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# The Impact of the Digital Economy on Transformation and Upgrading of Industrial Structure: A Perspective Based on the "Poverty Trap"

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**Abstract:** Breaking the "poverty trap" has gradually become the core topic of economic research. The transformation and upgrading of industrial structure is considered an essential means to break the "poverty trap". How to use the digital economy effect to change the allocation of capital and labor factors and realize the transformation and upgrading of industrial structure is a significant issue in this paper. The study focuses on examining the development of China's digital economy between 2013 and 2021, uses the entropy method to measure it, and conducts an empirical study through a fixed-effects model and an intermediary-effect model to investigate the influence and mechanism of the digital economy on industrial structure transformation and upgrading. The results indicate the following: Firstly, the digital economy plays a crucial role in facilitating the transformation and upgrading of industrial structure, and this conclusion was still robust even after controlling for a series of factors affecting the transformation and upgrading of industrial structure and correcting the endogenous estimation deviation by using instrumental variables. Secondly, through the heterogeneity analysis of regions with different economic development levels, it was found that compared with economically developed regions, economically backward regions need to pay more attention to the development of the digital economy. Thirdly, the examination of the mechanism revealed that the digital economy has realized the transformation and upgrading of industrial structure by optimizing the allocation of capital and labor. In this paper, Schumpeter's innovation theory is regarded as a new perspective to break the "poverty trap" and realize the transformation and upgrading of industrial structure, filling the gap in related research in this field. This study provides a suggestion for economically backward areas to break the "poverty trap" and provides theoretical support and practical guidance for the sustained economic growth of the whole country.

**Keywords:** digital economy; industrial structure transformation and upgrading; poverty trap



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## 1. Introduction

In recent years, the global economy and trade have entered a historic transformation period due to the intensification of trade conflicts among various countries as well as challenges in cross-border financing and investment. In this significant transformation, emerging economies have gradually taken the lead in driving global economic growth, while technological innovation and globalization have further expanded the geographical scope of trade. Consequently, enterprises need to not only adapt to the rapid changes in technology and industry, but they also face intensified market competition and deep integration of cross-border markets [1–4]. This situation compels countries to re-evaluate their economic strategies [5]. Data from the World Bank's "Poverty and Common Prosperity Report" show that the number of areas trapped in poverty around the world is gradually increasing, making the goal of eradicating extreme poverty by 2030 increasingly difficult [6]. This phenomenon is consistent with what Banerjee and Duflo, the 2019 Nobel Prize winners in economics, described in their book "Poor Economics" [7]. Many developing countries that have gotten rid of the "poverty trap" and are steadily moving toward a high-income state may see their income drop sharply due to various economic shocks, and some countries may even slide from the middle class to the edge of poverty.

It is a challenge for developing countries to get rid of the "poverty trap". Compared with developed countries, they often have a weak economic foundation and a single industrial structure, and their leading industries have a low position in the global value chain, mainly relying on low-end and low-value-added industries, which are easily affected by external economic fluctuations. The existing research points out that this kind of industrial structure may cause a region or country to be particularly vulnerable to global economic instability [8,9]. In order to get rid of the "poverty trap" and ensure sustained and steady economic growth, these countries or regions must deeply adjust and optimize their industrial structures and turn to higher value-added and technology-oriented industries [10,11]. Therefore, it is crucial to investigate the factors that influence industrial structure upgrading in order to prevent developing countries from falling into the "poverty trap".

Just as Schumpeter emphasized the importance of innovation to economic growth, in the process of economic development, the development speed and life cycle stages of different industries are different [12]. Some industries will gradually decline and withdraw from the market, and some industries will gradually grow and even dominate the market [13]. The dynamic change and development of this industry is the embodiment of industrial structure transformation and upgrading. The key to realizing the fundamental transformation and upgrading of industrial structure lies in continuously promoting technological innovation [14]. The digital economy has emerged as a key engine for technical innovation with the advancement of information and communication technology [15,16]. The core of the digital economy is information technology, including big data, cloud computing, artificial intelligence, etc. These technologies facilitate transforming and updating the industrial structure through enhancements in production efficiency, transaction cost reduction, and innovation stimulation. The digital economy, centered on information technology, offers businesses a pathway to undergo digital transformation to enhance their market competitiveness [17]. As more companies adopt these digital approaches, the entire industrial sector benefits, experiencing not only reduced production costs [18] and increased efficiency [19] but also the stimulation of greater innovation, leading to the transformation and upgrading of the industrial structure [20–23]. Although the digital economy brings many opportunities, there are also challenges. Some scholars believe that the digital economy's rapid growth could exacerbate particular industries' overconcentration and cause an imbalance in the industrial structure. [24]. Specifically, over-reliance on the digital economy could hinder the growth of the actual economy, especially for some traditional industries, which may face the risk of being eliminated if they cannot adapt to the digital transformation in time [25,26]. In addition, some argue that because the digital economy is a relatively new industry, it requires significant capital investment in its early stages, which accelerates its growth in economically developed areas while leaving economically underdeveloped areas with inadequate infrastructure, exacerbating the uneven development of regional industries [27,28]. This unbalanced development will further speed up the backward areas falling into the "poverty trap" [29]. Moreover, as the digital economy changes the traditional production mode, factors of production such as capital and labor force flow from economically backward areas to economically developed areas, resulting in stronger monopoly power and impacting the stability of industrial structure in economically backward areas [30–33].

Despite several studies examining the impact of the digital economy on the transformation and upgrading of industrial structure, scholars have considerable disagreement, and many problems need further study. First, does the digital economy promote the transformation and upgrading of industrial structure and prevent the "poverty trap"?

Second, what is the internal mechanism of the digital economy driving industrial structure upgrading (especially in how the digital economy affects the allocation of labor and capital)? Third, what disparities exist in the influence of the digital economy on industrial structure transformation at different levels of economic development? At the same time, most existing research is based on qualitative analysis and does not specifically address developing countries. By examining the connection between the digital economy and the upgrading and transformation of the industrial structure from the perspectives of the "poverty trap" and Schumpeter's innovation theory, this study aims to close the gaps in the literature. Firstly, we apply Schumpeter's innovation theory throughout the entire digital-economy-driven industrial structural transformation and upgrading while considering the macro-, meso-, and microdimensions. Following that, we explore how the digital economy facilitates this transformation and upgrading from the perspectives of capital and labor paths. To analyze the relationship between them more thoroughly, in this research paper, the chosen methodologies include the entropy method and the fixed-effects model. The entropy method can effectively determine the weight of each variable. Meanwhile, the fixed-effects model is helpful in capturing and controlling unobservable individual heterogeneity, thus ensuring the accuracy of estimation. As the country with the largest digital economy among developing countries, China gave the digital economy a core position in its macroeconomic strategy in 2012 [34]. However, due to the influence of historical issues, some economically backward areas are still prone to falling into the "poverty trap". Therefore, based on this theoretical framework, we use China's economic data from 2013 to 2021 to conduct empirical analysis. The results demonstrate that the digital economy significantly and positively promotes the transformation and upgrading of industrial structures. The digital economy indirectly influences this transformation and upgrading by enhancing labor and capital factors.

This paper utilizes quantitative analysis to discover the correlation between the digital economy and the transformation and upgrading of industrial structures in developing countries. We will particularly focus on how the digital economy impacts the allocation of labor and capital, aiming to assist entrepreneurs and managers in understanding the influence of the digital economy on the industrial structure and how to effectively transition and upgrade. Additionally, we will examine its role in economically underdeveloped areas caught in the "poverty trap" with the intention of aiding policymakers in recognizing the risks and challenges brought by the digital economy and in formulating corresponding strategies and measures to ensure that talent training, education, and social welfare policies keep pace with the times. In comparison to past research, the innovative aspects of this study are primarily reflected in two areas: On the one hand, taking Banerjee's "poverty trap" as a starting point, it explores how the digital economy influences the transformation and upgrading of industrial structures, providing a fresh perspective on the correlation between the digital economy and industrial transformation. The other, this study combines Schumpeter's innovation theory to discuss the influence of the digital economy on the transformation and upgrading of industrial structure from the macro-/meso-/microdimensions, which broadens the application field of Schumpeter's innovation theory.

