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The Impact of COVID-19 on the Jobs–Housing Dynamic Balance: Empirical Evidence from Wuhan between 2019, 2021, 2023

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Abstract: The COVID-19 pandemic, a significant public health emergency, has underscored the criticality of jobs–housing proximity. Static statistical research, however, struggles to uncover the mechanisms underlying jobs–housing balance, providing limited guidance for urban management. This paper adopts the concept of jobs–housing dynamic balance, analyzing the trends in jobs–housing balance in the metropolitan development area of Wuhan in the early and later period of the pandemic from the perspective of individual jobs–housing migration. Using mobile phone signaling data, we identified a stable population of 161,698 residents in June 2019, June 2021, and June 2023, and calculated jobs–housing synchronization and migration impact indices across seven regions. The study finds the following: (1) there is a pronounced misalignment of jobs–housing in the new cities of Wuhan's suburbs, with clear asynchronous in-migration and out-migration; (2) COVID-19 initially led to a unidirectional exodus of the local population for job purposes, significantly contributing to regional jobs–housing imbalance, followed by a partial rebound in the later stages; and (3) the stability of jobs–housing balance in suburban new cities lacking policy support and comprehensive urban functions is worse, primarily due to insufficient employment resilience and the out-migration of the employed population. This paper puts forward a set of recommendations for the sustainable development of suburban new cities. It offers insights into the theoretical advancement of jobs–housing balance and the dynamic, refined transformation of urban studies, enhancing urban managers' understanding of human–place interactions and new city construction.

Keywords: jobs–housing dynamic balance; residential migration; employment migration; Wuhan; resilience; public health emergency

Citation: Wu, L.; Yuan, M.; Liu, F.; Niu, Q. The Impact of COVID-19 on the Jobs–Housing Dynamic Balance: Empirical Evidence from Wuhan between 2019, 2021, 2023. *Land* **2024**, *13*, 1299. https://doi.org/10.3390/land13081299

Academic Editor: Maria Rosa Trovato

Received: 20 July 2024
Revised: 13 August 2024
Accepted: 15 August 2024
Published: 16 August 2024

1. Introduction

Jobs–housing balance is a hot topic in the fields of geography, sociology, and urban planning. In the 20th century, Kain [1] proposed the spatial mismatch hypothesis, identifying the phenomenon of long-distance commuting resulting from large-scale suburbanization and urban spatial restructuring. Many proponents believe that residents' long-distance commuting between workplace and residence is a significant factor contributing to traffic congestion, spatial segregation, social differentiation, and environmental pollution [2,3]. China acknowledges that the degree of jobs–housing separation and commuting congestion in China's large cities is still higher than other areas, particularly in the long-distance commuting between central cities and suburban clusters, such as between Beijing and Tongzhou [4,5]. In response, China prioritizes jobs–housing balance as a vital factor in the long-term construction and sustainable development of cities, while also proposing a series of policies to promote the integration of urban residential and production functions [6]. The perspective that exploring the mechanisms of jobs–housing balance/imbalance is an important approach to promoting healthy urban development and ensuring the well-being of residents has been widely accepted.

The concept, methods, and mechanisms of jobs–housing balance have been richly researched. Early research on jobs–housing balance focused on quantity, using boroughs as the regions of study, and posited that the number of local residents should roughly match the number of jobs available [7]. After discovering the issue of jobs–housing mismatch, the focus of research shifted to the proportion of local residents and employed individuals within a given area [8], and proposed measurement indices such as the jobs–housing ratio [9] and self-sufficiency ratio [10]. Influenced by the waves of behaviorism and post-humanism, researchers who were dedicated to the study of jobs–housing balance have begun to adopt a micro-perspective, focusing on the average jobs–housing commuting distance and time for regional commuters [3,11]. From a mechanistic perspective, scholars have identified a range of factors that influence the level of jobs–housing balance, including policy background, housing costs, income levels, and the built environment [2,12,13]. Thus, scholars have put forward optimization suggestions for jobs–housing balance, which include developing residential spaces, supplementing employment positions, and enhancing interaction between residential areas and adjacent industries [14]. However, the vast majority of existing studies are based on static comparisons at a single point in time, while research on dynamic trends is relatively scarce, which may not be sufficient to uncover the changing directions and fundamental drivers of jobs–housing balance [15]. This means that the empirical insights gained by urban managers and policymakers from the aforementioned research methods are limited.

Another significant issue is major public health emergencies. The widespread outbreak of COVID-19 in 2020 presented new challenges to urban sustainability, prompting the transformation of urban production and living activities [16]. Governments around the world have implemented a series of restrictive measures to prevent the spread of the pandemic and ensure residents' health, but these have also impacted residents' mobility and business operations [17], which could have a significant impact on the jobs–housing balance within cities. Firstly, residents might decide to reside in areas with greater accessibility and variety of facilities to avoid long-distance travel and to ensure the basic provision of daily necessities for healthy living [18,19]; they might also move to suburban and peripheral areas to reside in order to avoid crowds and the spread of the pandemic [20–22]. Secondly, residents may be unable to commute to distant workplaces due to travel restrictions and may even switch to telecommuting [23,24]; however, on the other hand, major public health emergencies inevitably lead to economic downturns and business bankruptcies/relocations [25], which may force residents to change their workplaces, traveling to more distant areas to earn a living [26]. Anyway, in the context of major public health emergencies, the balance and proximity of jobs and housing becoming even more important. In Carlos Moreno's newly introduced concept of the "15-Minute City", work is also factored into the fundamental assumption that "essential services must be close to residential areas", which is a key approach to ensuring urban sustainability [16]. Yet, there is a paucity of relevant research. Therefore, deepening our understanding of their impact on urban jobs–housing balance can benefit managers in devising targeted safeguard strategies, thereby enhancing the level of sustainable urban development.

Niu Qiang had proposed the concept and methodology of dynamic jobs–housing balance [27]. We believe that jobs–housing migration is the direct cause of regional jobs–housing balance and imbalance, and also an important factor in urban spatial restructuring. In the lives of residents, employment migration and residential migration are significantly and positively interrelated [28]. In the process of suburbanization, is it the case that individuals first relocate their workplaces or their residences, and does the migration of one element lead to the subsequent migration of the other? Clearly, the lag or hindrance of co-migration is a fundamental factor contributing to jobs–housing imbalance and long-distance commuting [29]. However, conducting comprehensive research on jobs–housing balance necessitates the acquisition of extensive and long-term samples of individuals' jobs–housing migration patterns, which is difficult to achieve through traditional methods such as questionnaires and interviews. This could be a major obstacle hindering the development of this theme. Nevertheless, the advent of big data now offers support for the dynamic transformation of jobs–housing balance research: data such as commuting trajectory data, mobile signaling data, and other Location-Based Services (LBS) data have significant advantages in tracking and identifying places of residence, employment locations, and measuring commuting distances [30,31]. In conclusion, shifting focus from static regional comparisons to the dynamic jobs–housing balance at the individual level has become an urgent priority, particularly in the post-pandemic era.

Therefore, we conducted a comparative study of the dynamic equilibrium between employment and housing, choosing Wuhan as the study object for the early and late COVID-19 epidemics. Initially, utilizing large-scale mobile signaling data, we identified the residents of Wuhan in 2019, 2021, and 2023, and monitored their movements in terms of residential and employment locations. Secondly, we conducted a comprehensive exploration of the changes in the level of jobs–housing balance and the main driving factors within the seven major regions of Wuhan based on the methodological framework of dynamic jobs–housing balance [27], and have proposed more refined policy suggestions based on this. The research has two major contributions: first, the development and validation of a research method for dynamic jobs–housing balance, which promotes the dynamic transformation of jobs–housing balance research; second, the exploration of the impact of major public health emergencies on dynamic jobs–housing balance, as well as the main mechanisms through which this impact is exerted.

