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The evolution of employment and workplaces in metropolitan regions during the pandemic: The case of Madrid

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ABSTRACT

Major metropolitan areas were faced with a disruptive pandemic considered at times to be capable of altering the role of economies of agglomeration and spatial interaction as fundamental economic drivers. Within this context, this paper seeks to analyse the performance and resilience factors of distinctive economic activities during the pandemic and to build a typology from the point of view of employment and its spatial evolution according to workplaces -both at intra-urban and regional levels- in the largest metropolitan region in southern Europe (Madrid). This study provides insights for the implementation of regional policies and urban planning in the post-pandemic scenario.

1. Introduction

The global economy faced a disruptive pandemic in 2020 leading to negative impacts in the short, medium and long term, which were visible at different spatial levels and in multiple dimensions of social reality (Tooze, 2021). Since its inception, different scenarios regarding the evolution of economic activities in urban regions around the world were projected, affected by mobility restrictions and population confinement, together with the blocking of global supply chains (Florida et al., 2023). Thus, a set of direct impacts on labour markets were identified which, in addition to job losses and a temporary reduction in migration flows, included the acceleration of business strategies of process automation, with e-commerce, e-business and remote working as the main exponents (Carvalho & Sgambati, 2023; Kniffin et al., 2021; Lund et al., 2021). Moreover, the different resistance and resilience exhibited by various economic activities in the recovery stages has led to reflection on their contribution to the sustainability of the urban development model (Brail & Kleinmanb, 2022).

The international literature on the effects of the pandemic in terms of urban economic activities and employment is extensive. Research challenges in this area include the complexity of the processes behind the observed trends, whether accelerated or reinforced by the pandemic (i.e. globalisation, offshoring, digitalisation, labour market flexibilisation), and the lack of adequate data to study them. For this reason, different alternative approaches have been adopted (e.g. Kresi & Bertin, 2023), as in studies that examine changes to the location of workplaces in cities around the world, especially with regard to increased remote working during the pandemic. Some of the most frequent approaches here include estimating the importance of 'working from home', based on survey data (e.g. De Fraja et al., 2021; Reuschke & Ekinsmyth, 2021) or job-posting locations (Kazekami, 2022); as well as changes to the movements of daily commuters based on mobile phone records (e.g. Monte et al., 2020; Mariotti et al., 2022a). In the case of Spanish cities, some studies have explored the evolution of employment at the municipal level (Gago-García et al., 2021; Salom-Carrasco et al., 2022; Sánchez-Moral & Solís, 2023).

Overall, the contribution of this paper is twofold. Firstly, it conducts a comprehensive analysis of changes in employment during the pandemic phases of crisis and recovery in economic sectors. This approach seeks to fill a gap in the existing literature, which has already included different factors (i.e. global supply chain integration, dependence on mobility, innovation and employment quality in analyses of employment changes and behaviour), albeit separately. It makes a methodological contribution by defining a typology of the behaviour of economic sectors during the pandemic. To do so, it conducts a thorough analysis of the administrative registry of Social Security affiliated

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workers in the metropolitan region of Madrid (>3.3 million records), the largest in southern Europe in terms of population and employment.

Secondly, it seeks to delve into the new geography of workplaces and employment in European metropolitan cities, both at the metropolitan and the intra-urban level. To this end, it proposes a methodology based on analysing employment via local indicators of spatial autocorrelation. This gives us the opportunity to identify whether the spatial redistribution of employment driven by the pandemic reinforces labour centres that are already in place, or whether it has prompted the establishment of new peripheral centres. And, in relation to this, to what extent do the advantages of agglomeration and spatial interaction, as well as proximity effects (*borrowed-sized*), maintain their influence on the location of employment in these contexts.

The paper is structured as follows. The second section reviews theoretical contributions on the evolution of economic activities during the pandemic, paying special attention to hypotheses put forward at the beginning of the pandemic regarding possible scenarios from a regional perspective. Section three explains the baseline data, indicators and methods used in the research. The fourth section draws up a typology of employment trajectories and considers the factors of unequal performance, while the fifth looks at the spatial trajectories of these categories and certain representative activities. The conclusions summarise some central ideas and discuss the implications of the study in terms of policies to promote and manage economic activities in metropolitan regions.

2. Theoretical framework

2.1. Factors accounting for the performance of economic sectors during the pandemic

The pandemic had a negative effect on national, regional and local economies, although the initial impact and subsequent recovery varied in intensity depending on economic activities. According to different international organisations (i.e. the European Central Bank), the crisis brought on by the pandemic may be split into the 2020 shock phase and the 2021 recovery phase (see for example De Santis & Stoevsky, 2023).

The temporary blocking of global value chains had negative consequences for important sectors such as automobiles, micro-electronic components, or fibre optics (Gerschel et al., 2020; KPMG, 2022). It also shed light on the impact of mobility restrictions, resulting from confinement, which especially affected sectors dependent on the movement of people, such as different means of transport and their related manufacturing industries, or those linked to the tourism cluster (Marcontell et al., 2020; Fletcher et al., 2020). Other services that require varying degrees of physical proximity and social interaction, such as the retail sector, cultural (concerts, theatre, cinema, museums…), or personal services, were also markedly affected (IDEA Consult et al., 2021). Finally, the increase in remote working, the rise of e-commerce and online entertainment may constitute factors behind decreased employment in artistic, recreational and entertainment activities in many cities.

Simultaneously, the pandemic would have created an opportunity for logistics and distribution companies, which were able to reinforce their e-commerce and home delivery strategies. Similarly, firms in sectors dealing with intangible goods such as information or knowledge, as well as advanced service activities, were better able to resist by replacing face-to-face work with remote work (Lund et al., 2021). To sum up, the trajectory followed by different economic activities enables us to systematically arrange a set of factors that explain the behaviour and unequal resilience of these activities during the pandemic:

- Degree of insertion in global production chains. The Covid-19 pandemic has revealed that relying on a limited number of countries and suppliers to provide intermediate and consumer goods creates exposes us to high risk of disruptive events. Thus, responses point to the restructuring of these chains, reducing their length (number of intermediate steps and cross-border flows) and geographical distribution, with lower risks associated with relocating to neighbouring countries -*nearshoring*- or countries that are part of the same trading bloc -*friendshoring*- (Pegoraro et al., 2020).
- Dependence on the mobility of people and goods. Sectors linked to the mobility of people, goods, information and capital have behaved differently, with the COVID-19 crisis initially restricting all types of physical movement. Moreover, the production of machinery and manufacturing elements linked to the transport sector was negatively affected by the aforesaid paralysis of global production chains.
- Spending on innovation. It is related to investment by companies in order to tackle the processes of digitalisation, automation, or the transformation of the production apparatus towards a green and decarbonised economy. The pandemic has led to increased spending on innovation, as previous trends in favour of remote working, e-commerce and automation have accelerated (Lund et al., 2021). Sectors with greater capacity to incorporate services linked to information and communications technologies, digitisation, automation or AI may therefore have been more resilient (Bürgel et al., 2023).
- Social interaction. During the pandemic, activities characterised by on-site customer service experienced the greatest drop in income and employment, involving hotel and catering, leisure, culture and parts of non-essential commerce (Carvalho & Sgambati, 2023; Florida et al., 2023). Conversely, other activities that were able to maintain contact with customers via remote working were less affected and have recovered more quickly, as is the case of sectors linked to the knowledge economy.
- Short-time work schemes (STWS). The approval of this type of schemes in various EU countries made it possible to maintain employment figures (Müller & Schulten, 2020), even if a company's activity ceased for a period of time.[1] In Spain, STWS helped to mitigate increased unemployment in different labour-intensive activities such as hotels, restaurants and retail (Méndez & Sánchez-Moral, 2023).
- Labour flexibility. Sectors with the highest proportion of precarious and unstable jobs, often linked to part-time work and low wages, are the hardest hit in times of crisis such as these.

In short, the pandemic has led to profound changes in the economy which, depending on the specific combination of the factors mentioned above, makes it possible to identify different dynamics or trajectories with regard to employment recovery. In this sense, some authors (De Vet et al., 2021) have proposed a classification that identifies four basic types of behaviour, exemplified by certain significant activities (Fig. 1). This research seeks to make further progress along these lines by proposing a greater number of behaviour types, obtained from the evolution of employment, and by means of a statistical analysis of their unequal presence in metropolitan territory.

All in all, this paper attempts to answer two initial research questions. What was the impact of the pandemic on employment evolution in different economic sectors within the metropolitan region of Madrid? And: Is it possible to establish a typology of employment trajectories during the pandemic? Hence, based on the prior literature review, the first working hypothesis is:

[1] According to the European Commission, short-time work schemes (STWS) are defined as ‘public programmes that allow firms experiencing economic difficulties to temporarily reduce the hours worked while providing their employees with income support from the State for the hours not worked. During the 2008 economic crisis, these schemes had already been implemented in some countries, and were used during the pandemic, with the support of the European SURE Initiative (European Instrument for Temporary Support to Mitigate Unemployment Risks in an Emergency (European Commission, 2020).

