Urban Spatial Structure in Barcelona (1902–2011): Immigration, Spatial Segregation and New Centrality Governance

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Abstract

This paper investigates the impact of the city's urban spatial structure in shaping population density distribution over time. This research question is relevant in Barcelona because urban population grew at a sustained pace in various decades due to intense immigration inflows. When the urban spatial structure fails to behave as the backbone of population density distribution, population distribution can suffer from polarization problems. We conduct our empirical study using an urban monocentric framework, tracking the different spatial distribution patterns of the overall population and a few selected urban communities in light of the degree of attractiveness of the central business district (CBD). To this end, we construct an original database by each district in Barcelona from 1902 to 2011 and perform an econometric analysis. Our results reveal that the urban spatial structure continued to be a crucial determinant over time for shaping the overall population distribution in Barcelona and in almost all selected communities. However, its importance fluctuated over time, bottoming out in the 1950s–1960s, and whose resurgence was mostly driven by the political initiative to create a new centrality in the urban periphery. This policy reinforced the attractiveness of the CBD, resulting in the de-facto avoidance of urban polarization.

Keywords Urban spatial structure · Population · Migration

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Introduction

Barcelona (Spain) has been a preferred destination for internal and international migrants since the beginning of the twentieth century.¹ The city represents an interesting case in the Mediterranean region given the availability of urban data on the presence of foreign communities since the early twentieth century. Notably, an impressive immigration arrival rate was recorded for the period from 1991 to 2008, when the share of foreign immigrants surpassed 20% of the population (Fig. 1).

The longstanding tradition of Barcelona as a migration destination makes this city a particularly good laboratory for understanding how an important increase in population size not only impact the socio-economic composition of the population but also has an influence on the possible rise or consolidation of spatial segregation.²

A number of historical studies have highlighted the ways socioeconomic events affect both the spatial structure and the social and demographic makeup of an urban population. Lévêque and Saleh (2018), for example, show that state industrialization in Cairo around the 1850s attracted rural migration inflows, but observe that this event deepened spatial segregation between Muslims and non-Muslims. In the case of Berlin, Hornung (2019) shows that the heterogeneous composition of migrant inflows (above all skilled immigrants) to Berlin's newly developed city quarters had beneficial results in economic terms by nurturing the creation of job-complementarities with natives.

Our analysis aims to understand the ways in which the urban spatial structure of Barcelona drove its population density distribution from 1902 to 2011. To this end, we focus on the population density distribution as well as the density distribution of a number of selected communities composing the total population. We approximate those density distributions by considering the spatial distribution of citizens in Barcelona according to their district of residence. The same holds when we refer to the density distribution of communities composing the total population. To achieve our objective, we investigate the determinants of those distributions (urban spatial structure being one of them) and its evolution over time in light of the progressive entry of important immigration flows (initially from elsewhere in Spain, and then from abroad) and the implementation of an administrative urban decentralization process from the late 1980s onward.

Through this analysis we refer to an urban monocentric model and approximate the spatial urban structure with the spatial distance between each spatial urban unit (namely the centroid of each urban district) and the central business district (CBD). Keeping this spatial structure in mind, our representation of the attractiveness of the CBD is

¹ According to data availability by district, we organize resident communities in Barcelona according to the individuals' place of birth. The main community consists of *Catalan* natives (born and living in Barcelona or Catalunya). We identify as *Spaniards* individuals born in the rest of Spain and migrating to Barcelona. Finally, *Immigrants* are individuals born out of Spain and migrating to Barcelona. Unfortunately, our data sources do not always provide separate information between Catalans born in Barcelona or arrived from the rest of the province in Catalunya. Hence, because of this technical limitation, we drop this distinction and we include all of them in the *Catalan* community. Still for data incompleteness at spatial level over time, we center our analysis on the city of Barcelona without taking into account all the municipalities in the Barcelona Metropolitan Area.

² Migration flows provide evidence that (urban) communities change, and differ in terms of cultural, social, and, potentially, economic background.

Fig. 1 Share (%) of foreign immigrants in Barcelona (1902–2011) (Source: Our database)

embedded in the estimated elasticity associating the population density distribution with the distance to the CBD.

The magnitude of the estimates of that elasticity turns out to be crucial for our analysis. It stands for the sensitivity of the population density distribution with respect to the distance to the CBD (of course, conditional to other covariates that could be included in the estimation), and quantitatively approximates the changes in population density each time we approach or set far apart from the CBD. The magnitude indirectly gives a flavor of the relative propensity of population to set close to the CBD, or, in other words, their degree of preferences for choosing a place of residence in the proximity to the CBD.

Referring to the contribution of the literature we discuss in “[Framework of Analysis and Research Hypothesis](#)” section, this elasticity is not expected to be constant over time, particularly when a city experiences an important rate of population growth and needs to accommodate the new incomers. Under these circumstances, there is an increased risk that the CBD loses its centrality in shaping population distribution, thus leading to situations of spatial polarization in its urban premises (as ethnic enclaves or ghettos, for instance).

The relevance of this research question for the case of Barcelona stems from an important need to better understand how the urban spatial structure of the city of Barcelona reacted to considerable national and international migration inflows, providing insights about the consequent creation (or not) of enclaves that could lead to social fragmentation and, indirectly, social instability in city governance.³

³ We focus here on the city of Barcelona, without taking into account the corresponding metropolitan area (AMB). While we consider the latter in our discussion, the same type of long-run data is not available for this larger zone. The AMB was officially established in 2010, although an informal definition of this area (in administrative terms) was already in use as early as the 1960s. At present, the AMB covers a total surface of about 634 km², 48% of which makes up the urban area. It includes 36 municipalities surrounding Barcelona. According to administrative data (*padró*), the size of the overall population of the AMB is about 3.2 million inhabitants (2015), 49% of whom live in Barcelona (in 1991 the same percentage was about 52%) (Source: <http://www.amb.cat/s/home.html>). The data at hand thus highlight the central role of Barcelona in the AMB. Its relative importance as a capital with respect to the other cities in the AMB has long been sizable; indeed, it still accounts for about the half of all the population in the AMB.

Barcelona proves to be a valuable setting thanks to the unique availability of spatial data for different communities. By spatial segregation we mean the propensity of various resident communities to concentrate in different (and separated) urban spatial units (known here districts). Identifying the determinants of the distribution for each urban community – or in the general population – requires identifying the determinants of each community's density distribution, among which we include the urban spatial structure. The scope of this exercise is to be able to detect similarities or differences according to how the urban spatial structure shapes the community density distribution. Crucially, this outcome means approximating whether population communities encompass the accessibility to (expected) urban points of attraction (the CDB, for instance) in a different manner. Such an approach also implies managing heterogeneity issues associated with the coexistence of various communities and different types of people (e.g., workers, retirees, etc.) in each community who may indirectly share similar or different priorities in selecting their place of residence, which, by aggregation, translates into similar or different shapes for community density distribution.⁴

Our quantitative empirical analysis relies on a monocentric urban model. In particular, this framework allows exploiting the idea of accessibility as the main driver in citizens' location decisions. To run our estimations we build an original database by merging official administrative records at the city-district level (for a number of years), which provides information on the population composition (number, age, gender, place of residence and of origin) for each district in Barcelona. Our data sources combine *census* data with local administrative information (*padró*), but the lack of complete data with spatial information prevents us from having a full and balanced panel for the period we are taking into account. The choice to focus the analysis at the district level is justified by two principal concerns. First, the need to work with a spatial unit that is sufficiently flexible to compare results across decades. Second, the ability to account for a centrality reform that facilitated important structural administrative initiatives aimed at avoiding the creation (or consolidation) of segregation spaces in the city from the 1980s onward.

Empirical evidence suggests that changes in Barcelona's urban spatial structure reduced the attractiveness of the CDB up the 1960s. This was mostly due to the annexing of surrounding municipalities that became part of urban districts such as Horta or Sarrià, but also the spreading of shanties due to the first waves of Spanish immigrations, as discussed in "[Barcelona: Migration at a Crossroads](#)" section. This trend, however, later reversed.

Our results highlight the strength of the CBD in attracting rich or qualified people, as an aspect that differentiates European from US cities; in the latter the wealthy are more likely to live far from the center so as to enjoy larger dwellings while paying for commuting costs (Duranton and Puga 2015). In Barcelona, the combination of novel urban governance and population inflow enhanced rather than dampened the attractiveness of the CBD. In addition to reinforcing the role of the CBD, it was effective in endowing the peripheral areas with amenities and services that favored the spread of the population, but also limited the consolidation of spatial segregation.

The remainder of the paper is organized as follows. Second section outlines the theoretical framework underpinning our analysis and presents our research hypothesis.

⁴ For instance, different income profiles. The propensity of different communities to cohabit the same urban spatial unit is discussed in García-López et al. (2020).

Third section provides an overview of Barcelona as a destination for migrants from an historical perspective. Fourth section introduces our database and some preliminary statistics, while Fifth section discusses the quantitative results of the econometric exercise. Finally, sixth section concludes the paper.

Framework of Analysis and Research Hypothesis

The choice for a place of residence in cities is not random, but are shaped by a number of economic and social factors. Various contributions in the literature point to the relevance of the economic status of a neighborhood in making such a decision, together with other social features such as education level, labor skills, or individuals belonging to the same ethnic group and living in the same spatial unit (Duranton and Puga 2015). Within this body of work, Epifani and Nicolini (2013) and Epifani et al. (2020) develop a probabilistic approach (applicable to different spatial scales, namely either urban or regional levels) to assess the determinants for population density distribution. They approximate individual preferences relying on features that define neighborhood status (following Rosenthal and Ross 2015), as well as accessibility, intended as individuals' ease of access to amenities or other facilities in which they are interested. A fundamental working hypothesis is that location decisions are dependent on accessibility. More specifically, individuals decide where to reside in light of available options for traveling to their place for work or leisure purposes. This empirical application (focusing on Massachusetts) concludes that despite the rising importance of neighborhood status features in location decisions, the spatial structure approximating the degree of accessibility to a point of interest still plays a dominant role in shaping individual location choices. The decision on the part of Epifani and Nicolini to focus on Massachusetts was driven by the possibility of exploiting a monocentric spatial structure *à la* von Thünen, fixing Boston (and the correspondent core census tract, in accordance with the scale of analysis) as the CBD.

