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IEB Working Paper 2022/08

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Version November 2022

Cities

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THE ROLE OF HISTORIC AMENITIES IN SHAPING CITIES *

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ABSTRACT: The existence of amenities matters to understanding people's residential choices. Our theoretical model extends the standard urban model by introducing exogenous amenities to explain population allocation within cities. To estimate the model predictions, we focus on historic amenities using detailed geolocated data for 579 European cities. We analyze how the shape of city centers endowed or not endowed with these amenities is affected. We measure historic amenities with the location of buildings from the Roman, Medieval, and Renaissance-Baroque periods. Our results show that cities with historic buildings in their centers have steeper population density gradients, are more compact and centralized, and have been less affected by the suburbanization processes caused by transportation improvements. Heterogeneity analyses show that the quantity and the quality of historic buildings also matter. Several robustness checks controlling for natural and modern amenities and testing for the spatial scope of these amenities verify our main results.

JEL Codes: R4, R2, O4
Keywords: Amenities, History, Buildings, Density, Transportation

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* Financial support from the Ministerio de Ciencia e Innovaci´on (research projects RTI2018-097401-B-I00, PID2019-108265RB-I00 and PID2021-128227OB-I00), and Generalitat de Catalunya (research projects 2017SGR796 and 2017SGR1301).

1. Introduction

During the last decades, the distribution of the population within cities has changed with a decreasing proportion of people living in the center compared to their suburbs. Yet suburbanization is a reality also in Europe: the average population growth rate between 1961 and 2011 was 27 percent higher in the suburbs than in the central cities. Interestingly this process has not been uniformly distributed in all the cities, which is a fact that our paper helps to explain.

One potentially missing explanation is the existence of local amenities. The seminal works by Rosen (1979) and Roback (1982) already introduced the idea that amenities have an impact on how cities grow and, more specifically, they could be a key element to understand people's residential choices within cities. City centers provide urban areas with their own special identity, which in turn is considered an important amenity. There is extensive evidence suggesting that amenities are important in understanding urban form and the sorting of heterogeneous residents within cities.

However, empirically, it is not easy to disentangle the impact of heterogeneous amenities on cities, especially because many of them are endogenous. Some empirical research on urban amenities has focused on exogenous amenities such as the weather (Rappaport, 2007) or natural amenities (Lee and Lin, 2018). In this line, the goal of this paper is to explore the role of a very specific type of urban amenities, the historic amenities, on the residential location patterns within cities. We specifically consider amenities in the city's center associated with historic monuments and buildings, which create an attractive environment for those who live in those areas. Compared to modern urban amenities, the cultural heritage forms belong to the past and as such are predetermined; thus, historic amenities can be considered to be exogenous, although we investigate this issue thoroughly.

We first present a simple model that, inspired by the standard urban models, introduces exogenous amenities to explain population location within a city. The model makes three main predictions for cities with strong central amenities: 1) they have steeper density gradients, 2) they are more compact and 3) they are less impacted by the decentralized process due to transportation improvements connecting the city center to the suburbs. Next, we estimate a reduced form version of these three predictions using a new, unique database. We consider 579 cities in 29 European countries between 1961 and 2011. The central cities of Europe have a very rich history. Some of them date back to the Roman era, others thrived during the Medieval years or the Renaissance, while others were founded or gained importance after the Industrial Revolution. They have inherited monuments, buildings, parks, and other urban infrastructure from these past eras. This architectural heritage is aesthetically pleasing and creates an attractive environment for those who live in those areas and, as a result, generates historic amenities.

In order to take into account differences in the endowments of urban historic amenities of these city centers, we draw on different historic sources to identify the exact locations of their historic buildings in three different periods: a) the Roman (amphitheaters, theaters, circuses, and temples); b) the Medieval (castles, cathedrals, churches and monasteries, and other civic buildings) and c) the Renaissance-Baroque (16th–19th centuries) (palaces, opera houses, concert halls, and other civic buildings). An analysis for the whole of Europe is methodologically challenging because we need to assemble data for many cities of different countries and for a long period. Our new comprehensive dataset on historic amenities is a contribution in its own right. For example, we know that nearly half of the cities in our data have at least a historic building in its center and we identify the 851 historic monuments that are located in the city centers of these cities.

While historic amenities could be considered exogenous, there are still some identification issues we address by using instrumental variables. We are able to predict the presence of historic buildings with variables stating the importance of cities in the past for political, economic and religious reasons.

Our results confirm the model's predictions. In the first empirical analysis, we estimate a classical density function to obtain the density gradients for cities distinguishing between cities with and without historic amenities in their centers. We corroborate that population density decreases with the distance to the CBD in both types of cities, but we also find that density gradients are steeper and significantly different in cities with central historic amenities. For example, the 2011 gradient was 0.3 percentage points steeper in cities with historic amenities. Additionally, we test for the changes of these gradients during the period 1961-2011, and we confirm that they decrease over time from 2% to 1.6% and from 1.7% to 1.1% in cities with and without historic amenities, respectively, between 1961 and 2011. These results confirm the existence of a suburbanization process but also that cities with historic amenities are less affected.

In our second empirical analysis, we investigate for the same dataset the degree of centralization among cities with and without central historic amenities. A city is more centralized if a higher percentage of its population lives in the center. By considering transportation networks, geography, and past population we obtain that the share of central city population is 3.7 percentage points higher in cities with historic central amenities. Controlling for natural and modern amenities and socioeconomic characteristics, the results hold, and we also find that this evidence is stronger when we introduce the quantity and the quality of historic buildings.

Finally, in our third empirical analysis, we run a quasi-experiment to test whether cities with historic centers are less affected by the possible suburbanization processes caused by an improvement of transportation networks connecting the city centers to the suburbs. In particular, we focus on the impact of highway expansions during the period 1961–2011 on the share of the central city population. Our results show that the each additional highway ray reduces the share of central cities' population by 7.5%, as evidence of suburbanization, but the effect is significantly 2 percentage points smaller for cities with historic amenities in the city center. This indicates that those cities can retain the population in their centers even with better connectivity with the suburbs. As in the previous analyses, results hold when we consider natural and modern amenities and socioeconomic characteristics. Interestingly, the effects are stronger the greater the quantity and the quality of historic amenities,

Our paper contributes to different strands of the literature. First, it contributes to the literature that uses insights from history to understand key aspects of urban economics (see Hanlon and Heblich (2022) for an exhaustive review and Lin and Rauch (2022) for an interesting approach on under which conditions history matters). In particular, we add new evidence to the research that uses historic data on buildings to analyze the distribution of the population across space.

In the same line, our work is also related to the literature on development and geography and the question of persistence in the spatial distribution of the population (Davis and Weinstein, 2002, Bleakley and Lin, 2012, Ahlfeldt et al., 2015, Michaels and Rauch, 2018). This persistence might be caused by geographic features or amenities. All these papers examine the effect of historic natural experiments on the location of population and economic activity. Two recent papers are focusing on urban disamenities to explain the sorting of populations within cities. Heblich et al. (2021) analyze the long-run effects of coal pollution in England to explain current segregation patterns and Ambrus et al. (2020) show evidence that the impact of 19th cholera epidemics in London is still affecting its neighborhoods' income distribution today.

We also contribute to the literature that assesses the amenity value of cities starting from the seminal paper by Glaeser et al. (2001). More recently, there has been an increasing line of theoretical and empirical research that tries to explain the mechanisms of sorting heterogeneous residents within cities (Couture and Handbury, 2020, Gaigné et al., 2017, Almagro and Domínguez-Lino, 2021). Our research specifically contributes to this literature by focusing on the value of historic amenities to explain residential locations within cities while controlling for other possible endogenous amenities. In contrast to this literature, we also emphasize their variation across cities and historic periods.

Finally, our paper is related to a recent body of literature that examines the effects of historic urban amenities on the housing market. For different periods and using different estimation methods, the works by Van Duijn and Rouwendal (2013), Koster and Rouwendal (2017) and Koster et al. (2016) show that historic amenities (also referred to as 'cultural heritage') have a clear impact on housing prices and income sorting in Dutch cities. In a similar vein, the contribution of Ahlfeldt and Holman (2018) specifically analyze the effect of the value of architectural amenities in England on residential property prices. In a related approach and with data from the city of Denver, Zhou (2021) shows that the historic district designation led to considerable housing price appreciation in the treated areas. Franco and Macdonald (2018) find similar results in their analysis of the cultural heritage amenity in conservation areas in the city of Lisbon. Interestingly, there is a related research line that analyzes the benefits (Ahlfeldt et al., 2017, Been et al., 2016) and the costs (Hilber et al., 2019) of the local policies that preserve buildings in the city centers for historic, cultural or architectural reasons. Compared to the aforementioned studies, our analysis is unique in exploiting the location of historic buildings in Europe's city centers to understand how people have more preferences to live close to this environment and how this behavior changes cities' shape with time.

The rest of the paper is organized into 6 sections and 3 Appendices. Section 2 develops the theoretical model. In Section 3 we describe the data. In Section 4 we present the results of the estimations of density gradients. Section 5 shows the results of centralization. Section 6 reports the results of the response of cities to an infrastructure improvement connecting the city center to the suburbs. Finally, in Section 7 we highlight the main results and conclusions.

2. Theory

To explain household locations within cities, the standard urban models predict that, after a reduction in transportation costs, moving away from the city center implies a reduction in population density together with the lower land and housing prices to compensate for the commuting costs of living in the suburbs. Despite clear limitations, the monocentric model still remains useful to understand cities' shape. As Duranton and Puga (2015) state, although the model is oversimplified, it has some advantages that make it to remain a very useful analytical tool that with some simple modifications can be remarkably accurate. Indeed, there is empirical evidence that shows the existence of declining gradients in populations, land, and housing prices (McMillen, 2006). More recently, Liotta et al. (2022) investigate the empirical relevance of the monocentric model for 192 worldwide cities and show that the predictions of the model on urban sprawl, density, and rent gradients are robust. Furthermore, Duranton and Puga (2022) very precisely estimate the gradient of house prices for the US MSA and show how it decreases as the distance to the center increases.