The primary contributions of this study are outlined below: First, it develops a theoretical model for the impact of the digital economy on industrial upgrading, enriching research findings on the digital economy and industrial structural transformation and upgrading, and expanding research on the causative factors of industrial upgrading. Second, it utilizes empirical research to reveal the underlying mechanisms by which the digital economy influences industrial upgrading, thereby opening up parts of the "black box" of mediating mechanisms and offering clearer strategic direction for labor and corporate decision-makers. Third, it explores the effect of the correlation between the digital economy and industrial transformation and upgrading within the context of developing countries. This addresses the existing gap in attention given to developing countries in current research, providing practical policy recommendations for policymakers and offering reference for developing countries to escape the "poverty trap" and achieve "common prosperity".

## 2. Theoretical Logic and Mechanism Analysis

### 2.1. Theoretical Logic

In his 1939 theory of economic cycles, renowned economist Schumpeter proposed that economic systems do not exhibit steady, linear development. Instead, they experience a cyclical flow consisting of "prosperity—recession—depression—recovery". When the economy is at a low point in the cycle, innovation plays a crucial role, effectively breaking this cycle and reshaping and expanding existing industrial and exchange structures [35,36]. Such innovation is not limited to new products or technologies. In his innovation theory, he further identifies five forms of innovation: new products, new technologies, new markets, new resource allocations, and new organizational structures for production. Behind these various innovative activities is the driving force of entrepreneurial spirit. Schumpeter emphasized the indispensable intrinsic connection between this entrepreneurial spirit and innovation, asserting that only true entrepreneurs can identify and seize the opportunities presented by innovation. He was also firm in his belief that systemic innovation is the key to driving economic progress. Among all innovation strategies, those that place the market and customers at the center are the most crucial. This approach not only ensures that innovative activities are closely tied to market needs but also makes innovation more targeted and effective [12]. Scholars like Eliasson, building upon Schumpeter's innovation theory, have suggested in their research that an economy's developmental capacity depends not solely on external conditions but more importantly on its intrinsic drive—its innovative capability [37]. This innovative capability not only propels the economy forward but also profoundly influences market structure [38], thereby determining industrial upgrading and transformation and further shaping the overall landscape of the economy.

In order to enhance comprehension regarding the manner in which the digital economy drives the transformation and upgrading of industrial structures as well as its potential role in breaking the "poverty trap", it is necessary to begin with Schumpeter's theory of innovation and investigate its impact at the macro-, meso-, and microlevels. This research methodology will facilitate a deeper understanding of the digital economy regarding innovation and its significance in transformation of industrial structure.

#### 2.1.1. Macrolevel

At the macrolevel, when integrating Schumpeter's economic cycle theory, the digital economy serves as a catalyst for economic advancement and not only represents innovative economic fluctuations but also holds the potential to break through the traditional "poverty trap".

Traditionally, many regions have been stuck in this trap due to a lack of capital, technology, and labor, making it difficult for them to achieve sustained economic and social progress. The emergence of the digital economy revitalizes these domains. Due to the pervasive utilization of digital technology, the marginal cost of acquiring information and expertise has significantly decreased, providing greater opportunities to participate in economic activities. This underscores the key role of technology and innovation in driving economic development forward [39]. The digital economy offers new production tools and business models to regions that have long been economically disadvantaged, expanding their consumer markets. These changes not only significantly enhance production efficiency but also give rise to entirely new consumer demands [40], providing momentum for economic growth. Therefore, advancements in digital technology not only stimulate emerging industries but also challenge traditional ones. This in turn facilitates the process of transformation and upgrading of the industrial structure, helping economically disadvantaged regions to break out of the "poverty trap" and enter the next cycle of economic activity.

2.1.2. Mesolevel

At the mesolevel, Schumpeter's five innovative forms provide a powerful analytical framework to analyze how the digital economy can help regions break through the "poverty trap" and realize industrial structure change [12].

First, the digital economy demonstrates innovation in the realm of products. It drives the advancement of cutting-edge technologies, aids the improvement of traditional products and services, and gives birth to entirely new digital products and services [41]. These new products meet consumer demands for efficiency, intelligence, and personalization, thereby stimulating consumer upgrades and industrial innovation. Secondly, with technological innovation as its core driving force, the digital economy not only effectively improves production efficiency but also fosters cross-industry technological integration and innovation, injecting new vitality into the entire industrial development [42,43]. Thirdly, the digital economy both broadens market boundaries and creates entirely new markets and consumer groups on a global scale. For instance, the rise of cross-border e-commerce allows goods and services to circulate more rapidly, breaking geographical and national boundaries, gaining new consumer markets, and promoting external industrial expansion [44]. Fourthly, resource allocation based on digital technology is more precise and efficient. With the support of this technology, limited resources can be used more effectively, ensuring liquidity within the entire economic system. Moreover, through deep analysis of big data, optimal resource allocation can be achieved, thereby enhancing production efficiency and economic benefits [45]. Fifthly, the digital economy brings about revolutionary changes in industrial organization. Influenced by the digital economy, traditional industrial organizational models are being reshaped with a greater emphasis on efficient connections and collaborations between supply and demand. This transformation not only optimizes resource utilization and improves economic efficiency but also opens new avenues for value creation [46,47].

In summary, through these five forms of innovation, the digital economy has robust momentum in facilitating the transformation and upgrading of industrial structures. It offers residents in various regions powerful means to increase income, improve productivity, and ultimately break the "poverty trap", entering a new cycle of economic development.

2.1.3. Microlevel

At the microlevel, the digital economy invigorates market entities, aiding in the transformation and upgrading of industrial structures. Enterprises serve as decision makers and drivers of innovation at this level, directly shaping market competition and thereby influencing the structure and dynamic evolution of industries. Schumpeter's innovation theory also provides us with a theoretical framework for understanding how the digital economy facilitates industrial structure transformation and upgrading by stimulating the innovative vitality of companies [12].

Firstly, in the digital age, the entrepreneurial spirit emphasized by Schumpeter is imbued with deeper meaning. Entrepreneurial activities become key driving forces of economic development. In this era of increasing informatization and digitization, entrepreneurs can identify and exploit new business opportunities and create new combinations of production factors, which afterward facilitate the upgrading and transformation of industrial structures [48,49]. This view aligns with that of the Austrian School of Economics by emphasizing that the market is a dynamic process driven by innovation.

In addition, Schumpeter's theory emphasizes the core significance of systemic innovation in the transformation of industrial structures. The digital economy serves as a critical driver for systemic innovation, enabling companies to better understand market demands, customer behaviors, and competitor dynamics, thereby formulating more precise and targeted innovation strategies. When enterprises innovate in a sustained and systematic manner, the industry as a whole gradually transforms and upgrades, forming a new structure that is more efficient, flexible, and responsive to market changes. Therefore, the digital economy not only increases the success rate of corporate innovation but also facilitates the transformation and upgrading of industrial structures on a broader scale [50].

Lastly, innovation focused on market and consumer needs is especially critical in the digital economy era. With the rapid advancement of information technology, market and consumer demands are changing quickly. Schumpeter's theory suggests that only innovations that deeply understand and rapidly respond to market and consumer demands can succeed. By offering technologies like big data analytics, the digital economy enables companies to detect market trends, identify consumer preferences, and quickly adjust innovation strategies.

The digital economy has a dual effect of enhancing the efficacy of business innovation and driving the overall transformation and advancement of industrial structures. As enterprises improve their economic performance, this directly influences residents' income. Increased income undoubtedly helps residents and even entire societies escape the "poverty trap".

### 2.2. Mechanism Analysis

The digital economy has emerged as a prominent catalyst for the transformation and upgrading of industrial structures as the global economy undergoes a rapid process of digitalization. To understand and analyze the inherent mechanisms behind this transformation, this article adopts the perspectives of two fundamental factors: capital and labor. The aim is to explore in-depth how the digital economy impacts these elements to break free from the "poverty trap" and thereby promote industrial structural transformation and upgrading.

From a capital standpoint, in the historical processes of industrialization and modernization, capital has been considered a key driving force. For instance, Rosenstand-Rodin's "Big Push" theory holds that when developing countries or regions fall into a bottleneck period with relatively weak economic development capacity, in order to break through the bottleneck, they must invest in industries or industries in a targeted, large-scale, and rapid manner [51]. Nurkse's "vicious cycle of poverty" theory emphasizes that the primary cause of poverty and underdevelopment in developing countries lies in their own capital insufficiency. In the macroeconomic operations of developing countries, they face vicious cycles of both demand deficiency and supply deficiency. These two aspects influence each other, persistently recur, and constitute a long-term vicious cycle. They are the primary reasons that lead to poverty and underdevelopment in these countries or regions, making economic advancement difficult to achieve [52]. However, the digital economy, as an advanced evolutionary stage or derivative form of the industrial economy [53], provides a new lens through which issues of capital scarcity and poverty traps can be seen. By integrating modern elements like information technology, data analytics, and network connectivity, the digital economy revolutionizes traditional methods of capital allocation and flow. In the context of the digital economy, efficient online platforms minimize information asymmetry and search costs, facilitating more precise and efficient matches between investors and fundraisers [54]. These changes not only alleviate mismatches in the supply and demand of capital across industries and regions but also accelerate the scope and speed of capital flows. Importantly, by enhancing the precision and effectiveness of capital allocation [55], the digital economy addresses the capital shortages pointed out by Rosenstein-Rodan and Nurske. Therefore, driven by the digital economy, capital not only serves as a key support for transforming and upgrading industrial structures but also offers an effective solution to the "poverty trap".

