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The Impact of the Digital Divide on Labor Mobility and Sustainable Development in the Digital Economy

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Abstract: This paper explores the ways in which the digital divide affects labor in the context of sustainable development within the digital economy. It discusses the effects of major indicators such as digital infrastructure construction, digital industry development, and digital-inclusive finance on labor mobility. Although existing research has analyzed the ways in which the digital economy enhances economic vitality, there is insufficient research that investigates how the divide between digital access and usage can be effectively reduced to promote sustainable development. Therefore, through empirical analysis and mechanism research, this study used quantitative measurement and regression analysis methods to conduct an in-depth analysis of the dual effects of digital access and usage divides on the long-term marginal impact for labor. The results show that improving digital infrastructure such as broadband and fiber optic networks not only significantly boosts the economic vitality of underdeveloped areas, but also enhances their ability to participate in sustainable development. This enables more laborers to access new job opportunities and resources provided by the digital economy. While narrowing the digital use divide initially increases labor mobility, uneven dissemination may create barriers to information access, thus limiting mobility. Our research indicates that the development of the digital economy promotes cross-regional labor mobility, which is particularly prominent in the digital platform economy, facilitating more sustainable economic growth. After controlling for variables such as the level of economic development, this positive impact remains robust. This paper suggests that digital infrastructure construction and training in digital skills should be strengthened to narrow the digital divide and promote sustainable, balanced regional development and increased economic vitality.

Keywords: digital economy; labor mobility; digital divide; urbanization; inter-regional migration; sustained innovation

Citation: Chen, J.; Xu, Z. The Impact of the Digital Divide on Labor Mobility and Sustainable Development in the Digital Economy. *Sustainability* **2024**, *16*, 9944. https://doi.org/10.3390/su16229944

Academic Editors: Jun (Justin) Li and Stephan Weiler

Received: 7 October 2024
Revised: 6 November 2024
Accepted: 13 November 2024
Published: 14 November 2024

1. Introduction

The rapid development of the digital economy, while driving economic growth, has also led to uneven development. Due to disparities in infrastructure, technological capabilities, and talent reserves across regions, particularly imbalances in the construction and proliferation of digital infrastructure between urban and rural areas and between eastern and western regions, some areas are able to fully leverage digital technologies and platforms to create new economic value, while less developed regions struggle to keep pace due to a lack of resources and technology. This disparity has created a "digital divide". The primary contradiction associated with China's development—namely, unbalanced and inadequate development—is also reflected in the progress of the digital economy. The digital economy intensifies this disparity, making access to digital technologies and economic resources even more unequal between the eastern and western regions, as well as between urban and rural areas, thus exposing deeper issues in regional development.

A direct manifestation of the development of the digital economy is the rise of the internet platform economy [1]. Platforms such as ride-hailing and food delivery services have created a multitude of new jobs. These new positions not only address employment issues for a portion of the labor force but have also led to a rapid increase in flexible employment, thereby altering the traditional labor market structure. Concurrently, the proportion of labor in traditional sectors such as manufacturing and construction, historically populated by migrant workers, has declined [2]. This indicates that the digital economy is, to some extent, substituting labor demand in traditional economic sectors. The development of the digital economy has also prompted changes in work modalities [3]. Increasingly, job roles are being distributed and managed through digital platforms, with many tasks that originally depended on physical locations or centralized management transitioning online. This trend has made work more flexible and decentralized, with a notable increase in job fragmentation. Many workers can now engage in multiple professions simultaneously or earn income through short-term, project-based work instead of traditional full-time employment [4].

As the digital economy gives rise to a plethora of new occupations, the trends observed in labor migration are also changing. Traditionally, labor migration from rural to urban areas was influenced by fixed industrial structures (such as manufacturing and construction) and uneven regional economic development. However, in the context of the digital economy, new digital occupations have increased labor mobility [5]. Developed digital cities and platform-based economies have driven the migration of labor from rural or less developed areas to developed cities, promoting a spatial redistribution of labor [6]. Cities that have an advantage in the digital economy are able to leverage digital platforms and technologies to create new productivity, further driving economic growth and development [7]. Conversely, the migration of labor to developed regions exacerbates the drain of talent and economic stagnation in less developed areas.

According to data from the Ministry of Human Resources and Social Security of China, over 45% of new occupations created between 2019 and 2021 were digital professions. This proportion highlights the significant impact of the digital economy on the generation of employment opportunities and reflects the rapid penetration of digital technologies across various industries. Overall, digital occupations account for 6% of all professions, indicating that the digital economy's reshaping of the overall economy and employment structure is accelerating [8].

In addition to the digital economy itself, changes in other social systems and infrastructure have promoted labor mobility. The improvement of transportation infrastructure has made the cross-regional movement of labor more convenient. Reforms in the household registration system have reduced institutional barriers to labor migration, and the accessibility of information due to the internet has made it easier for people to find job opportunities and information. These factors collectively accelerate the spatial flow of labor, prompting more individuals to migrate to regions with a well-developed digital economy [9].

Therefore, does narrowing the digital divide promote the development of the digital economy? What impact does the digital economy have on labor mobility? How does the digital divide influence labor mobility? To address these questions, this paper investigates the impact of the digital economy on labor mobility based on data related to labor migration and the development of the digital economy. Through an empirical analysis of indicators such as digital infrastructure, the development of digital industries, and inclusive digital finance, this study aims to provide valuable insights into the role these factors play in labor mobility.

2. Literature Review and Hypothesis Development

2.1. Analysis of the Relationship Between Narrowing the Digital Access Gap and Promoting Labor Mobility

With the rapid development of the digital economy, the internet and related technologies have become crucial to the generation of economic activities, information dissemination, and labor markets. Chinese digital economy studies have gradually formed a framework based on industrial digitization, digital industrialization, digital governance, and data value, with data-driven economic and social innovation becoming a major trend for the future [10]. For instance, an analysis of panel data from 271 Chinese cities from 2011 to 2018 summarized the positive impact of the digital economy on the industrial structure, leading to improvements in terms of both its quantity and its quality [11]. The digital economy can reduce transaction costs, enhance market potential, and increase knowledge spillover, which promotes the geographical concentration of China's manufacturing industry [12].

The advancement of the digital economy not only benefits the local economy but also has positive effects on neighboring cities [13], with reductions in poverty becoming increasingly significant. However, regional disparities can lead to widening differences [14]. On an individual level, the digital economy increases job flexibility, which is particularly beneficial to the younger generation, those with low human capital, and non-agricultural households [15], with digital literacy being a key factor [16]. Thus, the digital economy fosters a unified labor market by enhancing labor mobility, expanding entrepreneurial activities [17], and optimizing the allocation of labor between urban and rural areas and across regions, thereby reducing imbalances [18]. By improving the flow of information, reducing information asymmetry, and enhancing the efficiency of labor allocation, the digital economy facilitates the integration of regional markets [8].

However, the digital divide continues to have a significant impact on labor mobility, socioeconomic equality, and equitable access to information [19]. Research indicates that the existence of the digital divide exacerbates income disparities between regions; for every unit increase in the digital divide, the income gap widens by 0.134 units [20]. In this context, the digital access gap, an essential dimension of the digital divide, primarily reflects the disparities in digital infrastructure (such as broadband and fiber optic networks) across different regions; such disparities affect people's ability to access the internet and use digital tools [21]. Even for college graduates seeking employment, the digital divide can reduce their social networks, ability to access information, work efficiency, and risk preferences [22]. Narrowing the digital access gap, particularly by improving the fiber optic infrastructure, could promote the development of the digital economy, creating more favorable conditions for labor mobility [23].

Some studies indicate that the digital divide is primarily the result of differences in family attributes such as education and income, which account for approximately 63% of the divide, while differences in infrastructure account for approximately one-third [24]. However, this assertion is based on information obtained twenty years prior to our study; it should therefore only be treated as a reference, as it may no longer be applicable. The development of the digital economy could lead to significant improvements in the efficiency of resource allocation, particularly in terms of capital, products, and labor. The digital economy is progressively improving resource allocation. However, as the digital economy continues to develop, the effects of this optimization gradually diminish [25]. The digital access gap mainly manifests as an imbalance in digital infrastructure among different regions. Developed areas typically have high-speed broadband and extensive fiber optic network coverage, while in less developed areas, the infrastructure is often outdated, making internet access more challenging.

Improving the fiber optic infrastructure, especially in less developed regions, will significantly reduce the digital access gap, allowing more regions and populations to access the internet and participate in the digital economy. As such, it will provide more equitable opportunities for digital participation across the whole of society. The improvement of digital access has propelled the development of the digital economy, which relies on the rapid dissemination of information, technological innovation, and the emergence of new industries, all of which require an efficient digital infrastructure. One manifestation of digitization is the growing prevalence of remote employment. Currently, the demand for remote work greatly exceeds the supply, reflecting the growing interest of both employees and employers in this work format, which holds significant developmental potential [26].

