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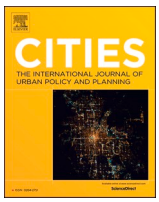

The impact of remote working on residential mobility in the metropolitan region of Madrid

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ABSTRACT

Large cities are facing the interlocked effects of multiple crises. In particular, the pandemic crisis induced residential relocation changes with the support of remote working. Nevertheless, the spatial implications involved remain unclear due to a lack of studies empirically integrating this variable. This research aims to study the impact of remote working on residential changes in Madrid in the period 2019–2021 ceteris paribus other residential relocation determinants, i.e. distance to the workplace, dwelling attributes, transport facilities and amenities. A local indicator of propensity to remote working is estimated using the complete administrative registry of the Social Security Office. We conclude that remote working impacts significantly on the relocation of young and middle-aged adults, although some of them may stay in their location to take advantage of agglomeration economies and social interaction. In particular, remote working impacts significantly on movement from the core city to suburban and rural areas, whereas evidence for movement in the opposite direction is less conclusive. In addition to digital connectivity and remote working, the availability of certain amenities can attract and retain these individuals. The research allows us to reflect on implications for housing affordability and for urban planning and policy intervention.

1. Introduction

Large cities are facing a global polycrisis marked by multiple interactions and crossover effects (Lawrence et al., 2022). The pandemic, which hit metropolitan areas especially hard, created a major health and socio-economic crisis with a significant impact on urban trajectories (Wolff & Mykhnenko, 2023), and in particular on internal migratory patterns (Stawarz et al., 2022; Wolff & Mykhnenko, 2023; Haslag & Weagley, 2024). In this context, remote working has emerged as a key factor in shaping not only the residential changes observed during the pandemic, but also these new ways of working and living in the post-pandemic city (Florida et al., 2023). Consequently, remote working plays a role in the housing affordability and ecological crisis that many large cities are also experiencing.

Remote working is not a new phenomenon, but the associated literature has expanded considerably in recent years. One strand of this literature has focused on population socio-demographic differences and labour market variables to explain the unequal propensity to work from home, providing substantial evidence of a greater tendency to do so among young, skilled workers and those of higher socio-economic status (Althoff et al., 2022; Mongey et al., 2021). Since cities are well endowed with skilled workers, activities suitable for remote working (Samek Lodovici et al., 2021) and good telecommunication infrastructures (Budnitz & Tranos, 2022), the impact of remote working on city-level outcomes constitutes an important dimension of the debate. Several studies have documented population migration towards peripheral metropolitan and rural residential areas, resulting in the well-known "donut effect"[1] (Ramani & Bloom, 2021). However, this trend is far from being homogeneous across socio-demographic groups and territories. Very recent studies have reported a "teleworking paradox", whereby some skilled workers seem to prefer to remain in main core cities in order to leverage social interaction and knowledge spillovers (Wong et al., 2025), and have even observed a centripetal movement of remote workers from the major cities' hinterlands, causing a "shadow effect" on small and medium-sized cities (Bjerke et al., 2025). Simultaneously, various studies have examined the impact of city dwellers'

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[1] Following the original nomenclature of the authors, we use the term "donut" instead of "doughnut".

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relocations on local housing markets in terms of the demand for second homes, short-term lets and rising housing prices (Colomb & Gallent, 2022; Gallent & Madeddu, 2021; Liu & Su, 2021).

Despite all the above, the spatial implications of the hybrid and remote working "revolution" remains unclear (Bjerke et al., 2025), as does the effect of pandemic-related mechanisms such as amenity migrations (Wong et al., 2025). One major reason is the lack of studies on residential location choice during the pandemic that empirically integrate remote working, as underlined by Ilham et al. (2024) and Jansen et al. (2024). Such is the case of a few studies in Spain that have indirectly referred to remote working when explaining the out-migration trends from central cities to suburbs and commuter towns (González-Leonardo et al., 2022; Marigil-Alba et al., 2025). In addition, many studies have failed to integrate a life course perspective. Notably, the evidence confirms the strong impact exerted by the pandemic on life-cycle transitions that primarily take place at young adult ages; i.e. entry into post-secondary education, labour market entry and early career development (Settersten et al., 2020). All the above constitute significant limitations since many studies have found that remote working interacts with personal and place characteristics —i.e. the availability of housing and amenities— in the residential decision-making process (e.g. Colomb & Gallent, 2022; Liu & Su, 2021; Ramani & Bloom, 2021).

Obviously, previous studies have been challenged by the scarcity of sufficient data to study the impact of remote working on pandemic mobilities, especially when differentiating by socio-demographic and professional groups (Althoff et al., 2022; Jansen et al., 2024). Many studies have estimated exposure or propensity to work remotely based on the shares in activities observed before the pandemic (e.g. Barrero et al., 2021; Mondragón & Wieland, 2022; Ramani & Bloom, 2021), while others have made use of ad hoc surveys or have "creatively" analysed temporary mobilities by means of big data, such as mobile phone (Colomb and Gallent, 2022) or social media data (Marigil-Alba et al., 2025).

The aim of this research was to study residential changes in the metropolitan region of Madrid (MRM hereafter) in the period 2019–2021 and the impact of residential relocation factors, including remote working. To this end, we analysed the information on intra-regional migration flows recorded in the Residential Variation Survey (EVR)[2] conducted by the Spanish National Statistics Institute (INE). In addition, a *local indicator of propensity to work remotely* (hereinafter LIPWR) was constructed. This uses the regional results of an ad hoc survey conducted by the INE during the pandemic to determine propensity to work remotely based on data obtained from Social Security administrative records of more than 3 million workers in the region. The LIPWR allows us to capture the influence of local occupancy and industry structure required by Althoff et al. (2022). Moreover, to the best of our knowledge, this is the first study in Spain to analyse the impact of remote work ceteris paribus residential relocation determinants, such as distance to work, housing costs, transport and urban amenities, differentiating inflows and outflows among different age groups in order to capture the heterogeneity of the spatial effects.

In short, two main questions guided our study: *What role (if any) did remote working play as a factor in residential relocation during the pandemic in Madrid?* And *for which groups and under what conditions?* This provided the opportunity to disentangle the complex residential behaviours of different age groups, yielding novel evidence about the preferences of middle-aged individuals. At the same time, empirically integrating remote working has advanced the evaluation of opportunities and challenges for workers in metropolitan areas. In this context, a third question emerges: *What lessons can be learned in order to balance potential benefits of agglomeration and housing affordability in large cities?*

The rest of the paper is organised as follows. Section 2 reviews the theoretical framework of the research. Section 3 explains the methodology, paying particular attention to the *local indicator*. Section 4 presents the econometric results. Section 5 presents the main conclusions and research implications for policy and urban planning.

2. Residential (re)location determinants: a review

Understanding the impact of remote working on residential relocation trends during the pandemic requires a comprehensive theoretical approach. On the one hand, it is necessary to consider job-induced changes linked to employment opportunities —including remote working opportunities— which have formed the focus of traditional migration studies, as well as local moves within the same labour market associated with housing market inducements —including the question of amenities— which is often considered in residential mobility approaches (Clark & Davies Withers, 1999). Notably, the available evidence confirms that internal migration during the pandemic seems to have occurred over relatively short distances, with non-work considerations becoming more prominent in the residential decision-making process (see for example González-Leonardo et al., 2022). On the other hand, residential changes are also the result of a relocation choice process shaped by inter-related decisions on family size that may be influenced by socio-economic changes in the family unit (Clark & Davies Withers, 1999). Therefore, a life-cycle perspective can contribute to understanding individuals' priorities and spatial preferences (Clark & Huang, 2003; Van Acker & Witlox, 2009). The review presented here considers these dimensions and their evolution during the pandemic.