From a labor standpoint, under the background of the "poverty trap" and economic stagnation, the quality of labor, skills training, and labor mobility are seriously restricted. The lack of appropriate education and training opportunities makes it difficult for the labor force to adapt to the needs of new industries, further aggravating the difficulties of economic development. As Schultz [56] and Becker [57] believe in the theory of human capital, a high-quality labor force is the key to improving production efficiency and promoting economic development. It is believed that we should attach great importance to the investment of the labor force while attaching importance to the investment of material capital. Skilled investment in basic education and on-the-job training can not only improve the national quality and increase the stock of social capital but also improve the regional comparative advantage and industrial competitiveness. It can be seen that high-quality labor may both increase production efficiency and aid in the transformation and upgrading of the industrial structure. The enhancement of labor quality mainly depends on investment in physical strength and education. The low education and low skill level of the labor force will lead to a reduction in production efficiency and then form a vicious circle, which will cause the economy to stagnate and fall into the "poverty trap". In this context, the digital economy provides robust tools to break this deadlock. Specifically, digital platforms for online education and remote training lower the costs and barriers to skills and educational improvement, offering more individuals opportunities to develop their capabilities [58]. Additionally, the digital economy alters the dynamics of the labor market. For instance, remote work and digital labor free labor from time and location constraints. This not only improves the efficiency of labor utilization but also helps to better balance labor supply and demand [59]. Thus, the digital economy provides new avenues for enhancing labor quality and, by altering the way the labor market operates, further drives the transformation and upgrading of industrial structures.

## 3. Model Settings and Sample Selection

### *3.1. Model Setting*

In 2012, the Chinese government formally defined the digital economy as an inevitable choice for the new round of technological revolution and industrial transformation. Therefore, the selection of 2013 as the starting point is appropriate, as it marks the first year the government officially implemented relevant policies. Next, we examine the effects of the digital economy on the modernization and transformation of the industrial structure using panel data from 30 Chinese provinces from 2013 to 2021 (this analysis excluded Tibet, China, Hong Kong, Macao, and Taiwan due to data restrictions). During the data analysis phase, we performed a Hausman test. The test findings suggested that the fixed-effects model demonstrated greater robustness in its estimations. Moreover, the fixed-effects model was capable of controlling for unobserved individual heterogeneity that remained constant over time, thereby ensuring that the estimations were not biased due to omitted variables. Based on these considerations, we opted for the fixed-effects model. The empirical setting model is as follows:

$$Indust_{it} = \alpha_0 + \alpha_1 digital_{it} + \alpha_c X_{it} + \varepsilon_{it} \quad (1)$$

where $Indust_{it}$ refers to the level of industrial upgrading in province $i$ in year $t$. This paper measures from two perspectives: $Indust_1$ for the advanced level of industrial structure and $Indust_2$ for the rational level of industrial structure. $Digital_{it}$ refers to the digital economy development situation of province $i$ in year $t$, $X_{it}$ is other control variables, $\alpha_0$ is the intercept, $\alpha_1$ is the estimated parameter of the core explanatory variable, and $\varepsilon_{it}$ is the random disturbance term.

We drew on the methodologies of Baron and Kenny [60] and Wen et al. [61] to analyze the mediating impacts of capital and labor in the context of the digital economy's role in supporting the transformation and upgrading of industrial structures. We used capital allocation and labor allocation levels to investigate the mediating role of the digital economy on industrial structure. The stepwise regression method consists of three primary steps. First, it is imperative to assess the relationship between the independent variable and the dependent variable, as represented by Equation (1). Second, the association between the independent variable and the mediating variable should be examined, as indicated in Equation (2). Third, include the explanatory variable, mediating variable, and dependent variable in the model and test them together, as represented by Equation (3). The specific equations are as follows:

$$labor_{it}/capital_{it} = \beta_0 + \beta_1 digital_{it} + \beta_c X_{it} + \varepsilon_{it} \quad (2)$$

$$Indust_{it} = \gamma_0 + \gamma_1 dig_{it} + \gamma_2 capital_{it}/labor_{it} + \lambda_c X_{it} + \varepsilon_{it} \quad (3)$$

where $capital_{it}$ is the level of capital allocation and $labor_{it}$ is the level of labor allocation. These were our mediating variables in this study. $X_{it}$ is other control variables; $\beta_0$ and $\gamma_0$ are intercepts; $\beta_1$, $\gamma_1$, and $\gamma_2$ are estimated parameters of variables; and $\varepsilon_{it}$ is the random disturbance term.

*3.2. Indicator Selection and Data Sources*

Dependent Variable: *Indust* refers to the continuous adjustment of industrial structure and coordinated development of the industries' aim to meet the growing diversified needs of people's lives and can act as a key catalyst for economic progress. Generally, the transformation and upgrading of the industrial structure imply achieving both a more advanced and rational industrial structure [62]. This study elaborates on metrics for these two aspects. Industrial Structure Advancement ($Indust_1$): This paper adopted the measurement methodology from research by Xu Deyun et al. [63] to gauge the advancement of industrial structures. The transformation of industrial structures is a continual process of moving from lower to higher levels as primarily measured by the proportional relationship among primary, secondary, and tertiary industries as well as labor productivity across these industries. Here, $y_j$ is the proportion of income for the *j* industry.

$$Indust_{1it} = \sum_{j=1}^{3} \frac{Y_{i,j,t}}{Y_{i,t}} \cdot \frac{Y_{i,j,t}}{L_{i,j,t}} \quad j = 1,2,3 \quad (4)$$

The rationalization of the industrial structure ($Indust_2$) is an important part of industrial structure transformation and upgrading, forming the foundation for the advancement of the industrial structure. A reasonable industrial structure can reflect the effective allocation of various factor resources, achieve balanced development among various industries, and thereby maximize the utilization efficiency of labor factors. Such an industrial structure not only promotes coordination and balance among industries but also avoids over-reliance on a specific resource or industry, reflecting the health and sustainability of a country or region's economic development. The measurement of the rationalization of the industrial structure mainly refers to the method of Gan Chunhui [64], which serves as an indicator of the extent to which the industrial structure deviates. As the magnitude of the value increases, the industrial structure becomes increasingly irrational. The specific equation is as follows:

$$Indust_{2it} = \sum_{j=1}^{3} \frac{Y_{i,j,t}}{Y_{i,t}} \cdot \ln\left(\frac{Y_{i,j,t}}{Y_{i,t}} / \frac{L_{i,j,t}}{L_{i,t}}\right) \quad j = 1,2,3 \quad (5)$$

where $Y_{ijt}$ refers to the industrial added value of the *j* industry in the *i* region in year *t*, and $L_{ijt}$ refers to the number of employees in the j industry in the *i* region in year *t*. Since the $\frac{Y_{i,j,t}}{L_{j,j,t}}$ term has dimensions, we used the normalization method to make this term dimensionless.

Independent Variable: Level of Digital Economy Development (digital): This study utilized methodologies from the CITIC Research Institute, Zhao Tao [65], Zhang Yunping [66], and other scholars to construct an assessment system for the digital economy's development. Factors included the number of broadband internet users per 100 people, the proportion of computer services and software industry employees among urban unit employees, the per capita telecommunication service volume, mobile phone users per 100 people, and the China Digital Financial Inclusion Index. These factors were weighted through entropy methods to construct an index of digital economy development level.

Mediating Variables: Capital Level (capital) is a crucial factor in production that can influence production efficiency. The allocation and utilization of capital are directly related to the transformation and optimization of industrial structures. To quantify the effective allocation and utilization of capital, this study selected the ratio of outstanding loans to deposits in financial institutions as a proxy variable for the capital level. The size of this number reflects the capital utilization efficiency of financial institutions. Labor Quality Level (labor): Considering the digital economy, highly skilled and quality labor is crucial and irreplaceable. Despite the growing importance of high-skilled labor in the digital economy, such talent remains a scarce resource. Therefore, the level of higher education becomes an important indicator for measuring labor quality. In this context, we chose the proportion of students in higher education institutions relative to the total population as an indicator to measure labor quality.