Telecommuting has become increasingly common worldwide, particularly in the wake of the COVID-19 pandemic. Non-mandatory telecommuting arrangements generally lead to improvements in productivity and performance; however, for employees engaged in mandatory, full-time telecommuting, such as that resulting from external factors such as the pandemic, the effects are often negative or uncertain [27]. Thus, changes driven by automation and technological innovation present new requirements related to corporate recruitment and human resource management. Entrepreneurial skills such as innovation and creativity are deemed crucial in recruitment, especially in technology-intensive work environments [28].

When residents in less developed areas are able to participate in e-commerce, distance education, and online employment through the internet, local economic vitality increases. Additionally, greater access to job opportunities, entrepreneurial information, and skills training via the internet promotes the application of the digital economy in various fields. Therefore, the enhancement of infrastructure, such as fiber optic cables, not only enables less developed regions to catch up with the digitization process, but also promotes the growth of the digital economy of the entire country or region. Similarly, the digital economy has created more jobs: the introduction of Uber improved both employment and financial conditions for workers, and has been particularly beneficial to low-income groups, increasing labor participation rates and reducing unemployment [29]. Industry data obtained from six major European economies between 2009 and 2014 indicate that the increased procurement of intermediate goods from digital-intensive sectors is associated with an increase in employment, while the enhancement of information and communication technology (ICT) capital correlates with a decline in employment rates [30]. Different platforms attract different income groups, and the combination of online and traditional income sources exacerbates labor market stratification trends. High-income individuals are more likely to use capital platforms, while low-income individuals tend to utilize labor platforms, resulting in a layered phenomenon in both online and traditional labor markets [31].

The rapid development of the digital economy, particularly that driven by improvements in fiber optic infrastructure, has created a multitude of new employment opportunities. The internet grants the workforce rapid access to information about jobs across different regions and industries, reducing information asymmetry and enhancing the efficiency with which jobs are matched to individuals. The widespread adoption of digital technologies has provided more opportunities for cross-regional and even cross-industry employment. Emerging industries such as high technology, e-commerce, and fintech demand digitally skilled labor, and these positions are typically no longer constrained by geographic boundaries, enabling remote work and flexible employment through online platforms. Consequently, the development of the digital economy not only broadens the scope of employment but also mitigates geographical limitations, thereby promoting labor mobility.

Ultimately, narrowing the digital access gap not only directly promotes the development of the digital economy but also indirectly facilitates labor mobility. Improvements in infrastructure allow more workers to participate in national or global job markets via digital tools. This is of particular importance in less developed regions, where improved fiber optic infrastructure enhances people's access to information about jobs, distance education and training, and opportunities to engage in the various work models offered by the digital economy. In the context of cross-regional labor mobility, the improvement of digital infrastructure plays a crucial role. It enables the workforce in less developed areas to overcome information barriers, access better job opportunities, and achieve cross-regional mobility. Based on the above analysis, the following hypotheses are proposed.

Hypothesis 1. *Narrowing the digital access gap promotes labor mobility by advancing the development of the digital economy.*

2.2. Analysis of the Dual Role of the Digital Usage Gap on Labor Mobility

Macroeconomically, the digital economy promotes the agglomeration of industries in small- and medium-sized cities and the diffusion of industries in large cities, facilitating a more balanced industrial layout [32]. In regions with strong infrastructure, a high capacity for innovation, and a high level of marketization, the digital economy offers more pronounced inclusive growth effects [33]. Additionally, the development of the digital economy can significantly slow down the decline of the demographic dividend; this mitigating effect is particularly evident in the southeastern and southern regions of China, whereas the marginal ability of human capital in the western region more effectively counters this decline compared to the eastern and central regions [34].

Moreover, the development of the digital economy can significantly enhance the economic resilience of cities, especially in central China [35]. Labor mobility also manifests in the transition of primary and secondary industries to tertiary industries [36,37], leading to a shift in focus from agriculture and manufacturing to services, which may lead to the unidirectional or bicameral polarization of skill structures. This could potentially narrow the gender gap but may also result in a digital divide [38]. Furthermore, the digital economy's impact on labor mobility exhibits a threshold effect, with there being an increase in marginal effects beyond the breakthrough point; this contributes to a spatial spillover that promotes labor mobility in adjacent areas due to its high permeability and shareability [2].

A study utilizing data from 2011 to 2020 found that the development of the digital economy has significantly improved the total factor productivity (TFP) of China's manufacturing sector, with the most notable effects observed in the eastern coastal regions. Significant effects were also observed in the middle reaches of the Yellow River, the middle reaches of the Yangtze River, and the southwestern regions, with the latter being particularly prominent [39]. Scholars have noted that, despite the rapid growth of the digital economy at the provincial level in China from 2011 to 2020, a significant digital divide persists. The digital economy is most developed in eastern regions such as Beijing, Shanghai, and Guangdong, while the central and western regions lag behind. Despite these disparities, the digital economy is generally associated with higher levels of development nationwide, with high-level development in neighboring provinces spilling over and enhancing local digital economies [40].

Despite the increasing availability of internet access, the digital usage gap continues to affect certain groups and regions, preventing them from reaping the maximum benefits of the digital economy. When the development of the digital economy first began, the spread of the internet enabled the workforce to access information. The digital usage gap represents a significant barrier in regions that rarely engage with the digital economy, such as rural areas [41]. Reducing the digital usage gap grants more people online access to cross-regional and cross-industry job opportunities, particularly in areas that previously struggled to obtain information. The widespread availability of the internet reduces information asymmetry, enhancing the discoverability of job opportunities in different cities and regions via online platforms, and thus enhancing the convenience of job selection and mobility. As more people get online, resources such as online education and skills training become increasingly accessible, enabling the workforce, especially low-skilled workers, to enhance their skills through digital means, allowing them to relocate across regions or industries. Therefore, as the digital usage gap narrows, labor mobility is expected to increase significantly.

As the digital economy develops, the impact of the digital usage gap becomes increasingly complex. In some less developed regions or low-income groups, although internet access rates have improved, the actual usage level remains low. Researchers have noted that the digital divide may cause certain groups, such as elderly people, those with low educational attainment, manual laborers, and low-income individuals, to become "digitally vulnerable groups". These groups resist digitalization, fearing that technology will replace their jobs [42]. However, this line of research is limited due to its reliance on subjective public perceptions rather than actual skill measurements. Although perception can reflect people's attitudes and potential psychological barriers, it may not always accurately represent an individual's digital skills.

This uneven disparity prevents certain groups from fully utilizing the internet to obtain employment information, resources, or skills training. When the digital usage gap widens, groups with insufficient internet usage, such as low-skilled workers and residents of less developed areas, are at a disadvantage in terms of information access. They cannot quickly identify job opportunities or enhance their technical skills, which reduces their competitiveness in the labor market. This information asymmetry not only affects individual employment prospects but also reduces the overall mobility of these groups, hindering their transfer to developed regions or emerging industries. Consequently, the digital usage gap becomes a major obstacle to labor mobility. Moreover, as the digital economy continues to develop, the optimization effects gradually diminish [25]. In cities dominated by a highly skilled labor force, the influx of immigrants enhances the positive impact of the digital economy on occupational diversity; conversely, in cities dominated by a low-skilled labor force, immigration tends to weaken this impact [43].

The urban–rural digital divide in China also has a "damping effect" on urbanization [44]. Increasing the complexity of this issue, the internet usage rate is relatively high among migrant workers and the children that move with them to cities, but low among the elderly and among the children who are left behind. The digital divide between urban and rural areas is not only reflected by internet access; rural residents engage in online learning and work less frequently than urban residents, although there is little difference in their use of entertainment platforms [45]. This indirectly expands the digital divide across different platforms. The same is true for income. According to data from the China Family Panel Studies from 2010 to 2018, the digital divide has a more negative impact on the non-agricultural income of rural households than on agricultural income, with women, young and middle-aged laborers, and individuals in the eastern and central regions experiencing more significant negative effects [46].

Data from A-share listed companies in China from 2011 to 2020 indicate that the digital economy has significantly increased corporate labor demand, and that this shift is especially noticeable in the high- and low-demand scale quantiles [47]. Similarly, an analysis of 2020 data from China's rural revitalization survey found that e-commerce operations have boosted farmers' incomes by enhancing information access, reducing operational costs, and increasing financial support [48]. The level of internet development is also directly correlated with labor mobility: for every unit increase in a city's internet development level, the likelihood of labor out-migration decreases by 11.44% [49].

Therefore, the dual effect of the digital usage gap is evident: in the early stages, an increase in internet usage promotes labor mobility, but in later stages, the exacerbation of uneven internet usage among different groups and regions is a major impediment to labor mobility. Competition in the labor market is becoming increasingly reliant on digital skills and the efficient use of the internet; consequently, imbalances in the digital usage gap will result in the gradual exclusion of groups that fail to effectively utilize the internet, thereby hindering labor mobility. Based on the above analysis, the following hypothesis is proposed.

