

Urban densities and patterns: stylized facts and generic abstract tools

**Geoffrey Caruso**  
University of Luxembourg  
Luxembourg Institute of Socio-Economic Research, LISER

PERSPECTIVE-LAB  
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Outline

1. **Policy and scientific context**
2. **Stylized facts:** urbanised land and population density profiles across Europe
3. **Abstract tools:** simulation to understand policy effects in a controlled environment

1. Policy and scientific context

1. EU Policy - Urban Agenda Policy (see also PRDD)

A >15 years recognized challenge...

**with a strong normative assertion: compactness**

The Leipzig Charter, 2007, p.4

*An important basis for efficient and sustainable use of resources is a **compact settlement structure**. This can be achieved by spatial and urban planning, which prevents urban sprawl by strong control of land supply and of speculative development. The strategy of mixing housing, employment, education, supply and recreational use in urban neighbourhoods has proved to be especially sustainable. The strategy of mixing housing, employment, education, supply and recreational use in urban neighbourhoods has proved to be especially sustainable.*

...and a shared vision across Europe

European Commission, Cities of Tomorrow, 2011, p42

**more recently added with a second normative assertion: green!**


*A vision of the compact and green city*

'An important basis for efficient and sustainable use of resources is a **compact settlement structure**. This can be achieved by spatial and urban planning, which prevents urban sprawl by strong control of land supply and of speculative development. The strategy of mixing housing, employment, education, supply and recreational use in urban neighbourhoods has proved to be especially sustainable' (The Leipzig Charter on Sustainable European Cities)''


The **compact** and green city offers an interesting urban landscape, a healthy functional mix, and a good quality of architecture and design in its built environment

(public spaces, buildings and housing). It offers easy access to green areas and open space for everyone. It takes care of and makes use of its historical sites and monuments.

Since people no longer need to search for green areas outside the city, they have moved back to the centres and no longer need to go to work or to leisure facilities by car. As an alternative, they can easily hop on clean and convenient public transport, which works efficiently due to the **high concentration of passengers** and makes cities cleaner and quieter. Furthermore, it has prevented the countryside from suffering from urban sprawl, preserving it for agriculture, forestry and nature.



Urban Agenda for the EU



Sustainable Use of Land and Nature-Based Solutions Partnership

ACTION PLAN  
October 2018

**Urban Agenda for the EU**  
Amsterdam Pact, 2016  
**SUL-NBS action plan**

*"supporting sustainable land use through **promoting compact city development, reducing urban sprawl and minimising land-take – and nature-based solutions are regarded as one important tool and means through which this can be achieved.**" (p.6)*

## Urban Agenda for the EU

**Urban Agenda for the EU  
Amsterdam Pact, 2016  
Air Quality action plan**

- *very vague as to the role of urban planning*  
- *plans are so far rather information and technology orientated*

## 1. Policy and scientific context

1. EU Policy - Urban Agenda Policy (see also PRDD)
2. Scientific agreement on sprawl vs compactness

## Large agreement to halt 'excessive' sprawl

- **Environmental reasons:** Urbanisation => GHG Emissions, fragmentation of ecosystems, too demanding on energy resources that are limited,...
- **Economic reasons:** Urbanisation accommodates population growth but excess sprawl leads to **3 market failures** (Brueckner, 2000. Urban sprawl: diagnosis and remedies, IJRR)
  1. **Social value of lost green/natural space is underestimated** because of sequential/fragmented decision making => too much land is artificialized and access/view to nature is reduced
  2. Individuals do not account for their own effect on **congestion and pollution** => cities are too big and there is too much road infrastructure
  3. Real estate developers do not take up the **costs of public infrastructures** related to their projects. Developing land appears less costly, which promotes excess.

## .... but literature is not very supportive of compactness

Compact does not lead to shorter commuting

(e.g. Ewing and Hamid, 2015 rejoining Richardson)

How urban forms affect mobility behaviour is unclear

(e.g. Boarnet and Crane, 2001; Cervero, 2003)

Modest environmental gains given social and economic costs

(e.g. Breheny, 1997; Echenique et al., 2012; Williams, Burton, 2006)

Large compact cities may be no man's land for wildlife

(e.g. Wade et al., 2009)

urban form – transport                      urban form – environment

**=> more clever spatial arrangements of people, nature and networks**  
within urban regions than sprawl or compact to be found

