Research on the Evolutionary Characteristics and Influencing Factors of Total Factor Productivity in Wenzhou (2014–2023): A Dual Validation Based on the DEA–Malmquist Index and the Solow Residual Method

Chuting Lin, Weilun Huang[*]

School of Finance and Trade, Wenzhou Business College, Zhejiang, China
*Corresponding Author

Abstract: Total Factor Productivity (TFP) is a core indicator for measuring the quality of regional economic growth. Based on data from the Wenzhou Statistical Yearbook (2014–2023), this paper performs dynamic measurement and structural decomposition of Wenzhou's TFP using the Solow Residual Method and the DEA-Malmquist Index. The findings reveal that Wenzhou's TFP level declined over the decade, with an average annual decrease of 2.1%. Economic growth remains significantly dependent on the expansion of capital and labor scales, and an efficiency-driven transformation has yet to be fully realized. Results indicate that stagnant technological progress and deteriorating scale efficiency are the primary causes of the TFP decline, reflecting systemic bottlenecks in Wenzhou regarding translation, industrial structure optimization, and factor allocation. Although the decline has narrowed since 2021 due to digital transformation, the technological adaptability of small and medium-sized enterprises remains weak and the sustainability of efficiency improvements is insufficient. This paper reports that Wenzhou should increase R&D investment, accelerate industrial digitalization, optimize the market-based allocation of factors, and establish a system for talent attraction and cultivation to drive the transition from factor-driven to efficiency-driven economic growth.

Keywords: Total Factor Productivity (TFP); Wenzhou Economy; DEA-Malmquist; Technological Progress; Factor Allocation; High-quality Development

1. Introduction

Total Factor Productivity (TFP) is a core indicator for measuring the quality of economic growth, reflecting the combined contributions of technological progress, efficiency improvement, and the optimization of resource allocation in the production process[1]. An in-depth study of TFP in Wenzhou from 2014 to 2023 not only helps to clarify the intrinsic driving mechanisms of Wenzhou's economic growth, but also provides important decision-making references for promoting high-quality regional economic development.

As the birthplace of Chinese private economy and a pioneer of reform and opening-up, Wenzhou's total economic output steadily increased from RMB 430.281 billion in 2014 to RMB 873.06 billion in 2023, with an average annual growth rate of 7.8%, and has ranked 30th nationwide in terms of urban economic size for five consecutive years. However, under the background of the new economic normal, the extensive growth model that relies primarily on factor input expansion has encountered bottleneck constraints[2], making the improvement of total factor productivity a key pathway to achieving sustainable development[3].

Based on authoritative data from the Wenzhou Statistical Yearbook, this study adopts the Solow Residual Method and the DEA-Malmquist index approach to systematically measure and conduct multidimensional analysis of Wenzhou's TFP from 2014 to 2023. It comprehensively reveals the evolutionary trend of economic growth quality in Wenzhou and the deep underlying factors driving this process, and proposes targeted policy recommendations to promote high-quality economic development in the region.

2. Literature Review

2.1 Main Measurement Methods of TFP and

Their Evolution

The measurement of total factor productivity constitutes the foundation of related research and can generally be divided into two main categories: parametric methods and non-parametric methods. Among parametric approaches, the Solow Residual Method is the most representative. Its basic principle is to assume a specific production function, such as the Cobb-Douglas production function, and to attribute the portion of output growth that cannot be explained by the growth of factor inputs to TFP growth. For example, Wang et al. (2006)[4] and Shi (2012)[5] applied parametric models such as stochastic frontier analysis (SFA) to estimate regional TFP in China. However, the Solow Residual Method is sensitive to the specification of the production function, the assumed output elasticities of production factors, and the estimation of capital stock, which may lead to estimation bias[6]. When estimating TFP for Beijing, Shanghai, and Guangdong, Yang et al. (2025)[7] simultaneously employed the Solow Residual Method (SR method) and Data Envelopment Analysis (DEA), and found that the overall trends obtained from the two methods were largely consistent, thereby enhancing the robustness of their conclusions.

Non-parametric methods are represented by Data Envelopment Analysis (DEA) and its derived Malmquist index approach. This class of methods does not require a pre-specified production function and can effectively distinguish between changes in technical efficiency and technological progress. The DEA-Malmquist model has been widely applied to the dynamic decomposition of TFP at the regional, industrial, and firm levels (Liu, 2022)[1]. For instance, Lu and Zhou (2010)[8] incorporated semi-fixed inputs into the Malmquist index, making it more consistent with real production conditions. Jiang et al. (2025)[9] used this model to examine the driving effects of the digital economy on TFP in the circulation sector. Wang et al. (2010) further combined the slack-based measure (SBM) directional distance function with the Luenberger productivity index to incorporate energy consumption and pollutant emissions into the traditional TFP framework, thereby measuring a more comprehensive form of environmental total factor productivity[10].