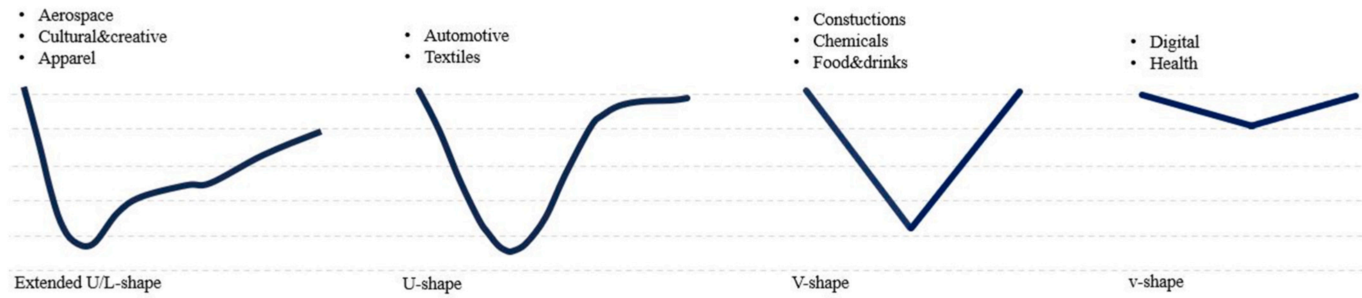

Fig. 1. Types of sectoral behaviour with regard to the pandemic. Source: Based on De Vet et al. (2021: 8). Authors' own.

[H1] There are differences in the evolution of employment at different phases of the pandemic, depending on the impact of explanatory contextual factors such as insertion in global value chains, dependence on mobility or social interactions; and various other structural factors such as international investment, innovation by firms, or the quality of employment.

2.2. The uneven spatial impact of the pandemic on employment in metropolitan areas

The impact of these global sectoral trends has been evident in large urban areas, with more or less lasting effects over time. In short, during the shock phase and the recovery phase, large cities and their metropolitan areas have undergone several transformations.

Initially, the loss of consumers, visitors and tourists to central areas due to mobility restrictions reduced the supply of commercial, leisure and cultural activities (De Fraja et al., 2021). After the first wave of the pandemic was over, urban centres once again became the sites of expansion of these activities, while Florida et al. (2023) have pointed to the redeployment of some as *central recreational districts*.

Business centres in many cities witnessed reduced levels of activity, which had a drag-down effect on nearby hotel, catering, commercial and personal services (gyms, hairdressing salons…) that were frequented by the employees of said offices (Florida et al., 2023). The progressive implementation of hybrid working models, a rising trend even before the pandemic (Shearmur, 2021), led to reduced demand for workspaces in conventional offices, as opposed to the expansion of other models focusing on flexible work, such as coworking (Mariotti et al., 2021; Zenkteler et al., 2022).

The expansion of e-commerce and e-business (another trend accelerated by the pandemic) also generated increased demand for storage space and jobs related to last-mile delivery for different types of goods. *E*-commerce has consolidated the expansion of the logistics sector in metropolitan areas (Rivera & Ruiz, 2021; Solís et al., 2019).

The spread of remote working during and after the pandemic (Althoff et al., 2021; Kniffin et al., 2021) has favoured the relocation of workspaces - the main focus of this article - as well as the reorganisation of residential space on a metropolitan scale. It should be noted that the notion of the 'workplace' was already under discussion before the pandemic, for example in the case of qualified professionals whose jobs are not conducted in fixed locations (Ojala & Pyöriä, 2018; Reuschke & Ekinsmyth, 2021; Shearmur et al., 2022). Furthermore, considering that some of the above-mentioned trends were already described prior to the pandemic, it is worth making a conceptual distinction between the acceleration and attenuation of pre-existing trends, as well as the appearance of wholly new ones.

At the same time, early evidence already suggested that remote working appears to provide new opportunities to relocate jobs in knowledge-intensive activities to residential suburbs and other areas away from large cities (López-Igual & Rodríguez-Modroño, 2020). This relocation to metropolitan environments is boosted by more affordable housing, good infrastructure and better environmental conditions (Ramani & Bloom, 2021; Carvalho & Sgambati, 2023; Colomb & Gallent, 2022; Ilham et al., 2024).

With regard to this evidence, a third question arises as to whether the pandemic led to short-term changes in the spatial distribution of economic activities in Madrid? To answer this question, three hypotheses are defined below for investigation:

[H2] The growth of remote working in sectors with a major presence in the CBD, such as business services activities or financial services, among others, may open the door to the progressive specialisation of these key areas in activities that are more related to consumption, leisure and recreation.

[H3] The rise of e-commerce and delivery economy strategies has led to increased employment linked to warehousing and logistics spaces, both within the central city and in the metropolitan region as a whole.

[H4] Jobs that may be performed either partially or wholly remotely - especially those linked to the knowledge economy - are more likely to be located in areas that do not belong to traditional central areas of the metropolitan region and the pandemic has increased said trend.

These hypotheses are limited to possible short-term behaviour induced by the pandemic, without the possibility of considering medium- or long-term trends due to the short period of time that has elapsed. However it may, in turn, encourage future research with a broader evolutionary perspective, allowing us to distinguish between temporary cyclical changes and more persistent ones, and to link them to the dominant trends since the start of the expansionary phase of the economic cycle in Spain and the European Union in 2013.

3. Data and methods

This research is methodologically organised into two main phases connected to the three research questions. The first phase seeks to analyse employment evolution during the pandemic in order to create a typology of economic sectors, as well as to understand the impact of both contextual and structural factors on the resulting categories. The second phase focuses on understanding the uneven spatial impact of the pandemic on employment, which translates into different spatial trajectories of employment within the metropolitan area of Madrid.

3.1. First methodological phase

In order to identify different employment trajectories by sector activities, we have used the microdata on workers affiliated with Spanish Social Security in the metropolitan region of Madrid. The affiliation to the Social Security covers all salaried workers with an employment contract and self-employed workers. More specifically, we analyse employment evolution in the shock and recovery phases, that is, in 2019–2020 and 2020–2021, according to the sector of company activity, based on the NACE rev 2 two-digit classification (87 branches). Moreover, the number of workers affected by an STWS by December 2020 and 2021 was also considered in the analyses. The strong concentration of these situations in a few activities makes it advisable to study the variations in employment by subtracting the workers who continue to be under an STWS, although this information is not available at the municipal level.

The performance of the employment trajectories is then studied by means of various indicators built according to the factors identified in Section 2. These indicators are measured at the sectoral level (given the limited statistical data available, it was necessary to combine varying sectoral aggregation levels); and whenever possible, at the start of the series. These indicators are:

- The average international investment per affiliated worker in the years 2018–2019 for each sector was obtained from foreign investment statistics (*DataInvex)* provided by the Ministry of Industry, Trade and Tourism.
- To characterise the degree of insertion of activities in global chains, an indicator was constructed based on the value of imports (from the rest of the country and abroad) over the value of production within the region, according to the *Input-Output Table* of the Community of Madrid (2018).
- Dependence on mobility was approximated by the value of intermediate consumption of goods or personal services by firms in the different sectors of activity compared to the value of their total production, according to the same *Input-Output Table* of the Community of Madrid (2018).
- Innovation was measured through the variable of average expenditure on innovation per company provided at national level by the *Innovation Survey* of the National Statistics Institute of Spain (2020).
- The job quality variables, approximated by the percentage of temporary contracts and part-time contracts within the different activities in 2019, was obtained from Social Security microdata files.
- The percentage of workers under STWS as of 31 December 2020 and 2021 was obtained from the *Employment Regulation Statistics* of the Ministry of Labour and Social Security.
- As a first approximation to the level of spatial concentration - and therefore the potential social interaction in spaces - the average distance to the nearest existing production unit of the same sector within the metropolitan region was calculated, according to information from the Community of Madrid (2019).

The differences observed in the mean of the indicators by trajectory type are studied from a descriptive perspective.[2] By means of an ANOVA and a non-parametric Kruskal-Wallis test[3] we can confirm the existence of globally significant differences in the indicator in question according sectoral trajectory types. Using a Bonferroni adjusted test of means, we can then identify the specific types that display significant differences in their means (differences are considered significant when the "*p*-value" in the different tests is below the set significance level of 0.01, 0.05 or 0.10).

3.2. Second methodological phase

In order to study the spatial trajectories of employment, three indicators are combined. Firstly, the variations in affiliated employment by municipality/districts[4] between 2019 and 2021 was studied, according to the types identified in the first methodological phase, as well as in a selection of specific activities within them. Secondly, the level of spatial concentration of employment and its evolution is studied, using both global and local Moran's statistics of spatial autocorrelation. The Global Moran's I (GMI) indicator is defined as:

$$I = \left(\frac{n}{S_0}\right) \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x-\overline{X})(x-\overline{X})}{\sum_{i=1}^{n} z_i^2}$$

where z_i is the deviation of an attribute for spatial unit i from its mean (x_i- $\overline{X}$), w_{ij} is the spatial weight between spatial unit i and j, n is equal to the total number of spatial units (215), and So is the aggregate of all spatial weights:

$$S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}$$

In short, positive and significant z-scores of the statistic ("p-value" <0.01) indicate the existence of spatial patterns of clustering among the spatial units considered; while negative and significant ones indicate that dissimilar values tend to cluster together.

The Local Moran's I (LMI) enables the identification of significant local clusters shaping the clustering patterns. This is calculated, according to the expression:

$$I_i = \frac{x_i - \overline{X}}{S_i^2} \sum_{j=1, j\neq 1}^{n} w_{i,j\left(x_j - \overline{X}\right)}$$

where x_i is an attribute for spatial unit i, $\overline{X}$ is the mean of the corresponding attribute, w_{ij} is the spatial weight between spatial unit i and j, and:

$$S_i^2 = \frac{\sum_{j=1, j\neq 1}^{n}\left(x_j - \overline{X}\right)^2}{n-1}$$

with n equating to the total number of spatial units.

In particular, LMI allows the identification of either: local clusters of high values surrounded by high values (*high-high*); low values surrounded by low values (*low-low*); high values surrounded by low values (*high-low*), o conversely low values surrounded by high values (*low-high*). From a dynamic perspective, the evolution of these spatial categories is analysed for the years 2019 and 2021.