## .... or even claim that sustainability is not related to "forms" but only behaviour, technology and processes

**The Compact City Fallacy**

Michael Neuman

The world has been abuzzing for months about the Urban Agenda for the EU, the European Commission's new initiative to address the challenges of urbanisation. It's a welcome sign that the EU is taking a holistic view of urbanisation, rather than just focusing on transport or energy. The Urban Agenda is a landmark document that sets out a vision for a more sustainable and inclusive urban future. It's a step in the right direction, but it's also a step that needs to be taken with care. The Urban Agenda is a complex document, and it's easy to get lost in the details. But one thing is clear: the Urban Agenda is a vision for a more sustainable and inclusive urban future. It's a vision that needs to be taken seriously, and it's a vision that needs to be implemented with care.

*"the attempt to make cities more sustainable only by using urban form strategies is counterproductive"*

**Growing Cities Sustainably**

**Does Urban Form Really Matter?**

Marcell H. Ederington, Anthony J. Hagness, Graham Mitchell, and Axel Naudts

The problem of urban sprawl has long been recognized as a major challenge to sustainable development. The Urban Agenda for the EU is a landmark document that sets out a vision for a more sustainable and inclusive urban future. It's a step in the right direction, but it's also a step that needs to be taken with care. The Urban Agenda is a complex document, and it's easy to get lost in the details. But one thing is clear: the Urban Agenda is a vision for a more sustainable and inclusive urban future. It's a vision that needs to be taken seriously, and it's a vision that needs to be implemented with care.

## 1. Policy and scientific context

1. EU Policy - Urban Agenda Policy (see also PRDD)
2. Scientific agreement on sprawl vs compactness
3. Need to reconceptualize density - not a single metric

### Density alone to be reconsidered – not a sufficient norm

*"policy needs to be more versatile in its conceptualisation of density. At the moment, spatial density in policy terms is viewed mostly as the number of dwellings per area."*

**PROGRESS IN PLANNING**  
 Review  
**Clarifying and re-conceptualising density**  
 Christopher T. Boyko\*, Rachel Cooper

**Abstract**  
 As a spatial concept, density is a useful tool in guiding and controlling land use. However, policymakers, practitioners, academics and citizens are often unclear about how density, and especially higher densities, can be best defined to create and sustain the design of urban environments. Barriers related to definitions, calculations, concepts and correlations with relevant issues prevent progress. Thus re-conceptualising density beyond a single unit of units to area. More needs to be done to show that density plays a key role in planning, architecture and urban design, and that definitions of density cannot be done in isolation of a whole host of issues related to the built and natural environment. To that end, this paper aims to clarify some of the issues surrounding density, particularly about academic definitions, calculation terms, the advantages and disadvantages of increasing densities, its close and interesting relationship between density and issues pertinent to the design of urban environments. With these relationships in mind, a new way of thinking about density in that effort—though a necessary re-conceptualisation—that captures density into its component parts, allowing scholars, policymakers and practitioners to understand what aspects of density have been examined and what gaps in our present reality, a re-conceptualisation of density is presented, illustrating that density is more than a quantitative calculation that exists on its own, rather, for density to be considered as an integral part of the urban environment, both "hard" (i.e., quantitative) and "soft" (i.e., qualitative, contextual).

Fig. 5. New conceptualisation of density.

### Density alone to be reconsidered – not a sufficient norm

**R+11**  
 36 logements de 70 m<sup>2</sup>  
 COS = 0,5  
 CES = 0,1  
 DB = 1,2  
 72 habitants  
 Densité : 143 hab / ha

**R+2**  
 36 logements de 105 m<sup>2</sup>  
 COS = 0,5  
 CES = 0,17  
 DB = 0,51  
 72 habitants  
 Densité : 143 hab / ha

**R+combles**  
 24 logements de 105 m<sup>2</sup>  
 COS = 0,5  
 CES = 0,33  
 DB = 0,49  
 60 habitants  
 Densité : 119 hab / ha

Chaque exemple a une surface de terrain de 5040 m<sup>2</sup> et une S.H.O.B. de 2500 m<sup>2</sup> et un C.O.S. de 0,5.

Le nombre d'habitants est calculé selon le nombre moyen de personnes par ménage en France en 2006 : 2,2 pour le collectif et 2,5 pour individuel.