Previous studies of residential location determinants have evidenced the importance of job-induced changes (see for example, Ilham et al., 2024; Van Acker & Witlox, 2009), with change of workplace being one of the main triggers for relocation (Clark & Davies Withers, 1999). Indeed, the interdependence of choice of workplace and residence has been a constant in the literature since pioneering standard Alonso-Muth-Mills (Bjerke et al., 2025). Having said that, activity and workplace location of the household's main income earner are among the aspects that were most affected by the COVID-19 pandemic (Ilham et al., 2024). While the dynamism of Central Business Districts (CBDs) languished, workplaces and growth in employment opportunities were observed to relocate to metropolitan peripheries, for example in services and logistics activities (Althoff et al., 2022; Florida et al., 2023) or ICT consultancy services (Carvalho & Sgambati, 2023; Sánchez-Moral et al., 2022).

Residential relocation processes have also been well documented. Early studies on internal out-migration patterns in large cities in the US during the pandemic confirmed the influence of distance of place of residence to the CBD, along with urban density and exposure to working from home. This led to the conceptualisation of the so-called "donut effect" (Ramani & Bloom, 2021: 8), also observed in European cities (see for example González-Leonardo et al., 2022; Marigil-Alba et al., 2025; Rowe et al., 2023; Vogiazides & Kawalerowicz, 2022). Other authors have reported a reinforcement of suburbanisation and counter-urbanisation processes, with colonisation of the extended rural hinterland of cities (Colomb & Gallent, 2022; Marigil-Alba et al., 2025). At this point, it is worth mentioning that recent studies indicate a centripetal movement of workers, drawn to city centres from the metropolitan hinterland in a context of hybrid remote working schemes, resulting in "shadow effects" for medium-sized cities and rural areas (Bjerke et al., 2025).

Regardless of whether these residential trends become consolidated, the adoption of remote working is seen as the most decisive factor for people relocating further away from their workplace in the long term (Ilham et al., 2024). However, the propensity to work remotely depends on a series of factors. Thus, "workability" tends to be greater in activities

[2] The EVR contains information about migration movements that correspond to residential changes between municipalities declared in the municipal registers. Hence, both terms (migration movement and residential change) are equivalent in this article. The accuracy of information derived from the authors' own work is their sole responsibility.

based on intangible goods, such as information or knowledge, or that can replace face-to-face work with remote work (i.e. finance, administration, education or research). Studies conducted before the pandemic had confirmed that workers in skilled occupations and self-employed professionals are initially more willing to adopt remote working (Dingel & Neiman, 2020; Mongey et al., 2021; Samek Lodovici et al., 2021). In addition, younger age groups are more likely to adopt remote working as they are more familiar with the new technologies (Graham et al., 2017; Sostero et al., 2020; Ishii et al., 2023), whereas gender exerts a weaker influence unless motherhood is taken into account (Kapitsinis, 2025). Education and income are other factors affecting the digital gap (Dingel & Neiman, 2020).

All in all, remote working reduces the importance of distance to work, and this had an enormous impact on daily mobility patterns during the pandemic. Firstly, an overall reduction in travel distance was observed, together with an increase in frequency of remote working (Shemer et al., 2022). Secondly, remote working led to a reduction in the number of commuting days and a shift towards off-peak travel, particularly at weekends (Huang et al., 2023; Rafiq et al., 2022). In addition, the drop in CBD dynamism was accompanied not only by a reduced footfall in restaurants, food stores and personal services, but also by an expansion in e-commerce and deliveries, which shifted part of consumption to the digital world, reducing the number of shopping trips (Althoff et al., 2022; Florida et al., 2023; Carvalho & Sgambati, 2023). Lastly, the risk perception of users in relation to COVID-19 contagion, the rise in remote working and public restrictions caused a significant reduction in public transport usage during the pandemic (Semple et al., 2023). At the same time, a resurgence in private car use for commuting and leisure trips was observed in many cities (Budnitz & Tranos, 2022), together with an increase in active (non-motorised) transport such as walking and cycling (Shemer et al., 2022).

Residential location choice is also affected by the trade-off between other factors, such as dwelling characteristics, housing affordability and proximity to services and amenities (Kim, 2006; Masoumi et al., 2021; Van Acker & Witlox, 2009). All these are strongly conditioned by an individual's life stage, priorities and preferences (Van Acker & Witlox, 2009); more specifically, young adults are attracted to city centres not only by employment opportunities but also by the urban lifestyle, whereas middle-aged workers seeking to start a family, as well as older workers, relocate towards metropolitan peripheries drawn by the availability of amenities and housing accessibility (Clark & Huang, 2003).

In this context, people may have redefined their needs during the pandemic and reshaped the value of urban amenities (Wong et al., 2025). Thus, "panic mobility" (Cohen, 2020) and announcements of lockdowns generated different "pandemic mobilities" (Colomb & Gallent, 2022), affecting the demand for short-term rentals and the temporary occupancy of owned second homes and family homes in rural regions (González-Leonardo et al., 2022; Zogal et al., 2022). In addition, the phenomenon of "digital nomads", half-way between temporary residence and permanent mobility, has accelerated in recent years (Colomb & Gallent, 2022; Turner, 2020). At the same time, as the importance of accessibility to the workplace and other out-of-home activities has reduced, migrants seem to have become more concerned about the attributes of their home, such as the space for accommodating activities (Gallent & Madeddu, 2021) or the availability of green spaces (Melo, 2022).

Amenities also seem to exert a greater influence. In particular, health amenities, which influenced relocations during the first waves of the pandemic (Wolff & Mykhnenko, 2023; Wong et al., 2025), may motivate people to stay at their residential locations (Hamidi et al., 2020). The implications of access to broadband services are more controversial. Although this has been associated with the likelihood of adopting remote working (Moser et al., 2022; Rafiq et al., 2022), the better digital connectivity observed in urban centres may counteract the desire to live in low density areas or in larger houses (Soler et al., 2021). In short, as Gallent and Madeddu (2021) contend, the pandemic seemed to open up new lifestyle possibilities, and for some it also presented a chance to live in locations that had never been unaffordable but had hitherto been impractical given the need to be close to work.

Nevertheless, these trends also created local housing market pressure and exacerbated the housing affordability crisis, especially in the case of sometimes labelled "superstar cities". These cities suffered from the combined effects of financialisation of housing, the restructuring of modern political economies and the spatial reconfiguration of labour markets (Storper, 2013; Rodríguez-Pose & Storper, 2020; Gyourko et al., 2013). Thus, the rise of agglomeration economies is driving a massive increase in housing prices because of the concentration of high-paying jobs and life opportunities, pulling in a highly skilled workforce willing and able to pay "whatever it takes" for access to these opportunities (Findeisen, 2022). Gentrification is a well-known consequence of this (Colomb & Gallent, 2022). Furthermore, in a context of economic uncertainties, housing affordability has become crucial, motivating people to explore suburban regions with lower housing and living costs, and transmitting the rise in housing prices with even greater intensity to regional areas (Florida, 2023; Jayawardena et al., 2024).

