

Differentiating the value of land from that of real estate to better understand the impacts of NNLT on housing affordability

THE ADDED VALUE OF COMPLEX MODELLING

Research Methods III: Seminar in Advanced Research Methods – RePIC master
Charlotte Bernier – 15 October 2025



Context

The NNLT target: a European ambition

- >> Communication from the European Commission in 2011 & 2023
- >> « **No Net Land Take** » by 2050 → Stop artificialisation

... locally declined

- >> In Flanders, with the “Bouwshift” policy
- >> In Wallonia, with the “Schéma de Développement Territorial”
- >> Drastic limitation of soil artificialization (“Stop-concrete”)
- >> Meet the growing demand for housing (↗ number of households)



**How to reconcile land restrictions and housing affordability ?
(in Belgium/Wallonia)**

The research journey

A walk through the *research reasoning process*

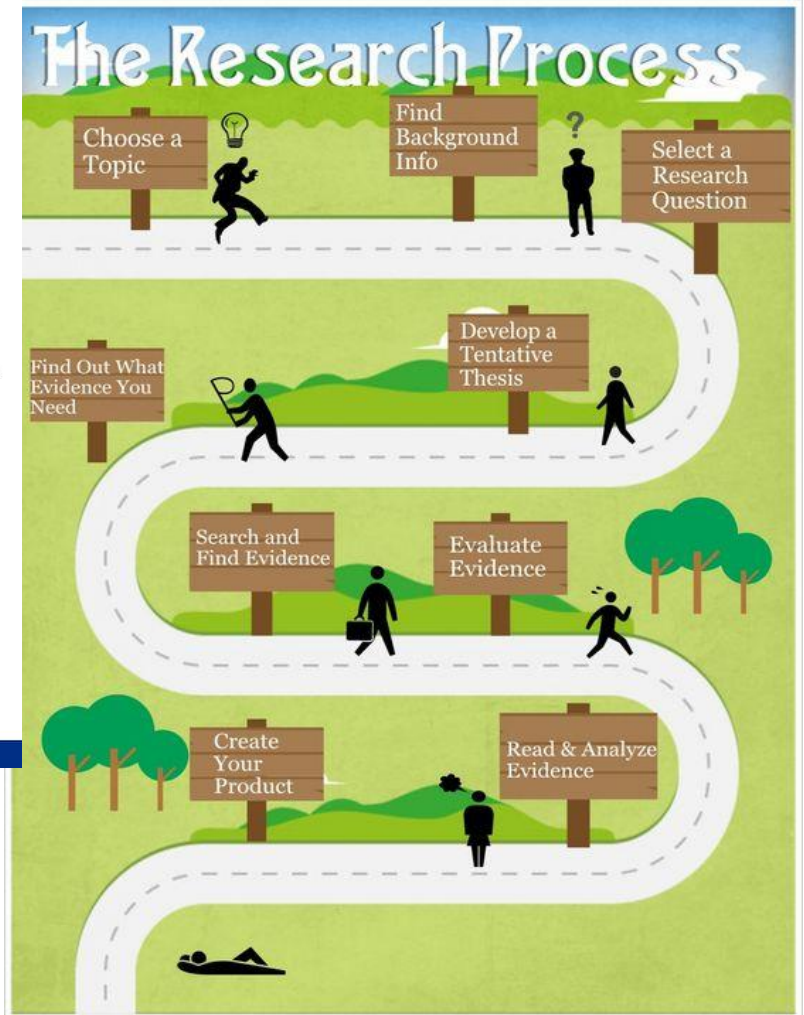
How did we move from a broad policy question to specific methodological decisions ?

How to reconcile land restrictions
and housing affordability ?

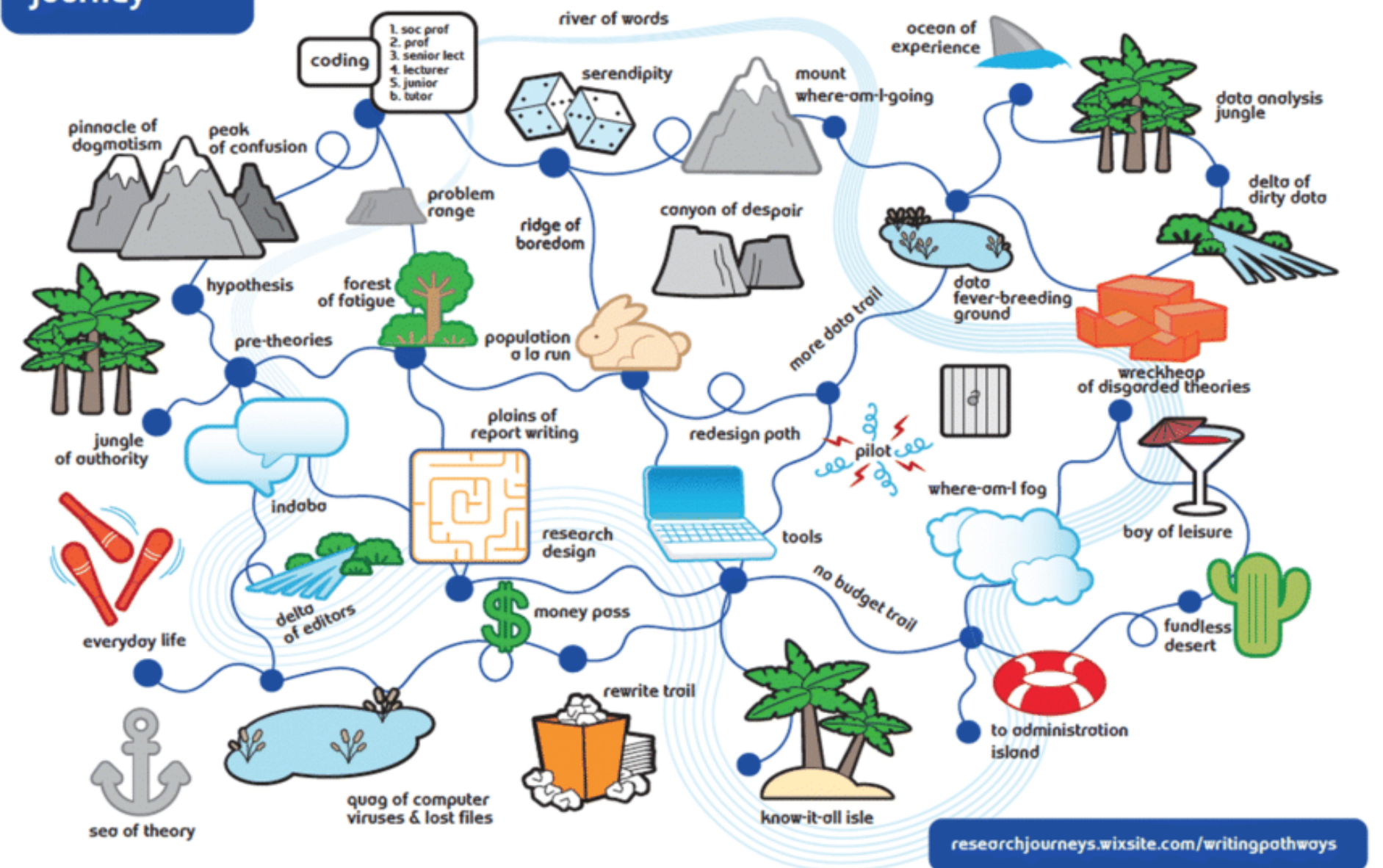


Complex modelization of housing
prices

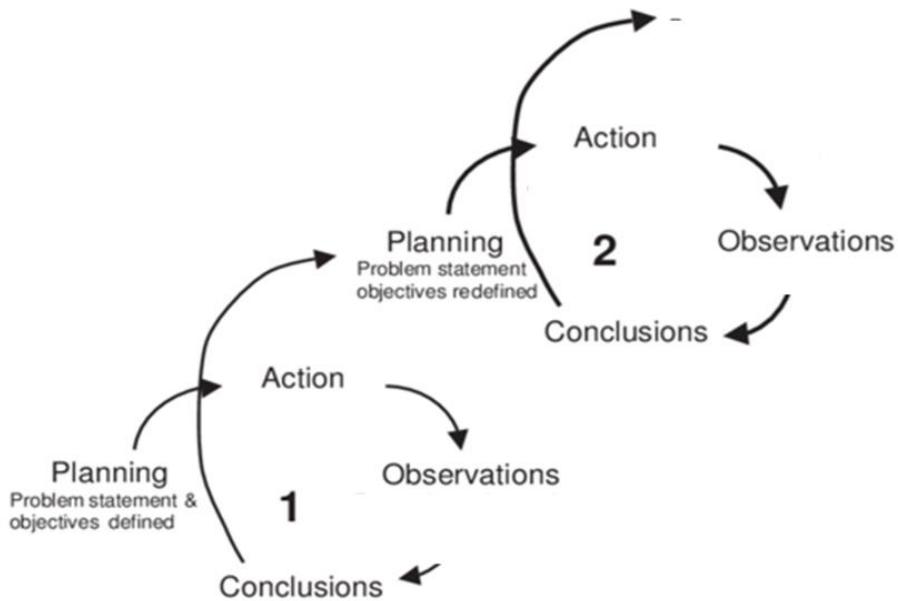
The research journey



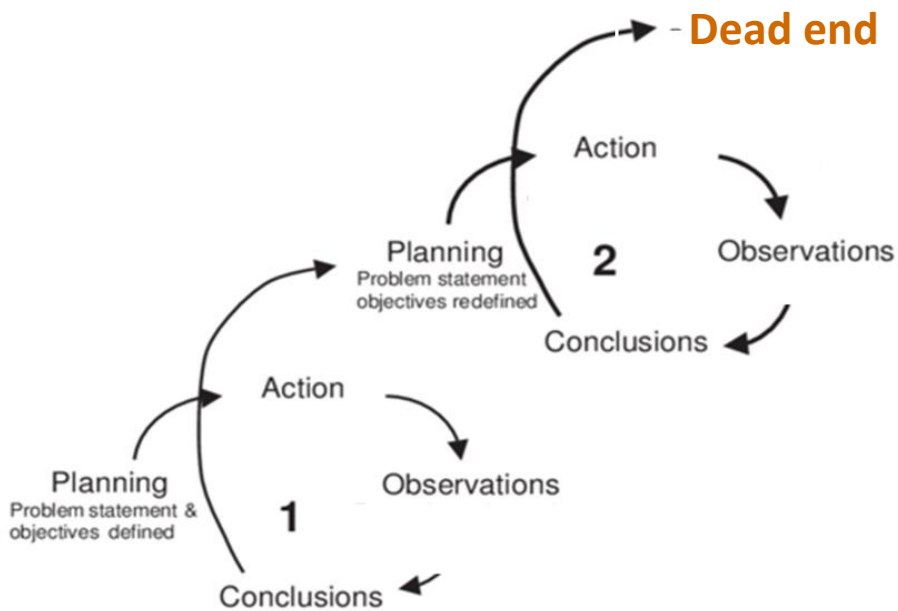
the research
journey



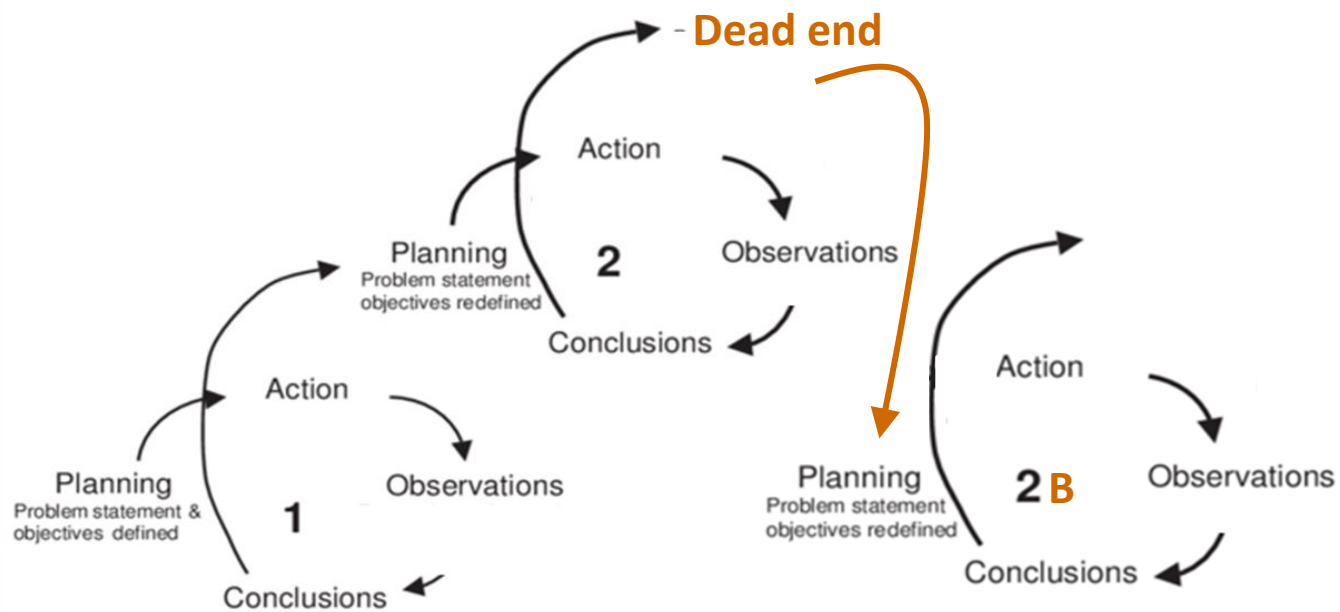
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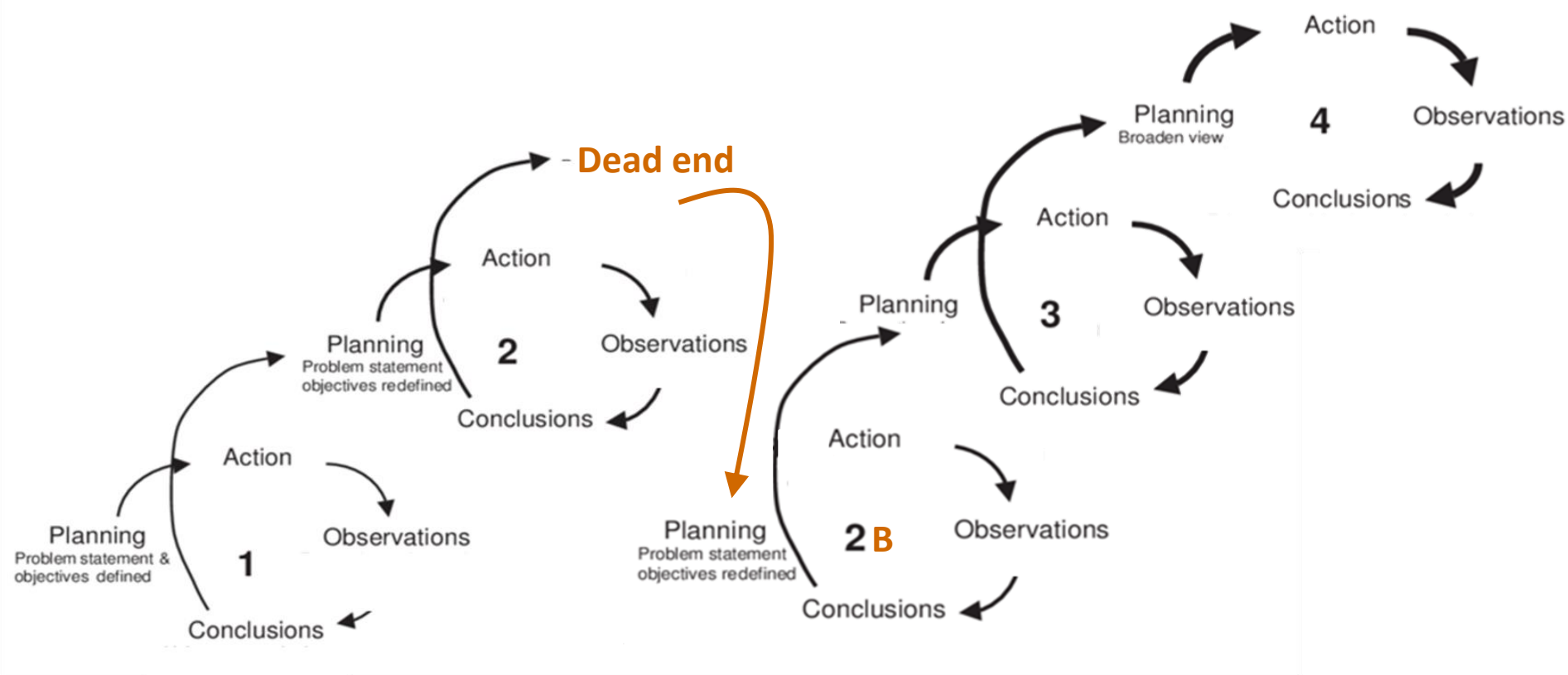
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The research journey



The research journey



The research journey



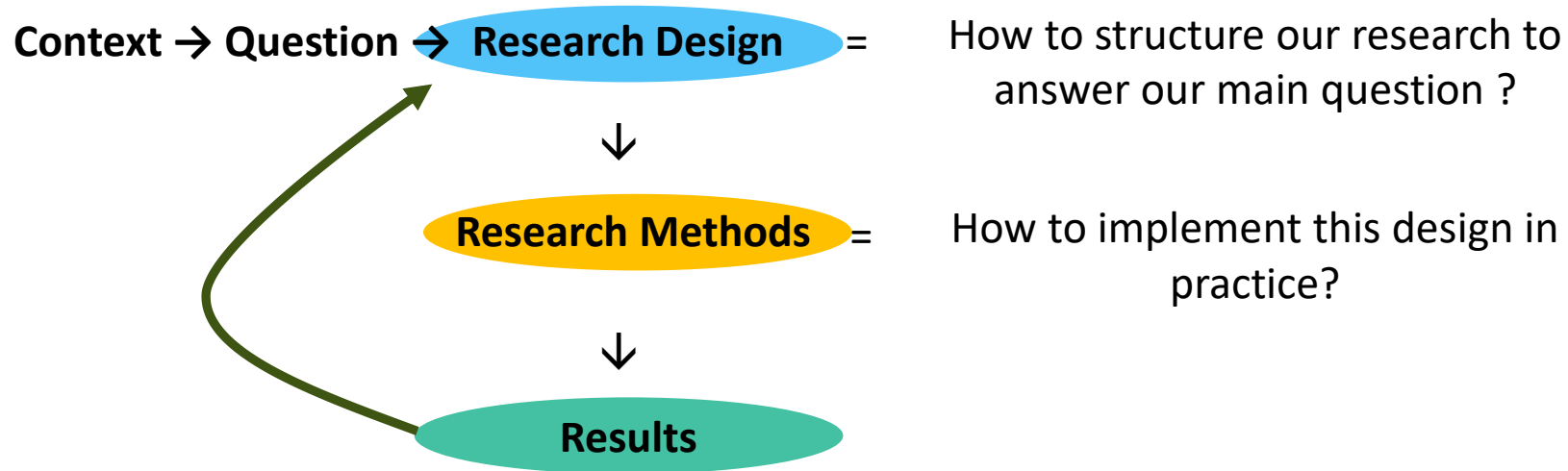
How to answer our question?

