Urban densities and patterns: stylized facts and generic abstract tools

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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.

...and a shared vision across Europe

European Commission, Cities of Tomorrow, 2011, p42

more recently added with a second normative assertion: green!

Urban Agenda for the EU

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)
Large agreement to halt ‘excessive’ sprawl

1. Policy and scientific context

2. Scientific agreement on sprawl vs compactness

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

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 (see also PRDD)
  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

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

1. Policy and scientific context

2. Scientific agreement on sprawl vs compactness

- even claim that sustainability is not related to “forms” but only technology and processes

- even claim that sustainability is not related to “forms” but only technology and processes

The Compact City Policy

Growing Cities
Sustainable

Michael J. Haskel

Sustainability is not limited to the use of energy, water, and materials but also the larger potential of urban form strategies to influence the human environment.

The attempts to make cities more sustainable are increasingly relying on urban form strategies to influence the human environment.
Density alone to be reconsidered – not a sufficient norm

Beyond density, need for multi-dimensional metrics

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

1. Policy and scientific context

1. EU Policy - Urban Agenda Policy (see also PRSD)
2. Scientific agreement on sprawl vs compactness
3. Need to reconceptualise 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 (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, museums, 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
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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)

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

1. **Goals and assumptions**
2. **Europe**
3. **Brussels**

**Source:**
- Ongoing FNR Scale-up project with P Killegaff, Y Wei and R Lemoy

**Dataset:** 300 cities

**Example:** Vienna and Urban Atlas
Homothetic scaling of urban forms

Introduction

Conclusion: cities are homothetic discs

N

Cities and scaling share of artificial land in the center, the linear model gives widely dispersed values, ranging from error. The results are illustrated on Figure 1. We observe that the results of the non-linear fit are in both cases, a square error is minimised, but not the same one: the linear fit of the logarithm linearly every 100m (a bit strange, maybe I should explain...).

Same data as in [1], Urban Atlas 2006, 300 LUZ. We focus on land use here.

Artificial land, and it decreases faster for smaller cities. Actually, [1] show that these profiles scale many urban areas. But this is not an easy problem. Cities are quite heterogeneous and different models: linear fit (L), two-parameter and exponential fit which we call SNL (for simple non-linear model),

\[ R(0) = 1 + \alpha \log N \]

Note: Scaling exponent

\[ \log(\alpha_N(\rho)) = \log(\alpha_L) - \alpha \log N \]

with \( \log(L_\rho) = \log(L_0) + \alpha \log N \)

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

<table>
<thead>
<tr>
<th>Linear (L)</th>
<th>Non-Linear (NL)</th>
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<tbody>
<tr>
<td>( L )</td>
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<td>( \alpha )</td>
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<td>( \rho )</td>
<td>( \rho )</td>
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</tbody>
</table>

Scaling exponent \( \alpha \) differs significantly from zero. Exponential parameter \( \alpha \) differs significantly from zero.

Relative) variations of land use in peripheral areas, which the non-linear model tends to disregard.

The city center is chosen as the location of the city hall.

With the results of a previous work [1], we expect a certain behaviour for these artificial land uses missing because the considered city is at the border of a country or next to a neighbouring city, which is the case of coastal cities. As a consequence, for these cities, a large part of land is missing,

Rescaling the x-axis only, by the square root of total population on the right.

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

Finding 1: Strong central trend ("law")

Cities are homotheties!

Finding 2: Square root is optimal rescaling

Rescaling distance to the center by \( \sqrt{N/N_0} \) population.
Empirical evidence to the intuition of Nordbeck 1971

It seems legitimate to claim that all urban areas have the same form and shape.

In the same way that a volcano is a volume of dimension 3, so we may consider population of a tätort [urban area] as a volume with the same dimensionality. The area of a tätort has the dimension 2.

It follows then that the $b$-value in the allometric formula $A = aP^b$ ought to be $2/3$.

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

1. Goals and assumptions
2. Europe
3. Brussels

Source:
- Ongoing FNR Scale-up project with P. Pühringer, Y. Wei and R. Lemoy
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!
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- Goals and assumptions
- Green space preference and density
- Pollution exposure and density

Source:
Abstract models? Why?

- Test "pure" effects
  - Test understood mechanisms
  - Test understanding mechanisms
- Geographical specificities/heterogeneities, by definition, cannot be explained, but blur our understanding of causal and policy effects
- 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 endogenous pollution effects.

Imagine...

- A city where all jobs are locate don a point where 2 regional roads cross
- Household settle one by one in the city
3. Abstract tools: simulation to understand policy effects in a controlled environment

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

Source:

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

=> WELFARE + SUSTAINABILITY GAINS

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Aggregated characteristics of the city after varying neighbourhood size

<table>
<thead>
<tr>
<th>Neighbourhood size</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1000</td>
<td>3000</td>
<td>5000</td>
<td>8000</td>
<td>10000</td>
</tr>
<tr>
<td>Population</td>
<td>150,000</td>
<td>150,000</td>
<td>150,000</td>
<td>150,000</td>
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<tr>
<td>Traffic</td>
<td>10,000</td>
<td>10,000</td>
<td>10,000</td>
<td>10,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Density (inhabitants/m²)</td>
<td>70</td>
<td>50</td>
<td>30</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Number of vehicles</td>
<td>2,000</td>
<td>2,000</td>
<td>2,000</td>
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</tr>
</tbody>
</table>
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Why should we impose strong density planning when a much better outcome would arise ‘naturally’ by facilitating short trips to green space and social interactions? (Invest in sidewalks, bike lanes,...)

Endogenizing traffic flows, pollution emissions and pollution exposure the model

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

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Figure 4. Households’ exposure (a) and emission contribution (b) averaged across network distance with increasing aversion γ to exposure during the commute (γ = 0.2, φ = 0).
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Being polluted vs Polluting

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Figure 6. Households’ exposure (a) and emission contribution (b) averaged across network distance with increasing aversion γ to exposure during the commute (γ = 0.2, φ = 0).
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Figure 7. Households’ exposure (a) and emission contribution (b) averaged across network distance with increasing aversion γ to exposure during the commute (γ = 0.2, φ = 0).
```
Urban form with endogenous traffic pollution: policy lessons

- Awareness of pollution reinforces suburbanisation: shifts density from the core to the periphery
- You must tax suburban households to reach Social Optimum (Schindler, Picard, Caruso, 2016) => those who pollute more pay for those who are more exposed
- Micro urban design reduces exposure
  - Green space at the center
  - Dead-end streets

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