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Who were the losers and winners during the Covid-19 pandemic? The rise of remote working in suburban areas

Ilaria Mariotti [a], Dante Di Matteo [b] and Federica Rossi [a]

ABSTRACT

The Covid-19 pandemic has rapidly altered the habits and lifestyles of every citizen worldwide and will have effects in the medium to long terms. The need for 'social distancing' has negatively affected urban areas and encouraged a rescheduling of working methods. Knowledge-intensive activities have been massively undertaken on a large scale in remote working, mainly carried out at home. Within this context, the paper explores the changes in working modalities towards remote working by focusing on the Lombardy region in north-west Italy. Specifically, it explores the renewed suitability of the municipalities outside the regional capital city of Milan with regard to remote workers during the pandemic and compares it with the period before the pandemic, and also it analyses which determinants play a role. The results show that municipalities closer to Milan with a strong broadband connection, a high concentration of knowledge workers and foreign immigrants are more suitable for hosting remote workers.

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KEYWORDS

remote working; Covid-19 pandemic; Milan; mobile phone data; knowledge workers

1. INTRODUCTION

The Covid-19 pandemic has influenced where we live, work, travel and commute. The social distancing and hygiene restrictions have affected: (1) the redefinition of the needs and functions of spaces for commercial and office use; (2) the geography of work; (3) new models of working spaces; and (4) a variety of remote working (RW) practices (Batty, 2020; Brail, 2021; Florida et al., 2021; Mariotti, 2022). The Covid-19 crisis has genuinely revolutionized the way of working, promoting an unprecedented massive shift to RW. Due to social distancing, a large part of human interaction had to take place virtually, and the only choice for organizations was to go digital. The terms 'remote working', 'teleworking' and 'working from home' are interrelated, and 'remote work' can be considered the broadest concept. According to the International Labour Organization (ILO) (2020), RW describes the situations where the work is entirely or partly carried out at an alternative worksite to the default place of work.[1]

The geography of work has changed. During the Covid-19 pandemic, knowledge workers started working from the first or second home (privately owned or long-term rented cottages, rural homes or apartments) in suburban or semi-peripheral areas, reducing daily commuting

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to the city centres (Mariotti et al., 2022a). In contrast, nearly two-thirds of workers in Europe remained tied to their workplaces, rendering telework difficult or impossible. These workers are the so-called 'essential workers', specialized in health and personal care, manufacturing and agriculture or involved in food provision and retail (Barbieri et al., 2020; Sostero et al., 2020).

The United States and Europe have experienced a 'departure' of inhabitants from the major cities towards suburban and peripheral areas; this trend has promoted residential relocation in the United States more than in Europe. In the largest US cities, people living in high-income neighbourhoods had greater incentive to relocate as they are more likely to work remotely and own secondary houses (Althoff et al., 2022; Bloomberg City Lab, 2021; Delventhal et al., 2022; Ramani & Bloom, 2021). Similarly, during the lockdown periods of 2020, Tokyo experienced the first net outmigration since 2013 (Ministry of Land, Infrastructure, Transport and Tourism of Japan, 2020, cited in Organisation for Economic Co-operation and Development (OECD), 2021), and in Spain, the population of municipalities with fewer than 2000 inhabitants increased (Gurrutxaga, 2021).

This phenomenon is still being researched in Italy. The focus of the few empirical studies is on the workers who have left the largest cities, first, Milan (Gorrini et al., 2021; Mariotti et al., 2021b) and the so-called 'South Working': the moving of remote workers to southern and inner areas of the country while working for employers based in the big cities of the north or even abroad (Di Matteo et al., 2022; Militello & Mirabile, 2020; Mirabile & Militello, 2022). Within this context, the paper aims to fill the gap in the literature by exploring the rise of RW during the first wave of the Covid-19 pandemic in the Lombardy region in north-west Italy. RW is proxied by the difference in the number of people commuting to the capital city of Milan in pre-pandemic times (April 2019, which is the reference baseline) from each municipality in Lombardy and the number of people commuting during the first phase of pandemic (April 2020) and shortly after (October 2020). This analysis allows the suitability of the municipalities outside Milan towards RW to be explored. New data come from the 'TIM Big Data – Data Visual Insight', which includes the presence and mobility of TIM's mobile network's users and is weighted to be representative of the entire population using mobile phones. The study aims to provide an answer to the following research questions:

- During the first and second phases of the Covid-19 pandemic, which municipalities in the Lombardy region were more suitable for remote workers who previously commuted to Milan?
- What are the main determinants explaining this phenomenon?

Georeferenced mapping and descriptive statistics, showing the change of human presence at the municipality level during and before the pandemic, allow the first question to be answered. Moreover, the determinants of the suitability of the municipalities in the Lombardy region towards the workers previously commuting to Milan are explored through an econometric analysis (ordinary least squares (OLS) estimation). To control for possible spatial dependence, a spatial diagnostic on the baseline OLS model is conducted and a spatial error model (SEM) is performed. Two additional spatially corrected models are provided to ensure the robustness of the results: a spatial Durbin model (SDM) and a spatial autoregressive model (SAR).

The results show that municipalities closer to Milan with a strong broadband connection, a high concentration of knowledge workers and foreign immigrants are more suitable to host remote workers. The paper's results might help policymakers frame tailored policy tools to deal with the subsequent phases of the pandemic.

The remainder of the paper is structured as follows. The introduction is followed by a literature review on RW and knowledge workers before and during the pandemic. A focus is placed on the studies investigating the impact of the Covid-19 pandemic with regard to the

geography of work. The third section describes the rise of RW in Lombardy municipalities during the pandemic and the correlation between knowledge and remote workers. The fourth section four presents the data and methodology, and the fifth section is dedicated to discussing the results of the econometric analyses. Conclusions and policy implications bring this paper to a close.

2. BACKGROUND

Several studies have been carried on the effects of the pandemic on how we live, work, travel and commute. This section briefly presents the results of the studies focusing on: (1) the rise of RW, the industries and workers involved, and the impact on workers' productivity, quality of life and well-being; and (2) the effects of the pandemic on the geography of work.

Since the Covid-19 pandemic enforced the closure of the workplace, a vast ad hoc social experiment took place, and RW became the standard working model for many employees with hitherto limited or no experience of working in this way (Sostero et al., 2020). Sostero et al. (2020) provided some data about the magnitude of the phenomenon, exploring the RW trends in European countries before and during the Covid-19 pandemic. In 2019, employees working from home regularly or, at least, sometimes amounted to more than 25% of the workforce in most Northern European countries, such as Sweden, Finland and the Netherlands. In contrast, this percentage was below 10% in Greece, Cyprus and Italy. This trend drastically changed during the Covid-19 pandemic when all countries experienced an increase in RW: the share of those currently working from home was over 30% in all but four European Union member states. In Italy, the percentage increased to 40%. The differences in the propensity to work remotely are related to an assortment of firm-specific factors, such as firm size, sector specialization and workers' occupation and skills.

Barbieri et al. (2020) developed an RW index by industry using Italian National Institute for Public Policy Analysis (INAPP) survey data. They showed that some sectors are more likely to experience RW given the characteristics of the occupations. These sectors include finance, real estate, professional activities and information and communication technology (ICT). Moreover, the RW rates across knowledge- and ICT-intensive business services are higher than in other sectors. These results were confirmed by several other studies (Del Rio-Chanona et al., 2020; Dingel & Neiman, 2020; Gallacher & Hossain, 2020; Holgersen et al., 2021).