Hypothesis 2. *Narrowing the digital usage gap will initially promote labor mobility, but as digital usage disparities intensify, widening the digital usage gap will significantly hinder labor mobility.*

2.3. The Digital Capability Gap and Labor Mobility

The enhancement of digital capabilities aligns with the evolving demands of the labor market. The number of jobs that require basic digital skills is increasing, especially in the context of the global economy's digital transformation; as such, individuals' digital capabilities are beginning to directly affect their employment mobility. Workers with digital skills are better equipped to adapt to changing work environments and to find more suitable jobs through digital platforms, thus further promoting their career mobility. The digital economy optimizes the labor structure by increasing the proportion of highly skilled labor. When the proportion of highly skilled labor exceeds 43.156%, the impact of the digital economy on the upgrade of industry is significantly enhanced [50]. Consequently, the wage levels of these workers increase substantially; however, this creates employment challenges for low-skilled laborers, reducing their income and widening the wage gap [51,52].

From the perspective of labor mobility, the digitization of production drives labor toward technical occupations, while the digitization of lifestyles drives labor toward service-oriented jobs, concurrently reducing the number of workers moving into production-oriented jobs [53]. Some studies have drawn different conclusions, suggesting that the digital economy provides more income-enhancing opportunities for low-skilled workers, promoting labor market equity [54] and significantly increasing the income of low-skilled workers [55]. Although these two viewpoints appear contradictory, this is not necessarily the case. The digitization of production and life has indeed changed the occupational demand structure of the labor market. At the same time, the digital economy, through the application of new business models, provides opportunities for more low-skilled workers. These outcomes can coexist, and they are analyzed from different perspectives and in terms of their impact on different levels of the labor market. In any case, narrowing the digital capability gap could inject new vitality into the labor market, particularly by providing more employment opportunities for low-skilled or non-technical groups.

Overall, the gap in digital capabilities is increasingly evident in inequalities related to digital behavior, digital protection, digital negotiation, and digital remedies [56]. In terms of income, it is not sufficient to merely bridge the access and usage gaps when aiming to reduce household income disparities; the skills gap is a key factor. Studies have found that the skills gap is closely related to characteristics such as the education and cognitive abilities of family members, and its impact on income disparity is more complex and profound [57]. Furthermore, the impact of the digital capability gap on labor mobility may not be significant, primarily because illiterate or semi-literate groups lack basic digital skills. Even as society pushes for digital transformation, these groups are still unable to effectively leverage new technologies to change their employment status. For example, they may be unable to fully utilize online job search tools or web-based training resources, which limits their employment opportunities. Therefore, in the absence of widespread digital education and skills training, the direct impact of the digital capability gap on labor mobility may not be apparent.

However, when controlling for variables such as educational level, economic development, and regional differences, the impact of the digital capability gap becomes more pronounced. In contexts with a certain level of economic, educational, and social foundation, a lack of digital skills emerges as a significant factor influencing individual career choices and mobility. For example, in regions with generally high educational attainment and advanced economic conditions, digital capabilities are crucial for employment mobility. Individuals with digital skills can utilize technology to access more job opportunities, participate in a greater array of economic activities, and even transcend geographical limitations through remote work; however, those that lack digital skills are excluded from such opportunities. This indicates that, once economic and social conditions reach a certain threshold, the digital divide may exacerbate labor market inequalities. Therefore, enhancing digital capabilities is not only a matter of skill acquisition, but also a vital means of addressing social inequality and promoting labor mobility.

The enhancement of digital capabilities would increase access to a broader array of informational channels, driving labor mobility. Individuals with digital skills are more able to obtain information about new job openings, remote work opportunities, and avenues for skill enhancement. They can find suitable jobs through online platforms and partake in digital training to boost their competitiveness, thereby increasing their employment mobility and cross-regional movement. Conversely, those lacking digital capabilities find it challenging to access these opportunities, which limits their career choices, especially in regions with a highly developed digital economy. This disparity in information access further exacerbates the impact of the digital divide on labor mobility. Based on the above analysis, the following hypothesis is proposed.

Hypothesis 3. *After controlling for other relevant variables, digital capabilities can have a significant positive impact on labor mobility.*

3. Variables, Data Resources, and Models

3.1. Sample and Data

To investigate the impact of digital economic development on labor mobility from 2011 to 2021, this study focuses on thirty provinces and municipalities in China. Labor mobility, the dependent variable, is assessed using data from the "China Statistical Yearbook" and the "China Labor Statistical Yearbook", specifically focusing on registered and resident populations. Indicators related to the digital economy are sourced from the Ministry of Industry and Information Technology's "China Digital Economy Development Index Report" and the *China Information Industry Yearbook*, while the Digital Inclusive Finance Index is provided by the Peking University Digital Finance Center. The control variable data are primarily drawn from the *China Statistical Yearbook* and the *China Regional Economic Statistical Yearbook*. To address missing data, linear interpolation methods are applied.

3.2. Variables

3.2.1. Explanatory Variables

In this paper, the explanatory variables are the level of digital economic development and its corresponding indicators. The digital economy, through specific indicators such as digital infrastructure, digital industry development, and digital inclusive finance, demonstrates its extensive impact on the economic, industrial, and social fields. For example, as shown in Table 1, digital infrastructure, such as domain names, IPv4 addresses, and broadband access ports, constitutes the physical foundation for the development of the digital economy; meanwhile, the use of mobile phones and the coverage of fiber optic cables reflect its infiltration into people's social life. The more advanced the infrastructure, the greater the potential for digital economic development. In terms of the digital industry, the number of information technology enterprises, the number of websites, and the prevalence of e-commerce activities reflect the transformation of traditional industries by digital technologies. Additionally, the sale of e-commerce and the revenue obtained from software businesses attest to the contribution of digital technologies to economic growth. Digital inclusive finance, through its breadth of coverage, depth of usage, and degree of digitalization, illustrates the role of the digital economy in enhancing the accessibility of financial services, improving service efficiency, and promoting financial inclusion. The development of inclusive finance highlights the significant role of digital technologies in bridging the financial divide [58] and promoting social equity [59].

Table 1. The indicator system for evaluating the development of the digital economy.

Primary Indicators	Secondary Indicators	Tertiary Indicators	Indicator Attributes
The level of digital economy development	Digital infrastructure	Number of domain names (in ten thousand)	Positive
		Number of IPv4 addresses (in ten thousand)	Positive
		Number of internet broadband access ports (in ten thousand)	Positive
		Mobile phone penetration rate (units per hundred people)	Positive
		Optical cable length per unit area (kilometers per square kilometer)	Positive
	Development of the digital industry	Number of information technology enterprises (units)	Positive
		Number of websites per hundred enterprises (units)	Positive
		Proportion of enterprises engaged in e-commerce transactions (%)	Positive
		E-commerce sales (billion Yuan)	Positive
		Software business revenue (billion Yuan)	Positive
	Digital inclusive finance	Coverage breadth index	Positive
		Usage depth index	Positive
		Digitization level index	Positive

This study employed the entropy method and principal component analysis to conduct a comprehensive evaluation of the digital economy. These two methods reflect the overall performance of digital infrastructure, digital industry development, and digital inclusive finance from different perspectives.

The entropy method determines weights based on data dispersion, dynamically adjusting weights by measuring the variability of each indicator. This ensures that indicators with greater dispersion have more influence in the comprehensive evaluation. The specific steps are as follows.

The first step is data normalization. The standardized value of the *i*-th sample under the *j*-th indicator is calculated. The normalized values are used to eliminate dimensional differences between different indicators. For positive indicators,

$$\mathrm{yij} = \frac{xij - \min(xj)}{\max(xj) - \min(xj)} \quad (1)$$

The second step involves calculating the indicator weight, which involves determining the proportion of the standardized value of the indicator relative to the sum of the standardized values of the same indicator across all regions.

$$\mathrm{pij} = \frac{yij}{\sum_{i=1}^{n} yij} \quad (2)$$

The third step involves calculating the entropy value.

$$ej = -k\sum_{i=1}^{n} pij \ln(pij), k = \frac{1}{\ln(n)} \quad (3)$$

The fourth step involves calculating the coefficient of variation, which reflects the degree of dispersion of a particular indicator.

$$gj = 1 - ej \quad (4)$$

The fifth step involves calculating the weights.

$$wj = \frac{gj}{\sum_{j=1}^{m} gj} \quad (5)$$

For example, indicators that exhibit significant differences across regions or time periods, such as the number of domain names, IPv4 addresses, and broadband access ports, will be assigned higher weights using the entropy method, thereby highlighting their impact.

In the assessment of the digital economy, the principal component analysis (PCA) method can effectively integrate relevant indicators. PCA extracts principal components that explain the overall variability through linear combinations, reducing dimensions and simplifying the evaluation. The specific steps are as follows.

The first step involves denoting the original data matrix as X, wherein the size of X is $n \times m$ (where n represents the number of samples and m represents the number of indicators). Each row corresponds to a sample, and each column corresponds to an indicator (such as the "number of domain names" and "number of IPv4 addresses"). To eliminate the dimensional differences among the indicators, it is necessary to standardize the data first. The standardized data matrix is represented as Z.

$$Zij = \frac{xij - \mu j}{\sigma j} \quad (6)$$

where μj represents the mean of the j-th indicator, and σj represents the standard deviation of the j-th indicator.

