Urban Economics

Lecture 2: Monocentric city model

Spring 2021
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Monocentric city model

- **In this lecture, we analyze the monocentric city model**
- **Origins in the work of Alonso (1964), Mills (1967), and Muth (1969)**
  - Alonso, W. (1964): *Location and land use*. Harvard University Press.
  - Mills, E. (1967): An Aggregative Model of Resource Allocation in a Metropolitan Area. *American Economic Review* 57(2), 197–210.
  - Muth, R. (1969): *Cities and housing*. Chicago: University of Chicago Press.

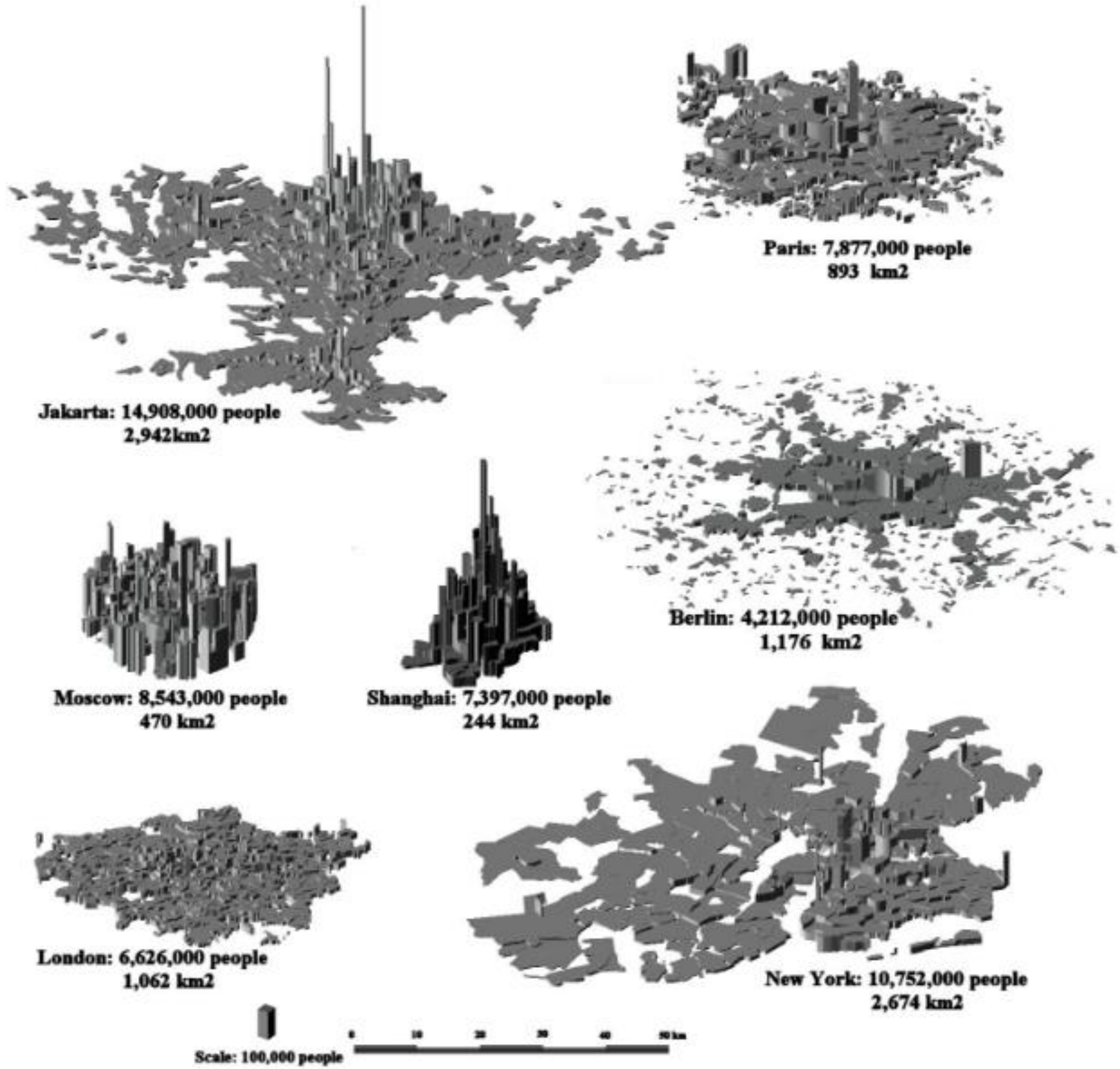
Monocentric city model

- Main goal of the model is to explain the empirical regularities that we observe in real-life cities
- Main mechanism is the relationship between commuting costs, housing prices, and housing consumption
- Another key ingredient is identical utility levels and developer profits across space, i.e. spatial equilibrium within the city

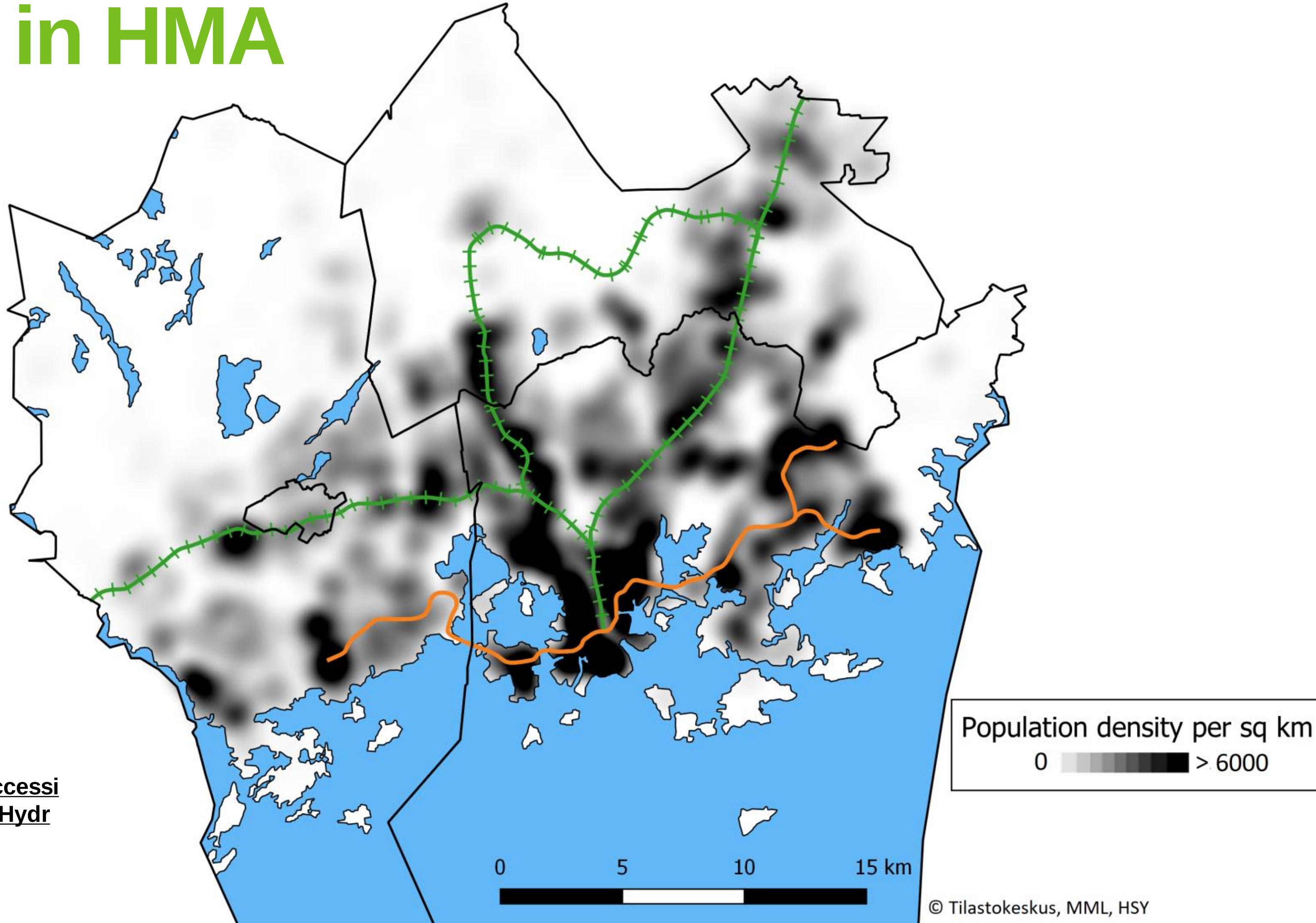
Outline

- Empirical regularities of real-life cities
- Monocentric city model assumptions
- Consumer analysis
- Producer analysis
- Empirical example
- This lecture will follow Brueckner's Chapter 2