How to reconcile land restrictions and housing affordability (in Belgium/Wallonia)?

Context → Question → Research Design = How to structure our research to answer our main question ?

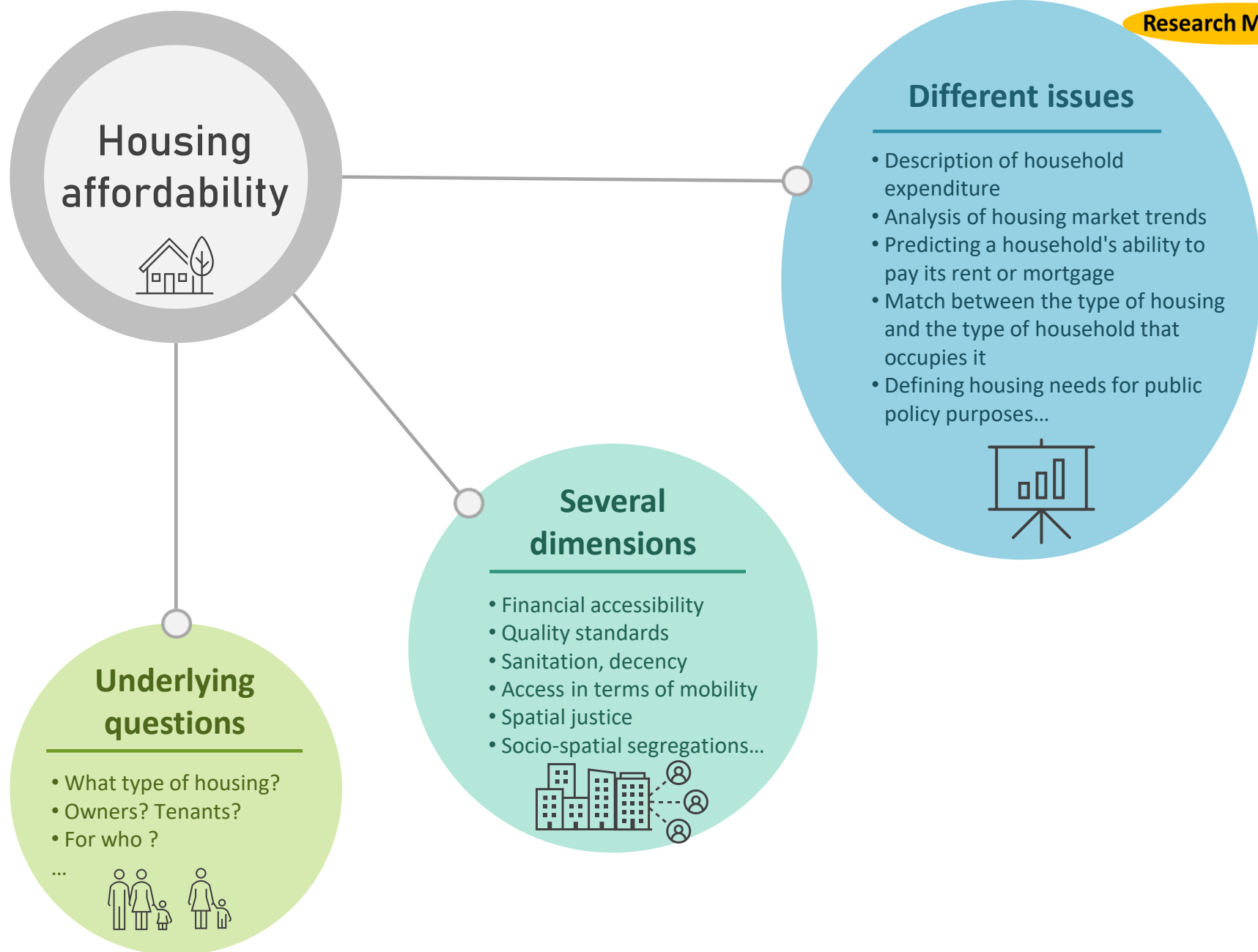
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How to answer our question?

How to reconcile land restrictions and housing affordability (in Belgium/Wallonia)?



Several dimensions

- Financial accessibility
- Quality standards
- Sanitation, decency
- Access in terms of mobility
- Spatial justice
- Socio-spatial segregations...



One dimension of housing affordability

Suspected as the most impacted dimension by the land restrictions of the NNLT policy

Several dimensions

- Financial accessibility
- Quality standards
- Sanitation, decency
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One dimension of housing affordability

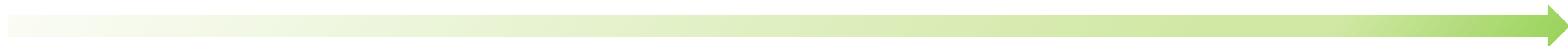
Suspected as the most impacted dimension by the land restrictions of the NNLT policy

➔ **Operationalization** of the theoretical/abstract concept of housing affordability

Operationalization

Transform an abstract concept

...into concrete and measurable indicators



Conceptual level	Dimensions	Operational indicator
Housing affordability (broad, multidimensional)	Financial accessibility	- Ratio of property prices to income - Estimated land and building values over time - ...
	Adequacy, localisation...	...
	Housing sanitation, quality ...	...

How to answer our question?

How to reconcile land restrictions and housing affordability (in Belgium/Wallonia)?

Focus = Financial access to housing



How to answer our question?

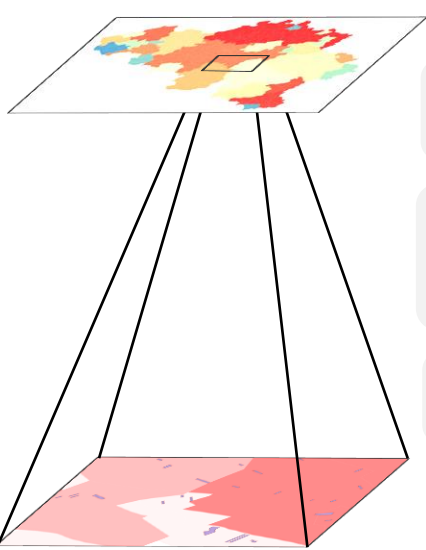
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- 1) What are the main causes of the increase in values/prices?
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Causes of increases in values?

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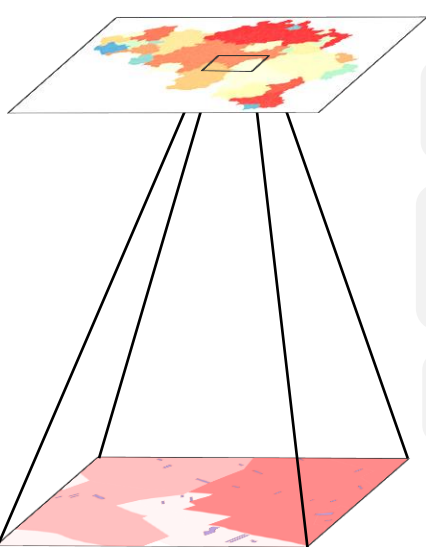
Inter-market scale: macroeconomic factors

↗ **Demand** (↗ number of households ; ↗ income ; ↘ borrowing rate)

Inelasticity of supply (scarcity of land, too long delays in obtaining permits, etc.)

Socio-economic disparities (↗ income or wealth gaps...)

Causes of increases in values?



Inter-market scale: macroeconomic factors

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Intra-market scale: housing, a combinatorial good



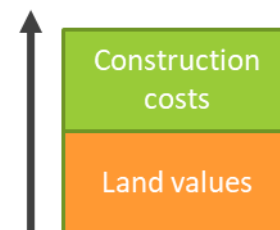
Build structure

Living surface area, quality and age of construction...

Land

Localisation, accessibility, quality of the physical and social neighborhood, relief...

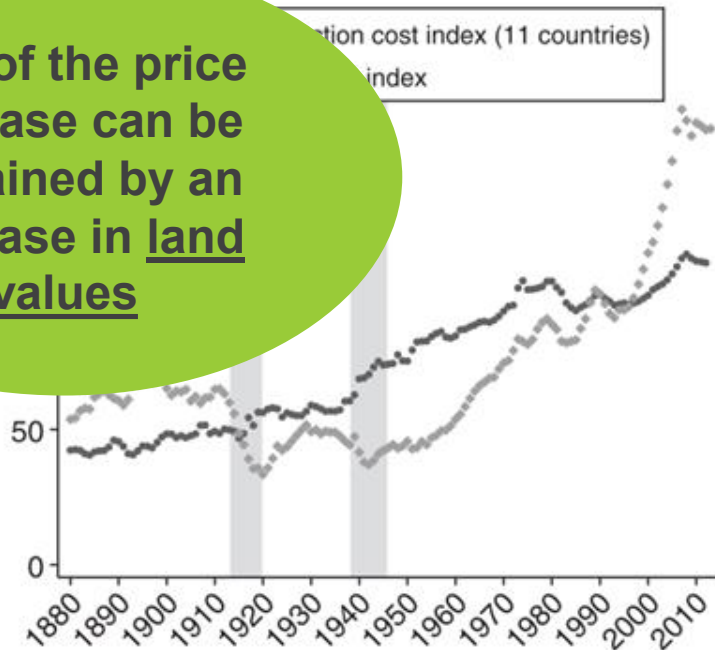
Real estate
values



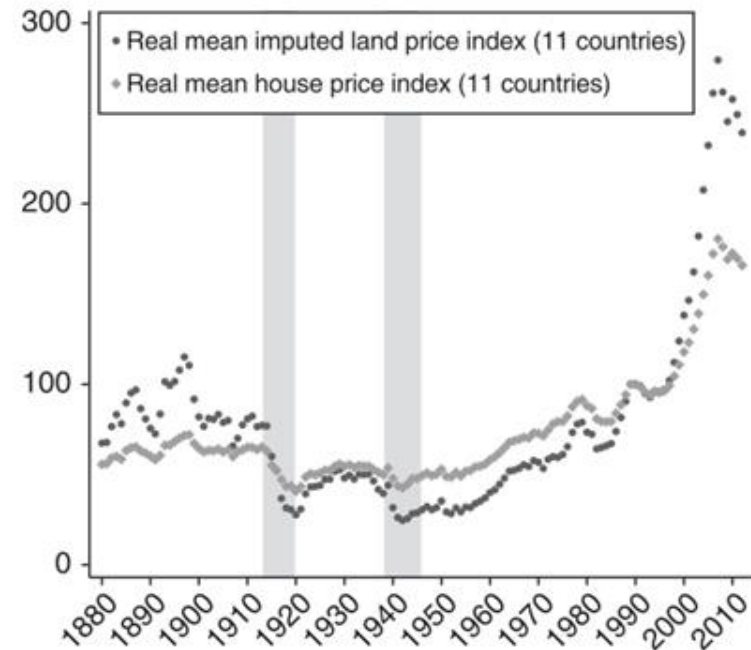
What share of the land?

Construction costs versus House prices

80% of the price increase can be explained by an increase in land values



Land prices versus House prices



Decomposition of land prices and construction costs in 11 OECD countries (Knoll *et al.*, 2017, p. 345)

What share of the land?

80% of the price increase can be explained by an increase in land values

Belgium

73 % in Flanders
54 % in Wallonia



Need clarifications

Impact of land supply restrictions?

Impact of land supply restrictions?

Norway, England...

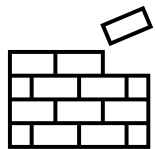
1945–1950

1980

Compact city model, containment of urban areas...

Continued ↗ increase in demand

Committed housing policy



Construction of many social housing
(Regulation of housing prices)

→ Housing affordability



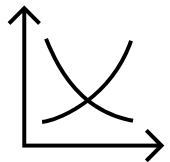
Neoliberal turning point



Political disengagement in housing

Market strategy and increasing reliance on the private sector to provide housing

(Deregulation of housing prices)



↗ increasing issues of housing affordability, socio-spatial segregation, socio-spatial polarizations and spatial justice

Impact of land supply restrictions?

Liberalized market context

+

Underdeveloped policy instruments for affordable housing



↗ issues of already existing problems of housing
affordability, socio-spatial segregation, socio-spatial
polarization and spatial justice



**Importance of a good inventory and a detailed
understanding of the dynamics**

How to answer our question?

How to reconcile land restrictions and housing affordability (in Belgium/Wallonia)?

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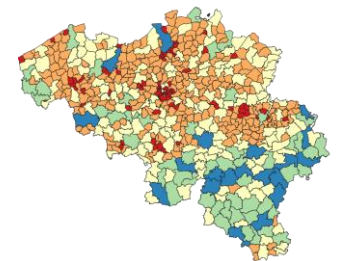
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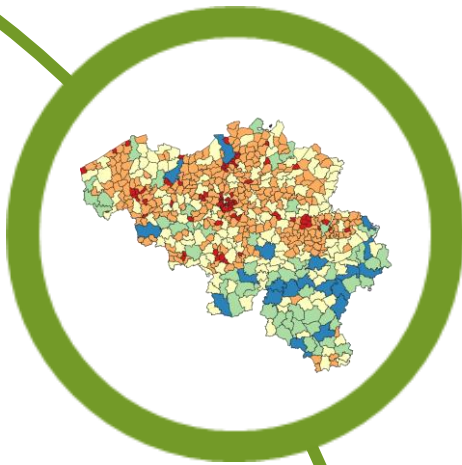
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A contextualized and detailed understanding of :

- the share of land in housing prices
- the impact of a limitation of (land) supply on housing affordability
- the real estate dynamics



Detailed mapping of real estates and above all, of land values



Mapping values

Why ?

