Economic Change and Restructuring (2023) 56:3475–3499
https://doi.org/10.1007/s10644-023-09539-z

The impact of digital economy on capital misallocation: evidence from China

Yanwei Lyu[1] · Yahui Ge[1] · Jinning Zhang[1]

Received: 20 January 2023 / Accepted: 5 July 2023 / Published online: 20 July 2023

Abstract

Capital misallocation is a serious threat to economic growth, and digital economy may have the potential to help curb capital misallocation. Based on the provincial panel data from 2006 to 2019, this study calculates digital economy and capital misallocation in 30 provinces of China. The classical econometric model and the spatial panel model are used to test the impact of digital economy on capital misallocation. The moderating effect model is constructed to analyze the moderating effect of innovation environment (financial development and talent agglomeration). The results show that digital economy significantly inhibits capital misallocation, this conclusion still holds after a series of robustness tests. In addition, there is a spatial spillover effect of digital economy on capital misallocation. Digital economy can inhibit not only local capital misallocation, but also neighboring capital misallocation. Financial development and talent agglomeration have a moderating effect in the relationship between digital economy and capital misallocation. Promoting financial development and talent agglomeration are conducive to enhancing the inhibitory effect of digital economy on capital misallocation.

Keywords Digital economy · Capital misallocation · Spatial spillover effect · Moderating effect

✉ Jinning Zhang
jnzhang003@163.com

Yanwei Lyu
lvyanwei@sdu.edu.cn; lyuyanwei@126.com

Yahui Ge
gegyh123@163.com

1 School of Business, Shandong University, Weihai 264209, China

1 Introduction

Efficient resources allocation is a major driver of productivity increase, and a decrease in total factor productivity (TFP) will inevitably result from misallocation of factors of production (Hsieh and Klenow 2009; Sandleris and Wright 2014). Existing studies have found that capital misallocation problem exists in many countries, especially in developing countries (David et al. 2021; Bun and Winter, 2022), and that this problem can inhibit productivity development and economic growth (Banerjee and Moll 2010; Bartelsman et al. 2013; Alam 2020). Affected by the market-oriented production factor institutional mechanism obstacles and administrative management, China has long faced the problems of low capital allocation efficiency and capital misallocation (Ljungwall and Tingvall 2015; Wu 2018; Chen and Lin 2019). Capital misallocation has resulted in inefficient markets and lower output levels, and has also led to excessive capital investment and overcapacity in some industries, which in turn has seriously hampered the economic development of China (Brandt et al. 2013; Yang et al. 2018). In this context, the Chinese government has made it very apparent that it should foster autonomous and orderly flow of factors as well as broadening the scope of market-oriented factor allocation, and accelerate the market-oriented factor prices reform. How to increase capital allocation efficiency and to decrease capital misallocation is an important issue that needs to be addressed in China.

Since the reform and opening up, China's marketization process has been continuously accelerating, and the level of marketization has been continuously improving. However, compared to the increasingly perfect product market, the marketization process of the capital factor market is significantly lagging behind, which also hinders the free flow of capital factors to varying degrees, resulting in an imbalance in the supply and demand structure, deviation from the optimal allocation state, and capital misallocation. The causes of capital misallocation are diverse, mainly originating from market imperfections, market segmentation, financial frictions, monopolistic forces, government intervention, information asymmetry, and so on. In the capital or credit market, due to frequent financial frictions and dysfunctional banking systems, the financial market is not perfect. In this situation, some companies have investment opportunities and investment needs but cannot timely allocate funds or receive funding support. Asymmetric information leads to ineffective allocation of funds between companies, resulting in capital misallocation (Buera and Shin 2013; Ruziev and Webber 2019). There are high tariffs, technological barriers, or local protectionism in the market, which limits the benign competition of enterprises, leads to inefficient resource allocation due to monopolistic phenomena, and exacerbates the distortion of the capital factor market (Lileeva and Trefler 2010; Zhang et al. 2021). Government behavior can also cause capital misallocation. In order to support the rapid development of certain industries or enterprises, the government may formulate unreasonable tax and fee reduction policies or restrict normal activities of enterprises. These unreasonable policies can disrupt market order, lead to disorderly development and expansion of capital, and ultimately result in capital misallocation (Restuccia and Rogerson 2017; Wu 2018; Zhao et al. 2020).

In recent years, data have increasingly become a driver of economic development as a new production factor (Ahmad and Schreyer 2016). Economic growth is significantly impacted by digital economy which is growing rapidly (Choi and Yi 2009; Myovella et al. 2020; Lyu et al. 2023). The digital economy is a new form of economy, with its core digital technology and information. Through the deep integration of digital technology and the real economy, it improves the digitalization, networking, and intelligence level of the economy and society, promotes economic development and the reconstruction of governance models. Digital economy has played a significant role in promoting low-carbon development (Zhang et al. 2022), increasing the scale of international trade (Abeliansky and Hilbert 2017), promoting industrial structure upgrading (Banalieva and Dhanaraj 2019), facilitating enterprise innovation (Teece 2018) and improving productivity levels (Tranos et al. 2021). The opportunity presented by the digital technology revolution is helping digital economy develop rapidly. Moreover, digital economy is gradually becoming the most promising and dynamic new field in China. The digital economy is playing a more stable and supporting role in the national economy. In 2021, the scale of China's digital economy reached 45.5 trillion yuan, a nominal growth of 16.2% year-on-year; and it is 3.4 percentage points higher than the nominal growth rate of GDP in the same period, accounting for 39.8% of GDP.[1]

Digital economy can provide unprecedented opportunities and challenges for the economic development of countries. Has the allocation of capital factors been optimized in the light of the digital economy's impact? The study of this issue is of relevance and vital value. Academics have conducted extensive research on this topic. Most scholars believed that digital economy can significantly inhibit capital misallocation. For example, Basu and Fernald (2007) found that new business models and new business models accompanying the digital economy not only promote TFP, but also reduce information asymmetry and optimize the resource allocation. Thompson et al. (2013) pointed out that producers can optimize the operational processes, improve the resource allocation structure, and reduce unnecessary losses and resource waste by using new digital technologies. Acemoglu and Restrepo (2018) argued that the impact of information technology and artificial intelligence on factors is more reflected in the increased efficiency of capital and labor allocation. Caputo et al. (2019) argued that digital technologies lead to lower factor costs and more efficient resource allocation. Li and Du (2021) conducted a study at the micro-firm level and found that the growth of the Internet can reduce resource misallocation. In addition, some scholars hold a different view from the above studies. Acemoglu and Restrepo (2018) believed that the overuse of AI technologies will have a substitution effect on the middle and lower labor force, leading to a misallocation of capital and labor, thus undermining productive efficiency. Wamba et al. (2017) found that in the case of misallocation with capital, labor, and data management capabilities, the high storage costs resulting from the rapid accumulation of data will crowd out a large number of productive resources and cause a misallocation of enterprise resources.