D'après Fouchier, 2007. Les densités urbaines et le développement durable, le cas de l'Ile-de-France et de la région parisienne. G.E. de l'Architecture/Conseil du Gouvernement pour la Région Ile-de-France, 211 p.

### Beyond density, need for multi-dimensional metrics

Housing Policy Debate • Volume 12, Issue 4  
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**Wrestling Sprawl to the Ground: Defining and Measuring an Elusive Concept**

George Galster  
 Wayne State University

Rayce Hanson  
 University of Maryland, Baltimore County

Michael R. Ratcliffe  
 U.S. Bureau of the Census

Harold Wolman  
 George Washington University

Stephen Coleman and Adam Prellage  
 University of Maryland, Baltimore County

1. Density
2. Continuity
3. Concentration
4. Clustering
5. Centrality
6. Nuclearity
7. Mixity
8. Proximity

**Abstract**  
 The literature on urban sprawl includes causes, consequences, and conditions. This article presents a conceptual definition of sprawl based on eight distinct dimensions of land use patterns: density, continuity, concentration, clustering, centrality, nuclearity, mixity, and proximity. Sprawl is defined as a condition of land use that is represented by low values on one or more of these dimensions.

### 1. Policy and scientific context

1. EU Policy - Urban Agenda Policy (see also PRDD)
2. Scientific agreement on sprawl vs compactness
3. Need to reconceptualize density - not a single metric
4. Need to connect density with behavioural fundamentals

Residential choice (1) is a trade-off between space and time

- Households trade-off

**housing costs vs transportation costs**

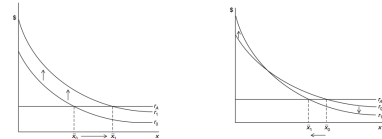
A larger/smaller private space or a shorter/longer time spent in transportation

- Alonso-Muth-Mills (1964) – standard urban economic model
- NB: In a perfect world, housing prices compensate the two costs => equally happy whatever the distance
- Explains density (and land value) decreasing with distance to main centers**

Residential choice (1) is a trade-off between space and time

Urban expansion is then explained by

- Population (migration) increase (translation effect)
- Increasing income or decreasing transportation costs (rotation effect)



Brueckner 2011

Residential choice (2) considers local density effects

- Households value localized amenities, related to local density

Low density amenities:

- Proximity to nature / green space
- = a powerful driver of sprawl, fragmented urbanisation
- Paradoxically, reinforced by compactness policies!
- cleaner air (?)

High density amenities

- Urban life: theaters, museum, cafés,... usually related to city size (agglomeration benefits)
- Social interactions in close proximity
- Nuisances: noise, heat islands, pollution

NB: In a perfect world housing prices also compensate this "voting with your feet" (Tiebout) and neighbourhoods competition

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2. Stylized facts: urbanised land and population density profiles across Europe
3. Abstract tools: simulation to understand policy effects in a controlled environment

2. Stylized facts: urbanised land and population density profiles across Europe

1. Goals and assumptions
2. Europe
3. Brussels

Source:

- Ongoing FNR Scale-it-up project with P Killgariff, Y Wei and R Lemoy
- Lemoy, R. and Caruso, G., 2018. Evidence for the homothetic scaling of urban forms. Environment and Planning B: Urban Analytics and City Science.
- Delloye, J., Lemoy, R. and Caruso, G., 2019. Alonso and the scaling of urban profiles. Geographical Analysis.

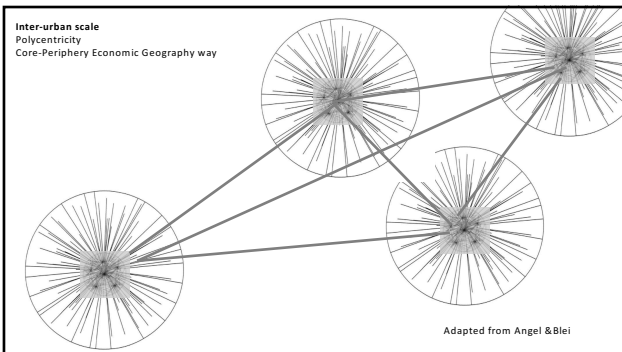
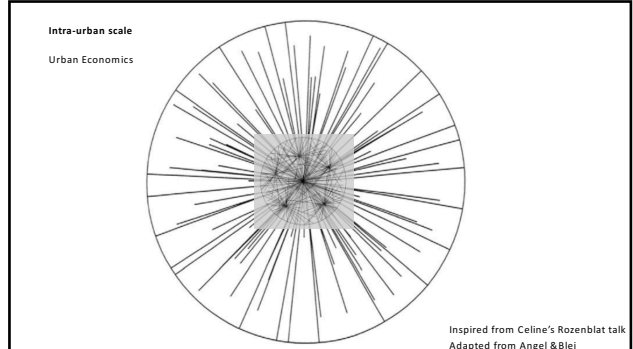
Goals