The second step involves calculating the covariance matrix C of the standardized data, which is given by the following formula:

$$C = \frac{1}{n-1} Z^T Z \tag{7}$$

The covariance matrix C is a symmetric matrix of size $m \times m$, with each element Cij reflecting the correlation between the i-th and j-th indicators.

By performing eigenvalue decomposition on the covariance matrix C, we obtain the eigenvalues $\lambda 1, \lambda 2, \ldots, \lambda m$ and their corresponding eigenvectors $e1, e2, \ldots, em$. The eigenvalue λj reflects the amount of variance explained by the j-th principal component, while the eigenvector ej represents the direction of the j-th principal component. The j-th principal component PCj is expressed as a linear combination of the original standardized data matrix Z and the eigenvector ℓj.

$$PCj = Zej \tag{8}$$

Among them, the principal component PCj is a linear combination of the original variables. The proportion of variance explained by each principal component is

$$\text{The explained variance ratio} = \frac{\lambda j}{\sum_{i=1}^{m} \lambda i} \tag{9}$$

In this way, the PCA method can retain most of the variability in the data while simplifying the original complex multidimensional data by using only a few principal components. This method not only reduces redundant information but also makes the evaluation system clearer and more rational. By retaining the principal components that explain a significant proportion of the data's variance, we can better understand the main characteristics of various aspects of the digital economy during the evaluation process.

3.2.2. Explained Variable

The dependent variable in this paper is the level of labor mobility. According to existing research [13,60], the labor mobility index uses the resident and registered populations, which are denoted as Lf. The formula is expressed as (Resident Population − Registered Population)/Registered Population × 100%.

3.2.3. Control Variables

The control variables in this paper include per capita GDP, the proportion of tertiary industry, the average wage of employees, foreign direct investment (FDI), and the level of urbanization. Specifically, per capita GDP is an important indicator that measures the economic development level of a region, reflecting the economic productivity and living standards of its residents. A higher per capita GDP usually indicates a higher level of economic development, which may attract more labor inflows. The industrial structure reflects the mode of economic development and the distribution of employment opportunities in the region. Regions with a higher proportion of tertiary industry generally provide more service sector jobs, attracting highly skilled and white-collar labor. Wage levels directly affect labor mobility. High-wage regions typically attract more incoming labor, especially when the cost of living is relatively low. An increase in the average wage of employees can also improve their quality of life, further driving labor mobility. FDI represents the region's degree of openness. High levels of FDI often indicate more international cooperation and investment opportunities, promoting local economic development and creating more job opportunities, thereby attracting labor inflows. Regions with a high level of urbanization typically offer more employment opportunities, better infrastructure, and higher living standards. These factors are particularly attractive to laborers from rural areas, who may migrate to cities in search of better living and working conditions.

3.2.4. Mediator Variable

The mediating variable in this paper is the digital divide index, which comprises three sub-indices. Specifically, the digital access divide (eddi) is represented by the inverse of the length of long-distance optical cables per 10,000 people per square kilometer; the digital use divide (uddi) is represented by the inverse of the extent to which users have internet access; and the digital ability divide (addi) is represented by the proportion of illiterate and semi-literate individuals aged 15 and above. Higher values of these indices indicate a deeper digital divide in the corresponding provinces. The final digital divide index is calculated using the entropy method.

3.3. Data Resources

We first truncate all continuous variables at 1%. Considering data smoothness, we use the logarithm of GDP per capita and average employee wages. The descriptive statistics of the above variables are shown in Table 2.

Table 2. Descriptive statistics of the variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
Lf	330	0.041	0.199	−0.158	0.703
Dei	330	0.138	0.108	0.021	0.566
lnPGDP	330	10.831	0.451	9.682	12.142
FDI	330	0.02	0.018	0	0.121
Urban	330	0.596	0.121	0.35	0.896
Ins	330	1.342	0.732	0.527	5.244
lnWag	330	11.069	0.352	10.351	12.179

According to the descriptive statistics, the mean labor mobility rate (Lf) is 0.041, with a standard deviation of 0.199; this indicates a relatively low rate of labor mobility with significant regional differences, ranging from −0.158 to 0.703. This suggests that while some regions experience a net outflow of labor, others have a net inflow. The mean value of the digital economy index (Dei) is 0.138, with a standard deviation of 0.108; this suggests that most regions have a moderate level of digital economic development with little variation, ranging from 0.021 to 0.566. The logarithm of per capita GDP (lnPGDP) has a mean of 10.831 and a standard deviation of 0.451, illustrating a relatively balanced level of economic development, with values ranging from 9.682 to 12.142. The mean proportion of foreign direct investment (FDI) is 0.02, with a standard deviation of 0.018; this indicates a generally low level of foreign investment across regions with minimal differences, ranging from 0 to 0.121. The mean urbanization level (Urban) is 0.596, with a standard deviation of 0.121; this reflects a relatively high degree of urbanization with some regional differences, ranging from 0.35 to 0.896. The mean proportion of tertiary industry (Ins) is 1.342, with a standard deviation of 0.732; this indicates considerable variation in the development of the service sector among different regions. The logarithm of average employee wage (lnWag) shows a mean of 11.069 and a standard deviation of 0.352, suggesting relatively stable wage levels across regions.

3.4. Correlation Analysis

Table 3 presents the correlation test results for all variables. Based on the correlation analysis, the following main conclusions can be drawn:

1. There is a high positive correlation (0.620) between the labor mobility rate (Lf) and the digital economy index (Dei), indicating that higher levels of digital economic development are associated with higher labor mobility rates.
2. Lf is also strongly positively correlated with the logarithm of per capita GDP (lnPGDP) and the level of urbanization (Urban), with correlation coefficients of 0.686 and 0.820, respectively. This indicates that economic development and urbanization significantly promote labor mobility.

3. The average employee wage (lnWag) has a positive correlation of 0.518 with Lf, suggesting that wage levels have a considerable positive impact on labor mobility.
4. The proportion of tertiary industry (Ins) is positively correlated with Lf, with a correlation coefficient of 0.617; this indicates that the development of the service sector promotes labor mobility.
5. Foreign direct investment (FDI) has a relatively low but still significant correlation with Lf (0.376), suggesting that the degree of openness to foreign investment has a limited effect on labor mobility.

Table 3. Correlation test results.

	Lf	**Dei**	**lnPGDP**	**lnWag**	**Ins**	**Urban**	**FDI**
Lf	1						
Dei	0.620 ***	1					
lnPGDP	0.686 ***	0.800 ***	1				
FDI	0.518 ***	0.685 ***	0.835 ***	1			
Urban	0.617 ***	0.480 ***	0.492 ***	0.600 ***	1		
Ins	0.820 ***	0.671 ***	0.883 ***	0.710 ***	0.542 ***	1	
lnWag	0.376 ***	0.127 **	0.244 ***	−0.0120	0.105 *	0.415 ***	1

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

These results indicate that economic development levels, wage levels, urbanization, and the development of tertiary industry all have significant positive impacts on labor mobility, while the influence of FDI is comparatively weaker.

3.5. Panel Independence Test

Given the characteristics of panel data, cross-sectional dependence might occur among individuals due to certain common factors. In such cases, traditional panel unit root tests (such as the Levin–Lin–Chu test and Augmented Dickey–Fuller test) may become invalid, potentially leading to spurious regression results. Therefore, it is necessary to perform a cross-sectional dependence test before conducting unit root tests on the variables to check for independence issues in the panel data. This can help to ensure the accuracy and validity of subsequent analyses. Table 4 presents the results of the panel independence test.

Table 4. Correlation test results.

Variable	**National Sample**	**Eastern Region**	**Central Region**	**Western Region**
Lf	86.61 ***	30.8 ***	22.04 ***	30.76 ***
Dei	87.21 ***	31.01 ***	22.15 ***	31.72 ***
lnPGDP	79.92 ***	27.06 ***	22.07 ***	28.62 ***
FDI	79.61 ***	29.24 ***	19.35 ***	29.04 ***
Urban	88.12 ***	31.31 ***	22.35 ***	31.37 ***
Ins	62.26 ***	24.54 ***	15.28 ***	19.87 ***
lnWag	59.26 ***	27.68 ***	17.63 ***	19.69 ***

Note: *** indicates significance at the 1% level. The null hypothesis of the CD test is "Panel independence exists".

As shown in Table 4, all variables passed the CD test at the 1% significance level, disproving the null hypothesis that "panel independence exists". This indicates that the panel data used in this study exhibit cross-sectional dependence. Therefore, in subsequent unit root tests, nontraditional methods must be adopted to accurately reflect the characteristics of the data.

3.6. Panel Unit Root Test

Before estimating the variables in the econometric model, it is usually necessary to conduct a stationarity test to avoid "spurious regression". When testing the independence of panel data, the results showed that the null hypothesis of "panel independence" was rejected at the 1% significance level, which was indicative of cross-sectional dependence. Therefore, traditional stationarity test methods (such as LLC, ADF, KPSS, etc.) were no longer applicable. Consequently, this paper adopts the CADF test to address the challenges posed by cross-sectional dependence [61]. The test results are shown in Table 5.

Table 5. Results of the panel unit root test.

