Urban Sprawl in Europe

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PRELIMINARY DRAFT

Abstract

Using the recent availability of the Urban Audit dataset, we provide some evidence on the extent and the evolution of urban sprawl in cities of the European Union in the years 1991-2001. The bigger and more populated European cities have experienced fewer sprawls than cities which are smaller in size. When the causes of sprawl highlighted for the United States context are investigated, we find that the predictions in terms of the percentage of ethnic minorities and crime rate are reverse for the European case and confirmed by our data. Besides, we identify two different European city structures and show that they reveal different sprawl experiences. In particular, urban sprawl is more likely to occur in cities with a high percentage of high-skilled individuals, high car ownership rates, good climatic conditions, large in-flows of non-EU citizens and a lively industrial structure. On the contrary, an efficient public transportation network, large shares of employment in services, bad climatic conditions and a high number of students seem to be factors preventing urban sprawl. These results may help understand the different urban patterns observed between Europe and the United States.

Keywords: population density, urban sprawl, crime rate, ethnicity, Europe, USA.
JEL classification: R11, R12, R14

1. Introduction

Urban sprawl is the spreading of a city and its suburbs over rural land at the fringe of an urban area. Urban planners emphasize the qualitative aspects of sprawl such as the lack of transportation options and pedestrian friendly neighborhoods. Conservationists tend to focus on the actual amount of land that has been urbanized by sprawl. Although urban sprawl has been extensively studied in the United States (see e.g. Brueckner, 2000, 2001; Glaeser and Kahn, 2001, 2004; Nechyba and Walsh, 2004), very few empirical studies have been undertaken in Europe. The objective of this paper is to provide some empirical evidence on urban sprawl in Europe.

Urban sprawl is one of the most important types of land-use changes currently affecting Europe. It increasingly creates major impacts on the environment (via surface sealing, emissions by transport and ecosystem fragmentation), on the social structure of an area (by segregation, lifestyle changes and neglecting urban centres), and on the economy (via distributed production, land prices, and issues of scale). It is therefore crucial to understand it better.

During the second half of the 20th century urban sprawl has become a mass phenomenon throughout the western world. Although suburbanization took also place in Europe during the post-war period, its dimensions were by far less expansive than in the United States. In the 1950s, numerous European countries were concerned about reshaping their cities. Besides, a lot of countries had been decimated by the war and many large cities such as Berlin, Vienna, Glasgow and Birmingham were stagnating, or even lost population (Bruegmann, 2005). The post-war period in the United States, on the contrary, was characterized by economic prosperity and a vast population growth (Burchfield, Overman, Puga and Turner, 2003). Within less than twenty years, the American population increased by fifty million people from 150 million in 1950 to 200 million in 1968. Some cities were even growing to a faster degree. In the same period the Los Angeles area more than doubled from under four to over eight million people. The Pheonix urbanized area grew almost fourfold, the San Jose area more than fivefold. In Europe, there was generally less growth in urban areas and therefore less pressure to develop the countryside. Besides, urban expansion was usually highly regulated. Planners and other government officials were able to intervene in city development more actively than their American counterparts. In Paris, for example, large parts of suburban settlements consisted of high-density

houses directly built by governmental bodies or were at least highly subsidized. This procedure was not common in the United States, where the private-market single-family home was the norm.

As long as the American metaphor has not been replaced by a European one, it will shape the perception of many Europeans. In fact, remarkably little research has been done on the development of a 'European' model (as least from economists). This was mainly due to the scarce availability of data on indicators of urban performance such as urban amenities, housing, job opportunities, skills and economic structure that limit the research possibilities in the European Union.

In this paper we use a recently available data set, the Urban Audit,[1] which claims containing information about more than 300 variables for 258 towns and cities in the European Union's fifteen member states and its twelve Eastern European candidate countries, measured at three different points in the 1990s. Unfortunately, the effective information delivered is much more limited. Its coverage is rather poor. For several countries many indicators are not provided and missing values generally do not occur for the same cities across variables (even though data coverage does improve over the decade). Nevertheless, it allows a first investigation on the existence and the extent of urban sprawl, as well as to collect some evidence on urban differences in indicators such as population size, density, economic conditions, human capital and amenities in the European context.