[1] See more details at: http://www.caict.ac.cn/kxyj/qwfb/bps/202207/t20220708_405627.htm.

The preceding studies have effectively explored the relationship between digital economy and capital misallocation, but the following flaws remain. Firstly, indicators such as internet development, digital technology and artificial intelligence are used to measure digital economy in the majority of existing research, and these indicators are relatively single and can only reflect a portion of the realities of digital economy. Given that digital economy is multifaceted and multidimensional, a more comprehensive and detailed indicator system needs to be constructed. Secondly, the spatial spillover effect of digital economy on capital misallocation may be forgotten. Given the significant spillover effects of digital economy and the spatially linked nature of regional economic activities, consideration of spatial factors is indispensable. Thirdly, fewer scholars have considered the moderating role of the innovation environment (financial development and talent agglomeration). Digital economy relies on a sound financial system and human capital to inhibit capital misallocation. The moderating effect of the innovation environment may have been overlooked in the existing research.

The possible marginal contributions of this study are as follows.

First, a newly comprehensive index evaluation system for China's digital economy is constructed from four aspects: digital economy development carrier, digital industrialization, industrial digitalization and digital economy development environment. At present, no unified and authoritative proxy indicators or indicator system have been developed for the measurement of the digital economy. Some literature uses a certain indicator or selects some representative indicators to measure the digital economy (Ren et al. 2021; Li et al. 2022a, b), but these indicators are relatively single and can only reflect some facts of the digital economy, lacking comprehensive measurement of the digital economy. The White Paper on China's Digital Economy Development Index 2019 decomposes the indicator system of the digital economy into basic indicators, industrial indicators, integration indicators and environmental indicators. Some scholars have established an evaluation system for the development of the digital economy based on the triple space theory of information network space, physical space and human social space. The above research has certain reference value for the construction and calculation of subsequent indicator systems, but it ignores the timeliness and availability of data, making it difficult to conduct in-depth research from an empirical perspective. This study constructs a comprehensive and detailed indicator system to measure China's digital economy.

Secondly, a spatial econometric model is used to explore the spatial spillover effect of digital economy on capital misallocation. Due to factors such as history, geography, and policies, China's economic development has shown a special spatial differentiation pattern, and there is also a strong spatial dependence and agglomeration in economic development between regions. As an emerging economic format, the digital economy also has similar characteristics. From existing research, it can be seen that digital economy has spatial correlation (Tranos et al. 2021; Ren et al. 2022). The development of digital economy in regions shows a highly clustered trend, and the development level of digital economy in regions with similar geographical distances is similar. Based on the above theoretical and practical foundations, we have found that in order to comprehensively explore the impact of the digital economy on capital misallocation, spatial factors need to be considered. Therefore, we use spatial econometric models to

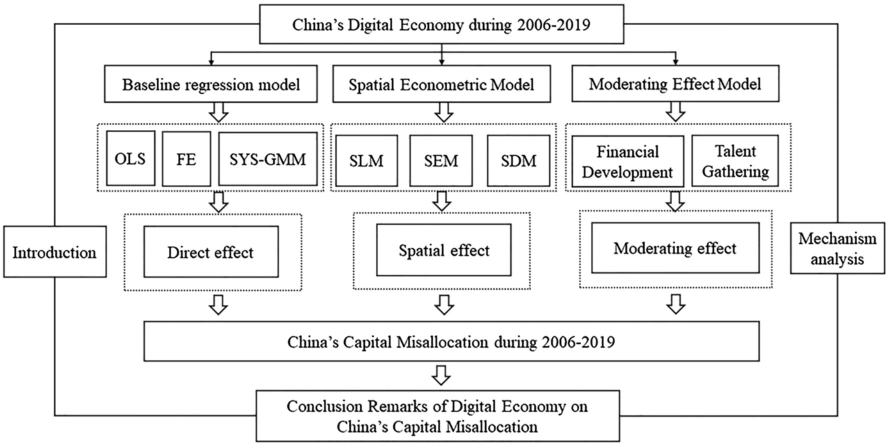


Fig. 1 Research framework in this study

incorporate geographic interactions and impacts into the model, in order to analyze the impact of the digital economy on capital misallocation.

Thirdly, considering the important role of innovation environment in the process of digital economy suppressing capital misallocation, we introduce innovation environment as a moderating variable to explore its moderating effect. The alleviation of capital misallocation in the digital economy depends on the degree of improvement of the innovation environment. Among them, financial development and talent aggregation, as important dimensions reflecting the innovation environment, will directly affect the diffusion and application of digital technology, and affect the allocation of capital. Specifically, the digital economy is in a rapid development stage, and financial frictions and talent shortages are the main obstacles restricting the application and diffusion of digital technology. If the level of financial development improves, the degree of talent aggregation increases, and the innovation environment is optimized, resources can be effectively utilized, achieving Pareto effective allocation. Therefore, it is necessary to measure the innovation environment and analyze its moderating effect from the perspective of financial development and talent aggregation.

The rest of this study is structured as follows. Section 2 describes the research mechanism used in this study. Section 3 discusses research methodology and data. Section 4 contains empirical findings. Section 5 presents research conclusions and policy recommendations. Figure 1 depicts the research framework.

2 Mechanism analysis and research hypothesis

2.1 Direct effect

Firstly, the digital economy has the characteristic of high permeability, which can redevelop traditional elements. Specifically, digital technology provides information channels and technical support for integrating data elements with capital elements by digitizing traditional elements, and plays a role in empowering and increasing efficiency of traditional production factors through data elements (Rosin et al. 2020). Secondly, the digital economy has substitutability characteristics. Data elements can replace traditional elements, leverage their efficiency, and facilitate production, exchange, distribution, and other processes. The new technologies, products, and industries generated by the digital economy can replace traditional inefficient technologies or outdated industries, providing high-quality supply to meet high and new market demands. At the same time, it can guide capital, talent, and knowledge to flow to industries with high capital allocation efficiency, and improve overall economic and social productivity. Finally, the digital economy can accelerate the sharing and dissemination of knowledge and information, reducing information blind spots. The digital economy can reduce information asymmetry, effectively reduce the cost of searching and matching information (Goldfarb and Tucker 2019), thereby accelerating the free flow of capital factors (Peitz and Waldfogel, 2012; Li et al. 2022a, b), reducing barriers to capital factor flow, and promoting and guiding capital to cluster in efficient industries. Based on the statements above, we propose our first hypothesis.

Hypothesis 1 Digital economy significantly inhibits capital misallocation.

2.2 Spatial effect

Digital economy is dependent on the robust modern information network to overcome geographic division and closure, and to broaden and deepen spatial connection of factors (Mayo and Wallsten 2011). Digital economy uses its own characteristics of permeability, integration and synergy to enable it to break through the limits of geographical distance, transcend spatial and regional constraints, achieve cross-regional division of labor and cooperation, and generate spatial spillover effects (Lin et al. 2017; Lee et al. 2022, Zhao et al., 2022). Digital economy facilitates the efficient connection and reorganization of factors in different spaces according to different needs. Digital economy can achieve effective allocation and integration of resource factors across regions in a short time, thus the efficiency of capital allocation can be significantly impacted across regions. The spatial spillover of data factors not only reduces the probability of local traditional factor misallocation and improves the efficiency of factor matching, but may also have an impact on the capital allocation in neighboring places. Based on these statements, the second hypothesis is proposed.