Looking at the socio-economic profile of remote workers in European Union countries, Sostero et al. (2020) pointed out that before the pandemic it was easier to observe RW among highly educated, full-time, permanent and high-income workers. These results are confirmed when looking at the pandemic period. Moreover, workers in the tertiary sector, and women a little more than men, started working from home in 2020, especially in cities and suburban areas.

Another interesting line of literature focused on RW effects on workers' productivity, quality of life and well-being (Baert et al., 2020; Choudhury et al., 2021; Fana et al., 2020; Manzini Ceinar & Mariotti, 2021; Okubo et al., 2020; Tavares et al., 2020). Baert et al. (2020) examined the employees' perception of telework on various life and career aspects, finding that respondents mainly attribute positive effects, such as increased efficiency and lower risk of burnout. Similarly, Fana et al. (2020) explored the RW effects on job satisfaction, motivation and work–life balance. They found a multifaceted picture depending on workers' occupation and family composition. In general, working from home increased satisfaction and productivity and allowed a better reconciliation of work–family duties. In contrast, especially during the pandemic, some workers suffered from isolation, and those with school-age children complained about distractions and a poor work–life balance (Craig & Churchill, 2021). The difficulties in reconciling teleworking with family life, household chores, dedication to children and

time/schedule management were also pointed out by Tavares et al. (2020) with regard to Portugal.

The second strand of the literature concerns the effects of the Covid-19 pandemic – and the subsequent rise of RW – on the geography of work. The need for social distancing and the chance for knowledge workers to work remotely, thus reducing commutes to the large urban agglomerations, has made suburban (and peripheral) areas more attractive places in which to live and work. Several studies (Bloomberg City Lab, 2021; Ramani & Bloom, 2021; and Althoff et al., 2022 for the United States; Delventhal et al., 2022, for the Los Angeles metropolitan area; Gorrini et al., 2021; and Mariotti et al., 2021b, for the city of Milan; Di Matteo et al., 2022, for the south working movement in Italy; and Gurrutxaga, 2021, for the case of Spanish regions) argue to what extent the 'departure from the big cities' will be a short-, medium- or long-term phenomenon, and the effects on the suburban and peripheral areas are questioned contextually.

Using US Census Bureau data, Bloomberg City Lab (2021) describes the shift from the big cities in the United States to suburbs and some smaller cities that might still give people proximity to their region. Indeed, in the most populated cities, the movements have been undertaken within a radius of 100–150 miles. The San Francisco Bay Area and New York City region experienced more dramatic shifts, which had already begun before the pandemic. Specifically, the areas around San Francisco and San Jose, two of the country's most expensive housing markets, saw a massive increase in the rate of permanent moves: more than 23% and 17%, respectively, compared with 3% nationally.

Ramani and Bloom (2021) measured the effect of Covid-19 on migration patterns and real estate markets within and across US cities. They found a 'Donut Effect', reflecting the movement of activity out of city centres to the suburban ring within cities: about 15% of the population and business establishments appear to have moved out of the centres of large cities during the first year of the pandemic. The suburbs have attracted much of this movement, thus experiencing a price growth divergence from their city centres of almost 15 percentage points. On the other hand, significant reallocation across cities did not happen, probably because workers typically commute to their business premises three days per week. Thus, commuting is still too frequent to allow employees to leave the cities where their employers are based.

Althoff et al. (2022) explored the impact of RW on the economies of major US cities. The analysis of mobile phone data shows that areas with a high share of business service workers among their residents at the beginning of the pandemic saw substantial outflows of workers who relocated to places with a lower population density. The analysis shows that the transition to more remote work is likely to affect regions and workers differently depending on their remote work potential.

Delventhal et al. (2022) studied the impact of working from home on the Los Angeles metropolitan area. They found that jobs moved to the city's core, while residents moved to the periphery; traffic congestion eased and travel times dropped; average real estate prices fell, with a decline in core locations and an increase in peripheries. Therefore, the impact on workers is heterogeneous: those who can work from home enjoy significant welfare gains by reducing their commute time and moving to more affordable neighbourhoods, while those who continue to work on site enjoy modest welfare gains due to lower commute times, improved access to jobs and the fall in average real estate prices.

Gurrutxaga (2021) analyses the case of Spain, exploring whether the registered populations in municipalities with fewer than 2000 inhabitants in Spanish regions have changed during 2020 compared with previous years. The results show an increase in the rural population in 13 of the 17 Spanish regions and an increase in the proportion of the rural population over the total population in 14 regions during 2020. These results contrast with the decreasing predominant trends in the previous years.

Only a few studies have explored the case of Italy, at least to the best of our knowledge. Mariotti et al. (2021b) investigated the change in the attractiveness of the Milan neighbourhoods during the Covid-19 pandemic (Kramer & Kramer, 2020) compared with the year before (2019) by using TIM's mobile phone data (TIM Big Data – Data Visual Insight). Results show that central neighbourhoods registered a drop in city users from −63% to −47%, while the peripheral areas experienced an increase in visitors during the day. Indeed, RW and the fear of taking public transport caused workers to value the time spent commuting differently and revalue working close to home. Semi-peripheral and peripheral neighbourhoods have achieved a renewed role in attracting remote workers, and co-working spaces represent a valuable alternative for those willing to improve their work–life balance through RW. A similar approach was applied by Gorrini et al. (2021), who gathered data for seven months (January–July 2020) through a network of 55 wi-fi sensors distributed in several department stores, shops and public services in Milan. Their results showed a significant decrease between the average number of mobile devices detected per day before the spread of Covid-19 and those recorded during the lockdown phase.

Di Matteo et al. (2022) measured the propensity to South Working[2] (e.g., working remotely from the south of Italy or the Italian inner areas) in Palermo, the capital city of Sicily (south of Italy), before and after the pandemic. The results of the econometric analysis showed that the tendency of remote workers to move to Palermo while working for employers based in the north of Italy or even abroad is more significant for men than women, for those in a relationship than single people, for those with a higher level of education (doctorate or bachelor's degree) and for self-employed workers than those in the public sector.

Most of these studies agree on the evidence that it is improbable that the pandemic will derail the long-standing process of urbanization and the economic role of cities. Innovation, creativity and economic growth require the clustering of talent and economic assets, face-to-face interaction, buzz, diversity and the critical mass only cities can provide (Storper & Venables, 2004). Several knowledge-intensive activities require the frequency of face-to-face interaction because the time (opportunity) costs associated with not having continuous face-to-face contact have increased with the quantity, variety and complexity of the information produced (McCann, 2008). History teaches that cities have driven recovery after major crises and catastrophes (Florida et al., 2021). Nevertheless, Martin (2021) stated that while cities are indispensable to human progress, they do not consistently score the most highly in terms of quality of life or life satisfaction. Therefore, we should:

> reimagine our cities, their role, structure and layout to highlight the social, environmental and health benefits of lower density and substantial greening, as well as the advantages of smaller cities, many of which are just as economically dynamic and resilient as large cities, if not more so. (p. 150)

This paper extends the analysis carried out by Mariotti et al. (2021b) about the city of Milan and explores the renewed suitability of the municipalities outside Milan for remote workers who commuted to Milan before the pandemic and analyses which determinants play a role.