The plan of the paper is as follows. We will first review the literature on urban sprawls and summarize the main predictions, both for the US and Europe (Section 2). Next, in Section 3 we present the Urban Audit dataset and collect some descriptive evidence on urban sprawl in Europe. The last part of this section then contains some simple regressions documenting correlations between the evolution of urban sprawl and the variables typically advocated by the theory as its main determinants. We conclude the paper with an investigation on the different characteristics of European cities using a principal component analysis (Section 4). This exercise is based on the more comprehensive information provided by the Urban Audit for the year 2001. Section 5 contains some discussion and policy implications.

[1] For information on this dataset, one can consult the following homepage: http://ec.europa.eu/regional_policy/conferences/urbanaudit2008/programme_en.htm

2. What causes urban sprawl?

In the standard monocentric framework (Brueckner, 1987; Fujita, 1989; Zenou, 2009), firms are all located in one location (the Central Business District or CBD) while individuals/workers have to decide to reside between the CBD and the city fringe. This creates a trade off for workers between locations close to jobs where housing prices are high but commuting costs are low and locations far away from the CBD when the reverse occurs. In this model, urban sprawl is measured by population density and/or the city fringes, which are both endogenous and depend on the (endogenous) housing size. A clear implication of that model is that a reduction of commuting cost will cause urban sprawl. As a result, access to cars, which reduces commuting costs, could be a good predictor for urban sprawl. This line of research is strongly pushed by Glaeser and Kahn (2004). Also as income rises, families desire to live in larger apartments/houses (if housing is a normal good) and will therefore reside at the periphery of the city. Similarly, since income is correlated to employment, higher employment rate will also cause urban sprawl.[2]

The monocentric framework can be extended to incorporate racial segregation and/or crime. In the first case, black (or any other "visible" ethnic minority) and white workers will locate in different areas of the city depending on the assumptions of the model. If one considers the American case where ethnic minorities tend to reside in the city-center (see, e.g. Rose-Ackerman, 1975; Yinger, 1976), then the higher the percentage of ethnic minorities, the higher is urban sprawl. This is the so-called "white flight" where whites want to fly to the suburbs to avoid living with the black population. Thus, inner city residents may wish to leave central cities not because they seek to form or join a particular (more homogeneous) suburb, but rather to escape inner city problems.

In a European monocentric-city model, where ethnic minorities tend to live in the suburbs, this relationship between the percentage of ethnic minorities in a given city and urban sprawl will be negative (and not positive as in the American case) because whites will on the contrary move to the city center to avoid living with ethnic minorities (see, e.g., Selod and Zenou, 2006, who analyze both the American and the European cases).

[2] For a formal analysis of the comparative statics results of the monocentric-city model, see Wheaton, (1974).

One can also incorporate crime in the monocentric framework (see e.g. Freeman, Grogger, and Sonstelie, 1996) and/or ethnic minorities (Verdier and Zenou, 2004). The predictions will be the same and even more pronounced because ethnic minorities are overrepresented in criminal activities. This will be again the "flight from blight" meaning that high-income white residents leave the central city in response to higher inner city crime rates (but also lower quality schools and general fiscal distress within the central business district).[3] For example, Cullen and Levitt (1999) find that a 10 percent increase in crime corresponds to 1 percent decline in central city population.

Introducing non-monocentric cities (see e.g. Ogawa and Fujita, 1982; Fujita, Thisse and Zenou, 1997; Henderson and Mitra, 1999) will basically not change these results, even if the labor market is explicitly introduced (as in Smith and Zenou, 1997; Coulson, Laing and Wang, 2001; Brueckner and Zenou, 2003). For example, in the duocentric model of Brueckner and Zenou (2003), blacks tend to mostly reside close to the CBD because of housing discrimination while whites tend to reside in the suburbs.

To summarize, there are five main causes of urban sprawl:

(i) **Access to automobile**, by reducing commuting costs, allows individuals/workers to commute further away from jobs and thus causes urban sprawl.

(ii) **An increase in income** induces families to live in larger housing and thus causes urban sprawl because land is cheaper in the suburbs.

(iii) **An increase in employment rate** increases urban sprawl because employment is positively correlated with income. Employment and income should therefore lead to the same results.

(iv) **An increase in the percentage of ethnic minorities in cities** leads to more urban sprawl in the US and less in Europe. Indeed white families dislike residing close to ethnic minorities and thus desire to live further away from them. Since ethnic minorities mostly live in city centers in the US and in the suburbs in Europe, an increase in the percentage of ethnic minorities will increase urban sprawl in the US and reduce it in Europe.

[3] From a theoretical viewpoint, the impact of local property taxes on urban sprawl has been studied by Brueckner and Kim (2003) and Song and Zenou (2006) in a monocentric framework and by Song and Zenou (2008) in a duocentric model.