Hypothesis 2 There is a spatial spillover effect of digital economy on capital misallocation.

2.3 Moderating effects

The optimization of the innovation environment enables the maximum use of resources and achieves Pareto efficient allocation (Fan et al. 2020). Financial development and talent agglomeration are important aspects that constitute the innovation environment (Buesa et al. 2010; Schmidt et al. 2016). Digital economy is in a phase of rapid development, and both financial frictions and talent shortages are major barriers to the application and proliferation of digital technologies. Therefore, we measure the innovation environment in terms of both financial development and talent agglomeration to analyze its moderating effect.

2.3.1 Financial development

Large-scale investments, significant investment risk, and lagged economic gains are characteristics of digital economy, which also faces the concomitant issues of high adjustment and financing costs. As a result, the development and spread of digital technology will be directly impacted by the availability of reliable and sufficient financial resources (Chen et al., 2022). Financial development regulates the relationship between digital economy and capital misallocation mainly by alleviating financing constraints, improving information asymmetry, and transforming traditional finance to digital finance. First, financial development can share the risks faced by active agents in investment, ease financing constraints (Love, 2003) and encourage the growth of industries related to digital economy. Second, the financial development platform and information disclosure system of financial institutions improve with increasing financial development level. Digital economy can reduce information asymmetry with the help of well-developed information disclosure mechanisms (Asongu and Moulin, 2016). Finally, the rise of digital finance has effectively corrected the problems of attribute misallocation, domain misallocation and stage misallocation (Chen and Zhang, 2021). Based on these, the third hypothesis is proposed.

Hypothesis 3 Financial development is conducive to enhancing the inhibiting effect of digital economy on capital misallocation.

2.3.2 Talent agglomeration

Intellectual capital has a significant role in digital economy affecting capital misallocation. Areas with a high agglomeration of talent have lower search and coordination costs, as well as more scientific and technological talent exchanges and collaboration. The concentration of talents accelerates the mining, transfer, absorption, and utilization of digital economy knowledge (Liu et al., 2019). In this situation, digital economy can continue to release the talent dividend, accelerate the transformation of digital technology results, and enhance the resource allocation capacity of digital economy. In addition, regional talent competition is encouraged by talent agglomeration. The regions will accelerate the enhancement of knowledge reserves and competitive capabilities in order to maintain competitive advantages (Zhou et al.

2018), thus providing more reliable intellectual backing for digital economy in each region (Wang and Guo, 2021). We propose the fourth hypothesis based on these statements.

Hypothesis 4 Talent agglomeration is conducive to enhancing the inhibiting effect of digital economy on capital misallocation.

3 Methodology and data

3.1 Model construction

3.1.1 Baseline regression model

The baseline regression model is created and listed in Eq. (1) to examine the impact of digital economy on capital misallocation.

$$\mathrm{MISCAP}_{it} = a_0 + a_1\mathrm{DIGE}_{it} + a_2X_{it} + \mu_i + v_t + \varepsilon_{it} \tag{1}$$

where i represents one investigated province, t represents one research year. MISCAP_{it} denotes capital misallocation, DIGE_{it} represents digital economy. X_{it} denotes control variables. a_0 is the intercept term. a_1 and a_2 are the estimation parameters for the core independent variable and control variables, respectively. μ_i denotes the individual effect and v_t denotes the time effect. ε_{it} is the random error term.

Considering that the model above is a static model, and that there may be time inertia in capital misallocation, the lagged one-period term of the dependent variable is added to the model. The estimation efficiency can be improved and the potential endogeneity problem may be overcome by using the system generalized method of moments (SYS-GMM). Therefore, the SYS-GMM is used for estimation.

$$\mathrm{MISCAP}_{it} = a_0 + \theta\mathrm{MISCAP}_{it-1} + a_1\mathrm{DIGE}_{it} + a_2X_{it} + \varepsilon_{it} \tag{2}$$

where the other parameters are established as described in Eq. (1), with $MISCAP_{it-1}$ being the lagged one-period term of capital misallocation.

3.1.2 Spatial econometric model

The relationship between digital economy and capital misallocation is further discussed by considering spatial factors and using spatial econometric model. The commonly used spatial econometric models are spatial lag model (SLM), spatial error model (SEM), and spatial Durbin model (SDM). In this study, the SDM is mainly used for analysis and the model is as follows.

$$\mathrm{MISCAP}_{it} = a_0 + \rho\sum_{j=1}^{N} W_{ij}\mathrm{MISCAP}_{it} + a_1\mathrm{DIGE}_{it} + \phi\sum_{j=1}^{N} W_{ij}\mathrm{DIGE}_{it} + a_2X_{it} + \sigma\sum_{j=1}^{N} W_{ij}X_{it} + \mu_i + v_t + \varepsilon_{it} \tag{3}$$

where ρ, ϕ and σ are spatial autocorrelation coefficients. ε_{it} is the random error term. The symbolic meanings of other variables are the same as in Eq. (1). W_{ij} is the spatial weight matrix based on the geographic distance dimension with the following equation.

$$W_{ij} = \begin{cases} 1/d_{ij} & (i \neq j) \\ 0 & (i = j) \end{cases} \tag{4}$$

where the distance between the geographic centers of two provinces is represented by d_{ij}.

3.1.3 Moderating effects model

The regression model constructed to explore the moderating effect of innovation environment on relationship between digital economy and capital misallocation is as follows.

$$\text{MISCAP}_{it} = a_0 + a_1\text{DIGE}_{it} + \alpha\text{FIN}_{it} + \lambda\text{DIGE}_{it} \times \text{FIN}_{it} + a_2X_{it} + \mu_i + v_t + \varepsilon_{it} \tag{5}$$

$$\text{MISCAP}_{it} = a_0 + a_1\text{DIGE}_{it} + \beta\text{TALENT}_{it} + \omega\text{DIGE}_{it} \times \text{TALENT}_{it} + a_2X_{it} + \mu_i + v_t + \varepsilon_{it} \tag{6}$$

In the above equation, FIN_{it} presents the financial development of province i in year t, and $TALENT_{it}$ presents the talent agglomeration.

3.2 Data

Dependent variable. Capital misallocation (*MISCAP*). We use the capital factor price relative distortion coefficient to measure capital misallocation. Below is the formula for the computation.

$$\text{MISCAP}_{it} = \left(\frac{K_{it}}{K_t}\right) / \left(\frac{s_{it}\beta_{Ki}}{\beta_K}\right) \tag{7}$$

In Eq. (7), i and t denote province and year, respectively. K_{it} and K_t are capital used by province i and national total capital, respectively. $s_{it}=Y_{it}/Y_t$ is the share of provincial output in national total output. β_{Ki} is the contribution of provincial capital use to output, estimated using the least square dummy variable method. $\beta_K=\sum_{i=1}^{N} s_{it}\beta_i$ is the value of capital contribution weighted by output.