Variable	National Sample	Eastern Region	Central Region	Western Region
Lf	−4.267 ***	−4.490 ***	−3.745 ***	−4.158 ***
Dei	−3.239 ***	−3.818 ***	−3.097 ***	−3.508 ***
lnPGDP	−2.647 ***	−3.254 ***	−3.617 ***	−2.867 ***
FDI	−3.232 ***	−3.443 ***	−2.898 ***	−3.336 ***
Urban	−2.703 ***	−2.721 ***	−3.541 ***	−2.894 ***
Ins	−3.159 ***	−2.766 ***	−3.717 ***	−3.243 ***
lnWag	−4.156 ***	−2.613 ***	−3.245 ***	−2.689 ***

Note: *** indicates significance at the 1% level.

According to the CADF unit root test results, all variable sequences were stationary at the 1% significance level. Therefore, these variables could be used for estimation in the panel regression model, facilitating its validity and accuracy.

3.7. Model Selection and Specification

To select the most appropriate panel regression model, this study conducted an F-test, LM test, and Hausman test to determine whether a fixed-effects model, random-effects model, or mixed-effects model should be used. As shown in Table 6, the test results are as follows:

Table 6. Test results for panel regression model selection.

Test Methods	Statistic	Model Selection
F-test	92.30 ***	Fixed Model
LM test	957.99 ***	Not using Mixed Regression Model
Hausman test	68.26 ***	Fixed Model

Note: *** $p < 0.01$.

Ultimately, we chose a two-way fixed effects model for the panel regression analysis.

To demonstrate the impact of the digital economy on labor mobility, we established a baseline regression model as follows:

$$Lfit = \alpha 0 + \alpha 1Dei + \delta Xit + \gamma i + \theta t + \varepsilon it \quad (10)$$

where Lf is the dependent variable, Dei is the independent variable, and X represents the control variables. The remaining terms are the error term and fixed effects. We employed dual fixed effects for year and province and included robust standard errors.

4. Results and Discussion

4.1. Baseline Regression

Based on the analysis of the baseline regression results, we observed that the variables had an impact on labor mobility (Lf) across different models. As shown in Table 7, the results are as follows:

(1) Model (1) includes only the digital economy indicator (*Dei*) and shows Dei has a significant positive impact on labor mobility (1.140 ***), with a relatively large coefficient. This indicates that the development of the digital economy significantly promotes labor mobility. This model does not control for year and province fixed effects.

(2) Model (2) adds year and province fixed effects while retaining only the digital economy indicator. At this point, the impact of *Dei* becomes insignificant (0.071); this indicates that, when time and regional differences are considered, the direct impact of the digital economy on labor mobility weakens, suggesting the possible presence of other unconsidered factors.

(3) Model (3) introduces multiple control variables (such as lnPGDP, FDI, Urban, Ins, and lnWag) without including fixed effects. At this point, Dei still exerts a significant positive impact on labor mobility (0.399 ***); this indicates that even when controlling for the economic development level, FDI, urbanization, industrial structure, and wage level, the impact of the digital economy remains significant. Additionally, the urbanization level (Urban) and the proportion of tertiary industry (Ins) have significant positive effects on labor mobility; meanwhile, the wage level (lnWag) has a significant negative impact, possibly because higher wages reduce the willingness of labor to move.

(3) Model (4) simultaneously controls the fixed effects for year and province and includes multiple control variables. In this case, the coefficient for Dei is 0.208 ***, remaining significant; this indicates that the digital economy continues to promote labor mobility. FDI shows a significant positive impact in this model (0.430 **); meanwhile, the impact of the urbanization level (Urban), although somewhat weakened, remains significant (0.549 ***). Other variables, such as the economic development level (lnPGDP), proportion of tertiary industry (Ins), and wage level (lnWag), become insignificant in this model.

Table 7. Baseline regression.

	(1)	**(2)**	**(3)**	**(4)**
	Lf	Lf	Lf	Lf
Dei	1.140 ***	0.071	0.399 ***	0.208 ***
	(14.31)	(1.24)	(4.67)	(3.34)
lnPGDP			−0.044	−0.027
			(−1.11)	(−0.85)
FDI			−0.049	0.430 **
			(−0.13)	(2.29)
Urban			1.345 ***	0.549 ***
			(12.10)	(4.11)
Ins			0.083 ***	0.006
			(8.29)	(0.41)
lnWag			−0.177 ***	0.018
			(−5.26)	(0.44)
_Cons	−0.117 ***	0.031 ***	1.508 ***	−0.241
	(−8.36)	(3.91)	(4.66)	(−0.51)
Year	NO	YES	NO	YES
Province	NO	YES	NO	YES
N	330	330	330	330
R^2	0.382	0.986	0.760	0.988
F	204.787	1.547	174.478	4.182

Note: *t* statistics in brackets ** $p < 0.05$, *** $p < 0.01$.

From the perspective of the control variables and fixed effects analysis, the model without fixed effects for province and year (Model (1)) shows that the digital economy has a significant impact on labor mobility. However, the model incorporating fixed effects (Model (2)) indicates a reduction in the significance of the impact of the digital economy, suggesting that time and regional differences play a crucial role in labor mobility. In the model controlling for multiple economic and social factors (Model (3)), the role of the digital economy remains significant. Furthermore, in the model that additionally controls for fixed effects (Model (4)), the positive impact of the digital economy persists; in addition, foreign direct investment (FDI) and urbanization become significant factors. This demonstrates that the digital economy significantly promotes labor mobility, especially when time and regional differences are considered.

4.2. Robustness Check

In the robustness check, the sample obtained from the four municipalities directly under central government was first excluded to ensure that the results were not influenced by these special administrative regions. Second, the lagged one-period digital economy variables were used to verify the lagged effect of the digital economy on labor mobility. Next, the digital economy indicators were calculated using the principal component analysis method. Finally, following methodologies used in the existing literature [62,63], the interaction term of the 1984 postal and telecommunication historical data with the previous year's national information technology service revenue was employed as an instrumental variable to effectively control for the endogeneity of the digital economy. As shown in Table 8, the results of different models demonstrate that the positive impact of the digital economy on labor mobility remained significant, thereby proving its robustness.

Table 8. Robustness check.

	(1)	**(2)**	**(3)**	**(4)**
	Lf	Lf	Lf	Lf
L.Dei		0.177 ***		
Dei2			0.052 ***	
			(4.45)	
Dei	0.183 ***			1.941 ***
	(2.98)			(4.06)
lnPGDP	−0.007	−0.026	−0.087 ***	−0.413 ***
	(−0.21)	(−0.73)	(−3.59)	(−3.33)
FDI	−0.079	0.515 **	−0.275	0.398
	(−0.75)	(2.53)	(−1.27)	(0.74)
Urban	0.268	0.637 ***	0.858 ***	1.631 ***
	(1.63)	(4.62)	(11.79)	(9.18)
Ins	−0.000	0.000	0.012 *	0.044 **
	(−0.02)	(0.01)	(1.80)	(2.45)
lnWag	−0.007	0.026	0.492 ***	−0.128 ***
	(−0.22)	(0.60)	(12.06)	(−2.60)
_Cons	−0.026	−0.383	−4.982 ***	4.621 ***
	(−0.06)	(−0.70)	(−11.56)	(4.45)
N	286	300	330	330
R^2	0.967	0.990	0.889	0.518
F	2.046	5.315	363.142	87.884

Note: *t* statistics in brackets * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

To verify the robustness of the bidirectional fixed-effects model and reduce the dependency of panel data, we employed the DCCE (Dynamic Common Correlated Effects) estimator and Driscoll–Kraay standard errors for robustness checks. The DCCE estimator is an extension of the traditional CCEMG estimator, which is capable of capturing dynamic features and cross-sectional dependency in panel data. It effectively addresses the impact of unobserved common factors by incorporating cross-sectional averages of both independent and dependent variables and allowing for lagged relationships. Driscoll–Kraay standard errors, on the other hand, provide robust corrections for cross-sectional dependence, autocorrelation, and heteroskedasticity by adjusting for cross-sectional units. Additional robustness tests are presented in Table 9.

Table 9. Robustness test: additional tables.

	(1)	**(2)**	**(3)**
	Lf	Lf	Lf
Dei	0.208 ***	0.656 *	0.208 ***
	(3.34)	(1.74)	(5.53)
lnPGDP	−0.027	−0.069	−0.027
	(−0.85)	(−0.64)	(−1.60)
Fdi	0.430 **	0.220 *	0.430 **
	(2.29)	(1.76)	(2.68)
Ubran	0.549 ***	0.497	0.549 ***
	(4.11)	(1.32)	(3.66)
Ins	0.006	−0.020	0.006
	(0.41)	(−0.71)	(0.88)
lnWag	0.018	−0.057	0.018
	(0.44)	(−0.43)	(0.48)
Cons	−0.241	0.014	−0.197
	(−0.51)	(0.01)	(−0.55)
N	330	330	330
R^2	0.988	0.2042	0.2092

Note: *t* statistics in brackets * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The results indicate that the variables Dei and Fdi remain significant across different models, particularly after Driscoll–Kraay correction, where their standard errors decrease and the significance increases. This suggests that, after correcting for cross-sectional dependence and heteroskedasticity, the results are more robust. When using the DCCE estimator, the coefficients change compared to the baseline model and the significance decreases slightly; this indicates that the results are more conservative when addressing dynamic features and cross-sectional dependence. Overall, both the DCCE estimator and Driscoll–Kraay standard errors show that the significance and direction of the core variables are generally consistent under different estimation methods, thereby enhancing the robustness and reliability of the study results.

