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The Impact of the Digital Economy on Population Dividends in China: Based on the Dual Perspective of Quantity and Quality

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Abstract: The demographic dividend plays an important role in promoting sustainable development in China. Here, we ask the question of how to use the digital economy to coordinate the "one body and two sides" of the demographic dividend. This study empirically examines the impact of digital economic development on the demographic dividend in a multidimensional way based on the panel data from 30 provincial-level administrative regions in China from 2011 to 2020. The study results show that (1) the digital economy significantly promotes the demographic quality dividend but exhibits a suppressive effect on the demographic quantity dividend; (2) the digital economy can indirectly influence the demographic quality and quantity dividends through urbanization; (3) when examining the threshold effects, the study uncovers noteworthy dynamics, whereby the urbanization levels serve as significant thresholds, showcasing "diminishing marginal effects" in the digital economy's influence on both population quantity and quality dividends; (4) digital economic development has a positive spillover effect on the demographic quantity dividend in adjacent areas. By clarifying these dynamics, the research results provide valuable insights into China's sustainable use of the digital economy to create a demographic dividend.

Keywords: digital economy; demographic quality dividend; demographic quantity dividend; urbanization; sustainable

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1. Introduction

In light of the profound evolution of the global economic landscape, China's economy has entered a new historical phase—transitioning from the era of "high-speed growth" to the "medium-high-speed growth" characteristic of the new normal [1]. This significant transformation is influenced by a complex interplay of various factors, with the reshaping of the population emerging as a pivotal element. Undoubtedly, the demographic dividend has played a substantial role in propelling the economic ascent of China and has served as a driving force for numerous developing countries over an extended period [2]. The challenges posed by a low birth rate, reduced labor supply, and aging population make it increasingly difficult to harness the quantitative demographic dividend. According to the statistics, the number of working-age individuals and their proportion of the overall population in China have experienced a double decline, with a decrease of 6.79 percentage points over the past decade [3]. Simultaneously, the accumulation of high-quality human capital remains a pivotal driver of economic growth [4]. Failure to tackle the issues associated with both population quality and quantity dividends could significantly impact the development of China's economy.

In recent years, the digital economy has emerged as the primary driver of future economic development [5]. Data from the China Academy of Information and Communications Technology (2020) demonstrate a consistent rise in the share of China's digital economy relative to its GDP, increasing from 14.2% in 2005 to 36.2% in 2019 [6]. This trend signifies a significant shift in China's economic growth model and structural optimization approach. The evolution of the digital economy offers significant opportunities to address both the qualitative and quantitative population dividends, albeit accompanied by significant challenges. While many scholars have delved into the relationship between the digital economy and the demographic dividend, there currently exist varying opinions on this matter. Some studies posit that digital technology has the potential to mitigate labor shortages and enhance productivity via improved efficiency, optimized resource allocation, and enhanced supply chain transparency [7]. In contrast, another perspective suggests that the digital economy has impacted the low-skilled labor force through the "substitution effect", while simultaneously increasing the skill requirements for employees in their existing positions through the "promotion effect" [8]. Coupled with the increasingly severe aging population and the diminishing demographic dividend, the impact of the digital economy on the demographic dividend becomes more complex. Against the backdrop of digital economic development, harnessing and leveraging the impact on the demographic dividend holds significant practical significance for achieving stable development and realizing the goal of shared prosperity.

At the same time, the process of urbanization can provide important support and impetus for empowering the population dividend through the digital economy. By aggregating resources to generate economies of scale, creating concentrated labor markets, and enhancing the construction of digital infrastructure, the process of urbanization has created different pathways for achieving both the population quantity dividend and the population quality dividend.

In conclusion, the research on the demographic dividend has been continuously evolving and deepening to adapt to the changing economic, social, and global environments. While past studies have covered various aspects of the demographic dividend, few have integrated both the quantity-based demographic dividend and the quality-based demographic dividend into a comprehensive analytical framework. Furthermore, there remains a gap in understanding how the digital economy empowers the demographic dividend. This undoubtedly will provide new perspectives and motivations for our research.

In light of this, the present study incorporates the digital economy into the analytical framework. Through an empirical analysis of the effects of demographic dividends from the dual perspective of the quantity-based demographic dividend and quality-based human capital dividend, this study verifies both the direct and indirect effects, such as the mediating effects, threshold effects, and spatial effects. This paper contributes to the theoretical and empirical research on the demographic dividend with Chinese characteristics. Specifically, we ask whether the digital economy can significantly promote the demographic quantity dividend and demographic quality dividend? Through what internal mechanism does the digital economy affect the demographic quantity dividend and the demographic quality dividend? Is there a non-linear effect? Does a spatial spillover effect exist? Providing in-depth answers to these questions will hold great significance for China's strategic initiatives for digital economic development, innovation-driven strategies, and the support of high-quality talent development. Given these factors, potential contributions are evident in the following three areas. Firstly, this study enhances the depth and breadth of research on the digital economy and population dividends by integrating population quantity dividends, population quality dividends, and the digital economy into a comprehensive analytical framework, thereby enriching the dimensions and perspectives of the existing literature. Secondly, it advances our understanding of the mechanisms underlying the influence of the digital economy on population dividends, contributing valuable insights to the field and expanding the knowledge base. Lastly, by investigating the non-linear relationship between the digital economy and population dividends, this study offers a nuanced understanding of how the digital economy impacts population dividends, providing detailed insights into the complex dynamics at play. Additionally, by taking into account the spatial characteristics of the digital economy and the spatial dependence of population dividends, this study employs a spatial Durbin model to analyze the spatial spillover effects of the digital economy on population dividends, thereby further enriching our understanding of the geographical implications of digital economic development.

2. Literature Review

2.1. The Digital Economy

The academic exploration of the digital economy has evolved extensively over time, from early theoretical inquiries to recent empirical investigations, reflecting a growing interest in and deepening comprehension of this field [8]. Initially, foreign scholars delved into the essence and characteristics of the digital economy at a theoretical level. For instance, Kling and Lamb (1999) defined the digital economy as production activities directly tied to digital technology [9]. Building upon this, Quah (2003) expanded the scope to encompass all economic endeavors conducted via the Internet, highlighting the comprehensive impact of digitization on economic realms [10]. Moreover, the OECD (2014) identified digital information resources as a novel factor of production [11].

In contrast, the research on the digital economy in China commenced later but has progressively diversified in recent years. The "Digital Economy Development and Cooperation Initiative", introduced during the Hangzhou Summit, marked a significant milestone by offering a clear definition of the digital economy. It characterizes the digital economy as a series of economic activities reliant on digitalized knowledge and information as primary production factors, leveraging information and communication technology for enhanced efficiency [12]. Subsequently, the "14th Five-Year Plan for Digital Economy Development", issued by the State Council in January 2022, underscored the centrality of data resources to the digital economy. It identified modern information networks as the primary carrier and highlighted the integrated application of information and communication technologies and full-factor digitization transformation as key drivers [13]. Liu (2022) characterized the digital economy as an emergent economic paradigm reliant on data as a principal production factor [14]. Xu (2020) defined the digital economy as an emerging method of economic development that uses data as a key production factor [15].

