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Assessment of the Stimulating Impact of Relevant Policies on Digital Transformation in China's Industrial Sector

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Abstract

The article evaluates the stimulating impact of government policy on digital transformation in China's industrial sector, focusing on quantitative identification of causal relationships between support instruments and enterprise digitalization dynamics. The empirical base comprises panel data from 1500 industrial companies across 15 subsectors for 2016-2023. At the micro-level, a composite Digital Transformation Index was calculated, aggregating digital asset investment intensity, technology implementation level, and operational efficiency. Policy intensity was operationalized through dummy variables for participation in "smart manufacturing" pilot zones, volume of R&D tax incentives, and direct subsidies. Results show sustained growth in investments and technology penetration among pilot zone residents. All policy instruments show significant effects in regression analysis: participation in pilot zones correlates with a 0.214-point index increase, tax incentives with 0.158 points per percentage point of revenue, and subsidies with 0.095 points. Substantial sectoral heterogeneity is observed, with maximum digitalization returns in electronics and precision engineering.

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Keywords

Digital transformation, Chinese industry, government support, pilot zones, econometric analysis, industrial policy, innovations, technological development.

Introduction

The global economic landscape is currently undergoing fundamental changes, driven by the Fourth Industrial Revolution, with digital transformation at its core. The industrial sector, as the basis of the real economy, is at the epicenter of these transformations. For the People's Republic of China, which is striving for high-quality economic growth and strengthening its position in global value chains, accelerating the digitalization of industry is a strategic priority at the national level. According to official data from the State Statistical Office of the People's Republic of China, the volume of China's digital economy in 2023 reached 54.8 trillion yuan, which is more than 42% of the country's GDP, while the contribution of the industrial sector to this indicator is steadily growing. The penetration rate of industrial Internet platforms in key industries, such as mechanical engineering and electronics, exceeded 49.5% [Kalinin, 2022], which indicates the scale of ongoing processes. However, this process is characterized by significant heterogeneity both at the sectoral and regional levels, which raises the question of the effectiveness of state support measures.

The Chinese government is implementing a comprehensive policy aimed at stimulating the digital transformation of industry. This policy includes a wide range of tools: from direct financial subsidies and tax incentives for research and development (R & D) to the creation of pilot zones of "smart production" and the development of industry standards for the industrial Internet of Things (IIoT). Only within the framework of the "Made in China 2025" program and subsequent initiatives, hundreds of projects were launched across the country aimed at introducing big data, artificial intelligence and cloud computing technologies into production processes [Wang, 2020]. Despite the scale of these efforts, the empirical assessment of the real incentive impact of these policies at the micro and macro levels remains a subject of scientific debate. Existing research often focuses either on the qualitative description of policy measures or on the analysis of individual cases [Dyachenko, Garmatin, 2018], leaving open the question of quantifying their combined effect and the comparative effectiveness of various tools.

This study aims to fill this gap by conducting a comprehensive econometric analysis aimed at assessing the stimulating impact of government policies on the dynamics of digital transformation in China's industrial sector. The key research objective is to identify and quantify the causal relationship between the intensity and nature of political support and specific indicators of enterprise digitalization, such as investment in digital assets, the level of adoption of advanced technologies, and productivity growth. Analysis of statistical data shows that the average annual growth rate of investment in fixed assets related to information technology in Chinese industry over the past five years was 16.3%, which is significantly faster than the overall growth of investment (5.8%). However, the variance of this indicator for regions under varying degrees of political patronage is extremely high [Baynev, Bin, 2020]. This highlights the need for a detailed study of the mechanisms through which political impulses are transformed into real investment and technological decisions at the enterprise level, and for determining the most effective configurations of state support.

Materials and methods of research

The empirical basis of this study is a comprehensive set of panel data covering the period from 2016 to 2023. The main sources of information were official statistical compilations of the State Statistical Administration of the People's Republic of China, annual reports of the Ministry of Industry and Informatization of the People's Republic of China, as well as data from the database of the Chinese

Center for Economic Research (CCER). For micro-level analysis, a sample of 1,500 industrial enterprises representing 15 key sub-sectors of the manufacturing industry was formed, whose financial statements are available in open sources, such as the Wind and CSMAR databases. This sample was stratified by the size of enterprises (small, medium, large) and their geographical location in order to ensure representativeness [Abramchikova, Shi, 2022]. Special attention was paid to the inclusion in the sample of both enterprises that are residents of pilot zones of digital transformation and receive targeted state support, and the control group of enterprises operating in standard conditions.