To guide our empirical strategy we now develop a simple model that extends the standard urban model by introducing amenities. We focus our attention on 'exogenous' amenities whose levels do not depend on the current economic conditions and, in particular, on current patterns of population location.

2.1 *Amenities and gradients*

Let the level of amenities as a function distance x from the CBD be denoted $a(x)$. Besides amenities, households consume land (q) and a composite non-land good (c), and their preferences are given by $u(c, q, a)$.

Let t, r and y denote commuting cost per kilometer, land rent, and income, respectively. The budget constraint is then $c + rq = y - tx$ and the utility function can be written as $u(y - tx - rq, q, a)$. Households maximize this expression with respect to q and taking r as given, which yields the following first-order condition:

$$\frac{\partial u(.)}{\partial q} = r\frac{\partial u(.)}{\partial c} \tag{1}$$

In equilibrium, land rent (r) and land consumption (q) must vary with distance (x) to ensure that every household enjoys the same utility level (u) in all locations. Thus,

$$u(y - tx - r(x)q(x), q(x), a(x)) = u \tag{2}$$

$r(x)$ is the so-called 'bid-rent' function for land and its slope can be found by totally differentiating (2) with respect to x:

$$-\left[t + \frac{\partial r(x)}{\partial x}q(x) + r(x)\frac{\partial q(x)}{\partial x}\right]\frac{\partial u(c,q,a)}{\partial c} + \frac{\partial q(x)}{\partial x}\frac{\partial u(c,q,a)}{\partial q} + \frac{\partial a(x)}{\partial x}\frac{\partial u(c,q,a)}{\partial a} = 0 \tag{3}$$

By (1), the $\frac{\partial q(x)}{\partial x}$ terms in (3) cancel out and, after rearranging, we obtain:

$$\frac{\partial r(x)}{\partial x} = -\frac{t}{q(x)} + \frac{1}{q(x)}\frac{\frac{\partial u(c,q,a)}{\partial a}}{\frac{\partial u(c,q,a)}{\partial c}}\frac{\partial a(x)}{\partial x} \tag{4}$$

that shows the land rent gradient, also well-known as the Alonso-Muth condition (Duranton and Puga, 2015).

In the standard urban model without amenities (e.g., Brueckner, 1987), the second term of (4) is zero and this condition shows that, at the equilibrium, land rent falls with distance to the CBD to compensate for the higher commuting costs. If there are central amenities that, for simplicity, are linear in distance (with $a(x) = \alpha - \beta x$ and $\alpha, \beta > 0$), the second term of the Alonso-Muth condition is also negative because $\frac{\partial a(x)}{\partial x} = -\beta < 0$ and, as a result, land rent must also compensate for 'inferior' amenities. Furthermore, the stronger the central amenities (larger amenity gradient β), the higher the amenity compensation and, therefore, the higher the (absolute value of the) land rent gradient.

2.2 *Amenities and the degree of centralization*

While the above computations show that r and q depend on x, t and u as in the standard urban model, these variables will also depend on amenities when they are present, with the effect of the amenity gradient β being of central interest. Land rent and land consumption can then be rewritten as $r(x, t, u, \beta)$ and $q(x, t, u, \beta)$. Letting $\bar{x}$ denote the distance to the edge of the city (assumed to be linear) the standard equilibrium conditions are

$$r(\bar{x}, t, u, \beta) = r_a \tag{5}$$

$$\int_0^{\bar{x}} \frac{1}{q(x, t, u, \beta)} dx = N \tag{6}$$

Equation (5) says that urban land rent equals agricultural rent r_a at the edge of the city, while (6) says that the urban population N fits inside $\bar{x}$ (note that $1/q$ equals population density and that the linear city is one unit wide).

The conditions (5) and (6) determine the equilibrium values of $\bar{x}$ and u as functions of the parameters, with the effect of the amenity gradient β and of commuting t being of particular interest. First, based on the findings related to the Alonso-Muth condition (with amenities) in (4), our hypothesis is that cities with strong central amenities, as captured by a large amenity gradient β, are more compact and centralized:

$$\frac{\partial \bar{x}}{\partial \beta} < 0 \tag{7}$$

While the hypothesis in (7) is intuitively appealing, it cannot be demonstrated as unambiguous general implication of the urban model. But adoption of special functional forms can overcome the ambiguities in a general analysis, allowing clearcut results to be derived. Accordingly, suppose that the main part of the utility function has a Leontief form, with amenities appearing additively. For use of Leontief preferences in other urban models, see Brueckner and Kim (2003) and Brueckner (2005). Then, the requirement that all urban residents enjoy the same utility level u becomes

$$a + min\{q, c\} = u \tag{8}$$

Since utility maximization will imply $q = c$, it follows that $min\{q, c\} = q$, allowing (8) to be written as $q = u - a(x) = u - \alpha + \beta x$. In addition, letting y denote income, the consumer budget constraint $c + rq = y - tx$ can be rearranged as $r = (y - tx)/q - 1$ after substituting $c = q$. Substituting $u - a(x)$ for q, conditions (5) and (6) then become

$$\frac{y - t\bar{x}}{u - a(\bar{x})} - 1 = r_a \tag{9}$$

$$\int_0^{\bar{x}} \frac{1}{u - a(x)} dx = N \tag{10}$$

Solving (9) and (10) for $\bar{x}$ and u using $a(x) = \alpha - \beta x$ yields

$$\bar{x} = \frac{y}{t + \delta\beta} \tag{11}$$

and where $\delta = (e^{\beta N} - 1)e^{-\beta N}(1 + r_a) > 0$. Since δ is increasing in β, a larger β raises $\delta\beta$ in (11). Then, by inspection, the $\bar{x}$ expression in (11) is decreasing in the amenity gradient β, so that (7) is satisfied. Thus, under the chosen functional forms, cities where the pull of central amenities is strong are more compact and centralized.

2.3 *Amenities and transportation improvements*

The standard analysis also shows that $\partial\bar{x}/\partial t < 0$, establishing that the city becomes more compact and centralized when commuting cost rises. When transportation improvements instead yield a decline in commuting cost, the effect on $\bar{x}$ is given by $-\partial\bar{x}/\partial t > 0$. Our hypothesis is that this effect is smaller with strong central amenities:

$$\frac{\partial}{\partial\beta}\left(-\frac{\partial\bar{x}}{\partial t}\right) < 0 \tag{12}$$

Based on the abovementioned Leontief utility function, and using (11), the relationship between distance to the edge of the city and commuting costs can be written as

$$-\frac{\partial\bar{x}}{\partial t} = \frac{y}{(t + \delta\beta)^2} \tag{13}$$

Since δ is increasing in β, a larger β raises $\delta\beta$ in (13). Then, by inspection, the $-\partial\bar{x}/\partial t$ expression in (13) is decreasing in the amenity gradient β, so that (12) is satisfied. Thus, under the chosen functional form, the urban expansion caused by a decline in t due to transportation improvements is smaller in cities where the pull of central amenities is strong.

In summary, this simple model extends the standard urban model by introducing exogenous amenities. It shows that amenities shape cities. In particular, cities with strong central amenities have steeper land rent (and population density) gradients, are more compact and centralized, and are less affected by transportation improvements.

3. Historic amenities in European cities

Our unit of analysis to define cities is the Functional Urban Area (FUA)[1] defined by the European Commission (Urban Audit Project) and the OECD. Each FUA consists of a central city (CC) and

[1] They were formerly known as Larger Urban Zone (LUZ).

its suburbs (SUB). The former is an urban center with at least 50,000 inhabitants, the latter is its commuting zone and it is made up of all municipalities with at least 15% of their employed residents working in the central city[2]. Our final dataset includes 579 central cities (and their suburbs and FUAs) located in 29 European countries: 26 member states of the European Union (EU)[3] and Switzerland, Norway, and Iceland.

To study the role of amenities in shaping cities, we focus our attention on historic amenities. We measure the current level of historic amenities in our 579 central cities through their historic architectural heritage. In this sense, we focus on well-preserved buildings from three historic periods and their most representative pan-European styles: Roman (and Greek), Medieval (Romanesque, Gothic), and 16th–19th c. architecture (Renaissance, Baroque).

The information for the Roman (and Greek) architecture comes from a digitized map version of Talbert (2000)'s *Barrington Atlas of the Greek and Roman World*. This map is part of the Digital Atlas of Roman and Medieval Civilization (DARMC) project of the Center for Geographic Analysis at Harvard University (`http://darmc.harvard.edu`). The Pleiades project of the Stoa Consortium (`https://pleiades.stoa.org`) gives access to the different elements that make up this map. In particular, we geolocate well preserved amphitheaters, theaters, circuses, temples, triumphal arches and aqueducts. As a whole, there are 575 Roman buildings in Europe (see Figures A.1a and A.1b in Appendix A), 173 within our sample of central cities (Table 1 Panel A). The Colosseum (Rome) and Maison Carrée (Nîmes) are some of the most known examples of this type of architecture.

Table 1: Historic architecture in Europe

Panel A
Number of historic buildings by periods and architectonic styles

Roman architecture	Within CCs	Within Europe	Medieval architecture	Within CCs	Within Europe	16th–19th c. architecture	Within CCs	Within Europe
All buildings	143	575	All buildings	416	1,456	All buildings	292	619
Amphitheaters	45	238	Castles	70	549	Renaissance	66	111
Theaters	26	158	Romanesque	106	473	Baroque	93	235
Circuses	13	63	Gothic	240	434	Operas, theaters	133	273
Temples, arches, aqueducts	59	116						

Panel B
Number of Central Cities with historic architecture

Historic vs. Non-historic		Historic periods		Period combinations	
With historic architecture	288	Roman	80	Only one period	177
UNESCO-designated World Heritage city	80	Medieval	204	Two periods	82
Without historic architecture	291	16th–19th c.	144	Three periods	29

The information for the Medieval period comes from different sources which help us to geolocate the most important buildings. First, we focus on castles as one of the most characteristic buildings of this period (9th–15th centuries). Using information from Toy (1939), Gravett (2001), Warner (2001), Lepage (2010), and Rongen (2013), we geolocate 549 castles in Europe (see top

[2] See `https://ec.europa.eu/eurostat/web/cities/spatial-units` for more details.