According to previous studies, remote workers tend to be knowledge workers and are more willing to operate in knowledge- and ICT-intensive business services (OECD, 2021; Sostero et al., 2020). Knowledge workers tend to live in large cities, exploiting the positive externalities of the several proximity forms (Glaeser, 2012; Moretti, 2012; Sánchez-Moral et al., 2022). The city is the best place in which to live and work for knowledge workers and creative people because it hosts areas with high amenity environments (Van Oort et al., 2003): from productive amenities (e.g., good access to clients, specialized labour, specialized firms, universities, transportation nodes and networks) to non-productive amenities (e.g., good access to urban amenities, such as restaurants, cafes, shops, cultural and entertainment services, good

environmental quality). As the Covid-19 crisis has underlined, remote workers are more willing to live and work in a municipality with good broadband availability and capacity, which was essential during the early 'stay at home' phases of the pandemic, thus allowing multiple heterogenous activities of adults and children to continue (e.g., online learning programmes and courses, school programmes, recreation and entertainment, etc.) (Zhang, 2021).

Nevertheless, knowledge workers are also willing to choose fewer central places (e.g., suburban areas) with good accessibility, high quality of life, availability and quality of primary services and residential units. This trend became more common during the pandemic because knowledge workers who worked remotely demanded larger flats in green neighbourhoods (Nomisma, 2021). All these characteristics, primarily the proximity to Milan and the accessibility of the big city, had a significant impact on real estate prices.

Similarly, foreigners in Italy prefer to live in less central places. According to the Italian Institute of Statistics (ISTAT) (2021), about 40% live in municipalities of fewer than 20,000 inhabitants and about one-third live in those with more than 100,000 inhabitants. The rest live in municipalities with 20,000–100,000 inhabitants. At the NUTS-2 regional level, foreigners make up more than 10% of the total in Emilia-Romagna, Lombardy, Tuscany, Lazio, Umbria and Veneto. Foreigners in Italy are mainly low-skilled workers (Barzotto et al., 2019; Bratti & Conti, 2018; Etzo et al., 2017). They come from developing countries, as is the case in other Southern European countries such as Spain (Kangasniemi et al., 2012).

Italy's lack of attractiveness to highly skilled foreign workers is also due to the lower returns on human capital for immigrants than for natives (Bratti & Conti, 2018). Foreign workers undertake jobs that tend to require a lower level of qualification than the worker's educational attainment and skills (overeducation phenomenon). This is mainly due to: (1) poor knowledge of the Italian language; (2) lack of recognition of the education level achieved abroad; (3) sociocultural motivations (ISTAT, 2015); and (4) discrimination in the labour markets of the host country (Fassio et al., 2018). As recently highlighted by Fassio et al. (2018, p. 3), trade unions or the corporatism of specific manufacturing sectors might affect how foreign competencies are integrated into the workplace.

3. DATA AND METHODOLOGY

The review of the studies about the emergence of RW suggests framing the following hypotheses tested in the empirical section:

Hypothesis 1: Municipalities hosting more remote workers have a better broadband connection.

Hypothesis 2: Municipalities with more remote workers are more suitable for hosting knowledge workers.

Hypothesis 3: Municipalities hosting more remote workers are closer to the city of Milan.

According to the Osservatorio Smart Working (2021), in Italy remote workers rose from 570,000 in 2019 to 6.58 million in March 2020 (during the strictest lockdown), decreasing to 5.06 million in September 2020.

The analysis of the dataset 'TIM Big Data – Data Visual Insight'[3] allows the measuring of the increase in remote workers in Lombardy municipalities during the pandemic, thus providing an answer to the first research question (see above). It includes data on the presence and mobility of the TIM mobile network's users, which represent about 30% of the nation's mobile phone users (AGCOM, 2022). These data are weighted to be representative of the entire population using mobile phones and are collected at the census areas' (ACE) statistical level provided by ISTAT, which corresponds to an aggregation of contiguous census tracts, the smallest Italian

statistical unit concerning the building block in an urban area.[4] Data at ACE level are then aggregated at the municipality level.

Specifically, the mobility data allow the analysis of the change in the inflows towards Milan from the other municipalities on three working days: one in April 2019 (before the pandemic), one in April 2020 and one in October 2020 (both during the pandemic). This analysis permits us to explore how commuting from the municipalities in the Lombardy region towards Milan has changed.

We chose April 2020 and October 2020 since they correspond to two different pandemic phases. In Italy, the progressive closure of non-essential economic and institutional activities at the national level started with the prime minister's Decree of 4 March 2020 (Gazzetta Ufficiale Serie Generale no. 55/2020).[5] Since then, three phases can be distinguished:

- March –May 2020: first strict lockdown when only 'essential activities', such as health and personal care, specific manufacturing activities, agriculture involved in food provision and retail, were allowed to operate.
- June –October 2020: the so-called 'second phase' when there was a gradual easing of the previous restrictions and containment measures and the economic activities reopened.
- November 2020–March 2021: second lockdown when there was a progressive closure of specific activities, differentiated across the Italian regions depending on the number of infections.

To provide an answer to the second research question and test the above research hypotheses about the main determinants of the spread of RW, we propose a base OLS model and a series of spatially corrected additive estimations to provide sensitivity checks. The baseline model takes the following form:

$$RW_{MI,m} = \alpha + \beta_{1;m} knowledge\ workers + \gamma \bar{X}_m + v_p + \varepsilon_m \quad (1)$$

where $RW_{MI,m}$ is the dependent variable and stands for remote workers. It represents the difference between the number of people commuting to Milan pre-pandemic (April 2019, which is the reference baseline) from each of the Lombardy m municipalities compared with the number of people commuting during the first wave of the pandemic (April 2020) and the 'second phase' (October 2020).

The main covariate of interest $\beta_{1;m}$ at m municipal level, able to explain RW in Lombardy, is the number of knowledge workers (Table 1). This variable is computed based on a nomenclature provided by ISTAT and includes four out of the nine macro-class of workers:[6] (1) legislators, entrepreneurs and senior management; (2) intellectual, scientific and highly specialized professions; (3) qualified professions in commercial activities and services; and (4) executive professions in office work. Knowledge workers have been almost wholly involved in the work-from-home dynamics, especially in large metropolitan areas (Vyas & Butakhieo, 2021). Their performance levels – creative, in particular – have benefited from the work-from-home and digital knowledge-sharing (Tønnessen et al., 2021). However, its long-lasting effectiveness is still questioned in emerging research (Waizenegger et al., 2020).

The knowledge economy still explains only around one-third of the RW growth during the 21st century (Felstead & Henseke, 2017). A large part of residuals needs to be explained, and never as now does it appear of paramount importance to understand the determinants of RW. Therefore, we use a vector of $\bar{X}_m$ covariates, which are useful for understanding the RW dynamics in Lombardy, the more harshly affected Italian region (Cerqua et al., 2021).

The first covariate is the share of foreign residents. In Lombardy, most of them live and work outside the capital city of Milan, being mainly employed in those 'essential' primary work

Table 1. Dependent and explanatory variables.