A mapping of land values for a better understanding of the residential real estate market in Belgium/Wallonia



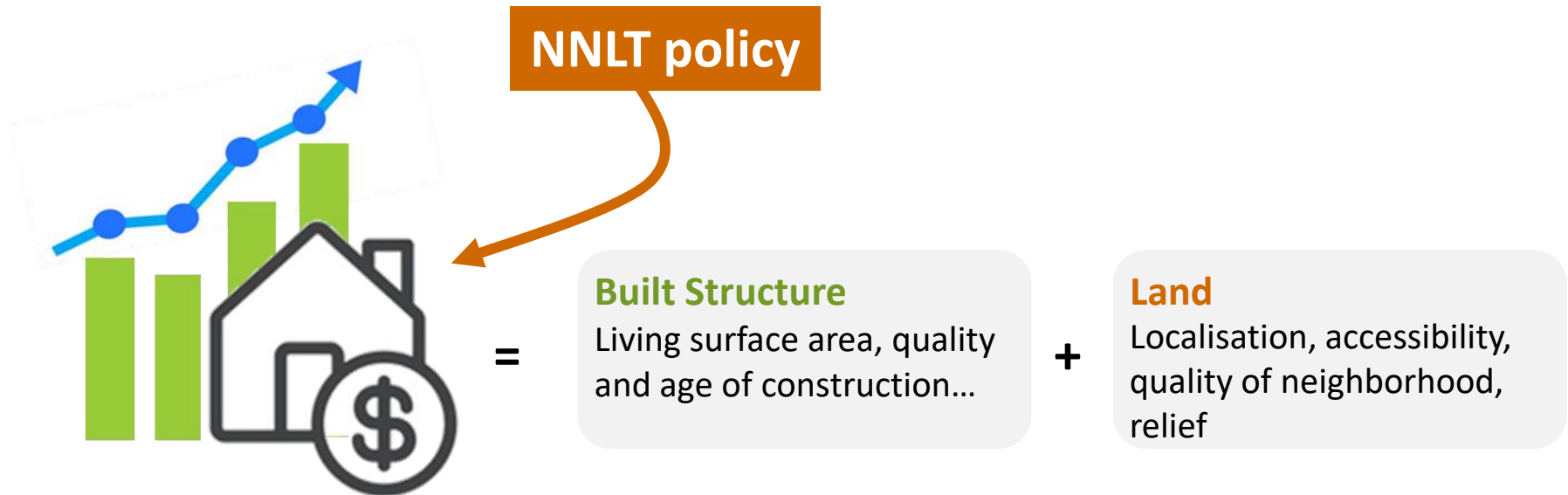
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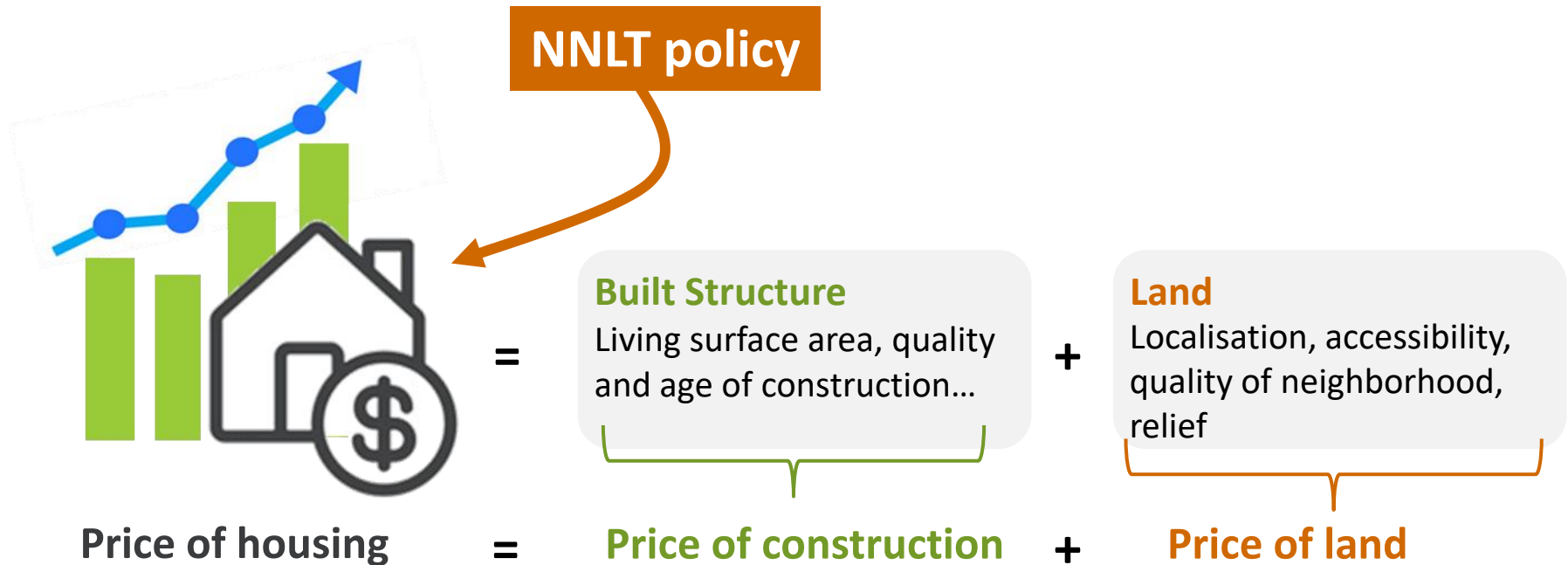
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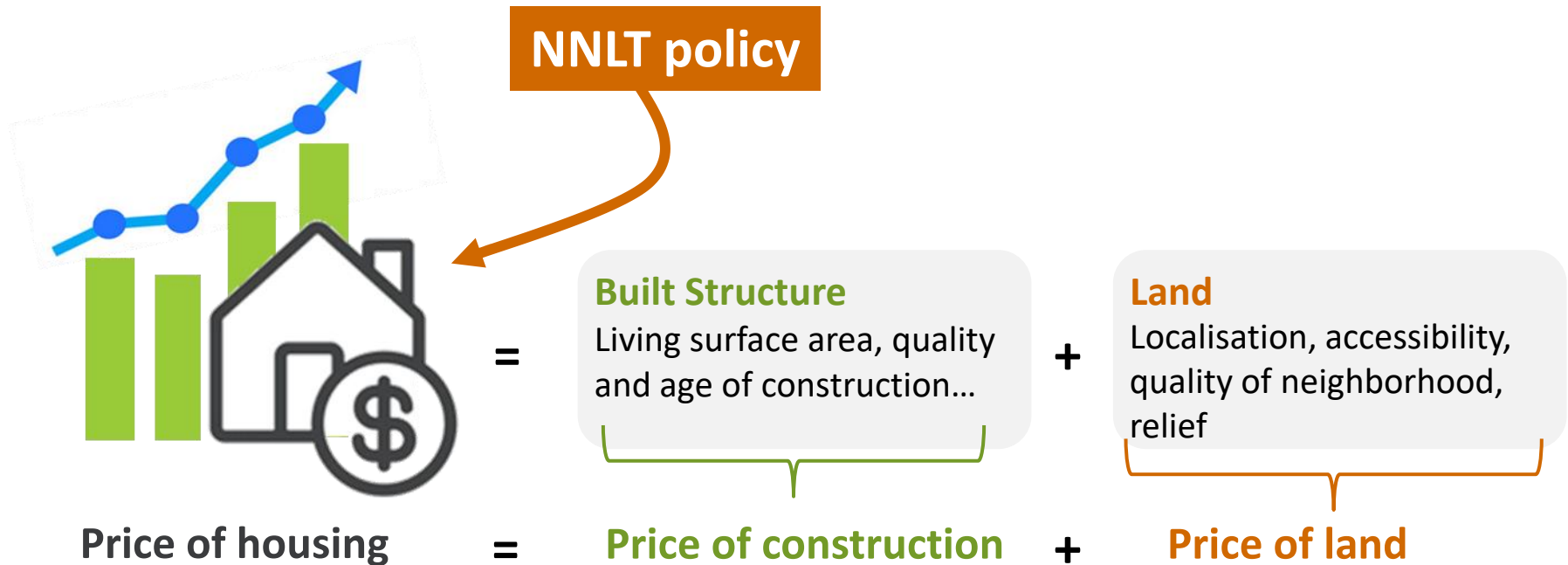
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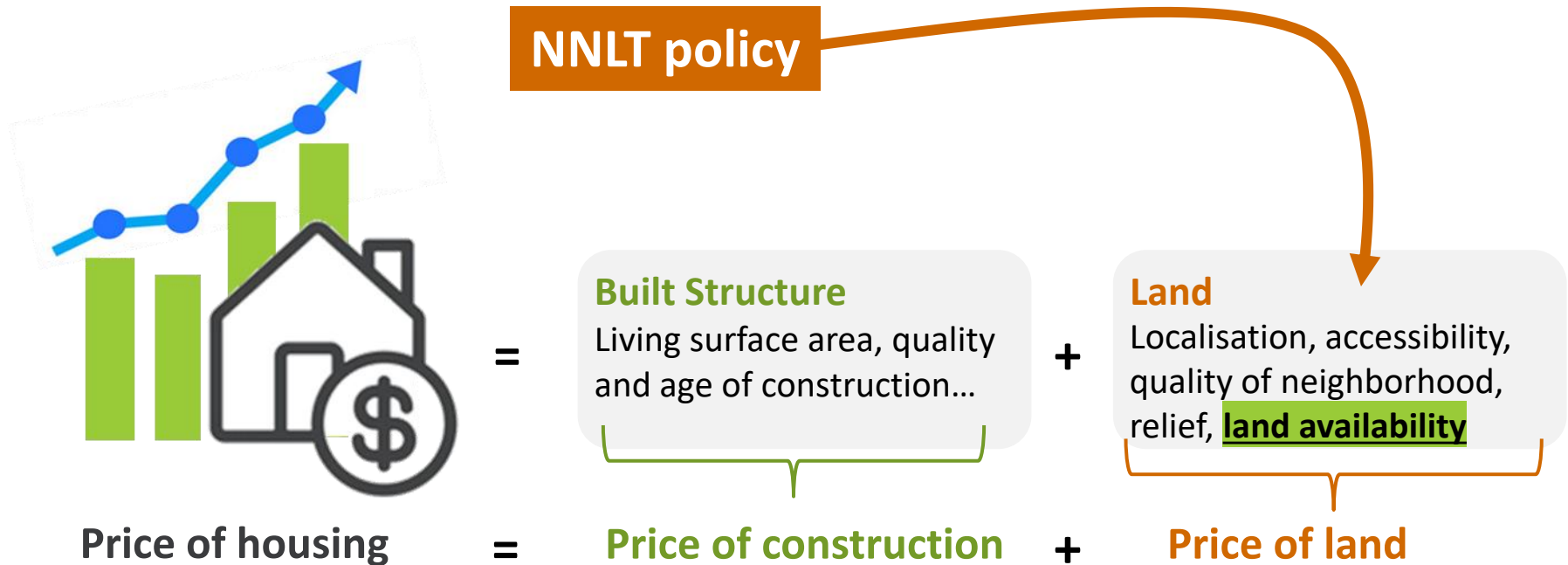
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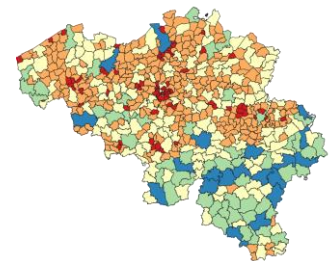
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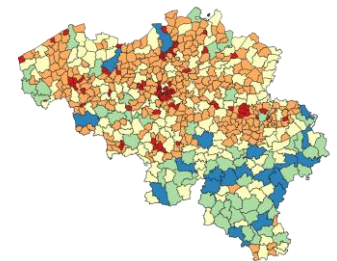
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NNLT policy

Built Structure

Living surface area, quality and age of construction...

+

Land

Localisation, accessibility, quality of neighborhood, relief, land availability

Price of housing

=

Price of construction

+

Price of land

||

Evaluate the share of land in housing prices

How to answer our question?