- Empirical validation of the standard urban model and of the distance trade-off
- First comprehensive and comparable analysis of urban land and density gradients for all European cities (>100 000 inh)
- Is there a common profile across Europe
- What is the effect of city size on the profile?
- What is the effect of the profile on environmental outcomes (pollution, heat islands, energy consumption, etc.) (ongoing PhD)



### Radial assumption? Polycentricity?

- Rationale: housing vs transport trade-off
- Monocentricity is not far from reality for a very large set of cities
- Center-periphery (radial) interactions are numerous and add to commuting trips
- Dominance of one center in polycentric systems
- Polycentricity depends on scale, i.e. delineation of cities (see later for a resolution)

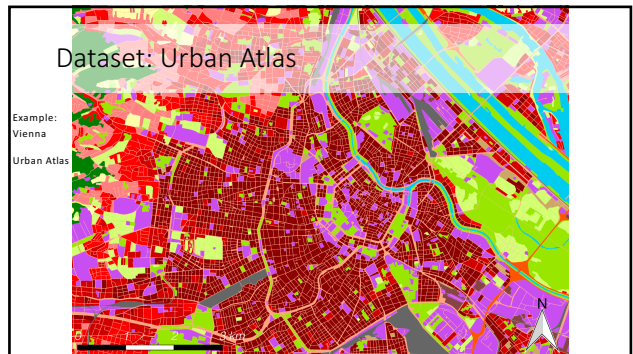
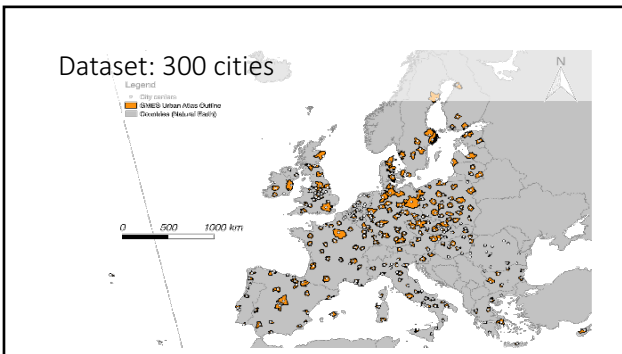