Variable	Unit	Mean	SD	Minimum	Maximum	Source (year)
Dependent variable						
Remote working (RW)[a]	Difference between the number of people commuting to Milan in the pre-pandemic period (April 2019) from each of the municipalities in Lombardy compared with the number of people commuting to Milan in the first wave of the pandemic (April 2020)	234.1	765.6	−10.9	12,344.9	TIM (2019; 2020)
Explanatory variables						
Knowledge workers[a]	Number of knowledge workers	1321.7	9220.7	0	345,595	ISTAT (2019)
Foreigners	Share of foreigners in the municipality	0.083	0.044	0.003	0.36	ISTAT (2019)
Real estate prices[a]	€/m^2 of residential units	886.06	265.4	453	2985	OMI – Agenzia delle Entrate (2019)
Broadband capacity[a]	Percentage of households in the municipality that are served by Fiber To The-Home technology	30.5	43.2	0	100	AGCOM (2018)
Distance to Milan[a]	Kilometres from the centre of Milan	67.5	37.5	8.2	223.3	OpenStreetMap (2020)
Provinces	Dummy variables	–	–	–	–	ISTAT (2020)

Note: [a]Variable added to the econometric analysis in logarithms.

categories (Anderson et al., 2021; Paul, 2020). Low-skilled foreign workers are willing to work in the Italian industrial districts. The latest classification of the Italian industrial districts by ISTAT (2015) identifies 141 districts specializing in 11 macro-sectors. A total of 33.7% of the manufacturing employment of industrial districts specialized in the Made in Italy industries is in the Lombardy region, and it contains 29 (20.6%) districts with a specialization in the mechanical industry (11 districts with 45.5% of the total employment in this sector) and textile and clothing (seven districts with 42.3% of the total employment). Another industry employing low-skilled foreign workers in Lombardy is transport and logistics. Indeed, the region is the centre of the so-called Regione Logistica Milanese (RLM) – Milano Logistics Region – which also includes the provinces of Novara in Piemonte and Piacenza Emilia-Romagna. Specifically, the logistics activities, which require large areas to operate, are mainly located outside the city of Milan, even if they are near it (Holl & Mariotti, 2017).

A second covariate is broadband capacity. Adequate broadband was essential during the early 'stay at home' phase since it enabled the continuation of not only knowledge working but also multiple heterogenous activities of adults and children, such as online learning programmes and courses, school programmes, recreation and entertainment, etc. (Zhang, 2021). As a natural consequence, RW potential substantially increases when municipalities are provisioned with better broadband (Crowley & Doran, 2020). We expect higher levels of broadband capacity are positively correlated with RW.

A third covariate concerns, per each municipality, the distance (km) from Milan. According to the Italian Statisticsl Institute (ISTAT), in the year 2020, around 80% of commuters to Milan originate from the municipalities of the Milan metropolitan area; therefore, we expect that the greater the distance from Milan, the lower the probability of experiencing RW. Indeed, most workers more than 100 km away are unlikely to commute to Milan and instead gravitate to other functional urban areas. A v geographical fixed effect at the p province level and a stochastic error term ε_m completes equation (1).

Finally, the fourth covariate regards residential units' average real estate prices. Both internal (e.g., building quality, central heating, availability of a lift) and context-specific characteristics (e.g., accessibility to the city centre, quality of urban space) form housing real estate prices. While the construction cost values the first, the second reflects locational advantages that can be translated in monetary terms into land rents based on the implicit willingness to pay for these advantages (Boscacci et al., 2017; Rosen, 1974). Therefore, residential units in municipalities closer to Milan and/or with good accessibility, high quality of urban space and availability of essential services are more willing to have, on average, higher real estate prices. Therefore, these municipalities tend to be more attractive for remote and knowledge workers.

Given the geographical pattern of the municipalities involved in this analysis, which all belong to the Lombardy region but in some cases are a long distance from Milan city centre, we provide a series of robustness checks by taking into account the eventual spatial dependence within the OLS. In the first instance, we use a spatial error model (SEM) to correct the baseline form of the OLS model. We used a spatial weight matrix W built upon contiguities between municipalities, and then we included it in (1), which becomes as follows:

$$RW_{MI,m} = \alpha + \beta_{1;m} knowledge\ workers + \gamma \bar{X}_m + \boldsymbol{\lambda W} + \varepsilon_m \tag{2}$$

where λ is the lambda spatial autoregressive coefficient interacted with the W spatial weights matrix, which quantifies the connection between the municipalities. The rest of the equation is as before, except for the v geographical fixed effect at the p province level, which was removed since it became unnecessary in the presence of the spatial error term. We decided to split the dataset depending on a distance criterion, which allows the creation of bands based on the distance from the city of Milan. In this way, we obtain five bands of municipalities that are within a

range of 20–100 km from Milan. We decided to exclude municipalities further than 100 km from the city as we noticed that at higher distances, the RW effect is likely to follow other patterns since municipalities that are a long way from Milan might have their reference central place in other provincial capitals or other metropolitan areas.

To individuate the presence of spatial dependence, we ran a series of diagnostic tests (Moran's *I*, Lagrange multiplier and robust Lagrange multiplier), and we noticed that the spatial error is significant when we consider the range of municipalities further than 40 km from Milan (Table 2).

Moreover, given that we have at our disposal two periods of observation for the dependent variable (April 2020/April 2019 and October 2020/April 2019), we reshaped our cross-section dataset into a panel dataset with two periods in order to exploit a spatial Durbin model (SDM) and a spatial autoregressive model (SAR) (Belotti et al., 2016) as well.

The SDM is a lag model which augments the SEM with the lag of covariates, which is obtained through the interaction of an average of the $\bar{X}$ covariates and the W matrix. This results in:

$$RW_{MI,m} = \boldsymbol{\rho W}(RW_{MI,m}) + \alpha + \beta_{1;m}knowledge\ workers + \gamma\bar{X}_m + \boldsymbol{W}(\beta_{1;m}knowledge\ workers) + \boldsymbol{W}(\gamma\bar{X}_m) + \varepsilon_m \quad (3)$$

where ρ is a scalar parameter indicating spatial dependence (LeSage, 2008), and both the dependent variable and the covariates are interacted with the W matrix. The SAR model is another variant of the SEM, which emerges as follows:

$$RW_{MI,m} = \boldsymbol{\rho W}(RW_{MI,m}) + \alpha + \beta_{1;m}knowledge\ workers + \gamma\bar{X}_m + u \quad (4)$$

where the spatial dependence is taken into account both in the dependent variable and in the error term (but not in the covariates), which, different from the previous model, becomes $u = \boldsymbol{\lambda W u} + \varepsilon_m$.

In the SEM, SDM and SAR, we only consider the change between October 2020 and April 2019 ('second phase') as a dependent variable in order to include only the period after the first generalized closures, when certain choices had been unavoidably forced by the contingent health emergency. The results of the OLS model are presented in Table 3; the results of the SEM are shown in Table 4; the results of the SDM and SAR are given in Table 5.

4. THE RISE OF REMOTE WORKING IN LOMBARDY

This section analyses the change in the commuting patterns of people from the municipalities of Lombardy to the capital city of Milan, thus providing an answer to the first research question: 'During the first wave of the Covid-19 pandemic, which municipalities in the Lombardy region were more suitable for remote workers who previously commuted to Milan?' by using the dataset 'TIM Big Data – Data Visual Insight'.