[3] Slovenia and Lithuania are not included because their population datasets were not available.

Figure A.2a in Appendix A), 70 of them within our central cities (Table 1 Panel A). The Edinburgh and Prague castles are two well-preserved examples.

During the Middle Ages, there were two architectonic styles with pan-European coverage. The (Pre-)Romanesque style ((8th–)11th–12th centuries) mainly centered on religious structures such as churches, cathedrals, monasteries, or abbeys. Besides ecclesiastical buildings, the Gothic style (12th–15th centuries) also includes examples of civilian buildings. Using information from Kubach (1975), Grodecki et al. (1977), Calkins (1998), Stalley (1999), Frankl and Crossley (2000), Coldstream (2002), Clark (2006), and Toman and Bednorz (2013, 2015), we geolocate 473 and 434 Romanesque and Gothic structures in Europe (see bottom Figures A.2b and A.2c in Appendix A), 106, and 240 within central cities, respectively (Table 1 Panel A). The Romanesque cathedral of Santiago de Compostela and the Gothic cathedral of Notre-Dame de Paris are among the most preeminent examples.

Finally, we consider the two pan-European styles that consecutively followed the Gothic: Renaissance architecture (16th–17th centuries) and Baroque architecture (17th–18th). Both styles include more civilian buildings than the previous ones, in particular palaces, *chateaux*, and residences. Furthermore, we also consider that during the 16th–19th centuries the performing arts gained importance and theaters, concert halls, and opera houses were built around Europe. Using information from Norberg-Schulz (1972), Murray (1979), Forsyth (1985), Bergdoll (2000), Coldstream (2002), Beranek (2003), Anderson (2013), and Salminen (2014), we geolocate 111, 235 and 273 Renaissance and Baroque buildings, and theaters, operas and concert halls in Europe (see Figures A.3a, A.3b and A.3c in Appendix A), 66, 93 and 133 of them are located within our sample of central cities (Table 1 Panel A). Good examples of these styles are Palazzo Medici Riccardi (Florence), Teatro alla Scala (Milan), El Liceu (Barcelona) or Palacio Real de Madrid.

Taking into account the presence of buildings from the above mentioned architectonic styles, we classify the 579 central cities into two groups: 288 cities with historic architecture and 291 cities without that historic architecture. Furthermore, among the historic cities, there are 80 of them that are UNESCO-designated World Heritage sites because their types of buildings illustrate significant stages in human history[4]. Brussels, Córdoba, Firenze, Grazz, Krakov, Lyon, Napoli, Prague, Rome, Salzburg, Sienna, and Warsaw, among others, are included because of their historic centers (Table 1 Panel B, Figure A.4a).

Regarding the three historic periods considered in this study, 80 central cities, such as Genova, Nice, Lyon or Rome, have Roman buildings. Medieval buildings can be found in 204 cities such as Barcelona, London, München or Paris. Finally, architecture from the 16th–19th c. period can be found in 144 central cities such us Berlin, Madrid, Warsaw or Wienn. As a whole, 177, 82 and 29 central cities have buildings only from one, two, and all three historic periods, respectively (Table 1 Panel B, Figure A.4b in Appendix A).

[4]This is criterion (iv). There are other 6 cultural and 4 natural criteria. See http://whc.unesco.org/en/criteria/ for further information.

4. Are gradients steeper in cities with strong central historic amenities?

We now turn our attention to empirically studying the role of historic amenities in shaping cities. To do so, we consider the model in Section 2 to guide our empirical strategy. The first prediction of the model stated that cities with strong amenities in their centers have steeper gradients. To test it, we adapt the traditional density function to study the spatial distribution of population within cities with and without historic amenities. In particular, we estimate the following two equations:

$$\begin{aligned}\ln(\text{Density}_{ij}) = \gamma_0 + \gamma_1 \times \text{Distance to the CBD}_j \times \text{No historic}_i \\ + \gamma_2 \times \text{Distance to the CBD}_j \times \text{Historic}_i + \epsilon_i + \mu_{ij}\end{aligned} \tag{14}$$

$$\begin{aligned}\Delta\ln(\text{Density}_{ij}) = \delta_0 + \delta_1 \times \text{Distance to the CBD}_j \times \text{No historic}_i \\ + \delta_2 \times \text{Distance to the CBD}_j \times \text{Historic}_i \\ + \delta_3 \times \text{Initial } \ln(\text{Density}_{ij}) + \epsilon_i + \mu_{ij}\end{aligned} \tag{15}$$

where $\ln(\text{Density}_{ij})$ is the log of population density in municipality j that belongs to city i. To compute it, we use population data provided by the Directorate-General for Regional and Urban Policy of the European Commission. These data come from population censuses collected every ten years at the municipal (LAU 2) level for the period 1961–2011 using 2011 local administrative boundaries.

Distance to the CBD_j is computed in km using GIS software and measures the distance from the centroid of municipality j to the centroid of the FUA's central city. Historic_i is a dummy equal to one if there are historic amenities in the central city of the FUA. Similarly, No historic_i is a dummy equal to one if there are no historic amenities in the central city of the FUA. As mentioned in Section 3, to measure historic amenities we consider the existence of well-preserved historic buildings. By interacting these two variables with Distance to the CBD_j we can isolate the associated effects for cities with historic amenities (with historic buildings) and without historic amenities (without historic buildings). We follow Glaeser and Kahn (2004) and use city fixed-effects (ϵ_i). μ_{ij} is the error term with the usual properties.

Equation (14) is a density function that we estimate for each year. γ_1 and γ_2 are the so-called density gradients for cities without and with historic amenities, respectively. The first prediction of the model holds if (1) γ_1 and γ_2 are negative, showing that population density decreases with distance to the CBD in cities without and with central historic amenities, respectively; and (2) $|\gamma_2| > |\gamma_1|$, showing steeper gradients in cities with historic amenities.

Similarly, Equation (15) is a growth density function that we estimate for each pair of years. δ_1 and δ_2 are growth density gradients for 'non-historic' and historic cities, respectively. If cities are undergoing a process of population suburbanization, the gradients are positive ($\delta_1 > 0$, $\delta_2 > 0$). In this case, the predictions of the model also hold if $|\delta_2| < |\delta_1|$, showing that the spatial structure of cities with historic amenities are less affected by the suburbanization process.

Figure 1a and Appendix Table B.1 show Ordinary Least Squares (OLS) results when we estimate the adapted population density function (Equation (14)) for each of the six years of our sample. The estimated coefficients for the two distance variables are negative and significant in each year ($\hat{\gamma}_1 < 0$ and $\hat{\gamma}_2 < 0$), indicating that population density decreases with distance to the CBD in both types of cities. The coefficients for cities with historic amenities are higher in absolute values than those for cities without historic architecture ($|\hat{\gamma}_2| > |\hat{\gamma}_1|$), confirming that (density) gradients are steeper in cities with central historic amenities. For example, while population density increased by each kilometer closer to the CBD by 2.0% in 2011 in cities with historic amenities, it only increased by 1.7% in cities without historic amenities[5].

The temporal evolution of gradients is also informative. In this case, both types of density gradients decrease over time ($|\hat{\gamma}_{1,2011}| < |\hat{\gamma}_{1,1961}|$, $|\hat{\gamma}_{2,2011}| < |\hat{\gamma}_{2,1961}|$), indicating the existence of a suburbanization process. For example, between 1961 and 2011 density gradients decreased from 2.0% to 1.6% and from 1.7% and 1.1% in cities with and without historic amenities, respectively.

Figure 1: Gradients in European cities with/out historic amenities

(a) Density gradients (b) Growth density gradients

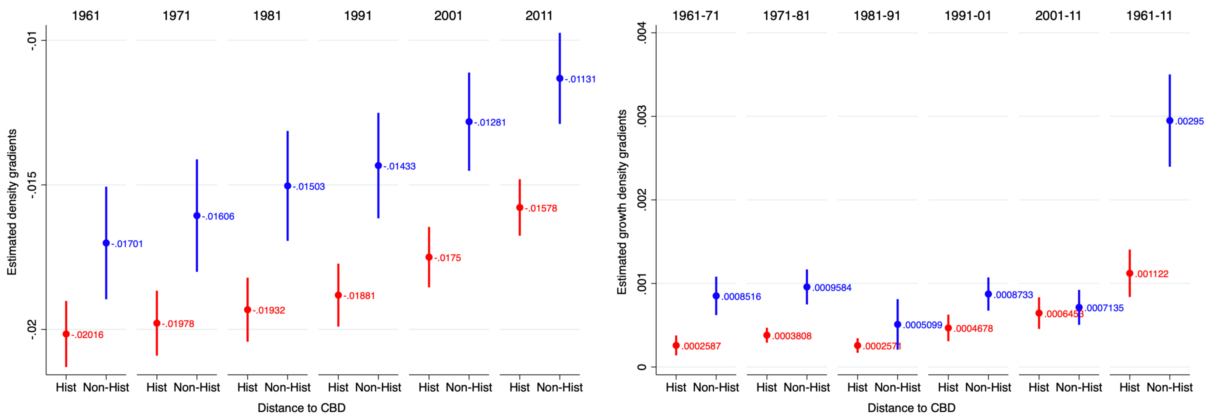

Figure 1b and Appendix Table B.2 report OLS results when we estimate Equation (15) for each decade (columns 1 to 5) and for the 50-year period (column 6). The estimated coefficients for the two distance variables are positive and significant in each period ($\hat{\delta}_1 > 0$ and $\hat{\delta}_2 > 0$), showing that population density is growing with distance to the CBD and, as a result, both types of cities are undergoing a process of population suburbanization. For example, between 1961 and 2011 population (density) grew by 0.3% and 0.1% each additional kilometer from the CBD in cities with and without historic amenities. This result verifies previous ones and confirms the finding by Garcia-López et al. (2015), who study the evolution of central city population and suburban population in European cities.