Population density in 7 major cities

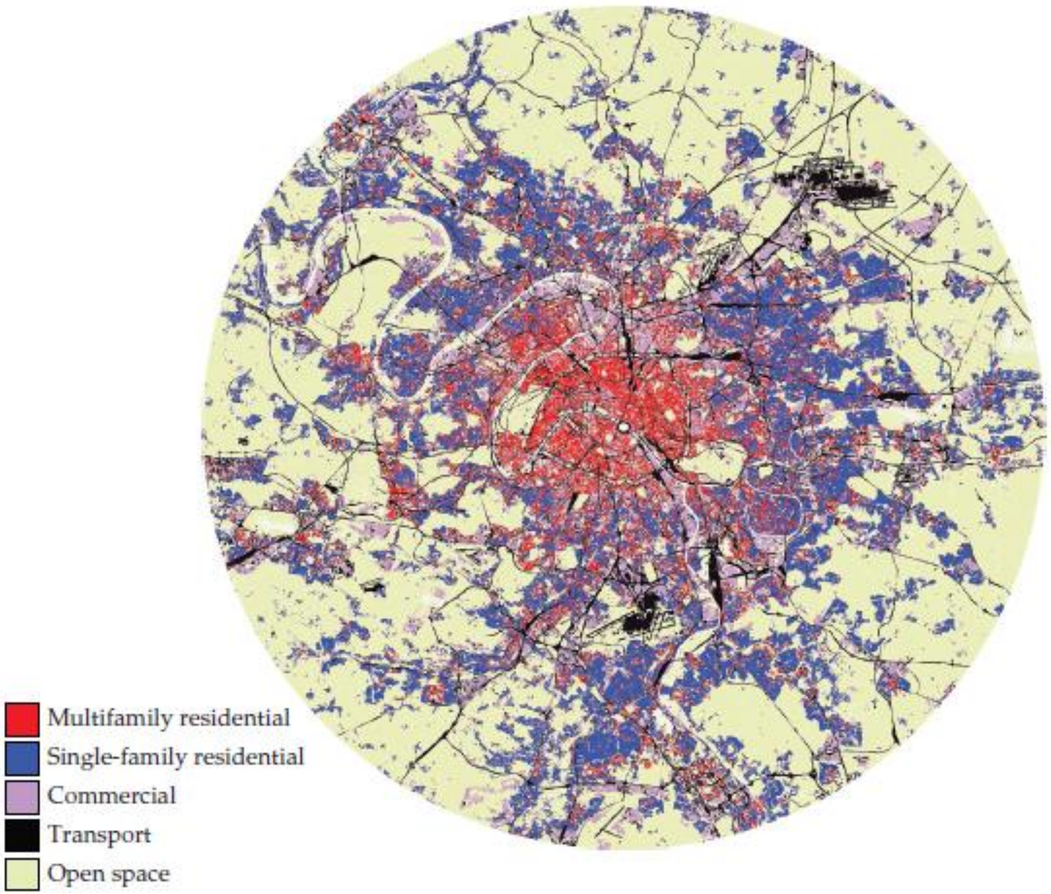


Population density in HMA

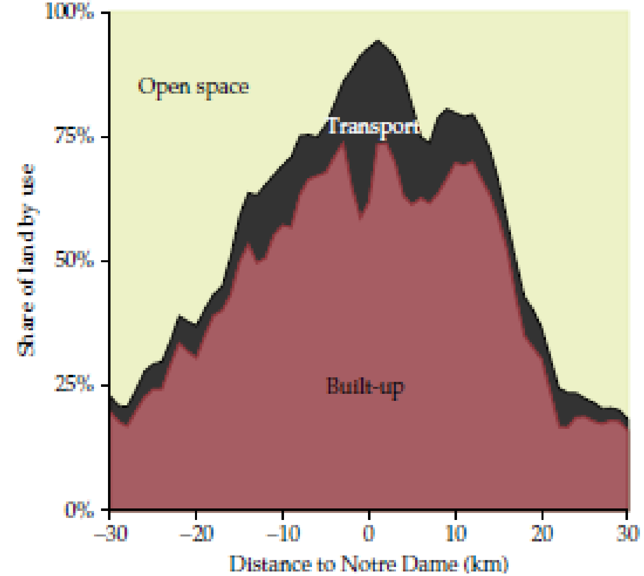


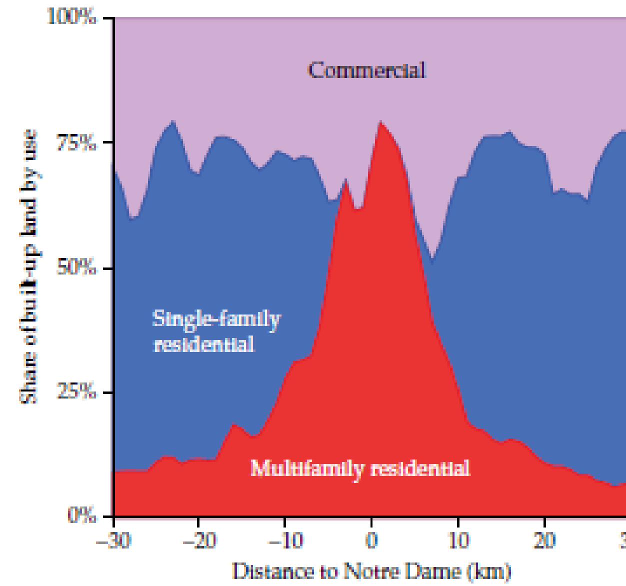
https://blogs.helsinki.fi/accessibility/files/2018/10/HSPA_Hydro_pulse50ms.gif

Land use in Paris

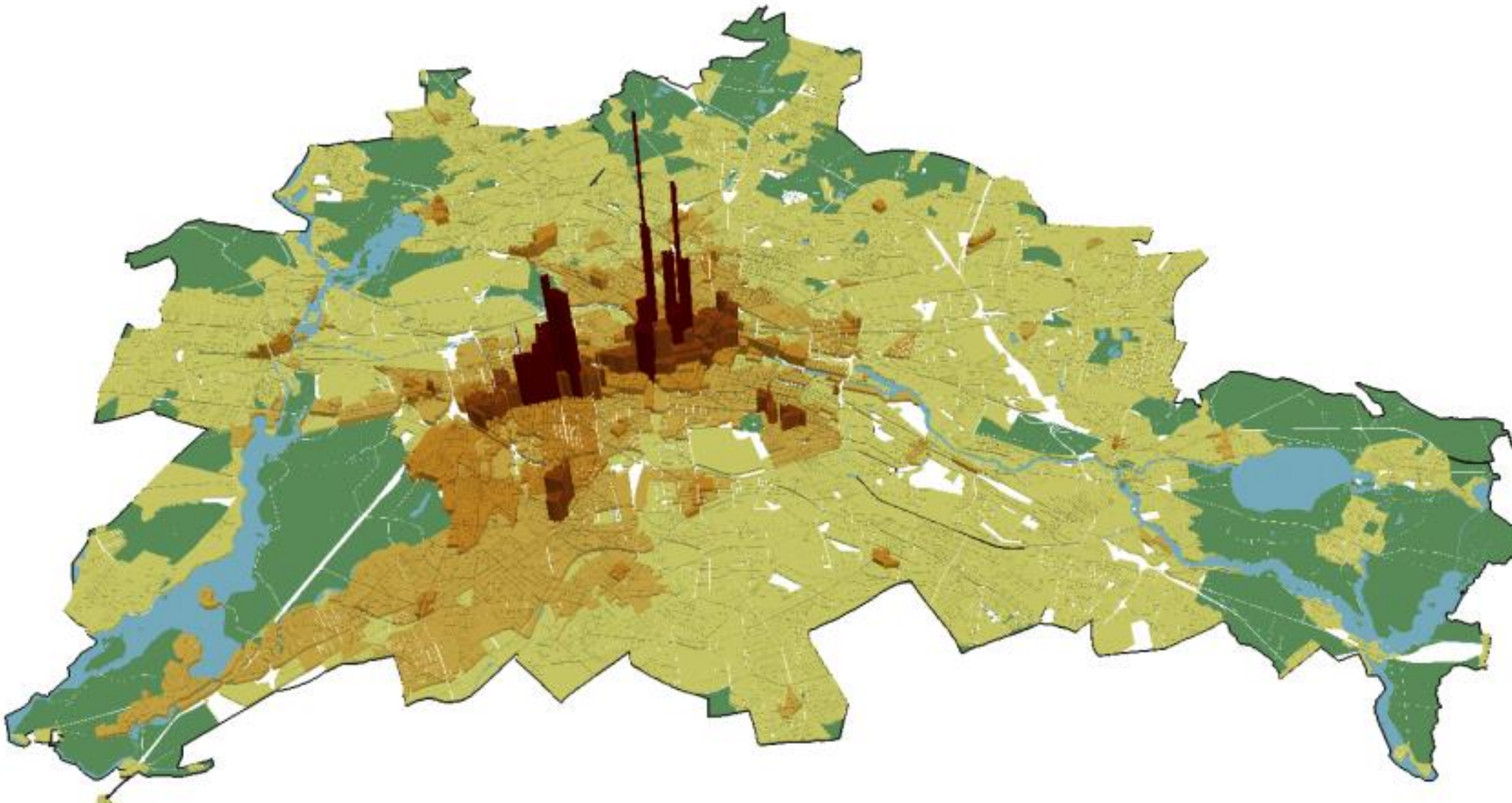


Duranton, G. & D. Puga. 2015. Urban Land Use. In G. Duranton, J.V. Henderson, W.C. Strange (ed.), *Handbook of Regional and Urban Economics*, Vol 5, 467-560



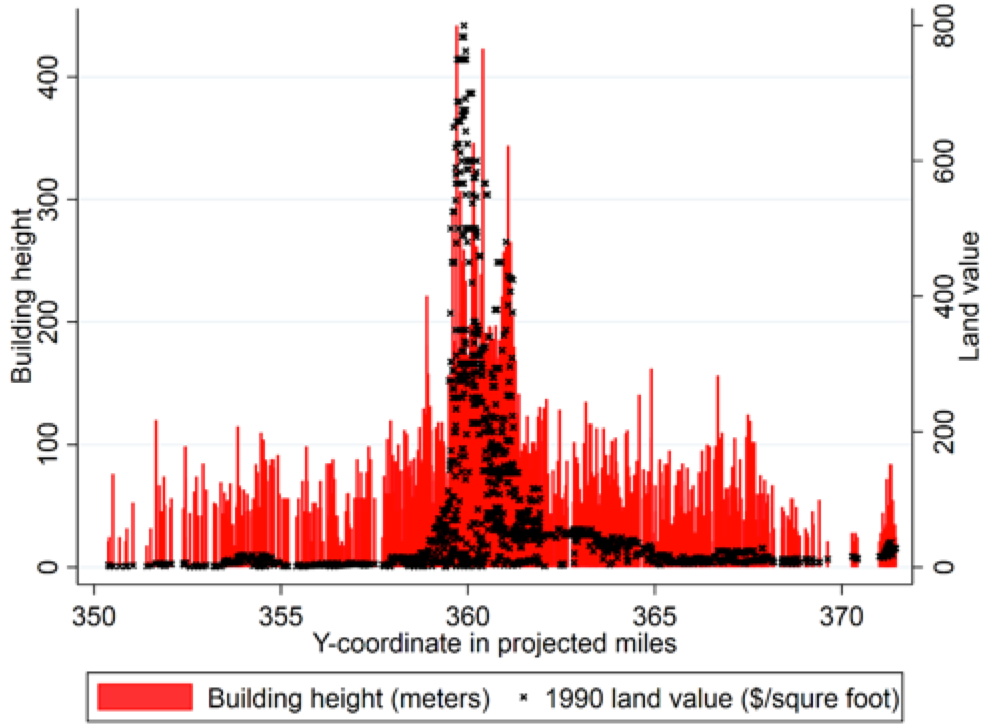


Land prices in Berlin



Source: Ahlfedt et al. (2015), *Econometrica*

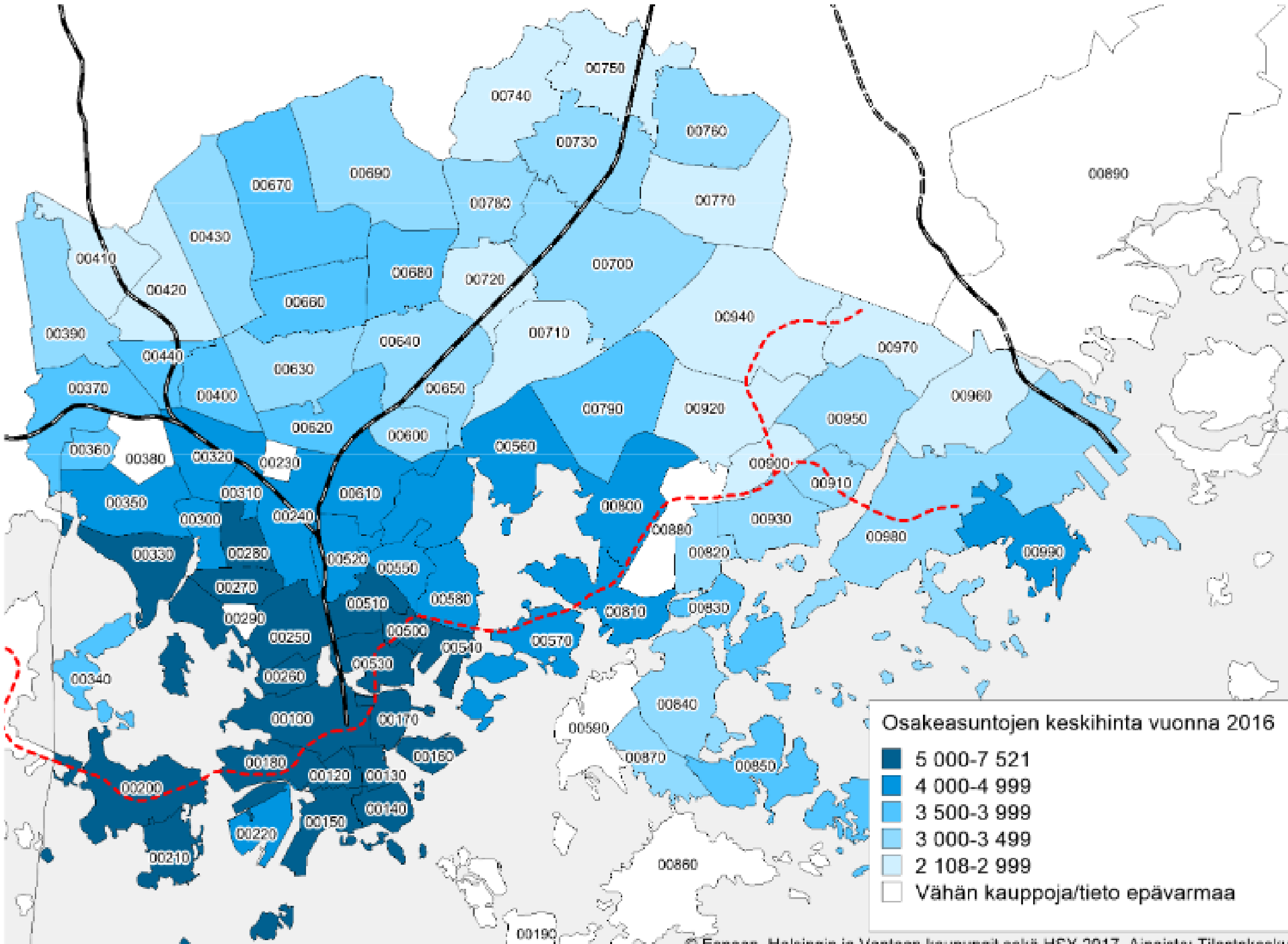
Building height and land prices in Chicago