The Cobb–Douglas (C–D) production function with constant returns to scale is selected to be the production function when estimating the output elasticity of capital using the Solow residual technique. The numerator K_{it}/K_t represents the actual proportion of capital use in each province to the national capital use. The denominator $\frac{s_{it}\beta_i}{\beta}$ denotes the theoretical proportion of capital use in each province when capital is efficiently allocated. The ratio measures the degree to which capital is misallocated in each province. Capital price in the province is too low and capital is over-allocated relative to the whole economy whenever the ratio exceeds 1. Capital price in the province is high and capital is under-allocated whenever the ratio falls below 1. If the ratio is 1, the capital allocation in the province has reached an optimal level and there is no misallocation.

Core independent variable. Digital economy (*DIGE*). This study is based on the connotation of the digital economy, focusing on the conditions, applications, and environment of the digital economy, and comprehensively constructing a digital economy indicator system. Specifically, 27 specific indicators were selected to measure the digital economy from four dimensions: digital economy development carrier, digital industrialization, industrial digitization, and digital economy development environment. Firstly, the carrier of digital economy development is the fundamental condition required for the development of the digital economy, including traditional and new digital infrastructure. Secondly, digital industrialization plays an important role in the development of the digital economy. Digital industrialization is centered around digital technology, with the communication and information industries as the main body. Thirdly, industrial digitization holds a significant proportion in the digital economy, emphasizing the deep integration of the digital economy and traditional industries, mainly manifested in the digitization of agriculture, industry, and service industries. Fourthly, the development environment of the digital economy is a good guarantee for its development, mainly including institutional environment and innovation environment. The indicators are weighted using a fully-arranged polygonal graphical indicator method to provide a comprehensive review of China's digital economy in each province. The specific indicator system is shown in Appendix A.

Control variables. Referring to the studies of Ding et al., (2018), Wang and Li (2022), industrial structure (*INDU*), trade level (*TRADE*), government intervention (*GOV*) and technology level (*TECH*) are selected as control variables. Among them, the ratio of tertiary industry added value to GDP is used to describe the industrial structure. The ratio of total import and export commerce to GDP is referred to as the trade level. Government intervention is expressed as the ratio of the amount of government fiscal expenditure to GDP. Technology level is expressed as the natural logarithm of the number of patent applications.

Moderating variables. Financial development (*FIN*) and talent agglomeration (*TALENT*). Financial development is characterized by the share of non-state sector loans; talent agglomeration is characterized by the share of tertiary education and above among the employed population.

In this study, 30 provincial-level administrative regions in Mainland China from 2006 to 2019 are studied (Tibet was excluded due to data limitations). All data are obtained from the *China Statistical Yearbook*, *China Electronic Information Industry Statistical Yearbook*, *China City Statistical Yearbook*, *China Science and Technology Statistical Yearbook*, *China Marketization Index Report* and provincial statistical yearbooks in previous years. The statistical description of all variables in this study is listed in Table 1.

Table1 Statistical description of variables

Variable	Definition	Obs	Mean	Std.Dev	Min	Max
MISCAP	Capital misallocation	420	1.492	0.950	0.211	4.681
DIGE	Digital economy	420	0.178	0.148	0.003	0.769
INDU	Industry structure	420	0.440	0.096	0.286	0.835
TRADE	Travel level	420	0.299	0.359	0.013	1.750
GOV	Government intervention	420	0.242	0.109	0.095	0.758
TECH	Technology level	420	10.113	1.589	5.784	13.602
FIN	Financial development	420	0.939	0.360	0.375	2.327
TALENT	Talent agglomeration	420	15.429	10.034	3.006	62.200

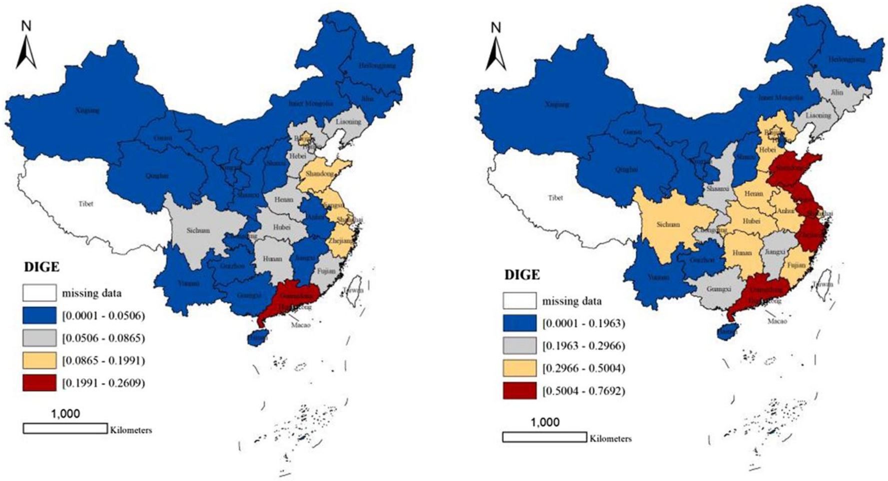
Table 2 The mean value of digital economy and capital misallocation from 2006 to 2019

Province	Digital economy	Capital misallocation	Province	Digital economy	Capital misallocation
Beijing	0.305	0.894	Hunan	0.186	0.774
Tianjin	0.122	3.126	Guangdong	0.519	0.754
Hebei	0.208	2.563	Guangxi	0.114	1.526
Shanxi	0.092	3.301	Hainan	0.032	1.623
Inner Mongolia	0.084	1.560	Chongqing	0.142	0.766
Liaoning	0.211	2.000	Sichuan	0.268	0.790
Jilin	0.107	3.329	Guizhou	0.075	1.079
Heilongjiang	0.110	1.480	Yunnan	0.089	1.032
Shanghai	0.265	0.363	Shaanxi	0.155	1.163
Jiangsu	0.446	0.717	Gansu	0.058	1.098
Zhejiang	0.353	0.901	Qinghai	0.024	1.780
Anhui	0.167	1.235	Ningxia	0.025	1.857
Fujian	0.227	0.906	Xinjiang	0.057	4.369
Jiangxi	0.110	1.125	Nation	0.178	1.492
Shandong	0.346	0.992	East	0.276	1.349
Henan	0.218	0.853	Central	0.151	1.614
Hubei	0.219	0.818	Western	0.099	1.547