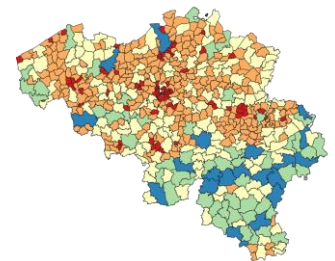
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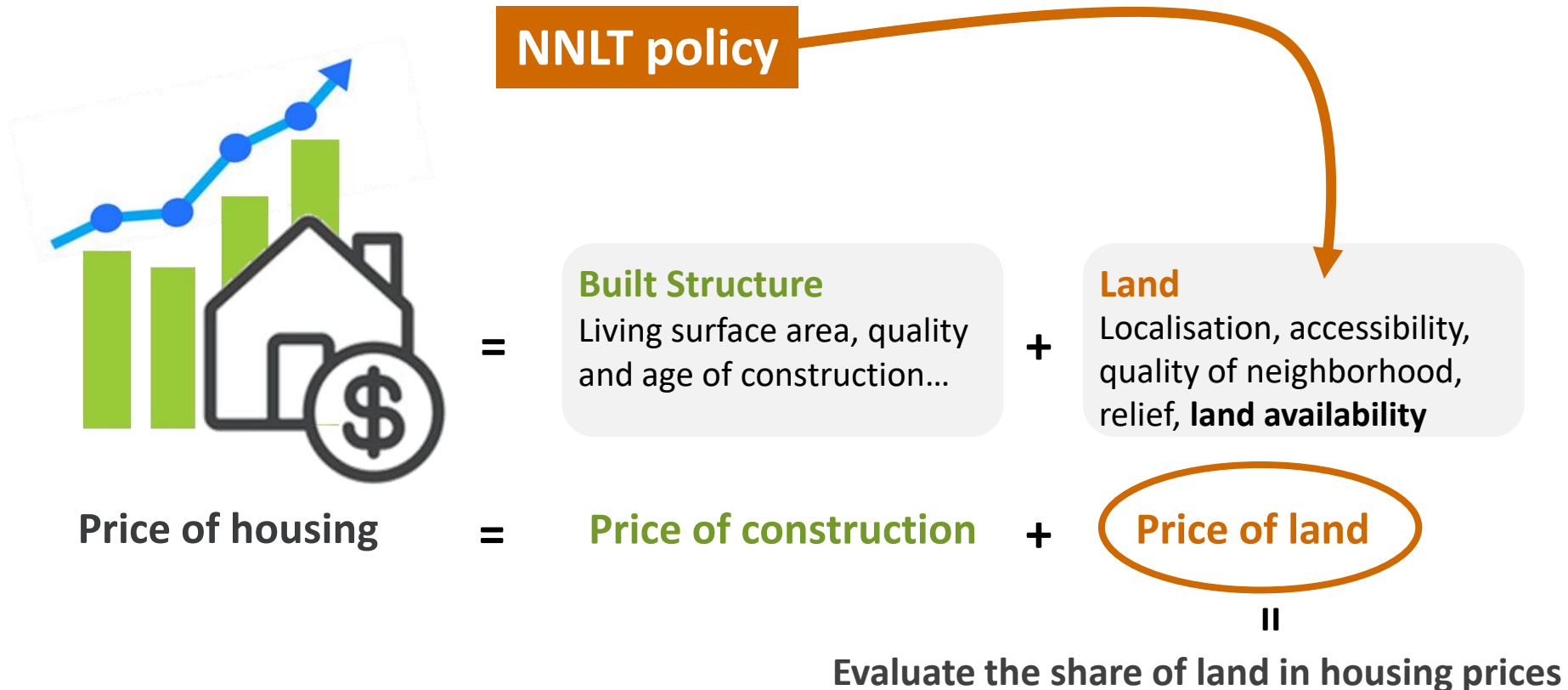
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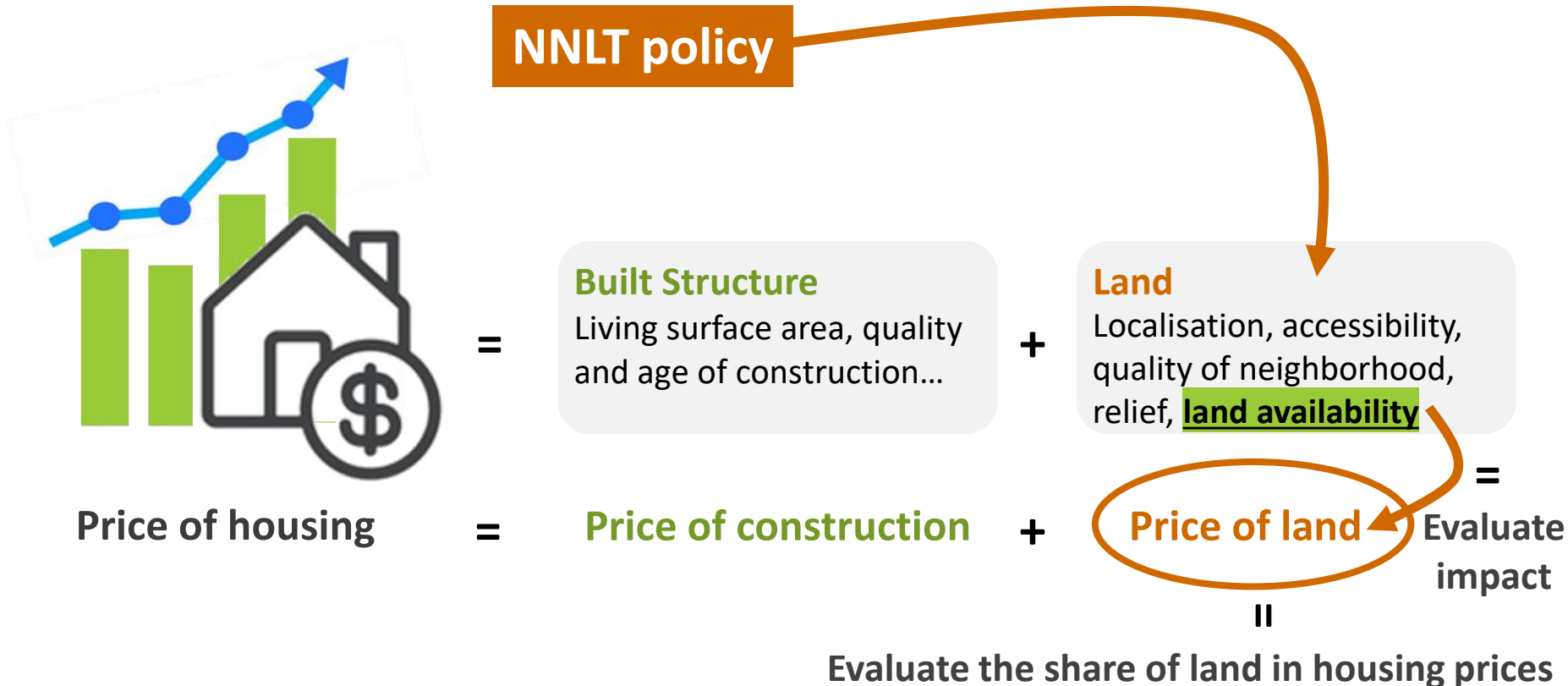
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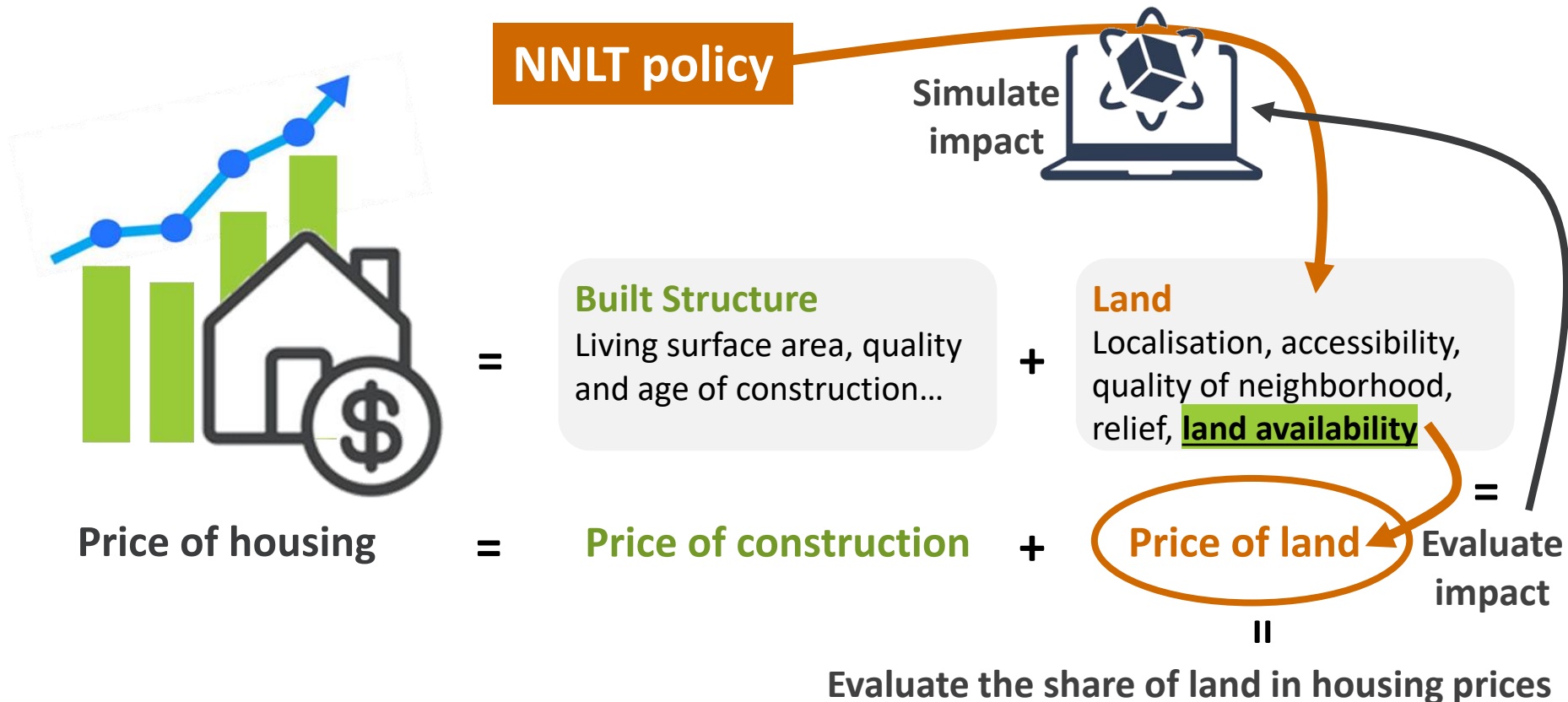
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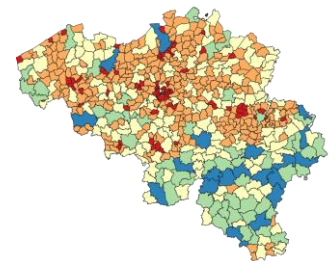
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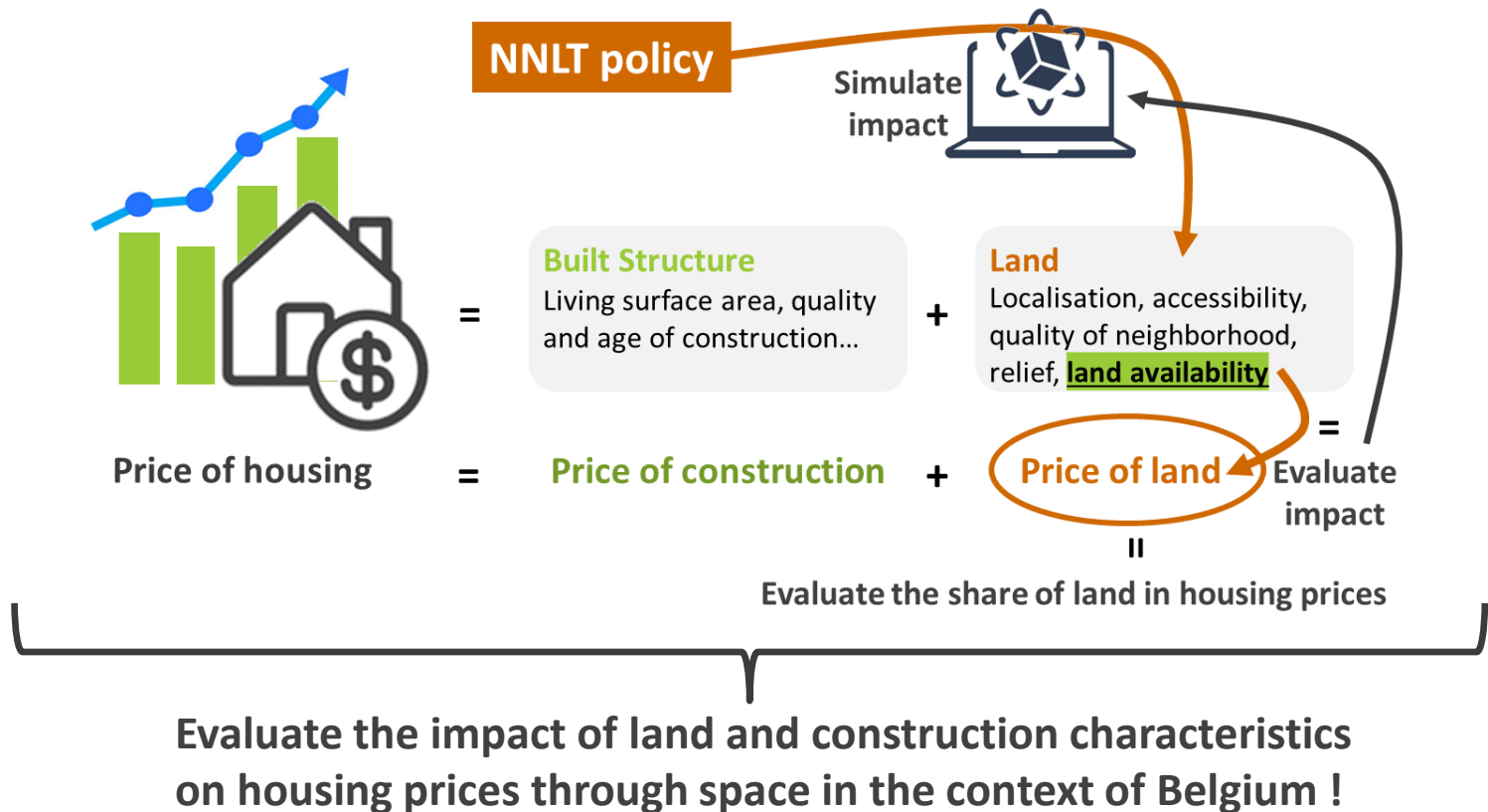
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Why ?

A mapping of land values for a better understanding of the residential real estate market

→ The little extra:

The common point of many measures to promote affordable housing is the **difficulty of their implementation without knowing the value of the land, even for built plots**. Without this, how can we ...

- Implement land value capture;
- Set up new forms of taxation based on land prices;
- Negotiate prices to set up a land production policy;
- Monitor the effective impact of the implementation of the NNLT by monitoring the value over time and space;
- ...

Concrete objectives

Does land actually drive the increase in real estate prices ?

- **Differentiate** land and real estate values, **even for plots already built**
- ➔ **Have a map of land values**
- Better understanding of the effect of variables on price over time and space, **including land availability**

What are the effects of NNLT? What initial situation?

- So far, what effects has land availability had on the price?
- **Simulate the implementation of the NNLT by modifying the land availability variable**

How ?

Differentiate land and real estate values, even for plots already built

➔ Having a map of land values ➔ EVALUATE

How ?

German, Finnish, Taiwanese experiences

- Need for greater transparency in real estate markets;
- Use of this knowledge to set up new tax systems such as split rate.



Land valuation in Nordrhein-Westfalen

How ?

German, Finnish, Taiwanese experiences

- Need for greater transparency in real estate markets;
- Use of this knowledge to set up new tax systems such as split rate.

BUT

➔ Evaluations carried out by local experts ➔ slow and expensive...



Land valuation in Nordrhein-Westfalen

= methodological adaptation to
research design challenges

Variables and data



=

Built Structure

- Living surface area
- House vs appartement
- Number of bathrooms
- Number of garage
- Energy efficiency
- Age of construction
- 2-3-4 facade ?
- Quality of material
- ...

+

Land

- Geographic position
- Plot area
- Slope of the plot
- Noise
- Access to work possibilities
- Access to services (shop, schools, healthcare...)
- Access to bus/train stations (by foot, bicycle, car...)
- Socio-economic quality of neighborhood (criminality, revenue, employment rate...)
- Access to nature
- Land availability
- ...

Variables and data

= methodological adaptation to
research design challenges

Variables and data



LEVEL I – Scale of the plot – Whole of Belgium

Sales data (2009 to 2020) obtained from SPF Finances/FOD Financiën with characteristics of the property and the plot (m², number of facades, rooms, garden, etc.)



Only houses datas
No energy efficiency datas
Bad quality of living area datas



Alternative ?

Web scrapping from sales website !

BUT

- Need to be done during a long time period to be accurate
- Not the ACTUAL sales prices
- Not the official datas → the method could not be institutionalized

Variables and data



LEVEL I – Scale of the plot – Whole of Belgium

Sales data (2009 to 2020) obtained from SPF Finances/FOD Financiën with characteristics of the property and the plot (m², number of facades, rooms, garden, etc.)

Various sources : noise pollution, accessibility to the employment center, to a train station, slope of the land, land availability, etc.

Variables and data

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LEVEL II – Statistical sector /neighborhood :

Various sources : income, quality of buildings, environment, nature, various aspects of social development, etc.

LEVEL III – Municipalities :

Various sources : social and economic context, etc.



Variables and data



15 variables **tested** to explain the price of the plot of land



22 variables **tested** to explain the price of real estate
(7 construction variables + 15 land variables)

How ?

Differentiate land and real estate values, even for plots already built

➔ Having a map of land values ➔ EVALUATE ➔ Econometric models

**Data
driven
Method**

Concrete objectives

Differentiate land and real estate values, even for plots already built

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Data
driven
Method

$$y = \beta x + \varepsilon$$

Concrete objectives

Differentiate land and real estate values, even for plots already built

→ Having a map of land values → EVALUATE → Econometric models

Data
driven
Method

$$y = \beta x + \varepsilon$$

$$y = \beta_{c1}x_{c1} + \beta_{c2}x_{c2} + \dots + \beta_{t1}x_{t1} + \beta_{t2}x_{t2} + \dots + \varepsilon$$

Price of housing

Construction
related variables

Land related
variables

$$y = y'_{\text{construction}} + y'_{\text{land}} + \varepsilon$$

Price of housing Modelized price of construction Modelized price of land

Concrete objectives

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Price of housing



Sales data

X = Construction
related variables

X = Land related
variables

β = Impact of the variable on price

Model = finding the
 β

Concrete objectives

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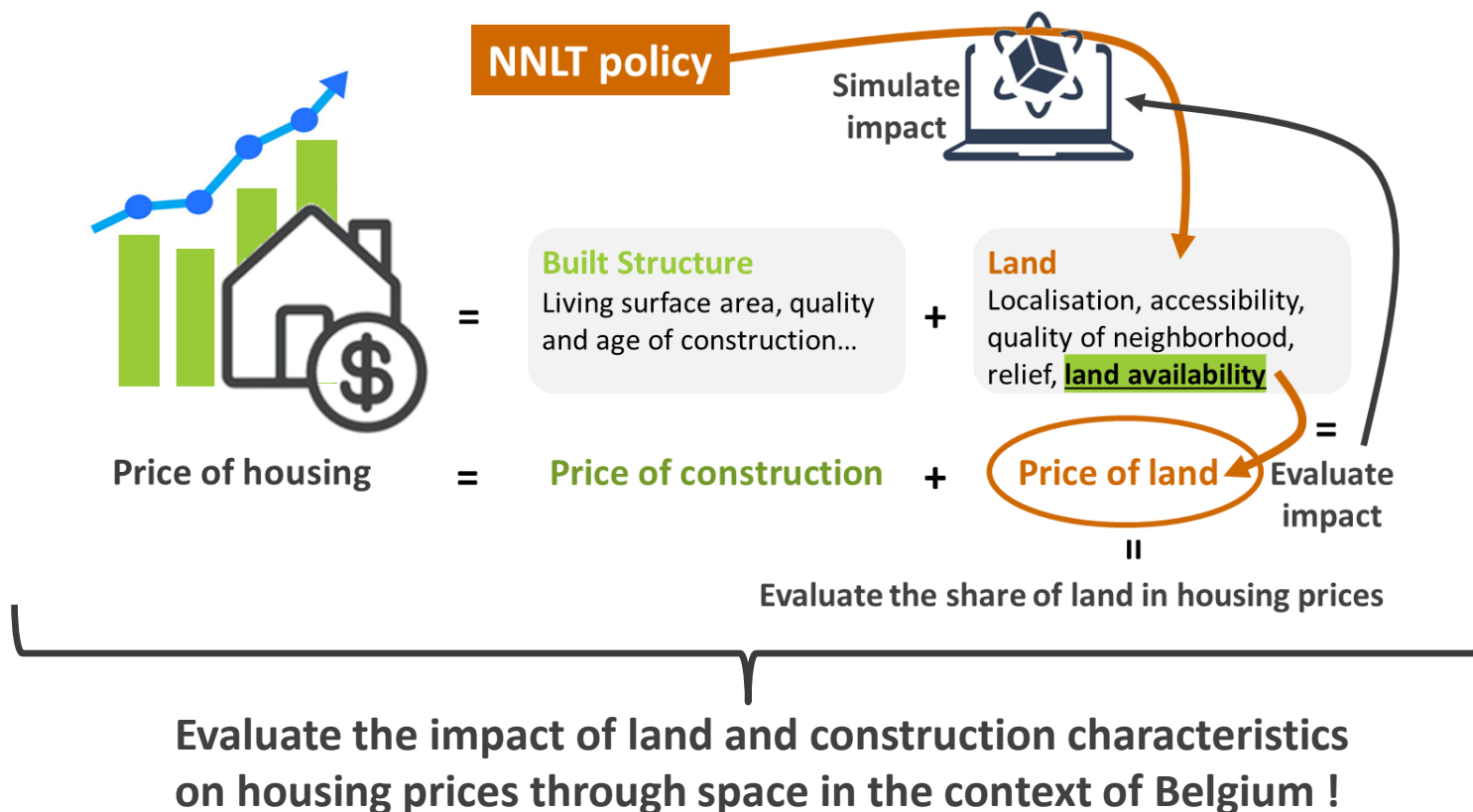
$$y = y'_{\text{construction}} + y'_{\text{land}} + \varepsilon$$

$$y'_{\text{land}} = y - y'_{\text{construction}} - \varepsilon$$

Modelized price of land = Price of housing — **Modelized price of construction** — Residuals from modelisation