Measurement of Other Control Variables. (1) Economic Development Level (pergdp): The economic development levels vary among different provinces, and economic advantages are significant drivers for the transformation and upgrading of industrial structures. This study used the logarithm of per capita GDP to measure the economic development level. (2) Marketization Level (market): Economies with a higher degree of marketization typically rely more on market mechanisms for resource allocation. Such methods of allocation usually better reflect the real demand–supply relationships and thus influence the formation and transformation of industrial structures. This study used a marketization index as the metric for measurement. (3) Population Density (population): The population size and density in different regions influence the region's industrial structure. High-end industries are developed based on the provision for people's regular life needs. This study measured population density as the total population of the area divided by the urban area size. (4) Foreign Direct Investment Level (fdi): Foreign direct investment can bring new technologies and management experiences, but it tends to concentrate in higher-yield industries, which might exacerbate the imbalance in the industrial structure. This study measured this by taking the ratio of foreign direct investment to GDP. Fiscal Intervention Level (fiscal): The government is a crucial component of national economic development. The scale and structure of the government will impact the transformation and upgrading of the industrial structure. The fiscal scale in this study is represented by the ratio of fiscal expenditure to GDP.

Relevant data came from the *China Statistical Yearbook*, *China Financial Yearbook*, *China Provincial Statistical Yearbook*, and *China Provincial Marketization Index Report*, and some missing data were supplemented with statistical annual reports of some cities or the calculation of the average annual growth rate.

### *3.3. Evaluation Methodology*

In comprehensive evaluations, both subjective weighting methods and objective weighting methods are commonly utilized. To ensure the authenticity of data calculations and minimize human errors, this study adopted the objective weighting method. Within this approach, the entropy method, rooted in the principles of information theory, is not constrained by the data type and distribution. It is adaptable to various data sets and is capable of handling vast amounts of data [67,68]. Hence, we opted for the entropy method as our evaluation tool. The evaluation model comprised a set of distinct steps, which are outlined in this order:

$$\text{Positive indicator}: Var'_{it} = \frac{var_{it} - var_{min}}{var_{max} - var_{min}} \quad (6)$$

$$\text{Negative indicators}: Var'_{it} = \frac{var_{max} - var_{it}}{var_{max} - var_{min}} \quad (7)$$

In Equation (6), it was primarily used to calculate positive indicators, where a higher value was more favorable for the development of the digital economy. Equation (7) was primarily for negative indicators, where a lower value was more desirable. $Var'_{it}$ represents the standardized data for indicator $i$ in year $t$, while $Var_{it}$ denotes the original data. $Var_{min}$ and $Var_{max}$ are the minimum and maximum values of the selected indicator, respectively.

$$\text{Determine indicator weights}: y_{it} = \frac{var'_{it}}{\sum\limits_{t=1}^{m} var'_{it}} \quad (8)$$

$$\text{Calculate the entropy value of the index } i\ : e_i = -k\sum_{t=1}^{m} (y_{it} \times \ln y_{it}) \quad (9)$$

$$\text{The information utility value of the indicator } i : d_i = 1 - e_i \quad (10)$$

$$\text{The weight of each indicator}: w_i = \frac{d_i}{\sum\limits_{t=1}^{n} d_t} \quad (11)$$

$$\text{Calculate the composite score of the indicator}: index_t = \sum_{t} (w_t \times var'_{it}) \quad (12)$$

### 3.4. Descriptive Statistics

Table 1 shows the descriptive statistics of the key variables for regression analysis. It can be observed that since 2013, China's industrial development has shown a dual trend of becoming more advanced and rational, marking a gradual transformation and upgrade of the industrial structure. Specifically, the mean value of the index for industrial structure advancement increased from 2.350 in 2013 to 2.435 in 2021. This indicates that China has been gradually moving toward industries with higher added value during this period. Meanwhile, the index for the rationalization of the industrial structure also gradually declined from 0.216 to 0.109. Simultaneously, the level of digital economic development also improved, rising from 0.243 in 2013 to 0.255 in 2021. This observation implies that China's industrial structure has become more balanced and aligns more closely with the long-term goals of economic development. Furthermore, the digital economy has demonstrated a robust growth trend, with its development index increasing from 0.243 in 2013 to 0.255 in 2021, reflecting the increasingly important role of digital technology in economic development. Based on this data, a tentative conclusion can be made regarding the possible positive association between the process of upgrading and transforming the industrial structure and the expansion of the digital economy.

**Table 1.** Descriptive statistics of the variables.

| Variable | N | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| $Indust_1$ | 270 | 1.410 | 0.745 | 0.665 | 5.244 |
| 2013 | 30 | 2.350 | 0.122 | 2.132 | 2.788 |
| 2021 | 30 | 2.435 | 0.114 | 2.259 | 2.814 |
| $Indust_2$ | 270 | 0.170 | 0.115 | 0.008 | 0.565 |
| 2013 | 30 | 0.216 | 0.141 | 0.021 | 0.565 |
| 2021 | 30 | 0.109 | 0.076 | 0.008 | 0.283 |
| Digital | 270 | 0.170 | 0.115 | 0.008 | 0.565 |
| 2013 | 30 | 0.216 | 0.141 | 0.021 | 0.565 |
| 2021 | 30 | 0.109 | 0.076 | 0.008 | 0.283 |
| Capital | 270 | 0.816 | 0.152 | 0.446 | 1.192 |
| Labor | 270 | 0.021 | 0.005 | 0.009 | 0.042 |
| pergdp | 270 | 9.324 | 0.465 | 8.647 | 10.780 |
| market | 270 | 8.239 | 1.848 | 3.580 | 12.390 |
| population | 270 | 5.476 | 1.292 | 2.068 | 8.275 |
| fdi | 270 | 1.780 | 1.396 | 0.010 | 7.960 |
| fiscal | 270 | 0.252 | 0.102 | 0.106 | 0.643 |

Next, we used a scatter plot to more intuitively explore the correlation between the digital economy and industrial structure. Figure 1 demonstrates a positive correlation between the level of digital economic development and the progression toward more sophisticated industrial structures. This is consistent with our earlier statistical descriptions, further confirming the positive role of the digital economy in promoting the transformation of China's industries toward higher added value. Similarly, the negative association between the level of digital economic development and the rationalization of the industrial structure suggests that an increase in digital economic development will reduce the deviation in the industrial structure, promoting its rational development. The scatter plot lays the foundation for our empirical analysis, and we will explore their connection further.

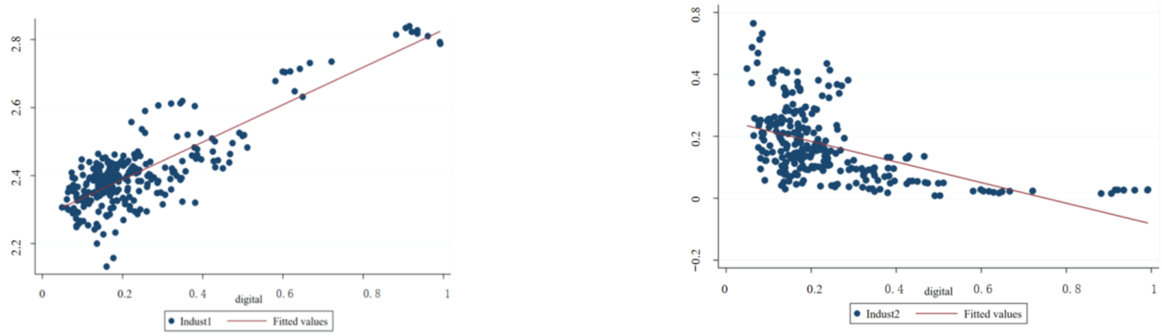


**Figure 1.** Scatter diagram.

## 4. Empirical Results Analysis

### *4.1. Result of Baseline Regression*

The panel regression findings for the 30 provinces in China from 2013 to 2021 are displayed in Table 2. Models (1) and (2) in Table 2, when employing bilateral fixed effects without incorporating control variables, a noteworthy positive association was seen between the degree of digital economic growth and the progress of industrial structure. Specifically, for every one-unit increase in the level of digital economic development, the index for industrial structure advancement improved by 0.077 units (β = 0.077, $p < 0.1$). Digital economic development significantly reduced the deviation index for industrial structure, promoting rationalization. For every one-unit increase in the level of digital economic development, the index for the rationalization of industrial structure decreased by 0.356 units (β = −0.356, $p < 0.01$). Models (3) and (4) in Table 2, we included control variables such as the economic development level, marketization level, population density, foreign direct investment level, and government intervention level, which are relevant to the transformation of industrial structure. The regression results obtained through the bilateral fixed-effects model revealed that even after including these control variables, the correlation between digital economic development and industrial structural transformation remained significant. That is, for every one-unit increase in the level of digital economic development, the index for industrial structure advancement rose by 0.1 units (β = 0.010, $p < 0.05$), while the index for the rationalization of industrial structure declined by 0.011 units (β = −0.011, $p < 0.1$).