In recent years, with improvements in national accounting systems, the capitalization of research and development (R&D) expenditures has been incorporated into the TFP measurement framework. Based on SNA2008 and CSNA2016, Du and Xu (2024) treated R&D as capital formation and re-estimated the growth rates of 'generalized TFP' for Chinese provinces from 1991 to 2019 using the SFA method[11]. Their results indicate that the contribution of R&D capital has shown a rising trend. Xu et al. (2025) also emphasized the importance of R&D capital in economic growth models[12].

2.2 Multidimensional Factors Affecting TFP

A large body of literature has explored the determinants of TFP from different perspectives. At macro level, economic policies and institutional environments play an important role. Local government behavior has been found to exert significant effects on TFP. Tax competition can generally enhance regional TFP by attracting firms and promoting industrial cluster, although the effects exhibit substantial regional heterogeneity[13]. In contrast, the expansion of local public debt may suppress TFP improvement by increasing firms' tax burdens and crowding out credit resources, particularly by imposing financing constraints on non-state-owned enterprises[14]. As a policy-oriented financial instrument, government-guided funds can support breakthrough innovation and investment in digital equipment, optimize capital allocation, and thereby enhance the TFP of recipient firms, with more pronounced effects observed in regions with lower levels of marketization and among state-owned enterprises[15-16]. From the perspective of institutional adaptability, Ye et al. (2022)[16] analyzed the transformation of the Wenzhou model and pointed out that the adaptability of local economic governance systems[17] is a key determinant of the success or failure of regional development models and TFP performance.

The development of digital finance has also been shown to significantly promote TFP improvement by alleviating information asymmetry, reducing service costs, expanding service boundaries, and optimizing the allocation of financial resources. Empirical evidence from Zhu et al. (2025)[18] suggests that digital finance can reduce the degree of financial misallocation and expand service coverage. Industrial agglomeration represents another important channel, as digital finance can further enhance TFP by promoting diversified industrial cluster.

At micro-level, enterprise digital transformation constitutes a core pathway for improving TFP. Liu (2025)[19] finds that digital transformation can directly promote firms' TFP, with underlying mechanisms including increased fixed asset investment, optimization of human capital, and the promotion of disruptive technological innovation, particularly at business model innovation. Moreover, environment uncertainty has been shown to strengthen the positive impact of digital transformation on TFP.

2.3 TFP, New Quality Productive Forces, and High-Quality Development

The concept of 'new quality productive forces' provides a new analytical framework for understanding TFP in the context of contemporary economic development[20]. A substantial increase in TFP is widely regarded as the core criterion for the development of new quality productive forces. These productive forces influence TFP through three main pathways-new technologies, new business forms, and new economic models-and generate three corresponding effects, namely labor optimization, industrial upgrading, and factor deepening. New technologies and factors deepening primarily drive technological progress by expanding the production possibility frontier, while new business forms, new economic models, labor optimization, and industrial upgrading mainly improve technical efficiency. Existing studies indicate that innovation-intensive regions such as Beijing, Shanghai, and Guangdong have experienced declining or decelerating TFP growth since 2009, with insufficient technical efficiency identified as the primary constraint, highlighting the urgent need to achieve breakthroughs through the development of new quality productive forces.

As an important component of new quality productive forces, the digital economy is closely associated with TFP improvement. The digital economy can drive high-quality development, particularly in the circulation sector, partly by enhancing circulation efficiency and TFP. This reflects the role of deep integration between digital technologies and the real economy in facilitating efficiency transformations.

2.4 Implications from Regional Case Studies: Evidence from Wenzhou

In-depth studies of specific regions provide valuable contextual insights. Existing evidence suggests that Wenzhou's TFP level has exhibited a persistent downward trend, with negative growth rates, indicating that economic growth has been highly dependent on factor input expansion. DEA-based analyses show that stagnation in technological progress constitutes the primary cause, accompanied by prominent problems of factor misallocation, such as excessive capital concentration in traditional manufacturing-and low scale efficiency. Although policy interventions implemented after 2021, including digital transformation initiatives, have begun to yield initial results, the weak technological adaptability of small and medium-sized enterprises implies that overall transformation remains a long-term challenge. This case corroborates the view of Ye et al. (2022)[16] that the 'Wenzhou model' requires enhanced institutional adaptability and governance system transformation, and also highlights the general urgency for traditional manufacturing regions to improve TFP through technological innovation, industrial upgrading, and optimization of factor allocation.