A monocentric model allows to deliver reasonable, but often incomplete, predictions (Duranton and Puga 2015). This strategy involves associating the idea of accessibility with ease (for individuals) of reaching the central business district (CBD), which is expected to be the centripetal urban point for work and leisure. Therefore, the idea of accessibility shapes the study of the importance of distance from the CBD as a determinant in location choice. In this sense, the model in this paper builds on the von Thünen orthodox framework as applied in the Alonso-Mill-Muth version. In the framework of a linear city, individuals maximize their utility function that depends on the consumption of land and a composite good for which they need to commute daily to the CBD, paying transport costs. In addition, they also travel to the CBD to supply labor and to obtain income (Fujita and Thisse 2013). The reading proposed by Duranton and Puga (2015) of this setting indicates that this model is able to accommodate several features of the real world, particularly the coexistence of heterogeneous agents in the same place, but also recurrent improvements in the urban transport system over time. In fact, changes in a transportation system directly influence the degree of accessibility, and this in turn has an impact on housing and land prices. Yet the increasing heterogeneity of residents makes it more complicated for the CBD to accommodate employment for everybody, making the land structure less monocentric.

However, the canonical model *à la* Alonso-Mills-Muth fails to consider that local amenities and other points of interest at a city level can also drive the urban population

distribution. Instead, this dimension is taken into account by the framework of the analysis of the so-called the Chicago School (as discussed by Burgess 1929, and in Park and Burgess 1925), according to which the important negative amenities at the city level makes that the income of residents increases with the distance from the city center. Indeed, Burgess (1929) approximates the structure of a city in five concentric circular zones: Zone 1 (the center) is the CBD, Zone 2 a transition zone, Zone 3 hosts work housing, Zone 4 is a place for better residences, and zone 5 the commuters' zone.⁵

According to Burgess's approach, households locate according to their own preferences for the characteristics of a neighborhood (distance from CBD but also amenities) subject to their income constraints. Hoyt (1964) emphasized that the idea of amenities has to be understood in a larger perspective stemming from naturalistic point of interests by also including good schools or good public services that contribute to shape the neighborhood quality and prestige.

Referring to the previous two frameworks of analysis, our contribution provides an empirical assessment of the determinants shaping population (and community) density distribution in Barcelona over time. We take into account the degree of accessibility to the CBD and other salient socioeconomic points of interest at the town level (above all with an important economic relevance of the economy of the city) without neglecting that individual location choices are driven by features of neighborhood status (natural amenities, for instance). In this respect, the great challenge of our analysis is to perform the empirical analysis for a period covering more than a century, for which data availability and comparability is an issue. In order to provide a consistent framework of analysis, we first need to identify a CBD that turns to be as such for Barcelona through a century. As discussed in García-López et al. (2020), the monocentric structure for Barcelona holds when selecting Plaça de Catalunya as the CBD. Second, beyond the CBD, the economic interest of the city of Barcelona has always been connected with the Port of Barcelona (discussed in "Barcelona: Migration at a Crossroads" section) and, hence, we need to include this point of interest in our framework. Finally, we have no complete data series to track specific features at a district level over time; thus, we opt to take into account them all by using the fixed effect at a district level and a proxy for the degree of accessibility of the district by means of the bus density.⁶ Overall, our first research hypothesis involves performing a quantitative

⁵ Recent literature uses the Chicago models (à la Burgess and Hoyt) to understand the spatial structure and spatial evolution of American cities. This is the case, for instance, of Meyer and Esposito (2015) for the city of Los Angeles (California), and Lee et al. (2020) for Columbus (Ohio). However, in various empirical studies, the sequence of the city zones as formulated by the Chicago school has been reverted by the Great Inversion Hypothesis (Ehrenhalt 2012) for which the distant gradient from the CBD presents a greater demand of high-income people for location residence in the city center. An example is Delmelle (2019), which exploits the Chicago models to explore the evolution of the sociospatial fragmentation in 50 US metropolitan areas for the period 1990–2010, but whose results turn to be more in line with the Great Inversion Hypothesis. The latter setting allows for understanding the back-to-the-city population displacement yielding to gentrification, according to which the center hosts the upper class and, overall, a general increase of the demand for an urban lifestyle. However, the recent population shift in a few US metropolitan areas cannot fully discard that they took place in a randomized manner, as posited by the approach of the Los Angeles school (Dear 2002).

⁶ In econometrics, the fixed-effect technique brings the advantages of controlling district characteristics featuring the spatial unit status as a whole and allows the difference between two spatial units (here districts). Put differently, this technique allows the difference between district 1 and district 2 in a city because we peg to each of them the fixed effect that is a specific group of features (natural amenities, social services, as well as the reputation effect, for instance) as a whole influencing the quality of life in that place. Each district fixed effect being assigned in an individual manner allows for these differences.

econometric analysis to estimate the elasticity of the main determinants of the population density distribution in Barcelona over time. As anticipated in “[Introduction](#)” section, the elasticity is our quantitative measure that links population (or community) density distribution to each of the selected determinants. The relative size of estimates as well as their statistical significance emphasize the main factors shaping population density distribution according to our hypothesis *H.1*:

H.1 Three main potential determinants are expected to shape the population density distribution in Barcelona over time: the urban spatial structure, represented by the elasticity of the distance from each urban district to the CBD; the accessibility to the Port, intended as economic center and measured by the elasticity of the distance from each district; and features at district level.

One relevant result we expect by performing the econometric exercise for *H.1* is quantifying the importance of the urban spatial structure; hence, the distance to the CBD over the other determinants we assume to shape population density distribution in Barcelona over time. This outcome is of the utmost relevance because previous studies have not explicitly centered on change in the degree of attractiveness of the CBD over time for understanding the variation in the spatial distribution of the overall population or, possibly, different communities. This open question is relevant since whenever the CBD loses its attractiveness, the urban spatial structure no longer plays a role in driving population distribution. This has important consequences in terms of social cohesion and, above all, in inducing an eventual rise in ethnic or social enclaves. Tackling this issue in the case of Barcelona is crucially connected to the considerable transformations that have occurred in population size. In “[Barcelona: Migration at a Crossroads](#)” section we discuss in further detail the important immigration inflows experienced by the city in the last century, first from the rest of Spain and then from other parts of the world. Generally, and in line with the predictions of Muth (1969), small population size typically sees a negative value of elasticities between population density and CBD distance. Empirical evidence presented in the literature confirms this finding for US and Canadian cities, where CBD attractiveness declines when population size increases (see, for example, Edmonston et al. 1985; Bunting et al. 2002). Such change is often due to improvements in the transport system, which favors the decentralization process. In the wake of the Chicago school framework, the contribution by Hoyt (1964) is of interest for the case of Barcelona. In this study, the author tackles the question of the evolution of the spatial urban structure when population grows and cities suffer from natural limitations (mountains, sea ...). In these circumstances the spatial structure of the cities cannot structurally change: the increase of population size pushes expansion in the city instead of rural areas outside the city. It could also fuel verticality in buildings or produce displacement movement between city zones, often driven by the ethnic dimension (white vs non-white, as in the case of the US) that mostly reflects important differences in average incomes. The effect of this expansion towards the rural areas goes back to the idea of Zone 5 in the Burgess framework (the commuter area), whose existence is guaranteed by the existence of transport infrastructures and possibly the public transportation system. When analyzing the causes and effects of the change of the city’s spatial urban structure, Hoyt (1964) discusses Barcelona as an example of expansion to the rural area jointly with the creation of the subway (the first metro lines

goes back to 1920s). Once more, this expansion towards the peripheral areas generates a reduction of the attractiveness of the CBD, yielding a reduction in size of the gradients of the distance from each point of the city to the CBD. Hence, plugging this question into our setting, our second research hypothesis turns to be the following quantitative exercise:

H.2 A sizable increase of population growth affects population density distribution and generates a change in the urban spatial structure in Barcelona that is expected to be embedded in variations of the estimated elasticity of the distance between each urban district and the CBD over time.

The collapse of the monocentric urban spatial model due to the loss of attractiveness of the CBD (here measured by the reduction of the absolute value of the elasticity of the average distance between each district) entails important consequences, yielding the creation of urban enclaves driven by income or racial components, for instance. The creation of these enclaves due to a polarization effect is detrimental to social urban cohesion. Lee et al. (2020) proposed an insightful analysis about this last effect when the population density distribution linked to the citizens' urban location decision is subject to two different trade-offs: the distance-dependent variable versus localized neighborhood amenities. In this situation, initiatives that yield a reduction of travel time (among places of different value) can help to reduce the probability of spatial polarization in case the accessibility to the CBD is a dominant factor for population density distribution. Instead, if neighborhood amenities are dominant the spatial segregation can be limited or controlled by investing in less favorite neighborhoods to push their attractiveness.

In line with the previous ideas, in Barcelona in the 1980s, the city sought to limit the creation of segregation spaces through the implementation of an urban development plan. The political aim was to elaborate a well-formulated urban organization that would improve living conditions in all districts by physically remodeling their structure, creating cultural spaces and other accessible amenities, and endowing each area with local public services. The idea of a “new centrality”⁷ of the city aspired to make the urban periphery attractive. An important push in this direction was the implementation of a program for the requalification of the city plan in view of the Olympic Games (1992). Previously, the city council had been active to eradicate the problem of the shantytown in a few districts, including the one that would have hosted the Olympic town. The *new centrality program* came into force from 1986 onwards and listed an important number of interventions whose main target was to improve the quality of the living conditions in each of the ten districts in Barcelona. The spirit behind this program was a radical reform of the urban environment of the city that did not limit benefits to the CBD only. The rationale of those initiatives was to reduce the discriminating (urban) differences between the center and the periphery of the city with a target to create a centrality for the periphery. This objective was achieved by the decentralization of several administrative services at the district level, such as the logistics and organization of public compulsory education or public healthcare services, but also cultural

⁷ This notion of “new centrality” is discussed in Salet and Savini (2015). The so-called Barcelona model is well developed in Marshall (2004).

and others leisure activities. Exporting features typical of downtown areas to the periphery helps avoid the creation of ghettos or enclaves since citizens' residence decisions cannot be driven by just the difference in terms of public services or amenities enjoyed downtown or in just one district. In addition, in the same years, the central administration of the city council was extremely active in improving the public transport networks to favor accessibility not only downtown but for all town districts (Ferrer and Nel-lo 1998; Garcia-Lopez et al. 2019).

