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Research on the Impact of Industrial Digitalization on High-Quality Economic Development: Evidence from China

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Abstract

This paper presents a New Keynesian dynamic stochastic general equilibrium model with price stickiness, employing macro-quarterly data and Bayesian estimation for parameter estimation. The study dissects the impact of industrial digitalization into three key components: total factor productivity shock, investment marginal efficiency shock, and capital-to-labor substitution shock. The paper then analyzes the mechanism through which industrial digitalization influences the high-quality development of the economy using impulse response analysis and historical variance decomposition. The result shows that: In terms of economic growth, all three types of shocks resulting from industrial digitalization contribute to output expansion, with the investment marginal efficiency shock rapidly boosting output in the short term. However, the technology shock has the most noticeable long-term effect on output growth. In the labor market, the investment marginal efficiency shock positively impacts employment and wages. The effects of the technology shock and capital-to-labor substitution shock on employment and wages first show suppression before enhancement. In the commodity market, the three shocks exert more pronounced effects in the medium and long term, bolstering investment and consumption to varying degrees. In light of these findings, policy recommendations include promoting the development of digital infrastructure, implementing proactive employment policies, offering robust industrial support for the digitalization of traditional enterprises, and fostering a favorable market environment.

Keywords

industrial digitalization, high-quality development, dynamic stochastic general equilibrium

1. Introduction

In recent years, information technology represented by big data, cloud computing and artificial intelligence has been developing rapidly. The related digital industry has been rapidly penetrating into other fields. Documents like the "14th Five-Year Plan" and Vision 2035 also emphasize the importance of fostering a profound integration between the digital economy and the real economy. They call for expediting the process of digitization and advancing industrial digitization. Expediting the digital transformation of industries and vigorously fostering emerging sectors like the digital economy has emerged as a crucial avenue to drive the high-quality development of China's economy. Currently, China's industrial digital transformation has reached a pivotal stage of transition, with the deep-level expansion of industrial digitization accelerating. Thus, it holds significant guiding importance to elucidate the transmission mechanism of how industrial digital transformation impacts the high-quality development of the economy.

Currently, research on industrial digitalization primarily centers around two key aspects: the motivation for industrial digitalization and the path of its implementation. To begin with, when it comes to the motivation for industrial digitalization, some scholars argue that the development of digital technology acts as a catalyst for enterprise digital transformation, and the thriving technology-intensive industries can help improve the overall industrial structure. In the equipment manufacturing industry and the integration of productive service industry motivation is mainly market demand, competitive pressure and technological innovation. The main reason for the transformation and upgrading of the traditional service industry and the reconstruction of the value chain system is the upgrading of Internet technology. Some scholars from the industrial perspective, the digital transformation of industry can drive industrial efficiency, promote industrial cross-border integration, reconfigure the competition mode of industrial organization and empower industrial upgrading. Ma Ming jie (2019) argued that the digital technology revolution contributes to the transformation of social production methods to digitalization. Liu Yuan sheng (2020) argued that the digital transformation of agriculture can effectively improve the effectiveness of the supply system. Zhu He liang and Wang Chun juan (2020) believed that the digital transformation of industry helps to promote the high-quality development of industry. Du Qing hao (2021) believed that digital technology helps optimize industrial organization and enhance industrial hierarchy. Furthermore, concerning the trajectory of industrial digital transformation, Liu Wei (2016) posited that China's industrial digitization ought to revolve around the industry itself. This involves fostering a profound integration between digital technologies and traditional industries, thereby fortifying industrial innovation. Lv Tie and Xu Meng zhou (2019) gave the digital transformation path of traditional industries from the three levels of enterprises, industries and parks. According to Yang Zhuo fan (2020), to address the risks associated with digital innovation and uncertainties, it is essential to proactively promote digital infrastructure, optimize the "supply chain", expand the "industrial chain", and extend the "value chain". Xiao Jing hua (2020) constructed a theoretical model of enterprise cross-system digital transformation and management adaptive change, revealing the internal mechanism of the deep integration of the new generation of digital technology and the real economy from the enterprise level. Zhang Xia heng (2020) contends that enhancing the mindset of enterprise digital transformation, concentrating on breakthroughs in digital core technology, eliminating bottlenecks in industrial chain digitization, and implementing business-friendly policies can effectively support SMEs in their digital transformation. Conversely, Wang Xuhui et al. (2018) outline a consumer-centered omni-channel digital integration approach for the digital transformation of the traditional retail industry. Wang Shu bai and Zhang Yong (2019) provide a comprehensive analysis of the digital transformation trajectory for foreign trade enterprises, examining both front-end and back-end aspects. While limited studies adopt the dynamic stochastic general equilibrium perspective for industry-based digital transformation, Christian Glocker and Philipp Piribauer (2020) analyze how the rise in online retail sales weakens the efficacy of monetary policy in the context of the retail industry's digital transformation. Zhang Liang gui et al. (2022) investigated the impact of structural changes in the digital economy on the dynamics of "leisure time - R&D efficiency", revealing an inverted U-shaped trend between the digital economy and high-quality economic development.

The present influence of industrial digital transformation predominantly relied on theoretical analysis, with limited empirical research. This paper dissects the dynamic impact of industrial digital transformation into three facets: technological shock, investment marginal efficiency shock, and capital-to-labor substitution shock. To accomplish this, we formulate a New Keynesian dynamic stochastic general equilibrium model. Following this, some model parameters are assigned values through the calibration method, and Bayesian estimation is conducted for other parameters using quarterly data spanning from 2007 to 2021. The impacts of the three types of shocks induced by the digital transformation of industries on economic development are then numerically simulated, considering impulse response and variance decomposition. A comprehensive analysis of the dynamic transmission mechanism of the impact of industrial digital transformation on economic development is undertaken to identify effective strategies for sustaining economic growth during the deepening process of industrial digital transformation. The primary innovations and marginal contributions of this paper can be summarized as follows: firstly, a comprehensive analysis of the three shocks stemming from industrial digital transformation's impact on the macroeconomy is incorporated into the theoretical model framework; secondly, a quantitative analysis of the effects of technological shock, investment marginal efficiency shock, and capital-to-labor substitution shock on economic fluctuations is presented; and thirdly, policy recommendations for industrial digital transformation are proposed in conjunction with the numerical simulation analysis.