2.5 Research Review and Outlook

In summary, research on TFP has developed into a comprehensive framework characterized by diverse methodologies, multidimensional perspectives, and multiple levels of analysis. The research focus has gradually shifted from traditional measurement and macro-level factor analysis toward closer integration with new development concepts-such as new quality productive forces, the digital economy, and green development-as well as micro-level firm behavior, including digital transformation and innovation, and deeper institutional reforms. Future research may be further advanced in several directions. First, it is necessary to develop higher-quality TFP measurement systems that are better adapted to Chinese complex economic conditions, incorporating new dimensions such as R&D capital, data factors, and environmental constraints. Second, greater attention should be paid to the micro-level mechanisms and concrete policy pathways through which new quality productive forces enhance TFP, particularly across different regions and industries. Third, stronger integration between case studies and macro-econometric analysis is needed to provide more targeted TFP improvement strategies for regions with diverse development models. Finally, future

studies should examine how the coordination of financial, fiscal, and industrial policies can more effectively facilitate a virtuous cycle among technology, industry, and finance, thereby sustaining long-term TFP growth.

3. Research Methods and Data Sources

3.1 TFP Calculation Method

This study employs the Cobb-Douglas Production Function and the Solow residual method to calculate TFP. The production function (1) is specified as follows:

$$Y_t = A_t \times K_t^{\alpha} \times L_t^{\beta} \qquad (1)$$

where Y_t denotes real GDP, K_t represents fixed capital stock, L_t denotes labor input, A_t is total factor productivity, and α and β are the output elasticities of capital and labor, respectively. Based on the literature review and regional economic characteristics, this study assumes α =0.4 and β =0.6.

Accordingly, the level of TFP is calculated using the following formula (2) :

$$A_t = Y_t / (K_t^{0.4} \times L_t^{0.6}) \qquad (2)$$

3.2 DEA-Malmquist Method

To overcome the dependence of the Solow residual method on the specification of the production function form and factor output elasticities, this study further applies the Data Envelopment Analysis (DEA) approach to conduct a non-parametric estimation and structural decomposition of total factor productivity changes in Wenzhou during 2014-2023. This method does not require a predefined production function and can effectively identify the relative contributions of changes in technical efficiency and technological progress.

The BCC model is adopted in this study. Wenzhou's economy is dominated by small and medium-sized enterprises (SMEs). By the end of 2021, SMEs accounted for as much as 99% of industrial enterprises above designated size in Wenzhou, and most of them faced diminishing returns to scale (DRS). These characteristics indicate that firms in Wenzhou find it difficult to improve efficiency through scale expansion and instead need to focus more on technological improvement and resource allocation optimization. Therefore, this study adopts the Malmquist Productivity Index (MPI) based on an input-oriented BCC model under the assumption of variable returns to scale (VRS).

3.3 Data Sources and Processing

The data used in this study are mainly obtained from the Wenzhou Statistical Yearbook 2023, Wenzhou Statistical Yearbook 2022, and annual statistical bulletins released by the Wenzhou Municipal Bureau of Statistics. All data have been strictly screened and cross-validated to ensure accuracy, consistency, and reliability.

3.3.1 Output indicator (Y)

Real regional gross domestic product (GDP) is used as the output indicator. Relevant data are reported in Table 1.

Table 1. GDP Data of Wenzhou, 2014-2023

Year	Nominal GDP (RMB 100 million)	GDP Growth Index (Previous Year=100)
2014	4302.81	107.2
2015	4619.84	108.3
2016	5045.4	108.4
2017	5453.2	108.4
2018	6006.2	107.8
2019	6606.1	108.2
2020	6870.9	103.4
2021	7585.0	107.7
2022	8029.8	103.7
2023	8730.6	106.9

Data source: Wenzhou Statistical Yearbook

3.3.2. Capital input indicator (K)

Fixed capital stock is used as the proxy for capital input. According to the Perpetual Inventory Method, fixed capital stock is calculated as (3) :

$$K_t = K_{t-1} \times (1 - \delta) + I_t \qquad (3)$$

where δ is the depreciation rate, assumed to be 5% in this study, and I_t enotes real fixed asset investment in the current year. The initial capital stock for 2013 is estimated using investment data from 2011–2013, yielding a value of RMB 1,192.05 billion.

3.3.3. Labor input indicator (L)

The total number of employed persons in the whole society is used as a proxy variable for labor input. The data are obtained from the 'Employment and Labor Remuneration' section of the Wenzhou Statistical Yearbook. This measure covers employment in urban units, private sectors, rural agricultural activities, and flexible employment, thereby providing a relatively comprehensive reflection of Wenzhou highly developed private economy and the coexistence of urban–rural dual employment structures.