4.3. Mechanism Test

We used the digital divide as a mediating variable and conducted the test using a three-step method, as shown in Table 10.

Table 10. Mechanism test.

	(1)	**(2)**	**(3)**
	Lf	ddi	Lf
Dei	0.208 ***	0.086 ***	0.254 ***
	(3.34)	(5.36)	(3.93)
ddi			−0.529 ***
			(−3.07)
_Cons	−0.241	0.608 ***	0.081
	(−0.51)	(4.97)	(0.18)
lnPGDP	−0.027	−0.018 **	−0.037
	(−0.85)	(−2.30)	(−1.20)
FDI	0.430 **	0.018	0.439 **
	(2.29)	(0.67)	(2.35)
Urban	0.549 ***	−0.013	0.543 ***
	(4.11)	(−0.38)	(4.12)
Ins	0.006	0.005	0.008
	(0.41)	(1.28)	(0.63)
lnWag	0.018	−0.034 ***	0.000
	(0.44)	(−2.72)	(0.01)

Table 10. *Cont.*

	(1)	(2)	(3)
N	330	330	330
R^2	0.988	0.936	0.988
F	4.182	14.507	4.923

Note: *t* statistics in brackets ** $p < 0.05$, *** $p < 0.01$.

(1) Model (1): The direct impact of the digital economy on labor mobility.

In the regression results shown in the first column, the influence of the digital economy (Dei) on labor mobility (Lf) is significant and positive, with a coefficient of 0.208 ***. This indicates that the development of the digital economy significantly promotes labor mobility. The digital economy can create more economic opportunities, enhance productivity, and increase employment, thereby attracting labor from other regions. This result suggests that the digitization process provides an impetus for labor mobility across regions. Additionally, foreign direct investment (FDI) and the level of urbanization (Urban) have significant positive impacts on labor mobility, with coefficients of 0.430 and 0.549 *, respectively. This demonstrates that the promotion of openness and urbanization plays an important role in facilitating labor mobility. However, the per capita GDP (lnPGDP), proportion of tertiary industry (Ins), and wage level of employees (lnWag) do not exhibit significance in this model, potentially implying that the influence of these variables on labor mobility is more indirect or mediated by other factors.

(2) Model (2): The impact of the digital economy on the digital divide.

In the regression results of the second column, the influence of the digital economy (Dei) on the digital divide (ddi) is significantly positive, with a coefficient of 0.086 ***. This indicates that while the development of the digital economy promotes economic growth, it may also exacerbate the digital divide between regions. The digital divide reflects the disparities among different regions or groups with regard to accessing and utilizing digital technologies. The rapid development of the digital economy might cause certain regions or groups to fall behind, thereby widening this gap. Furthermore, the per capita GDP (lnPGDP, with a coefficient of −0.018 **) and wage levels (lnWag, with a coefficient of −0.034 ***) have significant negative impacts on the digital divide. This implies that with improvements in economic development and wage levels, the digital divide is likely to narrow. These findings suggest that promoting economic growth and increasing the income of residents would reduce the digital divide.

(3) Model (3): The mediating role of the digital divide.

In the third column, the mediating variable, the digital divide (ddi), is included. The results show that the direct effect of the digital economy (Dei) on labor mobility remains significant and even strengthens (0.254 ***); meanwhile, the digital divide has a significant negative impact on labor mobility (−0.529 ***). This indicates that although the digital economy generally promotes labor mobility, the existence of the digital divide weakens this effect. Specifically, the digital divide acts as a negative moderating mechanism in the context of labor mobility. While the development of the digital economy creates opportunities for certain regions or groups, the digital divide hinders other groups or regions from fully leveraging these opportunities. Particularly in terms of access to digital technologies and information resources, the digital divide makes it difficult for some segments of the labor force to benefit from the advantages conferred by the digital economy, thereby reducing their mobility.

A further analysis of the digital divide could be conducted from the perspective of three domains: the digital access divide, the digital use divide, and the digital skills divide, as shown in Table 11.

Table 11. The impact of the different dimensions of the digital divide on labor mobility.

	(1)	(2)	(3)	(4)	(5)	(6)
	eddi2	Lf_w	uddi	Lf_w	addi2	Lf_w
Dei_w	0.703 ***	0.213 ***	0.025 ***	0.258 ***	0.166	0.207 ***
	(2.61)	(3.40)	(5.69)	(4.15)	(0.57)	(3.30)
eddi2		−0.007				
		(−0.71)				
uddi				−2.008 **		
				(−2.15)		
addi2						0.010
						(0.80)
lnPGDP	−0.175	−0.028	−0.000	−0.027	−0.287 *	−0.024
	(−1.09)	(−0.90)	(−0.04)	(−0.88)	(−1.94)	(−0.77)
FDI	1.838 *	0.443 **	−0.005	0.420 **	2.000 ***	0.410 **
	(1.85)	(2.40)	(−0.76)	(2.19)	(2.68)	(2.13)
Urban	−0.059	0.549 ***	0.009	0.566 ***	0.244	0.547 ***
	(−0.07)	(4.07)	(1.18)	(4.27)	(0.35)	(4.10)
Ins	−0.042	0.005	0.001	0.008	0.029	0.005
	(−0.67)	(0.39)	(1.29)	(0.62)	(0.44)	(0.39)
lnWag	−0.460 *	0.015	−0.008 ***	0.002	0.248	0.016
	(−1.74)	(0.36)	(−2.87)	(0.05)	(1.29)	(0.38)
_Cons	8.780 ***	−0.177	0.083 **	−0.074	−1.032	−0.230
	(2.99)	(−0.38)	(2.48)	(−0.17)	(−0.47)	(−0.49)
N	330	330	330	330	330	330
R^2	0.986	0.988	0.802	0.988	0.991	0.988
F	2.858	3.948	7.627	5.474	2.620	4.068

Note: *t* statistics in brackets * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

(1) Models (1) and (2): The impact of the digital access divide (eddi2).

In Model (1), the regression results indicate that the digital access divide has a significant positive effect on the digital economy (Dei_w), with a coefficient of 0.703 ***. This suggests that improving optical fiber infrastructure, thereby reducing the digital access divide, would significantly promote the development of the digital economy. Furthermore, in Model (2), the development of the digital economy has a significant positive impact on labor mobility, with a Dei_w coefficient of 0.213 ***. This indicates that improvements in infrastructure facilitate labor mobility.

(2) Models (3) and (4): The impact of the digital use divide (uddi).

In Model (3), the regression results for the digital use divide show a significant negative effect on labor mobility, with a coefficient of 0.025 ***. This indicates that while an increase in the number of internet access users promotes labor mobility, the effect is relatively limited. In Model (4), after including other control variables, the negative impact of the digital use divide becomes more pronounced, with an uddi coefficient of −2.008 **, significantly inhibiting labor mobility.

(3) Models (5) and (6): The impact of the digital ability divide (addi2).

In Model (5), the impact of the digital ability divide (addi2) on labor mobility is not significant, which may indicate that the direct influence of illiterate or semi-literate groups on labor mobility is relatively weak. However, in Model (6), after considering other variables, the coefficient of addi2 becomes 0.207 ***; this demonstrates that the digital ability divide has a significant positive effect on labor mobility.

The analysis indicates that different dimensions of the digital divide have significant varying impacts on labor mobility. Narrowing the digital access divide (e.g., improvements in optical fiber infrastructure) significantly promotes labor mobility, suggesting that comprehensive infrastructure is critical. The impact of the digital use divide is more complex; internet access can enhance mobility, but if this access is unevenly distributed, it can hinder mobility. Therefore, it is necessary to enhance the digital skills and usage capabilities of the workforce. The digital ability divide (the proportion of illiterate or semi-literate groups) significantly affects labor mobility, indicating that improving education and digital skills within the workforce could enhance mobility. Control variables such as foreign direct investment and urbanization also have significant positive effects on labor mobility. Overall, it is essential to narrow the gaps in digital access, usage, and ability in order to promote labor mobility.

4.4. Heterogeneity Analysis

The results of the heterogeneity analysis show that the impact of the digital economy (Dei_w) on labor mobility (Lf_w) significantly varies across different regions in China (eastern, central, western, and northeastern). As shown in Table 12, these regional disparities reflect differences in economic development, infrastructure construction, and policy support in each area, thereby leading to the digital economy having varying impacts on labor mobility.

Table 12. Heterogeneity analysis.