[5]As a robustness check, we estimate Equation (14) without city fixed-effects (ϵ_i) and add the Historic$_i$ and No historic$_i$ dummies as explanatory variables. The results, which are available upon request, verify that historic cities have steeper population density gradients, and a decrease in the absolute value of both historic and non-historic gradients over time. As it is well known, the estimated coefficient of the constant term of the traditional density function can be interpreted as the estimated population density in the center of the city (where the distance to the CBD is equal to zero). As a result, we can interpret the coefficients of these two dummies as the *average* population densities in the centers of the historic and 'non-historic' cities, respectively. Results for the two dummies also show that central city density is slightly higher in historic cities, and confirm the population suburbanization process with the decrease of the estimated central densities in both types of cities.

If we compare the coefficients of both types of cities, we find that those for cities with historic buildings in the city center are smaller than those for 'non-historic' cities ($|\hat{\delta_2}| < |\hat{\delta_1}|$). This latter result shows that the spatial structure of cities with historic amenities is less affected by the suburbanization process. When we do not control for the initial density, results hold with higher estimated coefficients.

To sum up, these results confirm (1) that cities with historic amenities have steeper gradients, (2) the existence of a population suburbanization process undergoing in European cities, and (3) the suburbanization process is less intense in cities with historic amenities.

5. Do historic amenities affect the degree of centralization?

The second prediction of the model refers to the degree of centralization: The higher the pull of historic amenities, the more compact and centralized the city. In other words, central cities with historic amenities house a higher proportion of the metropolitan population compared to their counterparts without historic amenities. To test this prediction, we estimate the following equation:

$$\begin{aligned}\text{Central city pop share}_{it} = \alpha_0 + \alpha_1 \times \text{Historic}_i \\ + \alpha_2 \times \text{Transport}_{it} + \alpha_3 \times \text{Geography}_i + \alpha_4 \times \text{Past Pop}_i + u_{it}\end{aligned} \tag{16}$$

where Central city pop share$_{it}$ is the percentage of the population living in the central city of the metropolitan area i in year t and directly measures the degree of centralization. By using this share as a dependent variable we also control for the overall effects on the metropolitan population while addressing its endogeneity issues.

Historic$_i$ is our main explanatory variable that measures the existence of historic amenities. As above mentioned, it is a dummy equal to one if there are well-preserved historic buildings in the central city. In particular, the coefficient α_1 measures whether the degree of centralization is different in central cities with and without historic buildings. The second prediction of the model holds if α_1 is positive, showing that the degree of centralization is higher (and increases more) in central cities with historic amenities (compared to their 'non-historic' counterparts).

We add three types of control variables. Transport$_{it}$ is a vector of time-variant variables that control for the effects of transportation networks in central cities. In particular, we consider the number of central city highway rays and the number of central city railroads. Geography$_i$ and Past Pop$_i$ includes time-invariant control variables related to geography and past populations. Specifically, we control for central city and metropolitan topographical characteristics (area, elevation and ruggedness), and for past populations from years 800 to 1800 according to Bairoch et al. (1988). u_{it} is the error term with the usual properties.

We estimate Equation (16) by pooling the six-year cross sections and adding year fixed-effects (Pool strategy). Since Historic$_i$ is a time-invariant variable, we cannot estimate this equation with city fixed-effects (Panel strategy) or its first-difference version (First-Difference strategy).

5.1 *Main results*

Table 2 reports results when we estimate Equation (16) using our Pool strategy. Column 1 shows OLS results. Since transportation networks are expected to be endogenous[6], column 2 reports Two-Stage Least Squares (TSLS) results using the number of 1810 postal road rays and the number of 1870 railroad rays as instruments.

Both OLS and TSLS results for our main explanatory variable, the Historic dummy, point out in the same direction and verify the second prediction of our model: Central cities with historic amenities house a higher proportion of the metropolitan population. In particular, the share of the central city population is 3.7 percentage points higher in cities with historic amenities (compared their 'non-historic' counterparts).

Table 2: Historic amenities and central cities, 1961–2011: Main results

Dependent variable:	Share of CC population	
	OLS [1]	TSLS [2]
Historic	0.0291^{b} (0.0116)	0.0374^{a} (0.0126)
Transport (CC highway rays, CC railroad rays)	✓	✓
Geography (CC and city area, elevation, ruggedness)	✓	✓
Past populations from 800 to 1800	✓	✓
Country dummies	✓	✓
Year fixed-effects	✓	✓
Adjusted R^2	0.41	
First-Stage F-statistic		36.59
		Instruments: 1810 road rays & 1870 rail rays

Notes: 3,474 observations (579 FUAs×6 years). Historic instruments are time-variant and computed by multiplying the number of each historic ray by the fraction of the network kilometrage in each country completed at each decade (excluding each city's own contribution). Robust standard errors are clustered by FUA and are in parenthesis. ^{a}, ^{b} and ^{c} indicates significant at 1, 5, and 10 percent level, respectively.

5.2 *Robustness checks*

Besides historic amenities, central cities might differ for other reasons. Following Brueckner et al. (1999), 'natural' amenities generated by topographical features such as rivers, hills, coastline, or protected green areas, and 'modern' amenities such as restaurants, sports facilities, theaters,

[6]As recent literature shows, reverse causation would be at work (Baum-Snow, 2007, Duranton and Turner, 2012). To deal with this identification issue, we rely on Instrumental Variables (IV) techniques to predict modern transportation using historic transportation networks. Since in some regressions we use panel data techniques with metropolitan and year fixed-effects, these instruments need to be time-variant. To this end, we follow Baum-Snow (2007) and Garcia-López (2012, 2019) by adopting a 'shift-share' approach *a la* Bartik (1991) using each historic (rail)road as the 'share' component and the evolution of the modern transportation network as the 'shift' component. Specifically, we use time-variant historic instruments computed by multiplying each time-invariant historic transportation variable by the fraction of the network kilometrage in each country completed at each year and excluding each city's own contribution. As shown by Garcia-López et al. (2015), the number of 1810 postal road rays and the number of 1870 railroad rays are relevant and exogenous historic instruments for both the number of highway rays and the number of railroad rays. However, since only highway rays significantly affected the central city population between 1961 and 2011, we only instrument the highway variable.

museums or universities might also shape the central cities. If cities with historic amenities have on average more of these other amenities than cities without them, then it would not be that surprising the significant effect of cities with historic amenities. In other words, if these other amenities are relevant, then the coefficient α_1 of Equation (16) would include their effects and, as a result, would be biased.

In order to take into account the effects of these other amenities, we include additional explanatory variables in Equation (16). To control for natural amenities, we add five variables. First, the percentage of green land area over the total land area of the central city is computed using information from the 2012 Corine Land Cover project. Second, a dummy that accounts for the existence of Natura 2000 protected sites. Third, a dummy for central cities with scenic walking areas and lookouts computed using geolocated information from TripAdvisor. Fourth, a dummy for central cities crossed by navigable rivers using information from WISE Large rivers and CIA World DataBank II shapefiles. Finally, we group the central cities according to their inland-coastal location to control for the presence of beaches using the Europe coastline shapefile.

To control for modern amenities, we consider five additional variables. First, the number of Michelin-starred and Bib Gourmand restaurants using information from the Michelin Red Guide. Using information from TripAdvisor, we geolocate and compute the number of non-historic museums, the number of 20th-century theaters and opera houses, and the number of spas and wellness centers. Finally, we consider the length of pedestrian streets using information and maps from OpenStreetMap.

Additionally, we also fear that some initial socioeconomic characteristics of the metropolitan areas might have also affected the level and evolution of the population in their central cities. In particular, those related to their size, income, and sectoral composition. To control for them, we consider four additional explanatory variables using data from the first available year: the 1961 metropolitan population, the 1981 income per capita, and the 1981 shares of employment in financial and business services and in non-market services.

Panel A of Table 3 reports results when controlling for natural amenities (column 1), modern amenities (column 2), and socioeconomic variables (column 3). In all three cases, the estimated coefficient of the Historic dummy remains positive and significant and with a value ranging between 3.2 and 3.7. In other words, after controlling for natural and modern amenities[7] and socioeconomic characteristics, we confirm the positive effect of historic amenities in central cities.

As previously commented, we agree with Brueckner et al. (1999) that historic amenities are largely exogenous. However, it is also true that most urban renewal policies and, in particular, the preservation of historic buildings are related to resident preferences for living close to such buildings and their claims for better quality neighborhoods.

To address these endogeneity concerns, we complement our IV strategy by also instrumenting historic amenities. Our idea is to predict the presence of historic buildings with variables stating

[7]A qualifier is important here. Despite natural amenities being largely exogenous, we admit that the first three natural amenities and all modern amenities are endogenous because their levels depend on the current patterns of population location. Furthermore, they may also be linked to historic amenities. This connection arises through the renovation of the central city's historic districts, which enhances historic amenities and may be responsive to the current socioecononomic levels (Brueckner et al., 1999).

the importance of cities in the past for political and/or religious reasons. Appendix Table C.1 reports cross-sectional probit[8] regression results showing the (marginal) effects of being important Roman, Medieval, or 1500–1850 cities on the probability of having historic buildings. We build these variables using information (1) from the DARMC project to identify the central cities that were important during the Roman period, and the Medieval period because they were major towns (circa 814, 1000, 1200 and 1450) or because they were bishoprics (circa 600, 900, 1000, 1200, and 1450), and (2) from Bairoch et al. (1988) (cities with more than 50,000 inhabitants between 1500 and 1850). Separated results in columns 1 to 3 show that Roman cities and major Medieval cities predict the Historic city dummy. However, joint results in column 4 show that only the Medieval city dummy has significant effects.