In 2014, the total number of employed persons

in Wenzhou was influenced by structural reforms such as the 'machine substitution' initiative and the 'output per mu' evaluation system, employment elasticity exhibited an inverted U-shaped trajectory. During 2014–2016, total employment expanded moderately and reached a temporary peak of 8.2542 million in 2016. From 2017 to 2019, with the acceleration of digital transformation in manufacturing and peak labor demand in traditional industries, total employment stabilized at around 8.30 million, with an average annual fluctuation of less than 0.3%. During 2020–2023, the combined effects of the COVID-19 shock and population outflow led employment to decline to 8.2537 million in 2020. Subsequently, emerging business models such as platform-based economy and live-streaming e-commerce absorbed part of flexible employment, and total employment slightly rebounded to 8.3000 million in 2023. However, it remained below the 2019 level, exhibiting transitional characteristics of plateauing at the peak followed by mild contraction.

3.3.4. Price index

This study uses the consumer price index (CPI) of Zhejiang Province (2014=100) to deflate nominal variables in order to ensure intertemporal comparability. During 2014–2023, the average annual increase in CPI in Wenzhou was 1.5%, with a cumulative rise of 15.6%, which was lower than the national average over the same period (17.2%). This indicates relatively moderate regional inflationary pressure. To verify the robustness of the deflation method, alternative deflation schemes using the GDP deflator and the fixed asset investment price index are further constructed. The average annual differences among the three price indices are less than 0.3 percentage points, and their impacts on real GDP and capital stock series are controlled within 1.5%, indicating that the CPI-based deflation results are reliable and sufficiently robust.

4. Results and Analysis of TFP in Wenzhou

4.1 Estimation Results of TFP Levels
Based on the above methodology and data, the TFP levels of Wenzhou from 2014 to 2023 are calculated as reported in Table 2.

4.2 Analysis of TFP Growth Rates
Table 3 reports the calculated growth rates of TFP and its contribution to economic growth.

Table 2. Total Factor Productivity (TFP) Levels in Wenzhou, 2014–2023

Year	Real GDP (billion CNY)	Capital Stock (billion CNY)	Employment (10,000 person)	TFP Level	TFP Index (2014=100)
2014	4302.81	14486.35	813.69	0.0321	100.0
2015	4619.84	17634.53	811.21	0.0298	92.8
2016	5045.4	21142.23	818.22	0.0277	86.3
2017	5453.2	24875.24	824.55	0.0259	80.7
2018	6006.2	28754.51	828.74	0.0244	76.0
2019	6606.1	32740.26	832.36	0.0233	72.6
2020	6870.9	36650.64	833.75	0.0224	69.8
2021	7585.0	40575.83	832.81	0.0225	70.1
2022	8029.8	44427.04	831.82	0.0217	67.6
2023	8730.6	48360.54	830.00	0.0212	66.0

Table 3. TFP Growth Rates in Wenzhou

Year	GDP Growth (%)	Capital Growth (%)	Labor Growth (%)	TFP Growth (%)	TFP Contribution to Growth (%)
2015	8.3	21.7	-0.30	-4.8	-57.8
2016	8.4	19.9	0.86	-4.2	-50.0
2017	8.4	17.7	0.77	-3.5	-41.7
2018	7.8	15.6	0.51	-2.7	-34.6
2019	8.2	14.0	0.44	-2.1	-25.6
2020	3.4	12.0	0.17	-5.9	-173.5
2021	7.7	10.7	-0.11	-0.4	-5.2
2022	3.7	9.5	-0.12	-1.4	-37.8
2023	6.9	8.9	-0.22	-0.4	-5.8

The estimated TFP growth rates reveal deep structural problems in Wenzhou's growth dynamics. During 2014–2023, TFP growth remained consistently negative, with an average rate of -2.8%, indicating that economic expansion continued to rely primarily on quantitative accumulation of capital and labor. The COVID-19 shock in 2020 led to a sharp decline in TFP (-5.9%), resulting in a negative contribution of -173.5% to GDP growth, thereby exposing the adverse effects of factor-intensive growth inertia.

Although the decline in TFP growth narrowed during 2021–2023, averaging approximately -0.7%, it remained in negative territory.

This suggests that digital upgrading and technological renovation have mitigated, but not reversed, the downward trend in efficiency. Meanwhile, the negative contribution of TFP to economic growth narrowed from -25.6% to -57.8% during 2015–2019 to a range of -5.2% to -37.8% in the later period. Despite this moderation, TFP has yet to make a positive contribution to growth.

4.3 Comparison with National and Peer Cities
Figure 1 are comparisons that conducted with the national average and selected peer cities.