(v) **Higher crime rates** increase urban sprawl in the US but decrease it in Europe because white families fly areas where crime is high. These areas are located in city centers in the US and in the suburbs in Europe.

Observe that *(i)*, *(ii)* and *(iii)* lead to the same predictions for both American and European cities while *(iv)* and *(v)* yield different predictions.

3. Evidence on urban sprawl in Europe

3.1 The Urban Audit Data

The Urban Audit (European Commission 2004) is a rather new dataset from Eurostat, the statistical office of the European Union. The aim of constructing such a dataset is "*to compare quality of life in towns and cities within the European Union*" (European Commission 2004). The Urban Audit contains information about more than 300 variables for 260 towns and cities in the European Union's fifteen member states and its twelve Eastern European candidate countries (altogether 27 European countries) measured at three different points in time: in 1991 (or in the period 1989-1993), in 1996 (or in 1994-1998), and in 2001 (or in 1999-2003). Cities are defined according to their administrative boundaries. In addition to the more conventional economic variables (such as employment structure, income, etc.), the dataset has a relatively large number of interesting indicators such as the quality-of-life, the percentage of residents who are not EU Nationals, the average time of journey to work, the percentage of journeys to work by car, bus, etc.

In principle, the Urban Audit dataset is ideal to attempt an investigation on the sources of urban sprawl in cities of the European Union. Indeed, having sprawl measures as well as detailed urban characteristics at several points in time for a number of cities enables us to evaluate the different theoretical predictions highlighted in Section 2 underlying the causes of urban sprawl. However, as mentioned in the introduction, missing values are a huge problem of such a data set. Constructing a growth rate, which needs observations of the same variable for the same city for at least two different points in time, and running a simple regression analysis reduces very easily sample size below 75 cities as soon as more than two explanatory variables are included. Therefore, although unique, such a data

set is obviously limited for conclusive investigations. In the following sections we exploit its information content on urban sprawl at its best, first for some descriptive statistics, then to document some correlations between the evolution of urban sprawls and the (available) changes over time in specific variables, and finally using a principal component analysis on the data at 2001, which is the year with the most extensive coverage.

3.2 Descriptive statistics

There are different ways of measuring urban sprawl (see, in particular, Galster et al., 2001; Nechyba and Walsh, 2004; Glaeser and Kahn, 2004). The standard definition of sprawl is the "tendency towards lower city densities as city footprints expand" (Nechyba and Walsh, 2004). Urban sprawl can take different forms. It may involve low-density residential developments. It can also take the form of planned communities. In any case, a common way to document the presence of urban sprawl over time is to look within urban areas at the evolving relationship between suburbs and central cities. Unfortunately, one limitation of our data is that we do not have information on within-city characteristics; in particular we cannot breakdown our data into central city and suburbs. We will thus measure urban sprawl at the city-level by the three following measures: (*i*) "land area", or "urban size", which is the total land area in a given city, (*ii*) "population density", i.e. the ratio of total resident population to total land area in a given city, (*iii*) "population density in working age", the ratio of resident population in working age to total land area in a given city.

In this section, we start by providing some simple evidence on the evolution of urban sprawl in the cities of the European Union. The variables are thus expressed in *growth rates* between 1991 and 2001[4]. Table 1 collects some descriptive statistics.[5] It reports information on the evolution of our three indicators of urban sprawls, as well as of total population and total working-age population.

Table 1 shows that the average growth in population size of European cities (around 0.34 percent) is much lower than that of US cities (average of 10 percent) during roughly the same period (Glaeser and Shapiro, 2003). This is probably due to the lower mobility of European workers and the still limited in-flows of non-EU citizens. This is also certainly due to the incredibly low (and declining)

birth rate in most European countries.[6] Indeed, when the population in working age is considered instead of the total population then the average growth is higher, although it remains below 2 percent during the period 1991-2001. Despite such a limited growth in population size, the average EU city expanded in area size by about 7.5 percent during that period and decreased its population density by roughly 2.6 percent. This is a sign of urban sprawl during the period 1991-2001.