As the scholarly interest in the digital economy increases, the efforts to classify and measure it statistically have gained prominence. In assessments of the digital economy, traditional single indicators such as the Internet penetration rate or per capita connectivity, which were commonly used in the past, are now considered too narrow and unable to fully capture the multifaceted evolution of the digital economy [16], leading to criticism from the academic community. Therefore, scholars have shifted their focus to more detailed assessments of the digital economy, mainly focusing on areas such as Internet development and digital finance. Brandt and Thun (2011) proposed a three-dimensional framework that integrates factors such as Internet accessibility and mobile phone penetration rates for evaluation. This framework considers multiple dimensions of the digital economy, making such assessments more comprehensive and accurate [17]. In China, the Information and Communication Research Institute (2017, 2019) has developed the Digital Economy Index (DEI) for evaluation purposes [18]. The China Academy of Information and Communications Technology introduced a four-dimensional framework for understanding the digital economy's connotations in July 2020. This framework comprises components related to digital industrialization, industrial digitalization, digital governance, and value-added data [19]. Meanwhile, Wu (2020) assessed the digital economy and constructed an index system based on its facets, offering a novel approach to scrutinizing its development trajectory [20].

Subsequently, empirical inquiries into the digital economy have unfolded across diverse research areas, exploring its impact mechanisms on economic development from myriad perspectives such as innovation [21], employment [22], productivity [23], and high-quality economic growth [24]. These investigations have also delved into how digital economic development influences aspects of industrial structural optimization [14], regional green innovation efficiency [25], and carbon emissions [26], providing vital insights for digital economic policy formulation.

2.2. The Demographic Dividend

In 1997, Mason introduced the concept of the "demographic dividend", emphasizing the relationship between the growth of the working-age population and economic advancement [27]. In its early stages, the research predominantly focused on establishing a foundational understanding of the definition of the demographic dividend and its impact on economic growth [28]. This phase emphasized the correlation between the increase in the working-age population and economic growth. Subsequent studies have shifted towards empirical analyses of the effects of the demographic dividend in various countries and regions [29], with a particular emphasis on East Asian countries such as China, Japan, and South Korea. Recent studies have increasingly focused on the potential challenges associated with the demographic dividend, including labor market pressure, excessive resource consumption, environmental issues, and aging challenges [30].

The demographic quantity dividend pertains to the economic benefits realized when a country experiences a relative increase in the working-age population, leading to a decrease in the non-working-age population, including children and the elderly. This phenomenon forms a "dividend" or economic advantage [31]. In addition, the study not only focuses on understanding the demographic quantity dividend and its contribution to economic growth but also explores its impact on the labor market, wages, and investment [32]. The demographic quality dividend encompasses the economic benefits arising from the improved education and skill levels of the working-age population [30]. Scholars have extensively studied the impacts of factors such as education, training, and health on labor productivity and how such enhancements drive economic growth [33]. The literature also emphasizes the enduring economic effects of skill upgrading, technological progress, and the accumulation of human capital [34].

2.3. The Digital Economy and Demographic Dividends

The relationship between digital economic development and population dividends has attracted widespread attention in the academic community, with many scholars dedicated to exploring the mechanisms of this dynamic interaction. Some scholars argue that the digital economy, through innovation, structural adjustment, and deepening effects, positively influences both the "quality" and "quantity" dimensions of population dividends. For instance, Liu et al. (2023) pointed out that the development of the digital economy has led to the emergence of emerging industries, increased job opportunities, and improved living standards, all of which contribute to realizing population dividends [35]. Additionally, the research by Zhou et al. (2023) indicates that the digital economy has provided mechanisms for sharing high-quality resources, further promoting the realization of population dividends [26]. Furthermore, the development of the digital economy has driven the rise of certain industries and high-end manufacturing, leading to increased demand for high-skilled talent [36]. This provides a new development path for the quality dividend of the population. Wu and Yang (2022) pointed out that the development of the digital economy has intensified the demand for human capital at different levels, further emphasizing the importance of the "quality" aspect of population dividends [37]. Moreover, Lordan and Neumark (2018) argue that the digital economy is changing traditional production, consumption, and employment patterns, thereby influencing shifts in human demand [38]. This viewpoint is also supported by Acemoglu and Restrepo (2018), who emphasize the importance of enhancing labor skills to adapt to changing times. These studies collectively reveal the positive impact of the digital economy on population dividends and the importance of human capital enhancements in realizing population dividends [39]. However, some scholars hold different views on the positive role of the digital economy in population quantity dividends and even suggest that it may have inhibitory effects. They point out that the rapid development of the digital economy provides new momentum and opportunities for economic transformation but may also inhibit the realization of population quantity dividends. With changes in economic structure, the rise of more high-end manufacturing and service industries may reduce the demand for low-skilled labor.

Autor (2015) noted that some conventional, repetitive labor is gradually being replaced by machines and software, which may inhibit the economic effects of population quantity dividends [40]. Brynjolfsson et al. (2014) also suggested that the development of the digital economy, especially the widespread application of automation and artificial intelligence technologies, may change the demand structure of the labor market, thereby weakening the role of population quantity dividends [41].

To sum up, while the previous research has addressed various aspects of demographic dividends, there has been a notable absence of studies that integrate the digital economy, demographic quantity dividends, and demographic quality dividends into a comprehensive analytical framework. Moreover, the mechanisms through which the digital economy influences both demographic quantity and quality dividends have not been thoroughly investigated, with few studies incorporating variables such as the levels of higher education development and urbanization into an analytical framework covering the digital economy and demographic dividends. Additionally, prior studies have often been confined to analyzing direct effects and linear impacts, neglecting a deeper exploration of the non-linear effects between the two, presenting new perspectives and motivations for our research. Lastly, examining the spatial spillover effects of the digital economy on demographic dividends will complement the existing research efforts.

3. Theoretical Mechanism

3.1. The Digital Economy and Its Direct Impact on Demographic Dividends

The theory of structural change provides an important foundation for understanding the interaction between the digital economy and population dividends. Structural change theory focuses on the impacts of changes in economic structure on the economic system and society. In the era of the digital economy, technological advancements and changes in industrial patterns have led to profound changes in economic structure, facilitating a transition from traditional industries to digitized and intelligent industries. This technological progress often accompanies changes in production methods and may result in traditional labor being replaced by digital and automated technologies. Firstly, the continuous advancement and widespread adoption of automation and artificial intelligence (AI) technology have empowered machines to execute tasks that were once reliant on extensive human labor [42]. The substitution effect of this technology has resulted in a diminished demand for human resources in certain industries, particularly those characterized by low levels of technological complexity or repetitive tasks [43]. This transformation fundamentally undermines the traditional advantages associated with the demographic dividend. Secondly, as the labor market undergoes structural changes, the skills demanded by the digital economy exhibit substantial disparities compared to those required in the traditional economy. The extensive integration of digital technology has amplified the demand for highly skilled and quality labor while concurrently diminishing the need for low-skilled labor [44]. Therefore, a simple labor force supply, particularly the supply of low-skilled labor, may not suffice to meet the demands of the digital economy. This could potentially weaken the effects of demographic quantity dividends. Ultimately, as the digital economy progresses, there is a gradual transformation in the overall socioeconomic structure, marked by a shift towards information technology, artificial intelligence, and other sectors of the digital economy. Emerging industries increasingly rely on technology and knowledge rather than the sheer labor quantity. Consequently, many traditional labor-intensive industries are at risk of disruption. The development of industrial intelligence is accelerating the automation of tasks, leading to the substitution of machines for humans [45]. The automation of jobs related to the digital economy may exacerbate income inequalities by displacing workers, potentially leading to significant unemployment.