Young workers are key protagonists in these processes; once the pandemic was over, they began to form families, have children and seek more space (Florida, 2023). Findeisen (2022: 382) differentiates between highly skilled professionals able to move their work online and relocate to secondary homes outside the urban cores or, in general, to housing in outer locations that offer connectivity; and young workers and those who cannot afford to move who opt for inner-city residential locations that provide access to amenities and office space by means of active transport. In this regard, Wong et al. (2025) contend that both the possibility and the intention to work remotely reveal the existence of a "teleworking paradox", whereby skilled workers who could initially work remotely are more likely to benefit from staying in city CBDs due to economic agglomeration effects related to participation in knowledge spillovers and connection with business partners and high-salary urban customers. Meanwhile, for other workers for whom the higher cost of living in cities is less of a concern, amenities —especially health services—represent a benefit of moving out. Interestingly, the authors also identify office workers as the main group that would gain from more work flexibility and lower living costs by moving to more rural or suburban areas close to second-tier cities, if remote working were available to them (Wong et al., 2025: 16).

In summary, the heterogeneity of the spatial effects of remote working, or the unequal behaviour of workers depending on their life-cycle stage, at a minimum questions the overall capacity of the "remote working revolution" to reduce regional disparities. Rather, the evidence suggests that in large cities, agglomeration economies are reinforced and housing affordability problems and inequalities are exacerbated. All this may negatively affect the attractiveness of large cities. Empirically integrating the propensity to work remotely when studying residential relocation factors thus seems necessary in order to better understand the spatial implications of remote working and guide policy and urban planning.

3. Data and methods

3.1. Case study

Madrid constitutes an internationally relevant case study. With more than 6.7 million inhabitants and spread over 8021.7 km^2, Madrid is the biggest metropolitan area in southern Europe. The central city houses

Table 1
Madrid: basic figs. (2021).

	Population (inhabitants)	Area (km^2)	Number of households
City of Madrid	3,277,451	605.77	1,322,855
Metropolitan area	2,954,996	2319.00	1,016,987
Rest of MRM	490,905	5097.25	207,001
Total	6,723,352	8021.70	2,546,843

Source: INE.

Table 2
Migration flows in the metropolitan region of Madrid (MRM) by municipalities of origin and destination.

Destination:	Origin: MRM		
	2019	2020	2021
MRM	151,619	140,006	158,996
Neighbouring provinces	28,286	35,365	31,875
Rest of Spain	67,188	73,104	74,128
Rest of the world	69,227	46,778	89,923
All	316,320	295,253	354,922

Origin:	**Destination: MRM**		
	2019	**2020**	**2021**
MRM	151,619	140,006	158,996
Neighbouring provinces	22,990	17,201	23,376
Rest of Spain	73,907	53,028	66,326
Rest of the world	173,056	93,518	121,090
All	421,572	303,753	369,788

Source: by the authors based on INE data (EVR, 2019, 2020, 2021).

nearly 49 % of the total population (3.28 million inhabitants) in just 605.77 km^2, reflecting a high urban density (Table 1). Meanwhile, 2.95 million inhabitants are located in the metropolitan area,[3] which extends over 2319 km^2. The rest of the metropolitan region presents a lower density (490,905 inhabitants in 5097.25 km^2), as it corresponds to the less urbanised periphery. Since the international financial crisis, Madrid, like other Spanish large cities, has maintained an international immigration level and a relative equilibrium of internal migrations between the central city, peripheries and rural municipalities (López-Gay, 2017; Rowe et al., 2023), with a slight trend towards suburbanisation as people have continued to seek a balance between access to urban services and quality of life (Gil-Alonso et al., 2021).

Madrid was one of the European urban regions worst hit by the pandemic due to several factors, including the transit of international passengers through its airport, urban density and social interaction. As a result, migration flows were altered. In Table 2, migration flows are classified according to the municipalities of origin and destination. Considering that migratory flows within the functional region of Madrid exceed its administrative boundaries, the neighbouring provinces of Avila, Cuenca, Guadalajara, Segovia and Toledo are included in a separate group (see Appendix A). In addition, the rest of the country and the rest of the world are included. A significant decrease in internal and international immigration was observed in 2019–2021, linked to mobility restrictions and lockdown measures. In contrast, immigration from intra-regional areas and neighbouring provinces grew by 4.8 % and 1.6 %, respectively.[4] Regarding outflows, migration to neighbouring provinces and the rest of the world increased considerably once some of the restrictions had been lifted (12 % and 30 %, respectively). All in all, intra-regional migration —the predominant flow— and migration to neighbouring provinces was reinforced, as observed by González-Leonardo et al. (2022), López-Gay et al. (2024) and Marigil-Alba et al. (2025) based on a similar local record database.

The pandemic also affected the number of households, which fell to 2,546,843 (down 4 % on the previous year) as a result of the decline in the number of residents and the return to family households, although spatial distribution remained highly concentrated in the city core (52 %) and its metropolitan area (39 %). The latest INE projections, which take into account the average reduction in household size, suggest a 21.8 % growth in the number of households for the period 2022–2027. In this context, access to housing, especially for the most vulnerable groups such as immigrants, has become a pressing problem since the international financial crisis (Martínez López, 2017).

3.2. *Description of the local indicator of propensity to work remotely*

This study was based on the construction of a local indicator of propensity to work remotely in the region of Madrid. As with other studies, we obtained our data from external sources (previous studies or surveys) to estimate the share of workers that could work remotely during the pandemic (see for example Mondragón & Wieland, 2022; Ramani & Bloom, 2021). However, instead of using pre-pandemic shares, we used the microdata of the Survey on Equipment and Use of ICT in Households (TIC—H), prepared by the INE, and the records of workers in the region obtained from the Social Security Office.

The TIC-H (version 2021) contained a specific block concerning remote working[5] and encompassed 15,027 individuals from all over Spain, of which 1369 resided in the region. In preparing the TIC—H, the INE seeks to ensure a sufficient sample size to provide reliable estimates in each region. An independent sample is designed to represent each

[3] There is no official delimitation of the Madrid metropolitan area. This study uses the metropolitan transport planning zones (Appendix A).

[4] This evidence may be interpreted in relation to the inter-regional centripetal movements described by Bjerke et al. (2025). Nevertheless, at local level the number of people moving from the rest of the MRM to the core and the metropolitan area represents less than 8 % of total movements, with a slight growth of 3.8 % between 2019 and 2021.

[5] The INE considers remote work in the TIC-H as work carried out using computers and telematic and telecommunication systems, that is, in a non-face-to-face manner outside company offices and where there is an internet connection.

region, as one of the survey's objectives is to provide data with this level of disaggregation. Meanwhile, the Social Security records include all persons who were working in any municipality of Madrid on the last day of 2020, a total of 3,244,975 individuals. From each database, we selected only those individuals with complete information who were resident in the region and over 15 years of age.

Unfortunately, it is not possible to identify individuals from either database because observations from both are presented in anonymised format. As an alternative, we used common observable characteristics to create links between the two data sources. Variables were created and transformed to have the same disaggregation of information in both databases.

Once we had homogenised the variables, we wanted to obtain estimates of the propensity to work remotely from the TIC-H as a function of these observable characteristics. We selected a discrete choice model for those workers (people aged 16 and over) who were resident in the region of Madrid in the TIC—H, where our dependent variable was the answer to the question of whether the employed person's main job allowed remote working, either totally or partially, applying the formula:

$$\mathrm{IPWR_i} = \mathrm{Prob(person\ i\ is\ allowed\ to\ work\ remotely} = 1) = \mathrm{F}(\mathrm{X_i}'\mathrm{b}).$$

Where F is the cumulative normal distribution, X_i is the vector of regressors of individual i and b is the vector of parameters. We considered the possibility of working remotely as being more important than whether the respondent actually did this activity in the reference week, since the reasons for not doing so might have been related to physical and/or cultural factors of both the company and the worker, but not to the more objective ability to exercise it. The regressors in this model consist of variables related to the characteristics of the employee's post, such as the firm's economic activity, type of contract, type of working day and the occupational level of the salaried worker, which are considered the most relevant ones in explaining the propensity to work remotely, albeit self-employed workers were excluded.[6] The supplemental material provides further details, including indicator robustness, also addressed in Arellano et al. (2024).