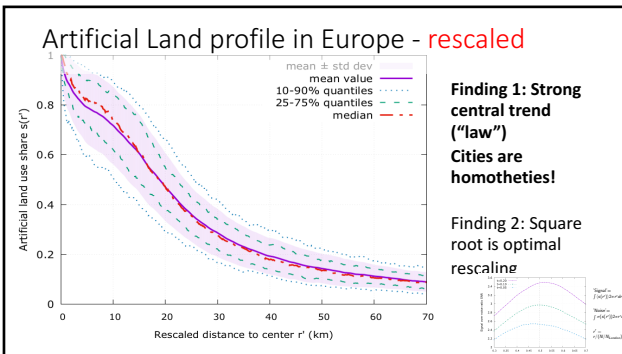
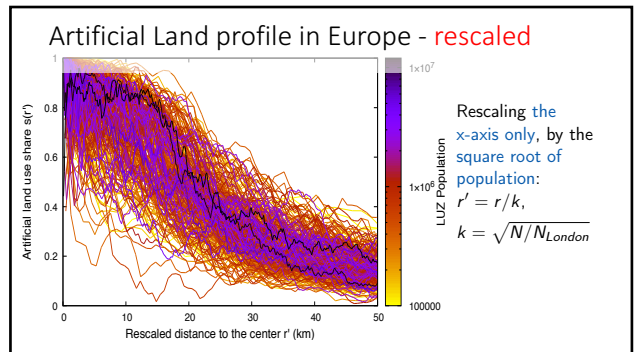
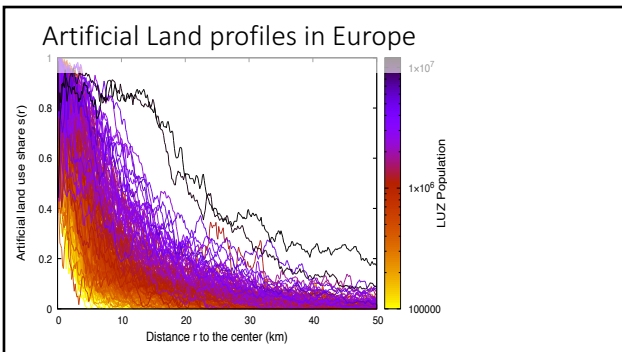
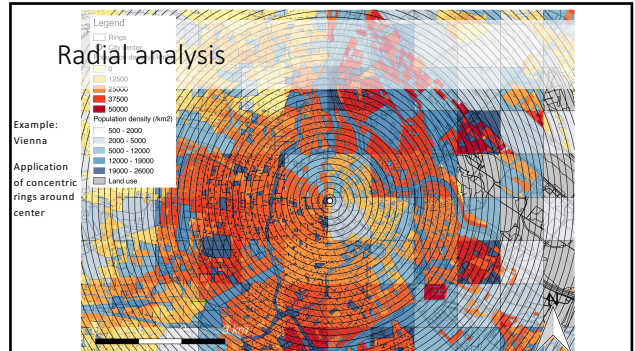
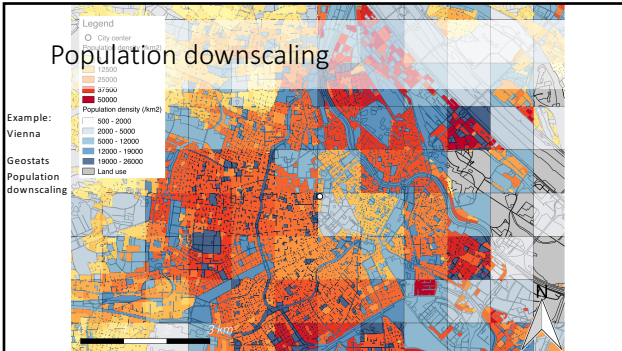
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Cont'd : Regression estimate of the urban land gradient for any city

Linear (L)  $\log(s_N(r)) \sim \log(a_N) - r/l_N$  with  $\log(l_N) \sim \log(l_1) + \alpha \log N$   
 Non Linear (NL)  $s_N(r) \sim a_N \exp(-r/l_N)$  with  $l_N \sim l_1 N^\alpha$

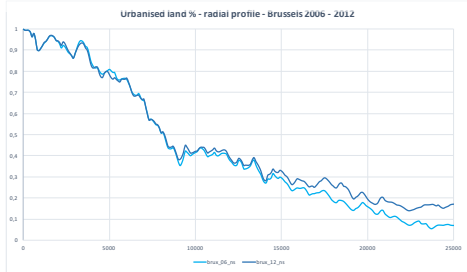
$\rightarrow$  imposed to 1

	L	NL	SNL	NL20	SNL20
Scaling exponent $\alpha$	0.310*** (0.024)	0.499*** (0.012)	0.512*** (0.014)	0.506*** (0.012)	0.512*** (0.011)
Exp(constant): $l_1$ (m)	124.2*** (45.4)	7.64*** (1.32)	6.23*** (1.24)	7.06*** (1.15)	6.64*** (1.03)
Observations	302	302	302	246	246
R <sup>2</sup>	0.356	0.847	0.816	0.886	0.897

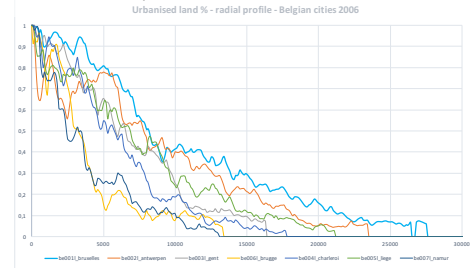
Note: \*\*\*p<0.01 Linear model on logs performs badly Coastal cities removed



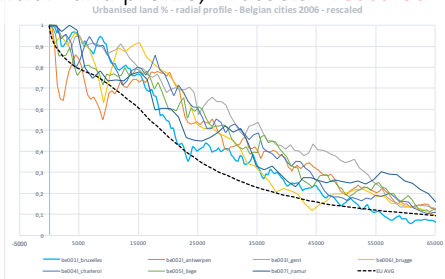
Artificial Land profile, Brussels - change