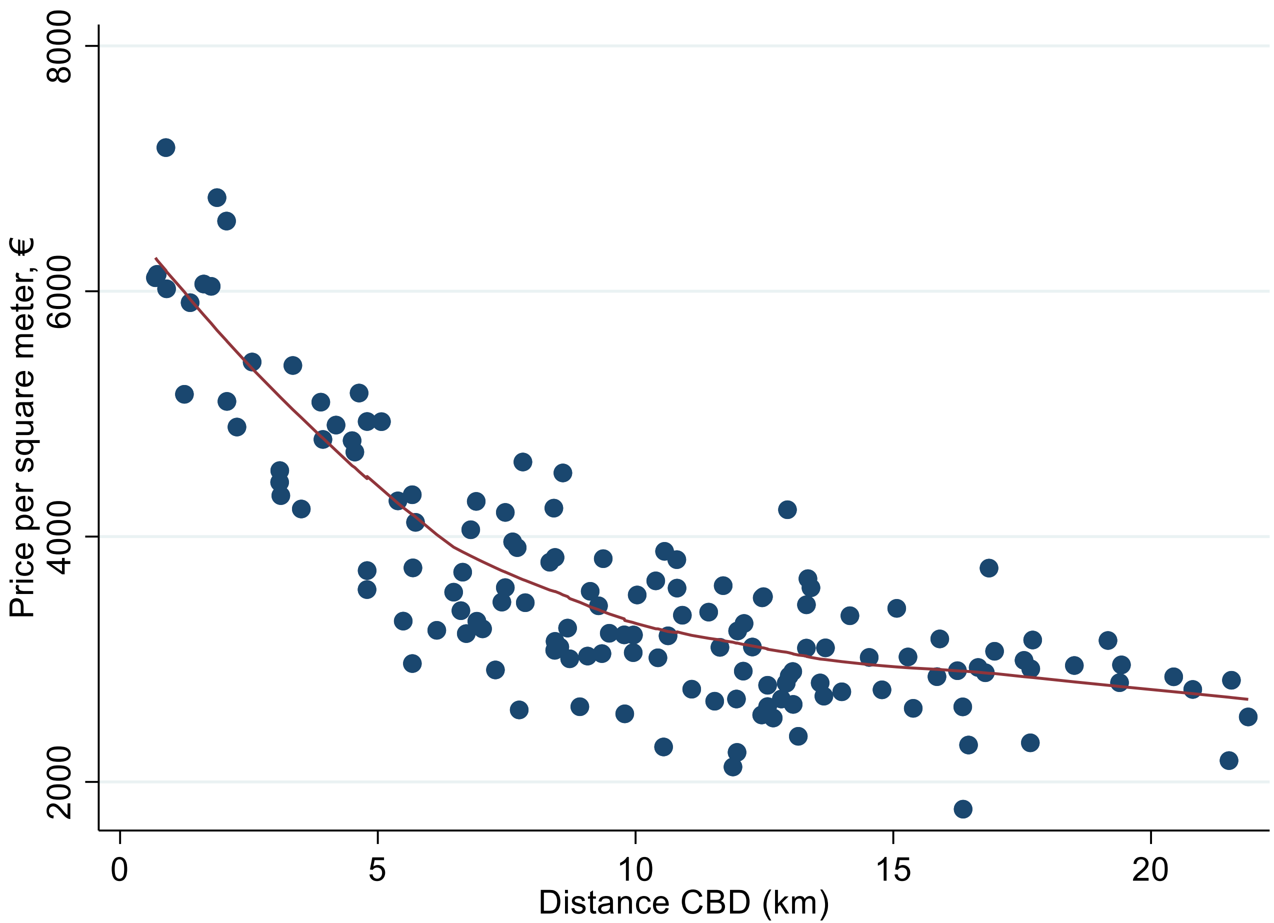
Source: Ahlfedt and McMillen (2018), *Review of Economics and Statistics*.

Notes: The building heights in 2014 are from Emporis.com. The 1990 land values are from Olcott's blue books. The y-coordinate is the vertical Cartesian coordinate in the State Plane Coordinate System (Illinois East).

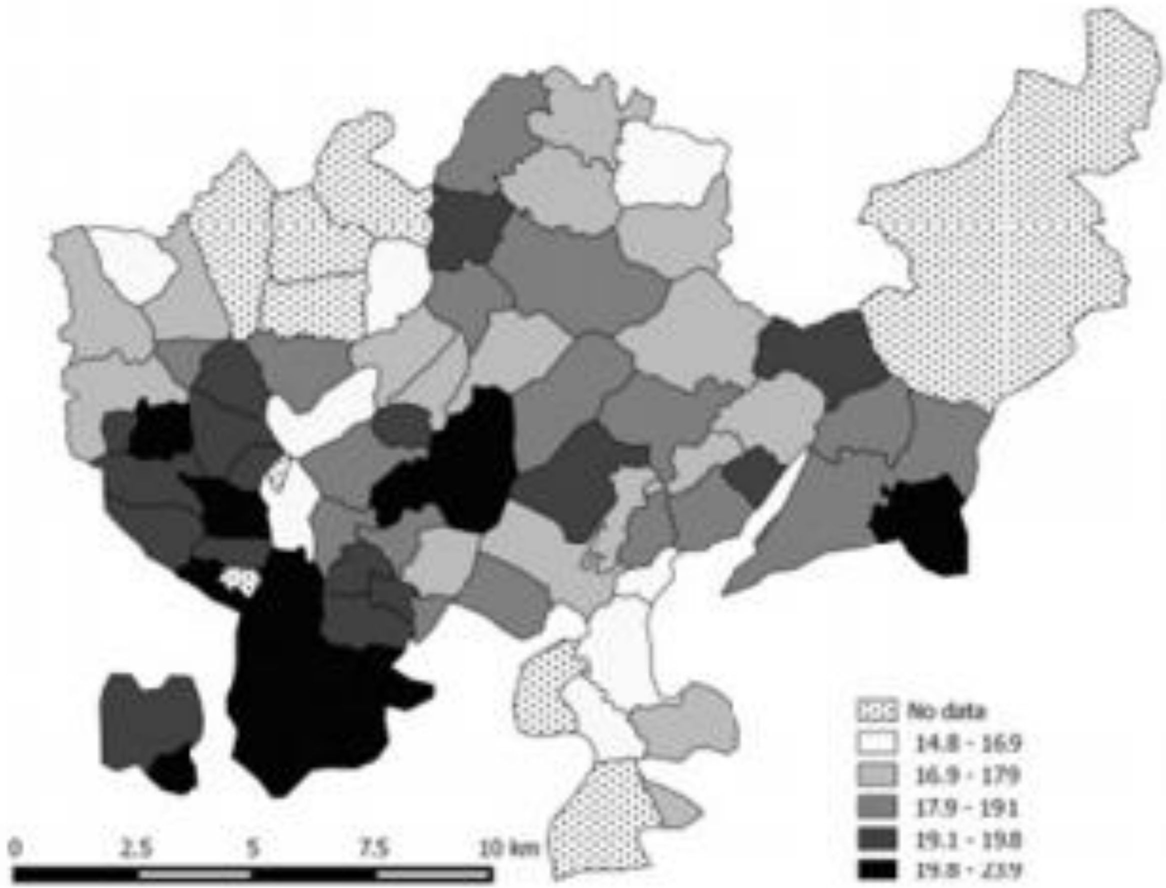
House prices (€/m²) in Helsinki postcodes



House prices (€/m²) in HMA postcodes



Monthly rents per square meter in Helsinki



Source: Eerola and Saarimaa (2018), *Journal of Housing Economics*.

Patterns

- **We generally see a pattern of declining density radiating from one center, or sometimes multiple centers**
- **Tall multi-family buildings tend to be located near the city center, while single-family houses are at the fringe**
- **Land and housing prices per square meter/foot tend to be high near the city center and lower farther away**
    - Think about the spatial equilibrium condition!
- **Of course, these patterns are not purely market driven as land use planning has played a major in role**
- **Next, we try to explain these patterns through a simple model**

Monocentric city model

Useful concepts – Land

- **Land rent is the price for using one unit of land, say a hectare, for one unit of time, say a year**

- **Land value is the price of buying one unit of land, again say a hectare**

- **Land is an asset; like any asset its price (= value) is the present value of the benefits (= net rent) from owning it**

Determination of land value

Value of a Land Parcel

Net Rent of Land in Year 2

$$V_L = \frac{R_{L1}}{(1+i)} + \frac{R_{L2}}{(1+i)^2} + \frac{R_{L3}}{(1+i)^3} + \frac{R_{L4}}{(1+i)^4} + \cdots$$

Discount Rate

$$= \sum_{t=1}^{\infty} \frac{R_{Lt}}{(1+i)^t} \approx \frac{R_L}{i}$$

Assumes R_L is constant over time

Important lesson: cheap land => cheap housing?

- **The price of land is high in some locations because people are willing to pay a lot for housing or commercial activities at that location**

- **It is not correct to say that the price of housing is high because land is expensive!**

- **Policy question: will we get cheap housing if the municipality sells land to developers at a discount?**

Useful concepts – Housing

- **Housing is measured in units of housing services = *q***
  - q = quality-adjusted square meters
  - Depends on housing characteristics
  - For now, we assume that floor space is the only characteristic
- ***p* = the price (rent) per unit of *q* per year or month (e.g. 20 €/m^2/month)**
- ***r* = rent for a housing unit = *pq* (e.g. 20*50 = 1000 €/month)**
  - If the unit is a rental apartment, r = contract rent
  - If the unit is owner-occupied, r is not observed

Determination of house value

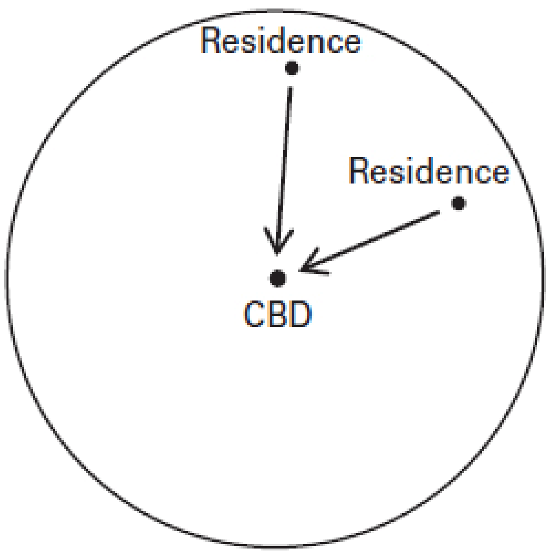
- ***V*** **= the value of a housing unit = the present value of the rental flow**

- **So, with a long lifetime, *T,* for housing:**

$$V = \sum_{t=1}^{T} \frac{p_t q_t}{(1+i)^t} \approx \frac{pq}{i}$$

Monocentric city model – assumptions

1. **All jobs are in the city center (central business district, CBD)**
   - Jobs do not take up space
2. **The city has a dense network of radial roads**



Monocentric city model – assumptions

1. **All jobs are in the city center (CBD)**
2. **The city has a dense network of radial roads**
3. **The city contains identical households or consumers or workers**
   - Same income/wage (y) and preferences (will be relaxed later)
4. **The residents consume (get utility from) only two goods: housing (q) and a composite good, say bread (c)**
   - The price of the composite good is the same everywhere (equal to 1)
   - Land and the housing that sits on it are allocated competitively to the highest bidder at each location