Table 3: Historic amenities and central cities, 1961–2011: Robustness

Dependent variable:	Share of CC population				ln(Population)	
	Panel A Other amenities			Panel B Endogeneity	Panel C Spatial scope	
	Natural	Modern	Socioeconomy	of Historic	Central city	Suburban
	TSLS [1]	TSLS [2]	TSLS [3]	TSLS [4]	TSLS [5]	TSLS [6]
Historic	0.0375^a	0.0332^a	0.0366^a	0.100^a	0.107^b	-0.0562
	(0.0129)	(0.0120)	(0.0120)	(0.0324)	(0.0523)	(0.0649)
Additional natural amenities	✓					
Additional modern amenities		✓				
Additional socioeconomic variables			✓			
Transport	✓	✓	✓	✓	✓	✓
Geography	✓	✓	✓	✓	✓	✓
Past populations from 800 to 1800	✓	✓	✓	✓	✓	✓
Country dummies	✓	✓	✓	✓	✓	✓
Year fixed-effects	✓	✓	✓	✓	✓	✓
First-Stage F-statistic	34.41	24.04	21.62	20.90	36.59	36.59
Instruments:						
1810 Postal road rays	✓	✓	✓	✓	✓	✓
1870 Railroad rays	✓	✓	✓	✓	✓	✓
Major Medieval town				✓		

Notes: 3,474 observations (579 FUAs×6 years). Historic instruments are time-variant and computed by multiplying the number of each historic ray by the fraction of the network kilometrage in each country completed at each decade (excluding each city's own contribution). Robust standard errors are clustered by FUA and are in parenthesis. ^{a}, ^{b} and ^{c} indicates significant at 1, 5, and 10 percent level, respectively.

In column 4 of Table 3 we report the results of estimating Equation (16) simultaneously instrumenting transportation variables (with 1810 road and 1870 rail rays) and the Historic city dummy (with the Medieval city dummy). The new TSLS estimated coefficient for the Historic dummy is significantly higher than its OLS abd TSLS counterparts in Table 2 and shows that the share of the central city population is 10 percentage points higher in cities with historic amenities (compared their 'non-historic' counterparts). As previously, these results confirm the second prediction of the model.

[8]Results are similar when we use linear regression.

Our third robustness check is related to the spatial scope of historic amenities. In our model in Section 2, we assume that cities are linear and amenities linearly decrease with distance to the CBD, i.e., $a(x) = \alpha - \beta x$. For simplicity, in our empirical approach, we assume that cities are made up of two parts: Central city and suburbs. In this spatial context, amenities only affect central cities and not the suburbs.

In Panel C of Table 3, we estimate Equation (16) using the log of the central city population and the log of the suburban population as dependent variables in columns 5 and 6, respectively. The new TSLS results show that (1) the central city population is statistically higher and increases more in central cities with historic amenities, and (2) the behavior of the suburban population is not statistically different between historic and 'non-historic' cities. As a result, these results confirm that historic amenities located in central cities only affect central cities and not the suburbs.

5.3 *Heterogeneity*

We now turn our attention to studying the heterogeneity of our results. First, we explore whether the effect of historic amenities on central city population change over time. Panel A of Table 4 shows TSLS results for 1961–1981 (column 1) and 1981–2001 (column 2) subperiods. Because the First-Stage F-static is low, column 3 reports Limited Information Maximum Likelihood (LIML) results for the 2001–2011 subperiod. The estimated coefficient of the historic city dummy remains positive and significant in all three subperiods, but it is slightly higher in the last one (0.05). This latter result could be related to the so-called 'urban revival', that is, the renewed interest in central cities and their amenities (Baum-Snow and Hartley, 2020, Couture and Handbury, 2020).

We also study whether the quantity of historic buildings affects the average results. To do so, in Panel B of Table 4 we estimate Equation (16) interacting the Historic dummy with different measures of quantity. In column 4 we consider the (number of) historic periods. As commented in Table 1 of Section 3, 177, 82, and 29 central cities have buildings only from one, two and all three historic periods, respectively. The estimated coefficients for the three historic interacted dummies reveal a 'cumulative' effect: The share of the entral city population is higher in cities with historic amenities and increases with the 'cumulative' number of historic periods. In column 5 we directly interact the historic dummy with the number of historic buildings. The related TSLS results show that the greater the number of historic buildings, the higher the share of the central city population. Jointly, these results confirm that quantity matters.

As explained in Section 3, 80 of our 288 cities with historic amenities are UNESCO-designated World Heritage sites because of their well-preserved and/or relevant historic buildings. This feature allows us to analyze whether the quality of historic amenities is important. Panel C of Table 4 reports TSLS results when we estimate Equation (16) interacting the Historic dummy with Unesco, a dummy equal to 1 for UNESCO-designated World Heritage cities, and with No Unesco, a dummy equal to 1 for 'non-UNESCO' cities. The estimated coefficients for Unesco and No Unesco historic cities confirm that historic amenities matter. They also show the effect is slightly higher for historic cities with UNESCO designation. Jointly, these results show that quality also matters.

Table 4: Historic amenities and central cities, 1961–2011: Heterogeneity

Dependent variable:	Share of CC population								
	Panel A Time			Panel B Quantity				Panel C Quality	
Years:	1961–1981 TSLS [1]	1981–2001 TSLS [2]	2001-2011 LIML [3]		TSLS [4]		TSLS [5]		TSLS [6]
Historic	0.0383^{a}	0.0368^{a}	0.0509^{a}	Historic × One period	0.0320^{b}	Historic	0.0273^{b}	Historic × Unesco	0.0455^{b}
	(0.0122)	(0.0136)	(0.0189)		(0.0138)		(0.0133)		(0.0217)
				Historic × Two periods	0.0459^{b}	Historic × Num. of buildings	0.00427^{c}	Historic × No Unesco	0.0348^{a}
					(0.0201)		(0.0022)		(0.0129)
				Historic × Three periods	0.0497^{c}				
					(0.0285)				
Transport	✓	✓	✓	Transport	✓	Transport	✓	Transport	✓
Geography	✓	✓	✓	Geography	✓	Geography	✓	Geography	✓
Past populations	✓	✓	✓	Past populations	✓	Past populations	✓	Past populations	✓
Country dummies	✓	✓	✓	Country dummies	✓	Country dummies	✓	Country dummies	✓
Year fixed-effects	✓	✓	✓	Year fixed-effects	✓	Year fixed-effects	✓	Year fixed-effects	✓
First-Stage F-statistic	43.91	29.20	14.65	First-Stage F-statistic	35.99	First-Stage F-statistic	35.55	First-Stage F-statistic	38.14
Instruments:				Instruments:		Instruments:		Instruments:	
1810 Postal road rays	✓	✓	✓	1810 Postal road rays	✓	1810 Postal road rays	✓	1810 Postal road rays	✓
1870 Railroad rays	✓	✓	✓	1870 Railroad road rays	✓	1870 Railroad road rays	✓	1870 Railroad road rays	✓

Notes: 1,737 observations (579 FUAs×3 years), 1,158 observations (579 FUAs×2 years) and 3,474 observations (579 FUAs×6 years) in regressions in columns 1 and 2, 3 and 4 to 6, respectively. Historic instruments are time-variant and computed by multiplying the number of each historic ray by the fraction of the network kilometrage in each country completed at each decade (excluding each city's own contribution). Robust standard errors are clustered by FUA and are in parenthesis. ^{a}, ^{b} and ^{c} indicates significant at 1, 5, and 10 percent level, respectively.

6. Do historic amenities weaken the suburbanization process?

The third prediction of the model shows that historic amenities weaken the suburbanization response to improved transportation. To test it, we focus our attention on highways because (1) the European highway network has experienced a notable expansion since the 1960s (Garcia-López, 2019), and (2) only highways affected the process of population suburbanization between 1961 and 2011 (Garcia-López et al., 2015).

Specifically, we depart from Equation (16) and add the interactions between Highway rays_{it} and No historic_i and Historic_i dummies as additional explanatory variables. As controls, we also add the interactions with the railroad rays variable. Since the two highway interactions are time-variant, we can now take advantage of the panel structure of our datasets and estimate the following equation using metropolitan fixed-effects (Panel strategy):

$$\begin{aligned}\text{Central city pop share}_{it} = & \beta_1 \times \text{Highway rays}_{it} \times \text{No historic}_i \\ & + \beta_2 \times \text{Highway rays}_{it} \times \text{Historic}_i \\ & + \beta_3 \times \text{Railroad interactions}_{it} + \epsilon_i + \nu_{it}\end{aligned} \tag{17}$$

where ϵ_i is the fixed-effect of city i and ν_{it} is the time-variant component of the error term.

With Equation (17), we estimate the effect of the number of highway rays on the share of central city population in cities with historic amenities (β_2) and without them (β_1). The third prediction of the model holds if (1) β_1 and β_2 are negative, showing that highway improvement cause a decline in the share of the central city population (i.e., population suburbanization) in cities without and with historic amenities, respectively; and (2) $|\beta_2| < |\beta_1|$, showing that highway improvements in cities with historic amenities cause less suburbanization.

6.1 Main results

Table 5 reports results when we estimate Equation (17) using Pool and Panel strategies (columns 1 and 2, respectively) and a First-Difference strategy (column 3). Column 1 reports TSLS results and columns 2 and 3 show LIML results when we instrument with the interactions between (No) Historic dummies and the 1810 postal road rays and the 1870 railroad rays. In all cases, First-Stage F-statistics are above or near the Stock and Yogo (2005)'s critical values or the rule of thumb (F>10).