According to the Lewis–Clark theorem, as the industrial structure advances towards sophistication, rationalization, and optimization, workers gradually shift from the primary and secondary industries to the tertiary industry. The development of the digital economy promotes the transformation of enterprises towards intelligence, automation, and digitization, which suppresses the employment opportunities for some low-end manual laborers through "mechanization replacing manpower." However, this will further enhance the level of the labor force. The digital economy, characterized by innovative organizational structures, models, and formats, significantly influences the integration and allocation of capital and labor elements, along with the optimization and upgrading of industrial intelligence resources [46]. These transformations, propelled by the digital economy, ultimately impact demographic quality dividends through qualitative and dynamic changes. From the perspective of the demographic quality dividend, the development of the digital economy necessitates a substantial influx of high-quality talent to support its growth. Firstly, the development of the digital economy profoundly influences the labor market model and the employment patterns of workers. The innovations related to labor tools and labor objects caused by technological progress have continuously created high-end jobs [47]. Secondly, the digital economy acts as a catalyst for both the horizontal and vertical expansion of the industrial chain within the labor market, while the development of Internet technologies can contribute to reductions in information asymmetries and transaction costs [48], the promotion of high-skilled labor, the stimulation of residents' entrepreneurial behaviors, and the creation of new jobs [49]. Such expansion strengthens innovation initiatives and accelerates the flow of data elements, facilitating resource sharing. Finally, the digital economy plays a pivotal role in providing educational resources to workers, aiding in the improvement of their human capital levels. Consequently, there is a heightened demand for high-skilled workers in response to the evolving requirements of the digital economy.

The hypotheses for this study are stated below.

H1: *The digital economy significantly inhibits the development of the demographic quantity dividend.*

H2: *The digital economy significantly promotes the development of the demographic quality dividend.*

3.2. The Influence Mechanism of University Innovation Ability

Urbanization Level

The digital economy, driven by digital technology, represents a new form of economic structure. Its vigorous development has provided fresh opportunities and motivation for urbanization. Grounded in the "technology–economy" paradigm theory, the evolution of the digital economy inevitably involves the remolding and upgrading of new technologies, thereby inducing significant structural changes during the development of the new economic landscape. This transformation brings about novel behaviors among economic urbanization entities and alters the dynamics of urbanization relationships. In China's endeavors towards the construction of a new urbanization model, the digital economy will serve as a catalyst for urbanization development through pathways such as digital transformation initiatives, the application of digital technology, and the use of inclusive digital finance, thereby having a conspicuous impact on population dividends. The development of the digital economy has spurred the widespread adoption of remote work and online collaboration initiatives, reducing people's reliance on cities. Firstly, the digitized work environment enables individuals to work in non-urban areas, weakening the allure of cities, particularly for those seeking a better quality of life and lower housing costs [50]. Secondly, the rise of the digital economy has altered the pattern of industrial distribution. Technology companies and innovative enterprises are more dispersed and no longer concentrated solely in traditional cities [51].

A slowdown in urbanization levels can cause restricted population mobility, limiting working-age individuals' ability to seek job opportunities in various industries and fields in cities. This exacerbates competition among the labor force for limited opportunities, leading to labor force "overlapping [52]". In non-urban areas, there may be relatively scarce resources, resulting in decreased income expectations. Families may increase their precautionary savings and consumption limitations may not be effectively alleviated [53], weakening household purchasing power levels and inhibiting the development of demographic quantity dividends.

It is worth noting that, as urbanization rates increase, the development of the digital economy may lead to structural changes in the labor market. In highly digitized cities, some traditional industries may face challenges, resulting in a decrease in corresponding positions. Additionally, reaching a certain level of urbanization may change the skill demands in the labor market. If the working-age population lacks skills related to the digital economy, they may struggle to meet market demands, limiting their employment opportunities. Consequently, the working-age population may face higher risks of unemployment, inhibiting the realization of demographic quantity dividends.

H3: *The digital economy influences demographic quantity dividends through urbanization.*

H4: *Urbanization acts as a threshold for the digital economy's impact on demographic quantity dividends.*

The digital economy, by inhibiting urbanization levels, further promotes demographic quality dividends. Firstly, inhibiting urbanization helps prevent the excessive concentration of resources in large cities, promoting a more balanced distribution of resources between urban and rural areas. Secondly, inhibiting urbanization can reduce occupational instability caused by migration, decrease population mobility and uncertainty, and provide a more reliable environment for long-term human capital investment [54]. Moreover, inhibiting urbanization can drive the digital economy to innovate and allocate production factors across a broader geographical scope. Dispersed innovation centers facilitate the more widespread allocation of research, talent, and capital resources, enhancing the overall innovation efficiency and thereby improving demographic quality [55].

It is noteworthy that, as urbanization rates increase, the digital economy may be more widely applied in urban areas. However, beyond a certain threshold, highly urbanized areas may experience the unequal distribution of digital skills. Additionally, as urbanization rates rise, the penetration rate of digital technology in the economy may gradually reach saturation. Initially, the widespread application of digital technology may yield significant demographic quality dividends. However, as urban areas become more digitized, the marginal effects of technology initiatives may diminish. This is related to the theory of technological penetration, whereby the initial application of technology has a significant impact but further increasing its application yields diminishing returns once a certain level is reached.

H5: *The digital economy influences demographic quality dividends through urbanization.*

H6: *Urbanization acts as a threshold for the digital economy's impact on demographic quality dividends.*

Based on the research purpose and logical structure of this paper, we constructed a diagram of the mechanism of action of action (Figure 1).

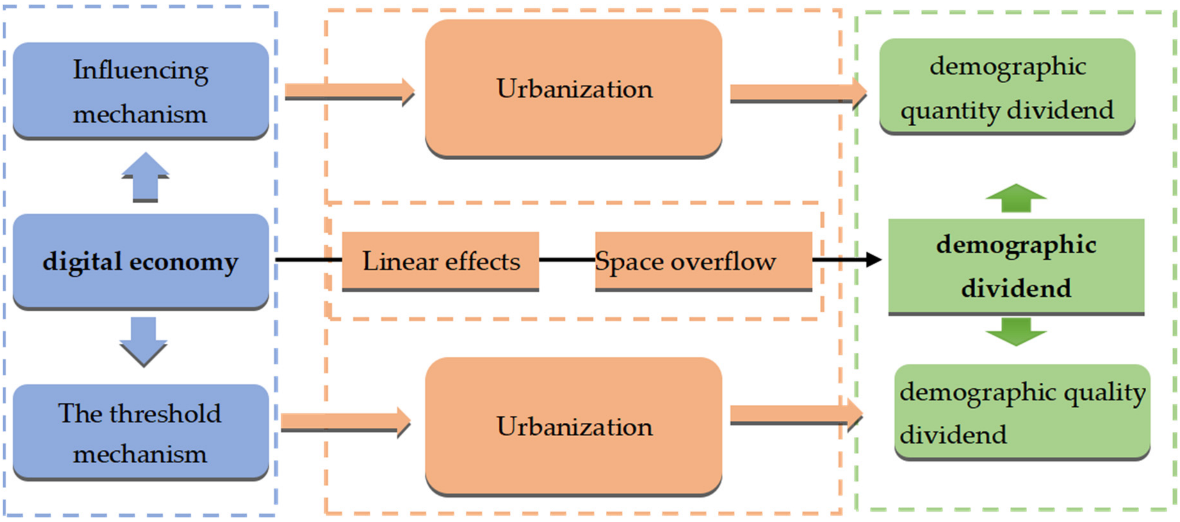

Figure 1. Diagram of the mechanism of action.

4. Research Design

4.1. Variable Description

4.1.1. Explained Variables

(1) Demographic Quantify Dividend (SL)

In the context of this paper, the demographic dividend is the variable under investigation. Typically, three indicators are employed to assess the demographic dividend.

Working-age population [56]: This indicator measures the population within the age range considered suitable for the workforce.

Proportion of employed individuals from the total population [32]: This indicator gauges the percentage of the population actively engaged in employment.

Total dependency ratio [57]: This ratio is calculated by considering the total number of dependents (non-working-age population) relative to the working-age population.

