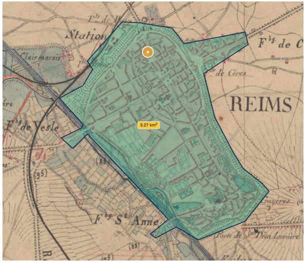
- Land use with the highest rental value (Rivalry)
- Indifference conditions across uses at the fringe,

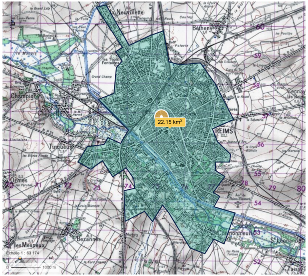
$$\rho_r = \frac{(q_r)^{1+\epsilon_r}}{1+\epsilon_r} = (1-\alpha)p\theta_r \left(\frac{L_r}{S_r}\right)^{\alpha}.$$

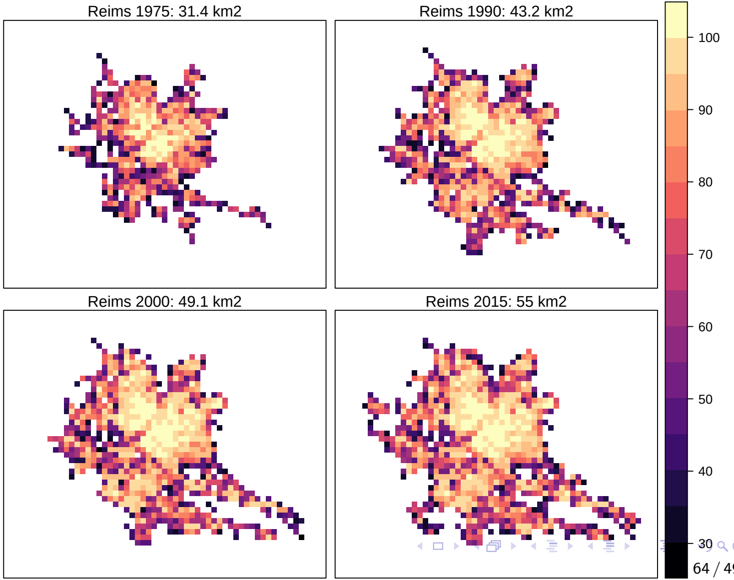
▸ back

GHSL Measurement - Reims

back

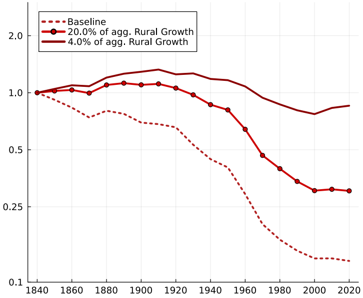




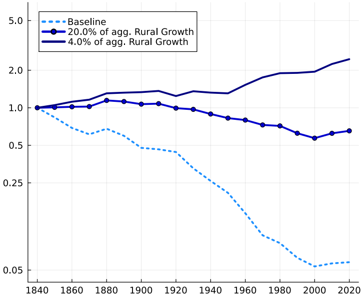


Sensitivity Analysis

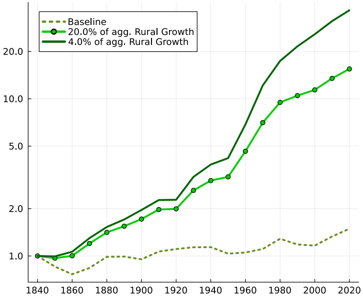
The role of rural productivity growth



(a) Average density (1840=1).



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



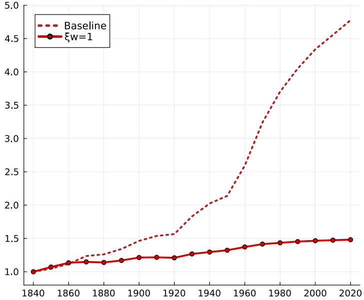
(c) Rental price of farmland.

back

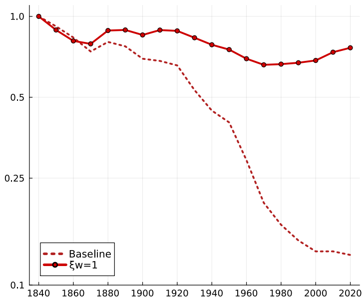
Sensitivity Analysis

The role of increasing commuting speed

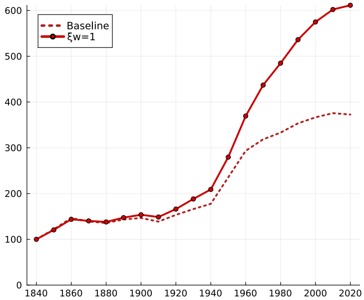
$$\tau(\ell) = a \cdot w_u^{\xi_w} \cdot \ell^{\xi_\ell}$$



(a) Commuting speed (1840=1).



(b) Average density (1840=1).



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

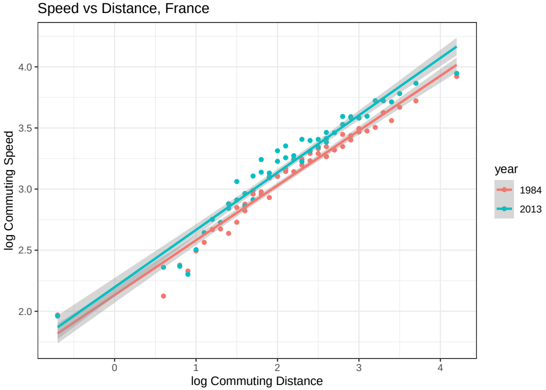
back

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