4 Empirical results and analysis

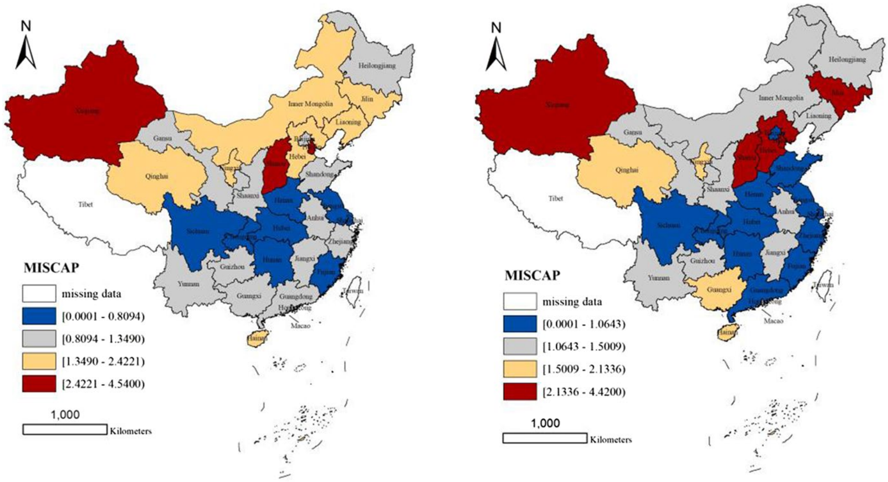
4.1 Measurement results of digital economy and capital misallocation

Digital economy and capital misallocation in each province of China from 2006 to 2019 are measured separately, and the results are shown in Table 2, their geographical distribution is shown in Figs. 2 and 3. It is evident that the mean value of China's digital economy during the examination period is 0.178, showing that digital



a. Digital economy, year2006 b. Digital economy, year2019

Fig. 2 China's digital economy in 2006 and 2019



a. Capital misallocation, year2006 b. Capital misallocation, year2019

Fig. 3 China's Capital misallocation in 2006 and 2019

economy development is still at a relatively low level with much room for growth in China. The mean values of digital economy in the eastern, central and western regions are 0.276, 0.151 and 0.099 respectively, showing that the eastern region has a much higher digital economy development level than the central and western regions. From the situation of each province, Guangdong, Jiangsu, Zhejiang, Shandong, Beijing and Sichuan have larger digital economy values and a higher level of digital economy development. Qinghai, Ningxia, Hainan, Xinjiang, Shanxi, Gansu and Guizhou have smaller digital economy values.

The mean value of China's capital misallocation index during the period under examination is 1.492, indicating that China's capital factor market in general suffers from over-allocation of capital. The mean values of the capital misallocation index in the eastern, central and western regions are 1.349, 1.614 and 1.547, respectively. The eastern region is more market-oriented and has better market mechanism, so capital can be better allocated according to market prices, and thus the degree of capital misallocation is relatively low. The capital misallocation in the central and western regions is much greater than 1. The government gives credit and financial subsidies to enterprises investing in the central and western regions, which to some extent depresses the interest rate level in the regions, but the marginal output value of investment in these regions is not high due to the weak level of technology and inadequate infrastructure, and the invested capital does not give full play to its proper role, and the capital factors are seriously over-allocated. According to the situation of each province, the capital misallocation index of Shanghai, Jiangsu, Guangdong, Chongqing, Hunan and Sichuan is obviously less than 1, indicating insufficient capital factor allocation. The capital misallocation index of Xinjiang, Jilin, Shanxi, Tianjin, Hebei and Liaoning is much greater than 1, indicating excessive allocation of capital factors. The capital misallocation index of Shandong, Yunnan, Guizhou, Fujian, Gansu and Zhejiang is close to 1, indicating good allocation of capital factors.

4.2 Results and analysis of direct effect

4.2.1 Baseline regression results

The ordinary least square (OLS), fixed effects (FE), and system generalized method of moments (SYS-GMM) are used to test the effect of digital economy on capital misallocation. The estimation results are shown in Table 3. It can be seen that both Hansen test and AR (2) test results pass the validity test of the instrumental variables and the SYS-GMM results are valid. The coefficient of digital economy on capital misallocation is significantly negative, whether using the OLS model, the FE model or the SYS-GMM model. Digital economy is conducive to overcoming the market information asymmetry problem, accelerating the transfer flow of capital factors, breaking the barriers to factor mobility. Therefore, it can improve the efficiency of capital allocation and significantly inhibits capital misallocation, hypothesis 1 of this study is verified.

4.2.2 Robustness test

The following four robustness tests are performed to make sure the study results are reliable. First, we replace the dependent variables. Considering that the C-D production function is used to estimate the output elasticity of capital when measuring capital misallocation, assuming neutral technological progress and fixed output elasticity and

Table 3 Baseline regression results

Variable	(1) OLS	(2) FE	(3) SYS – GMM
DIGE	−0.438*** (−2.594)	−0.424** (−2.531)	−0.533*** (−5.579)
L.MISCAP			0.971*** (276.411)
INDU	0.028 (0.133)	0.026 (0.125)	−0.765*** (−11.442)
TRADE	0.322*** (4.385)	0.351*** (4.761)	−0.231*** (−8.205)
GOV	0.577** (2.501)	0.469** (2.021)	−0.088** (−2.137)
TECH	0.114*** (6.316)	0.120*** (6.655)	0.066*** (9.665)
CONS	0.168 (0.790)	0.122 (0.899)	−0.097* (−1.657)
Ind/Year	–	YES	–
N	420	420	390
R^2	0.296	0.297	
AR (2)			0.730
Hansen Test			0.757

L. MISCAP denotes the first-order lagged term of the dependent variable capital misallocation

The values in parentheses are *t*-values or *z*-values

*, **, *** indicate significance at 10%, 5%, and1% levels, respectively. The following table is the same

elasticity of substitution. Therefore, the above assumptions are further relaxed and a more flexible trans-log production function is used to measure capital misallocation in order to avoid the problem of functional form error. Second, we change the regression model. Considering that the dependent variables in this study are capital misallocated as restricted variables greater than zero, the parameter estimates may be biased and non-consistent if regression is performed using OLS. Therefore, a panel Tobit regression model is further used for the regression. Third, to exclude the bias caused by outliers on the results, all indicators of the sample are subjected to 1% two-way tailing and re-regression using FE model. Forth, the 2006 and 2019 samples are removed and re-estimated using data from 2007 to 2018 in order to remove the effect of sample time selection. The estimation results in Table 4 all show that the coefficient is significantly negative, indicating the robustness of the previous estimation results.