After linking the propensity to work remotely to each potential Social Security worker through observable characteristics, we calculated the local average value according to the worker's municipality of residence. In this way, we created the LIPWR for each municipality.[7]

3.3. Regression models for residential flows

In order to analyse the impact of the LIPWR (jointly with other regressors) on the weight of intra-regional residential variations in the municipalities of Madrid, we performed regression models by Ordinary Least Squares (OLS) (see supplemental material). We considered two dependent variables, one representing the number of intra-regional immigration movements in the municipality m (I_m), and the other the number of intra-regional out-migration movements (O_m) in 2021.[8] The information for these variables comes from the Residential Variation Survey (EVR), which is prepared by the INE based on continuous municipal censuses. Focusing on the study of intra-regional flows (the largest) enabled us to more easily assess the impact of the different explanatory factors at the municipal level.[9]

The EVR provides people's personal characteristics, such as gender, age and place of birth, but not details about their labour market status. For people aged under 16 or over 64 years old, movement figures are small and/or conditioned by factors beyond their control. Even though we cannot identify in the EVR whether the people who move are working or not, focusing on the 16–64 age group helps us focus the study on working people.

The EVR is highly suitable for studying long-term residential changes, as a declaration of changes in the municipal registry is mandatory in Spain, and also for exploring short-term mobilities, compensating a certain level of underestimation of movements at the beginning of the pandemic, and overestimation in relation to the relocation of people to second homes. By analysing the year 2021, we reduced these problems (see González-Leonardo et al., 2022).

Given the disparity of population sizes in the municipalities, both variables were divided by the population living in the municipality m in 2021 (P_m) and multiplied by 1000:

$$IR_m = \frac{I_m}{P_m} \times 1000 \qquad OR_m = \frac{O_m}{P_m} \times 1000, m = 1, \ldots, 179$$

We used several age intervals to cluster the dependent variables. Movements were divided among the population in the same age range and resident in the municipality, following these two cases:

$$IR_m^{16-64} = \frac{I_m^{16-64}}{P_m^{16-64}} \times 1000 \qquad OR_m^{16-64} = \frac{O_m^{16-64}}{P_m^{16-64}} \times 1000, m = 1, \ldots, 179$$

$$IR_m^{35-49} = \frac{I_m^{35-49}}{P_m^{35-49}} \times 1000 \qquad OR_m^{35-49} = \frac{O_m^{35-49}}{P_m^{35-49}} \times 1000, m = 1, \ldots, 179$$

In addition to distinguishing between migration movements and age groups, we constructed two models for each of these options, a reduced model and a full model.

The reduced models consider the basic factors driving population flows during the pandemic, directly inspired by Ramani & Bloom (2021). These include pre-pandemic migration flows (2019), population density, the distance to the CBD in the municipality of Madrid and the LIPWR. Moreover, the monocentric conception of the original model was modified by introducing a more realistic indicator of distance to workplace throughout the proxy variable of percentage of individuals working and living in the same municipality (see Appendix C for description of the regressors).

The full models introduce two sets of variables according to the literature and related to the housing market and the density of services and urban amenities available in the municipality. We considered other factors such as the percentage of second homes and metropolitan train stations in the municipality, but they have not been included because of problems of high linear correlation and multicollinearity with other regressors or their reduced contribution to the model and their continued lack of statistical significance.

The lack of information on housing prices for each municipality obliged us to create an indicator approximated by the average rent for multi-dwelling housing. The use of rent prices as against property prices may represent an advantage in terms of capturing pandemic mobilities, while also reflecting highly stressed housing market areas. The indicator distinguishes between municipalities where no information is available, and others where it is. We divided this second group between municipalities with a figure above, below or level with the average for the

[6] The study focused on salaried workers because according to the TIC—H, the percentage of people whose job allows them to do remote work as self-employed workers is 29.2 %, compared to 36.4 % of salaried workers in Spain. Something similar occurs in Madrid, although the percentages increase to 40.4 % and 52.4 %, respectively. This result is conditioned by the higher proportion of several economic activities in the region, such as information and communication, finance and insurance, and scientific and technical professional activities, where employees are over-represented (to a lesser extent for the self-employed).

[7] The spatial distribution of the indicator confirms the greater propensity to remote working in the central city of Madrid and in the bordering metropolitan localities, especially to the west and north (see Appendix B).

[8] We use intra-regional outflows and inflows instead of net balances. Using net balances would complicate the interpretation of the effects of relocation factors.

[9] The EVR does not consider intra-municipal movements, something that could be relevant in large municipalities such as Madrid.

Table 3
Number of intra-regional flows per 1000 inhabitants in municipalities in the metropolitan region of Madrid (MRM) (2019–2021).

Classification by urban size (inhabitants)	Inflows			Outflows			Net flows		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
>500,000	12.92	10.56	12.39	16.60	16.63	18.12	−3.68	−6.07	−5.73
100,000–500,000	28.09	24.81	29.14	28.36	26.00	28.58	−0.27	−1.19	0.56
50,000-100,000	36.22	33.48	40.63	33.53	29.03	33.47	2.70	4.44	7.17
20,000–50,000	42.79	37.86	41.96	36.70	29.71	35.33	6.09	8.14	6.63
10,000–20,000	46.14	47.32	46.43	38.14	31.78	35.90	8.00	15.54	10.52
<10,000	56.73	62.96	55.47	41.62	34.47	39.87	15.11	28.49	15.59
Classification by zone	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
Madrid city	12.92	10.56	12.39	16.60	16.63	18.12	−3.68	−6.07	−5.73
Metropolitan area	33.58	30.54	35.66	31.81	27.93	31.59	1.77	2.61	4.07
Rest of MRM	52.50	57.36	51.02	38.73	32.39	37.50	13.78	24.97	13.53
MRM (total)	24.93	22.73	25.47	24.93	22.73	25.47	0.00	0.00	0.00

Source: by the authors based on INE data (EVR, 2019, 2020, 2021).

region of Madrid (we use the latter subgroup as the basis for the regression).[10]

4. Results and discussion

4.1. Intra-regional migration trends by age group

This section examines intra-regional migration flows based on the weight of flows of groups in the 16–64 age range (see Section 2). In order to understand spatial and temporal patterns, our analysis considers spatial delimitations of the region of Madrid (see Section 2) as well as the classification of municipal origin/density of municipalities according to urban size in 2021.

An overall reduction in mobility was observed when the pandemic broke out, with a drop in immigration affecting all urban strata except municipalities with fewer than 20,000 inhabitants (Table 3). However, most pre-pandemic levels had been restored by 2021, including in the core city of Madrid (>500,000 inhabitants), and most notably in medium-sized cities with 50,000–100,000 inhabitants in the metropolitan area. As a result, the largest metropolitan cities, with over 100,000 inhabitants, maintained their historic negative net migration balance. It is the reduction in immigration, rather than an "urban exodus", that explain these negative net migration figures, as observed in American cities (Whitaker, 2021) and also in Madrid, based on mobile phone network data (Marigil-Alba et al., 2025). Meanwhile, less populated municipalities or those in peripheral regional locations consolidated their net positive balance, which almost doubled during the worst part of the pandemic. This is in line with results from the US, the Netherlands and Germany, among many other countries, where people sought to move from densely populated areas in pursuit of lower contagion risks and a better quality of life (see for example Klopper & Kooiman, 2021; Stawarz et al., 2022).