Table 1. Evidence on urban sprawl for all EU cities

Variable in growth rate (1991-2001) (%)	Obs.	Mean	Std. Dev.	Min.	Max.
Population	263	0.34	8.28	-22.27	37.81
Population in working age	242	1.69	10.13	-23.23	44.79
Population density	160	-2.56	15.68	-79.55	85.04
Population density in working age	160	-2.08	15.47	-78.46	51.36
Land area	188	7.46	44.01	-29.73	497.18

The feature of the urban growth experiences of European cities which is instead common to US cities is their substantial heterogeneity. Indeed, Table 1 shows that the fastest growing city saw almost a 40 percent increase in its population over the period 1991-2001 whereas the slowest growing city decreased by more than 20 percent

Given the heterogeneity of growth rates between cities, the relevant question is then what are the cities that spread more and why. If we split the cities according to their population size (Tables 2 and 3 below), we find that urban sprawl is much stronger for cities at the bottom tail of the distribution than

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[4] Missing values for the year 1991 have been replaced with values at 1996 in the cases where such information is available.

[5] We will give some evidence on urban sprawl levels in Section 4 below.

[6] Urban growth in the EU appears to be largely driven by growth of national born population, and differences in birth rates between cities are found to be an important explanation of the observed differences in (national-born) population growth rates. Non-national European born and non-European born migrants contribute only marginally to urban growth differences (Bosker and Marlet, 2006). The volume of US interregional migration is 15 times higher than that of in the EU (Cheshire and Magrini, 2006).

for the more populated ones. Table 2 indeed reveals that the largest European cities experienced, on average, a negative population growth and an extremely limited increase in urban land area. On the contrary, Table 3, which focuses on the lower tail of the distribution of cities in terms of population, shows an average of 2.5 percent increase in population growth and a considerable land area growth of around 25 percent.

Table 2. Evidence on urban sprawl for the 25 percent largest EU cities

Variable in growth rate (1991-2001) (%)	Obs.	Mean	Std. Dev.	Min.	Max.
Population	76	-1.05	6.33	-16.14	16.90
Population in working age	69	-0.20	7.86	-17.71	17.75
Population density	48	-3.18	7.67	-34.80	12.96
Population density in working age	69	-0.20	7.86	-17.71	17.75
Land area	59	0.30	6.63	-25.72	39.97

Table 3. Evidence on urban sprawl for the 25 percent smallest EU cities

Variable in growth rate (1991-2001) (%)	Obs.	Mean	Std. Dev.	Min.	Max.
Population	57	2.47	10.59	-22.27	37.81
Population in working age	55	5.27	13.01	-23.23	44.79
Population density	38	-5.24	21.03	-79.55	19.04
Population density in working age	55	5.35	13.01	-23.23	44.79
Land area	39	23.28	89.90	-25.74	497.18

To better understand this simple evidence, we then look in more in detail at the extent of urban sprawl for the top 5 percent largest European cities (Table 4) and for the cities that grew most in area size (Table 5).

Table 4 shows that half of the most populated European cities experienced a 0 or even negative area growth (with Rome showing a decrease of 14 percent), whereas Table 5 reveals that the cities that spread more are low populated cities (within the lower 25 percent, with the only exception of Clermont and Grenoble). Interestingly, more than half of those cities are located in Turkey (and the remaining four are two in France and two in 2 Lithuania). Most of these Turkish cities are also the ones that display substantial population growth rates.

Table 4. Evidence on urban sprawl for the 5 percent largest European cities in 1991

City	Country	Population (%)	Population in working age (%)	Population density (%)	Population density in working age (%)	Land area (%)
Prague	Czech Republic	-3.71	2.41	-3.71	2.41	0
Berlin	Germany	-2.23	-0.26	-2.53	-0.26	0.30
Hamburg	Germany	2.22	1.82	2.18	1.82	0.04
Munich	Germany	-2.28	-4.40	-2.43	-4.40	0.15
Madrid	Spain	-2.38	-	-2.25	-	-0.14
Barcelona	Spain	-8.41	-	-8.16	-	-0.27
Paris	France	-1.26	-0.30	-	-0.30	0
Rome	Italy	-8.23	-13.23	7.03	-13.23	-0.14
Milan	Italy	-8.25	-14.66	-8.47	-14.66	0.23
Budapest	Hungary	-11.83	-8.35	-11.85	-8.35	-0.002
Wien	Austria	0.67	2.24	0.66	2.24	0
Warsaw	Poland	2.03	5.45	0.18	5.45	1.86
Bucharest	Romania	-8.08	-5.62	-	-5.62	-
London	UK	5.02	6.86	-	6.86	-