Table 4 Estimation results of robustness tests

Variable	(1) Replacement of variable	(2) Tobit	(3) Exclude outliers	(4) Shorten the time window
DIGE	−0.862** (−2.084)	−0.435*** (−2.618)	−0.424** (−2.481)	−0.568*** (−3.373)
INDU	4.363*** (8.409)	0.028 (0.133)	0.026 (0.125)	0.220 (1.056)
TRADE	−2.175*** (−11.961)	0.329*** (4.519)	0.349*** (4.658)	0.310*** (4.080)
GOV	−1.240** (−2.165)	0.554** (2.422)	0.541** (2.292)	0.490** (2.168)
TECH	−0.362*** (−8.121)	0.115*** (6.468)	0.117*** (6.517)	0.121*** (7.096)
CONS	5.595*** (16.662)	0.159 (0.698)	0.134 (0.978)	0.061 (0.462)
Ind/Year	YES	–	YES	YES
N	420	420	420	360
R^2	0.471		0.295	0.342
σ_u		1.001*** (7.654)		
σ_e		0.145*** (27.906)		

Table 5 The results of spatial correlation test

Variable	*DIGE*		*MISCAP*	
	Moran's I	*P*-value	Moran's I	*P*-value
2006	0.039	0.036	0.063	0.003
2007	0.037	0.044	0.068	0.002
2008	0.031	0.065	0.071	0.002
2009	0.026	0.088	0.071	0.002
2010	0.025	0.091	0.073	0.002
2011	0.022	0.108	0.072	0.003
2012	0.023	0.098	0.070	0.003
2013	0.034	0.055	0.067	0.004
2014	0.040	0.037	0.062	0.006
2015	0.048	0.021	0.052	0.014
2016	0.055	0.013	0.043	0.028
2017	0.051	0.017	0.033	0.055
2018	0.051	0.017	0.022	0.106
2019	0.052	0.016	0.012	0.185

Table 6 The test results of spatial econometric model

Statistics	Coefficient	*P*-value
LM (ERR)	29.751	0.000
R-LM (ERR)	47.627	0.000
LM (LAG)	0.595	0.441
R-LM (LAG)	18.471	0.000
Wald (ERR)	12.13	0.033
Wald (LAG)	10.63	0.059
LR-test (ERR)	11.88	0.036
LR-test (LAG)	10.48	0.063
Hausman test	46.65	0.000

4.3 Results and analysis of spatial effect

4.3.1 Spatial correlation test

Moran's I of digital economy and capital misallocation over the period 2006–2019 are measured using Stata (see Table 5). Moran's I of digital economy passes the significance level test of at least 10% in all years except for 2011 when it is not significant. Moran's I of capital misallocation is insignificant only in 2018 and 2019, while Moran's I passes the significance level test of at least 10% for all remaining years. This indicates that the spatial distribution of the dependent variables and the core independent variables is not random, but shows a significant positive spatial correlation characteristic (Table 6).

4.3.2 Identification and examination of spatial econometric model

A spatial econometric model test is required to determine the final spatial econometric model before conducting the regression. Referring to LeSage and Pace (2009), the presence of spatial correlation is first tested by constructing statistics for the Lagrange multipliers (LM) of the residuals and their robust form (Robust LM). The SLM and the SEM can be considered for the SDM if at least one of them passes the LM and RLM tests (Elhorst 2014). On this basis, the joint significance likelihood ratio LR test and Wald test are performed to determine whether the SDM could be reduced to SEM or SLM. As can be seen from the table, for the spatial econometric model selection of the digital economy and capital misallocation, at least one of the SLM and the SEM passes the LM and R-LM test. The LR and Wald test show that the SDM can't degenerate into the SLM and the SEM, so the SDM is selected for regression. In this study, the dual fixed-effects SDM is chosen for the analysis, and we also use the dual fixed-effects SLM and SEM to compare and to ensure the robustness of the results.

Table 7 The regression results of spatial econometric model

Variable	(1) SLM	(2) SEM	(3) SDM
DIGE	−0.525*** (−2.845)	−0.532*** (−2.890)	−0.587*** (−3.084)
INDU	−0.315 (−1.059)	−0.296 (−0.974)	−0.599* (−1.796)
TRADE	0.384*** (5.346)	0.371*** (5.201)	0.379*** (5.232)
GOV	0.394 (1.463)	0.333 (1.230)	0.320 (1.153)
TECH	0.099*** (3.353)	0.096*** (3.258)	0.088*** (2.913)
W × DIGE			−2.710** (−2.238)
W × INDU			−2.148 (−0.992)
W × TRADE			−0.000 (−0.001)
W × GOV			−4.980*** (−2.924)
W × TECH			−0.362* (−1.799)
Direct effect			−0.535*** (−2.708)
Indirect effect			−1.746** (−1.992)
Total effect			−2.281*** (−2.666)
σ^2	0.019*** (14.429)	0.019*** (14.441)	0.018*** (14.423)
N	420	420	420
R^2	0.216	0.215	0.107

4.3.3 Spatial effects regression results and analysis

The results in Table 7 show that, the coefficients of the core independent variables are significantly negative under all three spatial econometric models, further verifying hypothesis 1. Drawing on LeSage and Pace (2009), the spatial Durbin model impact is decomposed into direct and spillover effects. In terms of direct effects, the coefficient is significantly negative, which indicates that digital economy can effectively suppress capital misallocation in the region. In terms of indirect effects, the coefficient is significantly negative, showing that digital economy increases the rate of capital factors flow between regions. In addition, through the spillover of knowledge, information and technology, digital economy has a radiative effect on the efficiency of capital allocation in the neighboring regions, which significantly inhibits the capital misallocation of neighboring regions. The spatial

Table 8 The test results of moderating effects

Variable	Financial development		Talent agglomeration	
	(1)	(2)	(3)	(4)
DIGE	−0.325* (−1.935)	1.993*** (5.371)	−0.316* (−1.844)	1.068*** (3.967)
FIN	0.231*** (3.322)	0.579*** (6.995)		
DIGE×FIN		−1.919*** (−6.911)		
TALENT			−0.008*** (−2.669)	0.012*** (2.791)
DIGE×TALENT				−0.066*** (−6.451)
INDU	−0.524** (−1.974)	−0.657*** (−2.613)	0.209 (0.953)	0.025 (0.121)
TRADE	0.395*** (5.346)	0.115 (1.422)	0.286*** (3.711)	−0.032 (−0.364)
GOV	0.207 (0.857)	−0.120 (−0.516)	0.595** (2.531)	0.183 (0.787)
TECH	0.099*** (5.249)	0.045** (2.327)	0.141*** (7.217)	0.069*** (3.203)
CONS	0.391** (2.495)	0.776*** (4.905)	−0.068 (−0.447)	0.599*** (3.361)
Ind/Year	YES	YES	YES	YES
N	420	420	420	420
R^2	0.317	0.393	0.310	0.378

spillover effect of digital economy on capital misallocation exists, which verifies hypothesis 2.

4.4 Results and analysis of moderating effects

Financial development and talent agglomeration are important aspects of the innovation environment and affect how digital technologies are adopted and spread. Therefore, this study uses financial development and talent agglomeration as moderating variables to analyze the moderating effects.