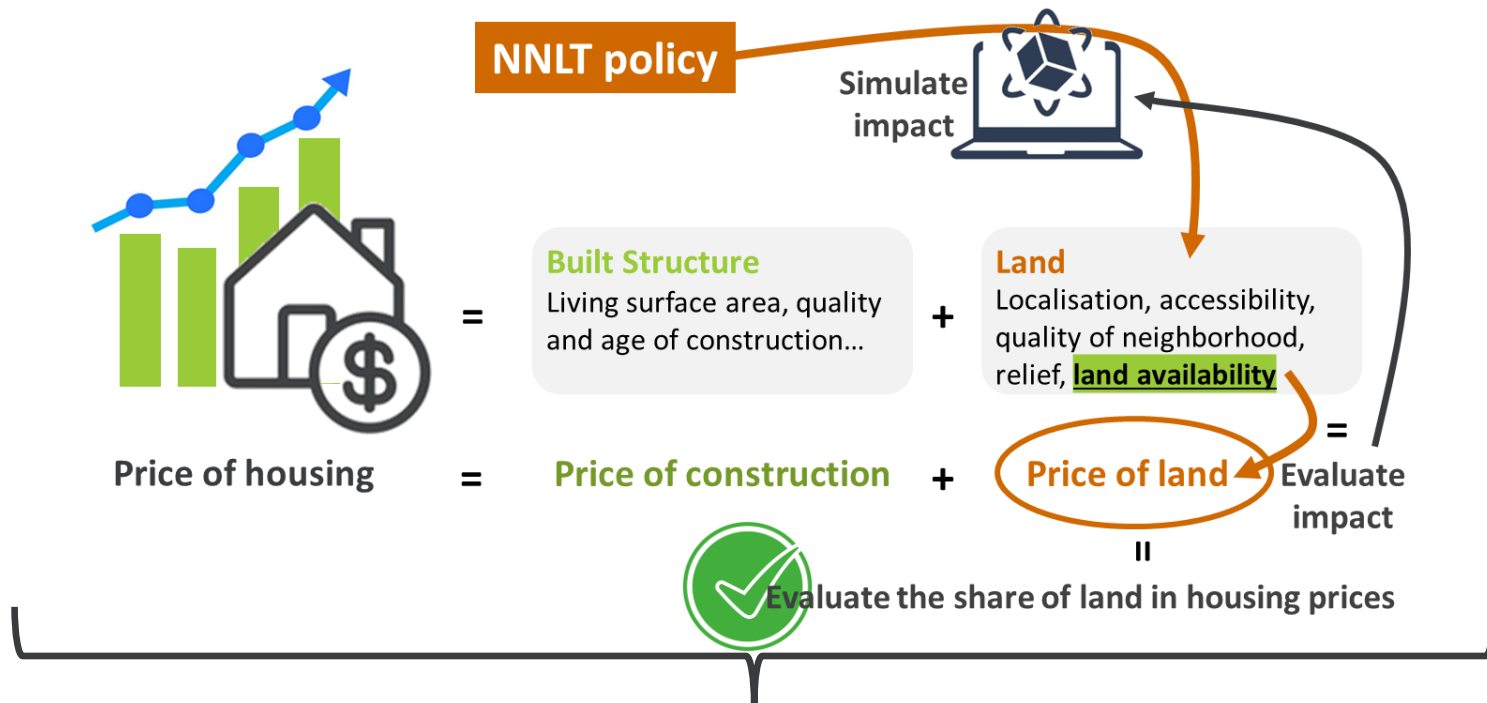
Why ?

A mapping of land values for a better understanding of the residential real estate market in Belgium/Wallonia



Why ?

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Evaluate the impact of land and construction characteristics on housing prices through space in the context of Belgium !

Concrete objectives

Differentiate land and real estate values, even for plots already built

➔ Having a map of land values ➔ EVALUATE ➔ Econometric models

**Data
driven
Method**

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Price of housing

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Land related
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Concrete objectives

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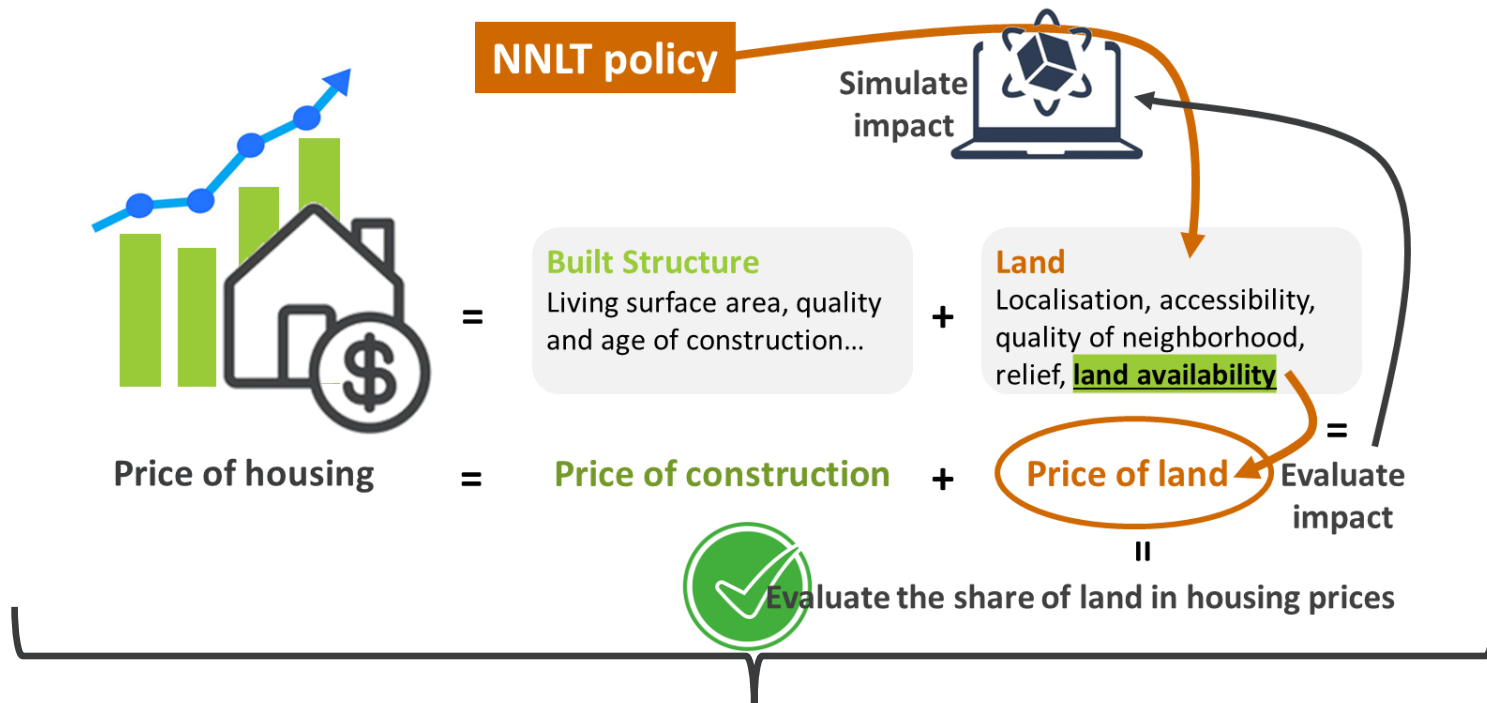
Land
availability

Enough & accurate
characteristics



Why ?

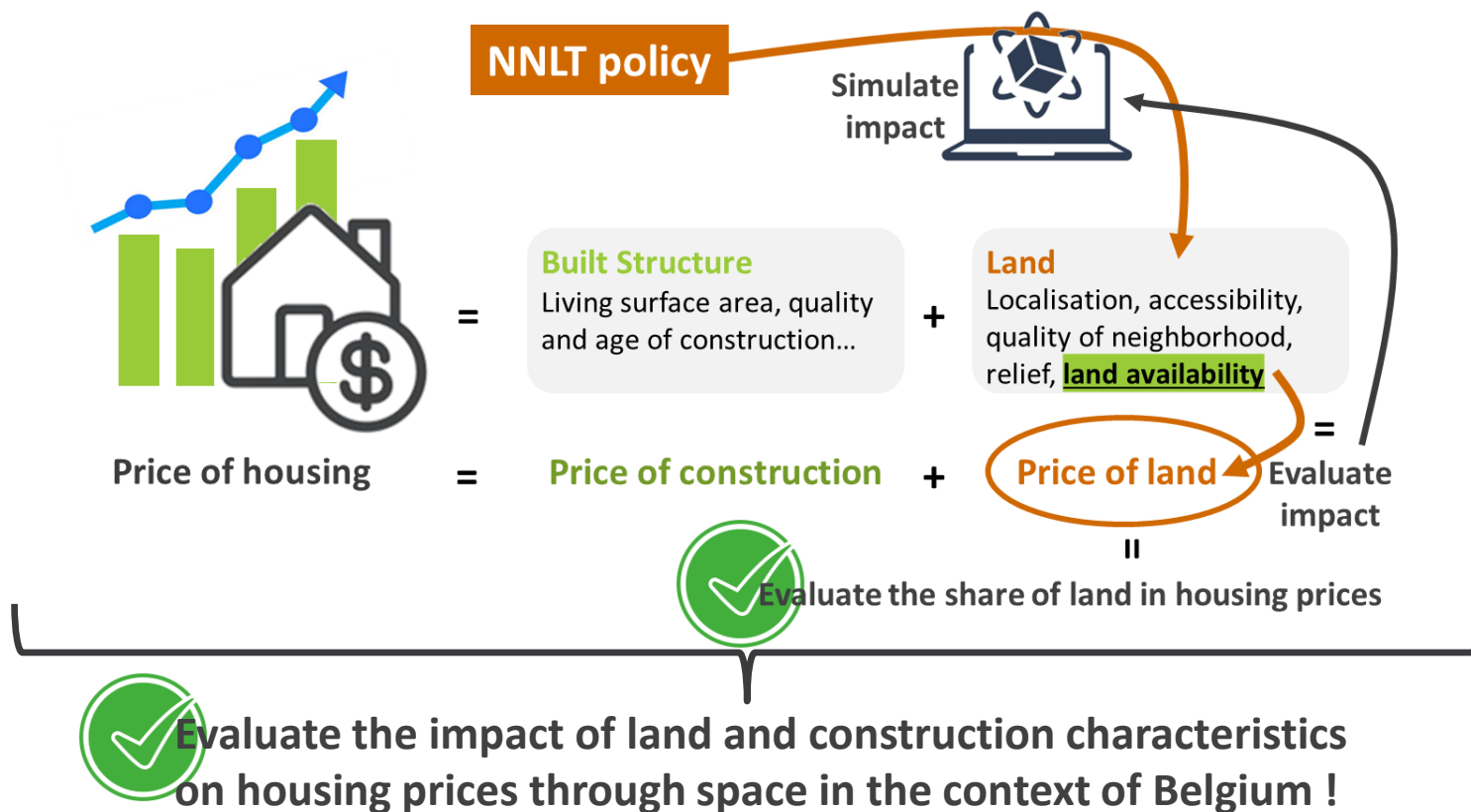
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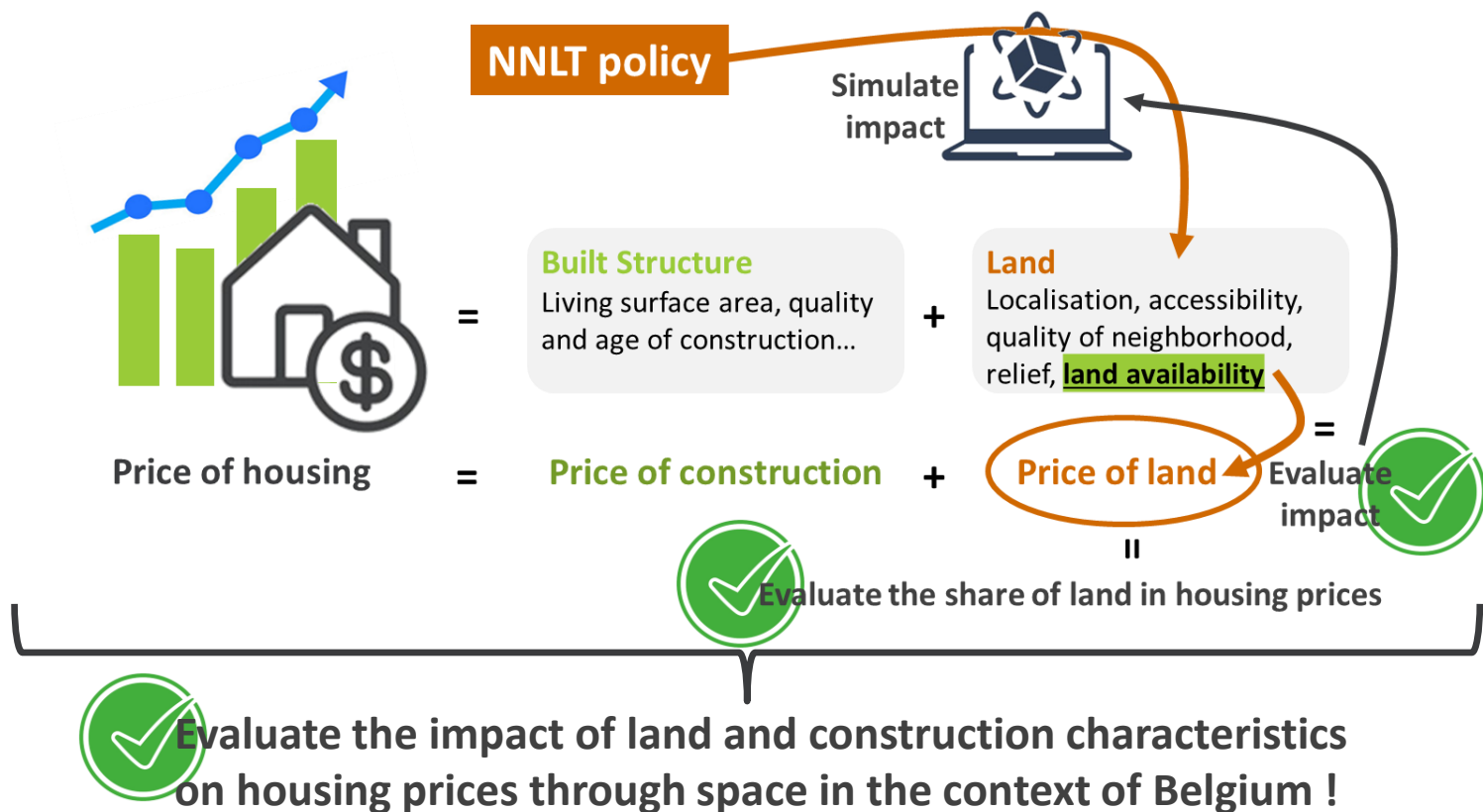
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Concrete objectives

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Price of housing

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variables

Model 1
« direction »

$$y = y'_{\text{construction}} + y'_{\text{land}} + \varepsilon$$

Price of
housing

Modelized price
of construction

Modelized
price of land

REAL Land
availability

Model 1 =
finding the β

Concrete objectives

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Price of housing

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variables

Model 1
« direction »

$$y = y'_{\text{construction}} + y'_{\text{land}} + \varepsilon$$

Price of
housing

Modelized price
of construction

Modelized
price of land

REAL Land
availability

Model 1 =
finding the β

Model 2
« direction »

$$y' = y'_{\text{construction}} + y'_{\text{land}} + \varepsilon$$

Price of housing
with NNLT

Modelized price
of construction

New modelized
price of land

NNLT Land
availability

Model 2 =
keep the β ,
change X ,
Find new prices

Concrete objectives

Differentiate land and real estate values, even for plots already built

→ Having a map of land values → EVALUATE → Econometric models

Data
driven
Method

$$y = \beta_{c1}x_{c1} + \beta_{c2}x_{c2} + \dots + \beta_{t1}x_{t1} + \beta_{t2}x_{t2} + \dots + \varepsilon$$

Price of housing

Construction
related variables

Land related
variables

Model 1
« direction »

$$y = y'_{\text{construction}} + y'_{\text{land}} + \varepsilon$$

Price of
housing

Modelized price
of construction

Modelized
price of land

REAL Land
availability

X LOW to see
impact on
prices!