2. Theoretical Analysis

Industrial digitalization primarily entails a transformative process wherein traditional industries leverage digital technology to upgrade their existing operations and forge new industries, novel business forms, and innovative business models. The journey of industrial digital transformation is marked by the following three key characteristics:

(1) The digital transformation of industries significantly propels progress in total factor productivity.

Successive industrial revolutions throughout human civilization have notably increased social productivity, particularly evident in the enhanced efficiency of production. Scholarly consensus attests that industrial digital transformation is a catalyst for total factor productivity improvement, primarily through three key mechanisms. Firstly, innovation empowerment is achieved as the improved innovation capabilities, driven by rapid digital technology development, diffuse into traditional industries through integration and transformation. This elevation in innovation fosters the creation of new products, business models, and operational paradigms, facilitating the conversion of innovative breakthroughs into productive outputs and enhancing production efficiency. Secondly, precise allocation of factors is realized through industrial digitalization, enhancing the mobility of production factors. By furnishing producers with more accurate production and consumption information, digitalization enables a more rational organization of production, minimizing resource wastage due to mismatches between production and consumption. This, in turn, reduces value consumption within the industrial chain, improving factor allocation efficiency throughout the entire chain from production to circulation and sale, thereby enhancing total factor productivity. Thirdly, efficiency improvement is achieved through the transformation of collaboration methods driven by digital technology. This transformation positively impacts the entire industrial chain, spanning research and development, production, circulation, and trading. In research and development, enhanced institutional collaboration becomes feasible; real-time information access in production reduces uncertainty, prevents overcapacity, enables flexible production, and enhances manufacturing efficiency. In circulation, the proliferation of e-commerce channels strengthens communication and feedback with consumers, integrating with modern logistics systems to expedite supply and demand alignment, thereby improving circulation efficiency. Transaction processes benefit from big data, providing high-quality signals, effectively reducing information asymmetry, activating idle funds, relaxing asset exclusivity constraints, lowering transaction costs, and ultimately improving transaction efficiency. This paper characterizes total factor productivity progress as a positive technology shock, manifested in the form of neutral technological progress.

(2) Industrial digital transformation expedites capital accumulation, enabling investments to be converted into capital at an elevated rate.

This acceleration is chiefly attributed to three key aspects: firstly, industrial digital transformation augments profitability. The network and bilateral market effects stemming from this transformation lead to a reduction in marginal costs. The evolution of digital technology enhances information exchange, lowering transaction costs and fostering inter-enterprise collaboration. This, in turn, promotes cross-border integration between industries, expanding the economy of scope. The rapid growth of Internet e-commerce and digital technology not only broadens market scales but also refines product division of labor, elevating the overall frequency of consumption and generating scale effects. Consequently, digital transformation introduces new profit models for enterprises, optimizes industrial structures, and enhances overall profitability. Secondly, the digital transformation of industries enhances the efficiency of production factor utilization. Digital technology activates idle capital in the market, with data emerging as a novel factor in production. This reduces reliance on traditional production factors and optimizes resource allocation. Digital deployment and intelligent production refine the production process, thereby improving factor utilization efficiency. Thirdly, industrial digital transformation improves prepaid capital. The upgrading and transformation of traditional industries through digital technology necessitate the acquisition of additional digital equipment for receiving and processing data, leading to increased upfront capital. This phenomenon is characterized in this paper as a positive investment efficiency shock, manifesting as a higher proportion of investment converted into capital.

(3) The digital transformation of industries exerts a profound impact on the employment market, categorized into the substitution effect and inhibition effect.

The former entails the integration of artificial intelligence, big data, and other digital technologies with traditional industries, resulting in the replacement of labor by new digital capital. This particularly affects roles involved in simple, repetitive tasks, purely physical labor, and those with clear regularities, making them susceptible to automation and leading to the direct elimination of certain employment positions. On one hand, the efficiency gains from the substitution of intelligent capital for labor contribute to the expansion of relevant industries, compensating for the reduction in jobs per unit of output through scale expansion. On the other hand, the optimization of the economic structure, prompted by the infusion of digital technology into traditional industries through inter-industry convergence and digital transformation, generates novel employment opportunities in the labor market. Some current studies suggested that as digital technology and related industries continue to advance, the turnover in labor jobs is more pronounced in low-skilled positions being replaced by machines. Artificial intelligence is increasingly capable of assuming a broader range of roles, leading to extensive substitution of machines for human labor. This paper characterizes this phenomenon as a positive capital-to-labor substitution shock, manifesting in the replacement of capital factors for labor factors in the production process.

3. Theoretical Model

The theoretical model in this paper is based on the New Keynesian assumptions, in which factors including monopolistic competition and sticky prices are introduced into the model. Combined with the analyses in the above paper, the technological shock, capital substitution shock, and investment marginal efficiency shock brought by the digital transformation of industries are integrated into the model in order to adequately reflect the impacts of the digital transformation of industries on the macroeconomy. The model mainly consists of three parts: Households, Producers, Government and Central Bank.

3.1 Households

Assuming that the environment consists of homogeneous households that exist indefinitely and that the utility of a representative household is affected by consumption and labor, assume that the utility function of a representative household in period t is:

$$U(C_t, N_t) = \log(C_t - bC_{t-1}) - \psi \frac{{N_t}^{1+\nu}}{1+\nu} \tag{1}$$

The goal of the household is to maximize lifetime discounted utility, i.e., to:

$$maxE_0 \sum_{t=0}^{\infty} \beta^t \, U(C_t, N_t) \tag{2}$$

Where β denotes the household utility discount factor, C_t and N_t represent the household's total consumption and total labor supplied at period *t*, *b* represents consumption habits, assuming $b > 0$, ψ is a parameter, and ν represents the inverse of the Frisch elasticity of labor supply.