2. Materials and Methods

2.1. Study Area

Wuhan, a provincial capital city located in central China, is currently undergoing rapid metropolitanization (Figure 1). With the growth of the population, its urban space has been continuously expanding outward, resulting in an evident trend of population suburbanization migration. According to Master Planning of Wuhan, its future development will focus on constructing a metropolitan development area, comprising 1 central urban area and 6 suburban new cities, serving as the primary areas for agglomeration and expansion in the future, with a total area of 3261 square kilometers [32,33]. Based on that, the current study has determined the regional boundaries of the central urban area and suburban new cities.

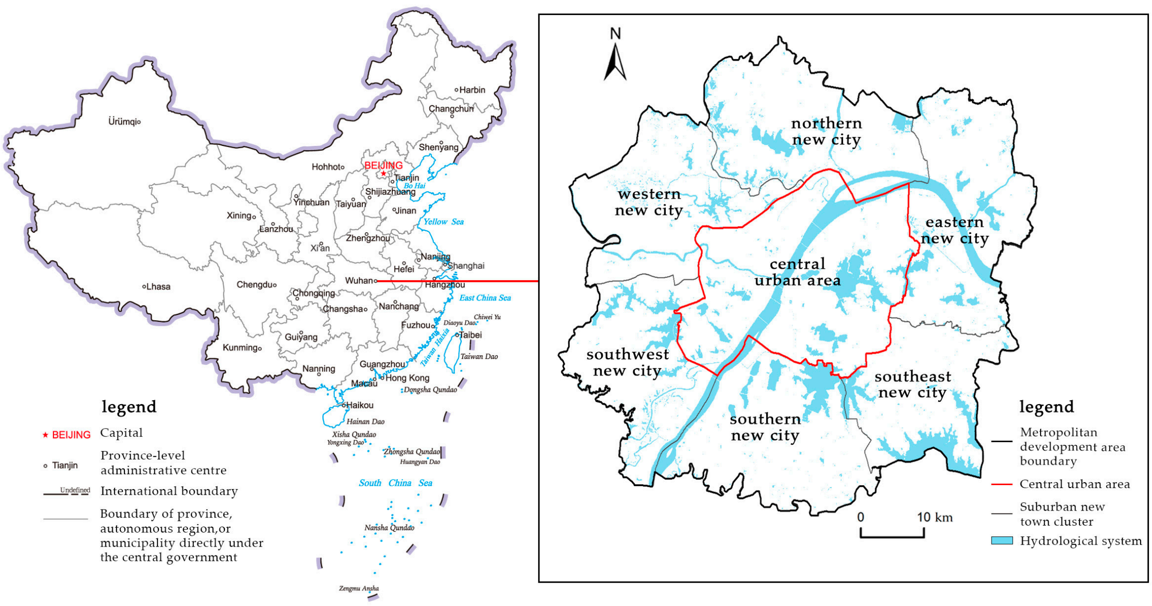

Figure 1. The study area.

Wuhan was the first to report the emergence of COVID-19 in December 2019, and drew national and global attention. It also implemented a series of measures to respond to the COVID-19 pandemic. Wuhan implemented strict quarantine measures from 23 January to 8 April 2020, restricting mobility and prompting a shift towards working from home [17]. After that, the Chinese government has adopted a series of policy measures to address the COVID-19 pandemic from 2020 to 2022, during which the employment market remained in a persistent state of distress, and it has also continuously impacted various activities of residents. Due to the increase in COVID-19 cases within China, many cities in the country adopted strict quarantine measures once again in the first quarter of 2022. In the fourth quarter of 2022, the Chinese government announced a significant policy shift on 7 December 2022. Municipal governments were granted more autonomy to determine how to modify the screening practices for COVID-19 cases, which was widely seen as marking the end of the COVID-19 era in China. In the current study, the period from 2019 to 2021 is designated as the early stage of COVID-19, while the period from 2021 to 2023 is considered the later stage of COVID-19.

2.2. Data

The data used in the current study are the mobile phone signaling data of Wuhan's Unicom subscribers, provided by the Smartsteps platform. The Unicom subscribers' market share in China was approximately 19% from 2019 to 2023. Specifically, the data used in this research cover the entire months of June 2019, June 2021, and June 2023, covering the entire course of the COVID-19 pandemic in Wuhan. This study focuses on the core users of China Unicom aged between 19 and 54 years old (i.e., the permanent residents who stayed in Wuhan for 10 days or more in the given month). According to existing experience [22,31], the location with the longest cumulative stay time from 9:00 to 17:00 every day was identified as the workplace, and the location with the longest cumulative stay time from 21:00 to 8:00 every day was identified as the residence.

To track individuals' jobs–housing changes, this study identified the same user at the beginning and end of the study period using the unique user identification number in the mobile signaling data. From this, we filtered out users who had both workplace and residence information across the three months, totaling 161,698 individuals. This accounts for approximately 2.60% of the total employed population in Wuhan in 2019, according to the Statistics Bureau of Wuhan Municipality. The data obtained have been tested and found to be representative and reliable [31].

2.3. Methods

2.3.1. Individual Jobs–Housing Migration and Dynamic Jobs–Housing Balance

The dynamic jobs–housing balance is influenced by individuals' spatial migration for employment and residence; compared to traditional research methods that focus on the outcome, this research method focuses primarily on the process of balance. Its measurement criteria for jobs–housing balance are as follows: if within a certain period, the level of jobs–housing balance in a particular area increases due to individual migration, it is seen as promoting dynamic jobs–housing balance. Conversely, if the level decreases, it is considered to be a dynamic jobs–housing imbalance.

Based on this definition, this study uses whether the pre-migration and post-migration workplace and residence are in the same region as the standard, and primarily investigates the 10 types of individual migrations represented in Figure 2. Among these 10 types of migrations, the following five can promote regional jobs–housing balance: synchronous employment in-migration, synchronous residential in-migration, simultaneous jobs–housing in-migration, synchronous employment out-migration, and synchronous residential out-migration. The remaining five types, however, would lead to jobs–housing imbalance.

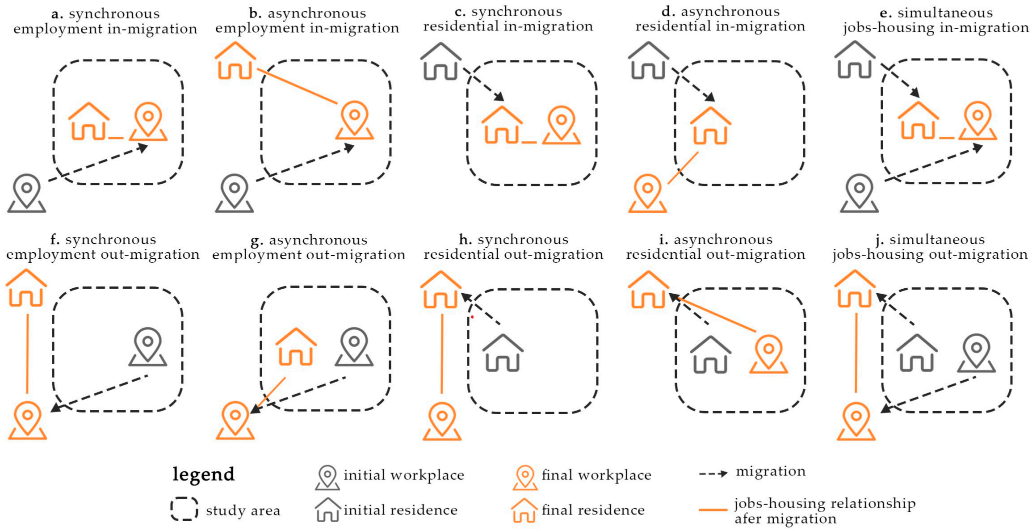

Figure 2. The conceptual schema of synchronous and asynchronous individual jobs–housing migration.