As can be seen from column (1) (2) of Table 8, the coefficient of the interaction term between digital economy and financial development is significantly negative, indicating that financial development significantly strengthens the inhibitory effect of digital economy on capital misallocation, which verifies hypothesis 3. Higher financial development level can optimize the financing environment for digital economy development and the capital allocation, improve the smooth flow of value chain, supply chain and industrial chain, and strengthen the inhibitory effect of digital economy on capital misallocation. From column (3) (4) of Table 8, we can see that the coefficient of the interaction term between digital economy and talent agglomeration is significantly negative, indicating that talent agglomeration significantly strengthens the inhibitory effect of digital economy on capital misallocation, which verifies hypothesis 4. The digital economy relies on knowledge and technology-intensive industries to mitigate capital misallocation, so the reliance on talent is more obvious. High-tech talents are more capable of acquiring, absorbing, transforming and utilizing knowledge, and regions with high agglomeration of talents are more conducive to the transformation of achievements and effective allocation of resources in digital economy.

5 Conclusion and policy implications

Based on the provincial panel data from 2006 to 2019, this study measures digital economy and capital misallocation in 30 provinces of China. The general panel models and spatial econometric models are used to examine the impact of digital economy on capital misallocation. And the moderating effect model is constructed to analyze the moderating effects of financial development and talent agglomeration.

The research's conclusions are as follows. First, the problem of capital misallocation is widespread in China, and the problem varies regionally. The capital misallocation in China is characterized by "high in the Midwest and low in the East" during the research period. Second, digital economy significantly inhibits capital misallocation, which was verified by a series of robustness tests. In addition, there is a spatial spillover effect of digital economy on capital misallocation. Digital economy can curb not only local capital misallocation, but also neighboring capital misallocation. Third, financial development and talent agglomeration reinforce the inhibiting effect of digital economy on capital misallocation. Based on these results, we propose the following policy recommendations.

First, the government needs to deepen the market-oriented reform of capital factors. Research shows that there is a capital misallocation problem in China's capital factor markets, with significant regional differences. The government should gradually reduce or eliminate barriers to capital flow, improve the institutional mechanism of the factor market. To enable factor prices to serve as a signal for the market to allocate capital, the government should create a fair system of factor prices. The implementation of differentiated policies based on the actual situation of each region, as well as the reform of the central and western regions, should be prioritized. In addition, different regions should strengthen exchanges and cooperation, encourage the flow and sharing of capital in exchanges and interactions, and narrow the gap of capital allocation capacity in different regions.

Second, it is important to promote the development of digital economy in a comprehensive manner. Digital economy significantly inhibits capital misallocation. Digital economy can inhibit not only local capital misallocation, but also neighboring capital misallocation. Therefore, digital technology should be used to drive the upgrading and transformation of capital factors, strengthen the synergistic development of data factors and capital factors. Moreover, the government should fully utilize the "dividend" effect of digital economy in allocation of capital, and guide the rapid development of digital economy. The construction of digital economy infrastructure should be improved and policies such as tax subsidies and preferential tax rates should be actively implemented to provide good protection for digital economy. It is necessary to accelerate the digitization of industries and digital industrialization, and to expand the new space for the development of the real economy with digitization.

Third, the government should promote the reform of the financial system and enhance the cultivation of talents. Research shows that financial development and talent agglomeration reinforce the inhibiting effect of digital economy on capital misallocation. Therefore, financial development and talent agglomeration should be taken as an important grip to alleviate capital misallocation. The government should accelerate the improvement of the financial market system, improve the information disclosure system of financial institutions, alleviate the problem of "difficult and expensive financing" faced by enterprises. A financing environment that is suitable, open and inclusive should be provided. The government should aim at the development direction of digital economy, focus on introducing and training scientific and technological talents, especially digital economy talents, and accelerate the establishment of a comprehensive, systematic and professional training and training system for digital economy talents.

Appendix

See Table 9

Table 9 Digital economy indicator system

First level indicators	Second level indicators	Third level indicators
Digital economy development carrier (DEDC)	Traditional infrastructure	Investment in the electricity, gas and water production and supply sectors
		Investment in the Transportation, storage and postal sectors
		Investment in the information transmission computer services and software sectors
		Investment in the health social security and social welfare sectors
	New digital infrastructure	Number of Internet broadband access ports
		Number of domain names
		Percentage of IP addresses
Digital industrialization (DI)	Communication manufacturing industrialization	Mobile communication phone production
		Microcomputer production
	Communication business industrialization	Total telecommunication business
		Mobile phone year-end subscribers
		Long distance fiber optic cable line length
	Communication service industrialization	Number of enterprises
		Information technology service revenue
		Information services and software industry employees
Industrial digitalization (ID)	Agriculture digitalization	Value added of traditional agriculture
		Rural electricity consumption
	Industrial digitalization	Industrial value added
		Expenditure on technical transformation of industrial enterprises above the scale
		Share of sales revenue in main business revenue of industrial enterprises above scale
	Service digitalization	Service industry value added
		Number of parcels delivery
		Per capita consumption expenditure on transportation and communication
		Per capita consumption expenditure on culture, education and entertainment

Table 9 (continued)

First level indicators	Second level indicators	Third level indicators
Digital economy development environment (DEDE)	Institutional environment	Marketization index
	Innovation environment	Intellectual property protection
		Innovation factor input intensity

Acknowledgements This study is supported by the National Social Science Foundation of China (20BJL032), the Natural Science Foundation of Shandong Province (ZR2021MG020), the Key R&D Program Project of Shandong Province (2022RZA02012).

Declarations

Conflict of interest The authors have no competing interests to declare that are relevant to the content of this article.

References

Abeliansky AL, Hilbert M (2017) Digital technology and international trade: is it the quantity of subscriptions or the quality of data speed that matters? Telecommun Policy 41(1):35–48

Acemoglu D, Restrepo P (2018) The race between man and machine: Implications of technology for growth, factor shares, and employment. Am Econ Rev 108(6):1488–1542

Ahmad N, Schreyer P (2016) Are GDP and productivity measures up to the challenges of the digital economy? Int Prod Monit 30:4

Alam MJ (2020) Capital misallocation: cyclicality and sources. J Econ Dyn Control 112:103831

Asongu SA, Moulin B (2016) The role of ICT in reducing information asymmetry for financial access. Res Int Bus Financ 38:202–213

Banalieva ER, Dhanaraj C (2019) Internalization theory for the digital economy. J Int Bus Stud 50(8):1372–1387

Banerjee AV, Moll B (2010) Why does misallocation persist? Am Econ J Macroecon 2(1):189–206

Bartelsman E, Haltiwanger J, Scarpetta S (2013) Cross-country differences in productivity: the role of allocation and selection. Am Econ Rev 103(1):305–334

Basu S, Fernald J (2007) Information and communications technology as a general-purpose technology: evidence from US industry data. Ger Econ Rev 8(2):146–173

Brandt L, Tombe T, Zhu X (2013) Factor market distortions across time, space and sectors in China. Rev Econ Dyn 16(1):39–58

Buera FJ, Shin Y (2013) Financial frictions and the persistence of history: a quantitative exploration. J Polit Econ 121(2):221–272

Buesa M, Heijs J, Baumert T (2010) The determinants of regional innovation in Europe: a combined factorial and regression knowledge production function approach. Res Policy 39(6):722–735

Bun JGM, de Winter J (2022) Capital and labor misallocation in the Netherlands. J Prod Anal 57(1):93–113