Commuting costs

- **The per-kilometer cost of commuting is *t*, so a resident living at distance *x* from the CBD incurs a commuting cost *tx***
  - Commuting has only a monetary cost
  - Later we will introduce the opportunity cost of time used in commuting
  - Also, everyone uses the same commuting mode so that *t* is the same for everyone
- **This leaves *y – tx* for expenditure on housing and the composite good (= disposable income)**
- **Disposable income decreases as *x* increases**

Housing consumption and budget constraint

- **A housing unit or a dwelling has variety of characteristics**
  - Floor space, yard size, construction quality, age, amenities
- **Here we simplify things and assume that dwellings differ only in size**
  - I.e. q represents square meters and p is measured as rental price per square meter
- **The consumer's budget constraint is $y - tx = pq + c$**
  - It states that the expenditure on bread and housing is equal to disposable income (income after commuting costs)

Consumer analysis

Consumer analysis

- **Consumers want to maximize the utility (welfare) they get from consuming housing and bread, while taking into account their budget constraint**
- **That is, the consumer chooses the *c* and *q* to maximize utility $U(c, q)$ subject to the budget constraint at each distance *x***
- **Location "choice" enters the problem only through commuting costs**
  - We assumed that dwellings differ only with respect to size, not with respect neighborhood amenities

Price of housing

- One of the empirical regularities that we saw earlier was that price pre square meter of housing falls as distance to the CBD increases (p falls as x increases)
- Can this simple model predict this regularity?
- Yes! And there are several ways to demonstrate this

Locational or spatial equilibrium

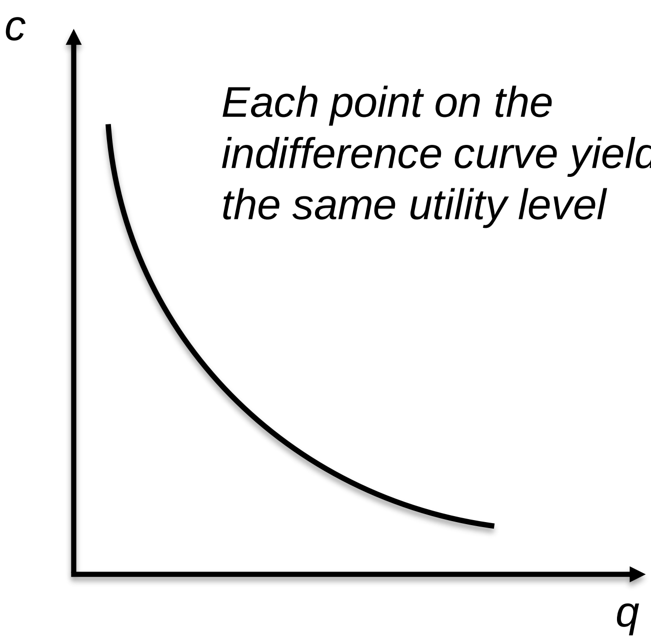
- **Everyone would want live right next to the CBD, but everyone cannot live in the same location**
- **But as consumers are identical, they must be equally well-off regardless of where they live in the city**
  - If this condition did not hold, then consumers in a low-utility area could gain by moving into a high-utility area (not an equilibrium)
- **This equilibrium can hold only if price of housing per square meter falls as distance increases**
  - Since higher commuting costs mean that disposable income falls as x increases, some offsetting benefit must be present to keep utility from falling

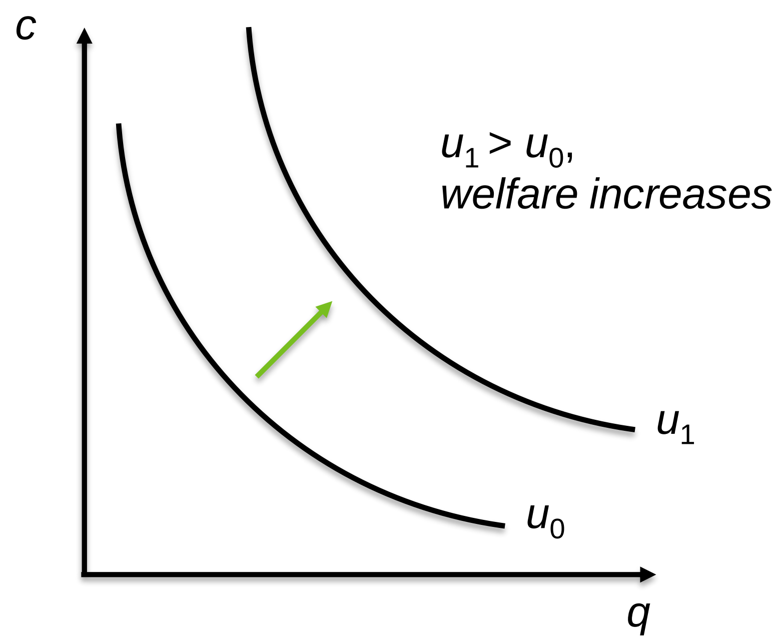
Locational or spatial equilibrium

- **Lower *p* at more distant locations serves as a compensating differential**
  - Compensating differentials arise in many economic settings
  - For example: dangerous or unpleasant jobs must pay higher wages than more appealing jobs with similar skill level requirements
  - Otherwise, no one would do the unpleasant jobs!
- **Note that here the price of the composite good is the same everywhere, and thus, cannot play a compensating role**
  - The prices of groceries and other non-housing goods are the same
  - May not be fully realistic, of course

Indifference curve diagram

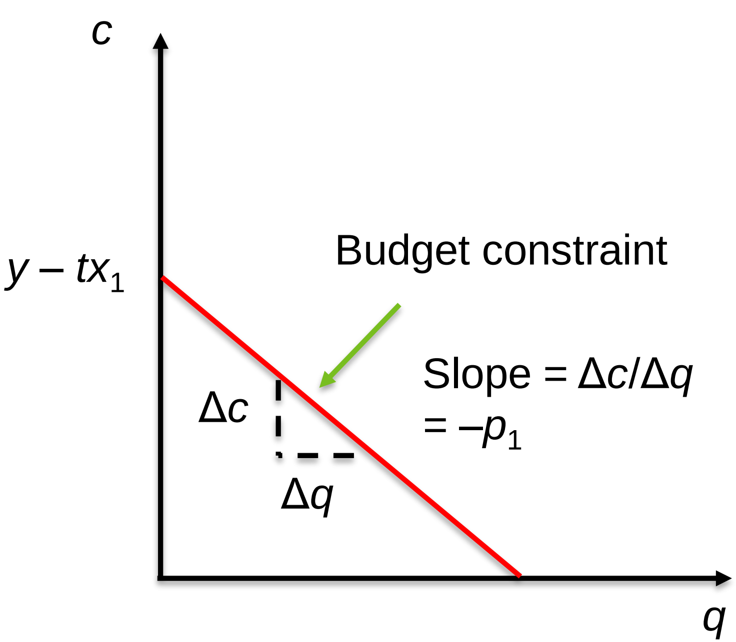
- A graphical way of deriving this result is using indifference curves and the budget constraint





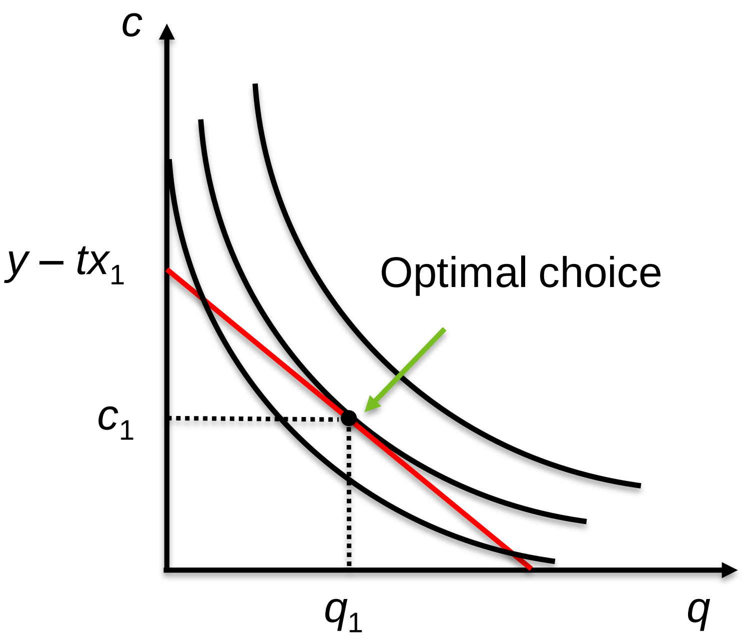
Budget constraint

$y - tx = pq + c$
$c = y - tx - pq$



- The figure depicts the budget constraint/line for a consumer living at a distance of x_1 away from CBD
- If housing consumption is zero, the consumer can consume $y - tx_1$ worth of bread
- When the consumer starts to consume housing, it must give up on bread consumption
- The slope of the budget line for consumer living at x_1 is $-p_1$