This study introduces the jobs–housing dynamic balance impact index E (hereinafter referred to as the impact index), which measures the dynamic jobs–housing balance by utilizing the difference between the change rate in same- and cross-regions due to individual migration over a given period. The specific calculation formulas are as follows:

$$E = R_S - R_D \tag{1}$$

$$R_S = \Delta S / S_0 \tag{2}$$

$$R_D = \Delta D / D_0 \tag{3}$$

In these formulas, R_S represents the change rate of same-region workplace–residences; R_D represents the change rate of cross-region workplace–residences; ΔS represents the change in the number of same-region workplace–residences; S_0 represents the number of same-region workplace–residences in the base year (referred to as the same-region number); ΔD represents the change in the number of cross-region workplace–residences; and D_0 represents the number of cross-region workplace–residences in the base year (referred to as the cross-region number).

The positive or negative value and magnitude of impact index E reflects the direction and extent of the development of jobs–housing dynamic balance. To verify the effectiveness of E, this study introduces the proportion of same-region jobs–housing numbers P. When $E > 0$, P will increase, thereby promoting jobs–housing balance, and vice versa. The specific calculation formula is as follows:

$$P = \frac{C_S \times 2}{C_S \times 2 + C_D} \tag{4}$$

In the formula, C_S represents the number of same-region workplace–residences and C_D represents the number of cross-region workplace–residences.

2.3.2. Assessment of Jobs–Housing Migration

This study utilizes synchronous and asynchronous indices to compare the quantitative relationships between the 10 types of individual migrations across different times and regions (calculation formulas are shown in Table 1). The higher the synchronous index and the jobs–housing simultaneous migration index, the more favorable they are for achieving jobs–housing balance, and vice versa. However, this also depends on the initial jobs–housing balance level at the base year.

Table 1. Synchronous and asynchronous index systems for jobs–housing migration.

Num.	Name	Formula	Explanation
(5)	Index of synchronous employment in-migration (I_{ws})	$I_{ws} = m_{ws}/\ S$	m_{ws} is the number of individuals who synchronously migrated their workplaces into a certain area during the study period
(6)	Index of asynchronous employment in-migration (I_{wa})	$I_{wa} = m_{wa}/\ S$	m_{wa} is the number of individuals who asynchronously migrated their workplaces into a certain area during the study period
(7)	Index of synchronous residential in-migration (I_{rs})	$I_{rs} = m_{rs}/\ S$	m_{rs} is the number of individuals who synchronously migrated their residences into a certain area during the study period
(8)	Index of asynchronous residential in-migration (I_{ra})	$I_{ra} = m_{ra}/\ S$	m_{ra} is the number of individuals who asynchronously migrated their residences into a certain area during the study period
(9)	Index of simultaneous jobs–housing in-migration (I_{wrs})	$I_{wrs} = 2m_{wrs}/\ S$	m_{wrs} is the number of individuals who simultaneously migrated their workplaces and residences into a certain area during the study period, so it needs to be calculated twice
(10)	Index of synchronous employment out-migration (O_{ws})	$O_{ws} = n_{ws}/\ S$	n_{ws} is the number of individuals who synchronously migrated their workplaces from a certain area during the study period
(11)	Index of asynchronous employment out-migration (O_{wa})	$O_{wa} = n_{wa}/\ S$	n_{wa} is the number of individuals who asynchronously migrated their workplaces from a certain area during the study period
(12)	Index of synchronous residential out-migration (O_{rs})	$O_{rs} = n_{rs}/\ S$	n_{rs} is the number of individuals who synchronously migrated their residences from a certain area during the study period
(13)	Index of asynchronous residential out-migration (O_{ra})	$O_{ra} = n_{ra}/\ S$	n_{ra} is the number of individuals who asynchronously migrated their residences from a certain area during the study period
(14)	Index of simultaneous jobs–housing out-migration (O_{wrs})	$O_{wrs} = 2n_{wrs}/\ S$	n_{wrs} is the number of individuals who simultaneously migrated their workplaces and residences from a certain area during the study period, so it needs to be calculated twice
(15)	Sum changes in the number of individuals after migration (S)	$S = m_{ws} + m_{wa} + m_{rs} + m_{ra} + 2m_{wrs} + n_{ws} + n_{wa} + n_{rs} + n_{ra} + 2n_{wrs}$	

2.3.3. Assessment of Jobs–Housing Dynamics Balance

The 10 types of migrations described above will affect the number of same-region and cross-region workplace–residences (Table 2) and alter the change rates in same-region and cross-region workplace–residences (Table 3).

Table 2. The impact of individual migration on jobs–housing balance.

Type of Migration	Impact on the Number of Same-Region Workplace–Residences	Impact on the Number of Cross-Region Workplace–Residences	Impact on the Total Number of Workplaces and Residences
Original status	-	-	-
Synchronous residential in-migration of m_{rs} individuals	$2m_{rs}$	$-m_{rs}$	m_{rs}
Synchronous employment in-migration of m_{ws} individuals	$2m_{ws}$	$-m_{ws}$	m_{ws}
simultaneous jobs–housing in-migration of m_{wrs} individuals	$2m_{wrs}$	No impact	$2m_{wrs}$
Asynchronous residential in-migration of m_{ra} individuals	No impact	m_{ra}	m_{ra}
Asynchronous employment in-migration of m_{wa} individuals	No impact	m_{wa}	m_{wa}

Table 2. *Cont.*

Type of Migration	Impact on the Number of Same-Region Workplace–Residences	Impact on the Number of Cross-Region Workplace–Residences	Impact on the Total Number of Workplaces and Residences
Synchronous residential out-migration of n_{rs} individuals	No impact	$-n_{rs}$	$-n_{rs}$
Synchronous employment out-migration of n_{ws} individuals	No impact	$-n_{ws}$	$-n_{ws}$
Simultaneous jobs–housing out-migration of n_{wrs} individuals	$-2n_{wrs}$	No impact	$-2n_{wrs}$
Asynchronous residential out-migration of n_{ra} individuals	$-2n_{ra}$	n_{ra}	$-n_{ra}$
Asynchronous employment out-migration of n_{wa} individuals	$-2n_{wa}$	n_{wa}	$-2n_{wa}$

Table 3. Calculation method for the change rate of synchronous and asynchronous zones based on individual jobs–housing migration.