Artificial Land profile, Brussels



Artificial Land profile, Brussels - rescaled

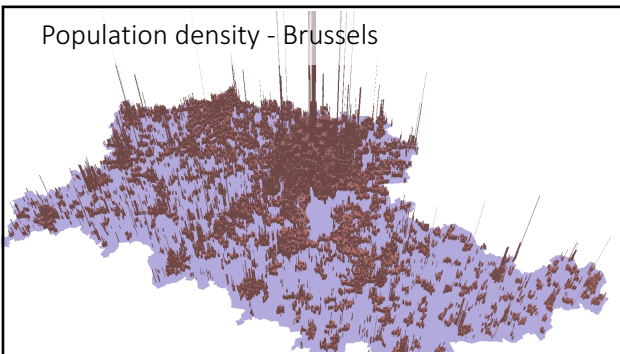


Stylized facts: Brussels urban land profile

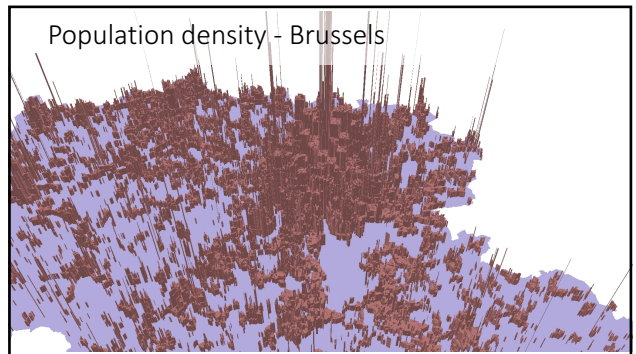
- Brussels functional area is urbanising in the periphery solely
- Higher shares of artificialisation compared to other Belgian cities but largely explained by population size effect
- After controlling for city size (rescaling),
  - Belgian cities are all more “urbanised” than European average
  - Relative to Belgian cities,
    - Brussels is less densely urbanised in periphery than expected
    - Brussels is more densely urbanised in the core than expected

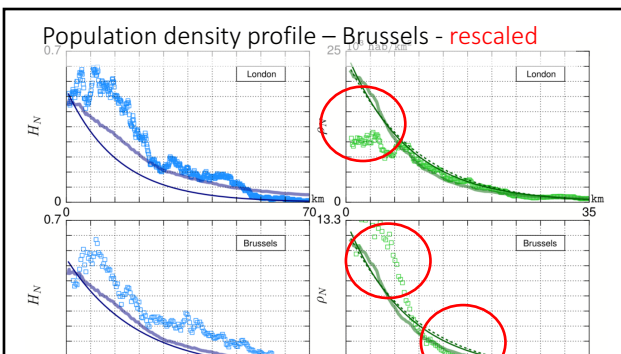
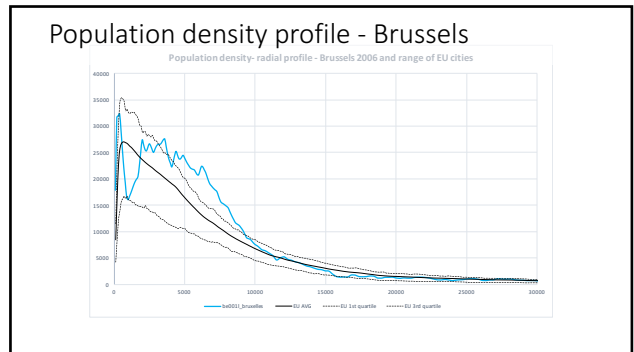
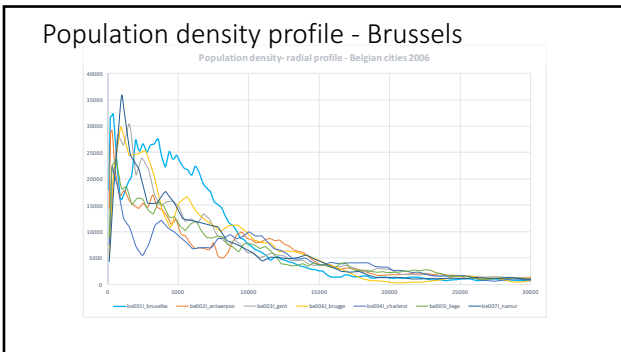
NB: Do not forget that EU average is an empirical observation, not a desirable norm!