Our empirical framework allows producing quantitative results in this respect. We are able to track the evolution of the attractiveness of the CBD and eventually assess whether the district or neighborhood initiatives limited the decline of the CBD attractiveness (represented by the drop in the absolute value of the elasticity of the distance between the place of residence and the CBD) and hence contrasted the polarization effect. This latter outcome can be achieved by estimating and comparing the elasticity of the distance between the place of residence (namely districts) and the CBD for the overall population and selected communities living in Barcelona at different moments in time. The effectiveness of the new centrality policy appears if the estimated elasticity associated with the distance from the CBD, for both the overall population and for individual communities, does not follow a monotonic decreasing trend. Preventing a progressive decreasing trend for all communities implies they all experience the same degree of physical accessibility to the CBD and physical proximity to district public services, meaning that no community is spatially segregated at an urban level. Therefore, on the basis of the previous arguments we can summarize our third research hypothesis as a quantitative approximation of:

H.3 The effectiveness of the new centrality policy, in contrasting the loss of attractiveness of the CBD (in shaping population density distribution), can be approximated by a non-decreasing trend of the absolute size of the estimated elasticity of the distance between each district and the CBD. If so, this policy is effective in limiting the creation of ethnic or social enclaves if the previous trend can be replicated for all communities composing the urban population.

Barcelona: Migration at a Crossroads

A key evidence underpinning our analysis is the impressive population growth in Barcelona over one century. Up to the 1960s Barcelona hosted important migration inflows from the rest of Spain and, later, from out of Spain. Barcelona has been an important trading center since Roman times. The strategic position in the Mediterranean area made this city a crossroads for trade and migration flows. On the one hand, industrialization experienced by the city (and its surroundings) in the nineteenth century, based mostly on the textile industry, attracted a significant number of immigrants from the rest of Spain, mostly from the southern regions. In fact, in 1930 about 56% of the residents were not born in Barcelona. The biggest group was made up of Valencians, living in the Barceloneta neighborhood, close to the port (Silvestre et al. 2015). On the other hand, the port itself made Barcelona an important stopover for maritime transit towards South America. Indeed, Barcelona has long been a place of transit and host to foreign

migration flows (Ibarz Gelabert 2010). The works of Silvestre et al. (2015) and Ibarz Gelabert (2010) show the salience of the abovementioned national immigration. Migrants were attracted by employment opportunities and high wages in the greater Barcelona area. Vacancies in the non-agricultural sector were especially important, an alternative option to the agricultural and mining sectors in the southern Spanish provinces of Almeria or Murcia. According to Silvestre et al. (2015), the considerable migration flows of the 1930s occurred simultaneously with a consolidation of Catalan identity that caused self-selection into non-Catalan groups, similar to that observed among cross-border migrants in other European Countries (e.g., the Irish in Great Britain or Italians in Belgium, France, or Germany).⁸

To these numbers, it is important to add immigration from abroad. According to Barcelona's Statistical Yearbook, which records the transit of individuals through the ports, in 1902 approximately 1670 foreign individuals entered Barcelona from different places around the world, but only 1140 left to move to other destinations. In their study of migration in Spain, Bover and Velilla (1999) show that up until the 1980s, migration in Spain accounted, on average, for 0.02% of population, while statistics for the city of Barcelona reveal that the share of immigrants had already reached about 2% of the population in 1902 (see Fig. 1).⁹

Figure 1 refers to international migration in Barcelona only, and shows that for most of a century it held constant, with an impressive rise from 1986 onward.

According to Busquets (2004), southern European cities that have experienced important changes in population composition (not just associated with birth rates) share the characteristic of complex urban development, and particularly, a distinctive pattern of residential development.¹⁰ Barcelona is no different. In the 1950s and 1960s, massive migrant inflows from the rest of Spain fueled the

⁸ There exists an interesting literature focusing on the composition of migration inflows in Barcelona (or Barcelona Metropolitan Area) as in Oyón et al. (2001); López-Gay and Recaño (2015) and Galeano and Bayona i Carrasco (2015). These studies are able to draw a very complete picture of the population composition and spatial distribution of incoming communities in different decades. They all agree that the first immigration wave in Barcelona (before the Civil war) displays a degree of spatial segregation lower than the second one which is mostly composed of immigrants from the Spanish southern regions. As for foreign immigrants, denser settlements can be found in neighborhoods with a consolidated tradition for hosting incoming residents (first from the rest of Spain and, later, from abroad) both in Barcelona and its Metropolitan areas. Also education of incoming groups changes across time above all when referring to the international migrants that were (on average) more qualified in the first wave. Unfortunately, this piece of evidence is available for selected moments in time and not all qualifying features of incoming residents are available with a spatial dimension. Therefore, for our analysis, we need to rely on other sources with a spatial dimension more consistent over time at the cost of a less rich information.

⁹ One important limitations of this analysis is the lack of complete and regular data with spatial features for the overall period. Official statistics providing data with the spatial detail are not regularly released. Therefore, our sample includes the available information providing data at district level in Barcelona for years 1902, 1947, 1965, 1970, 1986, 1991, 2001, 2008 and 2011. For years 1912 and 1920 only some data at district level are available.

¹⁰ To cite a few examples: Milan and its periphery receiving large national and then international migration inflows (Foot 2001); Marseille and Toulouse accommodating structural changes in the social and economic status of citizens (Mansuy and Maryse 1991), Lyon managing increasing commuting flows and struggling against a "paradox of scale" (Dumolard 1981), and Montpellier transforming from regional capital to technopolis and, finally, metropolis (Volle et al. 2010).

clustering of the immigrant community in peripheral areas of the city. Such migration gave rise to “shantyism,” or the creation of informal satellite communities that adjoined the established core of the city (i.e., today’s Eixample district),¹¹ among other forms of peripheral growth. Shantyism was a direct consequence of the arrival of thousands of job seekers, which Barcelona’s formal real estate system was unable to accommodate, allowing the amount of substandard housing to skyrocket.¹² Spreading from the hills surrounding the city up to Montjuïc, along the seafront, and some spaces in Eixample, Barcelona’s shanty communities were the first enclaves in which immigrants began to cluster, thus marking the starting point of our analysis.

Using data on dwelling properties, we are able to draw a general picture of the urban change that occurred in Barcelona (Fig. 9 in the Appendix). With reference to the city’s urban structure in 2011, consisting of 73 neighborhoods organized in 10 districts, for each selected year we mapped the percentage distribution of the stock of residences across the various neighborhoods.

Although we can produce maps from 1900 to 2011 according to available data, we focus our discussion in particular on three milestone years:

- 1940, the end of the Spanish Civil War and the beginning of the Francoist regime as well as the end of the first immigration wave.
- 1970, the end of the high internal migration period; and
- 2011, a representative year of the current situation, following both the 1979 introduction of democratic municipal governments for the implementation of urban planning and the real estate bubble during Spain’s profound internationalization.

The changing distribution of the stock of residences indicates that Barcelona enlarged its urban territory over time, spreading inland. The urban core — the place with the highest concentration of dwellings — has similarly expanded. In 1920, the inner core was El Raval,¹³ which now corresponds to part of the historical center of the city. The construction of new properties progressively displaced the residential barycenter away from the Roman perimeter outward. By 1940, the core residential neighborhood was Eixample, whereas in recent decades it has shifted upwards towards the neighborhood of Gràcia.¹⁴

Along with this movement, the construction of residential dwellings in peripheral areas belonging to the city’s external belt increased; a trend clearly aligned with an urban transformation spurred by the need to accommodate more national and international incomers in these areas.

¹¹ Refer to Fig. 8 in the Appendix for a visual representation of Barcelona and its principal urban districts.

¹² Interesting material referring to this particular historical period is available at <http://ajuntament.barcelona.cat/museuhistoria/ca/barraques-la-ciutat-informal>, provided by the Museo d’Història de Barcelona.

¹³ The map depicting 1900 data is not so different from the current one. For example, the core place of concentration (El Raval) remains unchanged. A settlement dating back to the Roman origins of the city, El Raval has been an active part of the commercial and civil life of Barcelona for centuries (Busquets 2004).

¹⁴ It is also worth mentioning the Barcelona suffered from other urban changes driven by the urban policies implemented during the dictatorship affecting the property system and, hence, citizens’ residential choices. Furthermore, until 1939, economic segregation turned into vertical segregation: higher income families were used to live at the first floor whereas poor families lived in the top floor (Vilagrà Ibarz 1997 and Cardesin 2016)

Data and Descriptive Statistics

Our empirical analysis relies on an original database, which gathers relevant information on factors shaping the population distribution in Barcelona. Our principal data source consists of the Annual Statistical Yearbooks published by the township administration, which contain relevant data on the demographic composition of Barcelona since 1902. These statistics supply aggregate data at (at least) city-district level and have been previously elaborated from individual census or administrative (*padrón*) records by the correspondent administrative officers. However, historical events (namely the Civil War, and then the Francoist dictatorship period) hinder the collection of complete information. Therefore, we begin with providing a preliminary analysis relying on an unbalanced sample with 114 observations for the overall population and a fewer for the different communities (as we list below Table 6). But, then we need to organize data according to comparable spatial criteria. One of our preliminary tasks was thus to elaborate the available information so as to make it consistent at the territorial level over time. This is definitely an important value added of our contribution: to our knowledge a similar dataset has not been built for a European city yet. Our scope to propose an investigation of the changes of the spatial urban structure over time approaches the idea of long-run analysis in the spirit of the evidence provided by Cutler et al. (1999) for the US.