All estimated coefficients are negative and significant ($\hat{\beta}_1 < 0$ and $\hat{\beta}_2 < 0$), indicating that highway improvements decrease the share of the central city population in both types of cities. The coefficients for the cities with historic amenities are smaller in absolute values ($|\hat{\beta}_2| < |\hat{\beta}_1|$), confirming the third prediction of our model: Historic amenities weaken the suburbanization response to highway improvements. In particular, in our preferred specification in column 2, results indicate that each additional highway ray decreases the share of the central city population by 7% in 'non-historic' cities and by 5% in historic cities. A simple test of equality of these two coefficients shows that the difference of 2 percentage points is significant.

Table 5: Historic amenities and highways, 1961–2011: Main results

Dependent variable:	Share of CC population			
	Pool TSLS [1]	Panel LIML [2]		First-Difference LIML [3]
Highway rays×No historic	-0.0931^{a}	-0.0746^{a}	Δ(Highway rays)×No historic	-0.0594^{a}
	(0.0229)	(0.0145)		(0.0097)
Highway rays×Historic	-0.0721^{a}	-0.0553^{a}	Δ(Highway rays)×Historic	-0.0403^{a}
	(0.0192)	(0.0083)		(0.0057)
|No H|-|H| highway coeff.	0.0210	0.0194^{c}	|No H|-|H| highway coeff.	0.0191^{b}
(F-test p-value)	(0.41)	(0.07)	(F-test p-value)	(0.02)
Railroad interactions	✓	✓	Railroad interactions	✓
Year fixed-effects	✓	✓	Year fixed-effects	✓
FUA fixed-effects		✓	FUA fixed-effects	✓
Geography, History, Country dummies	✓			
Historic dummy	✓			
First-Stage F-statistic	18.79	10.27	First-Stage F-statistic	15.11
Instr.: 1810 Postal road rays & 1870 railroad rays			Instr.: Δ(1810 road rays) & Δ(1870 rail rays)	
× No historic	✓	✓	× No historic	✓
× Historic	✓	✓	× Historic	✓

Notes: 3,474 observations (579 FUAs×6 years). Historic instruments are time-variant and computed by multiplying the number of each historic ray by the fraction of the network kilometrage in each country completed at each decade (excluding each city's own contribution). Robust standard errors are clustered by FUA and are in parenthesis. ^{a}, ^{b} and ^{c} indicates significant at 1, 5, and 10 percent level, respectively.

6.2 Robustness checks

As previously, we now check the robustness of the above results by (1) considering the effect of other types of amenities, (2) addressing the endogeneity of historic amenities, and (3) studying the effect of highways in the suburbs.

In Panel A of Table 6 we control for the effects of other amenities and socioeconomic characteristics. To do so, we add the interactions between the number of highway rays and each of the other amenities and socioeconomic indicators as explanatory variables. In column 1 we include the interactions with the natural amenities. Column 2 controls for the interactions with modern amenities. In column 3 we consider the interactions with the initial socioeconomic conditions of the cities. Since all three types of interactions are also endogenous, we use the interactions between the other amenities and socioeconomic indicators and the historic transportation networks (1810 postal road rays and the 1870 railroad rays) as additional instruments. Now the value of the First-Stage F-statistics ranges between 2.8 and 3.1 because of the high number of additional endogenous variables. LIML results in columns 1 to 3 confirm our preferred results in column 2 of Table 5: After controlling for natural amenities, modern amenities, and initial socioeconomic conditions, the suburbanization effect of highway improvements is significantly smaller in cities with historic amenities[9].

[9]As an additional robustness check we estimate separate regressions including each one of the other amenities and socioeconomic indicators. Results hold and are available upon request

Panel B of Table 6 reports results when we consider the endogeneity of the Historic city dummy. In particular, we estimate Equation (17) instrumenting the interaction of the highway rays variable and the (No) Historic dummies with the interactions of the historic transportation variables (1810 road and 1870 rail rays) and the Medieval city dummy (cities that were major towns and bishoprics between 814 and 1450 according to the DARMC project). LIML results in column 4 verify that the suburbanization effect of highways is significantly smaller for cities with historic amenities. In other words, after addressing (potential) endogeneity issues, historic amenities weaken the suburbanization response to highway improvements.

Table 6: Historic amenities and highways, 1961–2011: Robustness

Dependent variable:	Share of CC population				ln(Population)	
	Panel A Other amenities			Panel B Endogeneity	Panel C Spatial scope	
	Natural	Modern	Socioeconomy	of Historic	Central city	Suburban
	LIML [1]	LIML [2]	LIML [3]	LIML [4]	LIML [5]	LIML [6]
Highway rays×No historic	-0.1279^{a}	-0.0771^{b}	-0.1351^{c}	-0.1111^{a}	-0.2998^{a}	0.1057^{b}
	(0.0271)	(0.0332)	(0.0696)	(0.0331)	(0.0701)	(0.0443)
Highway rays×Historic	-0.0998^{a}	-0.0487^{c}	-0.1127^{c}	-0.0504^{a}	-0.1670^{a}	0.1096^{a}
	(0.0191)	(0.0295)	(0.0683)	(0.0060)	(0.0310)	(0.0235)
Highway rays×Natural amenities	✓					
Highway rays×Modern amenities		✓				
Highway rays×Socioeconomic variables			✓			
|No H|-|H| highway coeff.	0.0281^{b}	0.0284^{b}	0.0224^{c}	0.0607^{c}	0.133^{a}	0.00393
(F-test p-value)	(0.04)	(0.02)	(0.07)	(0.07)	(0.01)	(0.90)
Railroad interactions	✓	✓	✓	✓	✓	✓
Year fixed-effects	✓	✓	✓	✓	✓	✓
FUA fixed-effects	✓	✓	✓	✓	✓	✓
First-Stage F-statistic	2.85	3.29	3.10	6.49	10.27	10.27
Instruments: 1810 Postal road rays & 1870 railroad rays						
× No historic	✓	✓	✓		✓	✓
× Historic	✓	✓	✓		✓	✓
× Amenities/Socioeconomic	✓	✓	✓			
No interacted historic rays				✓		
× Major Medieval town				✓		

Notes: 3,474 observations (579 FUAs×6 years). Historic instruments are time-variant and computed by multiplying the number of each historic ray by the fraction of the network kilometrage in each country completed at each decade (excluding each city's own contribution). Robust standard errors are clustered by FUA and are in parenthesis. ^{a}, ^{b} and ^{c} indicates significant at 1, 5, and 10 percent level, respectively.

Finally, in Panel C of Table 6 we check whether the effect of highways is negative and different for central cities with/out historic amenities, as the theory predicts, and not for the suburbs. To do so, we estimate Equation (17) using the log of the central city population and the log of the suburban population as dependent variables in columns 5 and 6, respectively. LIML results confirm that highway rays decrease the central city population (column 5) and increase suburban population (column 6). Furthermore, the central city results in column 5 confirm that the suburbanization effect of highways is statistically smaller in cities with historic amenities. On the other hand, the growth effect of highways in the suburbs (column 6) is statistically the same in both 'non-historic' and historic cities.

6.3 *Heterogeneity*

We now analyze whether the smaller suburbanization response of cities with historic amenities is homogeneous when (1) considering the different periods of the suburbanization process, (2) the quantity of their historic buildings, and (3) the quality of the historic architecture.

Panel A of Table 7 shows results when estimating Equation (17) by subperiods. Column 1 reports TSLS results the 1961–1981 subperiod. Because the First-Stage F-statics are low, columns 2 and 3 report LIML results from the 1981–2001 and the 2001–2011 subperiods. Results show that highway effects on suburbanization were more important during the first 20 years of our study, and then they gradually reduced (but continued even in 2001–2011 of urban revival). Results also confirm that the effect for cities with historic amenities is smaller.

In Panel B of Table 7 we study whether 'more' quantity of historic buildings means 'less' suburbanization. Column 4 considers the interactions between highway rays in historic cities and three dummies for the number of historic periods (one, two, and three). Column 5 directly interacts with the number of historic buildings with the interaction between highway rays and the historic city dummy. In all two columns, we report TSLS results including the interaction between our historic instruments and the regimes as additional instruments. All results clearly show that quantity matters. In column 4 we observe that the suburbanization effect of highways decreases with the 'cumulative' number of historic periods. And results in column 3 confirm that the greater the number of historic buildings, the lower the suburbanization effect of highways.

Finally, in Panel C of Table 7 we analyze whether the quality of historic amenities is important. To do so, we estimate Equation (17) adding the interactions between the historic highway rays and the (No) Unesco dummies. TSLS results in column 6 confirm that quality matters: The suburbanization effect of highways is smaller in historic cities with UNESCO designation.