All of the household's income is used for consumption and investment, and the equation for the accumulation of social capital is:

$$K_{t+1} = z_t \left(1 - \frac{\phi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right) I_t + (1-\delta)K_t \tag{3}$$

where Z_t represents the investment transformation shock that satisfies the AR(1) process, δ represents the capital depreciation rate, and ϕ is a parameter.

In period *t*, the representative household's expenditures are consumption C_t, investment I_t, bonds B_{t+1} purchased in period *t*+1, lump-sum taxes T_t, and the cost of utilizing the capital stock RC_t, while its income comes from the labor wage $W_t N_t$, capital gains $R_t^k u_t K_t$, corporate profits Π_t, and bond proceeds $i_{t-1}B_t$ from the interest rate of i_{t-1} in period *t*. Thus, its budget constraint is:

$$C_t + I_t + \frac{B_{t+1}}{P_t} \leq \frac{W_t}{P_t} N_t + R_t^k u_t K_t + \frac{\Pi_t}{P_t} - T_t - RC_t + (1 + i_{t-1}) \frac{B_t}{P_t} \tag{4}$$

Where u_t represents the capital utilization rate with a steady state value of 1, defined as $\overline{K_t} \equiv u_t K_t$ effective capital, and R_t^k represents the rate of return on capital, defining that the cost of capital stock utilization has the following form:

$$RC_t = \frac{K_t}{z_t}\left(\chi_1(u_t - 1) + \frac{\chi_2}{2}(u_t - 1)^2\right) \tag{5}$$

where χ_1 and χ_2 are the parameters.

3.2 Producers

Suppose that there are two types of producers in the market, final goods producers and intermediate goods producers, where final goods producers face a perfectly competitive market and sum intermediate goods as final goods, while intermediate goods producers face a monopolistically competitive market and produce intermediate goods with differences using efficient capital $\overline{K_t}$ and labor N_t.

The production function of the final goods manufacturer is assumed to be a Dixit-Stiglitz type (1977) production function:

$$Y_t = \left[\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{6}$$

Where Y_t is the output of the final good, $Y_t(j)$ represents the output of intermediate vendor j, and ε represents the elasticity of substitution between intermediate goods.

Given the price of the final good P_t, and the price of the intermediate good $P_t(j)$, the producer of the final good maximizes profit in a perfectly competitive market by choosing the quantity of the intermediate good $Y_t(j)$.

$$max P_t Y_t - \int_0^1 P_t(j) Y_t(j) dj \tag{7}$$

A partial derivation of the production function of the final good with respect to $Y_t(j)$ yields, the demand function of the intermediate good:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} Y_t \tag{8}$$

Combining this with the fact that the maximum profit in a perfectly competitive market is zero, the total price index determination equation can be obtained:

$$P_t = \left[\int_0^1 P_t(j)^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}} \tag{9}$$

Assume that the production function of the intermediate goods manufacturer is of the Cobb-Douglas type, and let the production function of the intermediate goods manufacturer j be:

$$Y_t(j) = A_t \overline{K_t}(j)^{\alpha_t} N_t(j)^{1-\alpha_t} \tag{10}$$

Where A_t represents total factor productivity with a steady state value of 1 and α_t represents the output share of capital.

The demand constraint faced by intermediate goods manufacturers is:

$$A_t \overline{K_t}(j)^{\alpha_t} N_t(j)^{1-\alpha_t} \geq \left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} Y_t \tag{11}$$

The intermediate goods manufacturer seeks to minimize cost by setting the Lagrangian function as follows:

$$L \equiv -[w_t N_t(j) + R_t^k \overline{K_t}(j)] + \Psi_t(j)\left[A_t \overline{K_t}(j)^{\alpha_t} N_t(j)^{1-\alpha_t} - \left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} Y_t\right] \tag{12}$$

where $w_t \equiv \frac{W_t}{P_t}$ represents the real wage, and $\Psi_t(j) \equiv mc_t$ is the Lagrange multiplier representing the real marginal cost.

A partial derivation for labor and effective capital can be obtained:

$$R_t^k = \Psi_t(j) \alpha_t A_t \overline{K_t}(j)^{\alpha_t - 1} N_t(j)^{1-\alpha_t} \tag{13}$$

$$w_t = \Psi_t(j)(1-\alpha_t) A_t \overline{K_t}(j)^{\alpha_t} N_t(j)^{-\alpha_t} \tag{14}$$

Define the aggregate demand for labor and aggregate capital of intermediate goods manufacturers to be a simple summation of individual intermediate manufacturers:

$$N_t^d \equiv \int_0^1 N_t(j)dj \tag{15}$$

$$\overline{K_t} \equiv \int_0^1 \overline{K_t}(j)dj \tag{16}$$

Summing the first-order conditions above yields:

$$mc_t = \frac{w_t}{(1-\alpha_t)A_t}\left(\frac{\overline{K_t}}{N_t^d}\right)^{-\alpha_t} \tag{17}$$

$$R_t^k = mc_t\alpha_t A_t\left(\frac{\overline{K_t}}{N_t^d}\right)^{\alpha_t-1} \tag{18}$$

Price stickiness is introduced in the model in the manner of Calvo (1983) by assuming that a proportion of intermediate goods vendors with $\theta(0<\theta<1)$ in each period of the model are not able to re-modify their prices, and the rest of the vendors who are able to adjust their prices choose to price up to P_t^* in order to maximize their profits. At this point the aggregate price level can be expressed as:

$$P_t = [(1-\theta)(P_t^*)^{1-\varepsilon} + \theta(P_{t-1})^{1-\varepsilon}]^{\frac{1}{1-\varepsilon}} \tag{19}$$