### *4.2. Endogeneity Bias and Two-Stage Regression*

The analysis of the models presented in Table 2 demonstrates that a notable disparity exists in the regression coefficients both prior to and after the incorporation of control variables. The coefficient in Model (3) differed from that in Model (1) by nearly 0.07, while the coefficient in Model (4) differed from that in Model (2) by almost 0.34. This indicates that although we applied bilateral fixed-effects estimation and controlled for a range of variables to mitigate the impact of omitted variables that did not change over time, the regression results were still subject to endogeneity biases arising from omitted variables and other factors.

**Table 2.** Benchmark regression results.

| Variables | $Indust_1$ (1) | $Indust_2$ (2) | $Indust_1$ (3) | $Indust_2$ (4) |
|---|---|---|---|---|
| Digital | 0.077 * | −0.356 *** | 0.010 ** | −0.011 * |
| | (1.71) | (−3.03) | (0.004) | (0.006) |
| lnpergdp | | | 0.011 | 0.017 |
| | | | (0.39) | (0.25) |
| Market | | | 0.002 | −0.016 ** |
| | | | (0.81) | (−2.08) |
| Population | | | 0.057 | 0.131 |
| | | | (0.88) | (0.65) |
| fdi | | | −0.003 * | −0.011 *** |
| | | | (−1.83) | (v3.04) |
| Scale | | | 0.197 ** | 0.388 |
| | | | (2.28) | (1.46) |
| Time/region effect | NO | NO | YES | YES |
| Constant | 2.683 *** | 0.404 *** | 2.080 *** | −0.682 |
| | (62.82) | (3.59) | (4.87) | (−0.45) |
| Observations | 270 | 270 | 270 | 270 |
| R-squared | 0.979 | 0.888 | 0.980 | 0.900 |

Note: The robustness standard error is included in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. "YES" means the variable was regulated by the model. This also applies to the following tables.

The digital economy is an extension of information technology, meaning its development stems from the growth and widespread application of the information industry, which generally refers to productivity in areas such as communication, networking, and databases [69]. During the Republic of China period, China's telecommunications development lagged due to technical limitations compared to more advanced countries. By 1978, the telephone penetration rate in China was less than 0.5%, much less than the global average, hindering economic and social development. Since the opening-up and reform policy, China has vigorously promoted information technology construction, especially in basic telecommunications infrastructure [70]. Areas with historically high telephone penetration rates have deep-rooted foundations in information technology development. This background forms the foundation for the use of phone count as an instrumental variable connected to the degree of development of the digital economy. However, our estimation method used a bilateral fixed-effects model. If we used the number of landlines per million people in 1984 as an instrumental variable [71,72], these data lacked a temporal dimension and ran the risk of instrumental variable failure. To address this, we adopted the methodology of researchers like Nunn [73], using the interaction term between the 1984 count of landlines per million people and the previous year's national IT service income (*IV*) as an instrumental variable for digital economic development. Lastly, as smart communication methods become more widespread, traditional landline phones are gradually exiting the historical stage. Their geographical distribution is a product of a specific historical period and is not expected to impact the current state of excellent economic progress. Additionally, the national information technology service revenue from the previous year does not cause significant changes in provincial economic development, thus satisfying the exclusionary assumption for the instrumental variable.

The results of the two-stage regression with this instrumental variable are displayed in Table 3. For Model (1), we present the first-stage regression results of the number of landlines correlated with the digital economy. The F-statistic was 50.98, significantly larger than 10, indicating that the problem of weak instrumental variables was not present. Models (2) and (3) demonstrated that the influence of the digital economy on the advancement and rationalization of industrial structure is significant. This means that even after accounting for endogeneity issues, the conclusion that the development of the digital economy positively influences the transformation and upgrading of the industrial structure still holds.

**Table 3.** IV-2SLS regressions results.

| Variables | Stage I Digital (1) | Stage II $Indest_1$ (2) | Stage II $Indust_2$ (3) |
|---|---|---|---|
| Digital | | 0.574 *** | −2.310 ** |
| | | (0.191) | (1.159) |
| IV | −2.925 * | | |
| | (−1.90) | | |
| Constant | 20.471 *** | 2.250 *** | −1.407 |
| | (2.81) | (0.593) | (2.420) |
| Control variable/time/region effect | YES | YES | YES |
| Observations | 270 | 270 | 270 |
| R-squared | 0.889 | 0.968 | 0.676 |

Note: The robustness standard error is included in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The control variables included pergdp, market, population, fdi, and scale. This also applies to the table below.

### *4.3. Heterogeneity Test Based on Different Levels of Development*

China's expansive geography leads to significant regional variations in resource distribution and economic development levels. These regional disparities can in turn affect the development of the digital economy and its impact on the transformation and upgrading of the industrial structure. Two main factors contribute to this. First, areas with higher levels of economic development often have richer resources and more mature market environments, which can be conducive to developing the digital economy and its transformative impact on industrial structures. Conversely, areas with lower economic development may suffer from an imperfect market environment and a lack of digital technology infrastructure, which can hinder the development of the digital economy and its potential effect on the industrial structure. To explore these nuances, we segmented China's provinces into three categories—high, medium, and low economic development levels—based on their per capita GDP in 2013. Separate regression analyses were conducted for these categories to more accurately understand the specific impacts of digital economy development on industrial structural transformation.

Table 4 shows that although the digital economy had a notable positive impact on the industrial structure in all economic development levels, the effect differed among the low-, medium-, and high-development areas. Specifically, based on the results of Model (1) to Model (3) in Panel A, it was observed that as the level of economic development increased, the role of the digital economy in promoting the upgrading of industrial structure gradually weakened. The regression coefficients for low-, medium-, and high-level areas were 0.393 ($\beta = 0.393$, $p < 0.01$), 0.313 ($\beta = 0.313$, $p < 0.05$), and 0.236 ($\beta = 0.236$, $p < 0.01$), respectively. This trend implies that the digital economy has a stronger role in driving a more advanced industrial structure in areas characterized by comparatively lower levels of economic development. Based on Panel B's regression results, we further found that the digital economy had a significant impact on the rationalization of the industrial structure in low- and medium-level economic development areas, with coefficients of −0.445 ($\beta = -0.445$, $p < 0.1$) and −1.049 ($\beta = -1.049$, $p < 0.01$). In contrast, in high-level areas, the impact was not significant, indicating a more robust connection between the digital economy and industrial structure optimization in low- and medium-development regions. Table 4's Models (4)–(6) present estimates after excluding the data from the four municipalities. These estimates remained consistent with the prior results based on the full sample.

**Table 4.** Regression results under different levels of economic development.

| **Plan: A** | | | | | | |
|---|---|---|---|---|---|---|
| | **Low (1)** | **Medium (2)** | **High (3)** | **Low (4)** | **Medium (5)** | **High (6)** |
| Variables | | | $Indust_1$ | | | |
| Digital | 0.393 *** | 0.313 ** | 0.236 *** | 0.233 ** | 0.313 ** | 0.186 *** |
| | (4.33) | (2.16) | (3.60) | (2.14) | (2.16) | (3.52) |
| Constant | −0.361 | 1.728 *** | 1.223 *** | 1.230 * | 1.728 *** | 1.252 *** |
| | (−1.10) | (3.01) | (3.30) | (1.67) | (3.01) | (4.01) |
| R-squared | 0.759 | 0.544 | 0.952 | 0.724 | 0.544 | 0.937 |
| Plan: B | | | | | | |
| Variables | | | $Indust_2$ | | | |
| Digital | −0.445 * | −1.049 *** | 0.079 | −0.415 * | −1.049 *** | 0.252 ** |
| | (−1.76) | (−2.82) | (1.16) | (−1.74) | (−2.82) | (2.64) |
| Constant | −3.802 | −5.250 * | 4.018 *** | −2.878 | −5.250 * | 3.570 *** |
| | (−0.62) | (−1.74) | (5.31) | (−0.48) | (−1.74) | (5.60) |
| Control variable/time/ regional effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Observed | 90 | 90 | 90 | 81 | 90 | 63 |
| R-squared | 0.928 | 0.898 | 0.963 | 0.936 | 0.898 | 0.963 |

Note: The robustness standard error is included in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Based on the analysis above, it is evident that the digital economy holds unique significance for the transformation and upgrading of the industrial structure in regions with varying levels of economic development. This is particularly true for economically underdeveloped areas, where the growth of the digital economy has the potential to significantly accelerate industrial changes and facilitate the transformation and upgrading of the industrial structure. These underdeveloped regions often face a "poverty trap" due to the limitations of capital and labor that is characterized by a vicious cycle of low productivity, poor labor quality, and capital scarcity. However, with the rise of the digital economy, these areas have the opportunity to break out of this stalemate by improving capital efficiency, upgrading labor skills, and capitalizing on new market opportunities. The adoption of digital technologies has the potential to facilitate the transition and enhancement of the industrial structure, shifting it from conventional to modern and from low-value-added to high-value-added. Additionally, it can optimize the existing industrial structure, making it more rational. Consequently, this can help these areas escape the "poverty trap" and achieve more sustainable and balanced economic development.