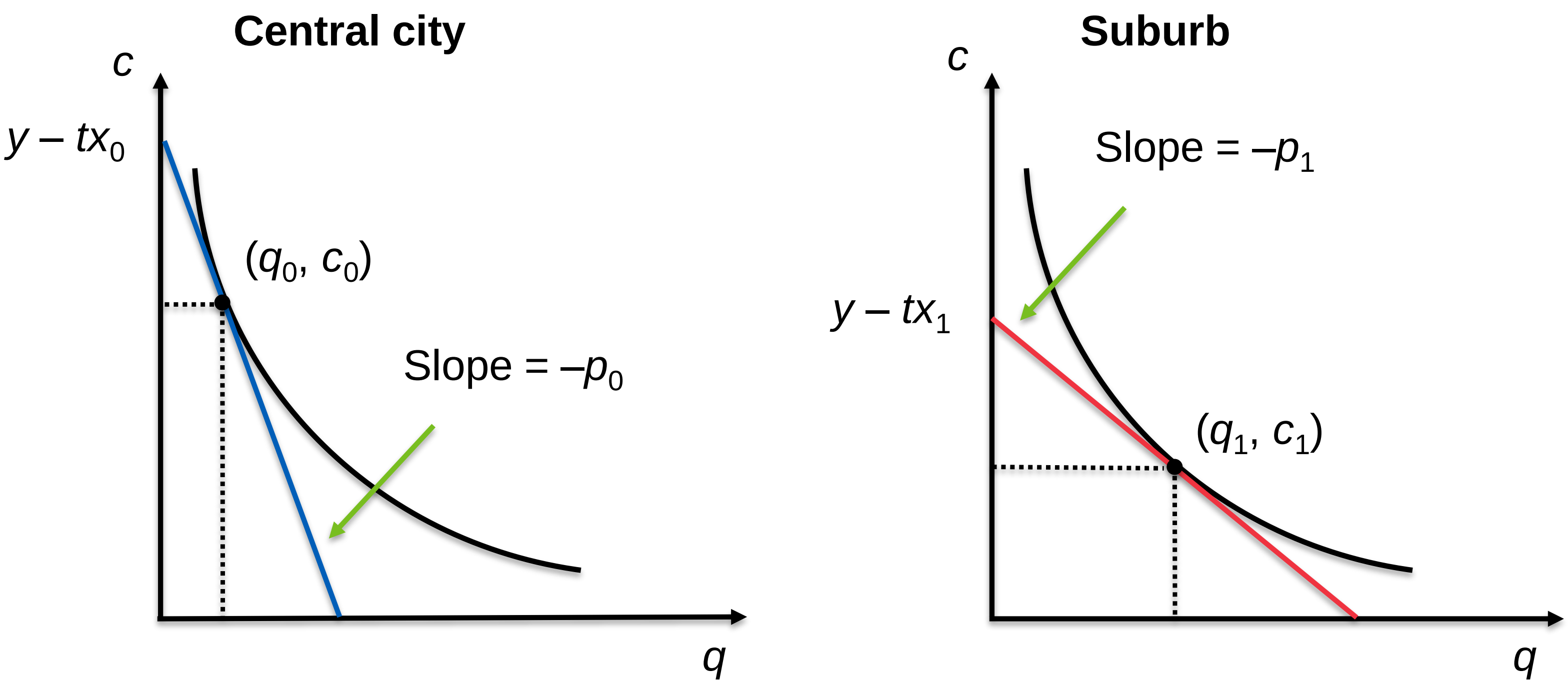
Indifference curve diagram



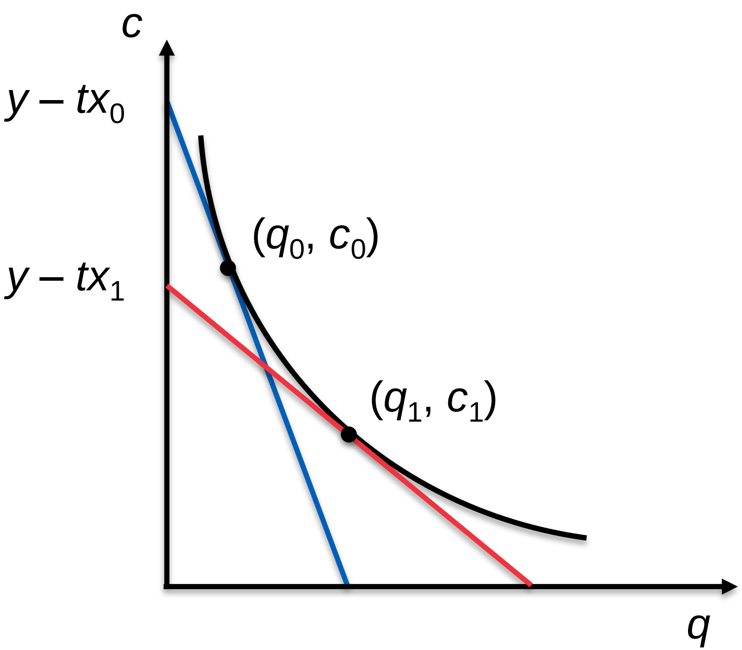
- The consumer chooses the point where the indifference curve is tangent to the budget line (c_1, q_1)
- This is the highest possible indifference curve that the consumer can reach within the budget constraint

Central-city and suburban consumer

- Consider now two consumers, one living central-city (x_0) and the other in a suburban location (x_1), so that $x_1 > x_0$



Central-city and suburban consumer



- What magnitude must the price of housing p_1 be at distance x_1 in order to ensure that the suburban consumer is just as well-off as the central-city consumer?
- The price must lead to a budget line that allows the suburban consumer to reach the same indifference curve as the central-city consumer
- That is, prices per square meter are higher in central-city, $p_0 > p_1$

Housing consumption in different parts of the city

- **The diagram reveals another important result of the model**
  - The suburban resident consumes more housing space ($q_1 > q_0$) and less bread ($c_1 < c_0$) than the central-city resident
  - This means that dwelling size q increases as distance x from the CBD increases
- **This substitution in favor of housing and away from bread is the consumer's response to the decline in the relative price of housing as *x* increases**
  - Remember that the price of bread is the same everywhere in the city

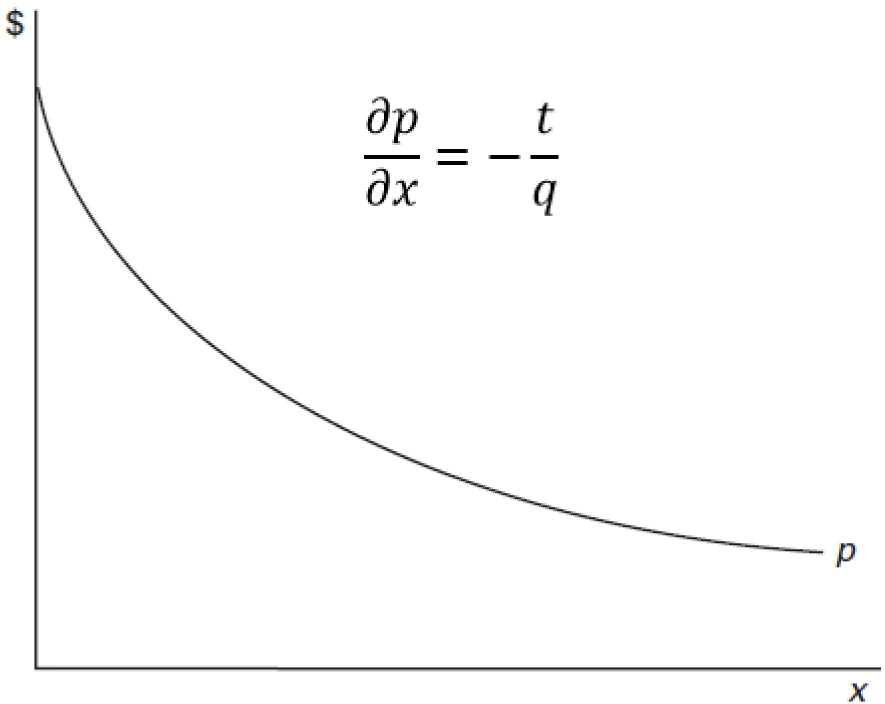
Model predictions

- **So far, the model's two main predictions are that as distance to the CBD increases**

  1. Price per square meter of housing falls; $p \downarrow$ as $x \uparrow$
  2. Size of the dwellings increases; $q \uparrow$ as $x \uparrow$

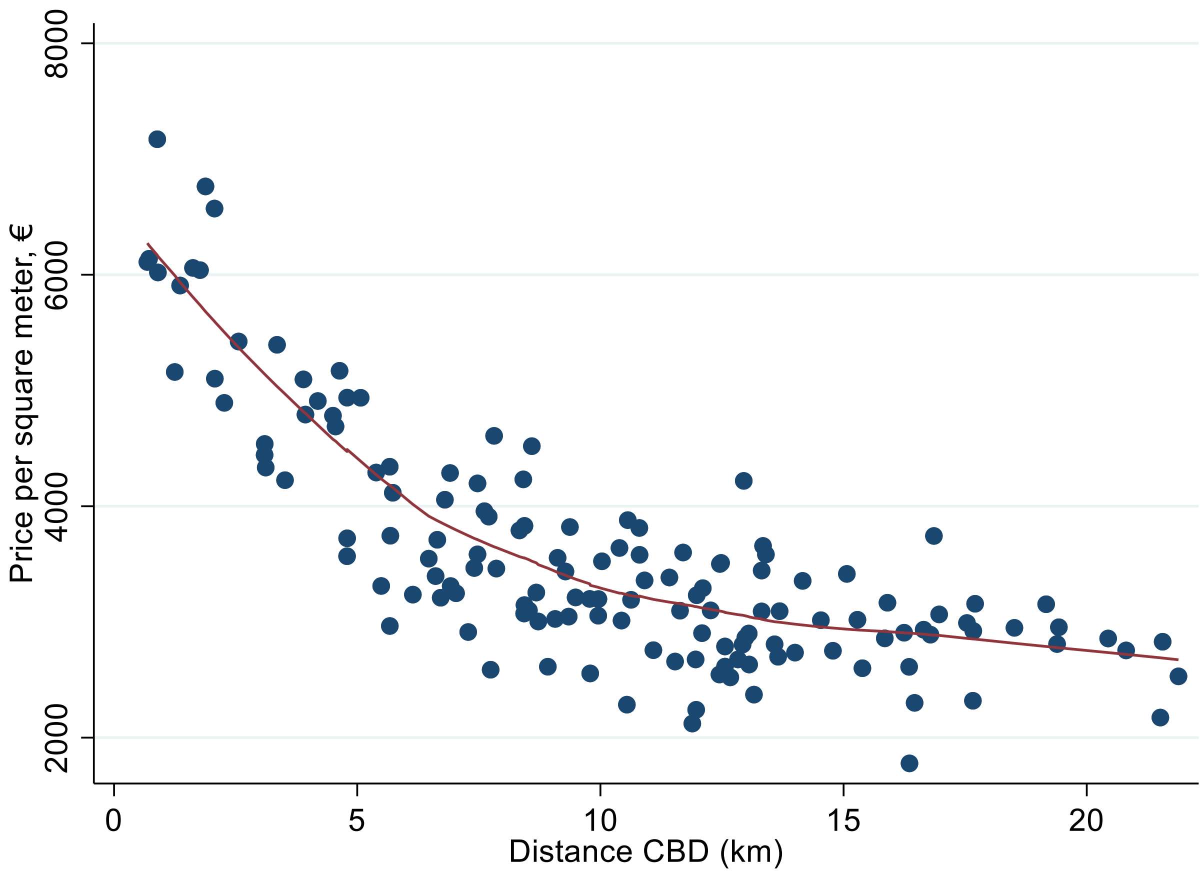
- **Two additional results concern the shape of the curve relating housing price *p* and distance *x* and the total price/rent *pq* and distance *x***

Housing price curve



- The price curve is convex if housing increases with *x*
- Consumers substitute cheaper housing for bread, so prices don't have to decline as quickly to compensate consumers

Housing price curve in HMA postcodes



Spatial behavior of total rent pq

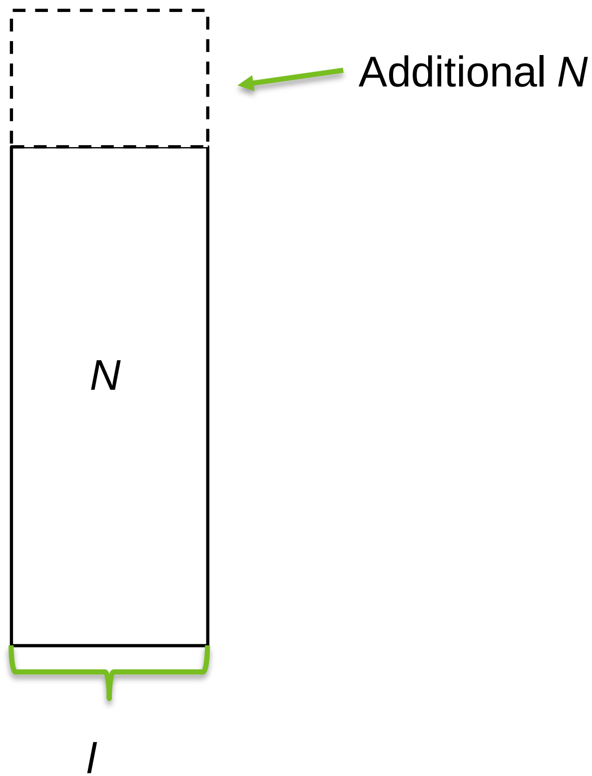
- **How does the total rent (pq) for a small central-city dwelling compare to the total rent of a larger suburban house?**
- **The answer is ambiguous**
  - Since p falls with x while q increases, the product pq could either increase or decrease
  - Which is the case, depends on the consumer's preferences or the shape of the indifference curve

Analysis of housing production

Analysis of housing production

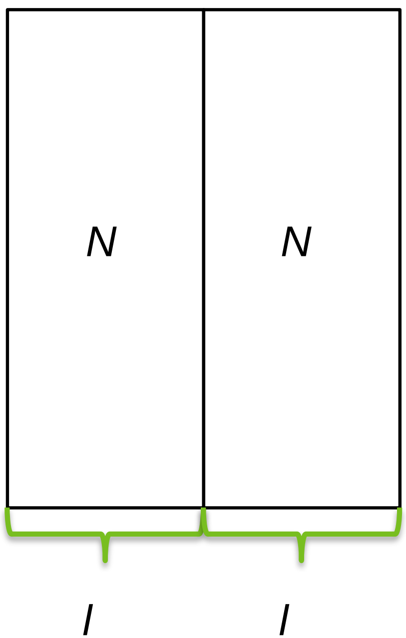
- **Now we turn to analyzing the production side of the market and shift the focus to the activities of housing developers who build structures and rent the space to consumers**
- **Again, this is a stylized model with several simplifying assumptions**
- **We assume that housing is produced using only land (l) and building materials (N)**
- **The production function for housing is $Q = H(N, l)$, where Q is the amount of floor space in the building (remember that q was dwelling size)**