Num	Name	Formula
(16)	The change rate of same-region after employment in-migration (R_{Swi})	$R_{Swi} = 2m_{ws}/S_0$
(17)	The change rate of cross-region after employment in-migration (R_{Dwi})	$R_{Dwi} = (m_{wa} - m_{ws})/D_0$
(18)	The change rate of same-region after residential in-migration (R_{Sri})	$R_{Sri} = 2m_{rs}/S_0$
(19)	The change rate of cross-region after residential in-migration (R_{Dri})	$R_{Dri} = (m_{ra} - m_{rs})/D_0$
(20)	The change rate of same-region after simultaneous in-migration (R_{Swri})	$R_{Swri} = 2m_{wrs}/S_0$
(21)	The change rate of same-region after employment out-migration (R_{Swo})	$R_{Swo} = -2n_{wa}/S_0$
(22)	The change rate of cross-region after employment out-migration (R_{Dwo})	$R_{Dwo} = (n_{wa} - n_{ws})/D_0$
(23)	The change rate of same-region after residential out-migration (R_{Sro})	$R_{Sro} = -2n_{ra}/S_0$
(24)	The change rate of cross-region after residential out-migration (R_{Dro})	$R_{Dro} = (n_{ra} - n_{rs})/D_0$
(25)	The change rate of same-region after simultaneous out-migration (R_{Swro})	$R_{Swro} = -2n_{wrs}/S_0$

This study uses the jobs–housing dynamic balance impact index to comprehensively measure the effects of employment and residential migration on the jobs–housing balance status of the area. The specific calculation formulas are as follows:

$$E_{wi} = R_{Swi} + \frac{1}{2}R_{Swri} - R_{Dwi} \tag{26}$$

$$E_{ri} = R_{Sri} + \frac{1}{2}R_{Swri} - R_{Dri} \tag{27}$$

$$E_{wo} = R_{Swo} + \frac{1}{2}R_{Swro} - R_{Dwo} \tag{28}$$

$$E_{ro} = R_{Sro} + \frac{1}{2}R_{Swro} - R_{Dro} \tag{29}$$

In these formulas, E_{wi} represents the impact index of employment in-migration, concluding the level of influence of synchronous and asynchronous employment in-migration, as well as simultaneous jobs–housing in-migration on jobs–housing balance; E_{ri} represents the impact index of residential in-migration; E_{wo} represents the impact index of employment out-migration; and E_{ro} represents the impact index of residential out-migration.

The specific calculation formulas of the impact index of in-migration, out-migration, employment migration, and residential migration are as follows:

$$E_i = E_{wi} + E_{ri} \tag{30}$$

$$E_o = E_{wo} + E_{ro} \tag{31}$$

$$E_w = E_{wi} + E_{wo} \tag{32}$$

$$E_r = E_{ri} + E_{ro} \quad (33)$$

In these formulas, E_i represents the impact index of in-migration; E_o represents the impact index of out-migration; E_w represents the impact index of employment migration; and E_r represents the impact index of employment migration.

The overall impact index E_s represents the influence of all jobs–housing migration on the dynamic balance of jobs–housing in the area. The specific calculation formula is as follows:

$$E_s = E_i + E_o = E_w + E_r = \sum R_S - \sum R_D \quad (34)$$

This study employs longitudinal and lateral comparisons of the aforementioned indices to analyze the impact of various factors on the jobs–housing dynamic balance in the suburban new cities in Wuhan.

3. Results

3.1. Synchronous and Asynchronous Characteristics of Jobs–Housing Migration

Targeting the "1 + 6" regions within the Wuhan metropolitan development area, this study established a square hexagonal grid with a side length of 330 m. Extracting totals by unit protects the privacy of individuals and is a common practice in cell phone data research [32]. First, it identified the employed population that experienced in-migration or out-migration between different regions during the periods of 2019–2021 and 2021–2023. Figures 3–6 depict the spatial distribution of the migration origins and destinations of this population. Subsequently, based on Formulas (5)–(15), the study calculated the synchronous and asynchronous indices of employment and residential in-migration and out-migration for the seven regions within the Wuhan metropolitan development zone, with the results presented in Tables 4 and 5.

By comparing the metric values, the following can be observed: ① In terms of the impact indices of in-migration, from 2019 to 2021, the indices of asynchronous employment and residential in-migration for all suburban new cities ranked first or second, and were much higher than other indices in the absolute majority of suburban new cities. From 2021 to 2023, the indices of asynchronous in-migration for all suburban new cities decreased significantly, while the indices of synchronous in-migration rose, but the indices of asynchronous in-migration still accounted for a high proportion. Additionally, during both periods, the indices of simultaneous jobs–housing in-migration were greater than the indices of synchronous employment and residential in-migration for the vast majority of suburban new cities, and in many suburban new cities, the indices of simultaneous in-migration were even greater than the sum of the two. ② In terms of the indices of out-migration, during both periods, the indices of synchronous employment out-migration were the highest across all suburban new cities, followed by the indices of synchronous residential out-migration as the second highest. Compared to the period from 2019 to 2021, the indices of synchronous employment out-migration increased significantly from 2021 to 2023. Additionally, there was a small proportion of asynchronous employment and residential out-migration during both periods. Compared to 2019–2021, the indices of asynchronous out-migration generally decreased from 2021 to 2023. At the same time, there was a certain proportion of simultaneous jobs–housing out-migration in each suburban new city, which directly led to a net loss in the jobs–housing population.