Figure 1. TFP Growth Rate and Economic Contribution

4.3.1 Comparison with the national average
According to data from the National Bureau of Statistics, Chinese average TFP growth rate during 2014–2023 was approximately 3.7%, contributing around 30–35% to overall economic growth. In contrast, Wenzhou's TFP growth remained negative throughout the period, with a consistently negative contribution to GDP growth. Figure 1 indicates a substantial divergence between Wenzhou's growth pattern and the prevailing national trend.
4.3.2 Comparison with Yangtze River delta cities
Compared with cities such as Shanghai, Hangzhou, and Ningbo, which generally exhibit positive TFP growth rates and contribution shares of 20–30%, Wenzhou's performance is significantly weaker. For example, Hangzhou recorded an average annual TFP growth rate of approximately 1.2% during 2014–2023, contributing about 15% to economic growth. This comparison in figure 2 underscores Wenzhou's relative lag in technological progress and efficiency improvement within the Yangtze River Delta region.

4.3.3 Comparison with other cities in Zhejiang

Province
Relative to cities such as Ningbo and Jiaxing, Wenzhou also exhibits inferior TFP performance. While these cities maintain positive TFP growth rates in figure 3, Wenzhou is among the few cities in Zhejiang Province where TFP growth has remained persistently negative. This outcome reflects the structural characteristics of Wenzhou's economy, which is dominated by labor-intensive manufacturing with relatively low technological content.

4.4 Dynamic Decomposition Based on the DEA–Malmquist Index
Using DEAP 2.1 software to estimate panel data for 2014–2023, the results are reported in Table 4.
Overall, TFP exhibits a declining trend, with recent signs of stabilization and slight recovery. During 2014–2020, the Malmquist Productivity Index (MPI) remained below 1, indicating an average annual TFP decline of approximately 1.2%, which is highly consistent with the negative trend obtained from the Solow residual approach. In 2020–2021 and 2022–2023, MPI slightly exceeded 1, suggesting marginal improvements in TFP, possibly attributable to

accelerated digital transformation and the effectiveness of post-pandemic technological investment. However, this improvement lacks persistence, as the MPI for 2021–2022 remained below 1 (0.987), indicating that Wenzhou's growth model transformation is still at an early stage.
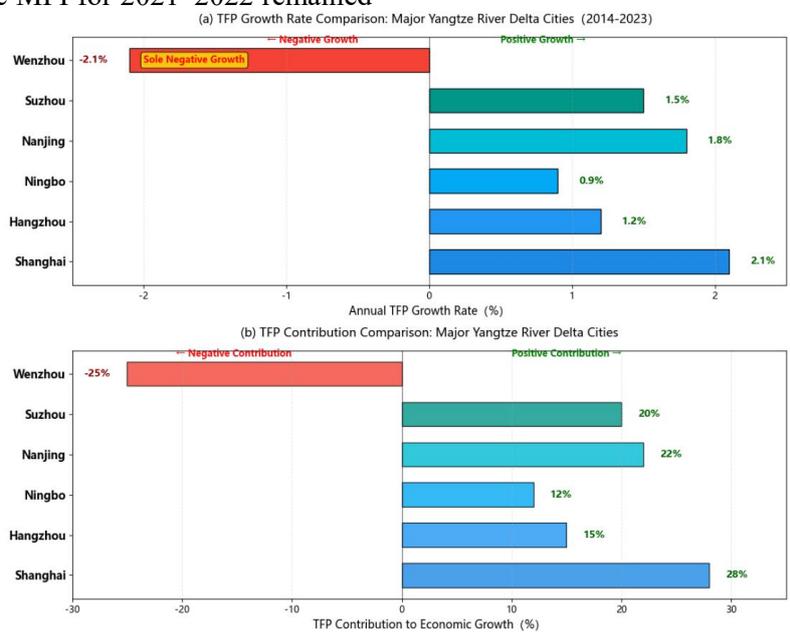