Caputo F, Cillo V, Candelo E, Liu Y (2019) Innovating through digital revolution: the role of soft skills and big data in increasing firm performance. Manag Decis 57(8):2032–2051

Chen S, Lin B (2019) Dual-track interest rates and capital misallocation. China Econ Rev 57:101338

Chen S, Zhang H (2021) Does digital finance promote manufacturing servitization: micro evidence from China. Int Rev Econ Financ 76:856–869

Chen X, Teng L, Chen W (2022) How does FinTech affect the development of the digital economy? evidence from China. North Am J Econ Financ 61:101697

Choi C, Yi MH (2009) The effect of the Internet on economic growth: evidence from cross-country panel data. Econ Lett 105(1):39–41

David JM, Venkateswaran V, Cusolito AP, Didier T (2021) Capital allocation in developing countries. World Bank Econ Rev 35(4):1102–1121

Ding S, Jiang W, Li S, Wei S (2018) Fiscal policy volatility and capital misallocation: evidence from China. In: ASSA Annual Meeting, Philadelphia, PA

Elhorst JP (2014) Spatial econometrics from cross-sectional data to spatial panels. Springer

Fan F, Lian H, Wang S (2020) Can regional collaborative innovation improve innovation efficiency? An empirical study of Chinese cities. Growth Chang 51(1):440–463

Goldfarb A, Tucker C (2019) Digital economics. J Econ Lit 57(1):3–43

Hsieh CT, Klenow PJ (2009) Misallocation and manufacturing TFP in China and India. Q J Econ 124(4):1403–1448

Lee CC, He ZW, Wen H (2022) The impact of digitalization on green economic efficiency: empirical evidence from city-level panel data in China. Energy Environ. https://doi.org/10.1177/0958305X221124225
LeSage J, Pace RK (2009) Introduction to spatial econometrics. Chapman and Hall/CRC, Boca Raton
Li M, Du W (2021) Can Internet development improve the energy efficiency of firms: empirical evidence from China. Energy 237:121590
Li D, Chen Y, Miao J (2022a) Does ICT create a new driving force for manufacturing?—evidence from Chinese manufacturing firms. Telecommun Policy 46(1):102229
Li J, Chen L, Chen Y, He J (2022b) Digital economy, technological innovation, and green economic efficiency—Empirical evidence from 277 cities in China. Manag Decis Econ 43(3):616–629
Lileeva A, Trefler D (2010) Improved access to foreign markets raises plant-level productivity… for some plants. Q J Econ 125(3):1051–1099
Lin J, Yu Z, Wei YD, Wang M (2017) Internet access, spillover and regional development in China. Sustainability 9(6):946
Liu Y, Zeng JY, Wang RY, Zhan PY, Pan ZL (2019) The relationship between geographical concentration of researchers and regional innovation in China. Econ Geogr 39(7):139–147
Ljungwall C, Tingvall PG (2015) Is China different? A meta-analysis of the growth-enhancing effect from R&D spending in China. China Econ Rev 36:272–278
Love I (2003) Financial development and financing constraints: International evidence from the structural investment model. Rev Financ Stud 16(3):765–791
Lyu Y, Wang W, Wu Y, Zhang J (2023) How does digital economy affect green total factor productivity? Evidence from China. Sci Total Environ 857:159428
Mayo JW, Wallsten S (2011) From network externalities to broadband growth externalities: a bridge not yet built. Rev Ind Organ 38(2):173–190
Myovella G, Karacuka M, Haucap J (2020) Digitalization and economic growth: a comparative analysis of Sub-Saharan Africa and OECD economies. Telecommun Policy 44(2):101856
Peitz M, Waldfogel J (eds) (2012) The Oxford handbook of the digital economy. Oxford University Press, Oxford
Ren S, Hao Y, Xu L, Wu H, Ba N (2021) Digitalization and energy: how does internet development affect China's energy consumption? Energy Econ 98:105220
Ren S, Li L, Han Y, Hao Y, Wu H (2022) The emerging driving force of inclusive green growth: does digital economy agglomeration work? Bus Strateg Environ 31(4):1656–1678
Restuccia D, Rogerson R (2017) The causes and costs of misallocation. J Econ Perspect 31(3):151–174
Rosin AF, Proksch D, Stubner S, Pinkwart A (2020) Digital new ventures: assessing the benefits of digitalization in entrepreneurship. J Small Bus Strateg 30(2):59–71
Ruziev K, Webber DJ (2019) Does connectedness improve SMEs' access to formal finance? Evid Post-Commun Econ Post-Commun Econ 31(2):258–278
Sandleris G, Wright ML (2014) The costs of financial crises: resource misallocation, productivity, and welfare in the 2001 argentine crisis. Scand J Econ 116(1):87–127
Schmidt S, Balestrin A, Engelman R, Bohnenberger MC (2016) The influence of innovation environments in R&D results. Revista De Administração (são Paulo) 51:397–408
Teece DJ (2018) Profiting from innovation in the digital economy: enabling technologies, standards, and licensing models in the wireless world. Res Policy 47(8):1367–1387
Thompson P, Williams R, Thomas B (2013) Are UK SMEs with active web sites more likely to achieve both innovation and growth? J Small Bus Enterp Dev 20(4):934–965
Tranos E, Kitsos T, Ortega-Argilés R (2021) Digital economy in the UK: regional productivity effects of early adoption. Reg Stud 55(12):1924–1938
Wamba SF, Gunasekaran A, Akter S, Ren SJF, Dubey R, Childe SJ (2017) Big data analytics and firm performance: effects of dynamic capabilities. J Bus Res 70:356–365
Wang H, Guo J (2021) The impact of innovative industrial cluster policy on regional innovation: evidence from a quasi-natural experiment in China. Discr Dyn Nat Soc 2021:1–12
Wang S, Li M (2022) Does industrial intelligence improve resource misallocation? An empirical test based on China. Environ Sci Pollut Res 29(51):77973–77991
Wu GL (2018) Capital misallocation in China: Financial frictions or policy distortions? J Dev Econ 130:203–223
Yang M, Yang F, Sun C (2018) Factor market distortion correction, resource reallocation and potential productivity gains: an empirical study on China's heavy industry sector. Energy Econ 69:270–279

Zhang J, Wang J, Yang X, Ren S, Ran Q, Hao Y (2021) Does local government competition aggravate haze pollution? A new perspective of factor market distortion. Socioecon Plann Sci 76:100959
Zhang J, Lyu Y, Li Y, Geng Y (2022) Digital economy: an innovation driving factor for low-carbon development. Environ Impact Assess Rev 96:106821
Zhao X, Liu C, Sun C, Yang M (2020) Does stringent environmental regulation lead to a carbon haven effect? Evidence from carbon-intensive industries in China. Energy Economics 86:104631
Zhou Y, Guo Y, Liu Y (2018) High-level talent flow and its influence on regional unbalanced development in China. Appl Geogr 91:89–98