Figure 1 shows the inflows into the municipality of Milan on one working day before the pandemic in April 2019 (blue line), during the lockdown in April 2020 (orange line) and during the continuation of the pandemic in October 2020 (grey line). As expected, the people inflows at 12.00 hours (maximum peak) during the pandemic drastically decreased compared with the pre-pandemic period, especially during the first lockdown of April 2020, when mainly 'essential workers' specialized in health and personal care, manufacturing and agriculture for food provision and retail (Barbieri et al., 2020; Sostero et al., 2020) could enter the city to work. However, even after the economic activities reopened in October 2020, the people inflows into Milan did not reach the 2019 level: at 12.00 hours, there were about 200,000 fewer people. It is

Table 2. Diagnostic tests for spatial dependence in OLS regression.

	< 20 km		< 40 km		< 60 km		< 80 km		< 100 km	
Type of test	**Coefficient**	***p*-value**	**Coefficient**	***p*-value**	**Coefficient**	***p*-value**	**Coefficient**	***p*-value**	**Coefficient**	***p*-value**
Spatial error										
Moran's *I*	1.026	0.305	0.679	0.497	2.602	0.009[a]	8.100	0.000[a]	6.662	0.000[a]
Lagrange multiplier	0.009	0.923	0.041	0.840	1.461	0.227	28.255	0.000[a]	18.193	0.000[a]
Robust Lagrange multiplier	0.835	0.361	0.087	0.768	4.045	0.044[a]	19.739	0.000[a]	17.194	0.000[a]

Note: [a]Presence of spatial dependence (error).

Table 3. Determinants of remote working in the Lombardy region.

	April 2020–April 2019 OLS	April 2020–April 2019 OLS	October 2020–April 2019 OLS	October 2020–April 2019 OLS
Knowledge workers	**1.091*** (0.037)**	**0.898*** (0.050)**	**0.940*** (0.036)**	**0.764*** (0.049)**
Foreigners		2.064*** (0.764)		0.960 (0.847)
Real estate prices		−0.116 (0.161)		0.064 (0.192)
Broadband capacity		0.002*** (0.0006)		0.002*** (0.0007)
Distance to Milan		−1.528*** (0.196)		−1.304*** (0.196)
Constant	−3.418*** (0.238)	4.600*** (1.703)	−3.040*** (0.238)	2.767 (1.898)
Province dummy	Yes	Yes	Yes	Yes
R^2	0.783	0.828	0.751	0.793
F-test ($p > F$)	462 (0.000)	672 (0.000)	274 (0.000)	469 (0.000)
Observations	1483	1456	1317	1295

Note: Robust standard errors in parentheses are clustered at the municipal level. Significance: *** at $p < 0.01$; ** at $p < 0.05$; * at $p < 0.10$.

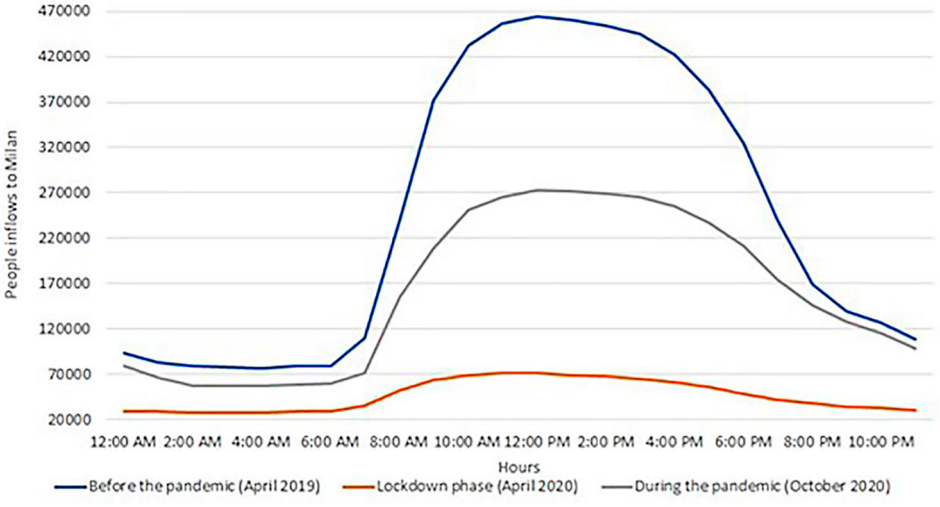

Figure 1. People inflows into the municipality of Milan before and during the pandemic.
Source: Authors' elaboration on 'TIM Big Data – Data Visual Insight' by MAUD Laboratory (DAStU, Politecnico di Milano).

conceivable that people who stopped commuting to Milan either lost their jobs or started to work remotely.

Figure 2a shows the differences between April 2020 and April 2019 (first phase of the pandemic) of the human inflows into the city of Milan. It emerges that the suburban municipalities (in red and orange) gained more people (from 5000–13,000 to 4000–5000). There are

Table 4. Determinants of remote working in the Lombardy region: spatial error model (SEM) with distance bands.

	(i) SEM < 20 km	(ii) SEM < 40 km	(iii) SEM < 60 km	(iv) SEM < 80 km	(v) SEM < 100 km
Knowledge workers	**0.740*** **	**1.008*** **	**0.938*** **	**0.748*** **	**0.639*** **
	(0.073)	**(0.060)**	**(0.042)**	**(0.034)**	**(0.031)**
Foreigners	−1.719*	2.148	4.275***	3.056***	1.752**
	(0.901)	(1.482)	(1.123)	(0.944)	(0.881)
Real estate prices	0.612*	0.556***	0.547***	0.649***	0.488***
	0.365	(0.136)	(0.141)	(0.138)	(0.134)
Broadband capacity	0.0007	−0.0005	0.0006	0.003***	0.004***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Distance to Milan	−1.040***	−1.294***	−1.292***	−1.505***	−1.693***
	(0.199)	(0.179)	(0.143)	(0.130)	(0.111)
Constant	−0.786	−2.162*	−1.866	−0.516	2.038*
	2.602	(1.271)	(1.187)	1.169	(1.069)
λ	−0.086	−0.141	0.502	0.892***	0.862***
	(0.697)	(0.586)	(0.357)	(0.104)	(0.131)
Wald test of $\lambda = 0$: $\chi^2(1) =$	0.015 (0.901)	0.059 (0.809)	1.973 (0.160)	72.976 (0.000)	43.195 (0.000)
Likelihood ratio test of $\lambda = 0$: $\chi^2(1) =$	0.016 (0.899)	0.061 (0.806)	1.512 (0.219)	15.995 (0.000)	11.959 (0.001)
Lagrange multiplier test of $\lambda = 0$: $\chi^2(1) =$	0.009 (0.923)	0.041 (0.840)	1.461 (0.227)	28.255 (0.000)	18.193 (0.000)
Variance ratio	0.858	0.711	0.720	0.704	0.701
Squared correlation	0.861	0.711	0.716	0.706	0.700
Log likelihood	−21.20	−533.10	−1152.72	−1616.60	−1923.56
Sigma	0.32	0.98	1.10	1.16	1.19
N	75	382	760	1031	1208

Note: Dependent variable: change in remote working potential by October 2020–April 2019; robust standard errors are shown in parentheses. Significance: *** at $p < 0.01$; ** at $p < 0.05$; * at $p < 0.10$.

Table 5. Determinants of remote working in the Lombardy region: spatial Durbin model (SDM) and spatial autoregressive model (SAR) with distance bands.