Model 2
« direction »

$$y' = y'_{\text{construction}} + y'_{\text{land}} + \varepsilon$$

Price of housing
with NNLT

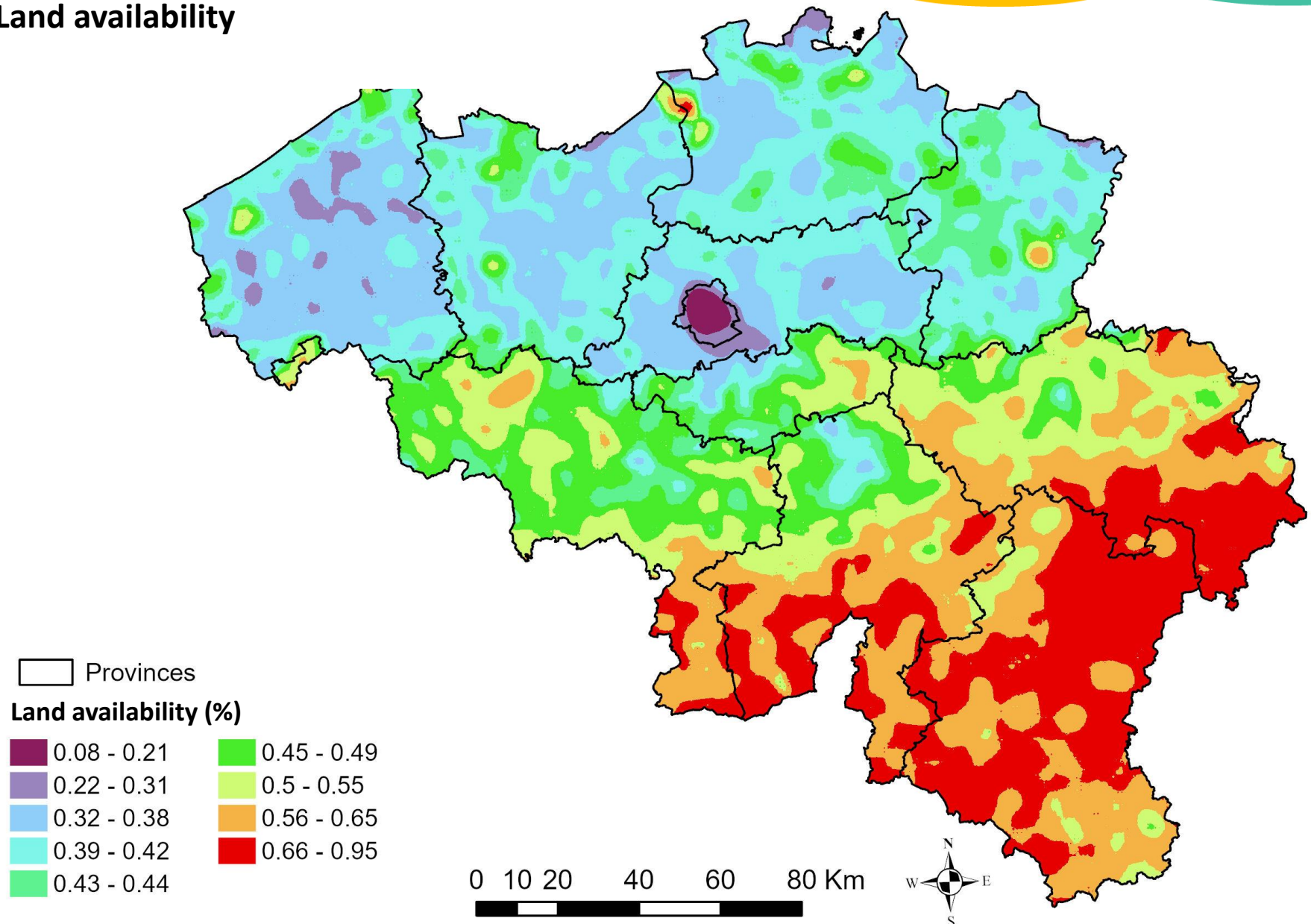
Modelized price
of construction

New modelized
price of land

NNLT Land
availability

Model 2 =
keep the β ,
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Find new prices

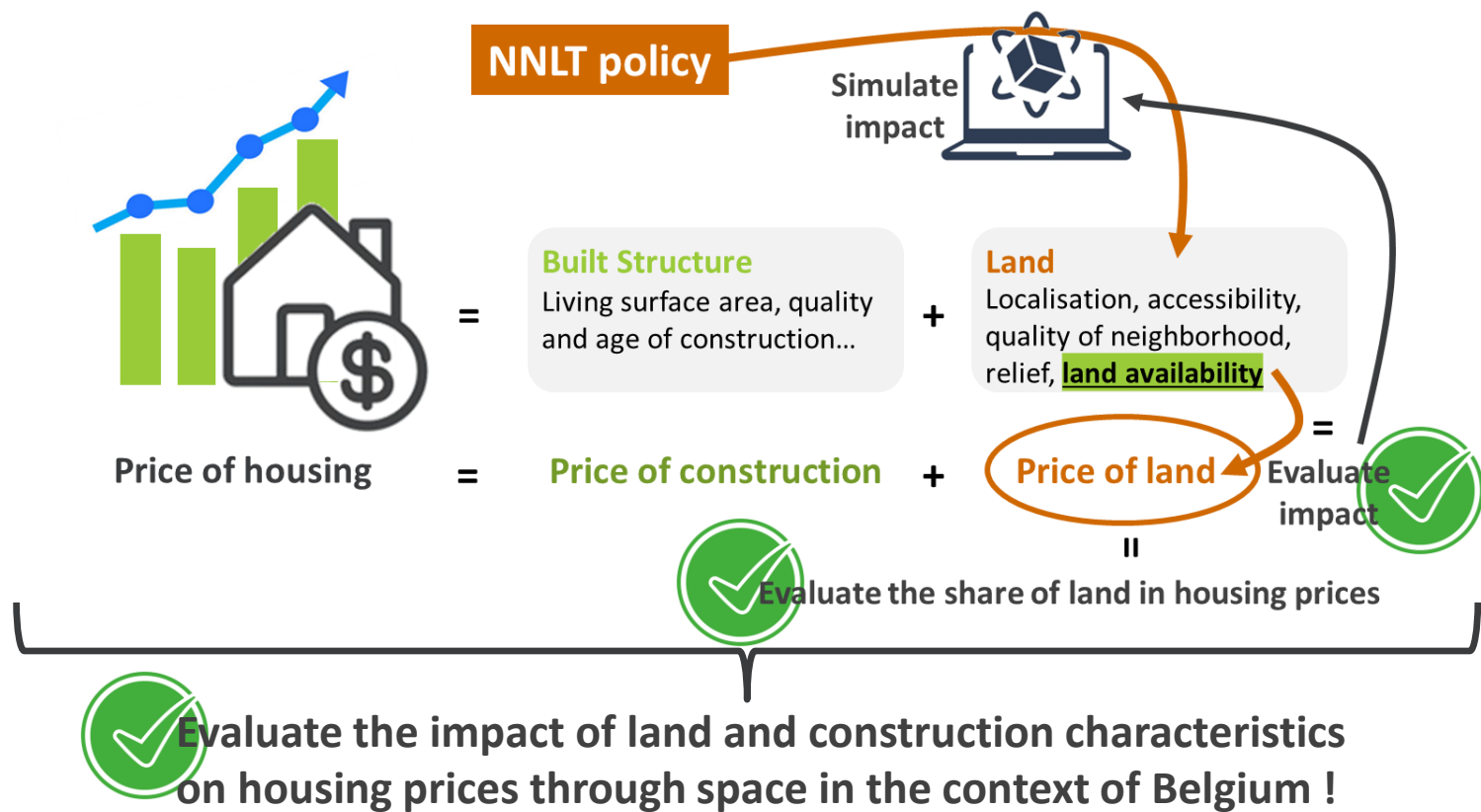
Land availability



Sources : SPF Finances, calculs C. Bernier

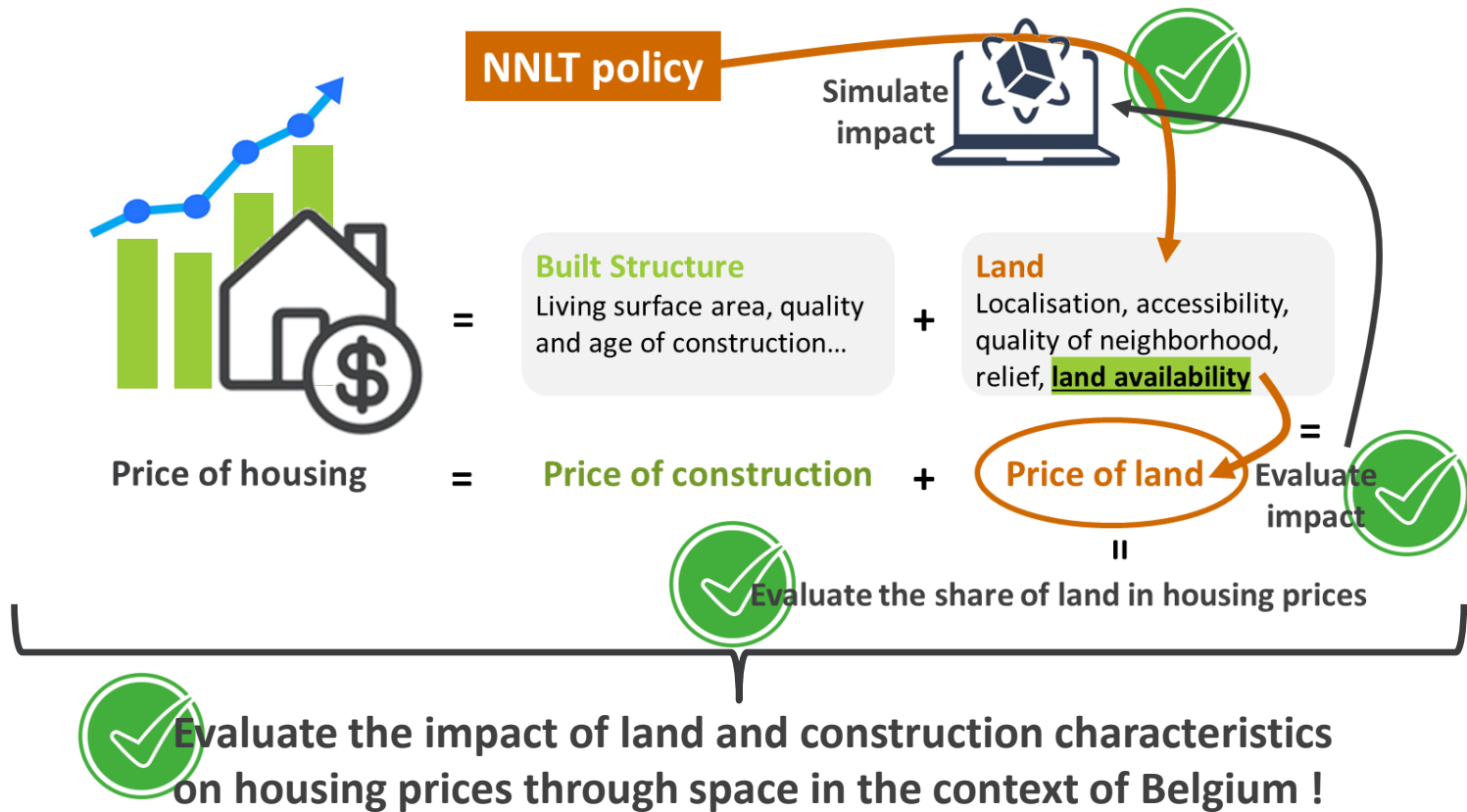
Why ?

A mapping of land values for a better understanding of the residential real estate market in Belgium/Wallonia



Why ?

A mapping of land values for a better understanding of the residential real estate market in Belgium/Wallonia



Concrete objectives

Differentiate land and real estate values, even for plots already built

→ Having a map of land values → EVALUATE → Econometric models

**Data
driven
Method**

$$y = \beta x + \varepsilon$$

$$y = \beta_{c1}x_{c1} + \beta_{c2}x_{c2} + \dots + \beta_{t1}x_{t1} + \beta_{t2}x_{t2} + \dots + \varepsilon$$

Price of housing



Accurate prices
data

Construction
related variables

Land related
variables



Accurate
variables/datas

Residuals from
modelisation

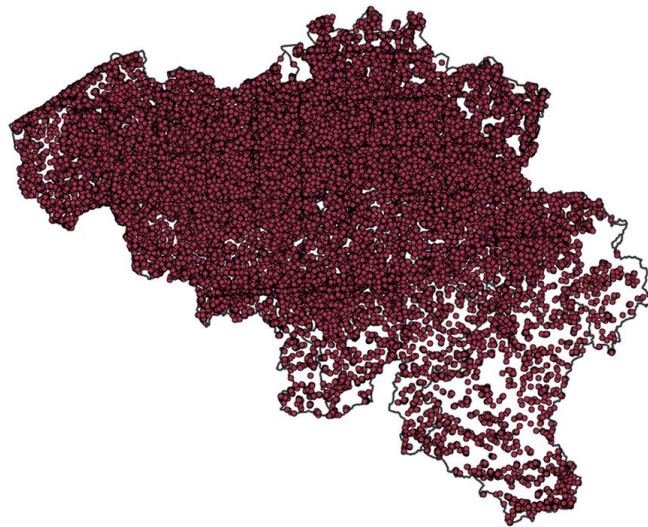


As small as
possible

Problems to solve

Data issues

- Belgian land registry data (sales data) of low quality and not often updated
- Different scales of data
- **Non-uniformity of the spatial distribution** of observations



Problems to solve

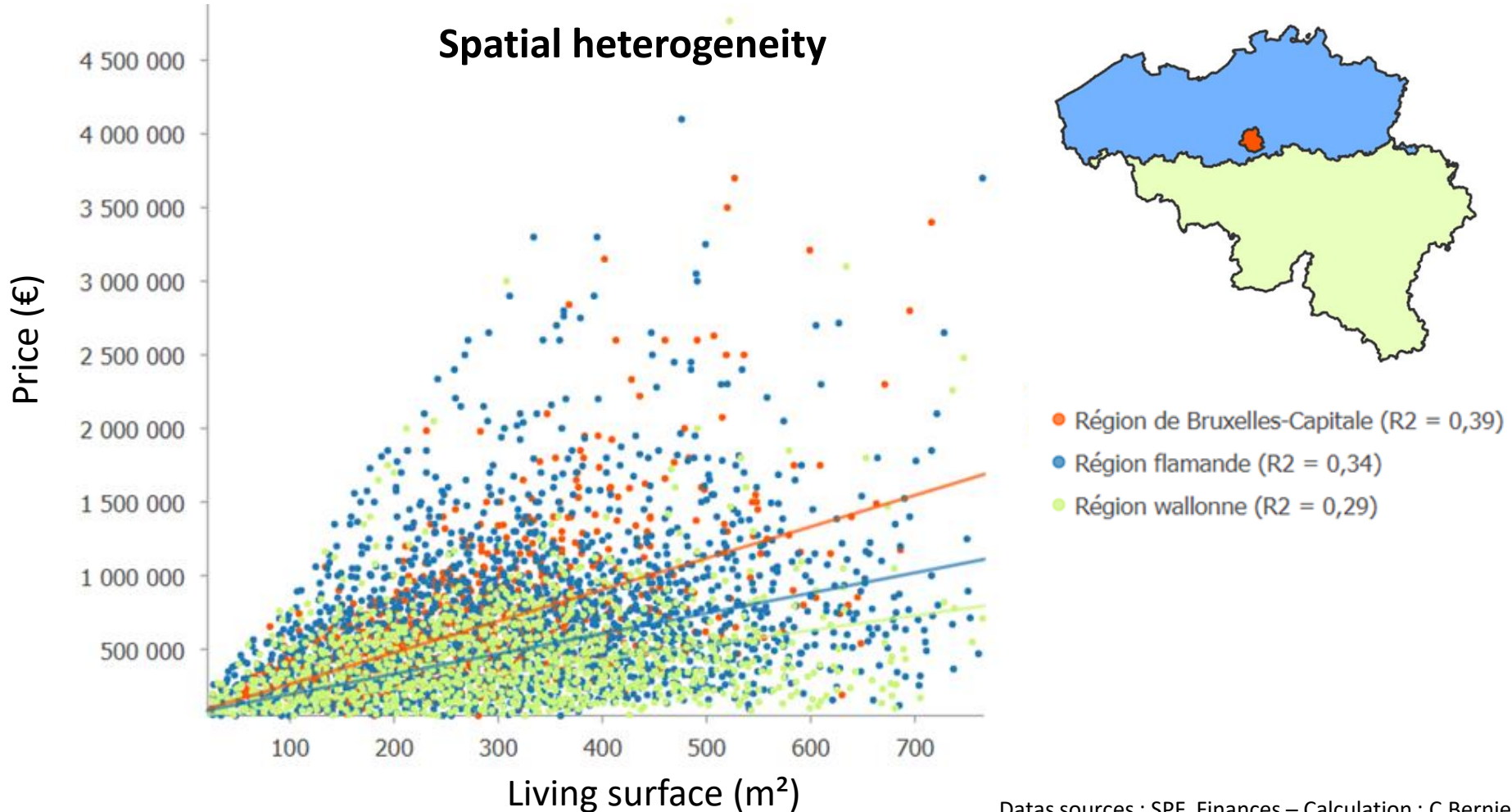
Data issues

- Belgian land registry data of low quality and not often updated
- Different scales of data
- **Non-uniformity of the distribution** of observations