For the purposes of this paper, the total dependency ratio is specifically chosen as the metric to quantify the demographic dividend. The total dependency ratio provides a comprehensive measure by considering the entire dependent population in relation to the working-age population.

(2) Demographic Quality Dividends (ZL)

Demographic quality dividends (ZL) are measured by the proportion of the population aged 6 and above with a high school diploma or having received higher education relative to the total population [58].

4.1.2. Explanatory Variables (DIG)

Currently, there are no standardized metrics for gauging the level of digital economic development. In this study, we reference the definition of the digital economy from the *China Digital Economy White Paper* published by the China Academy of Information and Communications Technology and integrate the research presented in [59]. Additionally, we establish a comprehensive evaluation system for the level of digital economic development based on the Digital Inclusive Finance Index released by Peking University. Guided by principles of scientific rigor, a systematic approach, operational feasibility, and data availability, this system comprises three primary indicators and twenty-two secondary indicators. Covering various facets such as digital infrastructure, digital industry development, and the overall level of digital economic development, further details are provided in Table 1.

Table 1. Comprehensive evaluation system of the development level of the digital economy.

Primary Index	Secondary Index	Three-Level Measure Index
Digital infrastructure development vehicle	Traditional digital economy infrastructure	Internet broadband access port density
		Number of Internet broadband access users
		Number of Internet domain names
		The proportion of the actual number of cable broadcast TV users of the total number of households
	New digital economy infrastructure	Optical cable density
		Mobile phone penetration
		Number of mobile phone users at the end of the year
		Capacity of mobile telephone exchange per unit area
Digital industry development	Digital industrialization	Software product revenue
		Information technology services revenue
		Total volume of telecommunication service
		Electronic information manufacturing revenue
	Industrial digitization	The proportion of enterprises with e-commerce transaction activities
		E-commerce sales
		Digital Financial Inclusion Index
		Number of websites per 100 companies
Digital economic development environment	Talent environment	Number of employees in information transmission, software, and information technology services
		Average number of students enrolled in colleges and universities per 100,000 population
		Number of R&D projects from industrial enterprises above a designated size
	Innovation environment	Intensity of R&D expenditure
		Total volume of technical contract transactions
		Number of patent applications

4.1.3. Mediating Variables

Urbanization (UR): Following the approach by Zhan et al. (2021), the ratio of the permanent urban population compared to the total population is calculated to measure the level of urbanization [60].

4.1.4. Control Variables

Control variables play a crucial role in ensuring the robustness of an analysis. In this study, several control variables are considered.

Economic development level (ED): The regional economic development level is assessed using the per capita GDP of each region. The calculation method follows the approach outlined by [61].

Government intervention (GI): The proportion of government fiscal expenditure from the GDP [62].

Foreign direct investment (FD): The ratio of foreign direct investment compared to the GDP [63].

4.2. Model Construction

In order to verify whether Hypotheses 1 and 2 are valid (i.e., to explore whether the digital economy, as assumed, affects the demographic dividend and demographic quality dividend), we followed the approach outlined by Yang et al. [58] and constructed a two-way fixed effects model for our research. In comparison to standard multiple regression and time series models, the two-way fixed effects baseline regression model provides more accurate estimates, better describes the relationships between variables, and more effectively controls for individual-specific and time-specific effects.

$$SL_{i,t} = \alpha_0 + \alpha_1 dig_{\ i,t} + \alpha_2 control_{\ i,t} + \mu_i + \xi_{i,t} \quad (1)$$

$$ZL_{i,t} = \alpha_0 + \alpha_1 dig_{\ i,t} + \alpha_2 control_{\ i,t} + \mu_i + \xi_{i,t} \quad (2)$$

Here, $SL_{i,t}$ represents the demographic quantity dividend of region i in period t, $ZL_{i,t}$ shows the demographic quality dividend of region i in period t, $dig_{\ i,t}$ represents the digital economy level of region i in period t, α is the coefficient to be estimated, *control* is the control variable, μ is the regional fixed effect, and ξ is the random error term.

In order to test Hypotheses 3 and 5, we establish a mediating effect test model based on the test idea proposed by Wen and Ye (2014), which is shown in Equations (3)–(5) [64]. The model aims to analyze the process and mechanism of influence of the independent variable X on the dependent variable Y. If the independent variable X influences the dependent variable Y through the variable M, M is said to be the mediator variable.

Hypothesis 3 suggests that the digital economy can influence population quantity dividends through urbanization, while Hypothesis 5 suggests that the digital economy can influence population quality dividends through urbanization. We attempt to examine whether urbanization serves as a mediating variable for the digital economy's impact on both population quantity dividends and population quality dividends through the following model. The specific test steps are as below.

Step 1: Test the total effect of independent variable X on dependent variable Y:

$$SL_{i,t} = \beta_0 + \beta_1 dig_{\ i,t} + \beta_2 control_{\ i,t} + \mu_i + \xi_{i,t} \quad (3)$$

Step 2: Test the effect of the independent variable X on the mediating variable M:

$$UR_{i,t} = \gamma_0 + \gamma_1 dig_{\ i,t} + \gamma_3 control_{\ i,t} + \mu_i + \xi_{i,t} \quad (4)$$

Step 3: After controlling for the effect of the independent variable X, the effect of the mediating variable M on the dependent variable Y can be tested:

$$SL_{i,t} = \delta_0 + \delta_1 dig_{\ i,t} + \delta_2 ur_{i,t} + \delta_3 control_{\ i,t} + \mu_i + \xi_{i,t} \quad (5)$$

If the coefficients a and b are significant, this proves that there is a mediating effect. If the coefficient c' is also significant, this means that the direct effect of the independent variable X on the dependent variable Y is also significant; otherwise, only the mediating effect holds.

To verify Hypotheses 4 and 6, which suggest that the impact of the digital economy on population quantity dividends and population quality dividends may not be linear, threshold regression models will be employed. These models, proposed by Hansen [65], are utilized to explain situations where economic behaviors or relationships undergo significant changes or discontinuities under certain conditions. In threshold regression models, the effects of variables may differ before and after reaching a certain threshold level. Therefore, in this study, threshold regression models will be used with urbanization as the threshold variable to examine the characteristics of the digital economy's impact on population quantity dividends and population quality dividends.

$$SL_{i,t} = \varphi_1 dig_{i,t} \times I(ur \leqslant \lambda_1) + \varphi_2 dig_{i,t} \times I(\lambda_1 < ur \leqslant \lambda_2) + \cdots + \varphi_n dig_{i,t} \times I(\lambda_{n-1} < ur \leqslant \lambda_n) + \varphi_{n+1} dig_{i,t} \times I(ur > \lambda_n) + \varphi control_{i,t} + \mu_i + \xi_{i,t} \tag{6}$$

$$ZL_{i,t} = \varphi_1 dig_{i,t} \times I(ur \leqslant \lambda_1) + \varphi_2 dig_{i,t} \times I(\lambda_1 < ur \leqslant \lambda_2) + \cdots + \varphi_n dig_{i,t} \times I(\lambda_{n-1} < ur \leqslant \lambda_n) + \varphi_{n+1} dig_{i,t} \times I(ur > \lambda_n) + \varphi control_{i,t} + \mu_i + \xi_{i,t} \tag{7}$$

4.3. Data Sources and Descriptions

For the empirical analysis, panel data from 30 provinces spanning the period 2011 to 2020 were utilized. Xizang was excluded due to a lack of data.

The primary data for the analysis were drawn from the "The China Statistical Yearbook" and "China Population and Employment Statistical Yearbook". The supplementary data were obtained from the EPS database and other relevant sources to enhance the comprehensiveness of the dataset.