Table 5. Evidence on urban sprawl for cities that grew the most in area size

City	Country	Population (%)	Population in working age (%)	Population density (%)	Population density in working age (%)	Land area (%)
Patras	Turkey	10.22	15.55	-49.94	15.55	20.21
Heraklion	Turkey	18.02	25.57	-43.16	25.57	107.64
Larissa	Turkey	16.13	21.29	-16.38	21.28	38.89
Kavala	Turkey	18.56	22.81	-59.93	22.81	195.88
Volos	Turkey	5.62	4.05	-64.85	4.05	200.54
Kalamata	Turkey	22.11	28.62	-79.55	28.62	497.18
Clermont-Ferrand	France	1.81	1.20	-	1.20	62.33
Grenoble	France	2.25	1.00	-	1.00	44.07
Panevėžys	Lithuania	-6.77	-5.86	-45.10	-5.86	69.83
Vilnius	Lithuania	-8.74	-4.47	-34.800	-4.47	39.97

The distribution of European cities in terms of agglomeration has decreased in mean and dispersion during those ten years, although such a decrease has not been substantial and the ordering remains almost the same.[7] Table 6 shows that the top 5 percent most dense cities in 1991 are still within the top 5 percent of the distribution of population density in 2001, with the addition of Brussels, Geneva and Porto and the least dense cities in 1991 remain within the bottom 5 percent, with the addition of Kalamata and Ajaccio.

Table 6. Evidence on urban agglomeration in EU cities

5 percent cities with the highest population density		5 percent cities with the lowest population density	
1991	**2001**	**1991**	**2001**
Athena	Athena	Toledo	Kalamata
Thessaloniki	Thessaloniki	Badajoz	Ajaccio
Barcelona	Barcelona	Perugia	Toledo
Pamplona	Pamplona	L'Aquila	Badajoz
Milano	Milano	Sassari	Perugia
Napoli	Napoli	Ponta Delgada	L'Aquila
Turin	Turin	Jönköping	Sassari
Lisbon	Lisbon	Umeå	Ponta Delgada
	Brussels		Jönköping
	Geneva		Umeå
	Porto		

3.3 Some simple regressions

In this section, we exploit our data as much as possible in an attempt to test the predictions highlighted in Section 2. Namely, we would like to see whether urban sprawl in European cities (as measured here by the growth rate of population density) is positively correlated to an increase in car ownership, income and employment, and negatively correlated to an increase in the percentage of ethnic minority (as measured by the percentage of non-European residents) and in crime rate.

[7] The means and standard deviations (in parenthesis) of population density are 2444 (2893.631) and 2233.385 for 1991 and 2001 respectively.

Table 7 presents our regression analysis results. To prevent data loss, we first include each of the key variables in turn as explanatory variables of urban sprawl, and then use all of them together.[8] Growth rate differences in population, income and employment are accounted for in all regressions.

Table 7. OLS estimation results
Dep. Var. Urban population density growth

Variables	(1)	(2)	(3)	(4)	(5)
Car ownership	-0.1281*** (0.0341)				-0.2155*** (0.0317)
Non-EU population		0.0071* (0.0041)			0.0363*** (0.0098)
Crime rate			0.0142 (0.0220)		0.0172 0 .0298
Real GDP per-capita	-0.0181 (0 .0531)	-0.0737* (0.0425)	-0.0566* (0.0342)	-0.0521 (0.0332)-	-0.2937*** (0.0690)
Employment rate	-0.3495*** (0.1062)	-0.1033 (0.0728)	-0.0385 (0.0488)	-0.0383 (0.0453)	-0.5522*** (0.1209)
Population size	0.5603*** (0.1215)	0.8059*** (0.0846)	0.8399*** (0.0719)	0.8376*** (0.0701)	0.6082*** (80.1171)
Obs. R2	41 0.60	57 0.65	72 0.70	74 0.70	30 0.83

Table 7 documents evidence in line with our theoretical predictions for the European context (Section 2). Firstly, in line with the US evidence, the estimated effect of income and employment is always negative. It is often also statistically significant. This means that richer people (either in terms of income or employment) tend to consume more land which increase urban sprawl (and thus decrease population density). As it is predicted, the effect of cars per capita is also in line with the US evidence. Indeed, the higher the growth rate in the percentage of car ownership per capita, the higher is urban sprawl (i.e. the lower is the population density growth rate). This is clearly because workers are ready to accept jobs located further away because of a more rapid transportation mode. The effects is

[8]As mentioned in the Introduction, missing values are a severe limitation of our dataset, in particular, because they generally do not occur for the same cities across variables.