To this end, we refer to the geographical urban structure of 1984 (at the district level, as in Fig. 8 in the Appendix that keeps unchanged till nowadays) and create the fit of the pre-1984 urban territorial organization to the former. Applying the same criterion, we also elaborate an ad-hoc neighborhood structure for each of the pre-1984 maps, allowing to run comparable estimations for each period and community. It was, however, necessary to introduce a conversion criterion due to the unavailability of relationship/conversion files. Exploiting the technique adopted by the US Census Bureau for the TIGER/Line program, and using geographical points of reference, we identified an equivalence criterion for the matching of district boundaries and land surfaces. We use these shares to convert all pre-1984 district areas (and associated variables) to the 1984 district boundaries as a weighted sum. As a result, we obtain a pseudo panel of comparable observations at the urban level for the period 1902–2011.¹⁵

In what follows, we provide a few preliminary comments on our data. Despite the expansion of the urban territory, population density (as the ratio between the total population in a district and the area of that district) continually increased up until 1965, mostly due to the people inflow from the rest of Spain (Fig. 2 and Table 4 in the Appendix).¹⁶ Then, up until 2001, the density dropped, while in the last years of the period of analysis there occurred an upturn in population density caused by the high inflow of international migrants. This movement confirms immigrant interest in settling in Barcelona, counterbalancing the tendency of natives and Spaniards to move to the surrounding municipalities in the larger metropolitan area (AMB).

¹⁵ More information about the empirical strategy adopted to get a comparable spatial structure over time is presented in Appendix A.

¹⁶ Population density is our measure for the dependent variables. It allows to control for both the size effect of spatial units and the potential vertical segregation issues discussed in footnote 8 that cannot be properly quantified.

Figure 3 complements the information presented in Fig. 1. It presents the spatial distribution of the share of foreign migrants over the total population. It pictures the distribution (in percentile) of the share of foreign immigrants –in percentage– intended as the ratio between the number of immigrant and the total population by district level for selected moments in time. We focus on three salient historical moments when this share dramatically changed (as in Fig. 1). First, 1902, the year our analysis begins. Then 1986, the year Spain joined the European Union and saw both an important degree of free circulation of people across the member states and the highest stock of immigrants, up until the 2008 financial crisis (the last year in the figure).

Figure 3 shows a slow but constant spread of foreign migrants across the different districts of Barcelona, confirming a steady increase of foreign-born immigrants in Barcelona and their progressive spatial diffusion across the urban area. That said, their relative concentration (in terms of percentage over the total district population) changes over time either due to an increase in the immigration inflow rate and variations in the local attractiveness of the different districts. Hence, areas with the highest shares of immigrants do not always consolidate spatially: we observe changes in the distribution for second-rank districts, moving south to north. It thus does not seem that a given spatial segregation pattern consolidates over time.¹⁷

In order to gain a preliminary statistical sense of the types of spatial distribution among the three different communities — Catalans, Spaniards, and Immigrants — in Barcelona we use a dissimilarity index (D-index) (Duncan and Duncan 1955). Our aim is to provide a general measure of the degree of the evenness of the distribution of the three selected communities for the whole city of Barcelona that is comparable over time despite urban administrative change in district structure.¹⁸ In doing so, we complement the statistics produced in Garcia-Lopez et al. (2020).

The computation of this index allows to discern the degree of spatial integration of the Spanish and immigrant community with respect to the Catalan one.

The D-index is the most common measure of segregation when referring to an urban environment. Its principal advantages are that it is independent of population composition and is quite reliable for comparisons over time. For a selected city at time t for any pair of communities (M , N) in a territorial unit i (for n units), the D-index is constructed as follows:

$$D_t = \frac{1}{2} \sum_{i=1}^n \left| \frac{M_{it}}{M_t} - \frac{N_{it}}{N_t} \right| \quad (1)$$

¹⁷ While these migration inflows had an important impact on the local labor market, our focus here is on the influence of the latter on the urban spatial structure of Barcelona, with particular interest in the issue of community density distribution.

¹⁸ The adoption of such an index is somewhat controversial. To this regard, Apparicio (2000 and Apparicio et al. 2008) provides a complete and extensive discussion on the different existing segregation indexes (as well as their advantages and limitations) that might be computed to depict different dimensions of segregation in a city. Some also take into account the spatial dimension underlying the data. While computing all of them would offer valuable insights, the considerable spatial administrative changes experienced by the city of Barcelona over the century makes producing results that can reliably be compared across time a challenge. In the light of these technical limitations, we restrict our preliminary empirical discussion to the Duncan index only.

Fig. 2 Evolution of the population and immigration density in Barcelona (1902–2011) in logarithmic scale (Source: Data from Table 4)

As presented in Eq. 1, the D-index assumes continuous values in (0, 1), with 0 being the most equal situation and 1 the most dissimilar. The index provides a measure of the proportion of the population of community N that needs to be displaced in order to negate the degree of dissimilarity between M and N in neighborhood i . A D-index greater than 0.6 usually indicates the presence of a high degree of segregation in a city, while a D-index below 0.3 reflects a low degree of segregation.

In Table 1 we compute the D-index for our three selected communities (Catalans, Spaniards and Immigrants) according to available data.

The results in Table 1 confirm the progressive consolidation of spatial segregation in Barcelona up the 1970s. Immigrants in particular suffered from spatial segregation, especially with respect to Spaniards, likely linked to competition for the same jobs. Of no less importance, however, were spatial segregation between Catalans and Spaniards, which strengthened during the most important period of in-land migration and held constant over time. Note that, in reference to immigrants, the changes in the D-index are somewhat associated with shifts in the spatial density distribution of this community.

The massive migrant inflows, first from the rest of Spain and then from abroad, fueled a clustering of immigrants in peripheral areas of the city (Busquets 2004). Simultaneously, the construction of residential dwellings in areas belonging to the city's external belt increased. This trend clearly aligned with an urban transformation driven by the need to accommodate more national and international immigrants in these areas.

In one of the first empirical studies on the location determinants of population density, Guest (1973) identifies the quality of the urban transport system and dwelling supply as the most relevant features defining population location choices.

1902

IMM_02

- < 1% (0) [1 : 1]
- 1% - 10% (0) [1 : 1]
- 10% - 50% (6) [1 : 4.450]
- 50% - 90% (4) [4.450 : 33.150]
- 90% - 99% (1) [33.150 : 35]
- > 99% (0) [35 : 35]

1986

IMM_86

- < 1% (0) [2.900 : 2.900]
- 1% - 10% (1) [2.900 : 4.300]
- 10% - 50% (4) [4.300 : 7.400]
- 50% - 90% (4) [7.400 : 19.300]
- 90% - 99% (1) [19.300 : 22]
- > 99% (0) [22 : 22]

2008

IMM_08

- < 1% (0) [2.500 : 2.500]
- 1% - 10% (1) [2.500 : 3.300]
- 10% - 50% (4) [3.300 : 8.450]
- 50% - 90% (4) [8.450 : 22.350]
- 90% - 99% (1) [22.350 : 27.300]
- > 99% (0) [27.300 : 27.300]

Fig. 3 Percentile spatial distribution of foreign immigrant share (%) as the on by district. (Source: Census and administrative data at district level for the selected years; authors' elaboration)

Table 1 Index of dissimilarity at district level (Duncan and Duncan 1955; Garcia-Lopez et al. 2020)

	Catalans		Spaniards*
	Spaniards*	Immigrants	Immigrants
1902		0.11	
1947	0.05		
1965	0.10		
1970	0.12	0.34	0.43
1986	0.15		
1991	0.15	0.30	0.40
2001	0.15	0.19	0.26
2008	0.14	0.22	0.13
2011	0.14	0.22	0.22

*Spaniards refer to the Spanish community in Barcelona that are people born in Spain but not in Catalunya and resident in Barcelona

From our data (mostly Table 5), we observe that in 1902 Barcelona was already home to a small foreign immigrant community, likely linked to the intense shipping activities of the commercial port. Over the decades, Barcelona then saw an increase in the average population density of the immigrant community, whereas the density of natives (Catalan) and the Spanish community slightly dropped. Two aspects could explain these shifts: the progressive relocation of households outside Barcelona's urban core to the larger metropolitan area and a changing real estate market. In Barcelona, the creation flow of buildings shows a stable downward trend; hence the housing market is not sufficient to accommodate a rising demand searching not only for cheaper places but also for access to individual dwellings. A joint reading of both pieces of evidence suggests that one should expect a reduction in the attractiveness of the CBD as a consequence of this important demographic change.

Finally, it is also of interest to analyze the evolution of the urban public transport system, which plays a relevant role in shaping population distribution. As we anticipated in "Introduction" section, the urban transport system is crucial for guaranteeing the degree of accessibility to the CBD. Among the various modes of public transport in Barcelona, public bus lines enjoy the reputation of being an easily and cheap accessible service (Vilagrassa Ibarz 1997; Fernández i Valentí 2006).¹⁹ In order to obtain data on bus-line density²⁰ at the spatial level for each year of our period of study, we rely on

¹⁹ These authors propose an interesting discussion about the spreading of the tramway and bus service. For several years, the two services were in place in Barcelona, the tramway being more expensive than the bus service. Right after the civil war, the tramway service was seriously affected by electric restrictions. In 1952, the township administration took the decision to improve the bus (and metro service) against the tramway whose service was definitely suppressed from 1971 up to 2004. In the light of these historical circumstances, the need to deal with time-consistent information about the degree of accessibility to the urban transport system and the lack of reliable georeferenced data referring for the tramway line-service, we exclusively focus on the bus service in our empirical analysis.

²⁰ The bus-line density is calculated as the ratio between the number of bus-lines per spatial unit and the area of that unit.

raw information on urban public transport in Barcelona available online.²¹ We first selected urban bus lines that have been operating for at least more than a year (hence, excluding experimental or summer lines). Then, for every line, we tracked the corresponding bus route on a map for each year to identify the districts or neighborhood served by each bus line. Finally, we aggregated the number of bus lines by district (or neighborhood) and year, and computed the correspondent spatial density. With this information, we expect to observe that a shifting density of bus services parallels a shifting density of the city's population.²² As shown in Fig. 4, we quantify this idea by depicting the trends in population and bus line densities. Despite the perfect collinearity in the final years of the considered period, the two trends are for the most part independent, with only a single instance of parallel movement, where change in the density of public bus transport overcomes that of population density. These results confirm that a general strategy was adopted by the public administration to improve the degree of accessibility of urban locations through a more efficient transport system only in the last years of the study period. Put differently, accessible means of transport did not represent a principal discriminatory feature in determining individuals' location choices for the overall period.

