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Land use patterns and sprawl: a spatial econometric threshold regression approach

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Motivation

- Urban Sprawl is regarded as a social undesirable phenomenon, as urban expansion
  - Subtracts resources to agricultural activities, challenging rural development
  - Threats the landscape

- The sentiment is exasperated by the belief the such urban expansion is sometimes unnecessary

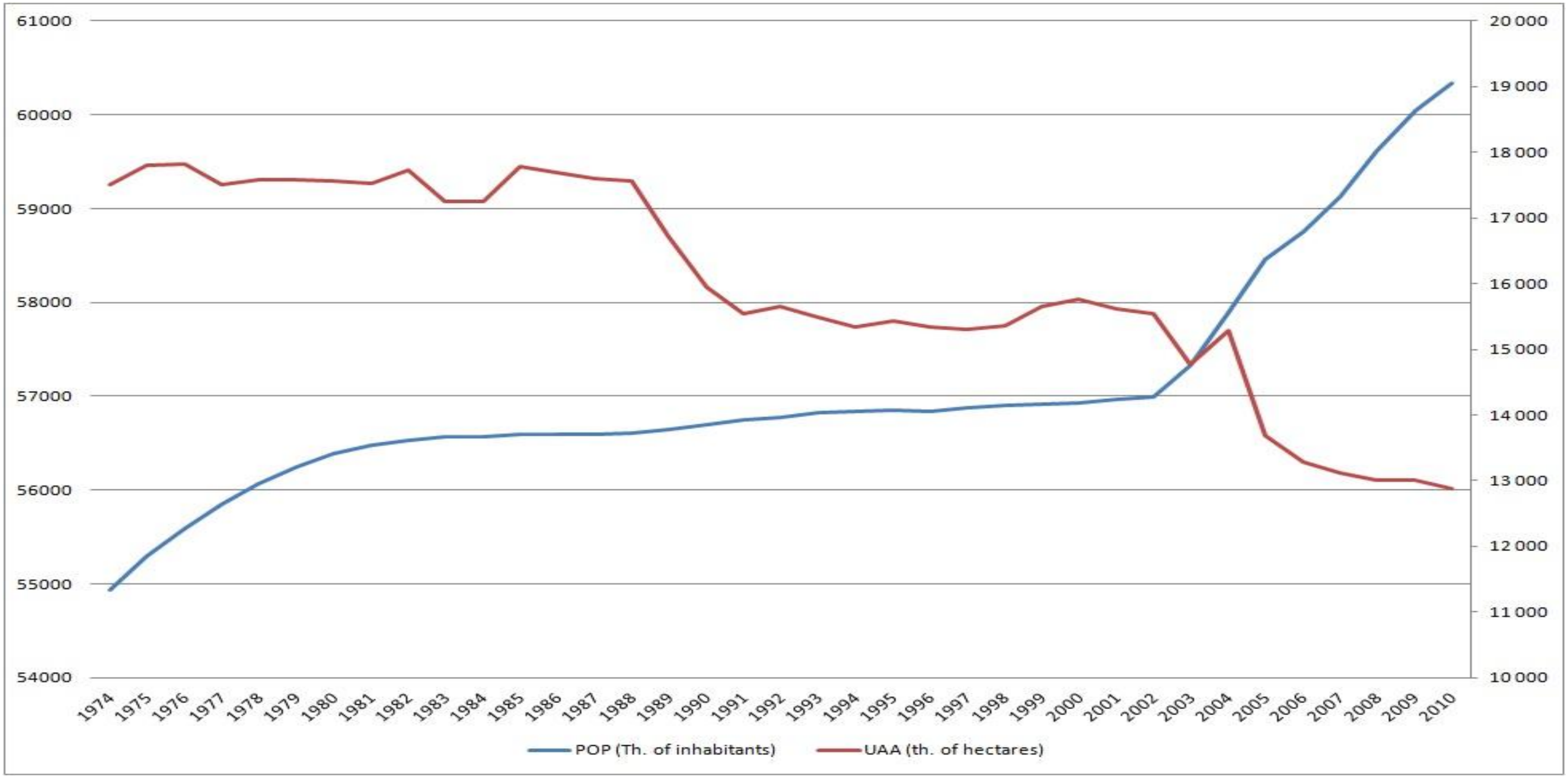
- Economists attempted to explain the size of cities as a result of socioeconomic forces, finding that population and income dynamics, jointly with infrastructure levels and agricultural land values, explain 90% of the variation in city-size, rejecting the argument of sprawl

- Estimates have always considered large cities (>50000 inhabitants) but sprawl is most relevant in small cities where agricultural land is basically more available and at a lower price

- Using a sample of small and large cities we find evidence consistent with the hypothesis of uncontrolled land take in very small and small cities

Background

- Land-use dynamics are primarily determined by the socio-economic and environmental forces. In particular, population growth is the main driver of urban expansion.



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Background

- However urban expansion has also dramatic consequences for agri-environmental equilibria

- Hence it is important to understand to what extent this urban expansion is
  - **necessary** meaning that responds to the increase in housing demand caused by population growth
  - **unnecessary** land take (speculative behaviours, land-consuming urban planning)

- The economists approach: utility maximizing households face a trade-off between housing price and the house-to-work commuting costs. The equilibrium fringe of the city is set where it is no more convenient for a single household to move far from the city.