Figure 2. Comparison of TFP Performance Between Wenzhou and Major Yangtze River Delta Cities(2014-2023)
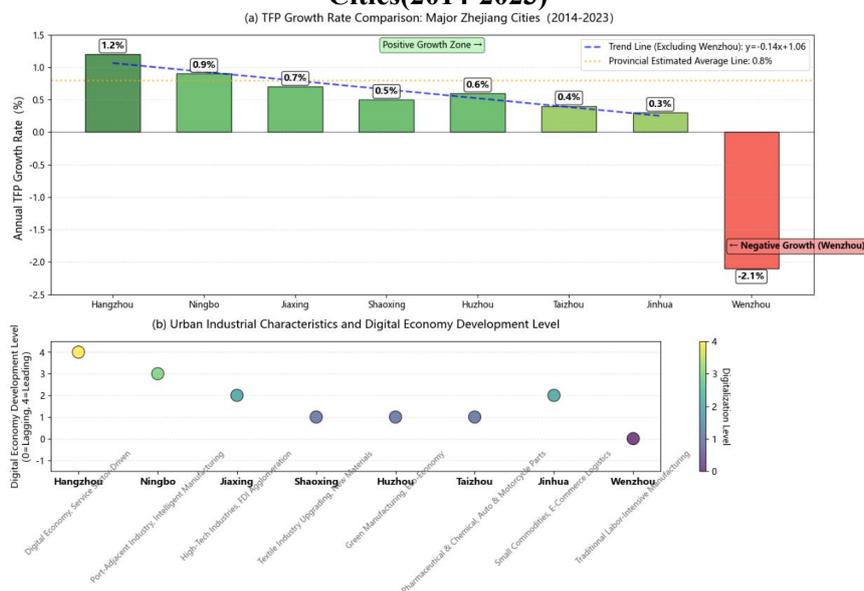

Figure 3. Zhejiang Cities: TFP Growth and Industry Profiles (2014-2023 Average)

Technological progress emerges as the primary driver of TFP decline. Except for the post-2020 period, the technological change (TC) index is consistently below 1, implying slow outward shifts-or even inward movements-of the production frontier. This finding corroborates concerns regarding insufficient R&D intensity and the lack of breakthrough innovation.

Table 4. DEA–Malmquist Decomposition Results

Period	MPI (TFP Change)	Pure Technical Efficiency Change (PTEC)	Technological Change (TC)
2014-2015	0.952	0.986	0.975
2015-2016	0.961	0.992	0.981
2016-2017	0.968	0.995	0.980
2017-2018	0.973	0.997	0.981

2018-2019	0.979	0.998	0.985
2019-2020	0.941	0.978	0.975
2020-2021	1.005	1.002	1.002
2021-2022	0.987	0.996	0.997
2022-2023	1.003	1.001	1.002

Note: MPI < 1 indicates TFP decline, while MPI > 1 indicates TFP improvement.

During 2014–2020, TC declined at an average annual rate of approximately 1.2%, reflecting the stagnation of the technological frontier due to the dominance of traditional manufacturing and insufficient R&D investment. After 2021, TC turned marginally positive, indicating initial effects of policy intervention. However, these gains remain limited and are concentrated primarily among leading firms, while small and medium-sized enterprises exhibit weak technological absorption capacity, thereby constraining overall TC improvement.

Technical efficiency remains relatively stable, while scale efficiency deteriorates. Pure technical efficiency (PTEC) remains close to unity with limited fluctuation, suggesting that firms allocate resources relatively efficiently under existing technologies. However, constraints in industrial upgrading limit the realization of economies of scale. Variable returns to scale (VRS) efficiency declined from 0.935 in 2014 to 0.857 in 2023, and scale efficiency decreased from 0.954 to 0.834, indicating that capital and labor inputs have exceeded optimal scale levels. This finding further supports the observed decline in capital productivity and investment efficiency.

4.5 Industrial and Innovation Structure Comparison

As shown in Table 5, Wenzhou exhibits pronounced systemic lag in industrial upgrading and innovation-driven development relative to the provincial average. The share of strategic emerging industries in Wenzhou is only 21.4%, which is 12.3 percentage points lower than the provincial average of 33.7%, indicating continued reliance on traditional manufacturing paths. The gap is even more striking in core digital economy manufacturing, where Wenzhou's share of 7.4% is less than one-third of the provincial average (21.1%), highlighting a substantial delay in digital and intelligent transformation. This structural deficiency directly constrains efficiency improvement and the expansion of the production frontier.

In terms of innovation inputs, Wenzhou's R&D intensity stands at 2.81%, slightly below the provincial average of 3.2%. Although the numerical gap is modest, when viewed alongside the persistent decline in TFP, it suggests potential bottlenecks in the effectiveness and output quality of R&D investment. Moreover, the lower share of high-skilled talent-12.5% compared with the provincial average of 18.3%-further exposes structural weaknesses in human capital. This deficit limits both the absorption of advanced technologies and the upgrading of industries toward higher value-added segments.

Table 5. Comparison of Industrial and Innovation Structure between Wenzhou and Zhejiang Province (2023)

Indicator	Wenzhou	Zhejiang Average
Share of Strategic Emerging Industries (%)	21.4	33.7
Share of Core Digital Economy Manufacturing (%)	7.4	21.1
R&D Intensity (%)	2.81	3.2
Share of High-Skilled Talent (%)	12.5	18.3

Taken together, Wenzhou underperforms the provincial average across all four dimensions-industrial structure, digital transformation, innovation intensity, and talent endowment-with particularly pronounced gaps in digital economy development and strategic emerging industries. This structural imbalance constitutes a fundamental cause of persistently negative TFP growth and highlights the deep challenges faced by Wenzhou in transitioning from scale-driven expansion to quality-oriented development.