statistically significant and non negligible in magnitude. Indeed, a 1% increase in car ownership per capita growth rate is associated with a 0.13% decrease in the growth rate of population density. Concerning the effect of ethnic minorities, we find that the higher is the percentage of non-European residents, the lower is urban sprawl, confirming our theoretical intuition about European cities. This is interesting since most US studies obtain the opposite results (see e.g. Glaeser and Kahan, 2004). We also obtain the same sign when considering growth rates in crime as explanatory variables of urban sprawl, even though the effect is not statistically significant. These results contradict US studies (such as for example Cullen and Levitt, 1999) but confirm our theoretical predictions of Section 2 in the European context (see also Patacchini and Zenou, 2008).[9]

It has to be clear, however, that *we are not claiming here any causal relationship*. Moreover, the number of observations is very small. Therefore, our evidence has to be only taken as suggestive of some possible correlations between different variables.

4. More descriptive evidence on urban sprawl in European cities

Even though our data set is quite limited, especially because of missing values, the information in 2001 has a relative good coverage and allows us to appreciate urban differences in a large set of amenities and disamenities,[10] economic opportunities, employment structure, human capital, transportation infrastructures and accessibility by air.[11] Table 9 reports in the first four columns a list of such variables, together with our sample descriptive statistics.

The purpose of this section is to exploit the variation in these city characteristics to identify different city structures and then analyze which structure is more likely to experience urban sprawl.

We adopt a *Principal Component Analysis* (PCA hereafter). Such a technique uses the correlation between a set of observed variables to develop a smaller number of artificial variables (principal

[9] The qualitative evidence remains roughly the same when country dummies are included. This indicates that the associations between urban sprawl and our variables of interests are not different when urban sprawl differences are investigated between and within countries.

[10] Amenities play an important role in explaining urban sprawl, see, e.g. Brueckner, Thisse and Zenou (1999) and Glaeser and Kahn (2004).

[11] These variables were not used in the analysis of the previous section (i.e. Section 3) because there are typically not available in 1991 and 1996.

components), without much loss of information. The reduction in variable "dimensions" helps to identify the observations that are more similar/dissimilar along various characteristics. The PCA creates uncorrelated indicators or components, where each component is a linear weighted combination of the initial variables. The importance of each original variable in the determination of the principal components (i.e. the weights or factor loadings) guides the interpretation of the results. The number of principal components is equal to the number of variables being analyzed. The number of retained components is based on the percentage of cumulative total variance explained. The components are ordered so that the first component (PC1) explains the largest possible amount of variation in the original data. The second component (PC2) is completely uncorrelated with the first component, and explains additional but less variation than the first component, subject to the same constraint. Subsequent components are uncorrelated with previous components; therefore, each component captures an additional dimension in the data, while explaining smaller and smaller proportions of the variation of the original variables. The higher the degree of correlation among the original variables in the data, the fewer components required to capture common information.

The Principal Component Analysis (PCA) is the optimal (in terms of mean squared error) linear scheme for compressing a set of high dimensional vectors into a set of lower dimensional vectors (principal components), thus enabling a more tractable organization of the data.

The output from a PCA analysis is given by a table showing the eigenvectors of the correlation matrix of the original variables (i.e. the factor loadings or weights for each variable in each component) with the associated eigenvalues, which give the percentage of total variance explained by each component. Because the original variables are standardized (i.e. with a contribution of the total variance equal to one), a common method to select components is to retain those with eigenvalues greater than one. In our application, we find that the first two components accounts for roughly 79 percent of the total variance (both having eigenvalues much greater than one) whereas the remaining components account for only trivial amounts of variance (all of them having eigenvalues smaller than one). This implies that the information content of our different indicators of urban characteristics can be appropriately summarized by the two derived variables, which represent different city structures.

Table 8 reports in the last two columns the importance of each original variable in the determination of these two artificial variables together with the absolute and cumulative percentage of the variance explained. Variables associated with positive weights load positively/negatively to the

components. The higher is the magnitude of the weight, the higher is the contribution of the associated variable. Table 8 thus shows that the first principal component captures the variance given by the large European cities, which are associated with high levels of total population, crime rates, high employment rates, large number of theatres and museums, efficient public transportation network and high levels of employment in services. The weights associated with climatic variables suggest that we are mainly talking about cities in the North of Europe.