- Using comparative statics it s demonstrated that the equilibrium size of a city depends on
  - Population and income **positively**
  - Transport costs and farmland values **negatively**

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City size models

$$U_i = \beta_0 + \beta_1 P_i + \beta_2 I_i + \beta_3 T_i + \beta_4 A_i + \varepsilon_i$$

- Brueckner and Fansler (1983) Wassmer (2006) Spivey (2008) Paulsen (2012) used this model to explain cross-city variation in urbanized area
- High shares of variation explained by the model (approximately 90%) lead to reject the sprawl

- Small cities
  - More available land and at a lower price
  - Influence of large cities

- Issues with estimation in small and contiguous cities
  - Contiguity relationships (house prices transmission, inter-city commuting)
  - Structural heterogeneity (different behaviour of small and large cities)

A method to explore structural instability in a spatial regression framework

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How small is small?

- Set up a spatial regression

$$U_i = \rho W U_i + \beta_0 + \beta_1 P_i + \beta_2 I_i + \beta_3 T_i + \beta_4 A_i + \sum_{k=1}^{K} \delta_k Z_{i,k} + \varepsilon_i$$

$$\beta_k = \beta_{k,0} + \beta_{k,1} D_i;$$

$$k = 0,1,2,3,4$$

$$D_i \left(P_i > P^* \right)$$

1. Estimate the model for all the values of P and find the value (threshold – T1) that minimizes the RSS

2. Estimate the restricted model without the population threshold and the unrestricted, with the threshold

3. Use the Spatial Chow test (Anselin, 1988) to validate the restriction

- Since this is a LR test it is possible to find a confidence interval for LR(P^*) and a confidence interval for P^*

How large is large?

- Having defined T1 we search for T2

$$U_i = \rho W U_i + \beta_0 + \beta_1 P_i + \beta_2 I_i + \beta_3 T_i + \beta_4 A_i + \sum_{k=1}^{K} \delta_k Z_{i,k} + \varepsilon_i$$

$$\beta_k = \beta_{k,0} + \beta_{k,1} D_i^1 + \beta_{k,2} D_i;$$

$$k = 0,1,2,3,4$$

$$D_i \begin{cases} D_i\left(P < P^*\right) \forall P^* < T^1 \\ D_i\left(T^1 < P < P^*\right) \forall P^* > T^1 \end{cases}$$

1. Estimate the model for all the values of P but T1 and find the value (threshold – T2) that minimizes the RSS
2. Estimate the restricted model with only one threshold and the unrestricted, with two thresholds
3. Use the Spatial Chow test to validate the restriction

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Time for numbers

- Municipalities in the Lombardy Region, year 2012

Variable	Description of the variable	Mean
U	Urbanized (residential, industrial and commercial) area - hundreds of hectares (DUSAF 2012)	2.79
P	Total Population - thousands of inhabitants (ISTAT 2011)	6.315
I	Average income – thousands of euros (MEF 2012)	19.509
T	Transport Costs – inverse of the number of vehicles (cars) per inhabitant (ACI 2012)	1.649
A	Farmland Value – thousands of euro per hectare (INEA 2012 and DUSAF 2012)	31.02
ROAD	Area occupied by the road network- hundreds of hectares (DUSAF 2012)	7.216
TRAIN	Area Occupied by the rail network - hundreds of hectares (DUSAF 2012)	1.8
AERO_D	Dummy - 1 if a portion of soil is occupied by airports (DUSAF 2012)	0.034
PORT_D	Dummy - 1 if a portion of soil is occupied by ports (DUSAF 2012)	0.048
CONSTR	Area occupied by - hundreds of hectares (DUSAF 2012)	3.751

Quantile	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Value	0.030	0.545	0.935	1.419	1.951	2.669	3.798	4.946	7.185	11.657	1274.31

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Results

- The first threshold is estimated at 18000 inhabitants and is significant
- The second threshold is estimated at 5500 inhabitants and is significant
- The second threshold is estimated at 50000 inhabitants and is not significant
- P, and T coefficients have the expected signs and are significant
- I coefficients have a negative sign and are not significant in small cities
- A coefficients have the wrong sign in small cities

	>18000	18000 – 5500	< 5500
Intercept	51.354*** (3.393)	14.508*** (1.459)	0.914*** (0.298)
P	0.087*** (0.004)	0.368*** (0.024)	0.531*** (0.033)
I	-0.275*** (0.064)	-0.189*** (0.032)	-0.009 (0.016)
T	-21.391*** (1.535)	-5.653*** (0.698)	-0.182* (0.102)
A	-0.028* (0.017)	0.012** (0.006)	0.009*** (0.003)
ROAD	0.023*** (0.004)		
TRAIN	-0.024*** (0.008)		
AIR	0.536*** (0.206)		
PORT	0.719*** (0.171)		
CONSTR	0.012*** (0.004)		
rho	-0.199*** (0.031)		

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Discussion

An increase of a city population by 1000 inhabitants translates into

- an increase of urbanized area of **8.7** ha in medium-large cities;
- an increase of urbanized area of **36.8** hectares in medium-small cities;
- an increase of urbanized area of **53.1** hectares in small cities.

Other things being equal, in small cities the land take associated to the dynamics of population is as much as seven times larger than in medium-large cities.