5. Empirical Analysis

5.1. Baseline Regression

In order to eliminate individual differences in the sample and obtain more robust regression results, we employed Stata software to conduct a regression analysis with double fixed effects, and the results are shown in Table 2. To examine whether the model is suitable for fixed effects regression, a Hausman test was conducted, yielding a value of 16.06 with a p-value of 0.0029, passing the significance test at the 1% level. Table 2 presents the baseline regression results for the impact of the digital economy on population quantity dividends. Model (1) analyzes the effect of the digital economy on population quantity dividends without considering control variables. Models (2)–(4) progressively add control variables. The coefficient of the digital economy remains significantly negative, at least at the 1% confidence level, with a value of −1.443. It can be observed that regardless of the inclusion of control variables, the digital economy significantly inhibits population quantity dividends, thereby supporting Hypothesis H1. This suggests that the digital economy significantly suppresses population quantity dividends.

Table 2. Regression results for population quantity dividends.

	(1) SL	(2) SL	(3) SL	(4) SL
Dig	−1.637 ***	−1.630 ***	−1.553 ***	−1.443 ***
	(0.346)	(0.403)	(0.378)	(0.380)
ED		−0.018	−1.533 ***	−1.953 ***
		(0.500)	(0.532)	(0.573)
GI			−3.420 ***	−3.692 ***
			(0.567)	(0.582)
FD				2.805 *
				(1.453)
_cons	3.205 ***	3.207 ***	4.249 ***	4.313 ***
	(0.040)	(0.085)	(0.190)	(0.192)
N	300.000	300.000	300.000	300.000
r2	0.661	0.661	0.703	0.707
r2_a	0.611	0.609	0.656	0.660

Here, ***, and * represent significance at the 1%, and 10% levels, respectively. Parentheses are used to indicate T statistics values. The adjusted R^2 represents the goodness-of-fit of the model.

Regarding the control variables, an increase in economic development levels suppresses population quantity dividends. The increased level of government intervention suppresses population quantity dividends because increased fiscal expenditure may be allocated towards improving the quality of children's education, leading families to focus more on educational investments for their children and reduce the number of births. Foreign direct investment has a positive effect on population quantity dividends, implying that FDI typically accompanies economic growth and new employment opportunities.

Next, we discuss the impact of the digital economy on population quality dividends, the results of which are shown in Table 3. In column (1), we only consider the core variables of the digital economy, with an estimated coefficient of 0.125, which is significant at the 1% level. In columns (2) to (4), as we gradually add control variables, the estimated coefficient for the digital economy remains significantly positive. This indicates that the digital economy can effectively promote population quality dividends, suggesting that for every unit increase in digital economic development, there is a 0.125 unit promotion effect on population quality dividends; thus, H2 is validated. Regarding the control variables, the level of economic development shows a positive but insignificant effect. The level of government intervention exhibits a significantly positive effect on population quality dividends. Foreign direct investment demonstrates a significantly negative effect on population quality dividends.

Table 3. Regression results for population quality dividends.

	(1) **ZL**	**(2)** **ZL**	**(3)** **ZL**	**(4)** **ZL**
Dig	0.125 ***	0.151 ***	0.150 ***	0.125 ***
	(0.030)	(0.035)	(0.035)	(0.034)
ED		−0.063	−0.045	0.049
		(0.043)	(0.049)	(0.051)
GI			0.041	0.102 *
			(0.053)	(0.052)
FD				−0.626 ***
				(0.130)
_cons	0.140 ***	0.150 ***	0.137 ***	0.123 ***
	(0.003)	(0.007)	(0.018)	(0.017)
N	300.000	300.000	300.000	300.000
r2	0.829	0.830	0.831	0.845
r2_a	0.803	0.804	0.804	0.819

Here, ***, and * represent significance at the 1%, and 10% levels, respectively. Parentheses are used to indicate T statistics values. The adjusted R^2 represents the goodness-of-fit of the model.

5.2. Robustness Test

To ensure the robustness of our research findings, we conducted tests from various perspectives of which are shown in Tables 4 and 5. To ensure robust conclusions, multiple verification methods were adopted. Firstly, we replaced the core explanatory variables. Secondly, we applied 1% two-tailed trimming to all variables to eliminate outliers. Finally, re-regression was achieved using data from 2012 to 2019. In various scenarios, the coefficient of the digital economy remained significantly positive, demonstrating the robustness of our conclusions.

Table 4. Population quantity dividend robustness test.

	(1) SL	(2) SL	(3) SL	(4) SL
Dig	−1.443 ***	−1.915 ***	−2.296 ***	−1.492 ***
	(0.380)	(0.388)	(0.483)	(0.533)
ED	−1.953 ***	−1.663 ***	−1.699 ***	−2.426 ***
	(0.573)	(0.598)	(0.565)	(0.725)
GI	−3.692 ***	−3.617 ***	−3.638 ***	−3.752 ***
	(0.582)	(0.542)	(0.574)	(0.673)
FD	2.805 *	2.683 *	2.462 *	2.039
	(1.453)	(1.374)	(1.436)	(1.539)
_cons	4.313 ***	4.257 ***	4.319 ***	4.419 ***
	(0.192)	(0.187)	(0.189)	(0.232)
N	300.000	300.000	300.000	240.000
r2	0.707	0.734	0.716	0.625
r2_a	0.660	0.691	0.670	0.549

Standard errors in parentheses; * $p < 0.1$, *** $p < 0.01$.

Table 5. Population quality dividend robustness test.

	(1) ZL	(2) ZL	(3) ZL	(4) ZL
Dig	0.125 ***	0.117 ***	0.195 ***	0.096 *
	(0.034)	(0.038)	(0.043)	(0.054)
ED	0.049	0.031	0.029	0.072
	(0.051)	(0.059)	(0.051)	(0.074)
GI	0.102 *	0.108 **	0.097 *	0.165 **
	(0.052)	(0.053)	(0.051)	(0.068)
FD	−0.626 ***	−0.619 ***	−0.599 ***	−0.638 ***
	(0.130)	(0.135)	(0.129)	(0.157)
_cons	0.123 ***	0.125 ***	0.122 ***	0.111 ***
	(0.017)	(0.018)	(0.017)	(0.024)
N	300.000	300.000	300.000	240.000
r2	0.845	0.837	0.848	0.808
r2_a	0.819	0.810	0.824	0.769

Standard errors in parentheses; * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5.3. Endogeneity Test

In this study, we employed instrumental variable (IV) methods to address endogeneity issues, using the interaction terms "national information technology service revenue from 2011 to 2020" and "fixed telephone lines per 10,000 people in 1984" as instruments. The results shown in Table 6 indicate that all instrumental variables pass the tests for under-identification and weak identification. This suggests that even after considering endogeneity issues, the research conclusions of this study remain valid.

Table 6. Endogeneity test.

	(1) SL	(2) SL	(3) ZL	(4) ZL
Dig	−1.443 ***	−19.826 ***	0.125 ***	1.026 ***
	(0.380)	(7.220)	(0.034)	(0.392)
ED	−1.953 ***	11.391 **	0.049	−0.605 **
	(0.573)	(5.444)	(0.051)	(0.296)
GI	−3.692 ***	−1.758	0.102 *	0.007
	(0.582)	(1.868)	(0.052)	(0.101)
FD	2.805 *	−7.723	−0.626 ***	−0.111
	(1.453)	(5.909)	(0.130)	(0.321)
_cons	4.313 ***	0.908	0.123 ***	0.731 ***
	(0.192)	(2.743)	(0.017)	(0.149)

Table 6. *Cont.*

	(1) SL	(2) SL	(3) ZL	(4) ZL
N	300.000	300.000	300.000	300.000
r2	0.707	0.193	0.845	0.924
r2_a	0.660	0.061	0.819	0.912

Here, ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively. Parentheses are used to indicate T statistics values. The adjusted R^2 represents the goodness-of-fit of the model.