Table 7: Historic amenities and highways, 1961–2011: Heterogeneity

Dependent variable:	Share of CC population									
	Panel A Time			Panel B Quantity				Panel C Quality		
Years:	1961–81	1981–01	2001–11							
	TSLS	LIML	LIML		TSLS		TSLS		TSLS	
	[1]	[2]	[3]		[4]		[5]		[6]	
Highway rays×No historic	-0.100^{a}	-0.0413^{b}	-0.0150^{b}	Highway rays×No historic	-0.0726^{a}	Highway rays×No historic	-0.0817^{a}	Highway rays×No historic	-0.0753^{a}	
	(0.0171)	(0.0202)	(0.00741)		(0.0141)		(0.0160)		(0.0146)	
Highway rays×Historic	-0.0646^{a}	-0.0352^{a}	-0.0126^{a}	Hwy rays×Hist.×One period	-0.0698^{a}	Highway rays×Historic	-0.0697^{a}	Hwy rays×Hist.×Unesco	-0.0451^{a}	
	(0.0108)	(0.0114)	(0.00361)		(0.0155)		(0.0117)		(0.0082)	
				Hwy rays×Hist.×Two periods	-0.0483^{a}	Hwy rays×Hist.×Num. buildings	0.0017^{c}	Hwy rays×Hist.×No Unesco	-0.0633^{a}	
					(0.0069)		(0.0010)		(0.0010)	
				Hwy rays×Hist.×Three periods	-0.0440^{a}					
					(0.0085)					
Railroad interactions	✓	✓	✓	Railroad interactions	✓	Railroad interactions	✓	Railroad interactions	✓	
Year fixed-effects	✓	✓	✓	Year fixed-effects	✓	Year fixed-effects	✓	Year fixed-effects	✓	
FUA fixed-effects	✓	✓	✓	FUA fixed-effects	✓	FUA fixed-effects	✓	FUA fixed-effects	✓	
First-Stage F-statistic	13.22	4.44	5.80	First-Stage F-statistic	6.34	First-Stage F-statistic	6.31	First-Stage F-statistic	6.98	
Instr.: 1810 Postal road & 1870 railroad rays				Instr.: 1810 road & 1870 rail rays		Instr.: 1810 road & 1870 rail rays		Instr.: 1810 road & 1870 rail rays		
×No historic	✓	✓	✓	×No historic	✓	×No historic	✓	×No historic	✓	
×Historic	✓	✓	✓	×Historic×One period	✓	×Historic	✓	×Historic×Unesco	✓	
				×Historic×Two periods	✓	×Historic×Num. buildings	✓	×Historic×No Unesco	✓	
				×Historic×Three periods	✓					

Notes: 1,737 observations (579 FUAs×3 years), 1,158 observations (579 FUAs×2 years) and 3,474 observations (579 FUAs×6 years) in regressions in columns 1 and 2, 3 and 4 to 6, respectively. Historic instruments are time-variant and computed by multiplying the number of each historic ray by the fraction of the network kilometrage in each country completed at each decade (excluding each city's own contribution). Robust standard errors are clustered by FUA and are in parenthesis. ^{a}, ^{b} and ^{c} indicates significant at 1, 5, and 10 percent level, respectively.

7. Conclusions

In this paper, we examine the role of historic amenities on residents' location decisions between the city center and the suburbs and how they change during the last decades. With a simple theoretical model extended from the standard urban model and introducing exogenous amenities, we predict that cities with strong central historic amenities: (a) have steeper population density, (b) are more centralized (with a higher percentage of the population living in the city center), and (c) are less affected by the process of suburbanization due to transportation improvements that connect the city center with the suburbs. To measure these historic amenities, we geolocate more than 2,600 buildings from the Roman, Medieval, and Renaissance-Baroque periods located in 579 European cities.

We organize our empirical strategy to test the predictions of our model in three different exercises. First, distinguishing historic and non-historic cities and using a traditional density function, we study the spatial distribution of population within cities during the period 1961-2011. Second, applying the same distinction we estimate whether the cities with and without historic amenities concentrate different percentages of the population in their city centers. And third, using a quasi-experiment of the investments in new highways connecting the city centers and their suburbs, we test for different levels of suburbanization response in cities with and without historic amenities. Our findings show that, indeed, cities with historic buildings in their city centers have a steeper density gradient, are more centralized, and are less affected by suburbanization processes caused by infrastructure improvements. Interestingly, these results are stronger the greater the quantity and the quality of the historic amenities.

It is important to acknowledge that there could be other factors affecting spatial density, the degree of centralization, and the suburbanization processes such as local land use regulations (e.g. height restrictions) or tourism negative externalities. Due to the lack of data for all the cities in our database, we cannot include these aspects in our empirical analysis. However, if we assume that they might act as population dispersion forces, as a result, our estimates have to be considered lower bound estimates as they would be higher if we could control for them.

Our results add new evidence to the importance of European history to understand the modern shape of cities. Additionally, they confirm that central amenities are valued by some residents who, even in a continuous process of suburbanization, prefer to live in the city centers. As a consequence, more work is needed to better understand the potential segregation processes between the city centers and their suburbs that nowadays our cities might be suffering.

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Appendix A. Historic buildings in Europe

Figure A.1: Roman architecture in Europe

(a) Amphitheaters, theaters and circuses (b) Temples, triumphal arches and aqueducts

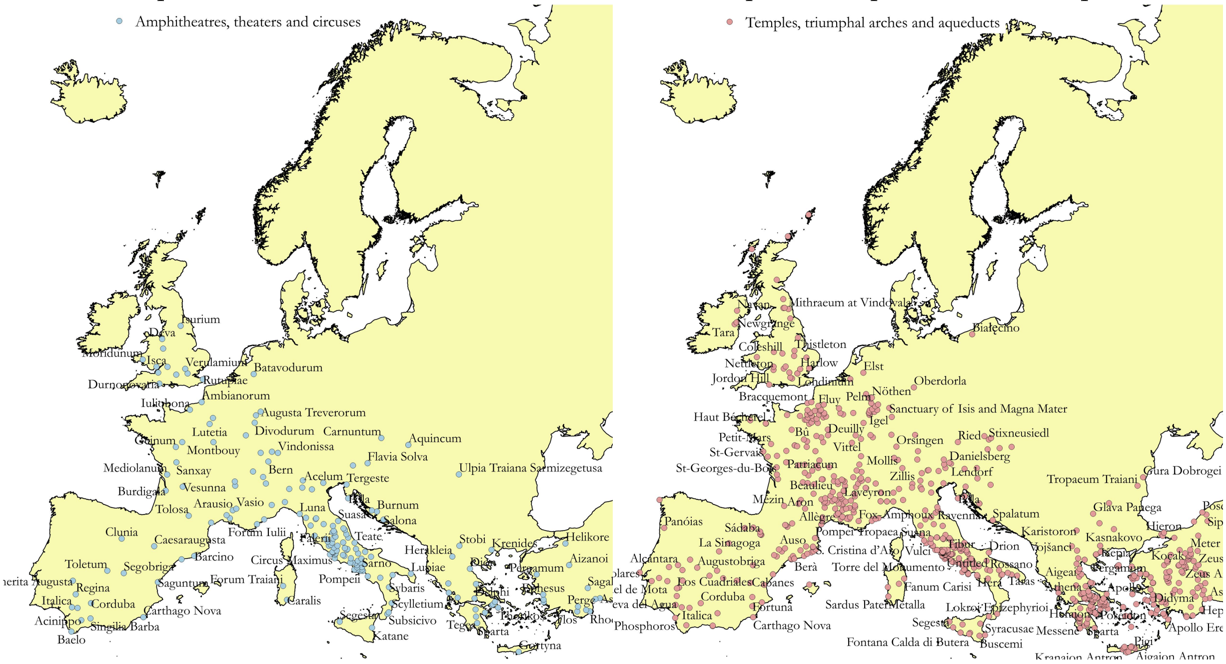


Figure A.2: Medieval architecture in Europe

(a) Castles

(b) Romanesque

(c) Gothic

Figure A.3: 16th–19th c. architecture in Europe

(a) Renaissance

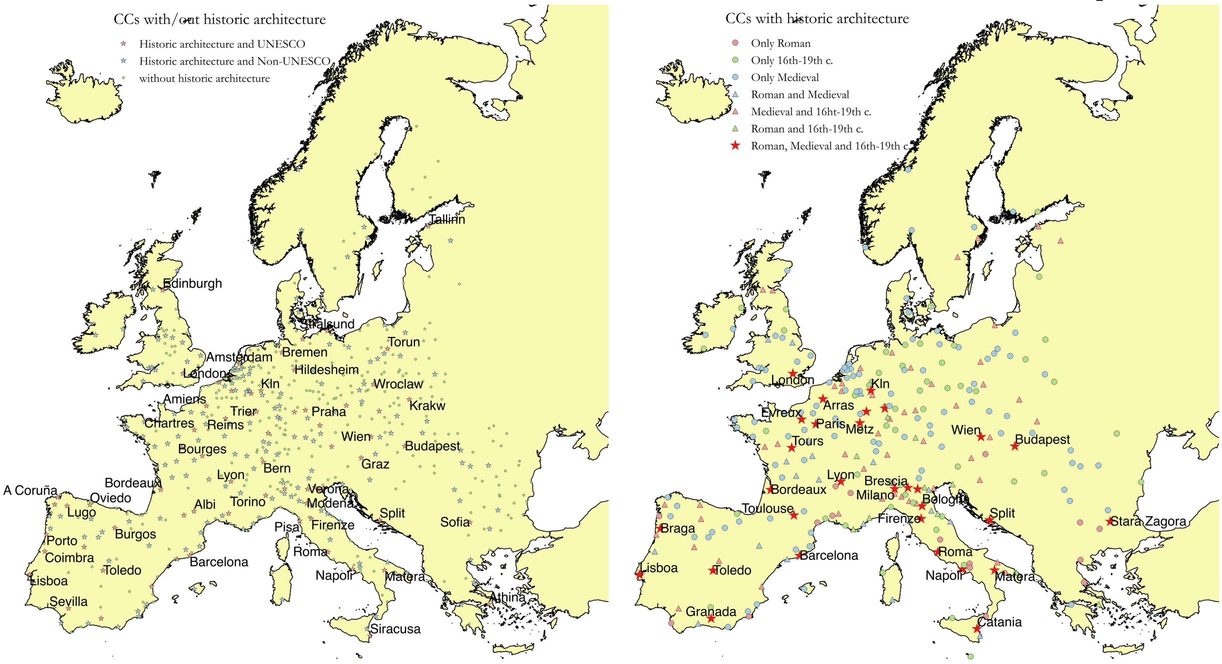
(b) Baroque

(c) Theaters, opera houses and concert halls

Figure A.4: Historic architecture in Europe's cities

(a) Cities with/out historic architecture

(b) Architecture from different historic periods



Appendix B. Population density functions

Table B.1: Historic amenities and density gradients, 1961–2001

Dependent variable	ln(Population density)					
Years:	1961	1971	1981	1991	2001	2011
	OLS	OLS	OLS	OLS	OLS	OLS
	[1]	[2]	[3]	[4]	[5]	[6]
Distance to the CBD × No historic	-0.01701[a]	-0.01606[a]	-0.01503[a]	-0.01433[a]	-0.01281[a]	-0.01131[a]
	(0.00118)	(0.00118)	(0.00116)	(0.00111)	(0.00103)	(0.00096)
Distance to the CBD × Historic	-0.02016[a]	-0.01978[a]	-0.01932[a]	-0.01881[a]	-0.01750[a]	-0.01578[a]
	(0.00069)	(0.00068)	(0.00067)	(0.00066)	(0.00064)	(0.00059)
Adjusted R^2	0.956	0.955	0.953	0.952	0.952	0.954

Notes: 35,060 observations (for 579 FUAs). All regressions include FUA fixed-effects. No historic is a dummy equal to one if there are not historic buildings in the city. Historic is a dummy equal to one if there are historic buildings in the city. Historic and No historic dummmies are included as explanatory variables in all regressions. Robust standard errors in parenthesis. When standard errors are clustered by FUA, all coefficients remain significant. [a], [b] and [c] indicates significant at 1, 5, and 10 percent level, respectively.