Firm profit maximization can be expressed as:

$$\max_{\{P_t(j)\}} E_t\sum_{s=0}^{\infty}\theta^s\, SDF_{t,t+s}\frac{\Pi_{t+s}(j)}{P_{t+s}} \tag{20}$$

where $SDF_{t,t+s} \equiv \beta^s\frac{U_{C,t+s}}{U_{C,t}}$ stands for the stochastic discount factor, and $\frac{\Pi_t(j)}{P_t}$ stands for the real profit function of the intermediate goods vendor *j* at period *t*:

$$\frac{\Pi_t(j)}{P_t} \equiv \frac{P_t(j)Y_t(j)}{P_t} - [w_tN_t(j) + R_t^k\overline{K_t}(j)] \tag{21}$$

For the above maximization problem, a partial derivation of $P_t(j)$ can be obtained:

$$P_t^* = \frac{\varepsilon}{\varepsilon-1}\frac{X_{1t}}{X_{2t}} \tag{22}$$

Where X_{1t} and X_{2t} are auxiliary variables.

$$X_{1t} \equiv E_t\sum_{s=0}^{\infty}(\theta\beta)^s\lambda_{t+s}mc_{t+s}P_{t+s}^{\varepsilon}Y_{t+s} \tag{23}$$

$$X_{2t} \equiv E_t\sum_{s=0}^{\infty}(\theta\beta)^s\,\lambda_{t+s}P_{t+s}^{\varepsilon-1}Y_{t+s} \tag{24}$$

Organized into differential form as:

$$X_{1t} = \lambda_t mc_t P_t^{\varepsilon}Y_t + \theta\beta E_tX_{1,t+1} \tag{25}$$

$$X_{2t} = \lambda_t P_t^{\varepsilon-1}Y_t + \theta\beta E_tX_{2,t+1} \tag{26}$$

Defining the price markup $\mathcal{M} \equiv \frac{\varepsilon}{\varepsilon-1}$, the repricing inflation rate $\pi_t^* \equiv \frac{P_t^*}{P_{t-1}}$, and defining $x_{1t} \equiv \frac{X_{1t}}{P_t^{\varepsilon}}$, and $x_{2t} \equiv \frac{X_{2t}}{P_t^{\varepsilon-1}}$.

$$x_{1t} = \lambda_t mc_t Y_t + \theta\beta E_t x_{1,t+1} \pi_{t+1}^{\varepsilon} \quad (27)$$

$$x_{2t} = \lambda_t Y_t + \theta\beta E_t x_{2,t+1} \pi_{t+1}^{\varepsilon-1} \quad (28)$$

$$\pi_t^* = \mathcal{M}\pi_t \frac{x_{1t}}{x_{2t}} \quad (29)$$

3.3 Government and Central Bank

Since this paper focuses on the impact of three shocks arising from the digital transformation of industries, fiscal policy is assumed to include only government consumption. Government spending is assumed to be a variable share of expenditure ω_t^g, and government consumption G_t is derived from a one-time aggregate tax, i.e.:

$$G_t = \omega_t^g Y_t \quad (30)$$

$$G_t = T_t \quad (31)$$

The Taylor rule is used for monetary policy:

$$i_t = (1-\rho_i)i + \rho_i i_{t-1} + (1-\rho_i)\left(\phi_\pi(\pi_t - \pi) + \phi_y(logY_t - logY_{t-1})\right) + \epsilon_t^i \quad (32)$$

where ϕ_π and ϕ_y represent the extent to which the interest rate responds to the inflation gap and the output gap, and $\epsilon_t^i \sim i.i.d.N(0,\sigma_i^2)$, represents the random error term.

3.4 Exogenous Shocks

Total Factor Productivity Technology Shock:

$$a_t = \rho_a a_{t-1} + \epsilon_t^a, \epsilon_t^a \sim i.i.d.N(0,\sigma_a^2) \quad (33)$$

where $a_t = logA_t$.

Investment Marginal Efficiency Shock:

$$lnz_t = \rho_z lnz_{t-1} + \epsilon_t^z, \epsilon_t^z \sim i.i.d.N(0,\sigma_z^2) \quad (34)$$

Capital Substitution Shock:

$$ln\alpha_t = (1-\rho_\alpha)ln\alpha + \rho_\alpha ln\alpha_{t-1} + \epsilon_t^\alpha, \epsilon_t^\alpha \sim i.i.d.N(0,\sigma_\alpha^2) \quad (35)$$

Fiscal Policy Shock:

$$\omega_t^g = \left(1-\rho_g\right)\omega^g + \rho_g \omega_{t-1}^g + \epsilon_t^g, \epsilon_t^g \sim i.i.d.N\left(0,\sigma_g^2\right) \quad (36)$$

3.5 Equilibrium and Summing

In equilibrium, the bond stock B_t is 0 and labor supply equals labor demand, $N_t = N_t^d$, which can be obtained by summing the profits of intermediate goods manufacturers:

$$\frac{\Pi_t}{P_t} \equiv \int_0^1 \frac{\Pi_t(j)}{P_t} dj = Y_t - [w_t N_t^d + R_t^k \overline{K_t}] \quad (37)$$

Combining the constraints for representative households yields the total resource constraint equation:

$$Y_t = C_t + I_t + G_t + \frac{K_t}{z_t}\left(\chi_1(u_t - 1) + \frac{\chi_2}{2}(u_t - 1)^2\right) \quad (38)$$

Linearizing the price level gives:

$$\pi_t^{1-\varepsilon} = (1-\theta)(\pi_t^*)^{1-\varepsilon} + \theta \quad (39)$$

Summing the production functions of the intermediate goods manufacturers gives:

$$Y_t = \int_0^1 Y_t(j)dj = \frac{A_t \overline{K_t}^{\alpha_t} N_t^{1-\alpha_t}}{d_t^p} \tag{40}$$

which defines d_t^p as the price discrete kernel, is satisfied:

$$d_t^p = (1-\theta)(\pi_t^*)^{-\varepsilon}\pi_t^\varepsilon + \pi_t^\varepsilon \theta d_{t-1}^p \tag{41}$$

4. Parameter Calibration and Bayesian Estimation

The parameters in this paper are mainly categorized into two types: static and dynamic parameters, for the static parameters in the model, they are assigned values in the form of calibration; for the rest of the parameters in the model, they are assigned values by Bayesian estimation.