### *4.4. Mediation Effect Test*

The empirical findings presented above consistently show that the digital economy has a significant influence on the industrial structure. As elaborated in the section that discusses mechanisms, the influence of the digital economy on industrial structure is mainly manifested through its effects on capital and labor levels. Let us examine these in detail.

Firstly, let us consider the impact of the digital economy on capital levels. Models (1)–(3) in Table 5 demonstrate how the growth of the digital economy has improved capital investment efficiency, thereby propelling industries toward sectors with higher technological content and added value and thus promoting the advancement of the industrial structure. Furthermore, digital technologies like intelligent supply chain management and big data analytics have redefined the way capital is utilized. This has allowed for more flexible and precise alignment with industrial needs, leading to rational structural adjustments across various sectors. Such transformations have enhanced inter-industry linkages, thereby contributing to the rationalization of the overall industrial structure. In conclusion, the digital economy provides solid support for contemporary industrial upgrades and structural adjustments through the reconfiguration and optimization of capital.

**Table 5.** Regression results of the mediation effect test.

| Variables | Labor (1) | $Indust_1$ (2) | $Indust_2$ (3) | Capital (4) | $Indust_1$ (5) | $Indust_2$ (6) |
|---|---|---|---|---|---|---|
| Digital | 0.009 *** | 0.089 ** | −0.191 * | 0.495 *** | 0.083 * | −0.192 * |
| | (3.00) | (2.25) | (−1.81) | (2.94) | (1.94) | (−1.83) |
| Labor | | 1.152 | −10.412 *** | | | |
| | | (0.90) | (−3.35) | | | |
| Capital | | | | | 0.035 * | −0.206 *** |
| | | | | | (1.77) | (−3.40) |
| Constant | 1.104 | 2.041 *** | −0.454 | 0.132 *** | 1.927 *** | 0.715 |
| | (0.82) | (4.84) | (−0.32) | (4.42) | (4.34) | (1.00) |
| Control variable/time/regional effect | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 270 | 270 | 270 | 270 | 270 | 270 |
| R-squared | 0.867 | 0.980 | 0.910 | 0.968 | 0.980 | 0.909 |

Note: The robustness standard error is included in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Secondly, Models (4)–(6) suggest that with the extensive utilization of digital technology, the skillset demanded of laborers has fundamentally changed. This has led to extensive re-education and training initiatives to meet the skill requirements of the new economic landscape. Such skill upgrades not only enhance overall labor productivity but also stimulate a shift in the economy toward high-value-added industries. Additionally, highly skilled labor tends to concentrate on knowledge-intensive and innovation-driven industries, enhancing the industrial structure even further. Consequently, by elevating the skill levels of the labor force, the digital economy brings rationalization to the industrial structure in economically underdeveloped areas, making them more adaptable to today's highly globalized and technology-driven economic environment.

In conclusion, the development of the digital economy not only optimizes the allocation of labor and capital, reducing the costs of information asymmetry, but also promotes rationalization and upgrading of the industrial structure. It also facilitates cross-industry integration and high-end development. These transformations open up new pathways for breaking out of the "poverty trap".

## 5. Conclusions

The digital economy, as a byproduct of the information revolution, symbolizes a new wave of technological advancement and serves as a crucial catalyst for the transformation and upgrading of industrial structures. This research employed panel data encompassing 30 provinces in China over the period of 2013 to 2021 to examine the influence of the digital economy on the transformation and upgrading of industrial structures. The analysis was performed with a fixed-effects model. The study found that the development of the digital economy significantly promotes the advancement and rationalization of industrial structures. In contrast to the current body of research, which only selected the hierarchy coefficient of industrial structure [22] or only considered the upgrading of industrial structure [16,23] as the measurement index, this paper categorized industrial structure into advancement and rationalization, aiming at paying attention to the balance and rationality of the whole industrial system. The theory of industrial structure transformation and upgrading has been perfected, and the related research on digital economy and industrial structure transformation and upgrading has been enriched.

Secondly, in a heterogeneity analysis divided according to varying levels of economic development, it was found that regions with lower levels of economic development have greater potential for transformation and upgrading of industrial structure through the digital economy. Traditional studies on the heterogeneity of China's economic problems are mostly based on geographical location, such as east–middle–west [21]. However, considering that there are still differences in the level of economic development between different geographical locations, this paper divided the level of economic development according to high–medium–low, which could more accurately identify the difference in the impact of digital economy with different levels of economic development on the transformation and upgrading of industrial structure.

Thirdly, in the mechanism verification, it was found that the growth of the digital economy can optimize the allocation of capital and labor, improve resource allocation capabilities, and thereby promote the advancement and rationalization of industrial structures. The existing research on the mechanism of the digital economy and industrial structure transformation and upgrading mainly focuses on the research of innovation [74,75] and green total factors [23,76], while this paper analyzed it based on capital factors and labor factors, aiming at broadening the research field and deeply discussing how the digital economy affects the transformation of industrial structure. Not only does this paper provide a perspective on industrial restructuring from the lens of the digital economy, but it also offers insights on breaking the "poverty trap."

Based on this research, we offer the following policy suggestions.

First of all, strengthen digital infrastructure, particularly in economically lagging regions: The digital economy holds more significant potential for industrial transformation in less developed areas. However, the initial construction may require a great deal of money and encounter technological and talent bottlenecks. Therefore, the government and relevant institutions can set up special funds in economically backward areas to support the R&D and deployment of digital infrastructure. Through cooperation with private enterprises and international organizations, foreign investment can be effectively attracted, thus helping to build and maintain the facility. Digital infrastructure can bring more potential opportunities for local enterprises and residents, from obtaining information and knowledge to providing various services to promoting local employment and diversified industrial development and then upgrading the industrial structure, fundamentally breaking the "poverty trap" and promoting the overall improvement of the social economy. In addition, government departments should also ensure the security and stability of digital infrastructure.

Second, optimize the allocation of labor and capital to facilitate the transformation and upgrading of industrial structures. The effects of education and training related to digital applications have a certain lag. To encourage the transformation and upgrading of the industrial structure, the government and relevant institutions should first invest deeply in digital education and training to shorten this lag and ensure that a broader audience benefits. This not only provides workers with more opportunities to enhance their abilities and improve production efficiency but also cultivates new skills and professions to meet the new requirements of the industrial structure. Simultaneously, by promoting the digitization of capital markets through digital technology, capital allocation can be more effectively conducted. This includes attracting more investments through digital platforms and using data analysis to more accurately assess investment risks and returns, thereby optimizing the efficiency of capital use. Therefore, the government and regulatory agencies should also strengthen the digital transformation of the financial sector, providing investors and institutions with more efficient data analysis tools. This not only helps reduce transaction costs and enhance market transparency but also accelerates the decision-making process, stimulating capital flow and innovation and promoting the transformation and upgrading of the industrial structure.

Third, optimize the policy environment to incentivize the development of the digital economy. The government needs to provide a proactive policy climate in order for the digital economy to expand healthily. The crucial aspect here is how the government establishes a policy environment that is both active and equitable, balancing the relationship between innovative stimulus policies and social fairness. Although tax reductions and R&D subsidies can encourage more enterprises and individuals to actively participate in the digital economy, these incentives may still favor certain social strata or regions. Simultaneously, while strengthening intellectual property protection can ensure fair returns for innovators, excessive protection may inhibit other potential innovative activities. Therefore, establishing a balanced, fair, and innovation-encouraging policy environment requires deep cooperation between the government, enterprises, and society in various aspects. The government should ensure that policies not only encourage the growth of the digital economy and the transformation and upgrading of industries but also maintain policy fairness and stability in the advancement process, ensuring that every member of society can benefit from the "dividends" of the digital economy.