Overall, the empirical evidence discussed in this section emphasizes that the creation of dwellings in the peripheral areas of the city (and surrounding villages or towns), together with a progressively more efficient public transport system, favored the relocation of the urban population to outside areas.

Empirical Strategy and Results

In order to perform the empirical analysis, we rely on an augmented version of the population density distribution function for a monocentric urban structure inspired by the negative exponential function introduced by Clark (1951). The standard population function identifies that the gross population density at a distance x from the CBD is negatively proportional to the size of the distance itself. The CBD is generally recognized as the center of interest for labor or leisure purposes for all citizens. Garcia-Lopez et al. (2020) identify two specific places of interest known to have been important in the civil and economic life of Barcelona. Given the historical perspective of this analysis, we similarly selected two places that merit attention over the decades: Plaça Catalunya, labeled as the CBD, and a historical building in the old commercial port, labelled as the Port. Plaça Catalunya has long represented the core of the city's urban life in all dimensions, as reflected by the real estate market. In contrast, the old commercial port of Barcelona was originally the economic center for the city's trade industry but later developed into a tourism and leisure area. The Port is also not far from one of the city's major train stations, which has long served as a point of reference for Spanish-born immigrants arriving in Barcelona in search of work (Busquets 2004). This analytical strategy is not new in the literature. Other empirical work has exploited

²¹ This information is available at <http://www.autobusesbcn.es/>.

²² It is worth mentioning that while Barcelona implemented urban train and metro networks as well, the development plan favored uniform full accessibility across all districts and, hence, these means are less likely to be discriminatory, compared to the bus service, in terms of location choices. We have tested this conclusion and the results are available upon request.

Fig. 4 Percentage changes in public bus line density versus changes in population density. (Source: Our database)

the existence of sub-centers in identifying the gradient. The expected outcome is still a negative gradient, but flatter (see, for example, Garcia-Lopez (2010) or, for a review of existing results, Duranton and Puga (2015)). Furthermore, in order to take into account the presence of amenities or other district-based features that differentiate a district from another and represent the attractiveness to live there, we introduce fixed-effects (FE) .

Econometric Strategy

Given our working hypothesis, we select the following density function for a community h^{23}

$$D_{hj}(x) = D_{hj0} e^{[\alpha_{h1} \ln(x_{j0}) + \alpha_{h2} \ln(x_{j1})]} \quad (2)$$

in which $D_{hj}(x)$ is the gross population density at the centroid x of district (or neighborhood) j ,²⁴ x_{j0} the distance (in km) between point x and the CBD (Plaça Catalunya), and x_{j1} the distance from x to the historical building in the old port of Barcelona. In the spirit of Mills and Tang (1980), we considered D_{hj0} as a constant.

By log-linearizing eq. (2) we finally estimate

$$\ln D_{hjt}(x) = \alpha_0 + \alpha_{h1} \ln(x_{j0t}) + \alpha_{h2} \ln(x_{j1t}) + \alpha_{h3} \ln(B_{jt}) + \mu_t + \delta_s + \varepsilon_{hjt} \quad (3)$$

in which α_0 is a constant, and x_{j0t} and x_{j1t} preserve the meaning previously described.²⁵ It is, however, important to note that the distance from any location in Barcelona to Plaça Catalunya and to the Port are time-dependent due to changes in the definition of the centroids of each spatial-plot, a consequence of the progressive expansion of the city. The

²³ Guerois and Pumain (2008) argue that the negative exponential function is the best fit (among several other options) for examining population density in Barcelona.

²⁴ We refer to point x as the centroid of either the district or neighborhood.

²⁵ This research strategy is in line with that proposed by Adhvaryu (2011).

variable B_{jt} refers to bus-line density in location j at time t . The rationale for including this variable is based on the argument that the efficiency of the public transport network is an important determinant in shaping location choices. That said, there is a potential endogeneity problem between the bus-line density and the population density of the same urban parcel j . In order to overcome this limitation, we implement an IV estimation strategy in which we assess bus-line density using an index of the relative importance of the bus-line density in all spatial units $i \neq j$ over the total density of the broader Barcelona public transport system (namely bus, train, and metro lines). This instrument builds on a similar idea introduced by Card et al. (2014). The population density in a district is expected to be proportional to the quality of the transport service of the own spatial unit, but not directly to that of the other spatial units. The Montiel-Pflueguer statistics confirm that this index can be exploited as instrument in the IV estimations. Finally μ_t and δ_s are time and spatial fixed effects, respectively.

Our empirical exercise is built in two steps. The first examines the sample of original data (i.e., an unbalanced panel) in order to assess the average effect of the gradient across years and for all communities in Barcelona. The second exploits the pseudo panel and produces point estimates for the temporal evolution of the urban gradient, differentiating between communities.

The selection criterion for communities distinguishes between the two broad waves of migrants arriving in Barcelona: those from elsewhere in Spain and those from abroad. This classification guarantees statistical representativeness of these individuals in all urban neighborhoods.²⁶

We are aware that our community data (Catalans, Spaniards and Immigrants) are quite heterogeneous because we assign a citizen to a community according to a very general criterion (place of birth) but without being able to be more precise about the age, the income, the profession or the nationality (in the case of immigrants) of each citizen included in each community. Also, some of those personal features could be relevant at the time to picture their density distribution. In particular, the income level is crucial in selecting the place of residence in a monocentric setting, since renting or buying a property close to the CBD is more expensive than in the outskirts. Given the lack of precise data with those characteristics, we develop our analysis by adding two additional communities (the high-skill and the illiterate community) with the purpose to disentangle the relevance of the income dimension in assessing the centrality of the CBD. In these last communities we organize Barcelona citizens according to their profession (and hence expected income associated with that) irrespective of their nationality or place of birth. This is definitely a limited approximation, but still we are able to draw some conclusions about the income effect and the centrality of the CBD. The community of high-skilled individuals is likely to represent the wealthy and, similarly, the low-skilled is likely to capture individuals belonging to the lower end of the income distribution.²⁷

²⁶ A concern for representativeness prevents us from separately considering different subgroups of nationals that make up the immigrant community in each district.

²⁷ Note that information on the skill levels of the population is available only for the year in which we exploit census data. To overcome this problem, we introduce an ad-hoc criterion to define the high-skilled community. When data on education is available, we consider as highly-skilled those individuals with a university degree or more. In contrast, when this information is not available, we proxy with profession. We consider as members of the high-skilled community lawyers, doctors, professors, engineers, architects, priests, and all other professions that require university-level studies.

Estimation Results

The results of the first step of our empirical strategy for the unbalanced panel are presented in Table 2 for the period 1902–2011.

We consider the overall population (mostly composed of native Catalans), Spanish-born citizens, immigrants, the illiterate (i.e., low-skilled workers among both natives and immigrants), and the high-skilled (both immigrants and natives). For our econometric analysis, we follow the usual strategy. We begin by performing OLS benchmarking estimations and then, on the basis of the Montiel-Pflueguer statistics we first conduct the fixed effects estimations (FE) and then the IV (FE). Given the limited available number of control variables at the territorial level, the choice of the fixed effects is important. To define a representative measure of the features of the districts that remain constant over time, we introduce ad-hoc spatial fixed effects (δ_s) by identifying the urban districts that survived over time (*H-District*). This allows to preserve the time invariant condition, valuable for two reasons. First, we must keep track of the spatial units that were part of the urban territory of Barcelona for the entire period of analysis and that consolidated over time. This allows to identify a sort of reputation effect that these spatial units enjoy, as they became important references for individual location choices.

Second, the introduction of this type of spatial fixed effect takes into consideration all the policies for decentralized governance that were implemented by local administrations at the district level. These mostly refer to education or health care facilities, which are provided on a district basis, and can differ across areas.

The results of the FE estimations emphasize a clear difference between the determinants of density distribution for Spaniards and those for immigrants (more similar to the larger population, namely Catalan natives). For the former, the elasticity associated with the distance to the CBD is not statistically significant while for the latter it is negative and statistical significant. Therefore, the spatial density distribution of immigrants and natives confirms a quite common result in the literature since the CBD turns to be a centripetal point and a crucial determinant for shaping the spatial density distribution of those communities. Instead, for Spaniards, the distance to the CBD is not a crucial factor in shaping their spatial density distribution whereas the Port seems to be. This result could be understood by referring to the main motivation driving people from the rest of Spain move to Barcelona. If one considers that Spaniards principally moved to Barcelona in search of employment, it is plausible they were more prone to relocate closer to available jobs, mostly found near the Port (Silvestre et al. 2015 or Ibarz Gelabert 2010) and relatively far from the CBD.