The methodological framework of the study is based on the use of modern econometric methods for analyzing panel data. To assess the cumulative effect of the policy, we used the Fixed Effects Model, which allows us to control unobservable heterogeneous characteristics of enterprises that remain unchanged over time (for example, corporate culture, quality of management). As a dependent variable, a composite Digital Transformation Index (ICT) was constructed, calculated on the basis of three sub-indices: the intensity of investment in digital assets (the share of costs for software, automation and communications equipment in total capital investment), the level of digital technology implementation (estimated by the availability and scale of use of ERP systems, cloud services,etc.). IIoT technologies and big data analysis) and the impact on operational efficiency (measured through the dynamics of labor productivity and resource intensity).

The key independent variable is the intensity of political incentives, which was operationalized through several proxy variables. First, a dummy variable was created, which takes the value 1 if the enterprise is located in one of the state-approved pilot zones of "smart production" or industrial Internet demonstration zones [14], and 0 otherwise. Secondly, quantitative indicators were used, such as the amount of government subsidies received and the amount of tax deductions for R & D expenditures, normalized in relation to the company's revenue. The model also included a number of control variables that, according to theoretical assumptions [Golovenchik, Gospodarik, Wang, 2020] and previous studies, can influence the digitalization process: the size of the enterprise (the logarithm of total assets), its profitability (ROA), the level of debt burden (the ratio of borrowed capital to own), the age of the firm and industry affiliation. To check the robustness of the results and more accurately assess the causal effect, the Difference-in-Differences method was also used, comparing the dynamics of indicators in the "experimental" group (enterprises that were affected by new policies) and the control group before and after the implementation of these policies [Babkin, 2017]. The total volume of sources analyzed, including scientific publications, regulatory acts and statistical reports, exceeded 200 units.

Results and discussion

The central task of empirical analysis is to decompose the factors that determine the dynamics of digital transformation and quantify the contribution of public policy instruments. To do this, it is necessary to consider specific metrics that reflect both the investment activity of enterprises in the field of digitalization, and the real level of penetration of advanced technologies into production processes. The choice of indicators for analysis is determined by the need to move from general declarations to measurable results. Investments in R & D and digital assets are the primary indicator of companies ' readiness for transformation, while technology penetration rates show how much these investments are converted into real changes on the production site.

The conducted analysis makes it possible to identify a clear differentiation in investment activity between enterprises that are in the focus of state support (pilot zones) and other companies in the industrial sector. This difference is not static, but tends to increase over time, which indicates the

cumulative effect of implementing incentive measures. The choice of these indicators allows us to assess both the direct financial impulse and its long-term impact on the company's development strategy.

Analysis of the data presented in Table 1 reveals significant differences in the growth rate of investment activity. The average annual growth rate (CAGR) of R & D investment for enterprises in the pilot zones for the period 2019-2023 was approximately 18.8%, while for the control group this indicator was at the level of 8.8%. Even more pronounced divergence is observed in the segment of investments in digital assets: 23.1% for enterprises in pilot zones versus 7.7% for the control group. This indicates that government policies not only encourage general research and development, but also purposefully shift the focus of investment towards the acquisition and implementation of digital technologies. The disparity in growth rates leads to a significant increase in the gap: if in 2019 investments in digital assets in pilot zones accounted for 44.1% of the level of the control group for this indicator, then by 2023 this ratio has grown to 75.4%. This dynamic confirms the multiplicative effect of policy measures, when the initial impulse in the form of subsidies or benefits starts a self-sustaining cycle of technological re-equipment.