	(vi) SDM	(vii) SAR	(viii) SDM	(ix) SAR	(xiv) SDM	(xv) SAR	(xvi) SDM	(xvii) SAR	(xviii) SDM	(xix) SAR
	< 20 km		< 40 km		< 60 km		< 80 km		< 100 km	
Knowledge workers	**0.771*** **	**0.761*** **	**0.995*** **	**0.980*** **	**0.978*** **	**0.945*** **	**0.797*** **	**0.781*** **	**0.682*** **	**0.687*** **
	(0.049)	**(0.051)**	**(0.089)**	**(0.087)**	**(0.052)**	**(0.052)**	**(0.048)**	**(0.046)**	**(0.042)**	**(0.042)**
Foreigners	−1.172*	−1.361*	1.686	2.197*	4.211***	5.299***	3.341***	4.206***	2.339***	3.037***
	(0.705)	(0.736)	(1.186)	(1.200)	(0.988)	(0.990)	(0.934)	(0.925)	(0.869)	(0.865)
Real estate prices	0.466	0.419	0.524***	0.514***	0.469***	0.429***	0.576***	0.456***	0.496***	0.344**
	(0.344)	(0.292)	(0.049)	(0.051)	(0.072)	(0.098)	(0.093)	(0.097)	(0.110)	(0.143)
Broadband capacity	0.002	0.002	−0.00006	−0.0001	0.0004	0.0002	0.002***	0.002**	0.003***	0.003***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.0009)	(0.0009)	(0.0008)	(0.0008)
Distance to Milan	−0.982***	−0.901***	−1.233***	−1.212***	−1.288***	−1.258***	−1.547***	−1.535***	−1.754***	−1.698***
	(0.228)	(0.159)	(0.136)	(0.136)	(0.102)	(0.099)	(0.095)	(0.085)	(0.116)	(0.099)
Constant	−5.554	−6.480***	19.61	−6.354***	76.45**	−4.803***	37.32**	−2.436***	11.85**	−0.124***
	(41.98)	(2.257)	(14.76)	(0.804)	(26.23)	(0.773)	(15.26)	(0.720)	(13.97)	(1.267)
ρ (spatial dependence	0.954***	0.949***	0.930***	0.925***	0.945***	0.934***	0.948***	0.939***	0.951***	0.942***
presence)	0.015	(0.017)	(0.017)	(0.018)	(0.016)	(0.018)	(0.016)	(0.017)	(0.015)	(0.017)
R^2 between	0.901	0.872	0.794	0.788	0.798	0.783	0.784	773	0.775	0.766
Log-pseudo-likelihood	−5.312	−10.99	−841.12	−845.02	−1870.05	−1889.38	−2692.22	−2708.81	−3220.90	−3237.65
N	75	75	382	382	760	760	1031	1031	1208	1208
T	2	2	2	2	2	2	2	2	2	2
*N*t*	150	150	764	764	1520	1520	2062	2062	2416	2416

Note: Dependent variable: change in remote working potential by October 2020–April 2019; robust standard errors shown in parentheses are clustered at the municipal level. Significance: *** at $p < 0.01$; ** at $p < 0.05$; * at $p < 0.10$.

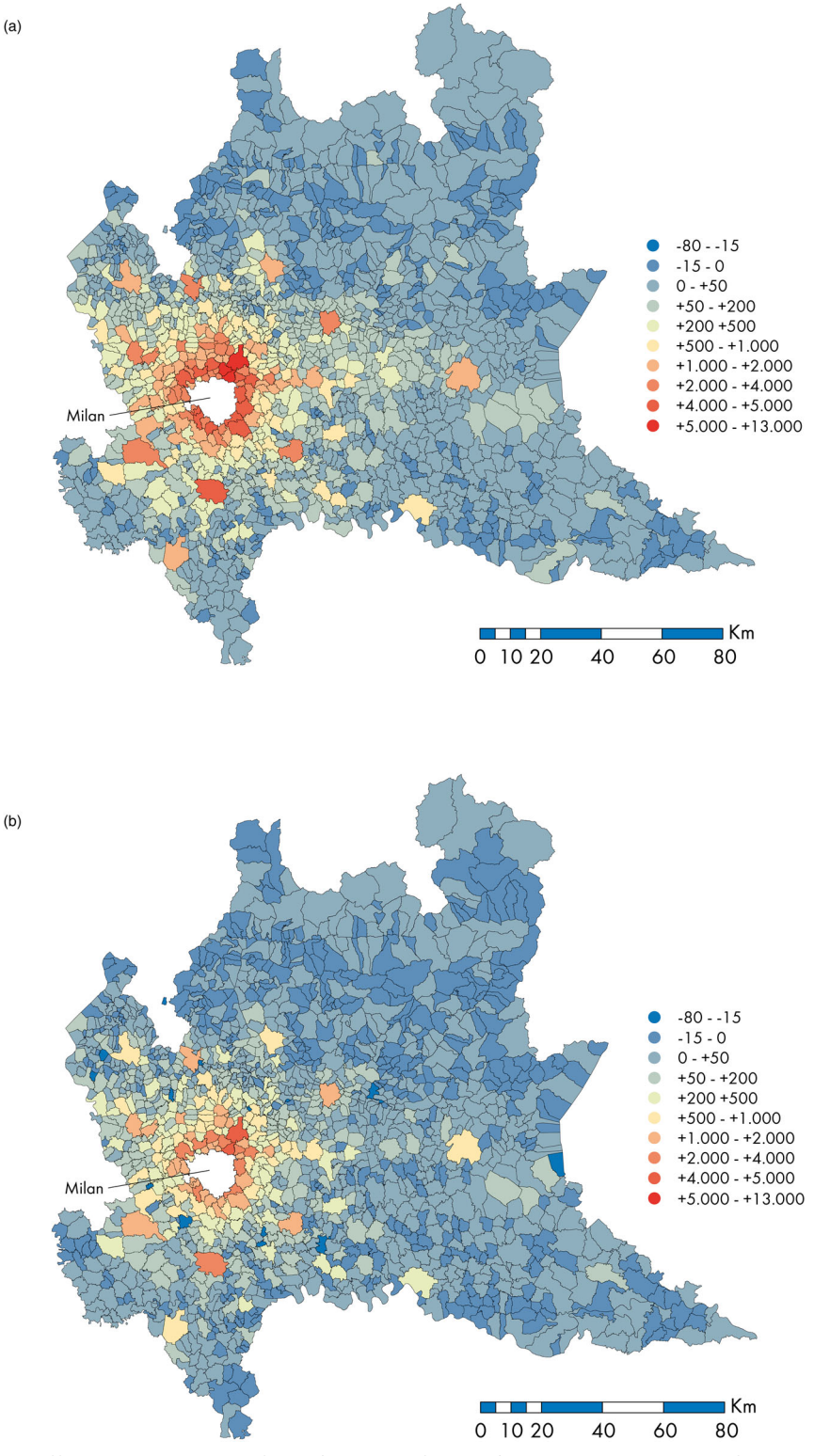

Figure 2. Differences in human inflows (number of people) into the municipality of Milan in April 2020 (a) and October 2020 (b) compared with April 2019.
Source: Authors' elaboration on 'TIM Big Data – Data Visual Insight'.

exceptions in the cases of the capital provinces of Bergamo, Brescia, Lodi and Pavia, which are further from Milan. Instead, the municipalities that gained fewer or even lost some human inflows are coloured in blue. The cities coloured in red in Figure 2 are those where the residents probably worked from home during the lockdown as commuting to work was impossible. This trend is confirmed in Figure 2b although to a lesser extent because workers in the second phase (October 2020) started travelling back to work.