4. Results and discussion

4.1. Employment trajectories during the pandemic in Madrid: An approach to the explanatory factors of sectoral performance

Regarding our first research question, employment evolution in the region during the pandemic displays a less marked fall than that of the GDP. Specifically, the initial impact between 2019 and 2020 is a fall in GDP of more than −6.5 % and a fall in employment of nearly −2 %. This crisis adjustment is very different from that recorded during the financial and real estate crisis of 2008, which led to an immediate rise in unemployment and a fall in the number of affiliated workers. The 2020–2021 recovery phase resulted in a GDP growth of over 10 % and 5

[2] The use of relative indicators by number of workers, enterprises or employment share limits the potential problem of size differences between the employment trajectories identified in the paper.

[3] Non-parametric tests are useful in small samples and/or when the assumptions of parametric tests are not met (i.e. lack of normality in data, unequal variances)

[4] The analysis combines two spatial units: 194 municipalities of the metropolitan region and 21 urban districts of the city of Madrid (see Appendix A). This approach provides a more accurate analysis of the spatial trajectories of employment. Additionally, by looking at Madrid's urban districts separately, we reduce the differences in the population/employment size of the city of Madrid compared to the rest of the municipalities.

% in the case of affiliated employment (Table 1).

One of the key reasons for improved employment has to do with the mitigating effect of STWS in protecting jobs during the pandemic. Thus, if we discount the number of workers under STWS from the figures of affiliated workers in the Community of Madrid, the initial fall in employment exceeds −5.6 %, in the same way that its growth in the recovery phase would exceed 8 %. Therefore, in order to properly identify the types of sectoral trajectories of employment, it is appropriate to consider affiliated workers, excluding those under an STWS.

Based on the average growth observed in each period for the activities considered here[5] (−5.13 between 2019 and 2021; +9.88 between 2020 and 2021), it has been possible to identify up to six employment trajectories according to the increase or decrease in affiliated workers (excluding STWS) above and below the threshold of ±5 % in the first phase and +/− 10 % in the second phase. For reasons of statistical analysis, it has been decided to maintain all activities classified at two digits of the CNAE-2009, although in some cases they have a marginal weight in the Madrid economy as a whole. The graphical representation of this typology is shown in Fig. 2 (see Appendix B).

The classification obtained displays notable differences in terms of the number of sectors that make up each type. The group of *resistant* activities, which have performed above average over the whole period (Type A1), consists solely of extraction activities related to construction, together with decontamination activities and other waste management services. Activities that resisted and responded better at the start of the pandemic, and then stabilised, are five in total (Type A2). Postal and courier activities, whose growth in the first phase of the pandemic can be linked to the demand for mail and home deliveries, are especially important here.

The number of activities that may be classified as *resilient* during the pandemic (Type B1) is also limited to eight. As in the previous cases, they are often associated with activities related to the provision of basic goods and the management and coordination functions of a metropolis during the first phase, such as energy and water supply, waste collection and treatment, building construction, along with business headquarters. Additionally, it is worth highlighting two types of activities identified in the scenarios projected at the start of the pandemic within this group, such as storage and transport-related activities, in relation to the demand for shipments and the reorganisation of urban logistics systems. We can also point to programming, consultancy and other computer-related activities as knowledge-intensive sectors that may have been better adjusted thanks to remote working strategies.

Compared to the above, as many as 27 activities had a relatively *stable* performance during both phases of the pandemic (Type B2). This is the case for most technology-intensive branches of the manufacturing industry (chemicals, pharmaceuticals, IT, electronics and optical products, etc.), as well as telecommunications and financial services. Around twenty activities exhibited a trajectory that may be described as *reactive* (Type C1), with an initial setback and subsequent increase in employment levels to figures similar to or even higher than those at the start of the pandemic, as levels of consumption by the population and businesses recovered, together with the volume of travel. This is a heterogeneous group, consisting of more traditional branches of the manufacturing industry (food, clothing, footwear, wood and furniture, etc.), together with business services and personal services. Special mention must be made of the inclusion of some of initially affected sectors such as travel agencies, hotels and catering and retail, and creative, artistic and entertainment activities.

Finally, a total of eight activities may be considered *declining*, as they display a much less dynamic behaviour, even within the general context of growth observed during the second phase of the pandemic (Type C2). They are characterised by their low technological and/or knowledge intensity, and belong to both the primary sector and the manufacturing or repair industry (manufacture of beverages, textiles, paper, electrical material, etc.).

For our second research question, we enquire about the impact of the main explanatory factors identified in the theoretical debate, on these sectoral trajectories. Table 2 displays the result of the comparison of the means of each group with respect to the variables selected by means of the Bonferroni test, together with the level of significance reached in the parametric and non-parametric tests[6] (see Section 3). Resistant activities (Types A1 and A2), which have had a more dynamic trajectory, show significant differences compared to the other groups. They have much higher levels of investment per affiliated worker, the differences being significant when compared with reactive and declining types. They are also more integrated in global chains and display higher expenditure on innovation per company, in line with De Vet et al. (2021)'s results on a different basis, although the differences are not statistically significant.

With regard to the employment characteristics indicators, there is a lower percentage of temporary, part-time employment, and workers under an STWS, establishing significant differences with more reactive trajectories in the case of the latter indicators. In terms of the spatial model of implementation, the results suggest that the most resistant activities during the pandemic are more widely dispersed in the regional map (according to the value of the distance to the nearest establishment), which translates into a higher dependence on transport services and a potentially lower spatial interaction with other establishments when compared to other sectors (notably, the difference with declining activities would not be statistically significant).

In resilient activities (Type B1), the level of average investment per affiliated worker is lower than in the previous group as is the degree of integration in global chains, or the innovation expenditure per company- not statistically significant in all these cases. The percentages of part-time and temporary employment (>23 % and 13 % respectively) stand out, in line with what was observed in the case of the more reactive trajectories (Type C1), with regard to which they set a significant difference in terms of the lower weight of STWS in the former. Other distinctive features compared to the first group are a high spatial concentration and social interaction with other companies in the sector at the regional level. Stable trajectories (type B2) show an intermediate level of investment, innovation expenditure, employment characteristics or spatial concentration, where the average values for these types of trajectories tend to be between the extremes.

The reactive and declining trajectories (Types C1 and C2) display a much lower level of investment per affiliated worker and expenditure on innovation expenditure by firms (significant in the case of the former indicator, compared to more resistant trajectories). These results suggest that the rapid recovery in output observed in the case of manufacturing industries - once the short-term supply shortage (De Vet et al., 2021) had been overcome - would not have been immediately passed on to employment, at least in the case of less technology-intensive activities.

At the same time, the levels of temporary, part-time employment or the presence of workers under STWS are among the highest, with a significant difference between Groups C1 and C2, confirming the positive impact of this policy instrument. Finally, their mode of implementation in the regional space points to a very high level of spatial

[5] The number of activities analysed is reduced to 83 due to the lack of available information to build the associated indicators on sectoral performance. This makes it necessary to exclude "General Government" sectors (NACE: 84), "Household activities as employers of domestic staff" (97) and "Activities of extraterritorial organisations and bodies" (99) from the study. Additionally, a small percentage of jobs do not have associated information on the activity sector.

[6] Considering the descriptive purpose of the analysis and the fixed number of observations available (83 economic sectors) it may be appropriate to group the "resistant" trajectories of employment (i.e. A1 and A2) together in order to reduce heterogeneity in the size of the types identified. The analysis with 5 types is fully presented as supplementary material.

Table 1
Evolution of Madrid's economy during the pandemic. Source: National Statistics Institute (INE), Social Security. Authors' own.

Indicators	2019	2020	2021	Variation 2020–2019	Variation 2021–2020
GDP (million €)	234,639	218,468	242,093	−6.89	10.81
Total affiliated workers	3,314,130	3,244,975	3,411,094	−2.09	5.12
Total affiliated workers (excluding STWS)	3,314,130	3,127,944	3,388,480	−5.62	8.33
Analysed affiliated workers (excluding STWS)	2,954,272	2,762,719	3,002,626	−6.48	8.68