Diminishing marginal return to capital



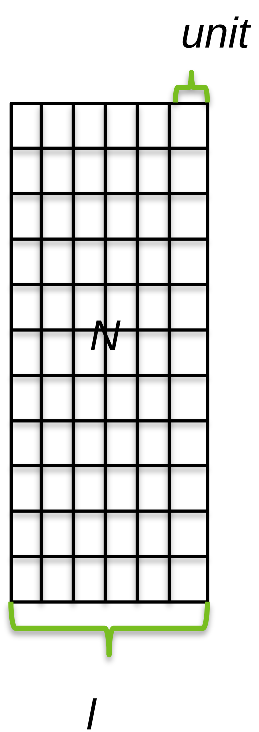
- With land input (size of the lot) held fixed, extra doses of building material lead to a smaller and smaller increases in floor space
- This makes sense as increasing N with fixed l makes the building taller
    - *Stronger foundation, thicker beams, elevators…*
- Note that we are assuming that the building completely covers the land area, so there are no yards
- Again, this assumption can be relaxed with the of price of complicating the model

Constant returns to scale



- Economies of scale are present when doubling both the capital and land inputs leads to more than a doubling of the floor space
- The figure suggests that doubling both inputs leads to exactly doubling of floor space
- Thus, we assume that housing production exhibits "constant returns to scale", at least approximately

Profit maximization



- The housing developer chooses the capital and land inputs to maximize profits, which leads to a building of particular height
- The developer also implicitly chooses the amount and size of the dwellings in the building
- The latter decision simply responds to consumer choices, i.e. the demand side of the market

Profit maximization

- **The developer's revenue from a building is *pQ* or *pH*(*N*, *l*), where *p* is the price per square meter of housing as before**
- **Input costs come from capital and land**
- **We assume that the developer rents the land and capital inputs**
  - Land rent per square meter is denoted with *r* and rent for capital with *i*
  - The price of capital is assumed to be fixed, i.e. there are no differences in physical building costs within the city
- **Production costs equal *iN* + *rl*, i.e. capital costs + land costs**

Equal profits across space

- **In consumer analysis, the utility or welfare of all consumers was the same everywhere in the city**
- **We have a similar spatial equilibrium condition on the producer side: profits are equal everywhere in the city**
  - If not, developers would not be willing to build housing everywhere
  - Because i doesn't vary with location, it is the spatial variation in land rent r that equates profits and makes developers willing to build housing throughout the city

Land rent as a compensating differential

- Central-city locations offer higher revenue per square meter than suburban locations
- This means that **land rents must be lower in the suburbs than at central locations**
- With r falling as distance x increases, the disadvantage of lower revenue is offset

Land rent as a compensating differential

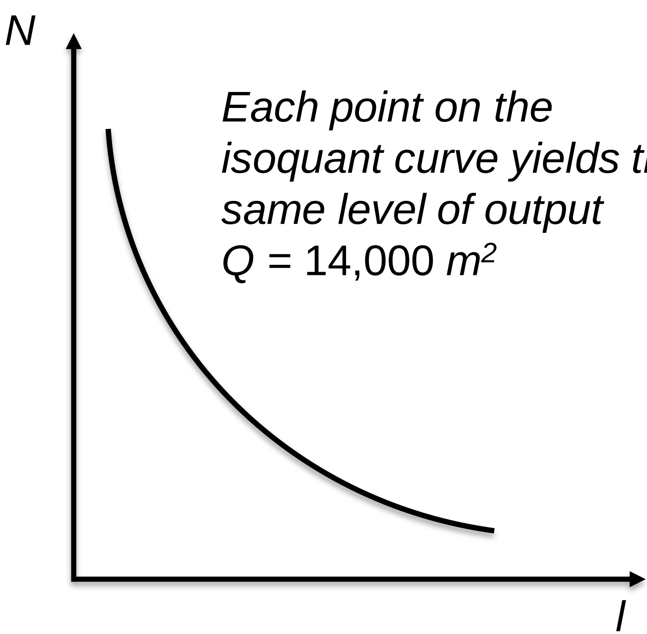
- **We can also think about this as a demand-based phenomenon**
  - Developers compete for prime locations where housing prices are high
  - This higher demand for land and competition among developers bids up land rents near the CBD
  - There is less demand for remote lots and land rents will be lower farther away from the CBD
  - Competition for prime locations drives land rents so high that uniform profits across space imply a zero-profit level (normal economic profit)

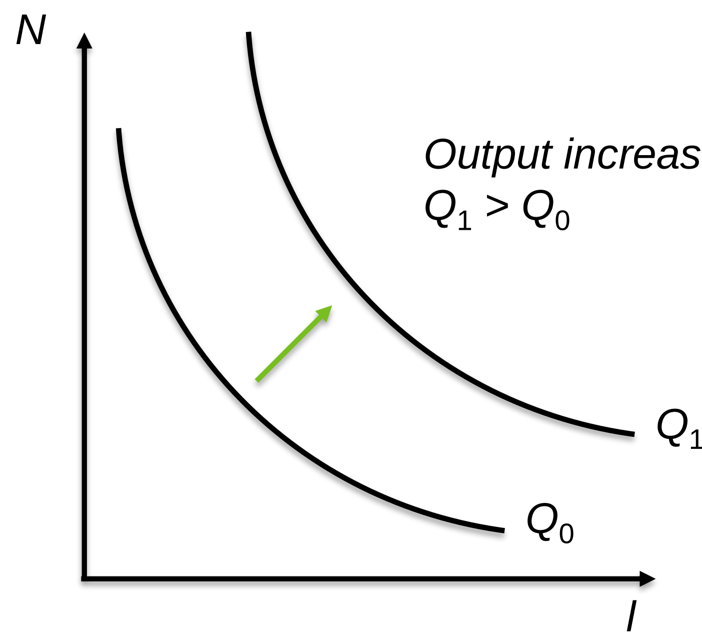
Building height and distance

- **With the price of capital fixed and land rent rising moving toward the CBD, the land input becomes more expensive relative to capital as distance to CBD declines**
  - This incentivizes developers to economize on land input and use more capital which leads to taller buildings
  - Conversely, as land gets cheaper moving away from CBD, developers use more of it and build shorter buildings
- **Overall, building height decreases as distance to the CBD increases**

Isoquant curve diagram

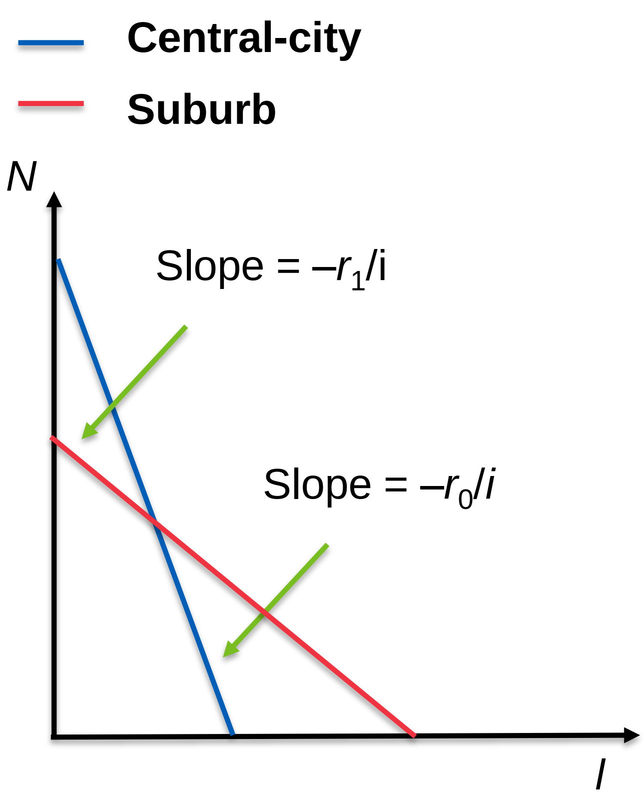
- A graphical way of deriving this result is to use a diagram illustrating cost minimization on the part of the developers
- Isoquant curves that show the combinations of inputs that yield the same output





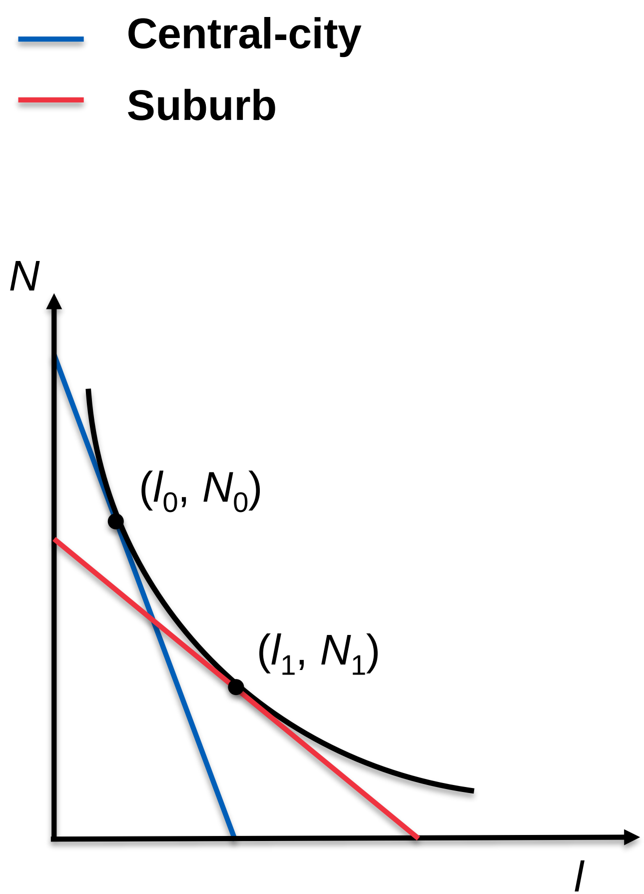
Iso-cost lines

Fix $iN + rl$ to some number



- **The figure depicts two iso-cost lines**
  - Iso-cost line = combination of inputs that cost the same total amount
  - Central-city developer at a distance of x_0 away from CBD with land rent r_0
  - Suburban developer with x_1 and r_1
  - The slopes of the iso-cost lines are $-r_0/i$ and $-r_1/i$, respectively
  - The slope for the central-city developer is steeper, because r_0 is high
  - I.e. the central-city developer has to give up more N in order to acquire additional units of land (iN buys you less l)

Central-city and suburban developer



- To produce Q square meters of floor space as cheaply as possible, each developer chooses the input bundle on lowest possible iso-cost line
- Developers facing different land rents (but same capital rents) use different amounts of inputs
- Since the central-city developer is using more capital and less land, the central-city building is taller than the suburban building