Estimations that also include public transport facilities (represented by the *bus-line density*) provide additional evidence. Before discussing the estimation results, it is important to stress that the introduction of the *bus-line density* variable may create endogeneity problems. That is, more individuals may choose to reside in districts with abundant transport facilities, but the presence of a relatively important number of people may induce improvements in the public transport offer. To test for potential endogeneity, we instrument the *bus-line density* in each spatial unit by the density of the public transport facilities (bus, tram, and metro) in the neighboring spatial units. The Montiel-Pflueguer statistics, run to assess the validity of this instrument, confirm that our choice allows to control for this issue. The results of the IV (FE) models reveal

Table 2 Unbalanced panel (1902–2011)

	Log population density ^a			Log Catalan density ^b			Log Spaniard density ^c		
	FE	IV	IV (FE)	FE	IV	IV(FE)	FE	IV	IV (FE)
Constant	17.5*** (4.02)	14.8*** (1.18)		-61.4*** (11.05)	13.7*** (1.21)	21.1*** (2.42)	-41.62*** (13.05)	16.41*** (2.21)	
Log_Distance_CBD	-1.3*** (0.412)	-0.4*** (0.104)	-1.16*** (0.41)	-1.02*** (0.44)	-0.45*** (0.11)	-0.60*** (0.22)	-1.39 (1.086)	-0.39*** (0.17)	-1.72* (0.95)
Log_Distance_Port	0.40* (0.20)	-0.23** (0.09)	0.37* (0.19)	9.6*** (1.23)	-0.11 (0.11)	-0.83*** (0.24)	7.40*** (1.75)	-0.52*** (0.15)	8.36*** (1.27)
Log_BusLine density		0.26*** (0.08)	0.006 (0.12)		0.19***	0.07 (0.15)		-0.18 (0.17)	-0.07 (0.10)
- Robust Durbin-Wu-Hausman test		36.90***			48.8***			135.08***	
Instrument:									
Montiel-Plueger test ($\alpha = 5\%$)		Ind_pub_transp_others	Ind_pub_transp_others		Ind_pub_transp_others	Ind_pub_transp_others		Ind_pub_transp_others	Ind_pub_transp_others
TIME DUMMIES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Fixed effects	H-District	H-District	H-District	H-District	H-District	H-District	H-District	H-District	H-District
F-test FE vs OLS	8.4***			11.8***			15.9***		
Errors	Robust	Robust	Robust	Robust	Robust	Robust	Robust	Robust	Robust
R-squared	0.53	0.65	0.46	0.81	0.62	0.46	0.63	0.12	0.60
Obs	114	111	106	93	90	106	84	84	77

*** 1%, ** 5%, * 10% degree of significance

^aData available: Year(# districts): 1902(10), 1912(10), 1920(10), 1947(10), 1965(12), 1970(12), 1986(10), 1991(10), 2001(10), 2008(10), 2011(10);^bData available: Year(# districts): 1902(10), 1947(10), 1965(12), 1970(12), 1986(10), 1991(10), 2001(10), 2008(10), 2011(10);^cData available: Year(# districts): 1947(10), 1965(12), 1970(12), 1986(10), 1991(10), 2001(10), 2008(10), 2011(10);

Table 2 (continued)

	Log Immigrant density ^d		Log high-skilled density ^e		Log illiterate density ^f	
	FE	IV	IV (FE)	FE	OLS	FE
Constant	-22.44 (16.06)	-3.76* (2.15)		-393.23*** (44.45)	9.17*** (2.04)	-77.96* (38.84)
Log_Distance_CBD	-1.23* (0.66)	0.73*** (0.18)	0.46 (0.73)	23.16*** (1.89)	-0.91*** (0.21)	2.08 (1.64)
Log_Distance_Port	5.00*** (1.79)	0.31* (0.16)	-8.84*** (1.89)	25.29*** (3.61)	0.62*** (0.11)	8.20*** (3.16)
Log_BusLine_density		1.60*** (0.17)	1.54*** (0.15)		0.73*** (0.13)	
- Robust Durbin-Wu-Hausman test		88.59***			0.67	
Instrument:						
Montiel-Pflueger test ($\alpha = 5\%$)			Ind_pub_transp_others			
TIME DUMMIES	YES	YES	41.38	YES	YES	YES
Fixed effects	H-District		H-District	H-District	H-District	H-District
F-test FE vs OLS	5.2***			39.34***	17.24***	19.78***
Errors	Robust	Robust	Robust	Robust	Robust	Robust
R-squared	0.90	0.65	0.84	0.91	0.80	0.96
Obs	94	91	83	50	47	50
						47

*** 1%, ** 5%, *10% degree of significance

^dData available: Year(# districts): 1902(10), 1947(10), 1965(12), 1970(12), 1986(10), 1991(10), 2001(10), 2008(10), 2011(10);^eData available: Year(# districts): 1902(10), 1986(10), 1991(10), 2001(10), 2011(10)

that while the quality of the transport system is not statistically relevant for Spaniards (confirming, for instance, their preference to settle close to places where they can find a job as the case of the Port, for instance), it is significant for (foreign) immigrants. Furthermore, the introduction of this variable makes the estimated elasticity of the distance to the CBD for immigrants statistically insignificant. In our reading, this result emphasizes the importance (for this group) of the quality of public transport for moving around the city and, hence, having easy accessibility to the urban points of interest.

In addition, the (IV) FE estimations highlight another difference between immigrants and the other communities. The former community value the Port as a centripetal point (hence with a negative estimated elasticity) while for the others it is a centrifugal location point with a positive elasticity coefficient estimate. As discussed in “[Introduction](#)” and “[Framework of Analysis and Research Hypothesis](#)” sections, this result can be associated with the main motivation for immigrants to move to Barcelona that is finding an employment. Being a historical economic center, the Port is an important source of employment in the commercial activities surrounding it (mostly relating to tourism like hotels, restaurants, etc.), above all for low-skilled individuals. The other two communities instead display a clear preference for settling far from the Port (the estimated elasticity is positive), as shown by the FE or IV (FE) estimations. It is plausible to think that for these two communities a district reputation effect plays a role in rendering this location less attractive. Quality of life or services provided in this district may be not be as appealing (or inferior to that offered in other parts of the city), and being native could help in obtaining such uncoded information and ultimately drive the decision to settle in a different district.²⁸ In addition, when considering the previous results, it is also possible that employment options for these communities, particularly for Spaniards, are found elsewhere; since the estimations suggest that the public transport system is not a relevant determinant in their location choice, they prefer to settle elsewhere, ideally close to their jobs.

Table 2 also presents the results for high-skilled and illiterate population density. As data are not always available for these two communities, our sample is necessarily smaller. Preliminary statistical tests show that there are no endogeneity problems associated with the log-bus-density variable, and that fixed-effect estimations are preferred. Due to collinearity with H-district effects, the variable referring to the distance to the Port is dropped. Both communities record a positive and statistically significant elasticity between their respective population density and bus-line density. In other words, the public urban transport system matters for both the high-skilled and illiterate community. Instead, a different behavior appears when considering the estimates for the elasticity of the distance to the CBD. While the community of illiterates displays a negative estimated elasticity with respect to the distance to Plaça Catalunya, the high-skilled community records a positive (and statistically significant) elasticity. Once more, the high-skilled community is more likely to settle in high-rent areas on the periphery of the city, where they enjoy the possibility of living in individual dwellings.

The estimates of the elasticity of the distance to the CBD is the backbone of the urban spatial structure and measure the attractiveness of the CBD for the different communities. A low absolute value of these estimates is likely to be associated with a low population (or community) density values in the proximity of the CBD. This finding may result from either the replacement of the selected CBD by another point of

²⁸ For instance, evidence suggests that illegal activities are usually more concentrated close to ports.

interest or an insufficient urban development plan, making the urban structure blurred and complicated to model. Indeed, in this case the latter can mask overlapping spatial layouts that cannot be properly identified. Overall, the first set of estimations confirms the statements relative to our hypothesis *H.1*: the CBD and the Port as well as de district features are relevant determinants for approximating the population and community density distribution in Barcelona over time. Estimates deliver important results: whereas district features are relevant for almost all communities, the distances from the CBD and the Port are not equally important, but, instead, significant differences appear. This could be a consequence of the average socioeconomic background of each community that, finally, influence the selection of the places of residence.

The Attractiveness of the CBD over Time

The second step of our empirical analysis aims to assess if the proximity to the CBD keeps being a key determinant of density distribution for all selected communities across time knowing that the population size experiences important changes due to the various immigration waves (our hypothesis *H.2*). To tackle this question, we need to track the estimates of the elasticity associated with the distance to Plaça Catalunya (CBD) for each community over time. In order to perform this exercise, we exploit the pseudo panel created for the period 1902–2011 jointly with the ad-hoc identification of urban districts for each point in time. In this way, we are able to produce and then plot point estimates for the elasticity between population (or community) density and the distance from the CBD. This allows to obtain comparable estimates and map their evolution so as to establish whether the absolute value of that elasticity declines with increases in population size.

The estimations are run using a reduced form of Eq. 2 in which we include as control variables the distance from the CBD and the Port only.

We gather estimates by decade and plot the elasticity of the distance to the CBD in Fig. 5.²⁹ All estimates are run according to the OLS method with robust-error correction.

It is important to emphasize a few common tendencies across the different communities. A first look reveals that from the beginning of the twentieth century up until the 1960s the estimates of the elasticity was either not statistically significant or the absolute value was less than one. During this span of time, Barcelona did not have a well-structured urban development plan and the spatial structure of the city saw the existence of ghetto areas (linked to shantyism), making the CBD (Plaça Catalunya) a not relevant point of interest for citizens at the moment to choose their place of residence. On the contrary, the CBD regains centrality for population and community density distributions after the Spanish transition to democracy (roughly from 1980 onward). At that time, the urban development plan first targeted the physical elimination of any residual of shantyism, followed by the introduction of the flagship program of the township administration: the decentralization at the district level of the managing of social and health services (“new centrality”). As the results of the estimates emphasize, these actions reinforced the centrality of CBD for density distributions displaying

²⁹ Recall that data referring to the different communities are not available for every single decade. Estimate outputs are included in Appendix C.

Fig. 5 Mapping estimations for elasticity-distance to Plaça Catalunya (CBD)

an increase of the estimate absolute value of the elasticity linking population (community) density distribution and the distance to the CBD. Figure 5 pictures this jumps around 1986. After that moment the value of the estimates is relatively constant over time up to 2011 despite the huge immigration inflow from abroad in 2000s. The shift allowed to avoid the creation of ghetto areas not only in the CBD (as often happens in US cities experiencing important population size increases) but also in the other urban districts. Indeed, the administrative centralization initiative made them gain their own attractiveness thanks to the implementation of social or public services for local residents, helping to control (and possibly deter) the deterioration of the quality of life over there (our hypothesis *H3*).³⁰ These initiatives continued to be effective, from 2000 onward, in inhibiting ghettoization of impressive foreign immigration inflows.

Although all communities share the same trend in Fig. 5 above all before the democratic period, there are interesting differences among the evolution of the elasticity estimates inside each community in recent decades.

First, the centrality of the CBD in shaping the distribution of immigrants and the community of high-skilled citizens is very relevant because the absolute value of their estimated elasticities is the highest. Instead, the evolution of the elasticity of the distance to the CBD for the remaining communities may be principally associated with an interest to reside close to their place of work, rather than the CBD returning to the argument discussed above. To this regard, the size of the estimates of the elasticity for the Spaniards is the lowest and is often not statistically significant, while for the illiterate community the distance to the CBD is almost never statistical significant, meaning that it is irrelevant for shaping their density distribution. In line with this interpretation, Busquets (2004) shows that a part of the Spanish community moved to cities close to Barcelona in a search of more affordable rental or buying opportunities.