Since the literature has underlined a correlation between working from home and knowledge workers, Figure 3 shows this correlation for the municipalities in Lombardy. The number of people not commuting to Milan in April 2020 compared with April 2019 is on the vertical axis of Figure 3a, while the number of people not commuting to Milan in October 2020 compared with April 2019 is on the vertical axis of Figure 3b. The number of knowledge workers living in each municipality in 2020 is on the horizontal axis of both figures. A general positive correlation emerges in both periods (Figure 3), thus confirming that municipalities with a higher concentration of knowledge workers are more willing to host remote workers during the pandemic.

5. RESULTS OF THE EMPIRICAL MODELS

Table 3 presents the results of the baseline OLS model. We first introduce the baseline model for both dependent variables, including only the main covariate of interest. We then include the $\bar{X}_m$ vector of control variables to further investigate the relationships with the RW that occurred during the early phases of the pandemic. As expected, there is always a positive and significant association between knowledge workers and RW in Lombardy. This confirms what is presented in Figure 3. First, it can be noticed that the coefficient of remote workers remains unchanged and strongly significant, even though possible confounders are considered.

The foreign residents are positively associated with the dependent variable (*RW*), and the coefficient shows a relatively high magnitude. This means that foreigners are not likely to commute to Milan because they are mainly involved in labour-intensive jobs in manufacturing or transport and logistics closer to the municipality where they live. As stated in the fourth section, the manufacturing plants (also belonging to the Italian industrial districts) and the transport and logistics centres are mainly located outside the municipality of Milan because of land availability at lower prices.

Regarding the real estate prices of residential units, there is no significant association with the dependent variable. This can be explained by the close relationship with the location of remote workers, who choose municipalities with good accessibility, amenities and quality of life.

The broadband capacity is confirmed to be a positive predictor of RW. However, it is visible that it exhibits only a limited magnitude in the coefficient. The Lombardy region – and the broader north-west of Italy – has the most significant first-generation broadband service coverage rate (Matteucci, 2019). This might explain the slight magnitude in the coefficient. In other words, the broadband capacity in Lombardy is not discriminative against RW because almost the whole area can guarantee adequate broadband infrastructure to enable working from home. Lastly, as expected, the distance to Milan shows a negative coefficient towards RW. As shown in Figure 2, the number of commuters going to Milan decreases when the distance is higher, meaning that the RW of Milan workers is not affected by municipalities a long distance from Milan.

The results of the SEM in Table 4 provide a first robustness check of the results. In particular, the main covariate of interest (knowledge workers) is always statistically significant and positively associated with RW for all the proposed distance bands. Interesting results come from the real estate prices, which, different from the baseline OLS, assume a positive and statistically significant association with RW, which is in line with the previously raised hypothesis about the

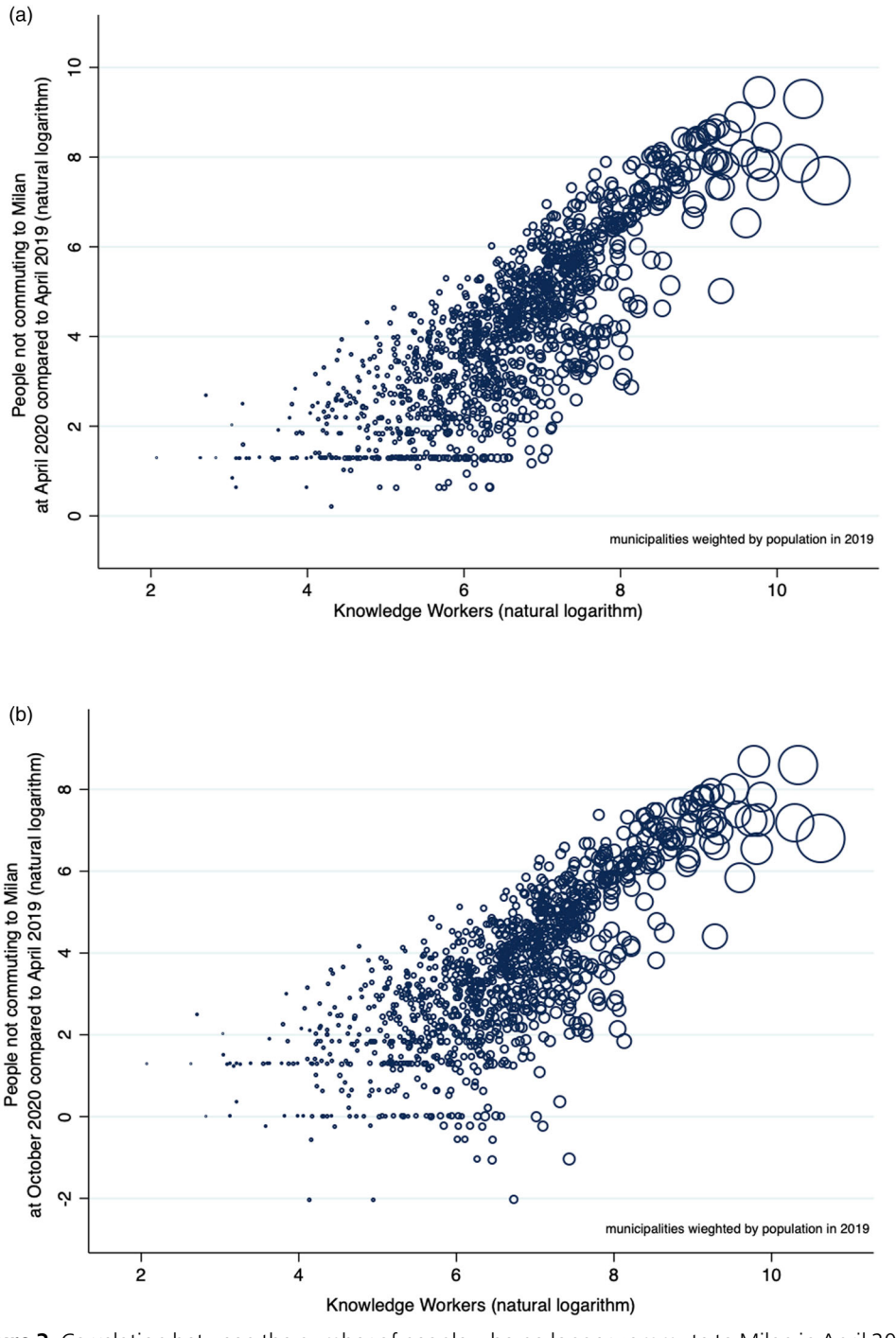

Figure 3. Correlation between the number of people who no longer commute to Milan in April 2020 (A) and October 2020 (B) compared with April 2019 and knowledge workers in the municipalities in Lombardy in 2020, excluding Milan.
Sources: authors' elaboration on 'TIM Big Data – Data Visual Insight' and ISTAT data.

quality of living enhancing the possibilities of RW. The broadband capacity is significant only when bands of municipalities that are more than 60 km from Milan are considered, and this reflects the need for a stable broadband to facilitate RW in places that are far from the central city, where the broadband capacity is not assured as much as in the nearby suburbs of the city of Milan *t*. The foreigner presence is positively associated with RW when bands beyond 40 km are considered, while the first distance band (< 20 km) is negatively associated with RW, and this is in line with literature explaining a higher presence of foreigners outside the central city of Milan. The geographically based variable related to the distance from Milan is always negative and statistically significant towards RW, thus confirming the previous hypothesis on this point. However, we notice that in the SEM, the λ parameter assumes significance only when larger bands are considered, for example, when municipalities further than 60 km from Milan are taken into account, meaning that the other results are not affected by particular spatial dependence.