	Eastern China	**Central China**	**Western China**	**Northeastern China**
	Lf_w	Lf_w	Lf_w	Lf_w
Dei_w	−0.039	0.660 ***	0.302	0.245
	(−0.37)	(4.51)	(1.54)	(0.36)
lnPGDP	0.077	−0.055 *	−0.190 ***	−0.328 *
	(1.11)	(−1.92)	(−3.74)	(−1.78)
FDI	1.023 ***	0.239	−0.533	−0.167
	(5.53)	(0.82)	(−1.38)	(−1.61)
Urban	0.272	−0.634 **	0.692 ***	−1.229 **
	(1.08)	(−2.05)	(2.64)	(−2.21)
Ins	0.003	−0.023	−0.035	−0.042 **
	(0.14)	(−1.25)	(−1.24)	(−2.29)
lnWag	0.447 ***	0.018	−0.094 *	−0.019
	(3.32)	(0.43)	(−1.74)	(−0.19)
_Cons	−5.878 ***	0.595	2.663 ***	4.476 **
	(−4.07)	(1.32)	(4.93)	(2.55)
N	110	66	121	33
R^2	0.992	0.979	0.935	0.967
F	14.343	5.670	9.375	12.792

Note: t statistics in brackets * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

(1) Labor Mobility in the Eastern Region

In the eastern region, the impact of the digital economy on labor mobility is not significant, with a coefficient of −0.039, which does not reach statistical significance. This phenomenon may be closely related to the maturity of the economic foundation and the complex factors associated with the labor market in the eastern region. The eastern region is economically developed, and the attraction of traditional industries and foreign-funded enterprises to laborers is already very strong, resulting in the digital economy having a relatively small marginal effect. Labor mobility in this region is more driven by other factors. According to the regression analysis results, the coefficient of foreign direct investment (FDI) is 1.023 ***, indicating that FDI significantly promotes labor mobility in the eastern region. Foreign-funded enterprises provide a large number of high-paying job opportunities in this region, making the east an important area of labor inflow nationwide. At the same time, the positive impact of wage levels (lnWag) is also significant, suggesting that the high wage levels in the eastern region is the main factor attracting labor. Therefore, although the digital economy is rapidly developing in the eastern region, its independent impact on the labor market is not as direct and significant as that of foreign investment and wage levels. This indicates that labor mobility in the eastern region has entered a relatively stable and mature state, where the incremental effect of the digital economy is comparatively weak.

(2) Driving Role of the Digital Economy in the Central Region.

In the central region, the digital economy significantly promotes labor mobility. According to the regression results, the coefficient for the impact of the digital economy (Dei_w) is 0.660 ***; this indicates that the digital economy has the most pronounced effect on labor mobility in this region. This may be because the central region is at a crucial stage of digital transformation, with the rise of the digital economy providing more employment opportunities and attracting an increased inflow of labor. Compared to the eastern region, the digital economy's promotion of labor mobility is particularly significant in the central region. On the one hand, the development of the digital economy has brought numerous new opportunities to the labor market in this region, significantly altering the patterns of labor mobility. The traditional industrial structure of the central region is gradually transitioning toward digitalization, with the digital economy injecting new momentum into the manufacturing and service sectors and thus enhancing labor mobility. On the other hand, policy support in the central region also plays a crucial role. In recent years, the government has vigorously promoted the construction of digital infrastructure and the development of digital industries, amplifying the positive effects of the digital economy on labor mobility. However, the level of urbanization (Urban) has a negative impact on labor mobility, with a coefficient of −0.634 **. This may show that the process of urbanization in the central region has not yet fully translated into an enhancement in labor mobility. In some areas, the progress of urbanization has been too rapid, failing to simultaneously create enough employment opportunities to attract labor. Therefore, although the level of urbanization has risen, its contribution to labor mobility remains unclear and is not yet fully aligned with the demand for labor. Overall, the digital economy has presented a strong driving force in the central region during its digital transformation phase. However, the negative impact of the urbanization process indicates that there is a need for improved coordination between urbanization and employment opportunities; this is in order to further optimize labor mobility.

(3) Impact of Urbanization in the Western Region.

Although the impact of the digital economy on labor mobility is positive in the western regions (with a coefficient of 0.302), it is not statistically significant. This indicates that despite the development of the digital economy in western China, its effect on labor mobility remains relatively weak. This is mainly attributed to the weak digital infrastructure and lower economic levels in these regions. Due to the lag in the development of network coverage and communication facilities, labor cannot fully utilize digital tools and platforms in these areas, limiting the effect of the digital economy on labor mobility. Moreover, the economic structure in the western regions is predominantly based on traditional resource-based industries, which have a relatively low demand for labor mobility and are less dependent on the digital economy. In contrast, the level of urbanization (Urban) has a significant positive impact on labor mobility, with a coefficient of 0.692 ***; this indicates that urbanization in the western regions plays an important role in promoting labor mobility. The rapid urbanization of these areas provides a large number of employment opportunities for the local rural population, promoting the migration of workforce from rural to urban areas and enhancing labor mobility. In this region, the employment opportunities and improved living conditions engendered by urbanization serve as the main driving forces for labor mobility, clearly surpassing the effects of the digital economy. Although the digital economy has some positive impact in the western regions, its effect on labor mobility is not yet significant; this is due to the limited infrastructure and economic levels of these regions. In contrast, the rapid advancement of urbanization stands out as particularly important in the western regions, serving as the main force driving local labor mobility. Therefore, in the future, the western regions should continue to strengthen the construction of digital infrastructure while promoting urbanization in order to comprehensively enhance labor mobility.

(4) Transformation Challenges in the Northeastern Region.

In the northeastern region, the coefficient of the impact of the digital economy on labor mobility is 0.245, but this is not statistically significant. This is related to the region's long-standing reliance on traditional heavy industries and state-owned enterprises, which have undergone slower transformation. Consequently, the development of the digital economy has lagged, leading to a weaker direct impact on labor mobility. The northeastern region continues to face a severe population outflow, with many young workers migrating to more economically developed areas. This has led to a shrinking local labor market, further diminishing the digital economy's ability to drive labor mobility. Moreover, wage levels (lnWag) do not have a significant impact on labor mobility in the northeastern region. More notably, the proportion of tertiary industry (Ins) has a significant negative impact on labor mobility, with a coefficient of −0.042 **. This indicates that the development of the service sector in the northeastern region is relatively slow, failing to provide sufficient employment opportunities and weakening its attractiveness to incoming labor. Accordingly, labor mobility in the northeastern region is constrained by multiple factors. The dominance of traditional industries, the lagging development of the digital economy, and the issue of population outflow contribute to the digital economy's inability to significantly promote labor mobility. Additionally, the slow growth of the service sector negatively impacts labor mobility. To improve this situation, the northeastern region needs to accelerate economic structural transformation, particularly by promoting the development of the digital economy and the service sector; this is in order to enhance the attractiveness of labor and maintain the vitality of the labor market.

In summary, the heterogeneous impacts of the digital economy on labor mobility across regions reflect the varying stages of digitalization in different areas. In the eastern region, the economy and labor market have matured, with labor mobility being more dependent on foreign investment and high wage levels. The central region's digital economy is rapidly developing, becoming the main driver of labor mobility. In the western region, due to insufficient infrastructure and the constraints of traditional industries, the role of the digital economy is relatively limited. Similarly, in the northeastern region, due to outdated industrial structures and population outflow, the digital economy's impact on labor mobility is not significant.

4.5. Provincial Heterogeneity Analysis

Furthermore, for the dependent variable of net population inflow rate, we considered its positivity and negativity and conducted a heterogeneity analysis according to province. As shown in Table 13, this method can more accurately reveal the specific characteristics and differences in labor and population mobility among provinces, thereby providing a basis for formulating targeted regional policies.

Table 13. Conducting a heterogeneity analysis based on provincial divisions.

	Positive Inflow Rate	**Negative Inflow Rate**
	Lf	Lf
Dei	0.023	0.741 ***
	(0.27)	(9.33)
lnPGDP	−0.250 ***	0.007
	(−4.10)	(0.37)
FDI	1.085 ***	−0.419 **
	(5.27)	(−2.15)
Urban	0.939 ***	0.237 **
	(3.45)	(2.28)
Ins	0.028	−0.031 ***
	(1.66)	(−3.39)

Table 13. *Cont.*

	Positive Inflow Rate	Negative Inflow Rate
lnWag	0.179	0.027
	(1.47)	(0.83)
_Cons	0.249	−0.604
	(0.17)	(−1.65)
N	143	186
R2_a	0.990	0.964
F	10.128	26.386

Note: *t* statistics in brackets ** $p < 0.05$, *** $p < 0.01$.

The heterogeneous impacts of the digital economy on labor mobility across regions reflect the varying stages of digitalization in different areas.

(1) Current Status and Impact of Regional Digital Economy Development.

In the eastern region, the economy and labor market have matured, with labor mobility becoming increasingly dependent on foreign investment and high wage levels. The digital economy in the central region is developing rapidly, thus significantly promoting labor mobility. In the western region, due to inadequate infrastructure and the constraints of traditional industries, the role of the digital economy is relatively limited. Similarly, in the northeastern region, outdated industrial structures and population outflow result in the digital economy having an insignificant impact on labor mobility.