Therefore, changes in the estimates of the elasticity associated with the distance to the CBD corresponding to an increasing population size in recent years is mostly driven

³⁰ In addition, this reinforced attractiveness of the CBD, jointly with the corresponding (statistical) loss of attractiveness of the Port (refer to the Appendix) is in line with the theoretical predictions underlining this econometric strategy (as discussed in Duranton and Puga (2015) for the case of the urban gradient in the presence of potential secondary sub-centers).

by the location decisions of immigrants and Catalans (the largest portion of the urban population). The density distribution of the cross-community of high-skilled follows the same trend. Relatedly, data at hand confirms that the portion of educated individuals in the overall population increased, but we have no tangible evidence for immigrants. Nevertheless, general evidence suggests that highly educated individuals make up a relatively important share of the last waves of (foreign) immigrants, above all among those from other EU countries and the US (Sanromá et al. 2015).

The centrality of the CBD for the high-skilled community is likely associated with the available services (in particular financial), as well as leisure opportunities and, hence, those features helps to understand the relevance this community is expected to grant to the proximity to the CBD.³¹

Finally, the Port of Barcelona merits further discussion. In our analysis, we used the latter as an additional point of interest for shaping population (and community) density distribution. Estimation results confirm the relevance of the latter for the total urban population and its communities up until 1920. After this year, the Port remains statistically significant only for the high-skilled community in the period right before and after the Olympic Games (1992), but with a different implication. The estimate elasticity is positive, meaning that this location is a truly centrifugal, rather than centripetal, point for this community. This behavior is likely associated with the deep structural transformation that took place in seaside neighborhoods (like Barceloneta) close to the old Port of Barcelona as a part of the urban intervention plan to prepare the city to host the Games. The work-in-progress situation may have made these urban plots uncomfortable to live in, pushing people away. To test this argument, in Table 3 we run the same estimations as those for Fig. 4 for the high-skilled community, but exclude the Barceloneta neighborhood (the area most affected by urban requalification for the Olympic Games). The idea seems to hold: in the new regressions the estimation of the elasticity from the Port is not statistically significant. It may also be that this situation affected the density distribution of natives more than immigrants. In Table 3, we replicate the same model by splitting the immigrant sample(s) between high and low-skilled immigrants, according to the criterion introduced in Sanromá et al. (2015).³² Referring to the distance to the Port, the estimation for elasticity is not significant, as for the other communities.

Overall, this set of estimations allows us to conclude that the development of structured urban planning led to a reinforcement of the historical CBD as a crucial centripetal point for almost all communities in Barcelona. Nevertheless, the point estimates allow to observe the urban distribution of the different communities, as in a typical monocentric urban style model, from 1986 onward. The high-skilled community is that with the greatest likelihood of locating near the CBD, while the Spaniards are the least likely, and the illiterate community seems to remain outside the competition.

However, the most relevant conclusion is that despite the increase of population size the CBD kept its centrality and its crucial role in shaping population (and community) distribution over time (*H.2*) and, above all in recent decades. The implementation of the new centrality policy is crucial not only to preserve the role of the CBD in shaping the

³¹ Assuming that high-skilled individuals are also likely to be able to devote a consistent part of their rent to this type of consumption.

³² Most immigrants from EU countries and North America are assumed to be high-skill individuals. Immigrants arriving from a sample of low income (or developing) countries in Latin America or Asia are assumed to be low-skilled.

Table 3 Pseudo panel for high skilled and select immigrant communities.
Estimation method: Robust OLS

		ldist_CBD	ldist_Port	Const	R-squared	Obs
1986	High Skilled	−2.30 *** (0.94)	1.44 (1.11)	12.87*** (3.70)	0.33	39
1991	High Skilled	−2.24** (0.89)	1.61 (1.07)	9.64** (3.99)	0.25	39
2001	High Skilled	−2.62** (1.12)	1.26 (1.06)	13.85*** (2.66)	0.33	69
2001	Log(High_skill_imm)	−2.53 *** (0.81)	0.66 (0.68)	14.96*** (1.78)	0.50	71
	Log (Low_skill_imm)	−1.97* (1.09)	0.47 (0.94)	13.32*** (2.60)	0.24	73
2008	Log(High_skill_imm)	−2.34*** (0.85)	0.27 (0.73)	18.09*** (1.84)	0.54	73
	Log (Low_skill_imm)	−1.06 (0.76)	−0.008 (0.66)	11.35*** (2.41)	0.17	73
2011	Log(High_skill_imm)	−2.42*** (0.90)	0.33 (0.77)	18.17*** (1.80)	0.53	73
	Log (Low_skill_imm)	−1.03 (0.77)	0.05 (0.68)	10.56*** (2.50)	0.14	73
Average (2001–2011)	Log(High_skill_imm)	−2.43*** (0.52)	0.43 (0.46)	16.99*** (1.30)	0.45	217
	Log (Low_skill_imm)	−1.35** (0.53)	0.17 (0.47)	11.74*** (1.59)	0.16	219

*** 1%, ** 5%, *10% degree of significance

Log(High_skill_imm): Immigrants born in France, Germany, Italy, UK, USA**Log (Low_skill_imm):** Immigrants born in Bolivia, Brazil, China, Colombia, Ecuador, Filipinas, India, Morocco, Mexico, Pakistan, Peru, Uruguay, Venezuela

density distribution of all communities in Barcelona but also to imprint them the same trend when the population size is growing at high pace, and, hence limiting the potential risk of spatial segregation (*H.3*).

Conclusions

In this study we track changes in centrality of the CBD as a determinant of the population density distribution of Barcelona over the twentieth century, when the city experienced an important increase in population size (mostly due to migration inflows). Our estimation results confirm that the urban spatial structure has shaped population (and community) density distribution over time in Barcelona (*H.1*) and that, in turn, it has been affected by sizable demographic change in the form of large immigrant inflows over the last two decades (*H.2*). Yet, rather than observing a progressive lack of attractiveness of the CBD as is usually expected by the literature, the new centrality policies put in place by local administrations prevented a weakening of the urban

spatial structure and hence deterred the consequences of spatial segregation as ghettos or other spatial enclaves (*H.3*).

In this sense, our estimates confirm the reinforcing centripetal effect of the CBD (Plaça Catalunya) for almost all of the analyzed communities. The effectiveness of these policies became evident from 1986 onward. A clear differentiation in terms of estimated elasticities between distribution density and distance to the CBD appears across communities and makes the CBD more attractive for high-skilled citizens during the period of intense immigration inflows. From an urban theory perspective, this result can be associated with the outcomes of policies supporting the centrality of the CBD through increased land value, which translated into higher levels of rent to live in this area. As a result of new centrality policies, Barcelona avoided the consolidation of a low-income segregation area in the city center (unlike that which has happened in some US cities). This occurred not only by enhancing CBD features and emphasizing accessibility, but also by limiting the creation of segregation spaces in the rest of the urban territory and heightening the attractiveness of the remaining districts through a combination of political and socioeconomic initiatives. The other selected point of attraction (the Port of Barcelona), was also a determinant in shaping location decisions before the Civil War. Afterwards, however, it loses any (statistically significant) relevance picturing population (and community) density distribution.

From a policy perspective, the implementation of an integrated urban development plan, focused on administrative decentralization and accessibility, helped to manage the challenges of a sudden urban population increase.

The CBD was able to adapt and reinvent its attractiveness by transforming and supplying valuable services for an increasingly important share of the population (e.g., high-skilled individuals). Furthermore, this effect has held even in the presence of a constantly improving public transport service, which might be expected to temper the CBD's attractiveness. To date, these policies have been effective in avoiding or limiting urban unbalances. It remains to be seen if they will be able to adapt to a changing socioeconomic environment and new forms of urban transformation, such as gentrification, in the future.

Further research could replicate this analysis with more detailed data. This would allow to better qualify the high/low skill features of the different communities in Barcelona. It would also favor more precise and conclusive quantitative estimations, as well as improve predictions that could aid policy decisions relative to urban planning.

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Compliance with Ethical Standards

The authors declare of not having any type of financial and no-financial conflicts of interests. Furthermore, this research does not involve human and/or animal participants.

Fig. 7 Current structure of Barcelona by district (from 1984 onward) (Source: Official township yearly statistics)

Legend:

- 1: Ciudad Vella
- 2: Eixample
- 3: Sants-Montjuïc
- 4: Les Corts
- 5: Sarrià - San Gervasi
- 6: Gràcia
- 7: Horta-Guinardó
- 8: Nou Barris
- 9: San Andreu
- 10: San Martí

Fig. 8 Map of Barcelona by district (as of 1984)

Appendix 2

Stock of dwellings

1900

1920

1940

Fig. 9 Percentile spatial distribution of the district-share of stock of dwellings (%) as the ratio between the number of dwellings by district and the total number of dwellings in Barcelona by year. (Source: administrative data at district level for the selected years; authors' elaboration)

1970

2011

Fig. 9 (continued)