A much more novel picture emerges when differentiating migration trends by age group. In the largest metropolitan cities, including Madrid, inflows of the 16–34 age group were higher than the rest (see Table 4). In contrast, inflows of the 35–49 age group dominated entries into all municipalities below the 100,000 inhabitants' threshold. The opposite is observed when looking at outflows, which presented a higher intensity in the 16–34 age group in all urban strata except the core city, where the intensity is similar to the 35–49 age group. Moreover, the weight of the outflows of individuals in the 35–49 age group in 2021 was 22.45 per 1000 individuals in the core city, while the weight in the region was 28.65.[11] In other words, the tendency to remain located in the city is greater despite that the city has very high levels of propensity to remote working.

All in all, we can confirm the role of the 35–49 age group in the positive net balance observed in municipalities below the 100,000 threshold (both in the metropolitan area and beyond) and in the negative net balance in the central city. Notably, the group presented a practical net zero balance in medium-sized metropolitan cities, a finding that has enabled us to elucidate the "unclear position" of the intermediate metropolitan ring referred to by Marigil-Alba et al. (2025).

In short, our results confirm that the pandemic has not substantially altered the historic life-cycle pattern, whereby young immigrant workers seem to be more attracted to urban centres, drawn by employment opportunities and lifestyle. In contrast, workers at household formation age or older tend to locate their residence in metropolitan peripheries, attracted by housing facilities and certain amenities (López-Gay, 2017). However, the pandemic seems to have reinforced out-migration, particularly among individuals aged between 35 and 49, as these are the main protagonists of movements towards less dense, peripheral areas. Similar results have been reported for German cities, with younger workers taking the leading role in this movement (Stawarz et al., 2022). These differences may be related to some delay in achieving independence among young Spaniards due to difficulties in accessing the labour market, labour precarity and housing affordability (López-Gay, 2017). The importance of the relocation process among middle-aged workers suggests the need to pay special attention to their behaviour with regard to residential relocation factors, including the propensity to work remotely, as we shall do in the next section.

4.2. The influence of remote working in the context of residential relocation determinants

The effects of residential relocation factors, including the propensity to work remotely, on residential relocations registered in 2021 (inflows and outflows) are shown in Table 5. We estimated a reduced model and full model (see Section 2) for both the 16–64 and the 35–49 age groups.

A first consideration is that pre-pandemic immigration flows (2019) negatively influenced immigration in the general 16–64 age group, confirming the disruptive nature of the pandemic (see model 1a in Table 5). In this context, inflows were observed in municipalities located at a significantly greater distance from the CBD. Notably, urban density

[10] Above-average values are found in the city of Madrid and neighbouring municipalities. Values below the average are found in small rural municipalities bordering other provinces (see Appendix B).

[11] This estimate is based on the assumptions that one movement equals one individual, and that natural population growth is equal in the city and in the region.

Table 4
Number of intra-regional flows per 1000 inhabitants in municipalities in the metropolitan region of Madrid (MRM), by age intervals in 2021.

Classification by urban size (inhabitants)	Inflows			Outflows			Net flows		
	16–34	35–49	50–64	16–34	35–49	50–64	16–34	35–49	50–64
>500,000	17.41	12.15	7.00	21.14	22.45	9.85	−3.72	−10.29	−2.85
100,000–500,000	41.95	29.27	15.09	40.37	29.32	14.83	1.58	−0.04	0.26
50,000–100,000	47.78	49.14	22.46	43.19	35.92	19.93	4.59	13.23	2.52
20,000–50,000	46.88	52.33	23.94	45.81	37.07	21.85	1.07	15.26	2.09
10,000–20,000	50.43	56.16	30.36	44.88	37.68	24.39	5.55	18.48	5.97
<10,000	62.69	65.55	36.19	50.59	43.21	25.22	12.10	22.34	10.98
Classification by zone	**16–34**	**35–49**	**50–64**	**16–34**	**35–49**	**50–64**	**16–34**	**35–49**	**50–64**
Madrid city	17.41	12.15	7.00	21.14	22.45	9.85	−3.72	−10.29	−2.85
Metropolitan area	45.51	40.06	19.34	42.44	33.07	17.93	3.08	6.99	1.41
Rest of MRM	55.98	61.00	34.55	47.78	40.07	24.36	8.20	20.93	10.18
MRM (total)	32.04	28.65	14.45	32.04	28.65	14.45	0.00	0.00	0.00

Source: by the authors based on INE data (EVR, 2019, 2020, 2021).

Table 5
OLS estimates for flows by age group in 2021.

	Inflows				Outflows			
	16–64 years old		35–49 years old		16–64 years old		35–49 years old	
	Model 1a	Model 1b	Model 2a	Model 2b	Model 3a	Model 3b	Model 4a	Model 4b
Dependent variable (2019)	0.007	−0.129*	−0.014	−0.073	0.253***	0.141**	0.052	−0.096
	(0.074)	(0.066)	(0.056)	(0.052)	(0.055)	(0.055)	(0.069)	(0.059)
LIPWR	32.910*	5.006	66.334***	12.445	10.003	−3.363	27.093	−12.625
	(18.643)	(18.682)	(23.968)	(25.881)	(11.576)	(12.243)	(21.276)	(20.587)
Distance to centre	1.078***	0.046	0.852***	0.119	0.310**	−0.003	0.588**	−0.033
	(0.240)	(0.253)	(0.297)	(0.349)	(0.148)	(0.164)	(0.268)	(0.277)
Workplace distance indicator	−88.376***	−63.948**	−105.900***	−106.032***	−21.24	−13.905	−32.133	−21.412
	(27.557)	(26.399)	(33.464)	(35.34)	(16.479)	(16.515)	(30.148)	(28.063)
Population density	−0.001	−0.003	−0.004	−0.004	0.000	0.001	0.000	0.004*
	(0.002)	(0.002)	(0.003)	(0.003)	(0.001)	(0.001)	(0.003)	(0.002)
Rent of multi-dwelling housing								
No information	18.700***	−1.819	24.131***	7.657	3.987	−2.865	10.103	−6.021
	(6.385)	(5.988)	(8.011)	(8.271)	(3.914)	(3.871)	(7.175)	(6.58)
Above the mean value	−1.084	−4.874	−5.261	−6.332	−2.614	−3.539	−3.869	−5.413
	(6.233)	(5.349)	(7.863)	(7.365)	(3.847)	(3.462)	(7.092)	(5.885)
Single-family dwelling		0.501		1.336		−0.646		−1.040
		(0.710)		(0.976)		(0.459)		(0.780)
Surface area of dwelling		−0.377		−0.301		0.050		−0.027
		(0.239)		(0.329)		(0.155)		(0.262)
Tourist apartments		−1.065*		0.354		−0.747*		−2.439***
		(0.608)		(0.839)		(0.415)		(0.670)
Internet bandwidth		0.072**		0.157***		0.134***		0.329***
		(0.032)		(0.044)		(0.021)		(0.036)
Suburban train stations		−10.160		−6.864		−31.651**		−61.489**
		(21.541)		(29.636)		(13.995)		(23.711)
Non-university educational centres		3.616**		3.313*		2.383***		1.918
		(1.461)		(1.919)		(0.903)		(1.547)
Health centres		6.183***		1.546		0.881		1.372
		(0.879)		(1.206)		(0.608)		(0.976)
Cultural facilities		2.360***		4.859***		−1.877***		−2.734***
		(0.746)		(1.033)		(0.506)		(0.84)
Green areas		−92.889		−108.654		−26.594		−159.684
		(325.744)		(448.051)		(210.917)		(358.677)
Constant	21.983	85.984***	32.379*	74.298**	20.530**	11.153	17.489	3.682
	(14.555)	(22.239)	(17.873)	(29.898)	(8.807)	(14.149)	(16.189)	(23.901)
R squared	0.394	0.599	0.318	0.462	0.304	0.494	0.147	0.473
Municipalities	179	179	179	179	179	179	179	179