Population density - Brussels



Population density - Brussels





Stylized facts: Brussels population density profile

- Brussels' overall profile tend to be more in line with a S-curve than standard negative exponential, i.e. plateau followed by a sharper decrease
- After controlling for city size (rescaling (1.8 mio inh.)),
  - Brussels is more dense in its core (up to 4km) than expected by the EU model
  - Brussels is less dense within its direct periphery (4 to 10 km) than expected by the EU model.
  - The farther periphery is in line with the EU model

NB: Do not forget that EU average is an empirical observation, not a desirable norm!

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2. Stylized facts: urbanised land and population density profiles across Europe
3. Abstract tools: simulation to understand policy effects in a controlled environment

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1. Goals and assumptions
2. Green space preference and density
3. Pollution exposure and density

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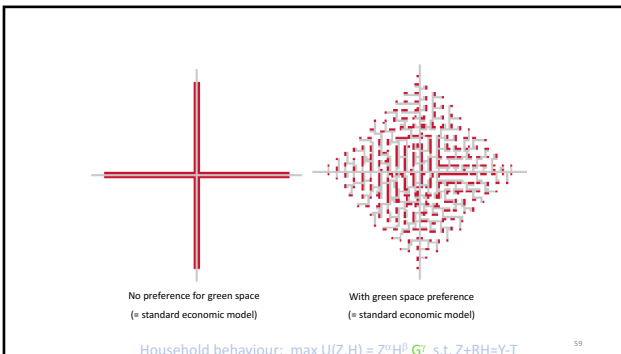
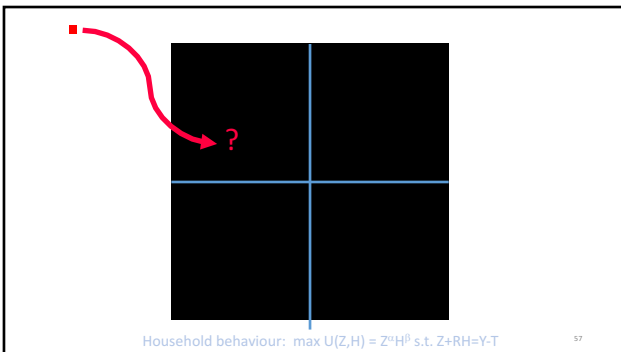
- Caruso, G, Cavallhès, J, Peeters, D, Thomas, I, Frankhauser, P, Vuidel, G. 2015. Greener and larger neighbourhoods make cities more sustainable! A 2D urban economics perspective. Computers, Environment & Urban Systems 54, 82-94
- Schindler, M, Caruso, G and Picard, P. 2017 Equilibrium and first-best city with endogenous exposure to local air pollution from traffic. Regional Science and Urban Economics. 62:12-23.

### Abstract models? Why?

- **Test "pure" effects**
  - Geographical specificities/heterogeneities, by definition, cannot be explained, but blur our understanding of behavioural and policy effects
  - First: understand mechanisms
  - Second: Computational power to apply to many different configurations (geography as an experimental science!)
- **Complex interactions:** for example: density is both the result and a determinant of the residential choice of households
- Our specific goals: understand the effect on urban form of **how the standard housing-transport trade-off interact with local amenities or endogeneous pollution effects.**

### Imagine...

- **A city where all jobs are located on a point where 2 regional roads cross**
- **Household settle one by one in the city**



### Appendix: NO BLACK BOX MODEL EXPLICIT BEHAVIOUR

Utility:  $U(Z, H, E, S) = \kappa Z^{1-\alpha} H^\alpha E^\gamma S^\delta$

**Budget:**

- Z: non spatial good (numéraire)
- H: plot size
- $\theta$ : unitary transport cost
- D: commuting distance along road network
- $\alpha$ : preference for housing ( $0 < \alpha < 1$ )
- $\delta$ : preference for social ( $\delta > 0$ )
- Y: income
- E: local green space externalities ( $E > 0$ )
- S: local social externalities ( $S > 0$ )
- R: land rent
- $\gamma$ : preference for green ( $\gamma > 0$ )
- $\kappa = \alpha^{-\alpha} (1 - \beta)^{\alpha-1}$
- S: local social externalities ( $S > 0$ )
- D: land rent

Neighbourhood:  $\bar{w}$  (window, viewshed, "amenity-shed")