Issues related to the use of classic OLS

- **Spatial heterogeneity** of the effect of certain variables on the price of housing (e.g., plot size)

Problems to solve



Datas sources : SPF Finances – Calculation : C.Bernier

Problems to solve

Data issues

- Belgian land registry data of low quality and not often updated
- Different scales of data
- **Non-uniformity of the distribution** of observations

Issues related to the use of classic OLS

- **Spatial heterogeneity** of the effect of certain variables on the price of housing (e.g., plot size)
- No consideration of the greater probable “resemblance” between two close entities than between two distant entities

Problems to solve

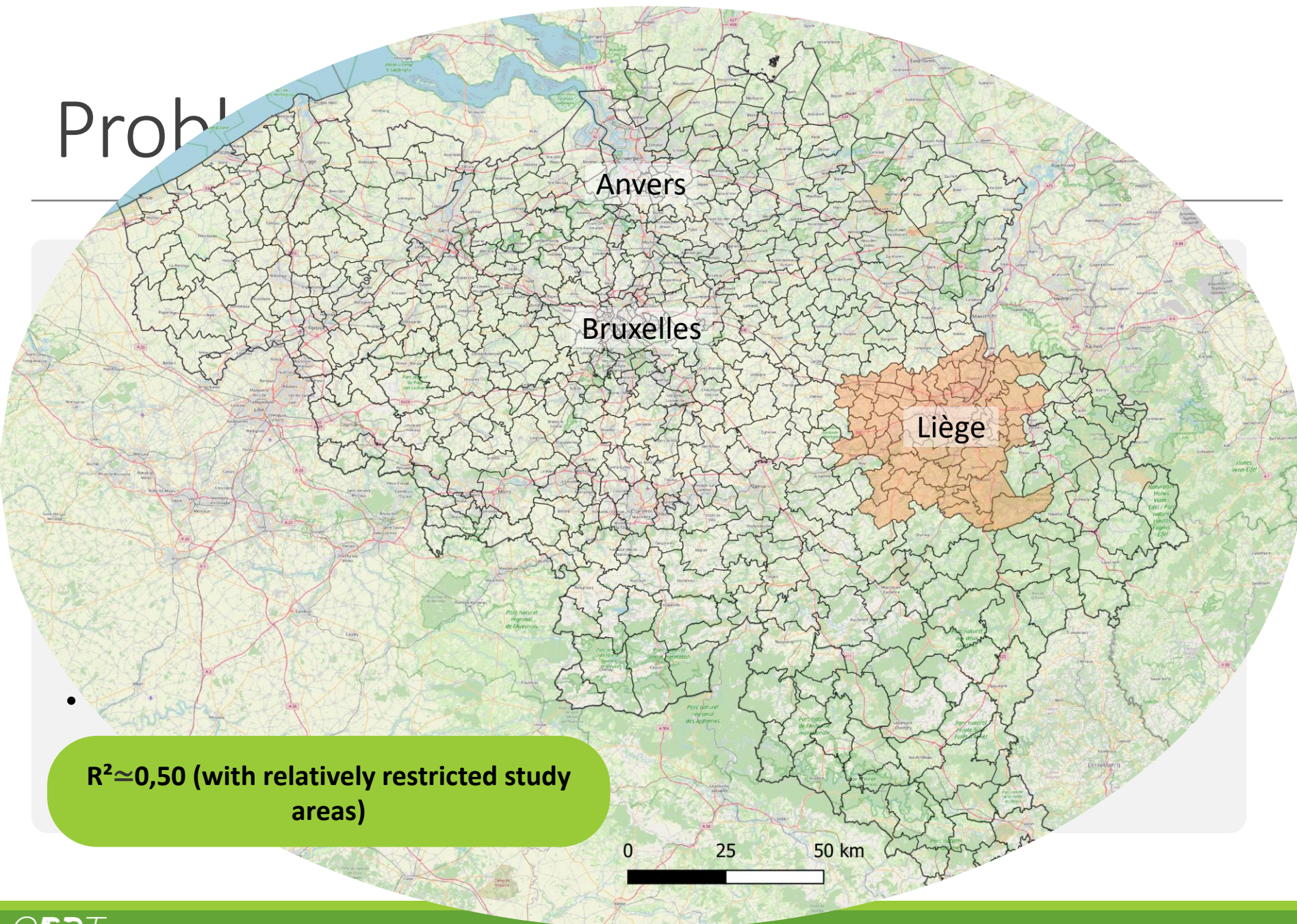
Data issues

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Issues related to the use of classic OLS

- **Spatial heterogeneity** of the effect of certain variables on the price of housing (e.g., plot size)
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- ➔ **Need to define the extent of the real estate market studied *a priori***

Probl

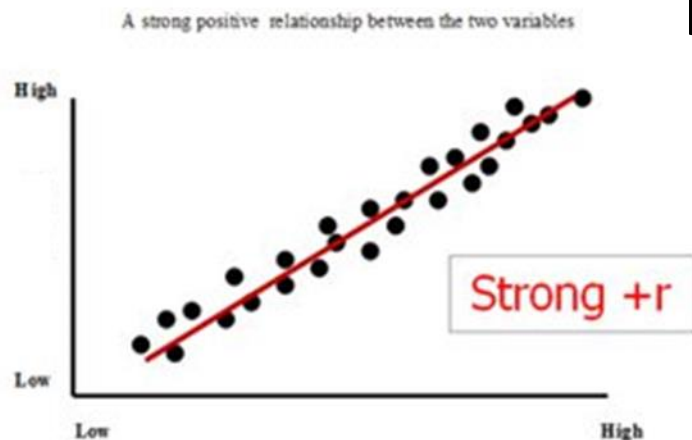


• $R^2 \approx 0,50$ (with relatively restricted study areas)

Quick R^2 explantation

$R^2 \approx$ How well does the model explain the variability of the independant variable = the price

$\approx$ How well does the model fit to the datas



R	Interpretation
0.00-0.199	Very weak
0.20-0.399	Weak
0.40-0.599	Medium
0.60-0.799	Strong
0.80-1.00	Very strong

So a $R^2 \approx 0,50$ is pretty bad for such a small area

Problems to solve

Data issues

- Belgian land registry data of low quality and not often updated
- Different scales of data
- **Non-uniformity of the distribution** of observations

Issues related to the use of classic OLS

- **Spatial heterogeneity** of the effect of certain variables on the price of housing (e.g., plot size)
 - No consideration of the greater probable “resemblance” between two close entities than between two distant entities
- ➔ Need to define the extent of the real estate market studied *a priori*

= methodological adaptation to
research design challenges

GWR models

GWR

- Allows **variation of regression coefficients** β_j
- Calibrates a separate regression model at each point using a “data borrowing” system that weights observations serving as regression points based on their distance from each other

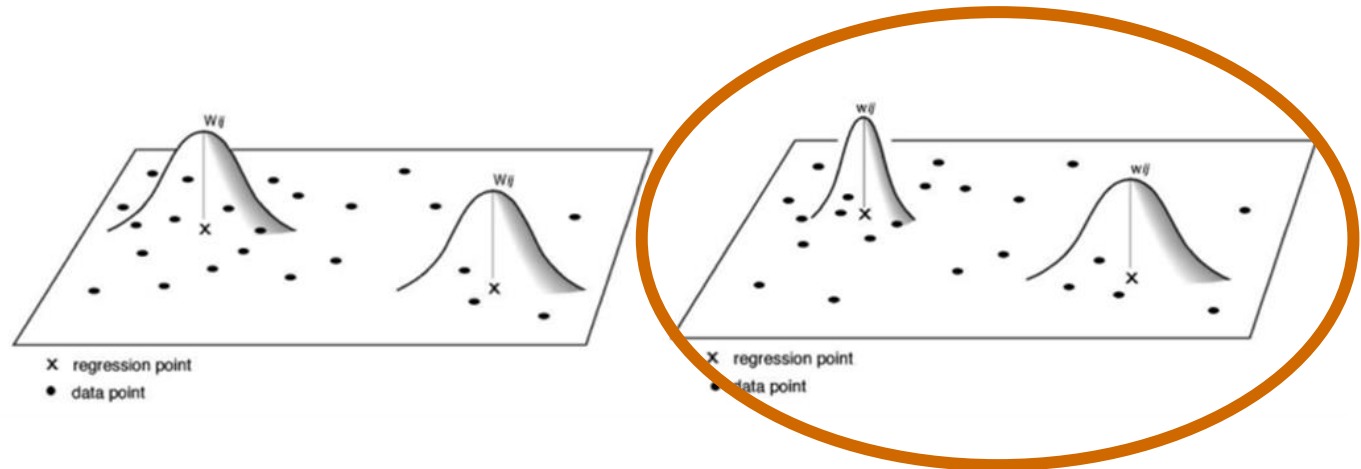
$$y_i = \sum_{j=0}^m \beta_j(u_i, v_i) x_{ij} + \varepsilon_i$$

With n observations where $i \in \{1, 2, \dots, n\}$ localised in (u_i, v_i)
 x_{ij} being the j^{th} independent variable and $\beta_j(u_i, v_i)x_{ij}$ the j^{th} coefficient
 ε_i the error term
 y_i the dependent variable (here the price)

GWR models

GWR

Adaptive Bandwidth Kernel



- Calculation of **ONE** optimal bandwidth/number of nearest neighbors
- Better handles irregularly shaped study areas, **non-uniform spatial distributions of observations**, and boundary effects

GWR = ONE unique bandwidth size/number of neighbors for all independent variables

(M)GWR models

MGWR

Allows variation of regression coefficients

AND a different bandwidth for all the variables considered

$$y_i = \sum_{j=0}^m \beta_j(u_i, v_i)x_{ij} + \varepsilon_i \quad \longrightarrow \quad y_i = \sum_{j=0}^m \beta_{bwj}(u_i, v_i)x_{ij} + \varepsilon_i$$

Where bwj indicates the bandwidth used to calculate β

Using the Python Package :

<https://mgwr.readthedocs.io/>

See as well :

<https://github.com/pysal/mgwr>

Exemple

- 10 299 land plot for Belgium
- 9 variables + intercept

OLS

$R^2 = 0,15$



GWR

Number of neighbors : 152

$R^2 = 0,61$

Taking into
account spatial
heterogeneity



MGWR

Variables	Number of neighbors	$R^2 = 0,76$
Employement	10298	
Land availability	566	
Plot Surface	15	
Noise	2507	
Flood risk	10298	
Prop_nature	348	
SocioEco 1	17	
SocioEco 2	10298	
SocioEco 3	221	

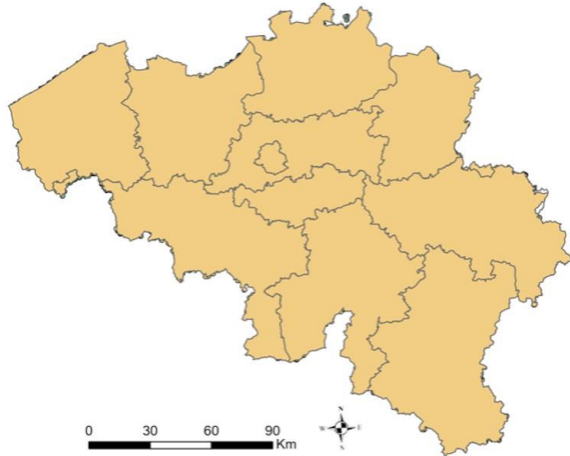
Taking into
account the
different scales
of influence of
the variables

OLS

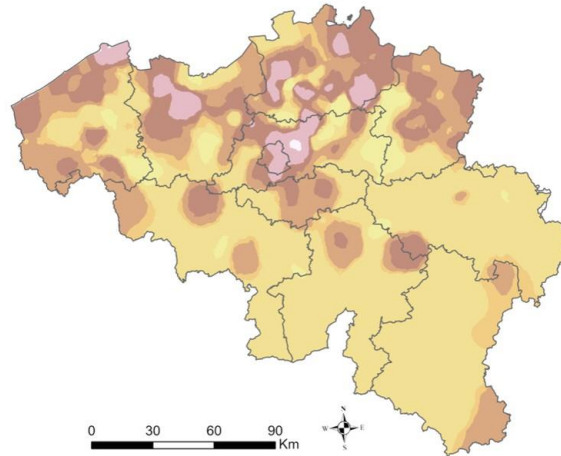
GWR

MGWR

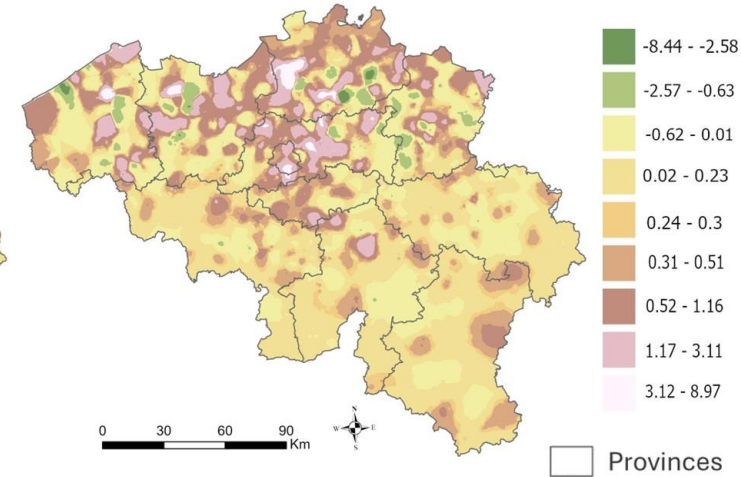
β global – Plot Surface



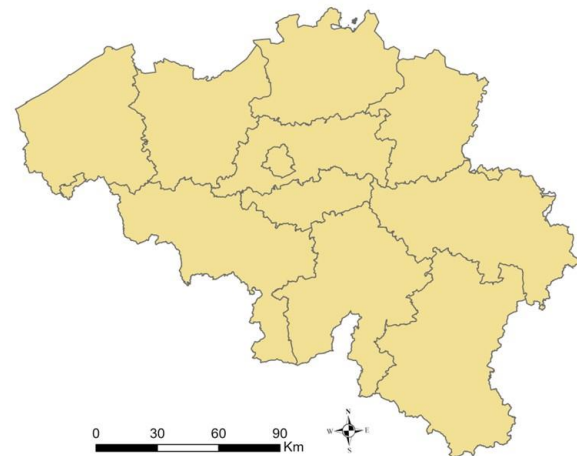
β local – Plot Surface
Number of neighbors = 152



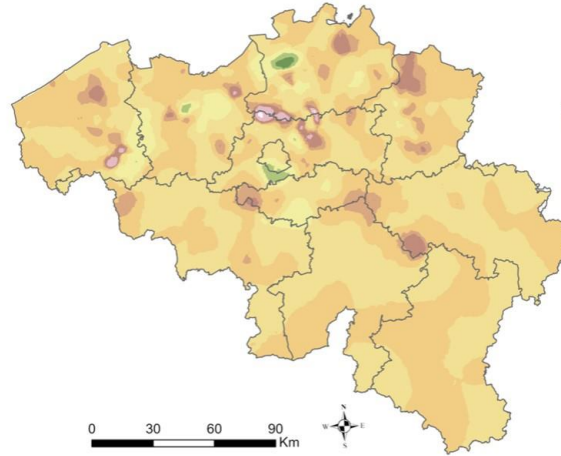
β local – Plot Surface
Number of neighbors = 15



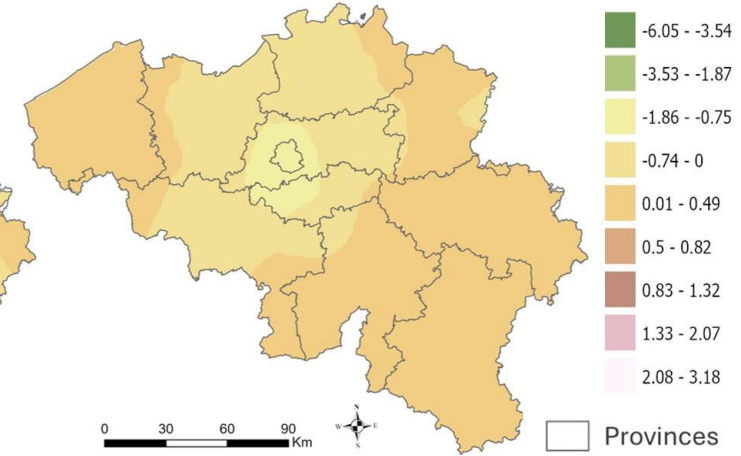
β global – Land availability



β local – Land availability
Number of neighbors = 152



β local – Land availability
Number of neighbors = 566



= methodological adaptation to
research design challenges

The problems of MGWR

MGWR

Although more efficient, MGWR models are however **very demanding in terms of calculation** and therefore time.