Predictions from producer analysis

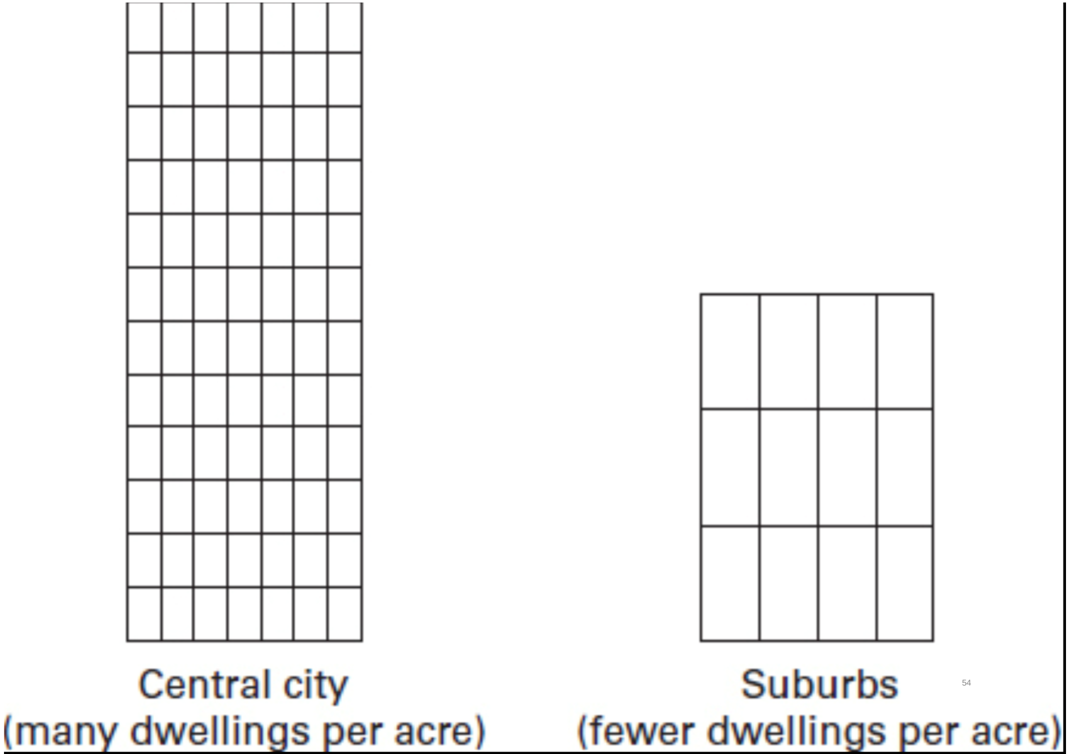
- **Two main predictions are that as distance to the CBD increases**
  1. Price per square acre of land falls; $r \downarrow$ as $x \uparrow$
  2. Building height decreases; building height $\downarrow$ as $x \uparrow$

Population density

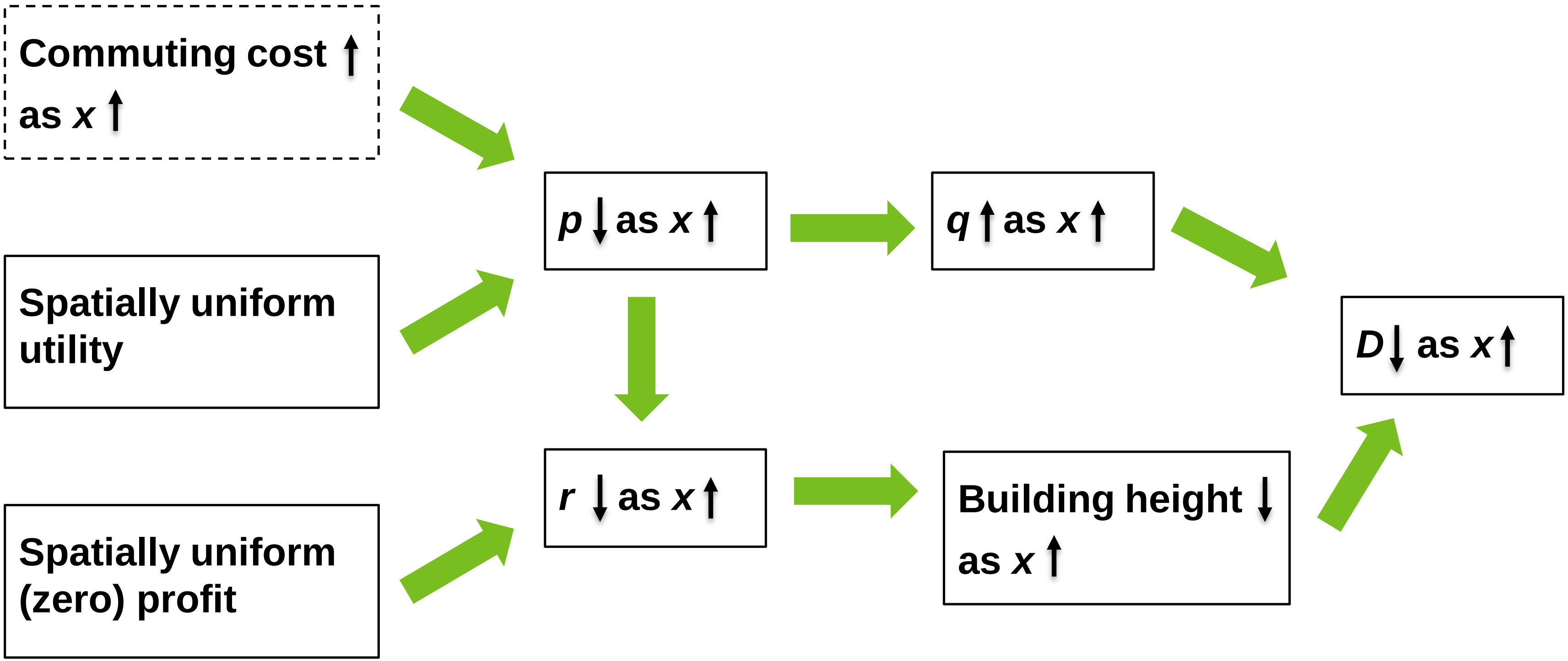
- **Combining the consumer and producer analysis yields a further result regarding population density in different parts of the city**
    - Population density (*D*) is measured as the number of people per km^2
    - Central-city location has tall buildings divided into small dwellings, while the suburb has short buildings divided into larger dwellings
    - This implies that population density is higher in the central-city
- **Thus, *D* falls moving away from CBD; $D\downarrow$ as $x\uparrow$**

Population density

Buildings and dwelling sizes in central-city and the suburb



Summary of the model logic



Empirical example – New metro line

OSKARI HARJUNEN

METRO INVESTMENT AND THE HOUSING MARKET ANTICIPATION EFFECT

Do people value accessibility and by how much?

- **One of the central predictions of the model was that house prices per square meter are higher in locations closer to the CBD with low commuting costs**
- **But the model is very stylized. In reality, locations differ in several other ways besides accessibility**
- **How can we know whether and by how much people really value accessibility?**
- **Solution: look at how prices change when accessibility changes and compare this to price changes in places where accessibility does not change (DID)**

West Metro extension

- Harjunen (2018, chapter of his PhD thesis) analyzes the price effects of the West Metro extension in the HMA
  - https://www.hel.fi/hel2/tietokeskus/julkaisut/pdf/18_01_25_tyopapereita_02_Harjunen.pdf
- The West Metro introduced eight new metro stations – two in Helsinki and six in Espoo
- The study focuses on the time period when the construction of the new line started, but before it became operational
- The idea is to see whether the is anticipated in the housing market already before the new line was operational

Research design

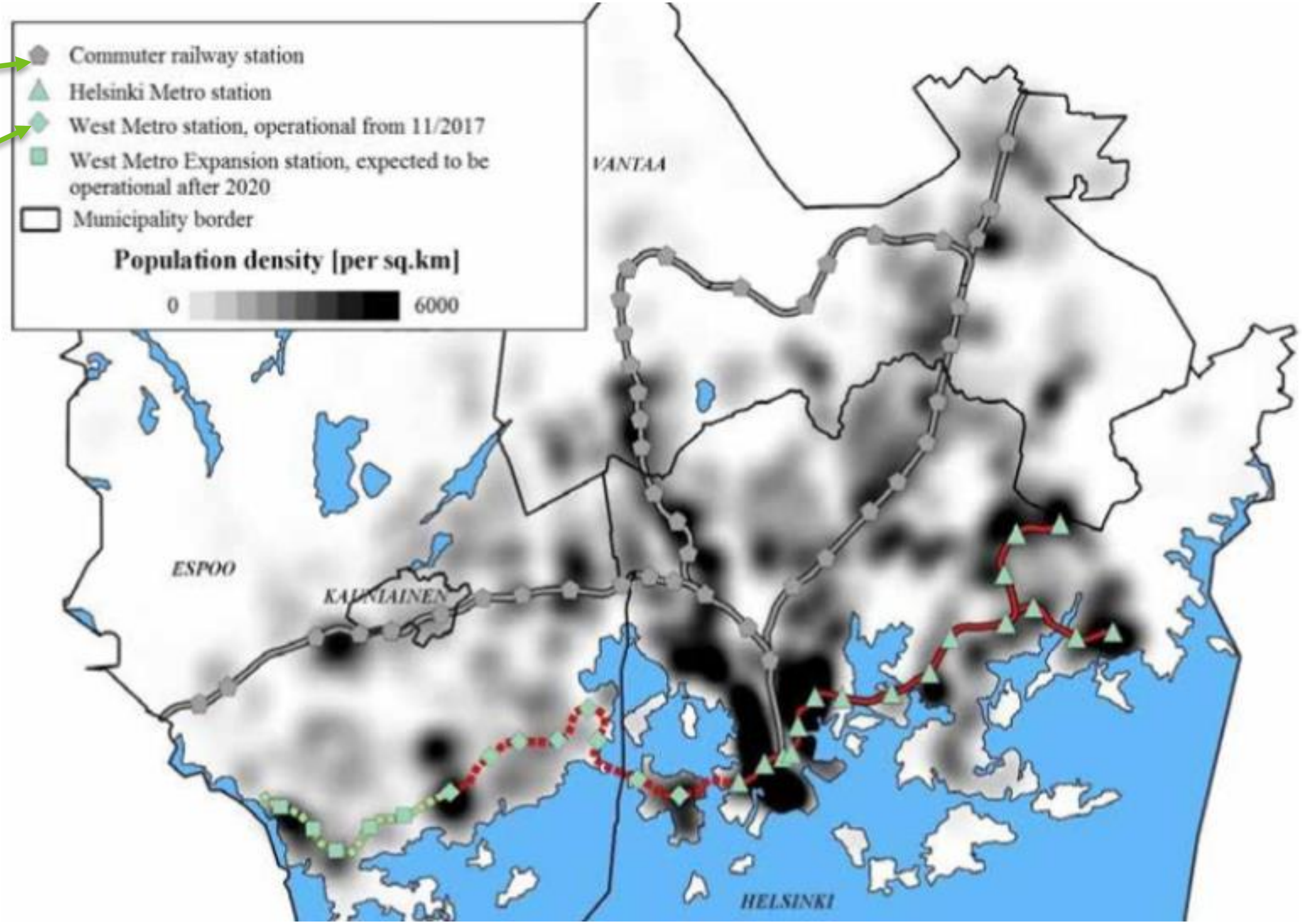
Fig. A2. A route map of the metro in Helsinki in 2016 (© HSL 2016)

Fig. A3. A route map of the metro in Helsinki and Espoo after west metro is operational in 2017 (© HSL)

Research design

Control

Treatment



Timing

- **The construction of the West Metro was finally approved in the city councils of Espoo and Helsinki in September 2008**
- **The underground master plan of the West Metro was approved in January 2009 and the official ceremony initiating the construction works took place 11th of November**
  - But in large scale the constructions began in 2010 after delays caused by the appeal process
- **In the study the "treatment period" begins at the start of 2010**
- **At this time, it was clear where the new metro stations will be located**

