Urban Scaling Laws: Foundations, Implications, Gaps

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Cities as complex systems

Physically, socially, economically, cities manifest as regularities, in spite of different historical trajectories and forces of growth. They also show heterogeneities!



Cities as complex systems

So, throughout, the science of cities to focus on what cities are (positive aspects) and on what they should be (normative aspects).



Cities as complex systems

Rising urbanisation Rising inequalities Are urbanisation and inequality connected?

85%

of Australia's 21.5 million people lived in urban areas in 2011. Source: Australian Bureau of Statistics, Census 2011, Populations of Significant Urban Areas to Total Population.

60%

of Australia's 21.5 million people lived in the 5 capital cities in 2011. Source: Australian Bureau of Statistics, Census 2011, Populations of Significant Urban Areas to Total Population.



A highly **urbanised** population

With significant & growing inequality

Living in a very small number of urban centres

Larger city = **higher** inequality?

Is this a **proportional** pattern? Then, no worries!

Does this grow **disproportionately**? (Income and housing costs)

Enter urban scaling laws



- Bettencourt, L., Lobo, J., Helbing, D., Kuhnert, C., and West. G., 2007, Growth, innovation, scaling, and the pace of life in cities, PNAS, 104(17), pp.7301-7306.
- Bettencourt, L., 2013, The origins of scaling in cities, Science, 340, pp. 1438-1441.

Enter urban scaling laws



Economic inputs:

- Lengths of roads
- Lengths of infrastructure networks
- Any measure of per capita expenditure on maintaining a city

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Enter urban scaling laws



Economic outputs:

- Income / GDP
- Patents
- Any measure of economic output or benefit
- But also diseconomies like crime, pollution, congestion
- Bettencourt, L., Lobo, J., Helbing, D., Kuhnert, C., and West. G., 2007, Growth, innovation, scaling, and the pace of life in cities, PNAS, 104(17), pp.7301-7306.
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Larger cities are more efficient, innovative, productive, diverse...



Fundamental ideas:

- Urban economics
- Increasing returns to scale
- Marshallian agglomeration principles

- City Size (Population)
 - Bettencourt, L., Lobo, J., Helbing, D., Kuhnert, C., and West. G., 2007, Growth, innovation, scaling, and the pace of life in cities, PNAS, 104(17), pp.7301-7306.
- Sarkar and Searle, SOAC2017
- Bettencourt, L., 2013, The origins of scaling in cities, Science, 340, pp. 1438-1441.

Larger cities are more efficient, innovative, productive, diverse...



Where Y = urban indicator, X = population, a = constant, b = scaling exponent. If b < 1, sub-linear If b = 1, linear

 $Y = aX^{b}$,

If b > 1, super-linear

- Bettencourt, L., Lobo, J., Helbing, D., Kuhnert, C., and West. G., 2007, Growth, innovation, scaling, and the pace of life in cities, PNAS, 104(17), pp.7301-7306.
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But, the validity of these findings is open to debate...



Complexity,

 Arcaute, E., Hatna, E., Ferguson, P., Youn, H., Johansson, A., and Batty, M., 2014, Constructing cities, deconstructing scaling laws, *Journal of the Royal Society Interface*, DOI: 10.1098/rsif.2014.0745.

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Figure I. [In color online.] Are larger cities greener or smoggier? Scaling of transport-related CO₂ emissions with the population size for US cities from the same dataset but at different aggregation levels. In red, the aggregation is done at the level of urban meas and in green for combined statistical areas. Depending on the definition of the city, the scaling exponents are qualitatively different, leading to two opposite conclusions. Data on CO₂ emissions were obtained from the Vulcan Project (http:// wican.project.atsu.od) (see Fragkias, 2013; Oliveira, 2014). Data on the population of urban areas and metropolitan statistical areas were obtained from the Census Bureau (http://www.oersus.org).

• Louf., R and Barthelemy, M., 2014, Scaling: Lost in the smog, Environment and Planning B: 41, pp. 767-769.