It is also important to analyze not only the amount of funding, but also the effectiveness of these investments, expressed in the degree of development of specific technologies. To assess this aspect, enterprises were classified according to the level of intensity of state support received, which includes both direct and indirect measures. Comparing this intensity with the penetration rates of key digital technologies allows us to identify a non-linear relationship and determine the threshold beyond which support begins to give the maximum return [Rastyannikova, 2019].

The data show a strong positive correlation between the intensity of state support and the level of technological equipment of enterprises. The transition from low to medium support intensity is associated with an almost twofold increase in penetration rates for all the technologies under consideration. For example, for IIoT, the indicator increases by 21.74 percentage points, which indicates a high elasticity of implementation of these technologies in relation to support measures. The most significant increase is observed in the transition from medium to high support levels, especially in the artificial intelligence segment, where the penetration rate increases by 14.64 percentage points. This may be due to the higher capital intensity and complexity of implementing AI solutions, which require not only financial injections, but also access to specialized competencies and infrastructure [4], which are often provided within the framework of targeted government programs. Interestingly, the gap in penetration between IIoT and big data analytics is narrowing as the intensity of support increases, which may indicate a synergistic effect when the introduction of one technology encourages the use of another.

To formalize the identified dependencies and assess the statistical significance of the influence of individual political instruments, a regression analysis was performed, the results of which are presented below. This model allows us to clear the effect of policy measures from the influence of other fundamental characteristics of the enterprise [11], such as size or industry affiliation, and to quantify the contribution of each tool to the final level of digitalization.

The results of the regression analysis confirm the statistically significant positive impact of all the considered policy instruments on the Digital Transformation Index. The coefficient for the dummy variable "Pilot Zone" is 0.214, which means that, all other things being equal, the presence of an enterprise in the pilot zone is associated with an increase in ICT by an average of 0.214 points. This confirms the effectiveness of the integrated approach applied in such zones. Tax incentives for R & D demonstrate the highest efficiency among direct financial instruments: an increase in the share of benefits by 1 percentage point of revenue leads to an increase in ICT by 0.158 points [Golovenchik,

Wang, 2020]. Direct subsidies also have a positive impact (coefficient 0.095), but their effect is almost 1.7 times weaker than that of tax incentives, which may indicate a more efficient allocation of resources by enterprises themselves under tax incentives compared to targeted subsidies. A high R-squared value (0.673) indicates that the variables included in the model explain more than 67% of the variation in the Digital Transformation Index.

Finally, to complete the picture, it is necessary to evaluate not only the process, but also the result of digitalization in terms of economic efficiency. The ultimate goal of transformation is to increase competitiveness and productivity, which can be measured through the return on investment [Konopiy, 2021]. A comparative analysis of cost effectiveness across different sub-sectors of industry reveals significant industry heterogeneity in policy impact.

An analysis of the data in Table 4 shows that the effectiveness of investments in digitalization varies greatly depending on the industry. The highest return is shown by the electronics and telecommunications equipment manufacturing sector, where each yuan invested in digitalization brings 1.48 yuan of added value. This sector also receives the highest level of government support. It is followed by precision engineering (1.27) and automotive (1.15). At the same time, in more traditional and capital-intensive industries, such as the chemical industry and metallurgy, the return on investment does not yet exceed one (0.93 and 0.78, respectively). This may be due to a longer investment cycle [Vasiliev, 2021], high inertia of production processes, and the need for deeper and more costly modernization of underlying assets to get the effect of digital add-ons. There is a clear positive correlation between the average level of state support and the efficiency ratio, which may indicate that the government purposefully supports industries with the greatest potential for return on digitalization, or the support itself helps to overcome barriers and increase investment efficiency.

Complex mathematical processing of the obtained data allows us to draw a conclusion about the complex, multi-factorial nature of the stimulating effect of public policy. Synthesis of the results of Tables 1-4 shows that the effect is not linear and homogeneous. The analysis of variance confirms that the difference in digitalization dynamics between the enterprises in the pilot zones and the control group is statistically significant at the level of 99%. Correlation and regression analysis (Table 3) not only confirms the existence of a link, but also makes it possible to rank tools by their effectiveness, revealing the superiority of indirect tax incentives over direct subsidies. Econometric modeling using panel data allowed us to establish that the cumulative effect of being in the pilot zone for three or more years is 30-35% higher than the effect in the first year, which indicates the presence of lags and increasing impact. Moreover, factor analysis has shown that about 40% of the total effect of the "pilot zone" is mediated not by direct financial injections, but by institutional factors: access to new infrastructure [Epikhina, 2021], reduction of administrative barriers, and the effects of knowledge agglomeration. Industry heterogeneity emphasizes the need for a differentiated approach to policy development, taking into account the specifics of production cycles and the potential for digitalization in each specific sector.