## 6. Limitations and the Future Directions

While this study has made significant strides in understanding the subject, there are certain limitations and areas for future exploration. First, this study primarily employed quantitative analysis. While the quantitative approach provided us with clear and intuitive results, it might have overlooked certain microlevel details pertinent to the research theme. Future studies might consider integrating both qualitative and quantitative methods for a more comprehensive exploration and interpretation of the research phenomenon. Secondly, the data utilized in this study were sourced singularly from national macroeconomic statistics. This might have confined our comprehension of certain specific contexts and backgrounds. To enhance the depth and breadth of the research, future investigations can delve into microlevel study results. Thirdly, the issue of omitted variable bias might have been present in this study. Even though control variables were chosen along with fixed-effects models combined with instrumental variables to mitigate the problem of missing variables, there still might have been other variables that affected the results. Future research should further explore other influential variables. Fourth, the current study primarily focused on the analysis of developing countries. In future research, it would be beneficial to broaden our scope to encompass various global economies. Doing so will aid in our exploration of industrial upgrading and economic development trends across diverse economic backgrounds.

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## References

1. Altig, D.; Baker, S.; Barrero, J.M.; Bloom, N.; Bunn, P.; Chen, S.; Davis, S.J.; Leather, J.; Meyer, B.; Mihaylov, E.; et al. Economic uncertainty before and during the COVID-19 pandemic. *J. Public Econ.* **2020**, *191*, 104274. [CrossRef] [PubMed]
2. Boylan, B.M.; McBeath, J.; Wang, B. US–China relations: Nationalism, the trade war, and COVID-19. *Fudan J. Humanit. Soc. Sci.* **2021**, *14*, 23–40. [CrossRef]

3. Kumar, S.; Maheshwari, V.; Prabhu, J.; Prasanna, M.; Jayalakshmi, P.; Suganya, P.; Benjula Anbu Malar, M.B.; Jothikumar, R. Social economic impact of COVID-19 outbreak in India. *Int. J. Pervasive Comp.* **2020**, *16*, 309–319.
4. Ntasis, L.; Kountzakis, C.E.; Koronios, K.; Dimitropoulos, P.E.; Ratten, V. *Developing Digital Marketing: Relationship Perspectives*; Emerald Publishing Limited: Bingley, UK, 2021; pp. 65–73.
5. Leach, M.; MacGregor, H.; Scoones, I.; Wilkinson, A. Post-pandemic transformations: How and why COVID-19 requires us to rethink development. *World Dev.* **2021**, *138*, 105233. [CrossRef]
6. World Bank. Poverty and Shared Prosperity. 2022. Available online: https://www.worldbank.org/en/publication/poverty-and-shared-prosperity (accessed on 10 October 2023).
7. Banerjee, A.V.; Duflo, E. *Poor Economics: A Radical Rethinking of the Way to Fight Global Poverty*; Public Affairs: New York, NY, USA, 2011.
8. Lin, J.Y.; Treichel, V. *Learning from China's Rise to Escape the Middle-Income Trap: A New Structural Economics Approach to Latin America*; World Bank Policy Research Working Paper; The World Bank Group: Washington, DC, USA, 2012; p. 6165.
9. Ozawa, T. *Institutions, Industrial Upgrading, and Economic Performance in Japan: The Flying-Geese Paradigm of Catch-Up Growth*; Edward Elgar Publishing: Bingley, UK, 2007.
10. Zhang, Q.Z.; Xu, M. Objective orientation and key measures of implementing modernization oriented industrial policy of industrial chain and supply chain. *Reform* **2022**, *38*, 82–93.
11. Duan, W.; Madasi, J.D.; Khurshid, A.; Ma, D. Industrial structure conditions economic resilience. *Technol. Forecast. Soc.* **2022**, *183*, 121944. [CrossRef]
12. Schumpeter, J.A. *The Theory of Economic Development*; Harvard University Press: Cambridge, MA, USA, 1934.
13. Audretsch, D.B.; Feldman, M.P. Innovative clusters and the industry life cycle. *Rev. Ind. Organ.* **1996**, *11*, 253–273. [CrossRef]
14. Zhou, S.L.; Wang, W.G. Scientific-Technical innovation; the optimization upgrade of industrial structure. *J. Manag. World* **2001**, *16*, 70–78.
15. Lan, Q.X. Digital economy: An important driving force for the development of the world economy. *Frontiers* **2020**, *9*, 80–85.
16. Guan, H.; Guo, B.; Zhang, J. Study on the impact of the digital economy on the upgrading of industrial structures—Empirical analysis based on cities in China. *Sustainability* **2022**, *14*, 11378. [CrossRef]
17. Kraus, S.; Jones, P.; Kailer, N.; Weinmann, A.; Chaparro-Banegas, N.; Roig-Tierno, N. Digital transformation: An overview of the current state of the art of research. *Sage Open* **2021**, *11*, 21582440211047576. [CrossRef]
18. Peron, M.; Sgarbossa, F.; Strandhagen, J.O. Decision support model for implementing assistive technologies in assembly activities: A case study. *Int. J. Prod. Res.* **2022**, *60*, 1341–1367. [CrossRef]
19. Simonetto, M.; Peron, M.; Fragapane, G.; Sgarbossa, F. Digital assembly assistance system in Industry 4.0 era: A case study with projected augmented reality. In *Advanced Manufacturing and Automation X 10*; Springer: Singapore, 2021; pp. 644–651.
20. Wu, X.X.; Ren, B.P. The path and policy adjustment of the reconstruction of resource allocation mechanism under the background of digital economy. *Reform. Econ. Syst.* **2022**, *40*, 5–10.
21. Li, J.; Su, Q.L. Empirical analysis of digital economy in promoting industrial structure upgrading. *Mod. Manag. Sci.* **2022**, *26*, 127–137.
22. Su, J.; Su, K.; Wang, S. Does the digital economy promote industrial structural upgrading?—A test of mediating effects based on heterogeneous technological innovation. *Sustainability* **2021**, *13*, 10105. [CrossRef]
23. Liu, Y.; Yang, Y.; Li, H.; Zhong, K. Digital economy development, industrial structure upgrading and green total factor productivity: Empirical evidence from China's cities. *Int. J. Env. Res. Pub. He.* **2022**, *19*, 2414. [CrossRef]
24. Körner, K.; Schattenberg, M.; Heymann, E.; Schneider, S.; AG, D.B. Digital Economics. Deutsche Bank Research. EU Monitor. 2018. Available online: https://scholar.google.com/scholar?hl=zh-CN&as_sdt=0%2C5&q=K%C3%B6rner%2C+K.%3B+Schattenberg%2C+M.%3B+Heymann%2C+E.%3B+Schneider%2C+S.%3B+AG%2C+D.+B.+Digital+economics.+Deutsche+Bank+Research.+EU+Monitor&btnG= (accessed on 20 October 2023).
25. Rozanova, N.M. Competition and monopoly in a digital era. *Obs. Nauk. Sovrem.* **2021**, *1*, 63–72. [CrossRef]
26. Yu, Z.; Liu, S.; Zhu, Z.; Fu, L. Spatial imbalance, dynamic evolution and convergence of the digital economy: Analysis based on panel data of 278 cities in China. *Sustainability* **2023**, *15*, 7422. [CrossRef]
27. Sama, L.M.; Stefanidis, A.; Casselman, R.M. Rethinking corporate governance in the digital economy: The role of stewardship. *Bus. Horiz.* **2022**, *65*, 535–546. [CrossRef]
28. Tao, C.Q.; Ding, Y. How does the digital economic policy affect the innovation of manufacturing enterprise: From the perspective of suitable supply. *Contemp. Financ. Econ.* **2022**, *44*, 16–27.
29. Senadjki, A.; Mohd, S.; Bahari, Z.; Hamat, A.F.C. Assets, risks and vulnerability to poverty traps: A study of northern region of Malaysia. *J. Asian Financ. Econ. Bus.* **2017**, *4*, 5–15. [CrossRef]
30. Heng, R.; Jia, K. Digital econo my promotes the reform of government governance: External challenges, internal causes and institutional innovation. *E-Government* **2020**, *20*, 55–62.
31. Sunigovets, O. Enterprise competitiveness in the digital economy. *SHS Web Conf. EDP Sci.* **2019**, *67*, 04012. [CrossRef]
32. Yao, J.H. *Digital Labor in Manufacturing and Services*; The Commercial Press: Beijing, China, 2017.
33. Chen, X.Y. A review of western scholars' research on capitalist labor-capital relations in the digital economy era. *Economist* **2022**, *34*, 37–44.