Table 8. Principal Components Analysis results

	N. obs.	Mean	Std. Dev.	PC1	PC2
Population size and density					
Total population	353	392879.1	724983.2	+0.38	-0.26
Population density	252	2233.38	2629.09	+0.19	-0.30
Non-EU population	298	3.75	4.22	+0.13	+0.21
Amenities and disamenities					
Sun hours per day	231	5.28	1.38	-0.22	+0.20
Rainy days per year	207	148.80	50.04	+0.29	-0.35
Number of theatres	197	10.14	18.20	+0.18	-0.03
Number of museums	221	13.81	21.20	+0.15	+0.02
Tourist hotel stays per capita	245	3.48	4.99	+0.04	+0.24
Total crime rates	250	75.32	56.99	+0.23	-0.20
Murders per capita	255	0.06	0.08	+0.16	-0.09
Economic opportunities, employment structure and human capital					
Unemployment rate	300	12.14	7.21	-0.15	+0.09
New firms	248	12.40	7.70	+0.03	+0.31
Headquarters	172	202.17	1812.38	+0.21	-0.19
Share of people working in trade, hotels and restaurants	279	21.57	8.25	+0.41	-0.12
Share of industrial employment	280	25.50	9.73	+0.10	-0.23
Share of highly educated people	177	0.20	0.06	+0.18	+0.33
Number of students	244	95.24	62.99	+0.32	-0.16
Real GDP per head	66	727315.4	4066965	+0.07	+0.21
Transportation infrastructures and accessibility					
Cars per capita	246	358.37	145.80	+0.09	+0.40
Public transportation network (km) per capita	171	8.36	68.98	+0.34	-0.07
Number of arrivals in closer airport	197	3773899	7629137	+0.18	-0.11
Eigenvalues				6.69	4.88
Percentage of explained variance				42%	37%

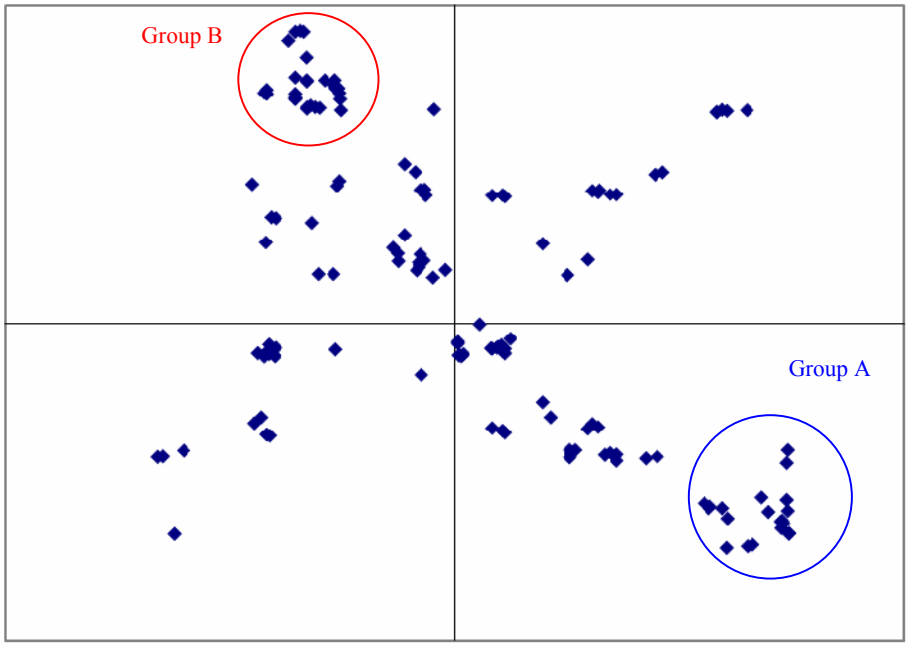
The second principal component, instead, capture a different city structure. Those are cities with low population density, low crime rates, high levels of human capitals, rich in tourists, with a high percentage of cars per capita, which seems to have higher levels of GDP per capita. These cities also collect larger percentages of non EU-nationals. The weights associated with climatic variables indicate

that cities with such structures are mainly located in the South of Europe. Here unemployment rates are anyway higher with respect to the North of Europe, which explains the positive sign of the weight for unemployment rate in this city structure.

To understand better what the European cities in those groups are, we plot in Figure 1 our observations on the plane spanned by the first two principal components. The distance from the axes indicates how much each city is close to the characteristics captured by each principal component.