Conclusions

The conducted research allows us to conclude that the state policy of China has a significant and statistically significant stimulating effect on the processes of digital transformation in the industrial sector. Empirical analysis has confirmed that enterprises that are in the focus of state support, in particular, residents of pilot zones of "smart production", show significantly higher rates of investment growth in both R & D and directly in digital assets. The average annual growth rate of these indicators for the target group of enterprises is 2-3 times faster than similar indicators for the control group, which indicates a high efficiency of resource concentration and the creation of favorable institutional

conditions. It is quantitatively confirmed that the intensity of state support directly correlates with the level of penetration of key digital technologies, such as the industrial Internet of Things, big data analysis and artificial intelligence.

An analysis of the comparative effectiveness of various policy instruments revealed important patterns. It was found that indirect incentive measures, in particular tax incentives for R & D, have a stronger impact on the final digital transformation index compared to direct financial subsidies. This suggests that giving businesses more autonomy in the allocation of savings contributes to more efficient and market-oriented investments in digitalization. At the same time, the complex impact within the pilot zones, combining financial, infrastructure and administrative measures, creates a synergistic effect that exceeds the sum of the effects from individual, disparate instruments.

At the same time, the study revealed significant heterogeneity of policy impact depending on industry specifics. High-tech industries such as electronics manufacturing and precision engineering show the greatest return on investment in digitalization, while in traditional capital-intensive sectors, this process is slower and requires more long-term and integrated support strategies. This indicates the need to fine-tune policy measures to reflect the industry's life cycle, technological structure, and potential for digital modernization.

The prospects for applying the results obtained are multifaceted. For government agencies, they can serve as a basis for optimizing the allocation of resources, shifting the focus towards the most effective incentive tools, and developing differentiated sectoral strategies. For the management of industrial enterprises, the results of the study highlight the importance of active interaction with government programs and strategic investment planning to maximize the return on digital transformation. Further research may focus on a deeper study of the long-term effects of digitalization on the competitiveness of enterprises in global markets, as well as on the analysis of the impact of digital transformation on the labor market and personnel qualification requirements in the Chinese industrial sector.

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Оценка стимулирующего воздействия соответствующей политики на цифровую трансформацию в промышленном секторе Китая

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Аннотация

Статья оценивает стимулирующее воздействие государственной политики на цифровую трансформацию промышленного сектора Китая, фокусируясь на количественном выявлении причинно-следственных связей между инструментами поддержки и динамикой цифровизации предприятий. Эмпирическая база представляет собой панель данных 1500 промышленных компаний из 15 субсекторов за 2016–2023 гг. На микроуровне рассчитан композитный Индекс цифровой трансформации, агрегирующий интенсивность инвестиций в цифровые активы, уровень внедрения технологий и операционную эффективность. Интенсивность политики операционализирована через фиктивную переменную участия в пилотных зонах «умного производства», объем налоговых льгот на НИОКР и прямые субсидии. Результаты показывают устойчивый прирост инвестиций и технологического проникновения у резидентов пилотных зон. В регрессии на индекс трансформации значимы все инструменты: участие в пилотной зоне связано с приростом индекса на 0,214 п., налоговые льготы — на 0,158 п. на каждый п.п. к выручке, субсидии — на 0,095 п. Отраслевая гетерогенность существенна: максимальная отдача от цифровизации наблюдается в электронике и точном машиностроении.

Для цитирования в научных исследованиях

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Ключевые слова

Цифровая трансформация, промышленность Китая, государственная поддержка, пилотные зоны, эконометрический анализ, промышленная политика, инновации, технологическое развитие.

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