5.4. Mechanism Test

Mediating Role of the Urbanization Level

The earlier sections comprehensively analyzed how the development of the digital economy mediates the transmission mechanism of population quantity dividends and population quality dividends through urbanization. To verify this mechanism, we employed the stepwise regression method for empirical testing, the regression results of which are presented in Table 7. Firstly, we examined how the development of the digital economy affects population quantity dividends through urbanization. The coefficient in column (2) is −0.164, which is significant at the 1% confidence level. This indicates that the digital economy plays a significant inhibitory role in urbanization, validating the second condition of the mediating mechanism's existence. In column (3), the coefficient of the urbanization level's effect on the population quantity dividends is 6.833, which is significant at the 1% confidence level. This suggests that urbanization significantly promotes population quantity dividends. Additionally, in column (3), the coefficient of the digital economy is −0.323, which is not significant, indicating a complete mediating effect of urbanization in the process of the digital economy inhibiting population quantity dividends; therefore, Hypothesis 3 is verified.

Table 7. The mediating role of the urbanization level.

	(1)	(2)	(3)	(4)	(5)	(6)
	SL	UR	SL	ZL	UR	ZL
Dig	−1.443 ***	−0.164 ***	−0.323	0.125 ***	−0.164 ***	0.066 *
	(0.380)	(0.024)	(0.373)	(0.034)	(0.024)	(0.036)
ED	−1.953 ***	−0.197 ***	−0.609	0.049	−0.197 ***	−0.023
	(0.573)	(0.036)	(0.545)	(0.051)	(0.036)	(0.052)
GI	−3.692 ***	−0.323 ***	−1.483 **	0.102 *	−0.323 ***	−0.016
	(0.582)	(0.037)	(0.598)	(0.052)	(0.037)	(0.057)
FD	2.805 *	0.829 ***	−2.861 *	−0.626 ***	0.829 ***	−0.325 **
	(1.453)	(0.092)	(1.503)	(0.130)	(0.092)	(0.144)
UR			6.833 ***			−0.363 ***
			(0.886)			(0.085)
_cons	4.313 ***	0.631 ***	0.003	0.123 ***	0.631 ***	0.352 ***
	(0.192)	(0.012)	(0.585)	(0.017)	(0.012)	(0.056)
N	300.000	300.000	300.000	300.000	300.000	300.000
r2	0.707	0.934	0.763	0.845	0.934	0.855
r2_a	0.660	0.923	0.723	0.819	0.923	0.831

Here, ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively. Parentheses are used to indicate T statistics values. The adjusted R^2 represents the goodness-of-fit of the model.

Furthermore, the results show how the development of the digital economy influences population quality dividends through the level of urbanization. In column (5), the coefficient is −0.164, which is significant at the 1% confidence level. This indicates that the digital economy has a significant inhibitory effect on the level of urbanization, confirming the second condition for the existence of the intermediary mechanism. In column (6), the coefficient of the urbanization level's effect on population quantity dividends is −0.363, which is significant at the 1% confidence level. This suggests that urbanization significantly suppresses population quality dividends. Additionally, in column (6), the coefficient of the digital economy is 0.066, which is significant positively, indicating that urbanization plays a partially mediating role in the process of the digital economy promoting population quality dividends. Specifically, the mediating effect accounts for 93.64% of the total effect. Additionally, the digital economy suppresses urbanization levels to promote population quality dividends, meaning Hypothesis 5 is verified.

6. Implementation Conditions

In order to further examine the impacts of various urbanization levels on the population quantity dividend and the population quality dividend, we adopted the urbanization level as a threshold variable and established panel threshold models for both the population quantity dividend and population quality dividend. Firstly, before conducting the threshold regression, it was necessary to verify the existence and quantity of the thresholds, the results of which are shown in Table 8. We employed a bootstrapping method with 300 self-samples, and the non-linear impact of the digital economy on the demographic dividend and the quality dividend of the population was initially tested, with the urbanization level used as the threshold variable.

Table 8. Results of the threshold effect test.

Threshold Variable		Model	Threshold Estimates	F-Value	*p*-Value	1%	5%	10%
UR	SL	Single	0.8431	59.28	0.0167	31.0224	38.5654	61.7526
		Double	0.8431 0.7002	21.17	0.0567	23.6020	28.1045	39.4094
		Triple	0.8755	27.68	0.24	48.0408	65.4287	97.3008
	ZL	Single	0.7018	47.24	0.023	52.056	36.459	30.665
		Double	0.7158 0.8755	25.51	0.170	39.308	30.091	26.543
		Triple	0.7018	7.28	0.677	45.487	25.550	19.287

The results in Table 9 demonstrate that the single threshold test passed the significance test, indicating the potential existence of a threshold for the urbanization level. It can be observed that when the urbanization level is below 0.8431, for each unit increase in the digital economy, the population quantity dividend decreases by 2.98. Conversely, when the urbanization level is >0.8431, the suppression of the population quantity dividend by the digital economy intensifies, with a coefficient value of −5.68, which is significant at the 1% level. This reveals a significant non-linear relationship between the digital economy and the population quantity dividend concerning the urbanization level, demonstrating the principle of "diminishing marginal returns." After reaching a certain level of input, each additional unit of urbanization may no longer result in a corresponding increase in the population quantity dividend. Instead, due to restricted population mobility and the excessive concentration of resources, there might be an increased demand for high-skilled labor in the labor market while the demand for low-skilled labor decreases relatively; therefore, Hypothesis 4 is verified.

Using the urbanization level as the threshold variable, the non-linear effects of the digital economy on the population quality dividends reveal that when the urbanization level is below 0.7018, each unit increase in the digital economy leads to a 0.60 increase in population quality dividends. However, when the urbanization level exceeds 0.7018, the promotional effect of the digital economy on the population quality dividends weakens, with a coefficient value of 0.45, which is significant at the 1% level. Highly urbanized areas may face challenges such as rising living costs, increased social pressure, and the uneven distribution of resources; therefore, Hypothesis 6 is verified.

Table 9. Results of the threshold effect regression.

	UR as the Threshold Variable			
	SL		ZL	
Variable	Value	t-value	Value	t-value
Dig (Less than the threshold value)	−2.98 ***	−10.65	0.60 ***	15.32
Dig (Above than the threshold value)	−5.68 ***	−11.21	0.45 ***	14.87
ED	−0.215	−0.34	0.01	0.02
GI	−3.99 ***	−7.06	0.37 ***	6.19
FD	2.46	1.64	−1.08 ***	−6.62

Here, *** represent significance at the 1% levels. Parentheses are used to indicate T statistics values. The adjusted R^2 represents the goodness-of-fit of the model.

7. Analysis of Heterogeneity

Considering the regional disparities across China in terms of economic development, resources, financial development, the initiation time of the digital economy, and mindset, it is plausible that the impacts of the digital economy on population dividends may vary. When examining regional samples, the impact of the digital economy on population dividends in the western region exhibits a significant negative effect, while its influence on the central and eastern regions is not significant. This discrepancy arises from the increasing demand for high-skilled labor brought about by the development of the digital economy. In the western region, the digital economy has not been able to generate equal employment opportunities compared to other regions. Additionally, there is a lack of adequate education and skill matching, resulting in a mismatch between the labor force and available employment opportunities.

The results in Table 10 demonstrate that the digital economy significantly enhances the population quality dividend in the eastern region, characterized by technological innovation and rapid development in digital industries. The eastern region's prominence in technological innovation creates a conducive environment for academic and career development, providing ample opportunities for individuals to acquire high-level technical and professional knowledge.