4.1 Static Parameter Calibration

The value of the household subjective discounting primer β is more stable, and in this paper, we take $\beta = 0.99$, which represents a steady state annual interest rate of 4%; the consumption habit coefficient b is taken as 0.7 with reference to Xie Chao feng (2015); the steady state value of labor N is taken as 0.33, which represents eight hours of work per day in the steady state; the inverse of the Frisch elasticity of labor ν is set to be taken as 1 with reference to Guo Yu mei et al. (2016); the depreciation rate of capital δ is taken as 0.025, denoting an annual depreciation rate of 10%; the elasticity of substitution of intermediate goods $\varepsilon = 11$ is taken to represent that the marginal cost of the vendor adds up to 10% at steady state; the steady state value of the share of capital output in the production function of intermediate goods vendors α is taken as 0.33 with reference to Yu Ma yong and Chen Dian dian (2021); and price stickiness θ is taken to be 0.75 according to Mei Dong zhou and Gong Liu tang (2011), which denotes that 75% of the intermediate goods per quarter vendors cannot adjust their prices, and all vendors adjust their prices once a year on average; the response coefficients ϕ_π and ϕ_y in Taylor's rule for the inflation gap and output gap are taken as 1.5 and 0.5 respectively with reference to the common settings. The calibrated values of each static parameter are summarized as shown in Table 1 below.

Table 1. Static Parameter Calibration Values

Parameters	Description	Value
β	Household Subjective Discounting Citation	0.99
b	Consumption habit coefficient	0.7
N	Steady state value of labor	0.33
ν	The inverse of the Frisch elasticity of labor	1
θ	Price Stickiness Parameter	0.75
δ	Capital depreciation rate	0.025
ε	Elasticity of substitution of intermediate goods	11
α	Steady state value of the share of capital output	0.33

ϕ_π	Response coefficients to the inflation gap in Taylor's rule	1.5
ϕ_y	Coefficient of response to output gap in Taylor's rule	0.5

4.2 Dynamic Parameter Estimation

The remaining parameters are the parameters that affect the dynamic nature of the model, this paper adopts the Bayesian method for estimation, before the estimation needs to be given to the estimated parameters of the a priori distribution, this paper refers to the settings of Smets and Wouters (2007), set the regression coefficients of the shocks of the a priori distribution of the mean is 0.5, standard deviation of the beta distribution of 0.1; set the exogenous shocks of the The prior distributions of the standard deviations of the exogenous shocks are all inverse gamma distributions with mean 0.1 and standard deviation $+\infty$. The Bayesian estimation results are shown in Table 2 below.

Table 2. Bayesian Estimation Results for Dynamic Parameters

Parameters	Prior Mean	Prior Standard Deviation	Posterior Mean	Prior Distribution Form	Posterior Distribution 90% Confidence Interval
ρ_a	0.5000	0.1	0.9521	Beta	[0.9513,0.9528]
ρ_z	0.5000	0.1	0.6879	Beta	[0.6735,0.6964]
ρ_α	0.5000	0.1	0.8699	Beta	[0.8571,0.8885]
ρ_g	0.5000	0.1	0.9503	Beta	[0.9458,0.9529]
ρ_i	0.5000	0.1	0.5065	Beta	[0.5038,0.5085]
σ_a	0.1000	$+\infty$	0.5551	Inverse Gamma	[0.4969,0.6017]
σ_z	0.1000	$+\infty$	0.3925	Inverse Gamma	[0.3400,0.4452]
σ_α	0.1000	$+\infty$	0.0209	Inverse Gamma	[0.0147,0.0287]
σ_g	0.1000	$+\infty$	0.0540	Inverse Gamma	[0.0473,0.0637]
σ_i	0.1000	$+\infty$	0.0126	Inverse Gamma	[0.0118,0.0136]

Figure 1 below gives the prior and posterior distribution plots of Bayesian estimation, the gray solid line is the prior distribution and the black solid line is the posterior distribution, it can be seen that the posterior distribution is more concentrated and the Bayesian estimation results are better.

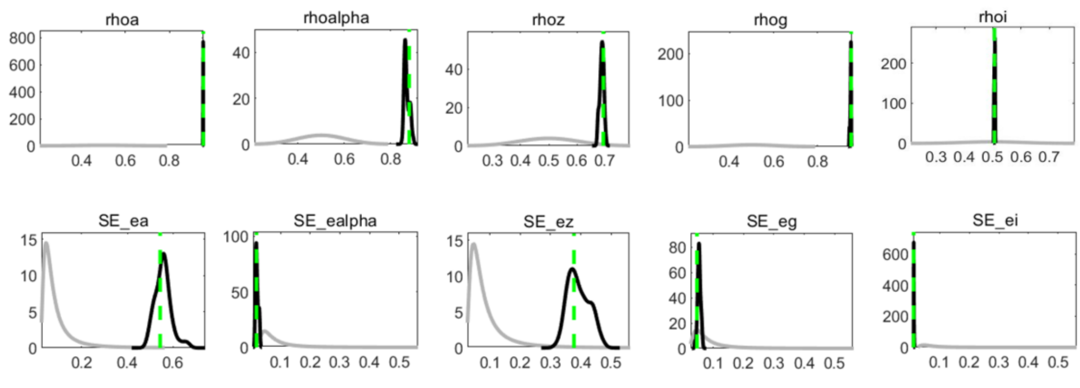

Figure 1. Plot of Prior and Posterior Distributions of Dynamic Parameters

5. Numerical Simulation Analysis

In the next part of this paper, numerical simulation analysis will be carried out by both impulse response analysis and variance decomposition to compare and analyze the impacts of technological shocks, capital substitution shocks and investment marginal efficiency shocks brought by the digital transformation of industries on economic development.