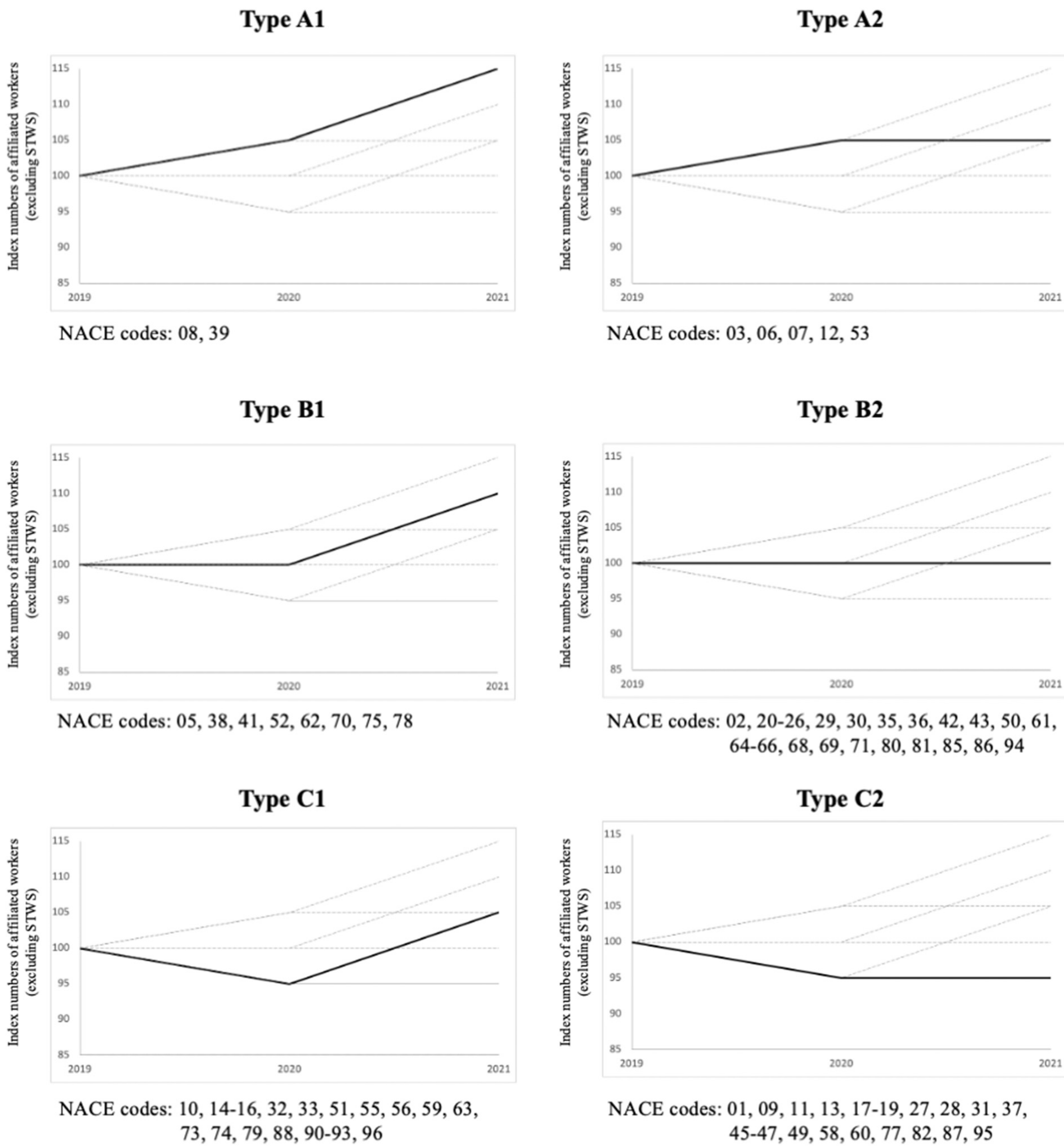

Fig. 2. Identification of employment trajectories in the region of Madrid. Source: Social Security. Authors' own.

concentration and interaction in the first case, and intermediate levels in the second, although the differences are not statistically significant. In any case, it seems evident that the decline and rebound observed in the production of this type of activities that are dependent on physical proximity and social interaction (idem), is also observed from the perspective of employment. In this sense, and in order to explore the issue further, the following section presents a dynamic analysis of spatial concentration through the Moran's I indicator, both at the global and local levels.

Table 2
Sectoral performance indicators by employment trajectories. Source: Authors' own.

	Means[1]					ANOVA test (P value)[2]	Kruskal Wallis test (P value)[2]
	A1-A2	B1	B2	C1	C2		
International investment per affiliated worker (thousands of euros)	129.063_{a}	$27.956_{a,b}$	$42.348_{a,b}$	9.507_{b}	$9.535_{b,c}$	0.048	0.127
Integration in value chains (%)	44.024_{a}	18.285_{a}	24.154_{a}	23.314_{a}	30.162_{a}	0.345	0.325
Spending on innovation per company (thousands of euros)	$1532.267_{a,b}$	$731.036_{a,b}$	1300.575_{a}	193.235_{b}	$546.132_{a,b}$	0.031	0.008
Weight of temporary contracts (%)	13.962_{a}	23.582_{a}	16.345_{a}	18.697_{a}	14.225_{a}	0.378	0.550
Weight of part-time contracts (%)	5.099_{a}	$13.229_{a,b}$	8.568_{a}	17.560_{b}	$9.416_{a,b}$	0.024	0.001
Weight of workers under STWS (%)	0.269_{a}	0.717_{a}	0.703_{a}	7.898_{b}	1.960_{a}	<0.001	<0.001
Weight of consumption of transport services (%)	6.731_{a}	4.995_{a}	2.753_{a}	2.299_{a}	4.081_{a}	0.131	0.016
Average distance to nearest company (meters)	4174.756_{a}	631.863_{b}	1217.101_{b}	840.473_{b}	$2056.811_{a,b}$	0.034	0.417

[1] Values in the same row and sub-table that do not share the same subscript are significantly different at $p < 0.10$ in the bilateral test of equality for column means. The tests assume equal variances. Tests are adjusted for all pairwise comparisons within a row of each sub-table using the Bonferroni adjustment.
[2] Differences in means between indicators are considered significant when "p-value" is below the set significance level of 0.01, 0.05 or 0.10.

4.2. The spatial impact of the pandemic on employment in metropolitan areas: Towards a new working location?

Since the start of the pandemic, there has been speculation on how the reorganisation of economic activities and workplaces or the phenomenon of remote working might have favoured a process of spatial deconcentration within urban regions, as was anticipated in our third initial research question. This second part of this paper analyses spatial employment trends between 2019 and 2021, according to the types identified in the previous section, together with a sample of specific activities. The analysis considers the evolution in both the districts of the city of Madrid and in the municipalities of the metropolitan region as a whole (see Section 2).

The overall evolution of employment is +3.86 %, maintaining a similar level of spatial concentration[7] (Table 3). Moreover, the weight of employment in the capital city, which is around 60 % of the total, points to a moderate level of polycentrism in the Madrid region (Nordregio et al., 2004). However, there are some differences according to the types identified, not to say internal changes that occurred during the pandemic within the city of Madrid.

A growth in spatial concentration is observed among the activities that we consider resistant and which had the lowest initial spatial concentration levels. If we focus on Type A2, which is the most frequent, the maps confirm employment growth throughout the areas surrounding the metropolis and in some districts of the city of Madrid according to the calculated variation rates. For its part, the reading of the behaviour of the local Moran's I index (Fig. 3A and B) points to the emergence of new clusters of activity in the southwest of the city, which are point to the adjacent metropolitan area (Getafe, Leganés, Pozuelo de Alarcón…). Thus, these new centres may be responsible for the slight decrease in the weight of the city of Madrid.

The activities that displayed the most stable and even resilient behaviour during the pandemic (Types B1 and B2) are the only ones to show reduced levels of spatial concentration, always down from very high starting levels. Their behaviour is very similar, but in the second case, which groups together industrial activities of high technological intensity and knowledge-intensive services, there is a fall in the weight of the central city, in line with the trends of recent decades (Méndez et al., 2007; Moral, 2009). Indeed, while employment increased in a dispersed fashion across much of the metropolitan region (Fig. 4A), there was a certain degree of decline in both the eastern part of areas surrounding the metropolis and in the city's interior. In both cases there were no significant changes to the spatial structure at the beginning and end of the period, with concentrations in the city of Madrid and its immediate surroundings continuing to be high (Fig. 4B).

Among reactive activities, related to the hotel industry or recreational services, an increase in spatial concentration was also observed, together with a simultaneous reduction in the weight of the central city. The maps point to positive developments in most of the metropolitan region, while in the city's interior, more than half of the districts experienced declining employment (Fig. 5A). Despite this, high spatial concentrations remained in almost all districts and in the nearest areas surrounding the metropolis (Fig. 5B). Declining activities also present very similar spatial behaviours to the latter, but their presence and concentration rose in the south of the region (Fig. 5C and D).

Beyond the uneven evolution noted according to identified sector types, it is worth asking about the spatial behaviour of different activities in relation to the hypotheses outlined at the start of the pandemic. Thus, for example, employment in financial and insurance activities grew by >13,000 in the region as a whole, half of them in workplaces located mainly in the northern sector of the capital, as well as in a large part of the surrounding area to the west, with a large number of business complexes. At the same time, there are occasional drops in the southern districts of the city and in some business expansion areas in other metropolitan sectors (Fig. 6A). In any case, the configuration of local activity clusters would not have been altered in these years (Fig. 6B), maintaining the image of skilled job concentration observed in recent decades in the region (Méndez et al., 2007; Solís et al., 2022).

The evolution of employment in retail trade confirms the existence of different spatial trajectories in an activity affected by the initial restrictions on mobility and the drive towards e-commerce, which explains the closure of less competitive shops and, at the same time, the rise of jobs that can be performed remotely. While there is a loss of jobs (>5000 affiliated workers) in the municipality of Madrid, the rest of the region displays growth (>3000 members), spread over a large part of the surrounding areas and the metropolitan periphery (Fig. 6C), which may be related to an increased demand due to residential changes during the pandemic (González-Leonardo et al., 2022). Similar trends have been observed in many other European large urban areas as London, Paris or Stockholm, reinforcing previous internal migration patterns (e.g. Colomb & Gallent, 2022). With regard to the fall in employment levels within the city, possible causes include reduced commercial activity near office areas, or reduced levels of tourism in central areas. At the same time, the dynamism observed in the districts to the south, which have an average lower-income population, may be associated with the persistent consumption of basic necessities. In spite of these recent trends, the starting territorial structure has barely changed, therefore the capital remains the main commercial node, together with the main

[7] Regarding the difference in employment volumes in the sectors analysed with reference to Table 1, it should be remembered that there is no detailed information on sector-based STWS at the municipal level. Additionally, around 5–6 % of the registries do not possess detailed spatial information, especially in the case of the interior of the city of Madrid.

Table 3
Evolution of affiliated employment and its spatial concentration by type of trajectories.

Indicators	A1	A2	B1	B2	C1	C2
Affiliated workers in the region of Madrid 2019	643	19,882	319,886	1,030,692	533,831	830,724
Affiliated workers in the city of Madrid 2019 (%)	15.86	74.36	64.25	63.00	64.46	52.39
Global Moran's I 2019	0.105	0.130	1.428	1.702	1.754	1.408
Global Moran's I 2019 (z-scores)[1]	2.675	7.678	35.154	41.470	43.570	34.246
Affiliated workers in the region of Madrid 2021	794	22,798	366,172	1,092,330	525,841	833,268
Affiliated workers in the city of Madrid 2021 (%)	19.40	67.41	64.89	61.96	62.22	51.77
Global Moran's I 2021	0.168	0.353	1.370	1.531	1.772	1.386
Global Moran's I 2021 (z-scores)[1]	4.172	15.732	33.901	37.398	43.744	33.536

Source: Authors' own.
[1] Note: all significant values with $p < 0.01$.

cities of the metropolitan area (Alcobendas, Getafe, Fuenlabrada, Móstoles…), as the largest consumer markets for the resident population (Fig. 6D).