Table B.2: Historic amenities and change in density gradients, 1961–2001

Dependent variable	Δln(Population density)					
Years:	1961-1971	1971-1981	1981-1991	1991-2001	2001-2011	1961-2011
	OLS	OLS	OLS	OLS	OLS	OLS
	[1]	[2]	[3]	[4]	[5]	[6]
Distance to the CBD × No historic	0.00085[a]	0.00096[a]	0.00051[a]	0.00087[a]	0.00071[a]	0.00295[a]
	(0.00014)	(0.00013)	(0.00018)	(0.00012)	(0.00013)	(0.00034)
Distance to the CBD × Historic	0.00026[a]	0.00038[a]	0.00026[a]	0.00047[a]	0.00065[a]	0.00112[a]
	(0.00007)	(0.00005)	(0.00005)	(0.00010)	(0.00012)	(0.00017)
Initial ln(Population density)	-0.00567[a]	-0.00431[a]	-0.01282[a]	-0.04501[a]	-0.06125[a]	-0.16141[a]
	(0.00085)	(0.00089)	(0.00120)	(0.00177)	(0.00176)	(0.00366)
Adjusted R^2	0.416	0.280	0.290	0.269	0.282	0.552

Notes: 35,060 observations (for 579 FUAs). All regressions include FUA fixed-effects. No historic is a dummy equal to one if there are not historic buildings in the city. Historic is a dummy equal to one if there are historic buildings in the city. Historic and No historic dummmies are included as explanatory variables in all regressions. Robust standard errors in parenthesis. When standard errors are clustered by FUA, all coefficients remain significant. [a], [b] and [c] indicates significant at 1, 5, and 10 percent level, respectively.

Appendix C. Instrumenting history

Table C.1: Historic amenities and the importance of cities in the past: First-Stage results (Probit)

Dependent variable:	Historic city dummy			
	[1]	[2]	[3]	[4]
Main Roman city dummy	0.2302[a]			0.1143
	(0.0771)			(0.0711)
Main Medieval city dummy		0.3242[a]		0.3127[a]
		(0.0291)		(0.0309)
Main 1500–1850 city dummy			-0.0764	-0.0148
			(0.0881)	(0.0766)
Pseudo-R^2	0.18	0.27	0.17	0.27
Transportation	✓	✓	✓	✓
Geography	✓	✓	✓	✓
Past populations	✓	✓	✓	✓
Country dummies	✓	✓	✓	✓

Notes: 579 observations. Robust standard errors are clustered by FUA and are in parenthesis. ^{a}, ^{b} and ^{c} indicates significant at 1, 5, and 10 percent level, respectively.

2018

2018/1, Boadway, R.; Pestieau, P.: "The tenuous case for an annual wealth tax"
2018/2, Garcia-López, M.À.: "All roads lead to Rome ... and to sprawl? Evidence from European cities"
2018/3, Daniele, G.; Galletta, S.; Geys, B.: "Abandon ship? Party brands and politicians' responses to a political scandal"
2018/4, Cavalcanti, F.; Daniele, G.; Galletta, S.: "Popularity shocks and political selection"
2018/5, Naval, J.; Silva, J. I.; Vázquez-Grenno, J.: "Employment effects of on-the-job human capital acquisition"
2018/6, Agrawal, D. R.; Foremny, D.: "Relocation of the rich: migration in response to top tax rate changes from spanish reforms"
2018/7, García-Quevedo, J.; Kesidou, E.; Martínez-Ros, E.: "Inter-industry differences in organisational eco-innovation: a panel data study"
2018/8, Aastveit, K. A.; Anundsen, A. K.: "Asymmetric effects of monetary policy in regional housing markets"
2018/9, Curci, F.; Masera, F.: "Flight from urban blight: lead poisoning, crime and suburbanization"
2018/10, Grossi, L.; Nan, F.: "The influence of renewables on electricity price forecasting: a robust approach"
2018/11, Fleckinger, P.; Glachant, M.; Tamokoué Kamga, P.-H.: "Energy performance certificates and investments in building energy efficiency: a theoretical analysis"
2018/12, van den Bergh, J. C.J.M.; Angelsen, A.; Baranzini, A.; Botzen, W.J. W.; Carattini, S.; Drews, S.; Dunlop, T.; Galbraith, E.; Gsottbauer, E.; Howarth, R. B.; Padilla, E.; Roca, J.; Schmidt, R.: "Parallel tracks towards a global treaty on carbon pricing"
2018/13, Ayllón, S.; Nollenberger, N.: "The unequal opportunity for skills acquisition during the Great Recession in Europe"
2018/14, Firmino, J.: "Class composition effects and school welfare: evidence from Portugal using panel data"
2018/15, Durán-Cabré, J. M.; Esteller-Moré, A.; Mas-Montserrat, M.; Salvadori, L.: "La brecha fiscal: estudio y aplicación a los impuestos sobre la riqueza"
2018/16, Montolio, D.; Tur-Prats, A.: "Long-lasting social capital and its impact on economic development: the legacy of the commons"
2018/17, Garcia-López, M. À.; Moreno-Monroy, A. I.: "Income segregation in monocentric and polycentric cities: does urban form really matter?"
2018/18, Di Cosmo, V.; Trujillo-Baute, E.: "From forward to spot prices: producers, retailers and loss averse consumers in electricity markets"
2018/19, Brachowicz Quintanilla, N.; Vall Castelló, J.: "Is changing the minimum legal drinking age an effective policy tool?"
2018/20, Nerea Gómez-Fernández, Mauro Mediavilla: "Do information and communication technologies (ICT) improve educational outcomes? Evidence for Spain in PISA 2015"
2018/21, Montolio, D.; Taberner, P. A.: "Gender differences under test pressure and their impact on academic performance: a quasi-experimental design"
2018/22, Rice, C.; Vall Castelló, J.: "Hit where it hurts – healthcare access and intimate partner violence"
2018/23, Ramos, R.; Sanromá, E.; Simón, H.: "Wage differentials by bargaining regime in Spain (2002-2014). An analysis using matched employer-employee data"

2019

2019/1, Mediavilla, M.; Mancebón, M. J.; Gómez-Sancho, J. M.; Pires Jiménez, L.: "Bilingual education and school choice: a case study of public secondary schools in the Spanish region of Madrid"
2019/2, Brutti, Z.; Montolio, D.: "Preventing criminal minds: early education access and adult offending behavior"
2019/3, Montalvo, J. G.; Piolatto, A.; Raya, J.: "Transaction-tax evasion in the housing market"
2019/4, Durán-Cabré, J.M.; Esteller-Moré, A.; Mas-Montserrat, M.: "Behavioural responses to the re)introduction of wealth taxes. Evidence from Spain"
2019/5, Garcia-López, M.A.; Jofre-Monseny, J.; Martínez Mazza, R.; Segú, M.: "Do short-term rental platforms affect housing markets? Evidence from Airbnb in Barcelona"
2019/6, Domínguez, M.; Montolio, D.: "Bolstering community ties as a means of reducing crime"
2019/7, García-Quevedo, J.; Massa-Camps, X.: "Why firms invest (or not) in energy efficiency? A review of the econometric evidence"
2019/8, Gómez-Fernández, N.; Mediavilla, M.: "What are the factors that influence the use of ICT in the classroom by teachers? Evidence from a census survey in Madrid"
2019/9, Arribas-Bel, D.; Garcia-López, M.A.; Viladecans-Marsal, E.: "The long-run redistributive power of the net wealth tax"
2019/10, Arribas-Bel, D.; Garcia-López, M.A.; Viladecans-Marsal, E.: "Building(s and) cities: delineating urban areas with a machine learning algorithm"

2019/11, Bordignon, M.; Gamalerio, M.; Slerca, E.; Turati, G.: "Stop invasion! The electoral tipping point in anti-immigrant voting"

2020

2020/01, Daniele, G.; Piolatto, A.; Sas, W.: "Does the winner take it all? Redistributive policies and political extremism"
2020/02, Sanz, C.; Solé-Ollé, A.; Sorribas-Navarro, P.: "Betrayed by the elites: how corruption amplifies the political effects of recessions"
2020/03, Farré, L.; Jofre-Monseny; J., Torrecillas, J.: "Commuting time and the gender gap in labor market participation"
2020/04, Romarri, A.: "Does the internet change attitudes towards immigrants? Evidence from Spain"
2020/05, Magontier, P.: "Does media coverage affect governments'preparation for natural disasters?"
2020/06, McDougal, T.L.; Montolio, D.; Brauer, J.: "Modeling the U.S. firearms market: the effects of civilian stocks, crime, legislation, and armed conflict"
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