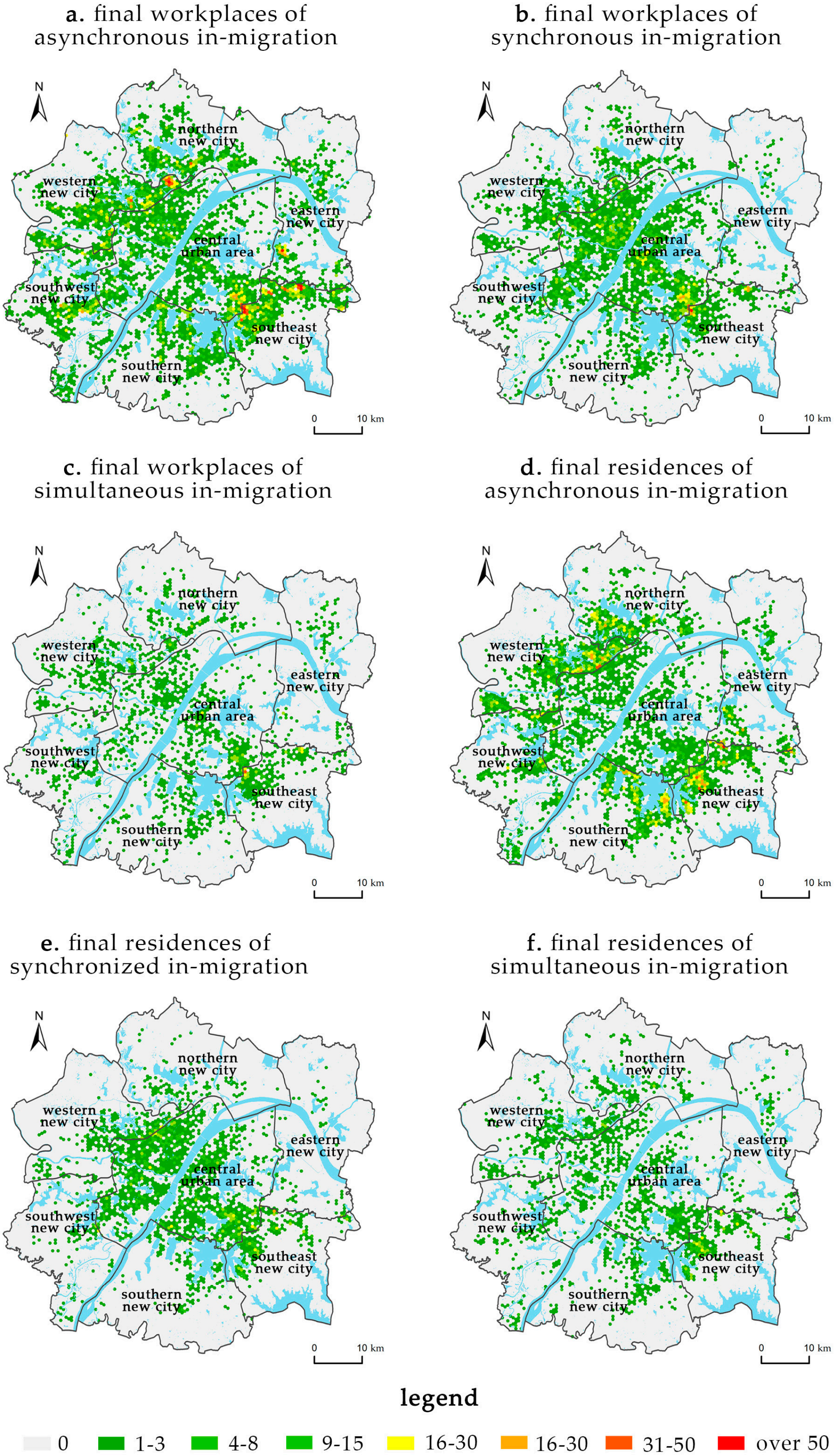

Figure 3. Destination based on jobs–housing in-migration in Wuhan, 2019–2021.

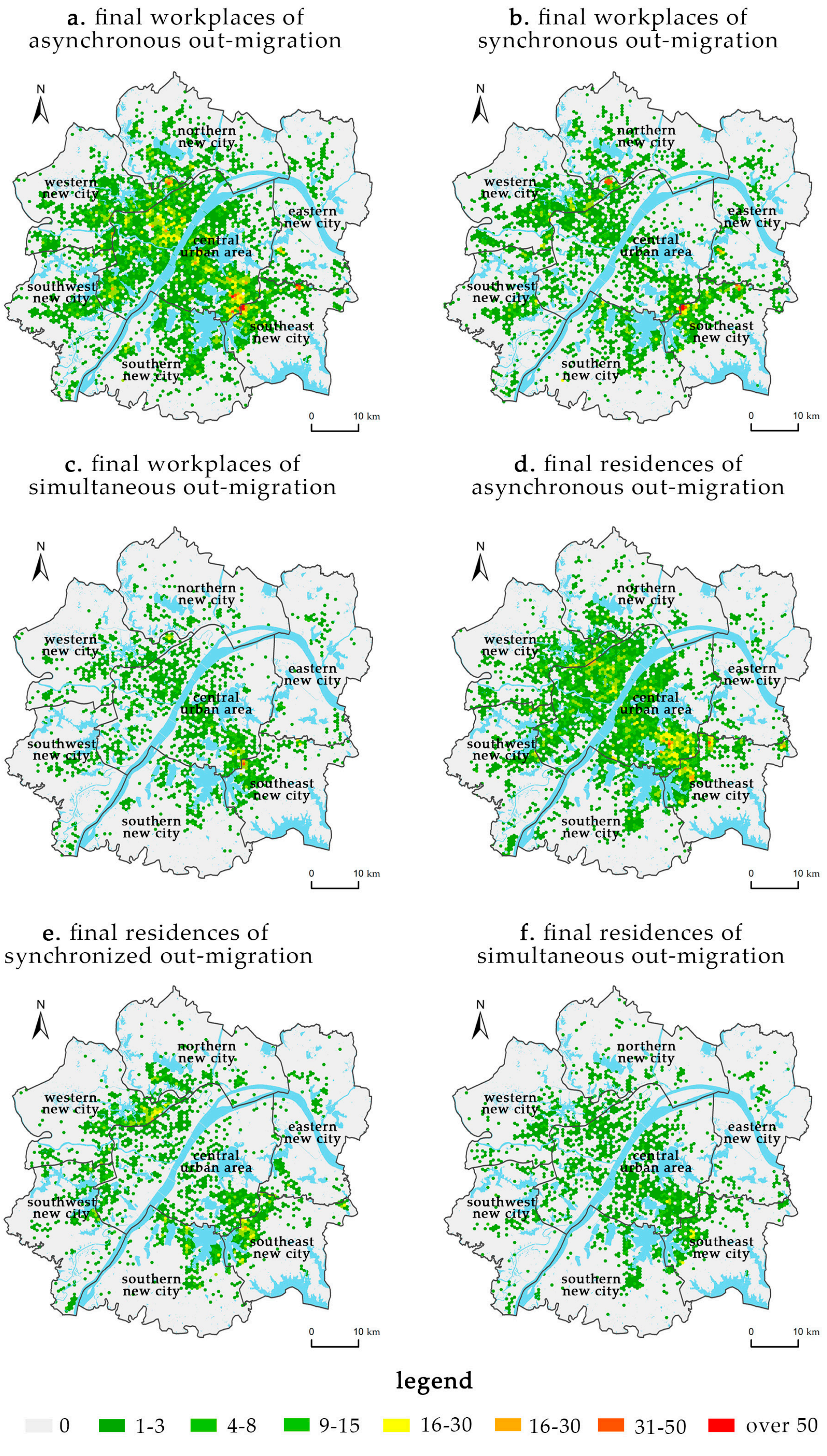

Figure 4. Destination based on jobs–housing out-migration in Wuhan, 2019–2021.