Arts, recreation and entertainment activities shows significant job losses in connection with the banning of shows in an initial attempt to limit the concentration of people, together with remote working and the surge in online entertainment. The city of Madrid was the hardest hit area in absolute terms (a fall of almost 1300 affiliated workers) while there was equivalent growth (almost 1200 affiliated workers) in the rest of the region, also reflected in the spatial distribution of growth rates (Fig. 6E). Again, however, it is worth noting the increase in concentration in parts of the central city, and in other areas of the metropolitan region, which would explain the emergence and decline of some centres. This is the case of Alcobendas, which joins the central city's leisure and recreation cluster, while more peripheral districts to the east and south of the central city are no longer part of it (Fig. 6F). All in all, regarding the eventual functional change in business centres in the recovery phase, in office spaces freed up by the pandemic, it should be noted that employment growth in recreational activities and fall in financial and insurance activities is only occasionally observed in the same areas at the same time, and outside the more characteristic CBD (Fig. 6E). Also, non-definitive results appear to have been obtained when seeking to understand such functional changes, for example, in North American cities (Leong et al., 2023).

In relation to the logistics sector (transport and warehousing), it should be noted that studies prior to the pandemic already highlighted that the business model focused on the Internet sale and purchase of products and services was exerting a positive influence on employment expansion and spatial deployment of the sector (Solís et al., 2019). During the pandemic, employment has continued to increase in the region (>3500 affiliated workers), and it is especially intense in neighbouring metropolitan municipalities, which boosts pre-existing logistics areas, close to the high-capacity radial transport hubs (Alcobendas to the north, Torrejón de Ardoz and Alcalá de Henares to the east, Getafe-Pinto-Valdemoro to the south), which, in addition to their accessibility, provide moderately priced real estate. This is also the case in the interior of the capital, to the east and southeast, linked to the "last mile" (Fig. 7A). Strong levels of concentration in these areas are confirmed, but it does not alter the pre-pandemic spatial pattern (Fig. 7B), a conclusion similar to that obtained in other cities such as Milan (Mariotti et al., 2022a). Postal deliveries display a very similar positive behaviour, with decreasing concentration towards suburban and peri-urban areas (Fig. 7C), but with greater changes in the city's interior that may respond to specific business strategies that require a detailed study.

Finally, certain spatial behaviours that are more directly affected by the remote working phenomenon and based on the results, high capacity for resilience, may be mentioned. One of the fastest growing activities during this period was computer programming (+21,000 jobs in the region as a whole and + 4700 in the central city). Positive rates of change stand out in the northern part of the city and most of the municipalities in the metropolitan area (Fig. 8A), in the city's advanced tertiary expansion zone. As a result, the spatial structure marked by the concentration in the municipality of Madrid and other neighbouring municipalities to the north and west of the areas surrounding the metropolis (Alcobendas, Pozuelo de Alarcón, Boadilla del Monte) is maintained. In spite of the fall in employment, Villaverde, another area where professional activities have recently expanded in the south of the city, has reinforced its relative position (Fig. 8B).

At this point and in line with research by Sánchez-Moral & Solís (2023), it was investigated whether these employment growth trends correspond to self-employed workers, who in theory may have greater flexibility in terms of relocating their activity to metropolitan areas further away from Madrid. The mapping shows that their growth tends to be located in a third ring of metropolitan cities of intermediate size (Fig. 8C), in addition to others closer to the west (Pozuelo de Alarcón, Boadilla del Monte) and southern metropolitan areas (Leganés, Fuenlabrada), where we find evidence of the emergence of new centres, which were not statistically significant at the beginning of the period (Fig. 8D). Similar trends in some other North American and European cities (Mariotti et al., 2022a; Monte et al., 2020) have been interpreted as evidence of the still limited capacity of remote working to modify the role of proximity and face-to-face relationships in urban economies, in contrast to what has been concluded in cities such as Paris or Oslo (Mariotti et al., 2022b).

5. Conclusions

The pandemic had a direct negative impact on labour markets in large urban areas during 2020, with a subsequent revival in 2021. However, these developments were very uneven across sectors of activity and led to a certain relocation of employment within them. The aim of this article is to provide empirical evidence in both directions. For this purpose, it researches the Social Security data of affiliated workers in the Community of Madrid, together with certain built indicators, in order to analyse the contextual and structural factors that affect sector-based performance. In this context, it should be mentioned that there are few regional indicators of sectoral performance and there are conceptual and operational problems to studying workplace changes within a remote working context, as was observed even prior to the pandemic. Furthermore, it is important to acknowledge the limitations of our research hypotheses, which are restricted to short-term spatial trends. Further research will be necessary to extend the evidence found in this study to medium and long-term scenarios, that is, to observe these trends since the start of the expansionary phase of the last economic cycle, and in relation to their potential consolidation in future years.

All in all, the research has confirmed the importance of strategic factors in the response of cities and their different activities to the pandemic, such as their degree of insertion in global value chains, greater or lesser dependence on mobility and social interaction, expenditure on innovation, or the possibility of including a significant

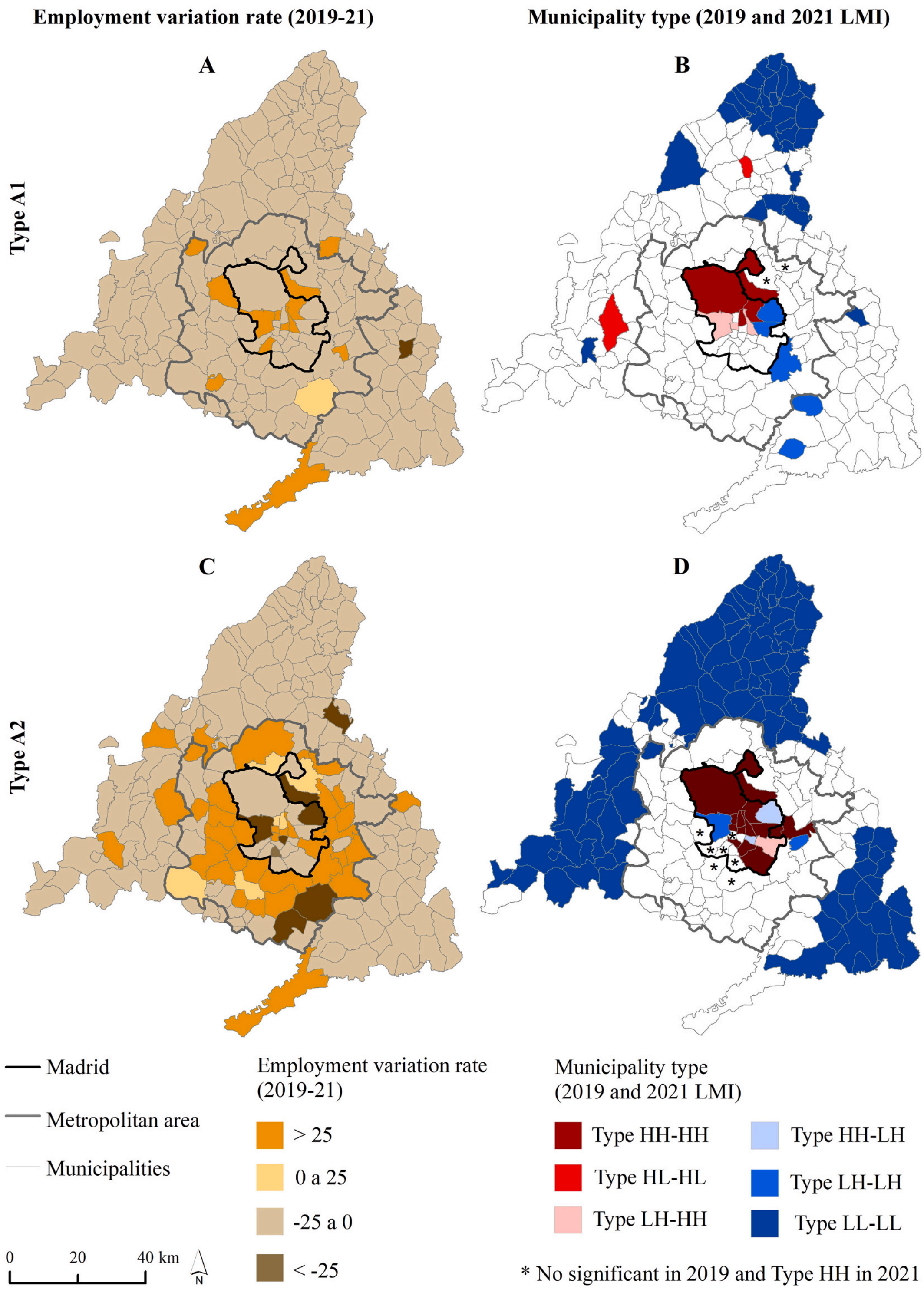

Fig. 3. Spatial behaviour in pandemic-resistant sectors, 2019–2021
Source: Authors' own.