But, the validity of these findings is open to debate...



 Leitao, J.C., Miotto, J.M., Gerlach, M., and Altmann, E.G., 2016, Is this scaling nonlinear?, Royal Society Open Science, DOI: 10.1098/rsos.150649.

Why are these findings interesting to us?

Back to the "bigger is better" claim/idea,

we wanted to explore specifically the dimension of **INEQUALITY**.

Hypothesis: Larger cities are richer, but they are also more unequal.

Aim	Data	Variables	Method
Study scaling			Linear regression
of incomo	Australia,	X: Population of	of log(popn)
orincome	Source: Australian	Significant Urban	against
and number	Bureau of	Areas, Y: No. of	log(variable)
of people in	Statistics (ABS),	people in each	&
incomo	Australian	income, rent or	Maximum
IIICOIIIE	Taxation Office	mortgage category	likelihood based
categories	(ATO)		model testing
with city size			

Sarkar, S., Phibbs, P., Simpson, R., Wasnik, S., 2016, The scaling of income distribution in Australia: Possible relationships between urban allometry, city size and economic inequality, Environment and Planning B, doi:10.1177/0265813516676488



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- Larger the city, more pronounced the super-linear behaviour of high income categories.
- Higher the cut-off for population size or densities, more pronounced the superlinear behaviour of high income categories.

Sarkar, S., Phibbs, P., Simpson, R., Wasnik, S., 2016, The scaling of income distribution in Australia: Possible relationships between urban allometry, city size and economic inequality, Environment and Planning B, doi:10.1177/0265813516676488



Larger the city, more pronounced the super-linear behaviour of high income categories.

Complexity, Criticality, Computation, 2017



Rent categories scale in the same way:

Lower rents sublinear and higher rents superlinear with city size

Complexity, Criticality, Computation, 2017



Mortgage categories scale in the same way:

Lower mortgage numbers sub-linear and higher mortgage numbers superlinear with city size

Complexity, Criticality, Computation, 2017



USA housing cost categories scale in the same way:

Lower costs numbers sublinear and higher costs numbers superlinear with city size

Sarkar, S., in review.

The geographic angle: Location Quotients



Complexity, Criticality, Computation, 2017

Note that these are not **proportional** but **disproportional** rises by city size.

This is empirical evidence for agglomerations of higher earners, higher living costs in larger cities, pushing lower income earners out, driving inequality.

Is there a role for policy and planning?

Complexity, Criticality, Computation, 2017

Sarkar, S. and Searle, G., 2017, State of Australian Cities SOAC conference, Adelaide.

Australia has unbalanced city size distributions: 2 very large cities, 3 large cities, no middle sized cities, lots of small cities. There is a "**missing middle**" of cities.

If larger cities drive disproportional agglomeration of high housing costs, planning must address this missing middle to take pressure off the largest cities.

Response: the balanced growth of smaller and medium sized cities that can provide similar opportunities as largest cities.

Complexity, Criticality, Computation, 2017

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Policy: Larger cities = more intra-urban inequalities

Australia's largest cities show polarisation and segregation in local housing and employment markets.

The larger a system gets, the higher the possibility for more spatial heterogeneities to arise.

If larger cities drive disproportional amounts of segregation, planning must address local segregation and local spatial inequalities in the largest cities.

Response: Having X number of affordable dwellings and Y number of people to be transported each day as targets is insufficient, their spatial distributions are critical.

Complexity, Criticality, Computation, 2017

Sarkar, S. and Searle, G., 2017, State of Australian Cities SOAC conference, Adelaide.

Conclusions

- More research needed into how scaling and agglomeration works: focus on not just the economies of scale and increasing returns, but diseconomies of scale too!
- The role of regions and smaller and medium sized cities as important as the largest cities.
- As system size gets larger, heterogeneities arise naturally, leading to segregation. Planned response needed on spatial distributions of housing and employment.

Thank you!

Questions?