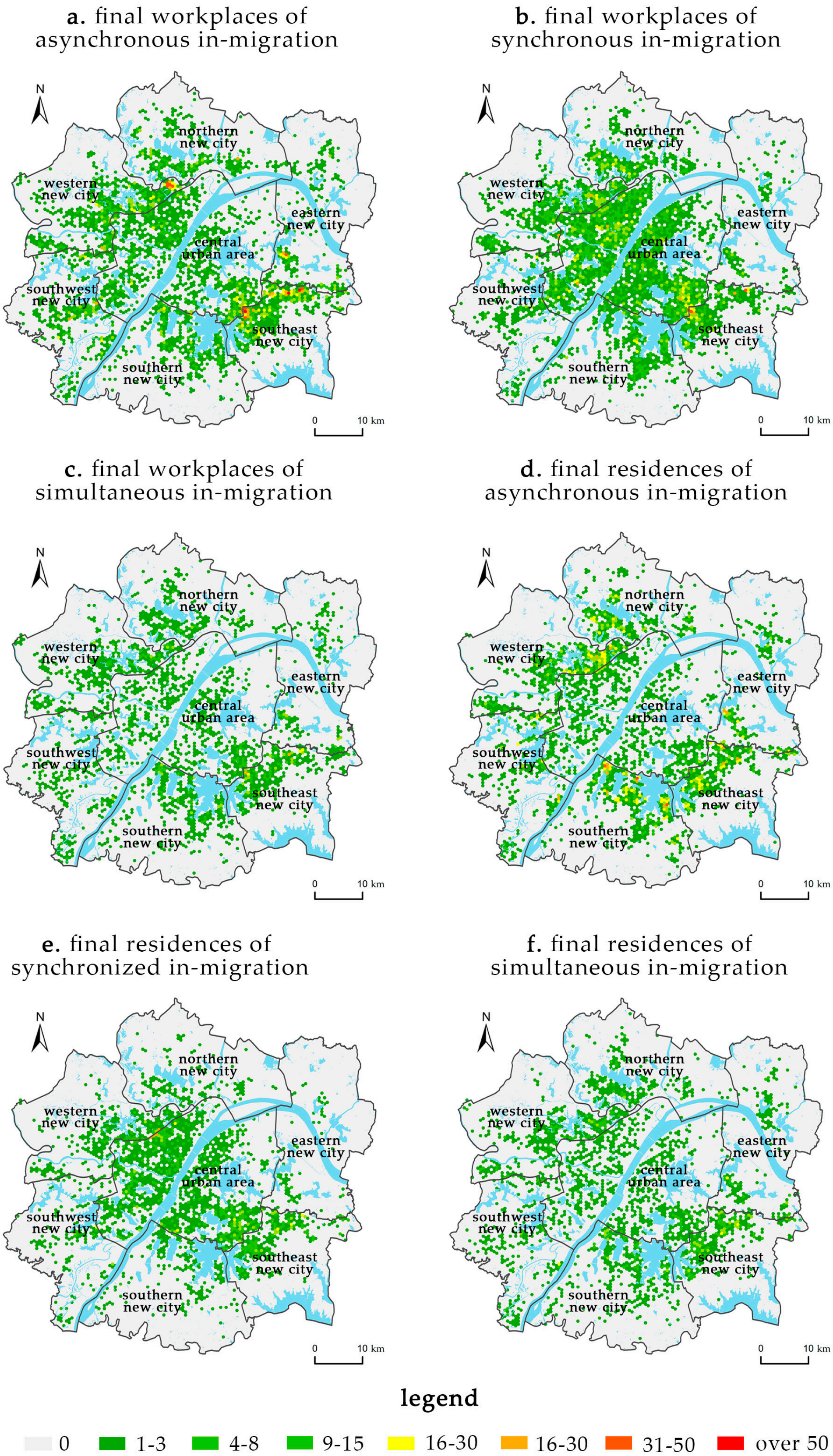

Figure 5. Destination based on jobs–housing in-migration in Wuhan, 2021–2023.

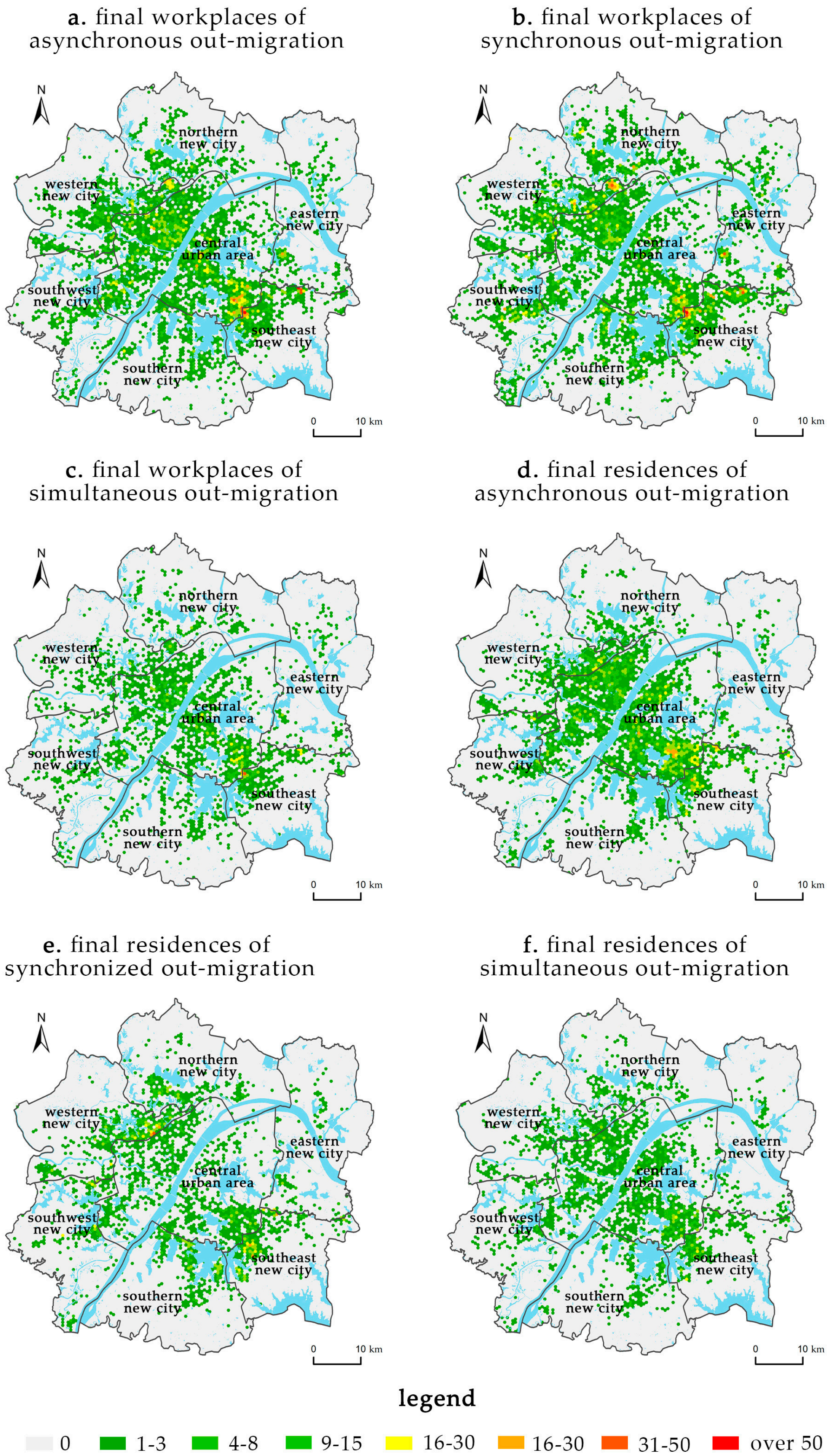

Figure 6. Destination based on jobs–housing out-migration in Wuhan, 2021–2023.

Table 4. The synchronous and asynchronous indices of individual jobs–housing migration in Wuhan suburban new cities in 2019–2021.

	Eastern New City	Southeast New City	Southern New City	Southwest New City	Western New City	Northern New City	Central Urban Area
Index of synchronous employment in-migration (I_{ws})	0.033	0.067	0.057	0.040	0.068	0.087	0.152
Index of synchronous residential in-migration (I_{rs})	0.035	0.046	0.030	0.035	0.033	0.030	0.104
Index of simultaneous jobs–housing in-migration (I_{wrs})	0.100	0.106	0.087	0.089	0.083	0.093	0.069
Index of asynchronous employment in-migration (I_{wa})	0.328	0.256	0.177	0.293	0.241	0.241	0.087
Index of asynchronous residential in-migration (I_{ra})	0.223	0.132	0.275	0.165	0.191	0.238	0.044
Index of synchronous employment out-migration (O_{ws})	0.134	0.137	0.119	0.138	0.141	0.107	0.061
Index of asynchronous employment out-migration (O_{wa})	0.071	0.077	0.102	0.109	0.096	0.074	0.036
Index of simultaneous jobs–housing out-migration (O_{wrs})	0.037	0.067	0.056	0.048	0.047	0.037	0.080
Index of synchronous residential out-migration (O_{rs})	0.025	0.065	0.069	0.045	0.066	0.074	0.202
Index of asynchronous residential out-migration (O_{ra})	0.013	0.048	0.027	0.041	0.034	0.018	0.166

Table 5. The synchronous and asynchronous indices of individual jobs–housing migration in Wuhan suburban new cities in 2021–2023.