Local density:  $\rho$

Open space amenities:

$E = e^{-\rho}$       Endogeneous rents

Social amenities:  $S = e^{\rho}$        $R^t(x) = [Y - \theta D(x)]^{1/\alpha} (U^t)^{-1/\alpha} \exp[-\beta \rho^{t-1}(x)]$

Net amenities:  $E^t S^t = e^{-\gamma \rho} e^{\beta \rho} = e^{-\beta \rho}$



### 3. Abstract tools: simulation to understand policy effects in a controlled environment

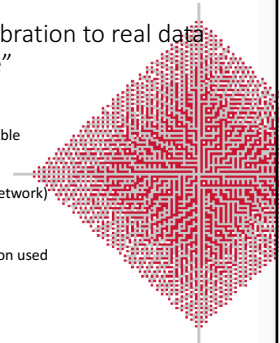
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### Base configuration after calibration to real data without geographical "noise"

- Radial push-pull (commuting vs housing costs)
- + Local push-pull (socialize vs nature) in a variable neighbourhood size
- + path-dependence (sequential location and network)

Fit to a 200 000 city  
 Data (housing rents) from Besançon, Brest, Dijon used to estimate neighbourhood green preferences



### Effect of Increasing neighbourhood size, i.e. facilitating non costly local trips to local amenities

=> WELFARE + SUSTAINABILITY GAINS

Aggregate characteristics of the city after varying neighbourhood size.

Neighbourhood size $\psi$	$\psi = 1$	$\psi = 2$	$\psi = 3$	$\psi = 8$
	600 m	1200 m	1800 m	4800 m
Population	171,197	165,658	166,323	166,936
Utility	19,916	21,268	21,484	23,630
Density (inhab per sq.km within footprint)	66	76	79	125
Roads (m) per inhab	11.11	7.61	5.37	1.27
Maximum distance to CBD (km)	36	33	32	26
% Green space within footprint	17.94	34.48	41.79	63.28



Why should we impose strong density planning while a much better outcome would arise 'naturally' by facilitating short trips to green space and social interactions? (invest in sidewalks, bike lanes,...)

### 3. Abstract tools: simulation to understand policy effects in a controlled environment

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### Endogenizing traffic flows, pollution emissions and pollution exposure the model

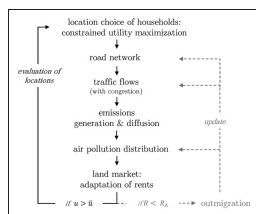


Figure 1. Processes of the ABM with the feedback of traffic-induced pollution on residential location choice.

### Being polluted vs Polluting

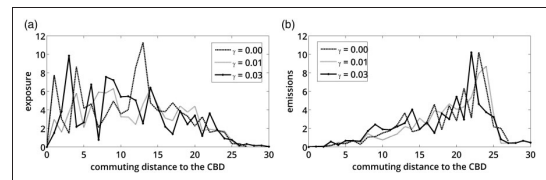
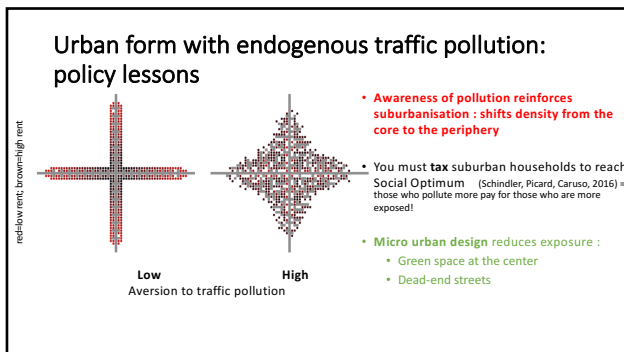


Figure 6. Households' exposure (a) and emission contribution (b) averaged across network distances with increasing aversion  $\gamma$  to exposure during the commute ( $\beta = 0.2, \phi = 0.0$ ).



### Conclusion/Opinion

- Density is not a goal *per se*
- Density can take many forms and none should be a taboo
- Whatever the local form, at the functional area scale - where most environmental effects should be considered - cities are very much the same
- Density is the result of a complex decision making on the household's side, not only from developers and planners
- Planning by density norms for environmental purpose, ignoring welfare impact, may have deep reverse effects
- Local design and intense integration of nature is a must in all case to avoid disbenefits and avoid further suburbanisation