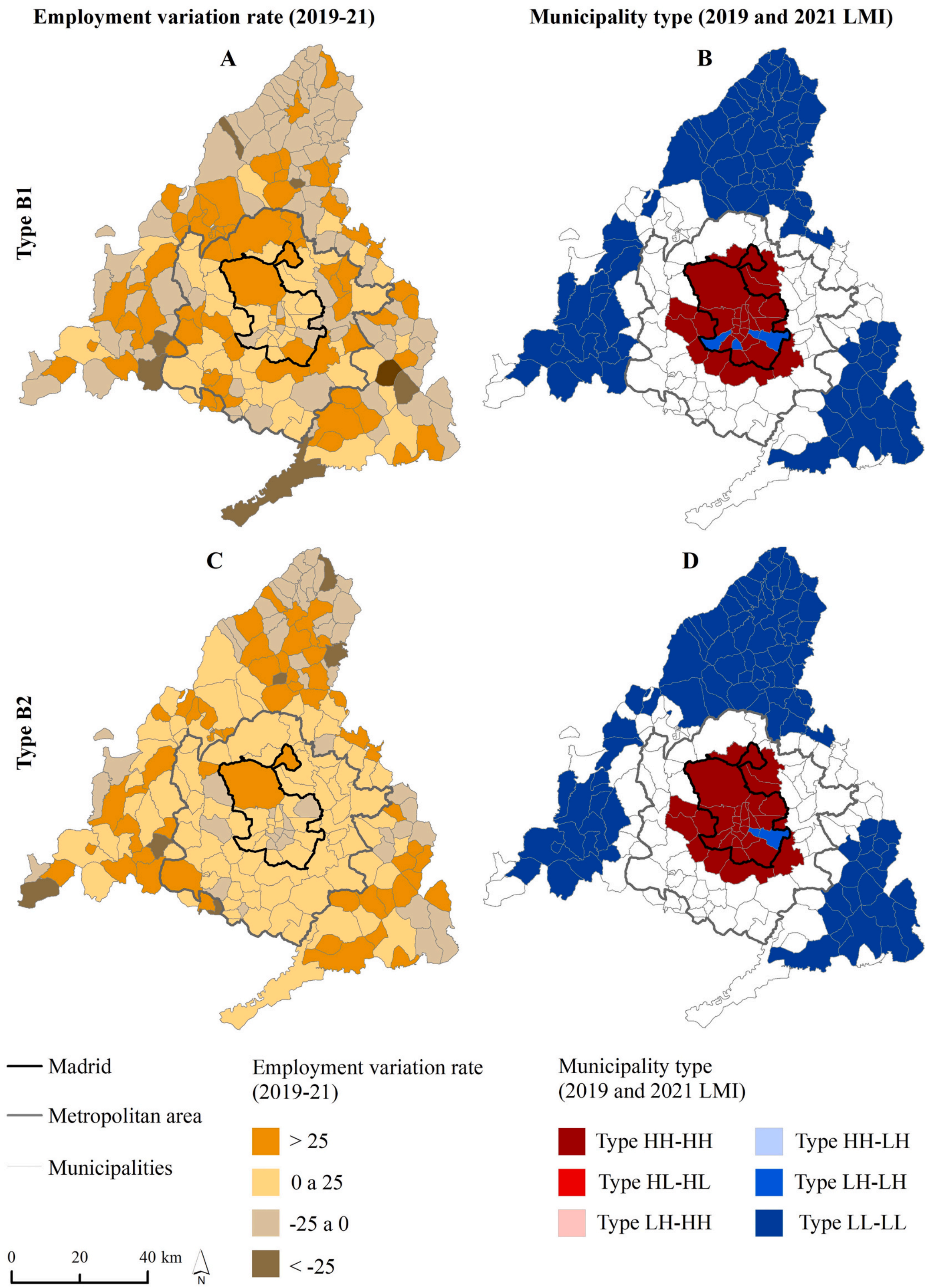

Fig. 4. Spatial behaviour in pandemic-resilient and stable sectors, 2019–2021. Source: Authors' own.

part of their workers in remote working systems (Hypothesis 1). This is in addition to the mitigating role of short-time work schemes (STWS). At the same time, the statistical analysis made it possible to establish a more developed typology of sectoral behaviour that supplements existing proposals in the international literature. On the one hand, there were seven activities classified as *resistant* as they displayed slightly increasing employment in these two years, yet of little importance except for postal and courier activities, boosted by e-commerce and home delivery. The eight activities considered *resilient*, where employment remained stable during the pandemic year and increased significantly afterwards, corresponded to the provision of basic supplies (water, energy, waste management), together with expanding logistics and knowledge-intensive services such as computer programming and consultancy activities or business headquarters, which benefited from the possibility of remote working. On the other hand, *stable* activities were much more numerous and maintained employment in the period

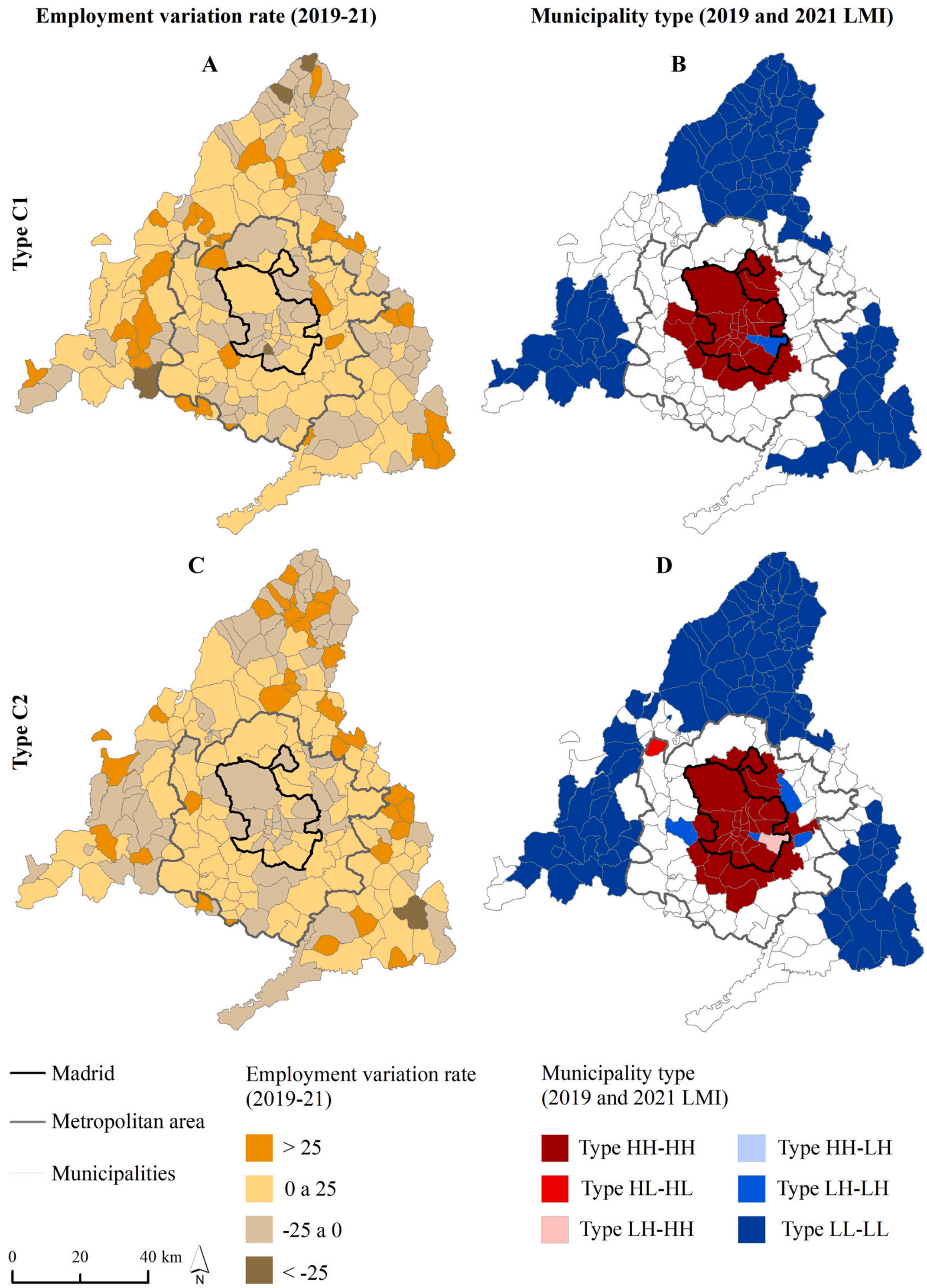

Fig. 5. Spatial behaviour of reactive and declining sectors during the pandemic, 2019–2021
Source: Authors' own.

under review, including many industrial sectors, as well as financial and telecommunication services. The counterpoint was provided by *reactive* activities, which suffered significant job losses in 2020 but made a rapid recovery the following year, as mobility restrictions were overcome while consumption experienced a revival, with much of trade, as well as business and personal services, or basic goods manufacturers, revealing their vulnerability to a disruptive event. This was maximised in a small group of *declining* activities, all of them low knowledge-intensive services, where employment was steadily reduced, in a process already visible beforehand and reinforced by the pandemic.