As an example - 16 CPU Server

- 14 600 plots of land (2019) + 15 variables
= 6 days of treatment
- 92 000 real estate properties (2019) + 21 variables
> 30 days of treatment
1TB of RAM required...



Identifying bandwidths is the longest part

Possible solutions

MGWR

Although more efficient, MGWR models are however **very demanding in terms of calculation**

Identifying bandwidths is the longest part



Verifying bandwidth stability with a restricted land price model → ok



Extrapolation of bandwidths found for land sold in 2019 for 2018 and 2017 data AND for houses datas → ok, 2 days instead of 6 !

Possible solutions

MGWR

Although more efficient, MGWR models are however **very demanding in terms of calculation**

Extrapolation of bandwidths found for land sold in 2019 for 2018 and 2017 data AND for houses datas → ok



Still we had to reduce our sample for houses from 90,000 to 18,000 houses...

Good results for 2019 : $R^2 = 0,77$!

Pretty good evaluation of the land prices for built plot... still in progress

Variables and data



15 variables **tested** to explain the price of the plot of land



9 in the final model

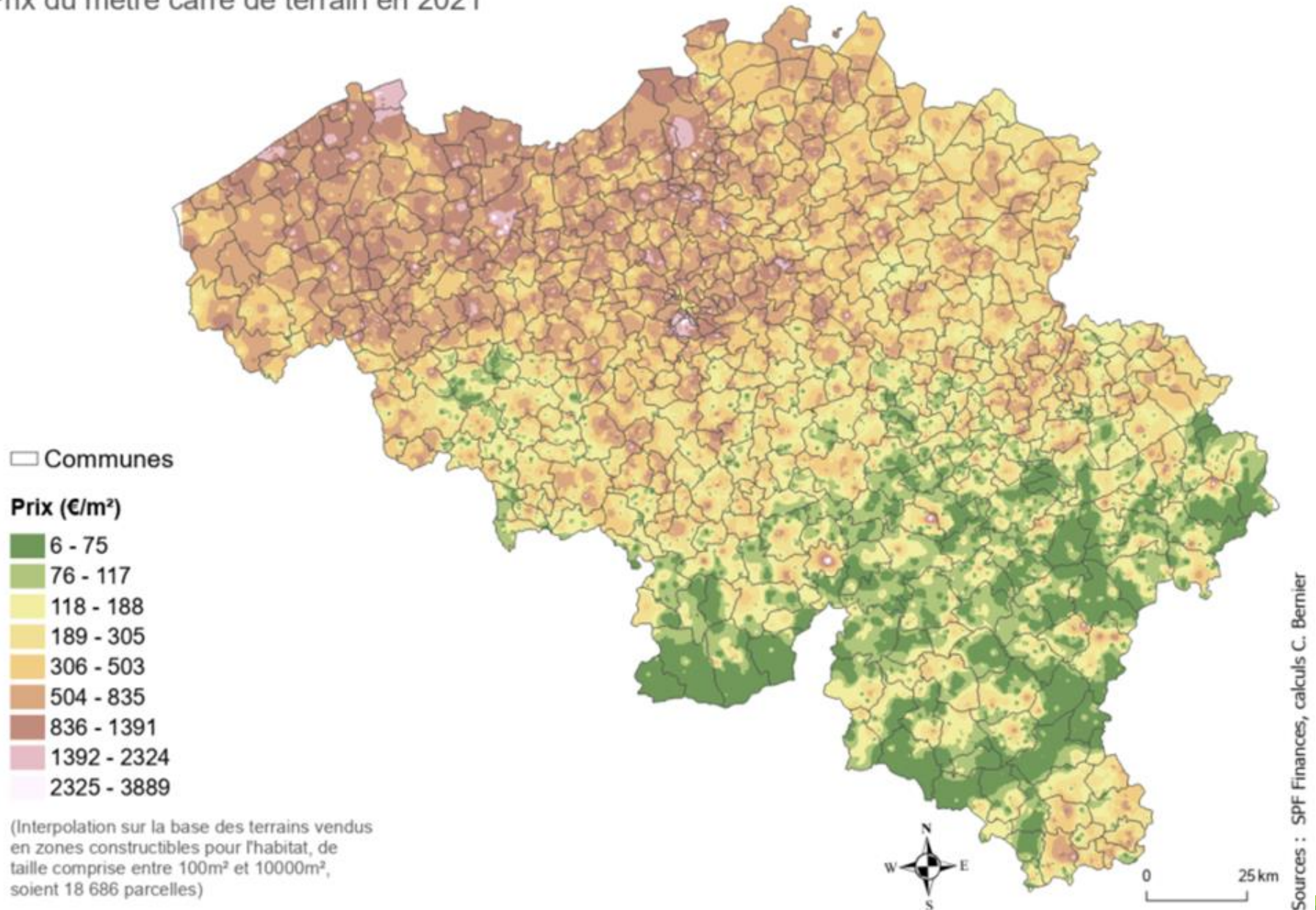


22 variables **tested** to explain the price of real estate
(7 construction variables + 15 land variables)

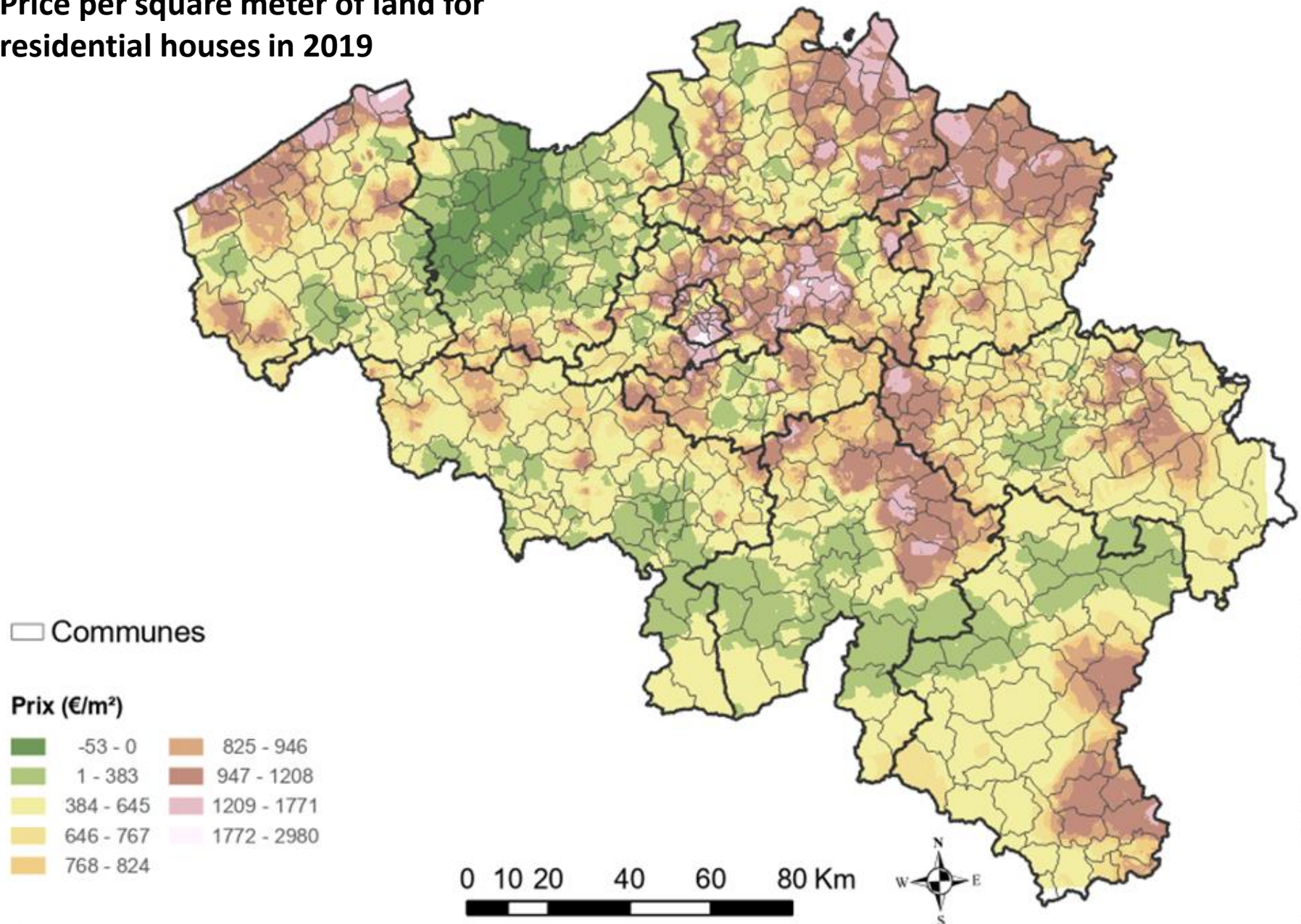


7 construction variables and 9 land variables in the final model

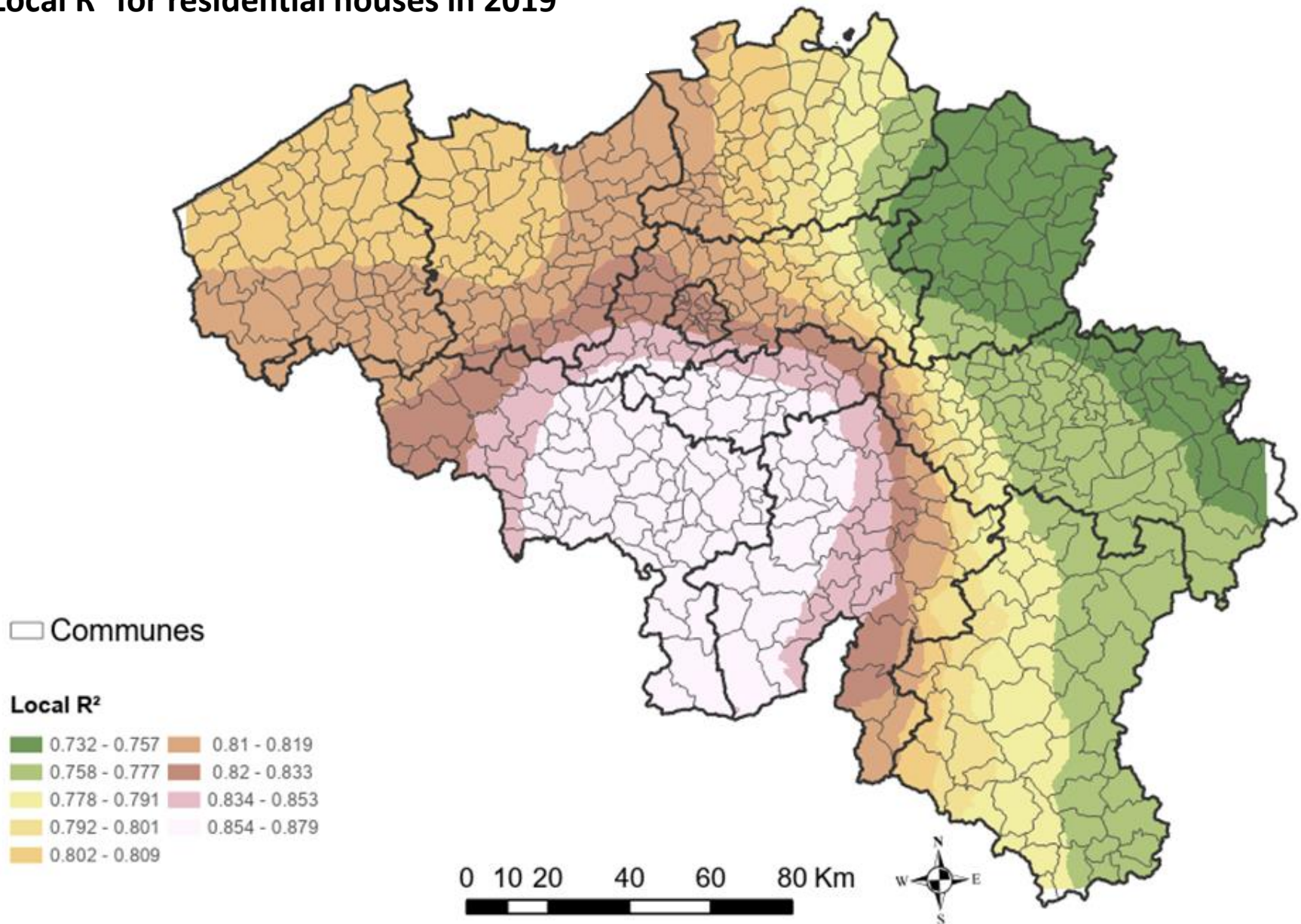
Prix du mètre carré de terrain en 2021



Price per square meter of land for residential houses in 2019



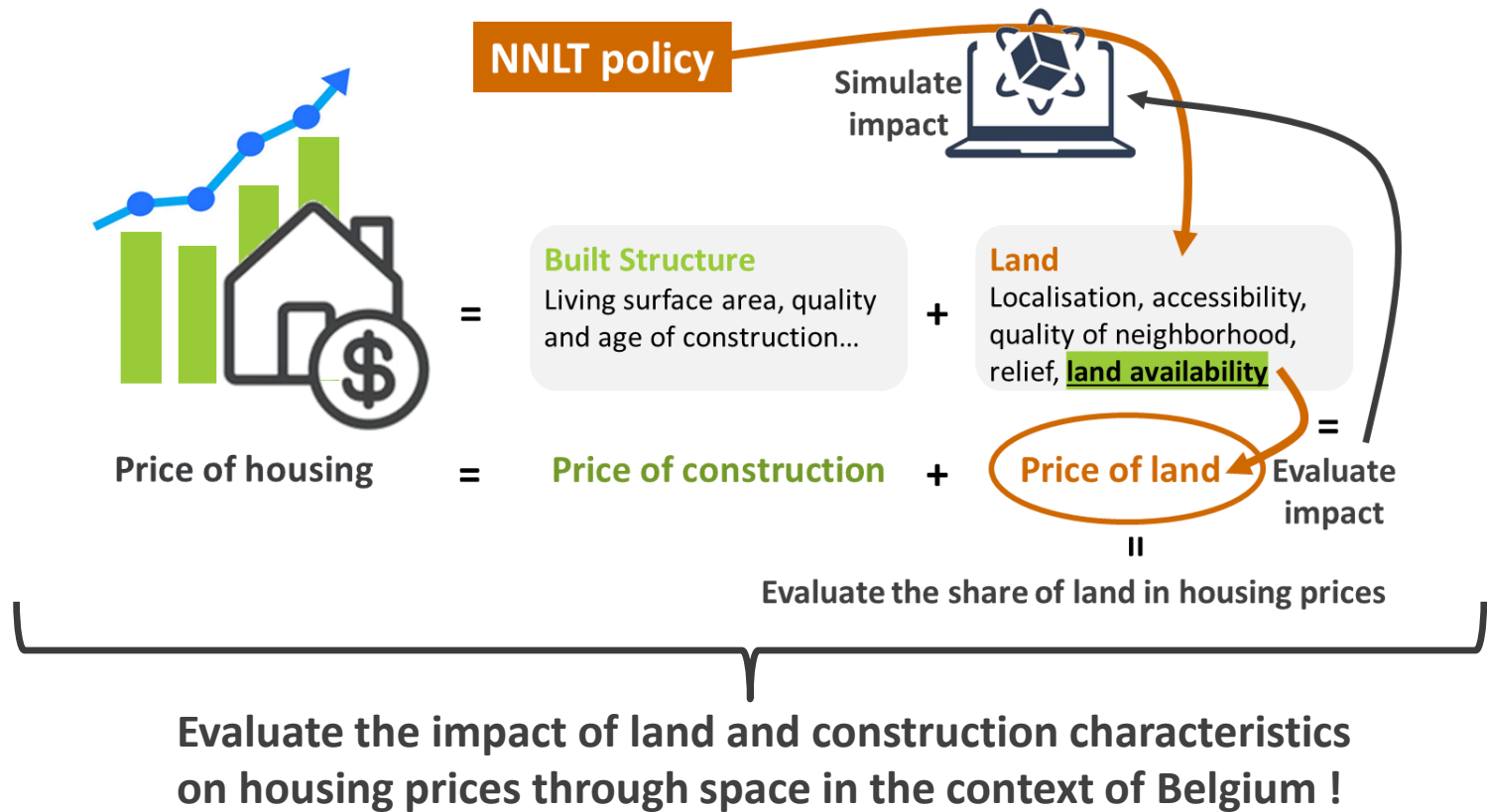
Local R^2 for residential houses in 2019



Sources : SPF Finances, calculs C. Bernier

Why ?

A mapping of land values for a better understanding of the residential real estate market in Belgium/Wallonia



To conclude

How to ... : Research design and methodology

What do we want to know ?

What do we already know ? → Literature

What else do we wanna know ? → What datas do we have ?

What can we do with that ? → Search and choose a method

Then ...



The research journey

A walk through the *research reasoning process*

How did we move from a broad policy question to specific methodological decisions ?

How to reconcile land restrictions
and housing affordability ?



Complex modelization of housing
prices

Thank you for your attention !

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