5.1 Impulse Response Analysis

In order to examine the dynamic impact of exogenous shocks brought about by the digital transformation of industries on the main economic variables, this paper sets 1% size of positive technology shocks, capital substitution shocks and investment marginal efficiency shocks, respectively, and the corresponding impulse responses are shown in Figure 2 below, with the horizontal coordinate being the simulation period and the vertical coordinate representing the ratio of changes in the team's response variables.

5.1.1 Impulse Response Analysis of a Positive Technology Shock

At the beginning of the positive technology shock of 1% size, capital utilization rate immediately increases by about 1.5%; output (0.1%), consumption (0.2%) and investment (0.7%) also increase; employment (-1.2%) and wages (-0.4%) are negatively affected to varying degrees. Subsequently, capital utilization gradually returned to its steady state value; output, consumption and investment rose rapidly to peak in period 9 (1.3%), period 7 (0.4%) and period 9 (2.5%), respectively, and then declined gradually, but all were above their steady state levels for a long time; employment and wages also began to turn positive in periods 5 and 3, respectively, and reached their peaks in periods 11 (0.3%) and 10 (0.8%), respectively. (0.8%), and then gradually decline to steady state levels. The transmission path of the impulse response to technology shocks is consistent with the previous theoretical analysis, as technological progress immediately brings about an increase in the utilization rate of capital, thus initially negatively affecting the labor market, and then the increase in production efficiency brought about by technological progress drives a rapid increase in output, and the investment in consumption in the market increases, boosting employment and raising the level of wages.

5.1.2 Impulse Response Analysis of Positive Capital Substitution Shock

Under a positive capital substitution shock of 1% size, output, consumption, investment, employment, and wages all exhibit impulse responses similar to those of the technology shock, with relatively small fluctuations; capital utilization, on the other hand, exhibits a positive response with a certain time lag, peaking at period 6 (0.8%). The intrinsic reason for such impulse response results is that the increase in capital utilization brought about by the technology shock manifests itself in the substitution of capital for labor in production, so that several economic variables exhibit similar response curves under both shocks.

5.1.3 Impulse Response Analysis of a Positive Investment Marginal Efficiency Shock

Under a 1%-sized positive investment marginal efficiency shock, output (0.5%), capital utilization (1%) and investment (0.6%) increase rapidly; employment and wages have a relatively small positive response followed by a rapid return to the steady state level; consumption decreases and then increases, exceeding the steady state value in the 9th period and showing a positive response in the long run. The transmission path of the investment efficiency shock is that an increase in the marginal efficiency of investment leads to a rise in investment, which raises the level of output in the short run and pushes firms to generate more demand for labor, which then leads to a rise in consumption.

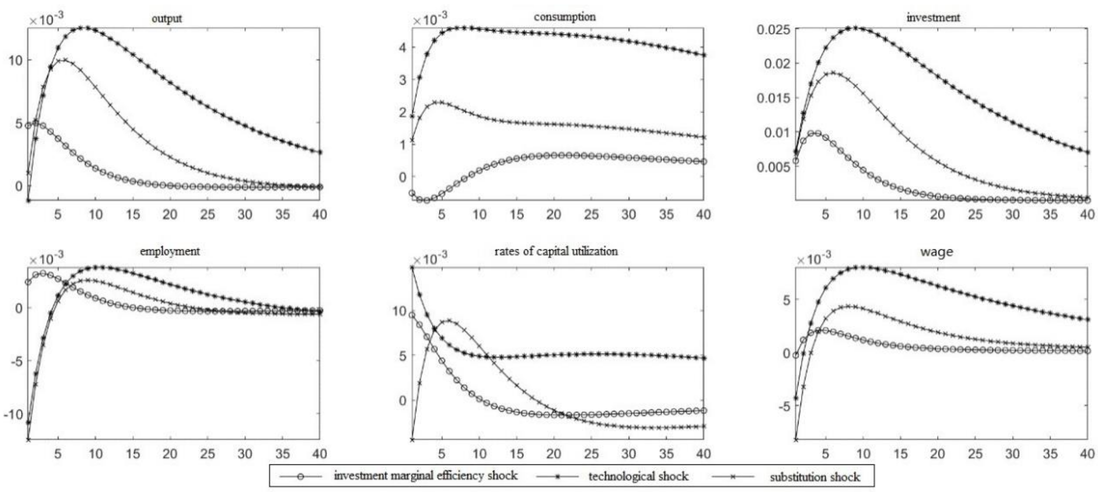

Figure 2. Impulse Response Plots of Three Shocks from Digital Transformation of Industries

Taken together, the above impulse response analysis shows that the marginal efficiency of investment has a greater impact on output in the short run, but in the long run, technological progress leads to the most significant economic growth. This also shows the importance of digital technological progress for economic development.

5.2 Variance Decomposition Analysis

In this paper, the variance decomposition of the fluctuations of the main economic variables in the model was carried out in the first, fourth, fortieth and infinite periods, respectively, and the results are shown in Table 3 below.