	Eastern New City	Southeast New City	Southern New City	Southwest New City	Western New City	Northern New City	Central Urban Area
Index of synchronous employment in-migration (I_{ws})	0.070	0.107	0.119	0.081	0.130	0.161	0.192
Index of synchronous residential in-migration (I_{rs})	0.035	0.063	0.036	0.054	0.044	0.033	0.100
Index of simultaneous jobs–housing in-migration (I_{wrs})	0.180	0.139	0.161	0.147	0.131	0.148	0.063
Index of asynchronous employment in-migration (I_{wa})	0.187	0.228	0.106	0.179	0.167	0.123	0.062
Index of asynchronous residential in-migration (I_{ra})	0.168	0.087	0.252	0.130	0.131	0.162	0.030
Index of synchronous employment out-migration (O_{ws})	0.198	0.165	0.131	0.214	0.180	0.172	0.117
Index of asynchronous employment out-migration (O_{wa})	0.072	0.068	0.093	0.091	0.106	0.088	0.046
Index of simultaneous jobs–housing out-migration (O_{wrs})	0.049	0.063	0.049	0.056	0.048	0.045	0.126
Index of synchronous residential out-migration (O_{rs})	0.030	0.045	0.036	0.023	0.041	0.049	0.134
Index of asynchronous residential out-migration (O_{ra})	0.012	0.035	0.015	0.025	0.023	0.018	0.129

By comparing the quantitative relationships between the indices, the following can be observed: ① In terms of the relationship between the indices of in-migration and the indices of out-migration, the ratio of the indices of in-migration to the indices of out-migration for each new city over the two periods was approximately 7:3, with the indices of in-migration generally higher than the indices of out-migration overall. ② In terms of the relationship between the indices of employment migration and the indices of residential migration, from 2019 to 2021, the indices of employment migration in suburban new cities were, on average, 30% higher than the indices of residential migration. From 2021 to 2023, the indices of employment migration were, on average, 38% higher than the indices of residential migration. Additionally, the indices of employment in-migration were higher than the indices of residential in-migration, and the indices of employment out-migration were higher than the indices of residential out-migration. However, in the southern new city, the numbers of employment and residential migration were roughly equal, with the indices of employment migration even slightly lower than the indices of residential migration during both periods. ③ In terms of the relationship between the indices of asynchronous in-migration and the indices of synchronous in-migration, from 2019 to 2021, the sum of the indices of asynchronous employment and residential in-migration in suburban new cities was significantly higher than the sum of the indices of synchronous in-migration, ranging from three to eight times greater. From 2021 to 2023, the sum of the indices of asynchronous in-migration for employment and residence in suburban new cities also remained higher than the sum of the indices of synchronous in-migration, but the ratio decreased substantially, ranging from one and a half to four times greater. The indices of asynchronous in-migration for both employment and residence were higher than their indices of simultaneous jobs–housing migration. ④ In terms of the relationship between the indices of synchronous out-migration and the indices of asynchronous out-migration, the sum of the indices of synchronous out-migration for employment and residence was significantly greater than the sum of the indices of asynchronous out-migration. From 2019 to 2021, the sum of the indices of synchronous out-migration for employment and residence in suburban new cities was two to five times the sum of the indices of asynchronous out-migration. From 2021 to 2023, this ratio increased to three to seven times, with the indices of synchronous out-migration for both employment and residence being higher than their indices of simultaneous jobs–housing migration in all cases.

3.2. Characteristics of Jobs–Housing Dynamic Balance

According to Formulas (26) to (34), this study calculates the impact of employment and residential migration on the jobs–housing balance for each suburban new city, obtaining different types of dynamic balance impact indices of employment and residential migration. According to Formula (4), the proportion of same-region workplace–residences in Wuhan's suburban new areas in 2019, 2021, and 2023 were calculated, with the data from the central urban area of Wuhan as a reference (Tables 6 and 7).

Table 6. The impact index of dynamic jobs–housing balance in Wuhan suburban new cities in 2019–2021.

	Eastern New City	**Southeast New City**	**Southern New City**	**Southwest New City**	**Western New City**	**Northern New City**	**Central Urban Area**
The overall impact index	−0.279	−0.181	−0.328	−0.314	−0.242	−0.221	−0.114
The impact index of in-migration	−0.084	0.155	−0.117	−0.026	0.010	0.067	0.265
The impact index of out-migration	−0.195	−0.336	−0.211	−0.288	−0.253	−0.288	−0.369
The impact index of employment migration	−0.097	−0.077	−0.070	−0.115	−0.059	−0.036	−0.059
The impact index of residential migration	−0.181	−0.103	−0.258	−0.199	−0.183	−0.186	−0.044
The impact index of employment in-migration	−0.093	0.057	0.020	−0.056	0.033	0.117	0.160
The impact index of employment out-migration	−0.004	−0.134	−0.090	−0.058	−0.092	−0.152	−0.219
The impact index of residential in-migration	0.009	0.099	−0.137	0.030	−0.022	−0.050	0.105
The impact index of residential out-migration	−0.191	−0.202	−0.121	−0.229	−0.161	−0.136	−0.150
the proportion of same-region jobs–housing numbers in 2019	0.376	0.426	0.527	0.404	0.452	0.425	0.840
the proportion of same-region jobs–housing numbers in 2021	0.385	0.415	0.497	0.389	0.438	0.419	0.825

Table 7. The impact index of dynamic jobs–housing balance in Wuhan suburban new cities in 2021–2023.

	Eastern New City	Southeast New City	Southern New City	Southwest New City	Western New City	Northern New City	Central Urban Area
The overall impact index	0.172	0.227	0.122	0.233	0.212	0.306	0.103
The impact index of in-migration	0.324	0.434	0.247	0.382	0.376	0.498	0.257
The impact index of out-migration	−0.151	−0.207	−0.126	−0.149	−0.164	−0.192	−0.154
The impact index of employment migration	0.247	0.188	0.299	0.277	0.295	0.413	0.100
The impact index of residential migration	−0.074	0.039	−0.177	−0.043	−0.083	−0.107	0.003
The impact index of employment in-migration	0.217	0.229	0.303	0.216	0.291	0.448	0.166
The impact index of employment out-migration	0.030	−0.041	−0.004	0.061	0.003	−0.035	−0.067
The impact index of residential in-migration	0.107	0.204	−0.055	0.166	0.084	0.050	0.091
The impact index of residential out-migration	−0.181	−0.166	−0.122	−0.210	−0.167	−0.157	−0.088
the proportion of same-region jobs–housing numbers in 2021	0.385	0.415	0.497	0.389	0.438	0.419	0.825
the proportion of same-region jobs–housing numbers in 2023	0.499	0.498	0.571	0.499	0.540	0.541	0.843

The analysis of different impact indices reveals the following: ① From the perspective of the overall impact index, the overall impact indices of all suburban new cities were negative from 2019 to 2021, and positive from 2021 to 2023. ② In terms of the in- and out-migration impact indices, the out-migration impact indices were all negative during both periods. From 2021 to 2023, the in-migration impact indices were all positive, but there were three suburban new cities with negative in-migration impact indices during 2019–2021. The absolute values of the in-migration impact indices from 2021 to 2023 were all greater than the absolute values of the out-migration impact indices. ③ In terms of the employment and residential migration impact indices, from 2019 to 2021, the employment and residential migration indices for all suburban new cities were negative, with the absolute value of residential migration being greater. From 2021 to 2023, the employment migration impact indices for all suburban new cities were positive, while the residential migration indices for most suburban new cities remained negative, but their absolute values had decreased compared to the period from 2019 to 2021. Additionally, the residential migration impact index for the southeast new city was positive from 2021 to 2023. ④ In terms of the employment and residential in-migration impact indices, from 2019 to 2021, the employment and residential in-migration impact indices for the various suburban new cities were a mix of positive and negative numbers, indicating unclear directionality. From 2021 to 2023, the employment in-migration impact indices for all suburban new cities were positive, with only the southern new city having a negative residential in-migration impact index. ⑤ In terms of the employment and residential out-migration impact indices, from 2019 to 2021, the employment and residential out-migration impact indices for all suburban new cities were negative. From 2021 to 2023, the employment out-migration indices for the eastern new city, southwest new city, and western new city were positive, while all the residential out-migration impact indices remained negative.