The analysis of the spatial behaviour recorded by each type, as well as their representative activities, makes it possible to establish differences that are no less important. Thus, greater spatial dispersion and lower spatial interaction is a trait associated with some of the most

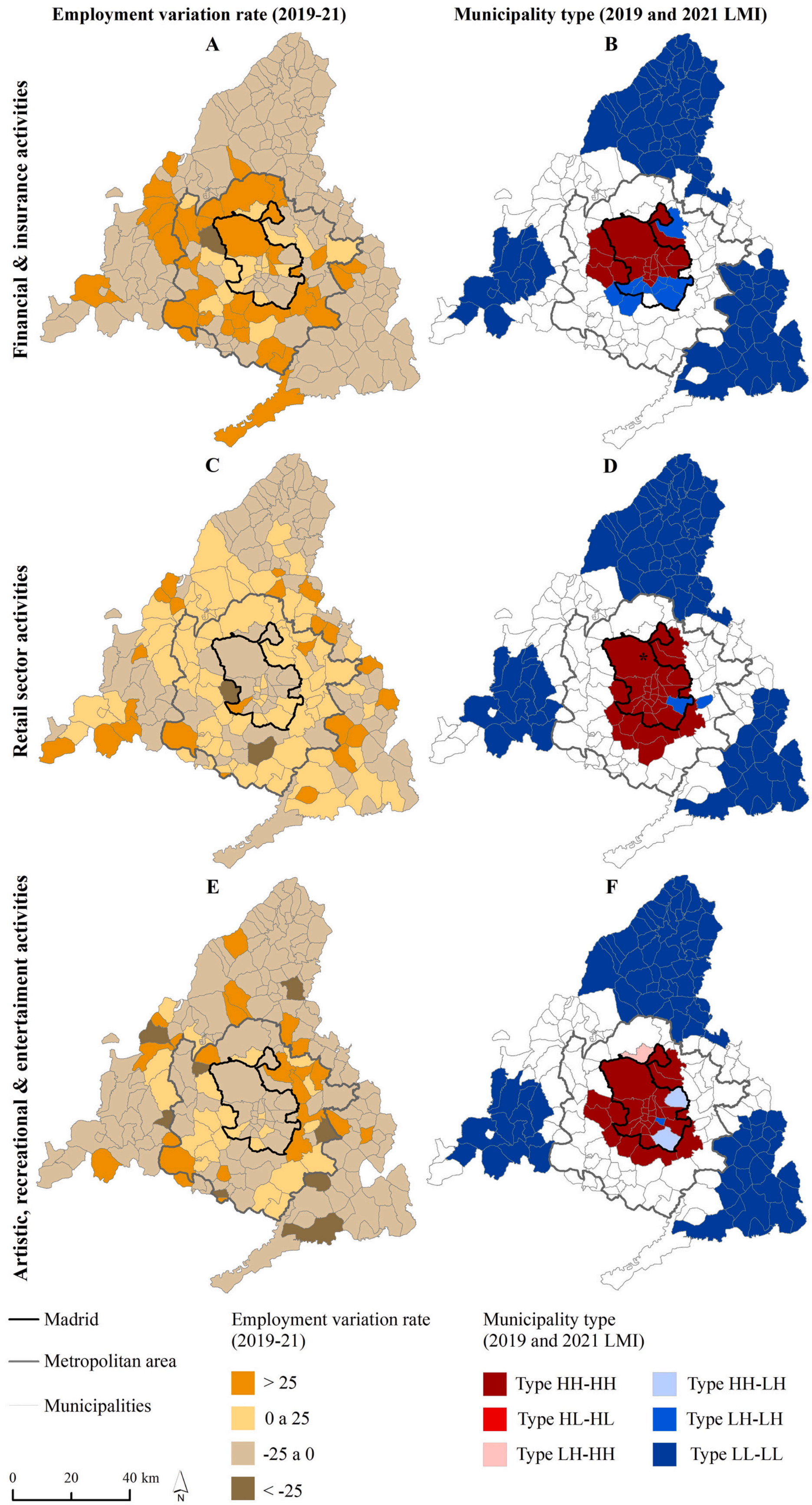

Fig. 6. Spatial behaviour of financial activities, retail, and the arts and recreation, 2019–2021
Source: Authors' own.

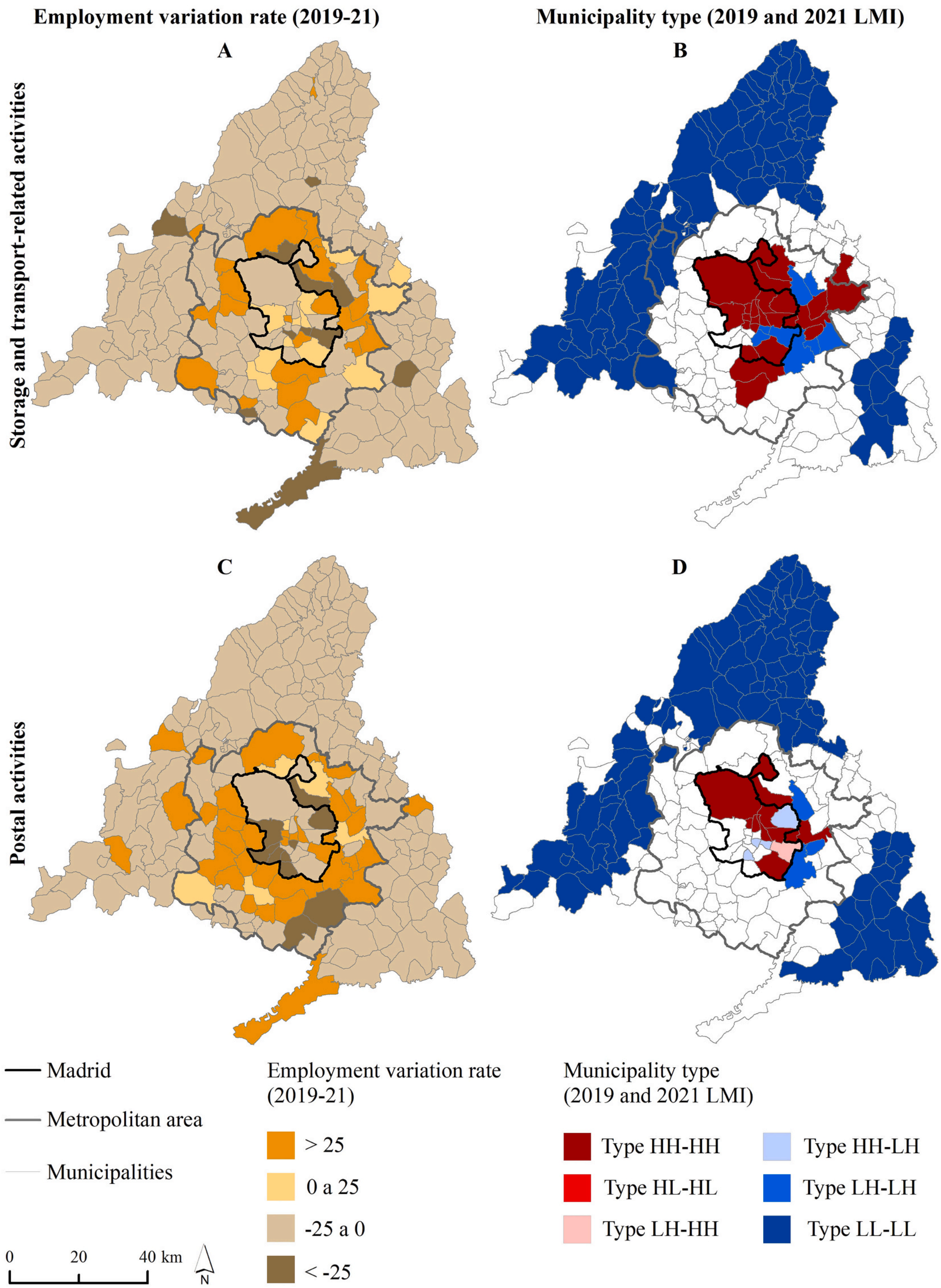

Fig. 7. Spatial behaviour of transport and warehousing activities and postal activities, 2019–2021. Source: Authors' own.

resistant activities. In this way, it is confirmed that part of the employment shifted to the suburban and even peri-urban areas of the city of Madrid, with varying intensities of this process that at least partially responded to changes in the location of the population and to the possibilities of decreased concentration offered by remote work, especially for knowledge-intensive sectors (Hypothesis 4). It is also worth noting the growth of employment in the metropolitan peripheral areas, associated with the boosting of logistics and home delivery systems (Hypothesis 3). On the other hand, concentrations within the main metropolitan centres where company and customer interactions are reinforced, appear to be associated with the more reactive behaviour of certain activities. In this regard, the joint evolution of activities such as finance, commerce or recreational activities does not seem to point, so far, to a functional change in the central business areas of the city of Madrid (Hypothesis 2).

All of the above confirms the existing heterogeneity in sectoral and spatial trajectories, which makes it necessary to observe the underlying economic and sector-specific characteristics in the recovery and