Table 10. Heterogeneity results.

	East		Middle		West	
	ZL	SL	ZL	SL	ZL	SL
Dig	0.111 **	0.309	−0.122	−2.155	−0.041	−1.912 **
	(0.052)	(0.655)	(0.188)	(1.668)	(0.139)	(0.870)
UR	−0.497 **	3.348	−0.330	10.327 ***	0.163	−1.971
	(0.191)	(2.403)	(0.291)	(2.582)	(0.289)	(1.801)
HE	−0.028	−2.942 **	−0.425	1.845	0.376	−3.777 **
	(0.101)	(1.265)	(0.267)	(2.363)	(0.249)	(1.553)
ED	0.024	0.477	−0.006	−1.562	−0.342	0.228
	(0.093)	(1.164)	(0.177)	(1.567)	(0.282)	(1.761)
GI	0.176	−1.367	−0.081	−1.752	−0.054	−1.588 **
	(0.165)	(2.072)	(0.125)	(1.107)	(0.105)	(0.654)
FD	−0.467 *	−3.397	−0.235	2.600	−1.030*	−1.716
	(0.245)	(3.082)	(0.374)	(3.312)	(0.576)	(3.596)
_cons	0.492 ***	1.828	0.328 **	−1.592	0.085	4.287 ***
	(0.141)	(1.776)	(0.152)	(1.346)	(0.144)	(0.898)
N	110.000	110.000	90.000	90.000	100.000	100.000
r2	0.879	0.782	0.913	0.896	0.824	0.760
r2_a	0.843	0.717	0.883	0.860	0.768	0.683

Here, ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively. Parentheses are used to indicate T statistics values. The adjusted R^2 represents the goodness-of-fit of the model.

8. Spatial Spillover Effect Analysis

China's geographical variety among its various regions fosters robust interconnections, facilitating significant influence from macroeconomic factors across neighboring areas. The digital economy, renowned for its openness, timeliness, and economic integration, effectively dismantles barriers to economic interactions imposed by geographical distance. Consequently, the emergence of the digital economy is poised to catalyze spatial spillover effects on the population dividend. Typically, this influx of job opportunities often stimulates population migration to rapidly developing regions or attracts immigrants to these areas, thereby bolstering the population dividend in such regions. However, the spatial spillover effects of the digital economy on the population quality dividend may not be significant. The enhancement of the population quality dividend necessitates extensive education, training, and skill development processes, which are relatively less susceptible to spatial spillover effects. Even in regions experiencing rapid development in the digital economy, the improvement of human capital requires considerable time and systematic education and training programs. Therefore, while the digital economy may create the conditions to enhance the population quality dividend, its impact is often localized rather than yielding comprehensive spatial spillover effects. Thus, we propose that the digital economy exhibits spatial spillover effects on the demographic quantity dividend in neighboring regions. Before estimating the parameters of the spatial econometric model, it is imperative to confirm the presence of spatial correlations among the explanatory variables. In this study, we employed the global Moran's I index method, utilizing both the adjacency matrix and the economic geographic distance matrix for analysis. The results, as shown in Table 11, indicate that the Moran's I scores for both the level of the digital economy and the population dividend from 2011 to 2020 are significant at the 1% level. This signifies a substantial spatial correlation and noticeable spatial clustering tendencies in the effects of the digital economy and population dividend across various regions.

Table 11. Moran's I index scores.

Matrix Type	Space Adjacency Matrix				Economic Geography Matrix			
Variable Name	Dog		SL		Dig		SL	
	Moran Index	z	Moran Index	z	Moran Index	z	Moran Index	z
2011	0.216 ***	2.156	0.342 ***	3.245	0.116 ***	2.888	0.163 ***	3.809
2012	0.229 ***	2.261	0.330 ***	3.089	0.122 ***	2.993	0.141 ***	3.334
2013	0.193 **	1.655	0.342 ***	3.173	0.094 ***	2.464	0.163 ***	3.737
2014	0.185 **	1.887	0.325 ***	3.046	0.094 ***	2.47	0.167 ***	3.834
2015	0.189 **	1.921	0.293 ***	2.745	0.098 ***	2.54	0.203 ***	4.47
2016	0.196 ***	1.982	0.292 ***	2.711	0.091 ***	2.422	0.148 ***	3.42
2017	0.197 ***	1.995	0.274 ***	2.565	0.079 ***	2.187	0.132 ***	3.123
2018	0.183 **	1.885	0.304 ***	2.847	0.07 ***	2.021	0.163 ***	3.731
2019	0.168 **	1.765	0.271 ***	2.562	0.061 **	1.856	0.156 ***	3.587
2020	0.148 *	1.599	0.275 ***	2.578	0.056 **	1.76	0.07 **	1.96

Here, ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively. Parentheses are used to indicate T statistics values. The adjusted R^2 represents the goodness-of-fit of the model.

Subsequently, we followed the testing approach [resented in [66], conducting LM tests, Wald and LR tests, and a Hausman test sequentially]. Ultimately, the spatial Durbin fixed-effects model in both time and space was selected. To ensure the robustness and reliability of the regression results, empirical tests were performed based on both the adjacency matrix and the geographic distance matrix. The outcomes are displayed in Table 12. For the results estimated using the economic geographic distance matrix, it can be found that the spatial autoregressive coefficient for the demographic quantity dividend is significant at the 1% level, with a positive coefficient for the spatial interaction term W*X.

Table 12. Space regression results.

	SL	Coefficient	Std. Err.	z	P > z	[95% conf.	Interval]
Main							
	Dig	−1.007367	0.3468773	−2.9	0.004	−1.687234	−0.3275003
	ED	−1.640145	0.5322955	−3.08	0.002	−2.683425	−0.5968646
	GI	−2.894175	0.5815734	−4.98	0	−4.034038	−1.754312
	FD	2.401518	1.351486	1.78	0.076	−0.2473459	5.050382
Wx							
	Dig	−1.997007	0.5871763	−3.4	0.001	−3.147851	−0.8461623
	ED	0.9968711	1.159781	0.86	0.39	−1.276258	3.27
	GI	−0.8862619	1.119402	−0.79	0.429	−3.080249	1.307725
	FD	8.659501	2.553073	3.39	0.001	3.65557	13.66343
Spatial							
rho		0.1773886	0.0756894	2.34	0.019	0.0290401	0.3257372
Variance							
sigma2_e		0.0224828	0.0018426	12.2	0	0.0188714	0.0260942

Parentheses are used to indicate T statistics values. The adjusted R^2 represents the goodness-of-fit of the model.

Table 13 illustrates the decomposition results. Initially, concerning the direct effects, the digital economy's advancement may precipitate a decline in the local population. For instance, the evolution of the digital economy might induce shifts in the labor market, whereby the adoption of automation and intelligent technologies could lead to unemployment or the migration of some traditional labor forces, directly impacting local employment and population figures. Subsequently, regarding the indirect effects, the development of the digital economy may also negatively influence the populations in the surrounding areas. This spillover effect may stem from factors such as a decline in the attractiveness of resources, alterations in employment opportunities, and increases in living costs.

Table 13. The decomposition results.

Matrix Type	Space Adjacency Matrix			Economic Geography Matrix		
	direct effect	indigo effect	gross effect	direct effect	indigo effect	gross effect
Dig	−1.104 ***	−2.468 ***	−3.572 ***	−1.269 ***	−8.138 ***	−9.407 ***
ED	−1.636 ***	0.774	−0.862	−1.371 **	1.536	0.168
GI	−2.928 ***	−1.638	−4.566 ***	−2.761 ***	−4.514	−7.274 *
FD	2.845 **	10.308 ***	13.154 ***	3.23 **	33.27 ***	36.501 ***

Here, ***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively. Parentheses are used to indicate T statistics values. The adjusted R^2 represents the goodness-of-fit of the model.