Note: the rent of multi-dwelling housing is a discrete variable, whose base is below or equal to the mean value in the region of Madrid. Standard errors in parenthesis. The significance levels are * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Source: by the authors based on INE TIC-H (INE); INE EVR (2021); Social Security Office; Autonomous Community of Madrid; Madrid Land Registry; Ministry of Economic Affairs and Digital Transformation.

does not seem to have exerted a significant influence on these entries, although this effect seems to be being captured by other variables (especially internet bandwidth, as we shall discuss below). Additionally, lower rents (namely small towns, which do not collect housing cost information) significantly attracted inflows in all age groups. In short, our results are in line with the "donut effect" described for American and European cities (e.g. Bjerke et al., 2025; Ramani & Bloom, 2021); particularly in Madrid, based on mobile phone network data (Marigil-

Alba et al., 2025). At this point, it should be noted that González-Leonardo et al. (2023) give a more sceptical interpretation, as the recovery observed in housing transactions in Spanish core cities, including Madrid, challenges the "donut effect" as a universal trend caused by COVID-19.

Furthermore, in line with Ramani & Bloom (2021), the greater propensity to work remotely from the destination exerts a significant attraction on the general reference age group, but with special intensity on flows in the 35–49 age group and younger (see models S1a and S1b in the supplemental material). Despite differences in data and methodologies, this evidence is in line with Kapitsinis (2025), who confirmed that the population aged 15–34 in European regions is positively associated with working from home, and with Hostettler Macias et al. (2025: 4), who found that working remotely is more common in the 36–55 age group in Switzerland. Furthermore, in one of the few attempts to empirically integrate remote working, Jansen et al. (2024) found that workers under 40 who work remotely in Italian metropolitan areas are significantly more likely to have already moved, while the probability significantly decreases for workers older than 45. On the other hand, municipalities with a lower percentage of people who both work and live there also seem to attract more inflows. This can be interpreted in relation to the overall reduction of the influence of distance to the workplace, observed already before the pandemic in Madrid (Sánchez-Moral et al., 2022) and other European cities through analyses of mobile phone and GPS tracking data in recent years (see Huang et al., 2023; Marigil-Alba et al., 2025).

The influence of housing characteristics and amenities is analysed using the full estimated model (see model 1b in Table 5). Firstly, inclusion of the new set of variables causes the effect of remote working to disappear in both age groups. Beyond statistical effects, this can be explained by the trade-off between residential relocation factors. With regard to housing characteristics (i.e. size, single-family dwelling), these seemed to have no influence. Indeed, López-Gay et al. (2024) previously found that moving into larger homes had less impact than other factors, particularly in Madrid compared with other large Spanish cities. An obvious explanation would be that affordability imposes a limit on the desire for particular housing characteristics, and a closer inspection by age group did indeed reveal that (all else being equal) municipalities with housing presenting a lower-than-average surface area attracted significantly more inflows in the 16–34 age group (see model S1b in the supplemental material). Similarly, a lower density of tourist apartments, interpreted as indicating an area with lower housing market pressure, attracted flows among individuals up to 49 years old (see models 2b in Table 5 and S1b in the supplemental material).

The availability of educational and cultural facilities attracts flows in both age groups. These results are fairly consistent with the life course perspective, which highlights the role of cultural facilities in young adults' lifestyles and educational amenities at the point of family creation. At the same time, the lack of influence of health facilities in the 35–49 age group can be interpreted as questioning the balance between agglomeration economies and (health) amenities, as observed by Wong et al. (2025) in European regions, with the former exerting a greater influence in Madrid.

Green areas had no significant impact. Apart from limitations on this indicator, this finding may indicate that good access to open spaces and leisure facilities can serve as a substitute for natural amenities (idem.). Likewise, the density of suburban train stations had little impact, reflecting the shift away from public transport that has been well-documented in US and European cities (Budnitz & Tranos, 2022; Semple et al., 2023). Further research is required to clarify the relationship with reliance on cars for commuting and leisure trips or with the rise of "micro-mobility", including personal and shared e-bikes and shared e-scooters, as observed in the neighbouring capital city of Lisbon (Melo, 2022).

Finally, the relationship between propensity to work remotely and internet bandwidth facilities, which presents highly significant and positive effects, merits special attention. In this regard, it seems that digital connectivity may be partially capturing the effect of the propensity to work remotely, especially among young and middle-aged people, as exploratory tests excluding internet bandwidth revealed (see models S9a and S9b in the supplemental material).

As mentioned at the beginning, the complexity of migration trends and changes suggests the need to consider the possible asymmetric influence of residential relocation factors. In contrast to immigration, outmigration movements tend to reproduce pre-pandemic patterns, although not in the specific case of the 35–49 age group (see models 3a and 4a in Table 5). Contradicting somewhat the "donut effect" explanations, this group's outflows tend to be more likely in municipalities far from the CBD and of higher urban density, which is consistent with the heterogeneity of spatial trajectories observed by Marigil-Alba et al. (2025) within the metropolitan ring. At the same time, the push-out effect of higher housing costs again seems to affect younger individuals to a greater extent (see the S3a model in the supplementary material). In this context, although the propensity to work remotely does not appear to have a significant influence, reference should again be made to the overlapping effects of internet broadband access. In short, remote working and/or digital connectivity generally favours population mobility. In this regard, it is worth noting that some local characteristics and amenities appear to act as population retainers, including the availability of public transport and cultural amenities, as well as the density of tourist apartments. Future research should explore whether this effect is related to the increased availability of accommodation for remote workers in these short-stay tourist establishments.

In summary, the dominant centrifugal movement of residents observed in Madrid at local level is in line with the "donut effects" described in many international studies on cities in the US (Ramani & Bloom, 2021), the United Kingdom (Rowe et al., 2023), France (Breuillé et al., 2022) and Spain (González-Leonardo et al., 2022; Marigil-Alba et al., 2025). This centrifugal movement acts simultaneously with a centripetal movement, more evident at inter-regional level, as described for the Swedish urban system (Bjerke et al., 2025). Indeed, the attraction exerted by the large city of Madrid during the pandemic, on the basis of agglomeration economies, contrasts with discourses about an "urban exodus" (Weisbuch, 2021).

In this context, and in response to the first research question, we found compelling evidence that the probability of remote working played a significant role in residential relocation during the pandemic, which was also observed, for example, in US and Italian cities (Jansen et al., 2024; Ramani & Bloom, 2021), but only indirectly in Madrid (González-Leonardo et al., 2022; Marigil-Alba et al., 2025). In any event, this effect seems uneven. Hence, regarding the second research question, we should point to the influence of remote working especially on the spatial behaviour of younger (and skilled) workers, as long as their inbound movements occur in municipalities closer to the place of work and with lower housing prices. In fact, these seem to remain the most decisive residential relocation factors (Ilham et al., 2024). Nevertheless, it cannot be ignored that many other individuals, even those belonging this group, remained located in the core city and in the medium-sized cities in the metropolitan area taking advantage of agglomeration economies and social interaction (Florida, 2023). Even in more remote areas within the MRM, not only the availability of health or educational amenities, but also other amenities connected to lifestyle and socialising, such as internet bandwidth and cultural facilities, seem to exert a greater influence as regards attracting these individuals.