4. Discussion

Firstly, the results of this study provide a detailed analysis from the perspective of individual migration of the dynamic relationship between employment and residential region in six suburban new cities and one central urban area of Wuhan City during the periods of 2019–2021 and 2021–2023. Compared with conventional assessment methods based on the ratio of the number of employed individuals to the number of residents and methods based on individual commuting distances and times, this study explores the process of jobs–housing dynamic balance through quantitative means from a multidimensional perspective of employment and residential migration, comparing different time periods. It enables a deeper interpretation of the employment and residential migration relationship in suburban new cities from the values and horizontal and vertical quantitative relationships of the indices. This approach facilitates a comprehensive understanding of the roles played by various factors such as time, space, and policy in both promoting and hindering the jobs–housing balance in suburban new areas.

Secondly, from a longitudinal comparison of different periods, the results confirm that the COVID-19 pandemic and other sudden events have a significant and universal impact on the employment and residential migration in different suburban new cities, thereby affecting the jobs–housing balance in these areas. The attention and demand for jobs–housing balance among individuals during the later period of the COVID-19 pandemic were significantly higher than during the earlier period. The COVID-19 pandemic struck the job market, particularly reducing the labor demand of enterprises in suburban new cities [34,35]. During the later period of the COVID-19 pandemic, numerous individuals who worked in suburban new cities but lived elsewhere opted to move their workplaces closer to their residences. This indicates that after the COVID-19 pandemic, various new cities have found it increasingly difficult to retain populations that commute between different regions for work and residence. During the later period of the COVID-19 pandemic, the overall impact indices of jobs–housing balance in all new cities were even higher than that in the central urban area. We argue that there is a moderating pullback after the abnormal migration caused by the epidemic.

Lastly, from a horizontal comparison of different new cities, the results show that there are differences in the ability of suburban new cities to regulate the jobs–housing balance. The southeast new city and the northern new city, for instance, had their various migration impact indices during 2019–2021 in line with the central urban area, which have relatively better capabilities in dynamically adjusting the jobs–housing balance. In 2021–2023, their overall impact indices were also generally higher than those of other suburban new cities, indicating that they have an advantage in maintaining the jobs–housing balance. In comparison, the southern new city is at a disadvantage among all the new cities. Therefore, we believe that new suburban cities with relatively simple and dysfunctional urban systems are more susceptible to shocks from epidemics. For instance, the East Lake New District in the southeast new city was approved as a national-level high-tech industrial development zone as early as 2001. Its construction environment surpasses that of other suburban new cities, with a more mature employment and residential adjustment that has entered a benign development stage characterized by attracting residence through employment opportunities. The northern new city has shown a clear orientation towards promoting jobs–housing balance in terms of employment migration, which may be due to the diverse industrial and manufacturing forms in the northern new city, offering a greater number of job opportunities. Additionally, the northern new city is adjacent to Wuhan Tianhe International Airport and Wuhan North Railway Station, one of the largest freight stations in Asia. With multiple subway lines already built or under construction, it enjoys a naturally advantageous location and transportation network. The southern new city, rich in historical and cultural resources and blessed with a superior living environment, has attracted more residential in-migration. However, the industrial transformation and upgrade in the southern new city has only just begun, with insufficient industrial settlement and construction of urban supporting facilities. Compared to other new cities that developed earlier, the southern new city has fewer job opportunities and is not yet able to effectively promote dynamic jobs–housing balance. Residents living or employed in these areas are more likely to be affected by major public health emergencies and make relocation decisions, thus creating a jobs–housing imbalance.

This study yields significant implications for urban policy. The stability of jobs–housing balance can be severely affected by major public health emergencies, with the vulnerability of employment being a primary manifestation. During the COVID-19 pandemic, the fragile jobs–housing balance in some suburban new cities was laid bare. These new cities were more significantly impacted by major events and had weaker post-event recovery capacities, making them more prone to developmental decline. Therefore, in the post-COVID-19 era, the future direction of suburban new city construction should focus on enhancing urban resilience and promoting the integrated development of industry and cities. Firstly, the stability of employment in suburban new cities is the foundation for a stable jobs–housing relation. New cities should reduce their dependence on specific industries, actively cultivate emerging industries, focus on supporting innovative industries, and enhance the resilience of the job market against risks. Secondly, the government should strengthen employment guidance for individuals, bolstering social welfare systems and leveraging housing subsidies alongside residential incentives to address a spectrum of residential requirements. Finally, there is a need for the government to prudently enrich and upgrade the ancillary facilities in outlying new cities. This approach will lure the labor force to migrate and establish themselves, providing them with congruent work opportunities whilst upholding a high-quality lifestyle.

5. Conclusions

The research validates and demonstrates the superiority of the measurement approach for assessing the dynamic jobs–housing balance, uncovering the fundamental patterns in the jobs–housing relationship in Wuhan's suburban new cities against the backdrop of the COVID-19 pandemic. The key findings are as follows: ① While all of Wuhan's suburban new cities exhibit strong appeal for both employment and residence, their capacity for aligning workplaces with residences significantly lags behind that of the central urban area. The mismatch between workplaces and residence is a major reason for the population loss in these new cities. ② Emergencies and urban management policies have a significant impact on the jobs–housing balance in the suburban new cities. The outbreak and continuation of COVID-19 have hindered the jobs–housing balance in all the suburban new cities in Wuhan. After the end of the pandemic, migration within these suburban new cities has facilitated a shift towards achieving a more balanced jobs–housing equilibrium. ③ New cities with poor employment stability and lagging construction of urban living facilities are more susceptible to disruptions from public health emergencies, leading to significant population out-migration and jobs–housing imbalance. This disruption is most clearly seen in the exodus of the workforce in these regions. Continued attention should be given to the stability of the employed population in suburban new cities.

Although this study provides valuable methods and insights, it also has limitations: This study did not consider the migration relationship between individuals outside the Wuhan metropolitan area and the suburban new cities in Wuhan, but the conclusions are still representative of the study. Additionally, this study did not take into account the role of individual and family attributes in migration. Studies have shown that the choice of residence is a result of a collective consideration by family members. When children are present, the commuting time and distance for both parents in the family are likely to be shorter [36,37]. Therefore, follow-up research that includes individuals with migrations both within and outside the region, and connects to the individual and family attributes of the research subjects, will provide a better understanding of the role of different influencing factors on the jobs–housing balance in suburban new cities, offering more valuable insights. Finally, it remains to be verified whether the results of the Wuhan migration study can be applied to other regions and countries. The methodology proposed in this study can provide research insights.

Author Contributions: Conceptualization, L.W. and M.Y.; Formal analysis, M.Y.; Methodology, L.W.; Writing—original draft, L.W.; writing—review and editing, F.L.; Validation, Q.N.; Supervision, Q.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Authors are not authorized to share raw cell phone data, but can provide regionally aggregated statistics.

Conflicts of Interest: The authors declare no conflict of interest.

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