34. Li, R.; Rao, J.; Wan, L. The digital economy, enterprise digital transformation, and enterprise innovation. *Manag. Decis. Econ.* **2022**, *43*, 875–2886. [CrossRef]
35. Schumpeter, J.A. *Business Cycles*; Mcgraw-Hill: New York, NY, USA, 1939.
36. Zhao, J. The internal mechanism of innovation and division of labor to promote Economic growth-comments on the dicision models of Romer and Yang Xiaokai. *J. Beijing Jiaotong Univ. (Soc. Sci. Ed.)* **2022**, *22*, 46–62.
37. Eliasson, G. *Schumpeterian Innovation, Market Structure and the Stability of Industrial Development*; IUI Working Paper; Research Institute of Industrial Economics (IFN): Stockholm, Sweden, 1986.
38. Levin, R.; Reiss, P.C. *R&D, Patents, and Productivity*; University of Chicago Press: Chicago, IL, USA, 1984; pp. 175–208.
39. Putsenteilo, P.R.; Humeniuk, O.O. Digital economy as the modern vector of reconstruction of the traditional economy. *Innov. Econ.* **2018**, *5–6*, 131–143.
40. Zhang, T.; Shi, Z.Z.; Shi, Y.R.; Chen, N.-J. Enterprise digital transformation and production efficiency: Mechanism analysis and empirical research. *Econ. Res.-Ekon. Istraz.* **2022**, *35*, 2781–2792. [CrossRef]
41. Manda, M.I.; Ben Dhaou, S. Responding to the challenges and opportunities in the 4th Industrial revolution in developing countries. In Proceedings of the 12th International Conference on Theory and Practice of Electronic Governance, Melbourne, Australia, 3–5 April 2019; pp. 244–253.
42. Wu, H.Q. New technologies such as the Internet of Things drive the digital economy. *China Inf. Secur.* **2017**, *8*, 48–49.
43. Ren, Z.Z.; Deng, F. Digital technology: Factor structure transformation and high-quality economic development. *Soft Sci.* **2023**, *37*, 9–14.
44. Schmidt, H.; Zhan, F.J. Taming the shrew: Is there a need for a new market power definition for digital economy? *Compet. Law Policy Rev.* **2018**, *4*, 137–167.
45. Fan, M.T.; Zhang, L. Digital economy, allocation of resource elements and coordinated development of urban and rural areas. *J. Southwest Minzu Univ. (Humanit. Soc. Sci. Ed.)* **2023**, *44*, 112–120.
46. Liang, Z.C. Analysis of the characteristics of industrial organization of network economy. *Foreign Econ. Relati. Trade* **2022**, *29*, 43–45.
47. Li, Y. The reformation of industry organization and policy recommendations in the digital economy. *J. Commer. Econ.* **2021**, *40*, 181–184.
48. Yu, D.H.; Wang, M.J. Digital economy, entrepreneurship and high-quality development of manufacturing industry. *Reform* **2022**, *38*, 61–81.
49. He, L. Data elements market-oriented reform, entrepreneurship and manufacturing digital transformation. *J. Hunan Univ. Sci. Technol. (Soc. Sci. Ed.)* **2022**, *25*, 65–76.
50. Zhou, Y. The systematic transformation of industrial innovation and its principle of policy mix in the digital economy. *Mod. Manag.* **2020**, *40*, 40–42.
51. Rosenstein-Rodan, P.N. Problems of industrialisation of eastern and south-eastern Europe. *Econ. J.* **1943**, *53*, 202–211. [CrossRef]
52. Nurkse, R. *Problems of Capital Formation in Underdeveloped Countries*; Cambridge University Press: Cambridge, UK, 2012.
53. Tapscott, D. *The Digital Economy: Promise and Peril in the Age of Networked Intelligence*; McGraw-Hill: New York, NY, USA, 1996.
54. Brynjolfsson, E.; McAfee, A. *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*; W.W. Norton & Company: New York, NY, USA, 2014.
55. Steinmueller, W.E. Knowledge-based economies and information and communication technologies. *Int. Soc. Sci. J.* **2002**, *54*, 141–153. [CrossRef]
56. Schultz, T.W. Investment in Human Capital. *Am. Econ. Rev.* **1961**, *51*, 1–17.
57. Becker, G.S. *Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education*; University of Chicago Press: Chicago, IL, USA, 1964.
58. Autor, D.H. Why are there still so many jobs? The history and future of workplace automation. *J. Econ. Perspect.* **2015**, *29*, 3–30. [CrossRef]
59. Shen, Y.; Zhang, X. Digital economy, intelligent manufacturing, and labor mismatch. *J. Adv. Comput. Intell.* **2022**, *26*, 655–664. [CrossRef]
60. Baron, R.M.; Kenny, D.A. The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *J. Pers. Soc. Psychol.* **1986**, *51*, 1173. [CrossRef] [PubMed]
61. Wen, Z.L.; Zhang, L.; Hou, J.T.; Liu, H.Y. Testing and application of the mediating effect. *Acta Psychol. Sinica* **2004**, *49*, 614–620.
62. Yuan, H.; Zhu, C.L. Do national high-tech zones promote the transformation and upgrading of China's industrial structure. *China Ind. Econ.* **2018**, *35*, 60–77.
63. Xu, D.Y. A theoretical explanation and verification of the form determination and measurement of industrial structure upgrading. *Public Financ. Res.* **2008**, *29*, 46–49.
64. Gan, C.H.; Zheng, R.G.; Yu, D.F. An empirical study on the effects of industrial structure on economic growth and fluctuationa in China. *Econ. Res. J.* **2011**, *46*, 4–16.
65. Zhao, T.; Zhang, Z.; Liang, S.K. Digital economy, entrepreneurship, and high–quality economic development: Empirical evidence from urban China. *J. Manag. World* **2020**, *36*, 65–76.
66. Zhang, Y.P.; Dong, C.; Luan, Q. Mechanism of digital economy promoting high-quality economy- based on evidence from the provincial panel date. *J. Univ. Jinan* **2021**, *31*, 99–115.

67. Zhu, X.A.; Wei, G.D. The excellent standard of nondimensionalization in entropy method. *Stat. Res.* **2015**, *31*, 12–15.
68. Chen, D.; Xiang, P.C.; Jia, F. Performance measurement of operation and maintenance for infrastructure mega-project based on entropy method and DS evidence theory. *Ain Shams Eng. J.* **2022**, *13*, 101591. [CrossRef]
69. Pols, A. *The Role of Information and Communications Technology in Improving Productivity and Economic Growth in Europe: Empirical Evidence and an Industry View of Policy Challenges, 50 Years of EU Economic Dynamics*; Springer: Berlin/Heidelberg, Germany, 2007; pp. 183–201.
70. Xie, K.; Yu, Y.Z.; Zhang, S.L. Quality of convergence between industrialization and informatization in China. *Econ. Res. J.* **2012**, *47*, 4–16.
71. Huang, Q.H.; Yu, Y.Z.; Zhang, X.L. Internet development and productivity growth in manufacturing industry: Internal mechanism and China experiences. *China Ind. Econ.* **2019**, *36*, 5–23.
72. Sun, J.; Chen, J. Digital economy, energy structure transformation, and regional carbon dioxide emissions. *Sustainability* **2023**, *15*, 8557. [CrossRef]
73. Nunn, N.; Qian, N. US Food Aid and Civil Conflict. *Am. Econ. Rev.* **2014**, *104*, 1630–1666. [CrossRef]
74. Sun, Y.; Zhang, X.H.; Zhao, T.Y.; Zhang, Y.F. The influence of digital techology innovation on Industrial Structure upgrade and its spatial effect-evidence from Yangze River economic belt. *Soft Sci.* **2022**, *36*, 9–16.
75. Zhang, X.W. Research on evolution of innovation model under condition of digital economy. *Economist* **2019**, *31*, 32–39.
76. Zhao, Y.; Kong, X.; Ahmad, M.; Ahmed, Z. Digital economy, industrial structure, and environmental quality: Assessing the roles of educational investment, green innovation, and economic globalization. *Sustainability* **2023**, *15*, 2377. [CrossRef]