The results of the SDM and SAR in Table 5 substantially confirm all the main findings of the SEM, and this is particularly true for the main covariate of interest (knowledge workers) and for the other covariates related to the real estate prices, foreigners and distance to Milan.

In summary, the results of the empirical analysis mean that we can state that the three hypotheses outlined in the second section can be confirmed. Indeed, municipalities with more remote workers have a better broadband connection, are more suitable for hosting knowledge workers and foreigners, and provide generally better living conditions (a determinant proxied by the real estate prices).

6. CONCLUSIONS AND POLICY IMPLICATIONS

This paper has shown that the Covid-19 pandemic changed the geography of work in Lombardy (north-west Italy) in the first wave of the pandemic. Densely populated areas such as Milan have suffered more negative health outcomes from the Covid-19 outbreak, have lost human presence and are also places where RW has been essential in protecting public health. Besides, cities such as Milan are characterized by the highest rental and living costs; thus, employers pay higher salaries (Moretti, 2012). Although the pandemic will not make cities lose their role, the rise of RW has underlined that many people will be able to avoid, or limit being forced to commute to work and may be able to go to the office two to three days a week instead of five. This 'new normal' will be a new work–life balance, favouring suburban areas and increasing demand for new working spaces and satellite offices to promote 'near working'.

The empirical analysis underlined that municipalities closer to Milan with a strong broadband connection, a high concentration of knowledge workers and foreign immigrants are more suitable for hosting remote workers.

The sudden spread of Covid-19 around Lombardy and northern Italy did not allow people to organize themselves and think about possible alternative locations. Indeed, the early lockdown for the whole of Lombardy and the other 14 provinces of northern Italy came around two weeks after the first ordinance by the Ministry of Health on the matter preventing the spread of Covid-19 (21 February 2020). Because of this, shortly before the entry into force of lockdown, some people who already owned a second home in less dense areas and remote places moved there during the lockdown. At the same time, relevant flows of non-resident workers hurriedly returned to their residence (especially in southern Italy, from where many Milan workers originate, Di Matteo et al., 2022). In such a scenario, real estate prices did not have an impact on RW. Still, it is likely that after two or more years since the beginning of the pandemic, real estate prices will influence the choice of permanent remote workers. Few iconic initiatives in these regards have emerged. For instance, several municipalities in Italy adhered to a programme[7] to revitalize highly depopulated rural communities by selling

uninhabited houses at the symbolic price of €1, with a commitment to renovate the property and live there for the medium to long term. In addition, there was a flourishing of bottom-up and top-down initiatives on the development of new working spaces in peripheral and rural areas to host remote workers, such as the so-called '*presidi di comunità*' promoted by South Working or generally co-working spaces (Mariotti et al., 2022b). Co-working spaces represent a valid alternative to remote workers by offering support services and flexible spaces and carefully managing the hosted professionals' well-being and health.

Recent developments on digital multilocality (Di Marino & Lapintie, 2018; Greinke & Lange, 2022) highlighted the importance of cyclicality of work between the central office workplace and private peripheral workplace since alternating between both increases work efficiency (Bürgin et al., 2021). Nevertheless, although the work-from-home arrangement reduces stress and increases general productivity, it is also true that the excessive exposure of work activities to everyday life may threaten the overall well-being since the isolation from supportive co-workers may counteract the positive effects of working from home (George et al., 2021). Indeed, the emerging *work-from-anywhere* model showed that the remote worker may benefit temporal and geographical flexibility at once, positively affecting the output (Choudhury et al., 2021; Mariotti et al., 2022a). Such advances suggest that entrepreneurs of co-working spaces will soon be called upon to manage an increasing demand for remote workers from many-sided organizations (Howell, 2022; Mariotti et al., 2021a) as the co-working space represents the 'third-place' alternative to working from home and working from the office.

The results of this study might help policymakers frame tailored policy tools to deal with the subsequent phases of the pandemic. Indeed, it is worth analysing the inflows and outflows of big cities such as Milan, which might change over time and affect the whole country. It is questioned whether the pandemic will widen the differences between regions since capital will be concentrated in prosperous cities (Brail, 2021; Mariotti, 2022). Without doubt, the pandemic has exacerbated structural and systemic inequalities since job losses have been greater for low-income earners than high-income earners (Brail, 2021).

Besides, exploring the attraction and retention of 'knowledge workers' is essential for the future of our cities and suburbs since several studies have confirmed the positive influence of knowledge workers on regional growth (e.g., productivity gains, the improvement of quality of life or local institutions) (Florida, 2003; Scott, 2006; Sánchez-Moral et al., 2022). As Tomaney and Bradley (2007) underline, cities that do not meet the residential requirements of this type of worker may face migration to other cities, affecting their global competitiveness. Furthermore, the lack of office workers in central business districts leads to job losses for lower income earners (Moretti, 2012), such as cleaners, restaurant staff and salespeople.

Further research might focus on analysing the effects of the pandemic on the geography of work and places, and researchers together with policymakers should reimagine our cities and suburban and peripheral areas, along with their role, structure and layout. Nevertheless, to reach this goal, fine-grained, real-time data are needed more urgently than ever.

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NOTES

[1] As stated by Sostero et al. (2020, p. 7):

> remote working could be done anywhere and not necessarily in the worker's home (e.g., in a third-party hub or shared office, while travelling or on the road). Both dependent workers (such as employees and dependent contractors) and independent workers can be considered remote workers if they perform part or all of their work away from their default worksite. … Moreover, the concept of telework is often restricted to employees only.

The International Labour Organization (ILO) (2016) defines 'working from home' as the work that takes place fully or partly within the worker's own home. This concept is independent of the default place of work and both independent and dependent workers can be 'working from home'.

[2] This phenomenon has been studied since 2020 by the association South Working – Working from the South (www.southworking.org), founded by a group of young professionals and students linked to the Community Global Shapers Palermo Hub and united by the condition of expat or out-of-towner.

[3] Recently, TIM has developed a platform called DVI (Data Visual Insight), which makes it possible to view and download mobile phone data in text format (CSV) with a very high temporal resolution (available every 15 min for a period no longer than two years before the current date) on a spatial resolution of the census area (ACE).

[4] ACEs have been defined only for Italian municipalities with an overall population of around 100,000 inhabitants. Each ACE hosts between 13,000 and 18,000 inhabitants, with some exceptions.

[5] See https://www.gazzettaufficiale.it/eli/gu/2020/03/04/55/sg/pdf/.

[6] For full details (in Italian), see https://www.istat.it/en/files/2013/07/la_classificazione_delle_professioni.pdf/.

[7] For details of the programme and the list of available houses, see https://casea1euro.it/.

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