Appendix 3

Additional tables

Table 4 Descriptive statistics

	Variables	Mean	Std deviation	Min	Max
1902	Population density	21,744.21	19,399.42	1,691.3	64,536.41
	Catalan density	13,588.57	12,515.07	1,345.58	41,751.86
	Spanish density	na			
	Immigrant density	399.75	392.82	11.27	1,267.46
	# Bus lines per spat. Unit	1.3	1.059	0	3
1912	Population density	21,864.14	17,764.83	1,524.42	58,392.27
	# Bus lines per spat. Unit	2.7	1.828	1	6
1920	Population density	25,316.15	19,708.21	1,875.6	64,802.38
	# Bus lines per spat. Unit	3.8	1.751	1	6
1947	Population density	32,435.3	30,459.4	3,718.3	105,036.2
	Catalan density	20,158.54	17,862.29	2,416.125	61,053.34
	Spanish density	11,444.96	12,143.3	1,150.77	42,248.57
	Immigrant density	625.29	571.79	95.08	1,727.7
	# Bus lines per spat. Unit	9.3	4.595	4	20
1965	Population density	30,860.86	24,242.79	6,244.761	95,114.23
	Catalan density	18,289.5	13,878.42	3,866.109	52,940.73
	Spanish density	12,194.18	10,335.82	2,122.405	41,232.76
	Immigrant density	377.18	264.54	67.7	940.73
	# Bus lines per spat. Unit	15	6.1938	6	29
1970	Population density	29,461.22	19,413.46	6,496.107	78,182.12
	Catalan density	16,365.44	10,277.12	3,639.27	40,330.82
	Spanish density	10,771.99	7,963.62	1,737.793	32,537.72
	Immigrant density	374.44	227.99	80.99	848.06
	# Bus lines per spat. Unit	17.25	6.312	7	31
1986	Population density	26,039.04	15,926	189.66	52,523.81
	Catalan density	17,096.18	11,019.37	129.569	37,517.29
	Spanish density	8,340.07	5,078.27	51.96	16,321.62
	Immigrant density	512.75	311.10	165.87	1,140.8
	# Bus lines per spat. Unit	9.71	5.73	1	29
1991	Population density	25,056.7	15,281.19	225.55	50,151.43
	Catalan density	16,629.99	10,677.62	163.35	35,291.36
	Spanish density	7,657.69	4,673.95	50.14	14,912.89
	Immigrant density	643.29	395.73	212.59	1,339.73

Table 4 (continued)

	Variables	Mean	Std deviation	Min	Max
2001	# Bus lines per spat. Unit	9.5	6.09	1	30
	Population density	23,469.06	14,988.18	33.954	56,885.65
	Catalan density	15,191.92	9,903.66	25.483	37,750.7
	Spanish density	6,421.87	4,623.88	7.77	20,451.48
	Immigrant density	1,664.88	1,353.04	517.72	4,726.00
2008	# Bus lines per spat. Unit	7.507	4.952	1	28
	Population density	25,186.4	15,673.6	77.57	59,024.3
	Catalan density	14,466.7	9,225.4	57.97	36,253.3
	Spanish density	10,719.76	7,337.75	19.60	29,206.36
	Immigrant density	4,472.80	3,352.25	1,125.03	12,283.29
2011	# Bus lines per spat. Unit	8.342	4.969	1	29
	Population density	24,956.64	15,467.52	74.558	59,442.82
	Catalan density	14,448.05	9,116.32	56.007	35,713.85
	Spanish density	5,163.304	3,582.03	10.361	15,455.7
	Immigrant density	4,521.75	3,113.65	1,121.05	11,223.9
	# Bus lines per spat. Unit	8.245	4.832	1	29

Table 5 Pseudo panel by decades: 1902–1970 (*Legend: *** 1%, ** 5%, *10% degree of significance*)

(Average 1902–2011)					1902					1912					1920				
	Idist CBD	Idist Port	Const	R-squared	Obs: 35	Idist CBD	Idist Port	Const	R-squared	Obs: 35	Idist CBD	Idist Port	Const	R-squared	Obs: 35	Idist CBD	Idist Port	Const	R-squared
Population	-0.64*** (0.14)	-0.39*** (0.11)	18.34*** (1.04)	0.47		-0.78*** (0.20)	-0.72*** (0.25)	21.04*** (1.05)	0.57		-0.41*** (0.15)	-0.59*** (0.23)	20.47*** (1.35)	0.64		-0.39*** (0.15)	-0.97*** (0.22)	20.39*** (1.33)	0.64
Catalans	-0.42*** (0.09)	-0.29*** (0.11)	15.03*** (1.05)	0.23		-0.76*** (0.22)	-0.91*** (0.27)	21.24*** (1.32)	0.67										
Spaniards	-0.22* (0.12)	-0.43*** (0.11)	13.50*** (1.23)	0.38															
Immigrants	-0.68*** (0.15)	-0.37*** (0.12)	17.05*** (1.11)	0.78		-1.01*** (0.30)	-0.76*** (0.36)	18.9*** (1.64)	0.52										
Illiterate	0.05 (0.28)	-0.5** (0.19)	10.98*** (2.30)	0.84		-0.53*** (0.15)	-0.75*** (0.19)	18.67*** (0.84)	0.69										
High-skill	-1.27*** (0.25)	0.32* (0.18)	16.1*** (1.81)	0.75		-1.50*** (0.35)	-0.27 (0.46)	18.19*** (2.11)	0.49										

1947					1965					1970				
	Idist CBD	Idist Port	Const	R-squared	Obs: 36	Idist CBD	Idist Port	Const	R-squared	Obs: 43	Idist CBD	Idist Port	Const	R-squared
Population	-0.86*** (0.29)	0.03 (0.45)	16.11*** (2.23)	0.37		-0.29 (0.20)	-0.16 (0.36)	13.51*** (1.98)	0.23		-0.28 (0.19)	-0.34 (0.25)	12.50*** (1.85)	0.15
Catalans	-0.88*** (0.29)	-0.11 (0.45)	16.55*** (2.3)	0.42		-0.42 (0.25)	-0.36 (0.46)	15.16*** (2.4)	0.39		-0.42 (0.25)	-0.36 (0.46)	15.06*** (2.4)	0.39
Spaniards	-0.84*** (0.30)	-0.07 (0.46)	15.64*** (2.29)	0.40		-0.27 (0.18)	-0.19 (0.36)	12.70*** (2.02)	0.22		-0.24 (0.17)	-0.11 (0.35)	11.69*** (1.98)	0.13
Immigrants	-0.91*** (0.31)	0.23 (0.43)	10.91*** (2.09)	0.32		-0.29 (0.27)	0.08 (0.36)	7.22*** (1.87)	0.11		-0.30 (0.21)	0.09 (0.32)	7.74*** (1.69)	0.18
Illiterate														
High-skill														

Table 6 Pseudo panel by decades: 1986–2011 (*Legend: *** 1%, ** 5%, *10% degree of significance*)

	(Average 1902 -2011)					R-squared	Obs: 38
	Idist	CBD	Idist	Port	Const		
Population	-0.64*** (0.14)	-0.39*** (0.11)	-0.39*** (0.11)	-0.39*** (0.11)	18.34*** (1.04)	0.47	
	-0.42*** (0.09)	-0.29*** (0.11)	-0.29*** (0.11)	-0.29*** (0.11)	15.03*** (1.05)	0.23	
Catalans	-0.22** (0.12)	-0.43*** (0.11)	-0.43*** (0.11)	-0.43*** (0.11)	13.97*** (1.23)	0.38	
Spaniards	-0.68*** (0.15)	-0.37*** (0.12)	-0.37*** (0.12)	-0.37*** (0.12)	17.05*** (1.11)	0.78	
Immigrants	0.005 (0.28)	-0.51*** (0.19)	-0.51*** (0.19)	-0.51*** (0.19)	10.98*** (2.30)	0.84	
Illiterate	-1.27*** (0.26)	0.32* (0.18)	0.32* (0.18)	0.32* (0.18)	16.14*** (1.81)	0.75	
High-skill							

1986						
	Idist	CBD	Idist	Port	Const	R-squared
Obs: 38						
Population	-1.48*** (0.70)	0.82 (0.74)	14.79*** (2.85)			0.22
Catalans	-1.55*** (0.70)	0.84 (0.73)	14.77*** (2.85)			0.24
Spaniards	-1.31* (0.72)	0.74 (0.75)	13.04*** (2.94)			0.17
Immigrants	-1.82*** (0.76)	0.96 (0.82)	12.58*** (2.62)			0.32
Illiterate	-0.30 (0.55)	-0.27 (0.52)	10.08*** (2.44)			0.11
High-skill	-2.30*** (0.74)	1.44* (0.78)	12.77 (3.03)			0.33

1991						
	Idist	CBD	Idist	Port	Const	R-squared
Obs: 38						
Population	-1.47*** (0.71)	0.86 (0.75)	14.40*** (2.8)			0.22
Catalans	-1.53*** (0.70)	0.88 (0.74)	14.30*** (2.8)			0.24
Spaniards	-1.31* (0.73)	0.77 (0.76)	12.60*** (2.94)			0.16
Immigrants	-1.80*** (0.75)	0.92 (0.81)	13.07*** (2.56)			0.34
Illiterate	-0.79 (1.04)	0.16 (1.17)	8.80*** (3.82)			0.07
High-skill	-2.21*** (0.71)	1.57*** (0.74)	9.67*** (3.34)			0.26

2001						
	Idist	CBD	Idist	Port	Const	R-squared
Obs: 73						
Population	-1.61*** (0.78)	0.88 (0.68)	10.80*** (2.01)			0.17
Catalans	-1.71*** (0.77)	0.96 (0.66)	10.40*** (2.05)			0.19
Spaniards	-1.37* (0.81)	0.90 (0.70)	7.39*** (2.11)			0.10
Immigrants	-1.82* (0.92)	0.48 (0.79)	13.63*** (1.99)			0.31
Illiterate	-0.67 (0.67)	0.17 (0.59)	2.99 (2.15)			0.02
High-skill	-2.78*** (0.58)	1.45* (0.84)	13.10*** (2.47)			0.33

2008						
	Idist	CBD	Idist	Port	Const	R-squared
Obs: 73						
Population	-1.46*** (0.72)	0.69 (1.87)	11.25*** (0.61)			0.19
Catalans	-1.59*** (0.69)	0.90 (0.59)	10.03*** (1.92)			0.2
Spaniards	-1.34* (0.76)	0.49 (0.65)	11.00*** (1.98)			0.17
Immigrants	-1.42* (0.78)	0.23 (0.67)	13.14*** (2.06)			0.25
Illiterate						
High-skill						

2011						
	Idist	CBD	Idist	Port	Const	R-squared
Obs: 73						
Population	-1.47*** (0.72)	0.73 (0.61)	10.99*** (0.61)			0.19
Catalans	-1.59*** (0.70)	0.92 (0.67)	9.82*** (1.88)			0.19
Spaniards	-1.35* (0.76)	0.87 (0.65)	7.27*** (1.96)			0.11
Immigrants	-1.40* (0.76)	0.28 (0.66)	12.63*** (2.05)			0.24
Illiterate						
High-skill						

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