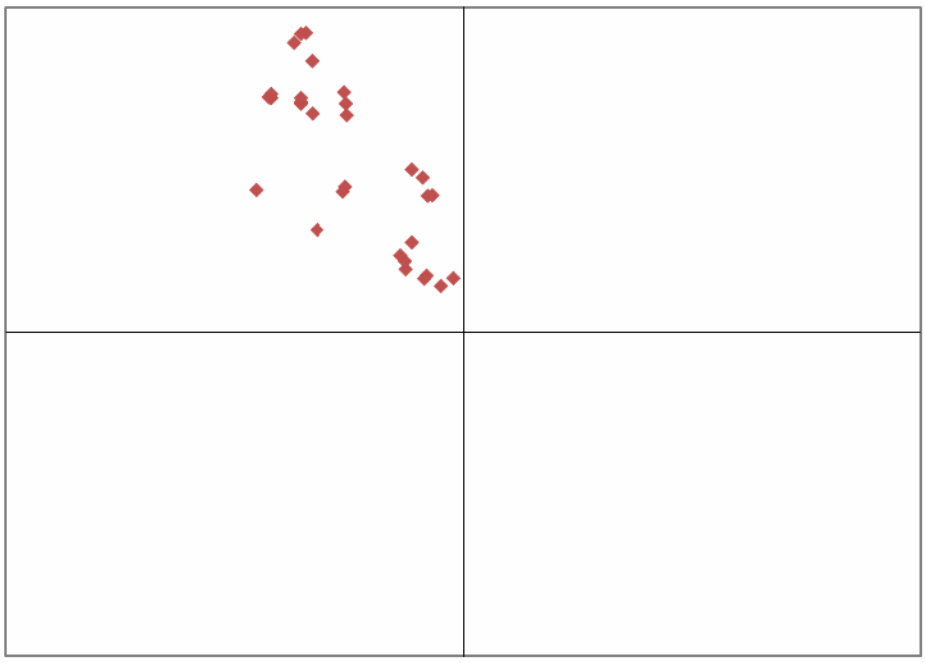
The scatter plot shows that the large majority of the cities are located in the north-west and south-east quadrants, confirming that the two principal components are roughly capturing the two different city structures of the European context. In the south-east quadrant, which contains cities positively correlated with the first principal component, we can clearly distinguish the large cities in the North of Europe, namely London, Brussels, The Hague, Madrid, Berlin, Hamburg, Munich, Paris, Milan and Rome (group A in Figure 1). The north-west quadrant, instead, shows a distinct cluster of cities (group B) which contains small cities mainly located in the South of Europe where the quality of life is high, including Florence, Perugia, Toulouse, Montpellier, Marseille, La Valletta, Toledo, and some cities in Turkey. Those are cities that are positively and highly correlated with the second principal component and negatively with the first principal component.

Figure 1. City structures in Europe



If we look more closely at such a distribution of cities in terms of urban sprawl, we find that all the cities that experienced the more marked increase in land size (above the mean) are all located in the North-west quadrant (Figure 2). This evidence thus indicates that urban sprawl is positively associated with city characteristics captured by the second principal component (i.e. low population density, low crime rates, high levels of human capitals, lots of tourists, high percentage of cars per capita, high levels of GDP per capita, good climatic conditions, large in-flows of non-EU citizens, high percentage of new businesses) and negatively with those determining the first principal component (i.e. high levels of total population, students, crime rates, employment rates, a large number of theatres and museums, an efficient public transportation network and high levels of employment in services). Looking in more detail at the importance of the different variables in determining those city structures (last two columns of Table 8) it seems that urban sprawl is more likely to be associated with a high percentage of high-skilled individuals, high car ownership rates, good climatic conditions, large in-flows of non-EU citizens and a lively industrial structure. On the contrary, an efficient public transportation network, typically concentrated in big-city centers, large shares of employment in services, bad climatic conditions and a high number of students seem to be factors preventing urban sprawl.

Figure 2. Cities with a fast rate of urban sprawl in the EU



5. Concluding remarks

In this paper, we have provided different empirical evidence on urban sprawl in cities of the European Union. We have seen that there are basically two city structures with different sprawl experiences. Cities mainly located in northern Europe, which are typically bigger with old centers, have experienced fewer sprawls than cities from southern Europe and Turkey, which are smaller in size and less dense. Similarities and dissimilarities in the process of urban sprawl between Europe and the United States are highlighted. As in the United States, history has shown that there is a positive correlation between prosperity and the degree of urban sprawl. We have showed here that as soon as people are affluent enough to be able to chose where they wanted to live and which transport mode they desire, they tend to live further away from the city centers. We have also showed that the predictions in terms of the percentage of ethnic minorities and crime rate are reverse for the European case and confirmed by our data. Even though our results are to be taken with caution, they reveal peculiarities of the European Union context that might be relevant to explain the different urban patterns between Europe and the United States.

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