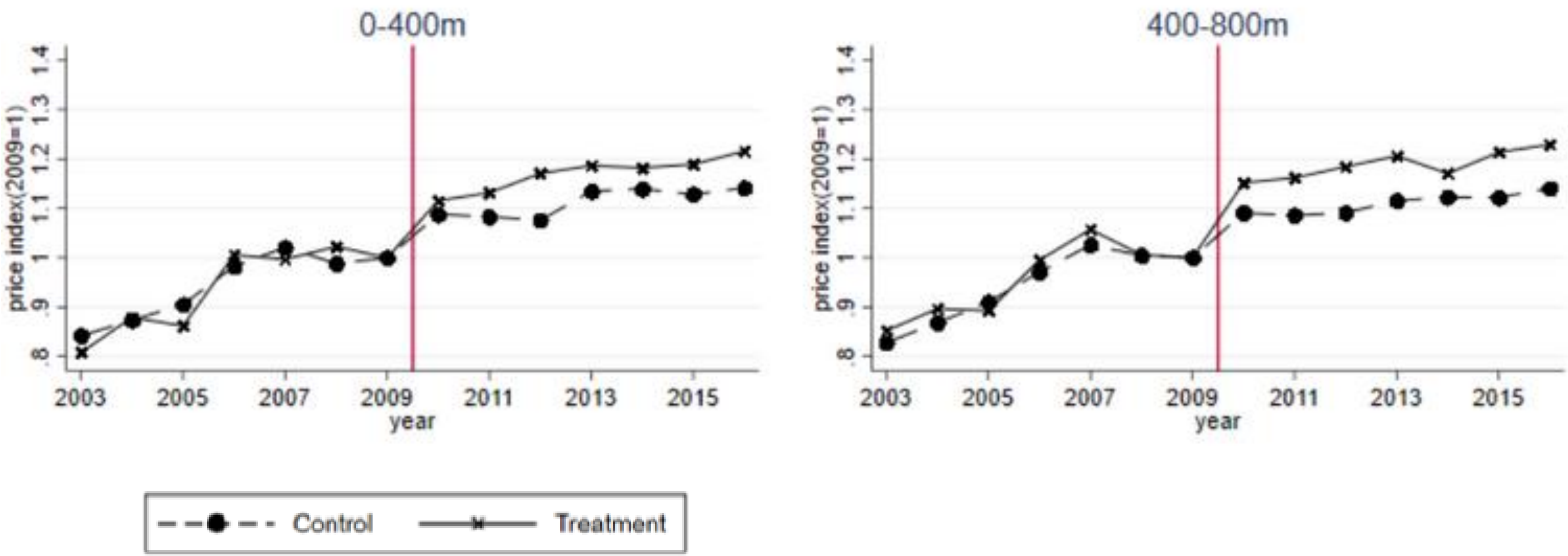
Data

- **Data comprises of transactions in Helsinki and Espoo from 2003 to 2016**
- **The data are collected by a consortium of Finnish real estate brokers and the dataset is refined and maintained by the Central Federation of Finnish Real Estate Agencies (KVKL)**
  - As not all real estate agencies participate, the dataset represents a sample (albeit rather large) of the total volume of transactions
- **The data include the transaction price and sale date for each dwelling as well as a rich set of dwelling characteristics including its exact location**
  - The sample is restricted to multi-story and row house sales

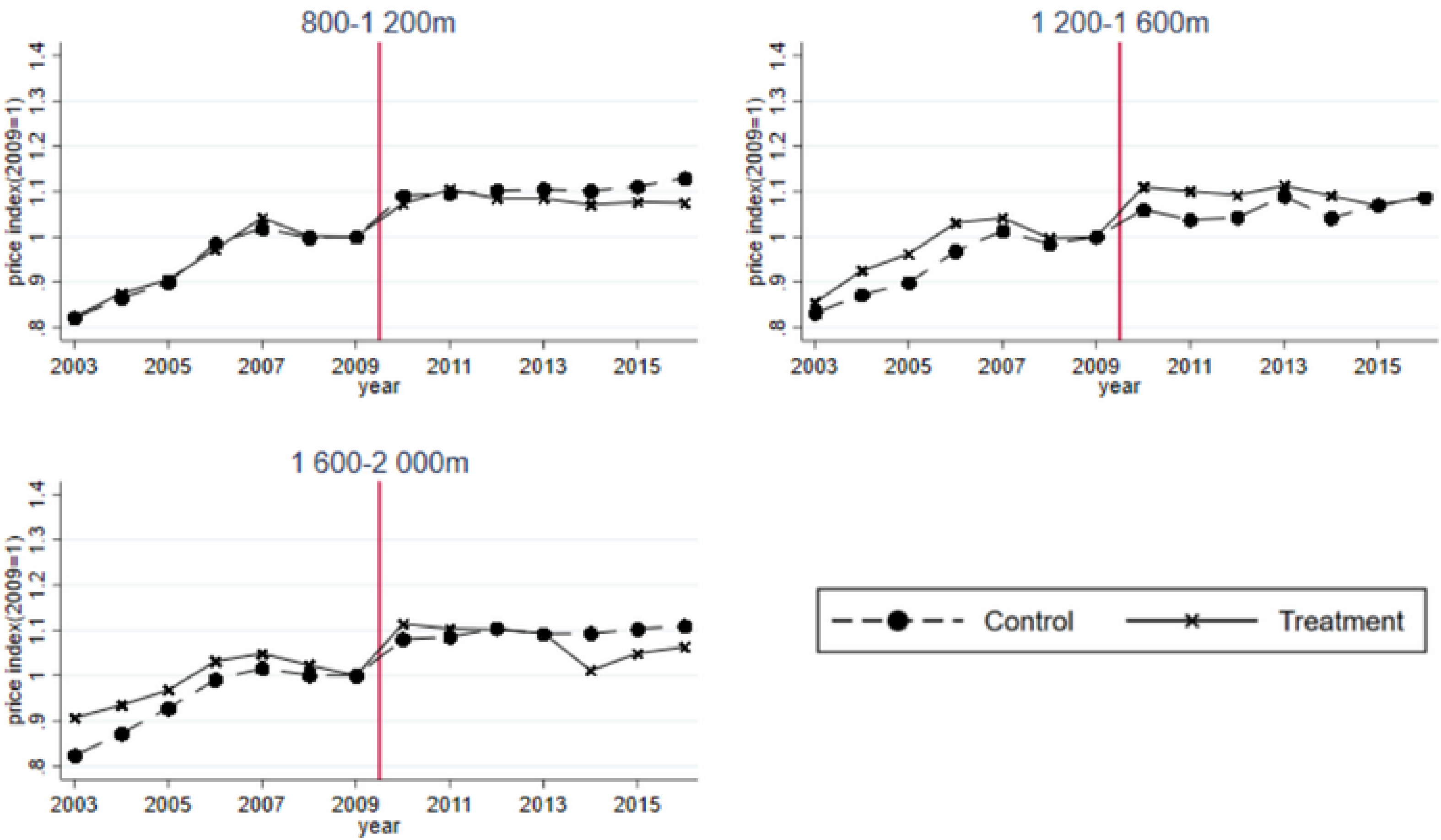
Data

Sample	Whole data (Helsinki and Espoo)	0 to 800m		800 to 1 600m	
Status		Treated	Control	Treated	Control
N	43 025	6 868	15 640	4 429	11 267
Sale price	223 668	252 024	196 154	311 661	199 122
	[110 007]	[119 458]	[78 980]	[156 343]	[82 107]
Square price	3 506	4 181	3 325	3 877	3 242
	[918]	[951]	[805]	[919]	[805]
Area	66	62	61	82	64
	[29]	[27]	[25]	[38]	[27]
Age	37	43	32	32	39
	[17]	[17]	[17]	[13]	[18]
Maint. Charge (€/m2)	3,5	3,8	3,5	3,5	3,5
	[1.2]	[1.1]	[1.2]	[1.2]	[1.3]
Floor number	2,4	2,7	2,5	2,3	2,3
	[1.6]	[1.7]	[1.5]	[1.5]	[1.4]
Floors in building	3,8	4,4	3,8	3,6	3,4
	[3.0]	[2.2]	[2.1]	[2.3]	[1.9]
Dist. to nearest station (m)	869	482	484	1 168	1 134
	[489]	[190]	[185]	[239]	[239]
Dist to CBD (km)	12	9	13	11,2	12,5
	[4.6]	[3.6]	[4.8]	[3.2]	[4.6]

Results – graphical

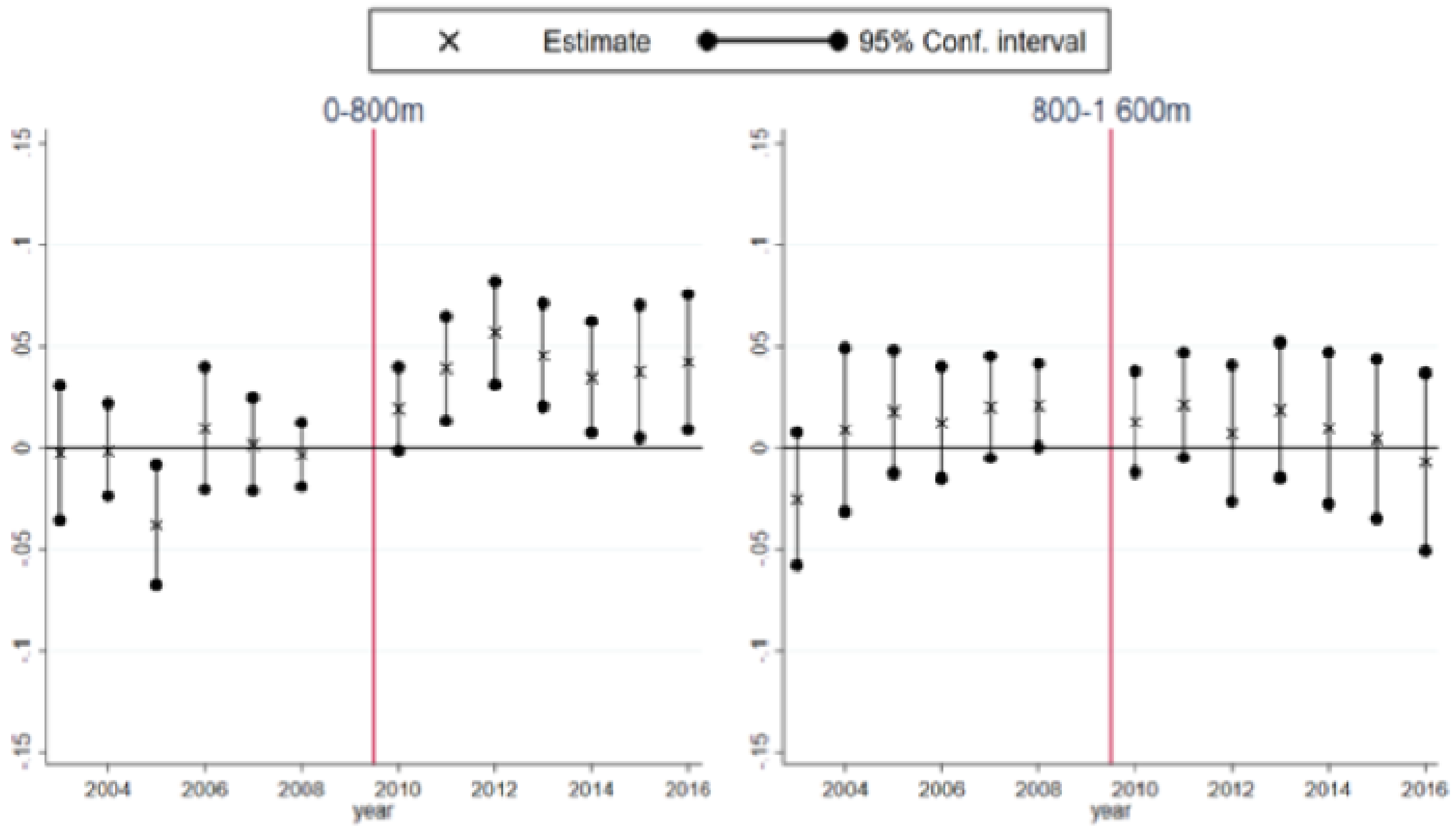


Results – graphical



Results – regression model

Fig. 3. Coefficients of yearly estimates, year 2009 omitted



Conclusion from the study

- **Housing markets start adjusting to the information about the infrastructure investment swiftly after the construction begins, years before the line becomes operational**
- **Apartments within 800 meters from the new metro stations, where the accessibility will be increased the most, experience a positive price increase that converges to around 4%**

- **Question: What are the likely further effects of this price increase in the old housing stock?**