Table 3. Results of the Variance Decomposition of the Main Economic Variables(%)

Period	Variable	Technological Shock	Capital Substitution Shock	Marginal Efficiency Shock to Investment	Fiscal Policy Shocks	Monetary Policy Shocks
1	Output	9.15	0.01	76.82	13.70	0.33
	Employment	95.79	0.18	2.38	1.63	0.01
	Wage	97.56	0.51	0.18	0.99	0.76
	Inflation	98.80	0.13	0.78	0.25	0.04
4	Output	76.03	0.12	21.64	2.15	0.06
	Employment	88.05	0.17	9.45	2.31	0.03
	Wage	89.84	0.21	8.63	0.90	0.42
	Inflation	95.78	0.10	3.75	0.33	0.04
40	Output	97.23	0.05	2.48	0.24	0.01
	Employment	90.07	0.11	7.92	1.89	0.02
	Wage	98.72	0.03	1.18	0.05	0.02
	Inflation	93.42	0.11	6.06	0.38	0.04
∞	Output	97.28	0.05	2.44	0.24	0.00
	Employment	90.84	0.10	7.25	1.80	0.02
	Wage	98.82	0.03	1.08	0.05	0.02
	Inflation	93.44	0.11	6.03	0.38	0.04

The results in Table 3 show that the main sources of fluctuations in output are technology shocks investment marginal efficiency shocks and fiscal policy shocks, which play a major role in short-run investment marginal efficiency shocks, but the main source of long-run output fluctuations is technology shocks. The main source of fluctuations in employment, wages, and inflation are technology shocks followed by investment marginal efficiency shocks. It can be seen that the most important source of contribution to the volatility of the above variables is technology shocks, followed by investment marginal efficiency shocks and fiscal policy shocks, with capital substitution shocks and monetary policy shocks contributing to a lesser extent.

6. Robustness Analysis

Referring to Deng Hong liang and Chen Le yi (2019), this paper conducts a robustness test of the simulation results from two perspectives: the sensitivity test of some model parameters and the data quality, which are used to illustrate the robustness of the results in this paper.

6.1 Sensitivity Test

In this paper, the sensitivity test of some parameters in the model is conducted to examine the potential impact of different values of the parameters on the simulation results. These parameters include the price stickiness parameter θ, the monetary policy parameters φ_π and φ_y. Adjusting the values of the above three parameters up or down by 10%, the impulse response plots obtained under different parameter scenarios are basically similar in shape to that of the benchmark model.

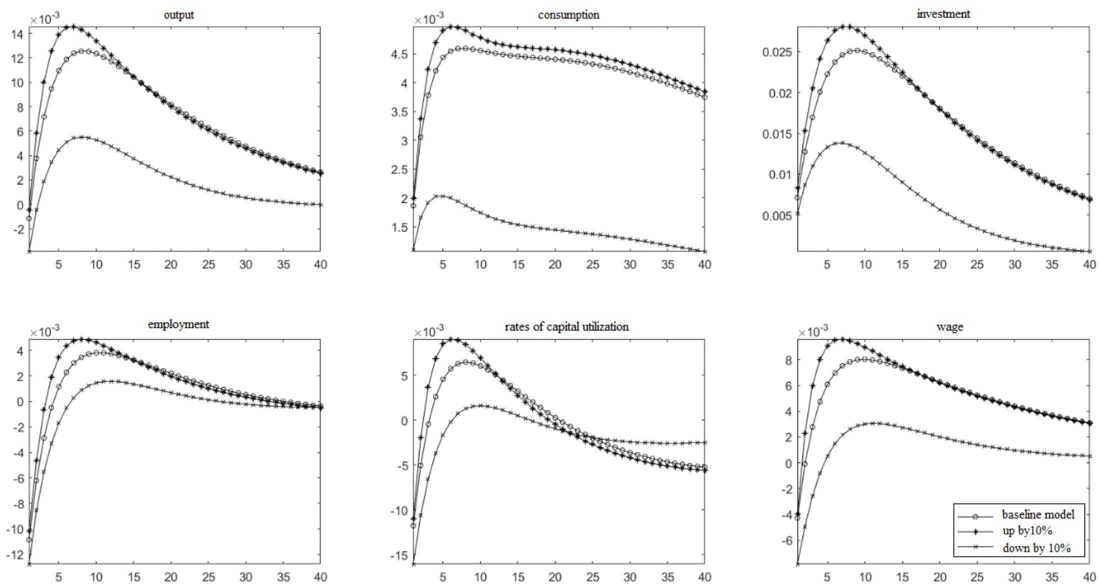

Figure 3. Impulse Response Plots of Key Economic Variables Subject to Technology Shocks at Different Parameter Settings

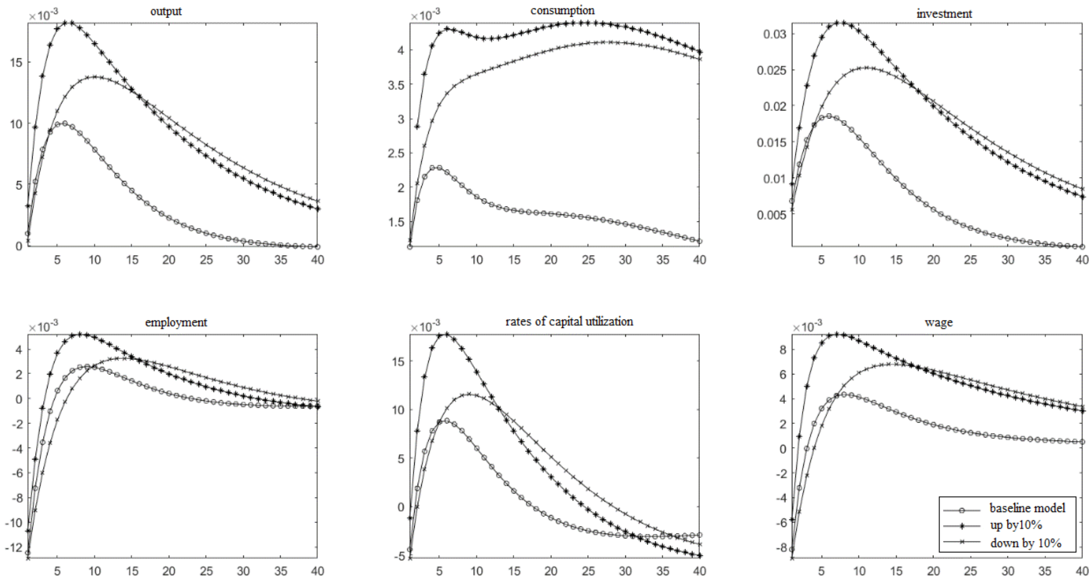

Figure 4. Impulse Response Plots of Major Economic Variables Subject to Capital Substitution Shocks under Different Parameter Settings