(2) Differential Impact of Digital Economy Development Index.

Further analysis revealed that the impact of the digital economy index (Dei) exhibits significant differences between provinces with positive and negative inflow rates. In provinces with positive inflow rates, the development of the digital economy shows no significant effect on labor mobility, possibly due to the maturity of the digital economy in these areas; this leads to diminished marginal effects. However, in provinces with negative inflow rates, the positive impact of digital economy development on labor mobility is highly significant. This indicates that, in these relatively less developed regions, the digital economy provides new employment opportunities and stimulates economic growth, thereby alleviating some of the labor outflows. For instance, in western provinces such as Chongqing and Shaanxi, although the overall economic development is relatively low, improvements in information infrastructure and the spread of e-commerce have begun to attract investments in digital industries, creating more job opportunities.

(3) Relationship Between Per Capita GDP and Labor Mobility.

The effect of per capita GDP (lnPGDP) also differs between provinces with positive and negative inflow rates. In provinces with positive inflow rates, the per capita GDP has a significant negative impact on labor mobility. This suggests that despite the higher economic levels in these regions, high living costs and competitive job markets may inhibit further labor inflows. This phenomenon is particularly evident in developed cities with high housing prices and high consumption rates. In contrast, in provinces with negative inflow rates, the impact of per capita GDP is not significant. This indicates that the level of economic development in these regions does not yet have an influence on labor mobility, which is more driven by factors such as insufficient employment opportunities.

(4) Comparative Impact of Foreign Direct Investment (FDI).

Foreign direct investment (FDI) also has varying effects on labor mobility in provinces with positive and negative inflow rates. In provinces with positive inflow rates, FDI has a significant positive impact on labor mobility, indicating that inflows of foreign capital can create more job opportunities and offer higher wages, thus attracting laborers. However, in provinces with negative inflow rates, FDI has a significant negative effect on labor mobility. This may be due to foreign investments predominantly flowing into capital-intensive industries, which have not effectively created sufficient employment opportunities.

(5) Impact of Urbanization Level on Labor Mobility.

The level of urbanization (Urban) has a positive impact on labor mobility in both models, but its effect is significantly stronger in provinces with positive inflow rates. In developed provinces, urbanization leads to improved infrastructure, convenient transportation, and high-quality public services, which enhance the appeal of the province to incoming labor. For example, Shenzhen, as a model city of urbanization, has attracted a large workforce through rapid urban expansion and industrial agglomeration. In contrast, in provinces with negative inflow rates, such as Sichuan and Guizhou, although urbanization also positively affects labor mobility, its impact is weaker. Urbanization in these regions may still be in its early stages, with insufficient infrastructure and public services.

(6) Impact Differences in the Tertiary Industry Proportion.

The proportion of tertiary sector (Ins) also shows distinct impacts on provinces with positive and negative inflow rates. In provinces with positive inflow rates, the influence of the tertiary sector on labor mobility is insignificant, indicating that the tertiary sector in these areas is relatively mature and that labor mobility is driven more by other factors. In contrast, in provinces with negative inflow rates, the proportion of tertiary sector has a significant negative effect on labor mobility. This may be because the tertiary sector in these provinces is of a relatively low quality and cannot provide sufficient opportunities for development or careers. For example, the tertiary sectors in provinces such as Jilin, Sichuan, and Anhui are predominantly labor-intensive and offer low-value-added services, making it difficult to attract and retain high-skilled labor.

Thus, the impact of the digital economy, per capita GDP, FDI, urbanization, and the development of the tertiary sector on labor mobility differs across different provinces. A detailed analysis of these factors could provide valuable reference points for formulating more targeted policies in various regions, thereby promoting rational labor mobility and coordinated regional economic development.

5. Conclusions and Recommendations

5.1. Conclusions

This paper examines the impact of the digital economy on labor mobility by analyzing relevant data from multiple perspectives. Firstly, we expand upon existing research by exploring the different roles of the “digital access divide” and “digital usage divide” in promoting labor mobility. We find that narrowing the “digital access divide”, especially through the widespread adoption of fiber optic networks, enables underdeveloped regions to participate in the digital economy, stimulates economic vitality in these areas, and promotes significant cross-regional labor mobility. Meanwhile, the “digital usage divide” indicates that, even when access is available, people’s ability to use digital technologies effectively differs across regions, significantly impacting labor markets and the regional economy.

Secondly, this paper systematically integrates multiple elements such as digital infrastructure, digital industry development, and digital inclusive finance to analyze how these factors drive labor mobility through different mechanisms. Through empirical research on various regions of China, we reveal the significant role of the digital economy in promoting labor mobility in underdeveloped regions such as the central and western areas, especially among low-skilled labor groups. Although the digital economy provides these groups with new opportunities and flexible working methods, there are some negative effects that require attention during policymaking.

Moreover, by distinguishing between areas of labor inflow and outflow, this paper reveals the varying impacts of the digital economy on different directions of labor movement. This finding provides new insights and empirical evidence for the formulation of policies that aim to achieve balanced regional development. Notably, even after controlling for variables such as the economic development level, urbanization level, industrial structure, and wage levels, the positive impact of the digital economy on labor mobility remains significant, indicating its direct and indirect role in improving regional economic conditions.

Finally, the robustness tests provide further confirmation of the wide applicability of the digital economy in promoting labor mobility. Overall, the digital economy does not only promote labor mobility, but also plays a crucial role in bridging the digital divide, promoting balanced regional development, and enhancing socioeconomic vitality. Through an in-depth analysis of its theoretical construction and practical application, this paper enriches research on the interaction between the digital economy and the labor market, providing new perspectives for future policy and research.

5.2. Recommendations

Based on the research and analysis of the digital economy and labor mobility presented in this paper, the following policy recommendations are proposed. First, the construction of digital infrastructure in less developed regions should be accelerated. The government should increase investment in digital infrastructure, such as fiber optic networks and broadband access, in these areas to bridge the regional "digital access divide". Improving these infrastructures will encourage residents to participate in the digital economy, create more employment opportunities, and boost economic vitality. Second, digital skills training should be enhanced and education should be made more widespread. Special policies should be formulated to promote nationwide digital skills training, particularly aimed at rural and less developed populations, to help them become more competitive in the context of the digital economy and to enhance labor mobility. The government should also encourage businesses to provide online skills training to enable the workforce to adapt to emerging digital professions. Third, the development of digital inclusive finance should be supported. Digital inclusive finance plays a crucial role in narrowing the financial gap. Policymakers should further promote the widespread coverage of digital financial services, especially in rural and less developed areas; this would enable more people to benefit from financial services and increase entrepreneurship and employment opportunities, thereby enhancing the vitality of the regional economy and promoting labor mobility. Lastly, the household registration system and employment information platforms should be optimized. The government could further reform the household registration system to reduce institutional barriers and facilitate cross-regional labor migration. Additionally, businesses and the government should jointly improve digital employment information platforms, enhancing the transparency and accessibility of employment information; this would enable more people to access job opportunities in a timely manner and promote labor mobility across regions. These policy measures could effectively enhance the economic development of less developed regions, narrow the digital divide, and strengthen the positive impact of the digital economy on labor mobility, thereby promoting balanced socioeconomic development.

5.3. Limitations and Future Research

Although this paper explores the impact of the digital economy on labor mobility and provides a range of empirical analyses and policy recommendations, there are still some research limitations. First, the time range and geographic coverage of the data may limit the broad applicability of the study's conclusions; this is especially the case in a rapidly changing digital economy, where the research may fail to reflect the latest trends and developments. Second, the indicators used in the study may not comprehensively cover all the factors that affect labor mobility, such as cultural and social environments and other non-economic factors that may have a significant impact on labor mobility. Additionally, although some variables were considered and controlled for in the paper, the interactions between other potential independent variables may not have been thoroughly explored. Moreover, despite attempts to address the issue of spatial dependence, further testing and model estimation are needed to resolve issues within the spatial autocorrelation model.

In future research, these limitations can be overcome through the following methods: firstly, the time range and geographical coverage of data could be expanded to include more countries and regions, as well as updated data, to better capture the dynamic changes in the development of the digital economy; secondly, the indicators used in the research could be enriched by incorporating more social and cultural factors to provide a more comprehensive analytical perspective. Additionally, more complex models, such as multilevel models or structural equation models, could be employed to explore the interactions and causal relationships between potential variables, enhancing the explanatory power and accuracy of the research conclusions. Specifically, regarding the issue of spatial autocorrelation, future research could improve the accuracy of model estimation by employing spatial econometric models and conducting spatial correlation tests and corrections. Finally, qualitative research methods, such as interviews and case studies, could be utilized to overcome the limitations of quantitative analysis and gain a deeper understanding of the micro-level mechanisms that determine the impact of the digital economy on labor mobility.

Author Contributions: Conceptualization, J.C.; methodology, J.C.; software, J.C.; validation, J.C.; formal analysis, J.C.; resources, J.C.; data curation, J.C.; writing—original draft preparation, J.C.; writing—review and editing, Z.X.; supervision, Z.X. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data queries can be directed to the corresponding authors.

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

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