9. Conclusions

Drawing on panel data encompassing 31 provinces in China from 2011 to 2020, this study integrated the digital economy into an analytical framework. Through an empirical analysis of demographic dividends from both population quantity and quality perspectives, this study developed several models, including bidirectional fixed effects models, mediation models, threshold models, and spatial Durbin models. These models were utilized to empirically examine the effectiveness and mechanisms underlying population quantity and quality dividends. The principal findings can be summarized as follows.

The study's findings shed light on the intricate relationship between the digital economy and China's demographic dividends. Overall, while the digital economy dampens population quantity dividends, it concurrently uplifts population quality dividends. These conclusions were rigorously validated through meticulous endogeneity and robustness tests. The findings of Acemoglu and Restrepo (2017) are consistent with ours, indicating that the development of industrial automation accelerates the substitution of low-skilled laborers for simple tasks, a process commonly referred to as the "machine replacing human" phenomenon.

From a mediation standpoint, the digital economy's impacts unfold distinctly; it hampers population quantity dividends by curbing urbanization levels yet concurrently propels population quality dividends.

When examining the threshold effects, we uncovered noteworthy dynamics, namely that the urbanization levels serve as significant thresholds, showcasing "diminishing marginal effects" in the digital economy's influence on both population quantity and quality dividends.

Delving into regional disparities, the study elucidates how diverse economic stages, resource allocations, digital economy initiation times, and ideological nuances across regions engender heterogeneous impacts of the digital economy on population dividends.

Lastly, in the realm of spatial effects, the study illuminates a broader reach; the digital economy not only shapes population quantity dividends locally but also has reverberating effects across neighboring provinces through spatial spillover effects, highlighting the interconnectedness of regional dynamics.

10. Policy Advice

This study's findings carry significant implications for both public policy formulation and business strategy initiatives, particularly amid the rapid pace of digital transformation. Firstly, gaining a nuanced understanding of the intricate relationship between the digital economy and population dividends can serve as a guide for policymakers and businesses alike, aiding them in integrating the digital economy into broader policy frameworks. This integration facilitates the optimization of the benefits of digital transformation while concurrently addressing the associated challenges. Secondly, this study highlights the pivotal mediating role of urbanization within this relationship, emphasizing the imperative for policymakers to prioritize urban planning and infrastructure development. Furthermore, the insights into the spatial dynamics unearthed by this study offer businesses strategic opportunities to expand their operations judiciously, capitalizing on the positive spillover effects of digital economic development. Lastly, recognizing the paramount importance of talent in propelling digital innovation and growth, businesses are urged to concentrate on talent management strategies.

10.1. Embracing a Dialectical Perspective to the Role of the Digital Economy in Population Dividends

To mitigate the adverse effects of the digital economy on population quantity dividends, proactive measures are imperative. Therefore, there is an urgent need to modernize labor market policies and social protection systems, ensuring their responsiveness to the evolving nature of work in the digital age. Policymakers must adopt a forward-thinking approach, moving away from solely safeguarding incumbent jobs that risk obsolescence due to technological progress. Instead, the focus should be on empowering workers to navigate transitions towards new and more promising employment opportunities. Such strategies may include the deployment of vocational training initiatives, comprehensive skill retraining programs, and targeted skill enhancement endeavors. Additionally, there is a crucial imperative to provide workers of all ages with avenues for lifelong learning, ensuring continuous adaptation to evolving job requirements and technological advancements. Furthermore, harnessing the positive influence of the digital economy on population quality dividends implies that individuals with higher skill levels and educational qualifications are likely to reap greater benefits from digitization. Therefore, policies should strive to enhance access to quality education for all, mitigate educational disparities, foster digital literacy and skill development, and expand the accessibility and inclusivity of the digital economy.

10.2. Promoting Urban–Rural Integration to Narrow the Urban–Rural Digital Divide

Initially, the government can foster the development of the digital economy in rural regions through targeted investment and policy support initiatives. This entails augmenting investments in digital infrastructure construction to ensure that rural areas possess the same level of high-speed broadband network coverage and communication facilities as their urban counterparts, thereby laying the groundwork for the digitization process in rural locales. Subsequently, the government can incentivize digital technology firms to extend their operations to rural areas through tax policies and financial assistance. Furthermore, the government should enhance the support for talent cultivation in rural areas, establishing a robust mechanism for nurturing rural digital talent. This should involve providing training and attracting individuals possessing skills conducive to the needs of rural digital economic development.

10.3. Upholding the Concept of Coordinated Development, Strengthening Regional Cooperation and Integration

The research findings reveal significant Moran's index scores for both China's digital economy and population dividends from 2010 to 2020, indicating substantial spatial correlations among the provinces. Consequently, when formulating plans for population dividends, provinces should prioritize strengthening cooperation and communication with neighboring regions. To this end, the government could establish regional cooperation mechanisms and platforms aimed at facilitating information sharing, resource integration, and project collaboration, thereby advancing the collective development of the digital economy across diverse regions. Furthermore, fostering industry synergy and innovation through the establishment of cross-regional industry alliances and research cooperation in institutions could bolster the overall competitiveness and innovation capacity of the regions. Concurrently, it is imperative to bolster the policy support for talent mobility by instituting cross-regional talent exchange platforms, enticing exceptional talent to migrate to regions with lower levels of digital economic development, thereby promoting the equitable allocation of talent resources. Through these concerted efforts, it will become feasible to effectively elevate the level of digital economic development across diverse regions, ultimately helping to achieve the balanced nationwide development of the digital economy.

Our study contributes novel insights to the understanding of the relationship between the digital economy and population dividends, building upon prior research in this domain. Firstly, we confirm the significant promotion of population quality dividends by the digital economy, corroborating the findings by Acemoglu and Restrepo. (2020) [43], who emphasized the role of emerging industries and skill enhancement in driving population improvements. However, our study advances this understanding by integrating both population quantity and quality dividends into a comprehensive analytical framework, thereby unveiling the inhibitory effect of the digital economy on population quantity dividends. This enrichment of the dimensions and perspectives offers a more nuanced view of the impact of digital economic development on population dividends. Secondly, we delve deeper into the indirect effects of urbanization on both population quantity and quality dividends within the digital economy context, thereby adding a subtle dimension to the existing literature. This finding aligns with Nagi et al. (2019) [55], underscoring the pivotal role of urbanization in facilitating the absorption of high-quality talent generated by the development of the digital economy. Furthermore, by identifying the urbanization level as a crucial threshold, we shed light on the non-linear relationship between urbanization and population dividends, broadening the research landscape. Lastly, our study extends the prior research by revealing the positive spillover effects of digital economic development on population quantity dividends in neighboring areas, thereby highlighting the broader regional implications of digital economic growth. This finding underscores the interconnectedness of digital economy dynamics across spatial boundaries, offering valuable insights for policymakers and businesses aiming to leverage digital transformation initiatives for population dividend enhancements.

While this study examines the different impacts of the digital economy on population quantity dividends and population quality dividends, the research is limited by its focus and constraints. Currently, urbanization is only considered as the mediating variable, leaving other potential mechanisms unexplored, which creates a "black box" worthy of further investigation. Future research studies could build on the theoretical foundation of this study to explore other potential mediating mechanisms, such as the mediating effects of variables such as income inequality. Additionally, due to database release delays and time constraints during writing, the data range in this study is limited to 2010–2020. Future research studies will have the opportunity to explore additional time periods.

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