5. Conclusions

The pandemic deeply altered the internal migration patterns in many large cities in the short-term. At the same time, there appear to be some permanent effects in relation to the capacity of remote working to make residential location choices more flexible, at least for a part of the active labour market population. This issue becomes of paramount importance

to ensure the maintenance of agglomeration economies and productivity, the very heart of urban economies, while assuring housing accessibility and large cities' attractiveness for living. Moreover, linked to the promotion of green amenities and the use of non-active transport modes, remote working can also contribute to urban sustainability.

Nevertheless, the spatial implications of remote working remain unclear. Directly inspired by other international studies, our study meets the challenge of empirically integrating remote working for the case study of Madrid, the biggest metropolis in southern Europe. To this end, a local indicator of the propensity to work remotely has been analysed along with the rest of residential relocation factors. It takes advantage of the results of a previous survey to assign probabilities to each worker on the basis of their occupational and activity information, and considers the characteristics of work contracts.

We can conclude that remote working propensity emerges as a significant factor in the residential location process of young and middle-aged adults towards less densely populated areas distant from Madrid's central core, motivated by professional or family reasons. As observed in North American 'superstar' cities (Florida, 2023), the movement of young remote workers in high-paying jobs towards suburbs and to other parts of the country may have important implications.

Firstly, given that propensity to work remotely depends on occupations, activities and personal characteristics, relocation movements are likely to reinforce existing urban inequalities. In this study, we cannot differentiate adult stayers and migrants because the available data only focus on residential variations. Nevertheless, according to our estimations many middle-aged adults appear to be remaining in the city of Madrid despite the higher levels of propensity to work remotely observed there. This behaviour can be linked to this group's high valuation of the benefits to be obtained from agglomeration economies and social interactions over potential benefits of moving.

Secondly, the relocation of middle-aged adults towards the metropolitan periphery increases the pressure on local housing markets. Our results show that the relocations of young and middle-aged people are often towards areas with lower housing prices —an attraction with a much greater weight than other housing characteristics-— but well supplied with urban amenities (i.e. Internet bandwidth, cultural facilities). In a context where remote work and/or digital connectivity tend to favour population mobility, certain short-term housing options and amenities (i.e. availability of public transport and cultural activities) may facilitate the anchoring of middle-aged adults in medium-sized and small cities in the metropolitan area.

In line with the third research question, different lessons can be learned from remote working experience during the pandemic, with the ultimate goals of assuring the attractiveness of the MRM, reinforcing its urban polycentrism and avoiding regional disparities. Thus, given the emergence of digital divides, investment in infrastructure is not enough; training policies are also necessary to attain digital equity. The residential preferences of young and middle-aged workers, especially those in high paid jobs, requires us to consider the impact of the fashionable 'talent attraction' strategies on the already highly gentrified city centres, acting to increase housing supply for youngsters in both the rental and the property markets, and regulating some forms of accommodation that are often extracted from the housing stock previously available for full-time residents, such as tourist apartments promoted via digital platforms and second homes (Colomb & Gallent, 2022). At the same time, the attractiveness of medium-sized and small cities in the metropolitan area, which initially present a good balance between economies of agglomeration and quality of life for remote workers, can be reinforced. In any case, caution should be paid to the potential transfer of high prices to this metropolitan periphery and an unsustainable increase in mobility associated with hybrid remote work. All this can be a challenge to Madrid's metropolitan governance due to the shared political responsibilities in labour and housing markets (national vs. regional government) and urban amenities (regional vs. local governments). Furthermore, the remote working regulations of private companies, sectoral associations and unions should also be considered.

The use of these databases and methods enabled us to delve into causal relationships in an integrated manner, controlling for remote working and a wide variety of residential relocation factors. In view of the general lack of appropriate statistics, the methodology used here combines ad hoc survey results with an administrative registry to mitigate data limitations. The main limitations of the study relate to the data on residential variations because some of the movements of younger adults may correspond to decisions taken at household level; in addition, there is a lack of information about movements within the municipality and professional groups, and interruption of the survey since 2022. Shortcomings in the explanatory factors relate to the exclusion of second homes due to multicollinearity problems, and the way of analysing distance to the workplace for the sake of simplicity. Lastly, we lacked detailed information to construct our local indicator of propensity to work remotely for the entire functional urban area, including municipalities in neighbouring provinces. Future research will have to improve these aspects. Furthermore, it would be desirable to complement this study with a qualitative approach that examines the strategies of workers and companies, especially from the point of view of the territorial implications of hybrid remote working schemes.

CRediT authorship contribution statement

Simón Sánchez-Moral: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Alfonso Arellano:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Roberto Díez-Pisonero:** Writing – review & editing, Writing – original draft, Visualization, Investigation.

Declaration of competing interest

None.

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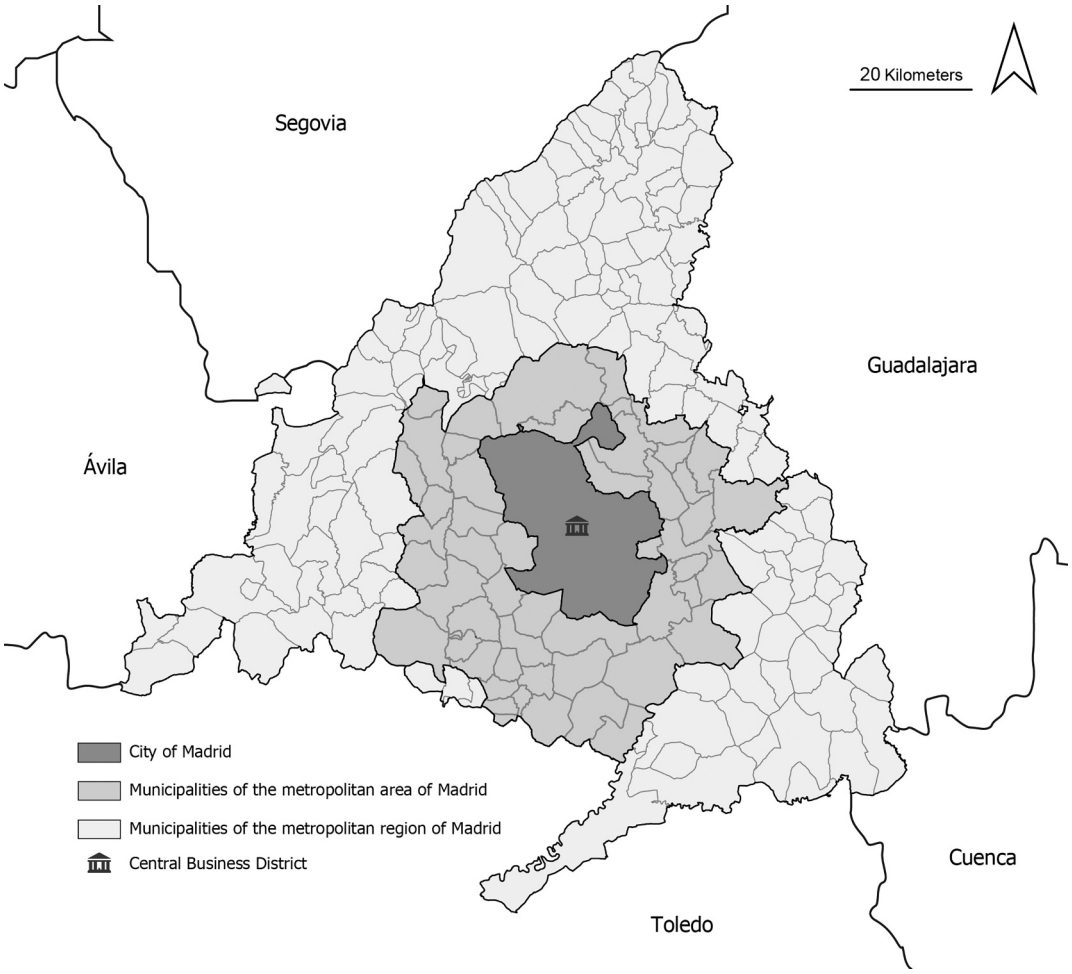
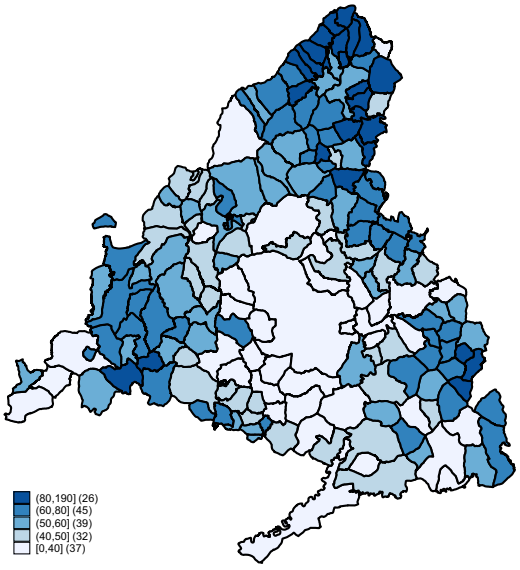
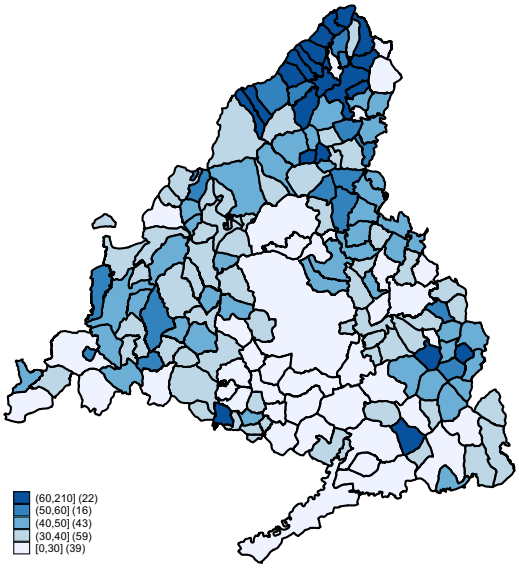
Appendix A