Accordingly, future policy efforts should focus on breaking path dependence on traditional industries, accelerating digital economy deployment, enhancing the efficiency of R&D commercialization, and fostering a more attractive talent ecosystem to provide solid structural support for reversing the negative trajectory of TFP growth.

5. Analysis of the Factors Influencing TFP Changes in Wenzhou

5.1 Technological Progress Factors

Correlate the data with figure 4, the dimension of technological progress exhibits a typical pattern of input expansion with output lag. From 2018 to 2023, R&D expenditure of above-scale industrial enterprises expanded at an average annual rate of 9.5%, with R&D intensity reaching 2.81% in 2023. This level remains below the national average of 3.2% and nearly one percentage point lower than that of innovation hubs such as Hangzhou and Shenzhen. Basic research accounts for less than 4% of total R&D spending, indicating that funds are primarily directed toward process improvements rather than fundamental breakthroughs.

Over the same period, the number of authorized patents increased from 42,000 to 48,700, while the share of invention patents rose only marginally from 6.6% to 7.8%. The number of invention patents authorized per RMB 100 million of R&D expenditure declined from 18.3 to 15.4, suggesting a dilution of innovation efficiency. The number of high-tech enterprises increased by a net total of 1,818 over five years, reaching 4,326 in aggregate; however, average R&D expenditure per firm fell from RMB 9.2 million to RMB 5.7 million. This indicates that newly added firms are predominantly small- and medium-sized technology followers, and a 'school-of-sharks' effect capable of pushing the production frontier outward has yet to form.
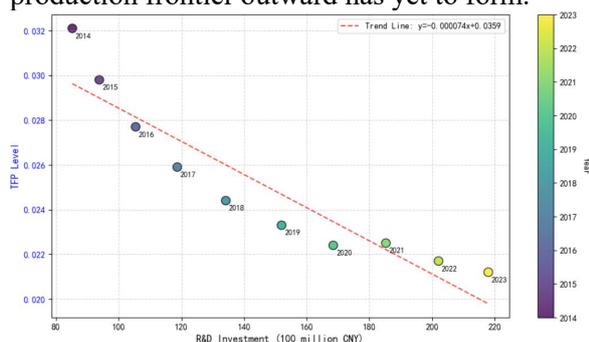

Figure 4. Relationship Between TFP Level and R&D Investment in Wenzhou(2014-2023)

Industrial technological upgrading investment grew at an average annual rate of 13.9%, reaching RMB 120 billion in 2023. Approximately 70% of this investment was concentrated in three traditional industrial chains-electrical equipment, footwear and apparel, and automobile and motorcycle components. Digital transformation largely remains at the stage of 'single-point equipment replacement', with equipment networking rates below 45%. The value of data-driven reconfiguration of production processes has yet to be fully realized. As a result, the elasticity of TFP with respect to the R&D capital stock remains at a low level of 0.06, significantly below the national average of 0.14.

5.2 Industrial Structure Factors

As can be seen in figure 5, the evolution of the industrial structure follows a path-dependent trajectory characterized by 'rising service sector share with a rigid industrial core'. Over the past decade, the share of the tertiary sector increased from 49.7% to 56.6%, while the secondary sector continues to dominate with a share of 41.3%. Within the industrial sector, a pattern of 'light locking' has emerged. In 2023, light industry accounted for 31.9% of above-scale industrial value added, while heavy industry accounted for 68.1%. The heavy industrial segment relies mainly on deep processing of imported intermediate inputs such as steel and non-ferrous metals, generating limited technological spillover effect.

Five traditional industrial clusters-electrical machinery, footwear, apparel, automobile and motorcycle components, and pumps and valves-collectively contributed 58% of above-scale industrial value added, yet their value-added rate stood at only 18.6%, which is 8.2 percentage points lower than the provincial average. Strategic emerging industries accounted for 21.4% of total output, and manufacturing within the core digital economy industries accounted for only 7.4%, both substantially below the provincial averages by 12.3 and 13.7 percentage points, respectively. This has resulted in low overall demand spillovers and a relatively flat learning curve for the industrial sector, with the pace of technological density upgrading lagging behind that of core Yangtze River Delta cities.