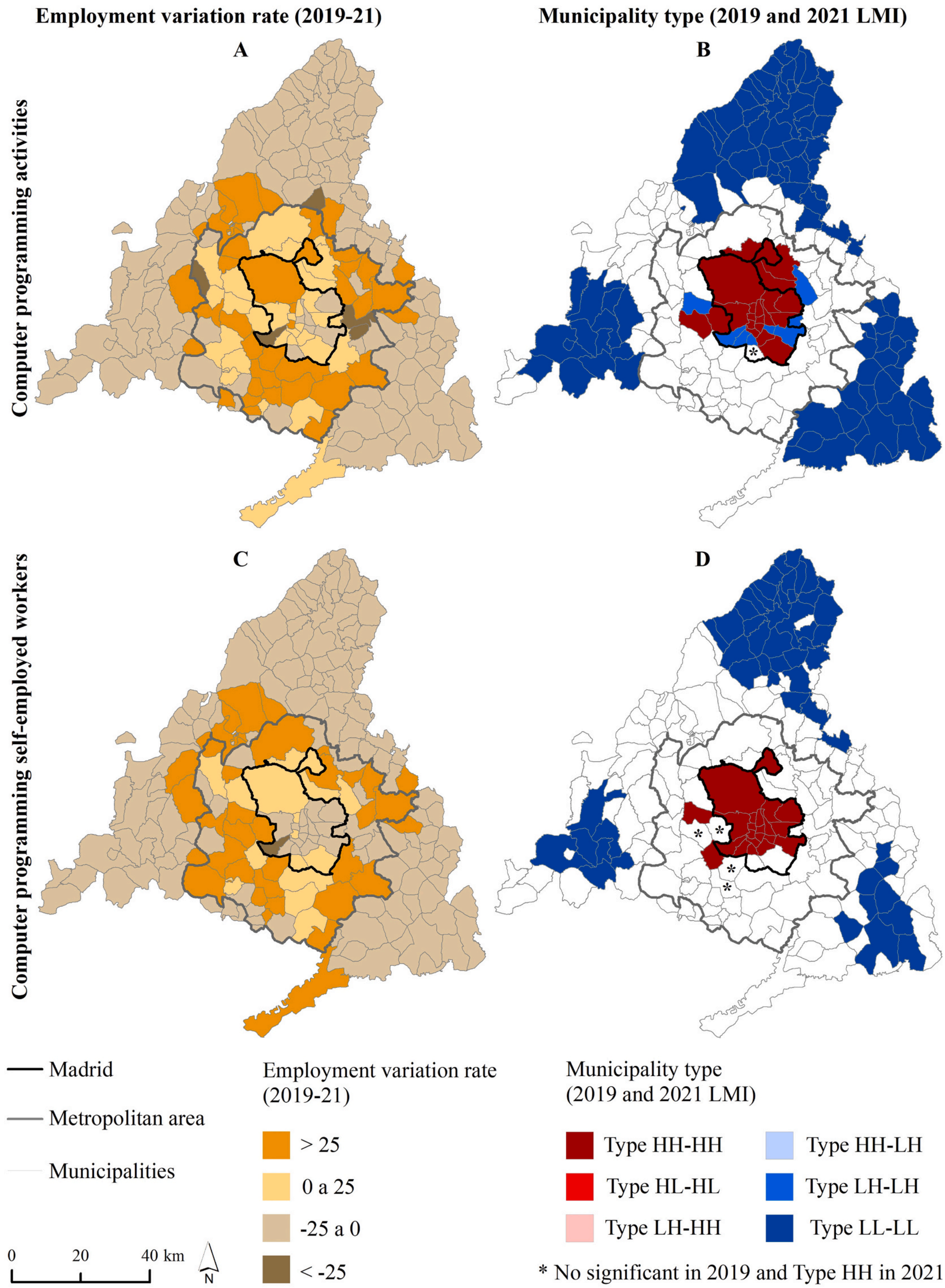

Fig. 8. Spatial behaviour of computer programming and self-employed workers in this sector, 2019–2021. Source: Authors' own.

resilience plans (De Vet et al., 2021:9). Within these plans, regional and urban policies can play a fundamental role in ensuring the competitiveness and sustainability of large metropolitan regions in the post-pandemic scenario such as Madrid but also others affected by similar general trends within their own unique contexts (Kresi & Bertin, 2023). More specifically, the experience of recent years has confirmed the need to maintain the attraction of foreign investment and stimulus derived from business innovation strategies. Furthermore, planning may reinforce polycentrism, making it possible for economic activities such as business services or others linked to leisure-consumption, among others, to continue to benefit from the advantages of agglomeration and spatial interaction, within a framework of greater deconcentration on a metropolitan scale; without forgetting, likewise, contributions to designing increasingly complex logistics and warehousing systems, which are increasingly in demand due to trends such as platform capitalism or the delivery economy. This will require consolidating the supply of services and the consequent residential attractiveness of peripheral metropolitan centres that, in addition to their higher environmental quality, now offer the opportunities for remote working, and which will also require paying attention to possible changes in people's mobility needs. Based on the conclusions of this study, our final stakeholders include policy makers, companies, urban developers and citizens.

CRediT authorship contribution statement

Simón Sánchez-Moral: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Eloy Solís:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation. **Ricardo Méndez:** Writing – review & editing, Investigation, Conceptualization. **Inmaculada Mohino:** Writing – review & editing, Formal analysis.

Declaration of competing interest

No potential conflict of interest was reported by the authors.

Data availability

The authors do not have permission to share the Social Security affiliation raw data.

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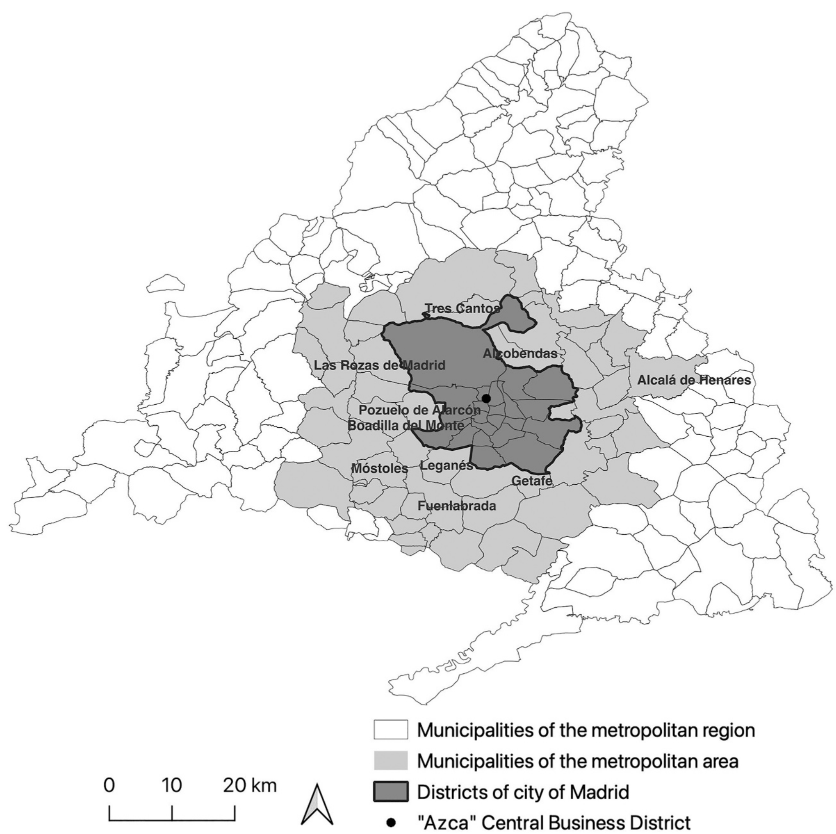
Appendix A. Location map. Source: Authors' own



Appendix B. Economic activities classifications. Source: Authors' own

Type A1

Cod.	Description	Cod.	Description
8	Other mining and quarrying	39	Remediation activities and other waste management services

Type A2

Cod.	Description	Cod.	Description
3	Fishing and aquaculture	12	Manufacture of tobacco products
6	Extraction of crude petroleum and natural gas	53	Postal and courier activities
7	Mining of metal ores		

Type B1

Cod.	Description	Cod.	Description
5	Mining of coal and lignite	62	Computer programming, consultancy and related activities
38	Waste collection, treatment and disposal activities (…)	70	Activities of head offices; management consultancy act.
41	Construction of buildings	75	Veterinary activities
52	Warehousing and support activities for transportation	78	Employment activities

Type B2

Cod.	Description	Cod.	Description
2	Forestry and logging	50	Water transport
20	Manufacture of chemicals and chemical products	61	Telecommunications
21	Manufacture of basic pharmaceutical products (…)	64	Financial service act., ex. insurance & pension funding
22	Manufacture of rubber and plastic products	65	Insurance, reinsurance & pension funding, excl. comp. Soc. Sec.
23	Manufacture of other non-metallic mineral products	66	Activities auxiliary to financial services and insurance act.
24	Manufacture of basic metals	68	Real estate activities
25	Manuf. of fabricated metal products, excl. mach. & equip.	69	Legal and accounting activities
26	Manufacture of computer, electronic and optical products	71	Architectural & engineering act.; technical testing & analysis
29	Manufacture of motor vehicles, trailers and semi-trailers	80	Security and investigation activities
30	Manufacture of other transport equipment	81	Services to buildings and landscape activities
35	Electricity, gas, steam and air conditioning supply	85	Education
36	Water collection, treatment and supply	86	Human health activities
42	Civil engineering	94	Activities of membership organisations
43	Specialised construction activities		

Type C1

Cod.	Description	Cod.	Description
10	Manufacture of food products	63	Information service activities
14	Manufacture of wearing apparel	73	Advertising and market research
15	Manufacture of leather and related products	74	Other professional, scientific and technical activities
16	Manuf. wood & products of wood & cork, exc. furniture (…)	79	Travel agency, tour operator & other reservation service (…)
32	Other manufacturing	88	Social work activities without accommodation
33	Repair and installation of machinery and equipment	90	Creative, arts and entertainment activities
51	Air transport	91	Libraries, archives, museums and other cultural activities
55	Accommodation	92	Gambling and betting activities
56	Food and beverage service activities	93	Sports activities and amusement and recreation activities
59	Motion picture, video & TV programme production (…)	96	Other personal service activities

Type C2

Cod.	Description	Cod.	Description
1	Crop and animal production, hunting and related service act.	45	Wholesale, retail trade & repair of motor vehicles (…)
9	Mining support service activities	46	Wholesale trade, except of motor vehicles and motorcycles
11	Manufacture of beverages	47	Retail trade, except of motor vehicles and motorcycles
13	Manufacture of textiles	49	Land transport and transport via pipelines
17	Manufacture of paper and paper products	58	Publishing activities
18	Printing and reproduction of recorded media	60	Programming and broadcasting activities
19	Manufacture of coke and refined petroleum products	77	Rental and leasing activities
27	Manufacture of electrical equipment	82	Office administrative, office support (…)
28	Manufacture of machinery and equipment n.e.c.	87	Residential care activities
31	Manufacture of furniture	95	Repair of computers and personal and household goods
37	Sewerage		

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cities.2024.105373.

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