20 Kilometers
Segovia
Guadalajara
Ávila
Cuenca
Toledo
City of Madrid
Municipalities of the metropolitan area of Madrid
Municipalities of the metropolitan region of Madrid
Central Business District

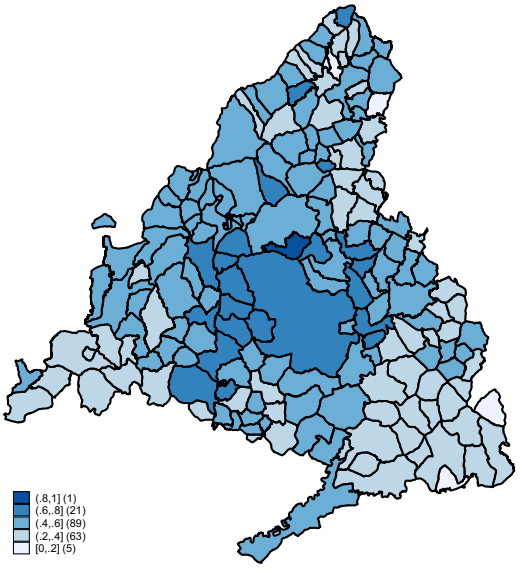
Appendix B. Distribution of variables by municipality



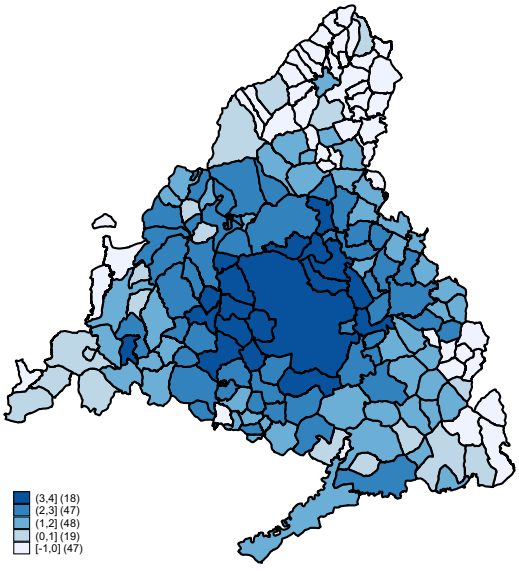
Intra-regional inflows (2021)



Intra-regional outflows (2021)



Local indicator of propensity to work remotely (2020)



Rent of multi-dwelling housing (2020)

Source: by the authors based on INE TIC-H; INE EVR (2021); Social Security Office; Autonomous Community of Madrid; Madrid Land Registry.

Appendix C. Description of regressors

Regressor	Description and source	Mean	St. Dev.
LIPWR	Average value of the indicator of propensity to work remotely by municipality (probability, between 0 and 1)[1,2]	0.446	0.137
Distance to centre	Distance to Madrid city CBD (km)	39.545	15.649
Workplace distance indicator	Weight of workers who live and work in the same municipality (between 0 and 1)[2]	0.251	0.085
Population density	Number of inhabitants in the municipality/total extension of the municipality (km^2) in 2020[3]	525.011	1127.796
Rent of multi-dwelling housing	Mean value (Euros/m^2) of the rent of collective dwelling by municipality in 2020. Discrete variable: 0 = No information, 1 = below or equal to the region of Madrid mean value (base group), 2 = above the region mean value[3]	1.101	0.787

(*continued on next page*)

(*continued*)

Regressor	Description and source	Mean	St. Dev.
Single-family dwelling	Number of single-family dwelling units/total extension of the municipality (km^2) in 2020[3]	2.333	3.426
Surface area of dwelling	Mean surface area of dwelling in the municipality (m^2) in 2020[4]	79.803	9.436
Tourist apartments	Number of tourist apartments/total population of the municipality in 2020 multiplied by 1000[3]	0.925	3.692
Internet bandwidth	Number of fixed broadband telephone lines/total population of the municipality in 2020 multiplied by 1000[5]	207.963	80.752
Suburban train stations	Number of suburban train stations/total population of the municipality in 2020 multiplied by 1000[3]	0.020	0.085
Non-university educational centres	Number of educational centers except universities/total population of the municipality in 2020 multiplied by 1000[3]	1.112	1.375
Health centres	Number of health clinics, health centers, and specialty centers/total population of the municipality in 2020 multiplied by 1000[3]	1.646	3.432
Cultural facilities	Number of theaters, museums and cinemas/total population of the municipality in 2020 multiplied by 1000[3]	0.421	2.482
Green areas	Weight of the municipality's surface area (km^2) that is green and wooded area in 2020 (between 0 and 1)[3]	0.002	0.007

Source: by the authors based on several sources: [1]TIC-H (INE); [2]Social Security Office; [3]Autonomous Community of Madrid; [4]Madrid Land Registry; [5]Ministry of Economic Affairs and Digital Transformation.

Appendix D. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2025.106462.

Data availability

The authors do not have permission to share data.

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