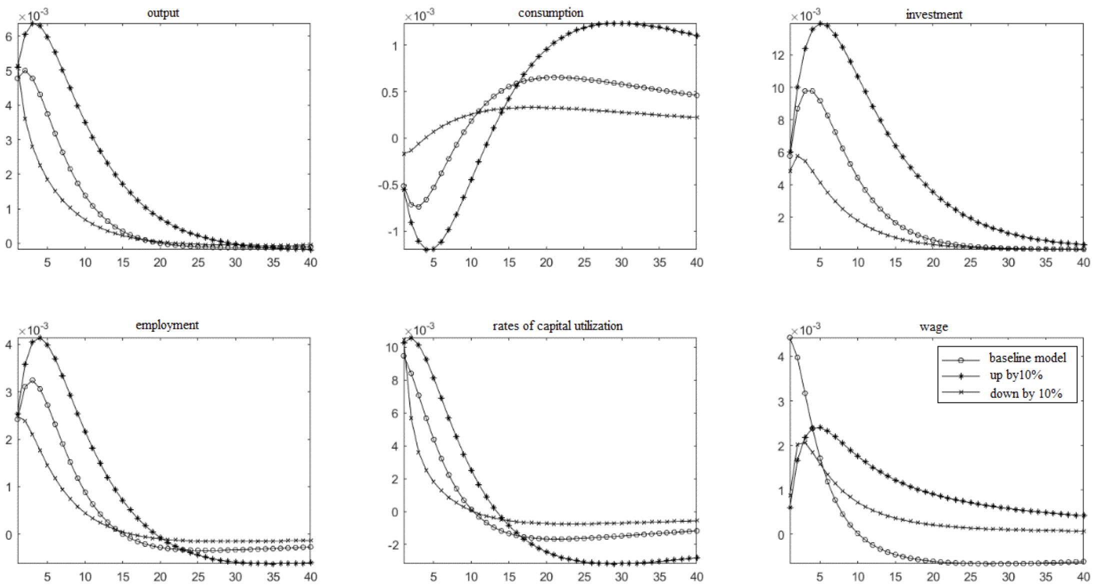

Figure 5. Impulse Response Plots of Major Economic Variables Subject to Shocks to the Marginal Efficiency of Investment under Different Parameter Settings

6.2 Data Quality Analysis

This paper utilizes the Chinese macro time series database constructed by Higgins and Zha (2015) to re-estimate the Bayesian estimation of the dynamic parameters in the paper, and the control results are shown in Table 4 below. It can be seen that the estimation results of the dynamic parameters related to the digital transformation of industries do not differ much from the results in this paper, which indicates that the data quality of the model in this paper is high and the simulation results are robust.

Table 4. Posterior Distribution Comparison Results

Variable	Baseline model		Compare model	
	Posterior Mean	Posterior Distribution 90% Confidence Interval	Posterior Mean	Posterior Distribution 90% Confidence Interval
ρ_a	0.9521	[0.9513,0.9528]	0.9517	[0.9501,0.9529]
ρ_z	0.6879	[0.6735,0.6964]	0.5498	[0.5446,0.5554]
ρ_α	0.8699	[0.8571,0.8885]	0.9492	[0.9458,0.9527]
ρ_g	0.9503	[0.9458,0.9529]	0.3175	[0.3097,0.3280]
ρ_i	0.5065	[0.5038,0.5085]	0.6961	[0.6872,0.7060]
σ_a	0.5551	[0.4969,0.6017]	0.4608	[0.4015,0.5408]
σ_z	0.3925	[0.3400,0.4452]	0.5691	[0.4804,0.7089]
σ_α	0.0209	[0.0147,0.0287]	0.0722	[0.0617,0.0841]
σ_g	0.0540	[0.0473,0.0637]	0.0203	[0.0176,0.0232]
σ_i	0.0126	[0.0118,0.0136]	0.0122	[0.0118,0.0126]

7. Conclusion

By developing a dynamic stochastic general equilibrium model encompassing technology shocks, capital substitution shocks, and investment marginal efficiency shocks, this study delves into the transmission mechanism and simulation effects of industrial digital transformation on economic development. The findings reveal that concerning economic growth, all three types of shocks induced by industrial digital transformation contribute to increased output. In the short term, the investment marginal efficiency shock rapidly enhances output, while in the long term, the most pronounced effect on output increase stems from technology shocks. Examining the labor market, the investment marginal efficiency shock positively influences both employment and wage levels, whereas technology shocks and capital substitution shocks initially dampen and later stimulate employment and wages. Evaluating the commodity market, the impact of the three shocks is more prominent in the medium and long term, exerting varying degrees of influence on investment and consumption. In light of these insights, the paper proposes the following policy recommendations:

Firstly, the crux of fostering long-term economic growth through industrial digital transformation lies in technological progress. Therefore, there is a pressing need to bolster the construction of digital infrastructure and intensify foundational research in digital technologies, including artificial intelligence, big data, and cloud computing, to enhance basic innovation capabilities. Secondly, while the short-term implications of industrial digital transformation on employment and wage levels may be adverse, proactive employment policies must be implemented to broaden job opportunities for workers. There should be a concerted effort to enhance the quality of the workforce by reinforcing education and training initiatives within enterprises, aiming to swiftly achieve structural transformation in the labor market. Thirdly, it is imperative to fortify policy support for the digital transformation of traditional industries and cultivate a conducive institutional environment. In the realm of finance, amplify investments in the digital transformation of traditional sectors and actively implement policies that benefit enterprises. In terms of talent acquisition, refine incentive mechanisms, facilitate the seamless integration of digital professionals and technical talents with diverse traditional industries, foster deeper collaboration between educational institutions, government bodies, and enterprises, and incentivize businesses to attract top talents and teams through mechanisms such as options and equity.

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