Due to the insufficient scale of emerging industries, traditional industries have maintained market share through a low-cost–low-profit cycle, with declining pricing power. From 2004 to 2023, the producer price index (PPI) for above-scale industrial enterprises cumulatively declined by 6.4%, suppressing firms' incentives to adopt production processes with higher technological complexity. This has led to an equilibrium trap characterized by low value added low R&D investment.
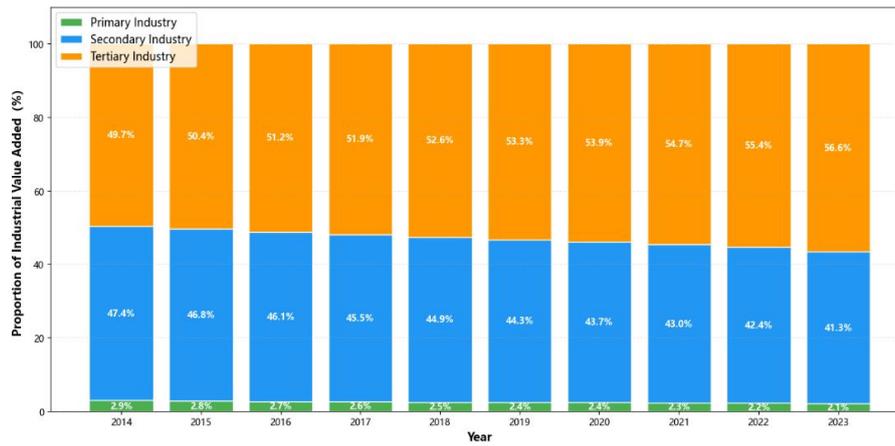
Data Source: National Bureau of Statistics [2014-2023]

Figure 5. Evolution of Industrial Value Added Structure in Wenzhou(2014-2023)

5.3 Institutional and Management Factors

The institutional and managerial dimension exhibits diminishing marginal returns, characterized by a weakening of first-mover advantages and lagging institutional adaptation. Private enterprises account for as much as 98.6% of Wenzhou's economy, and the city previously achieved rapid resource mobilization through a quasi-market-based institutional framework. However, with the accelerated construction of a unified national market, localized institutional rents have eroded rapidly. In 2023, Wenzhou ranked 38th nationwide in terms of business environment convenience, lagging behind Hangzhou and Ningbo by 12 and 9 positions, respectively. Notable deficiencies persist in key indicators, including business registration procedures, access to electricity, and property registration.

Regarding government service efficiency, although the coverage rate of 'one-stop online services' has reached 95%, the average number of required in-person visits for high-frequency administrative matters remains 0.8, compared with 0.3 in Hangzhou. The average time required for policy implement (i.e., the actual implementation and payment of approved policy benefits) is 45 days, which is 12 days longer than in Jiaxing, thereby increasing firms' institutional transaction costs. At the micro level, family-based and experience-driven management structures account for more than 70% of small and medium-sized enterprises. The average share of external directors on corporate boards is below 15%, resulting in limited strategic decision horizons and weak technological scanning capabilities. After receiving government R&D subsidies, firms'

secondary innovation conversion rate is only 28%, which is 10 percentage points lower than the national average.

The mismatch and time lag between institutional supply and enterprise demand amplify policy attenuation effects. As a result, the marginal contribution of R&D subsidies to total factor productivity declined from 0.18 in 2018 to 0.09 in 2023, displaying a typical trajectory of diminishing institutional dividends.

5.4 Factor Allocation Efficiency

Factor allocation efficiency is constrained by dual distortions of 'over-capitalization' and 'low-level labor equilibrium' in figure 6.

From 2014 to 2023, fixed asset investment in Wenzhou grew at an average annual rate of 10.2%, exceeding average GDP growth by 2.4 percentage points. The capital-output ratio increased from 3.37 to 5.54, while the incremental capital-output ratio (ICOR) deteriorated from 4.1 to 7.2. Each unit of capital generated only RMB 0.18 of GDP, which is 40% lower than the Yangtze River Delta average. Capital has been excessively absorbed by traditional manufacturing and the real estate sector. In 2023, loans to the electrical equipment and footwear industries accounted for 52% of manufacturing loan balances, while strategic emerging industries received only 18%, crowding out the financial space required for new technology diffusion.

The labor market exhibits a structural contradiction of 'ample quantity but insufficient quality.' Employment in the secondary sector accounts for 43.5% of total employment, yet labor productivity of above-scale industrial enterprises is RMB 199,000 per person, significantly below the provincial average of

RMB 237,000. High-skilled talent accounts for only 12.5% of the workforce, which is 5.8 percentage points lower than the provincial level. The city's index for attracting and retaining high-end talent has ranked among the bottom three in the province for several consecutive years.

The misallocation between capital and labor amplifies diminishing marginal returns to factor inputs, causing scale efficiency (SECH) to decline from 0.954 to 0.834, thereby becoming the core constraint dragging down TFP growth.
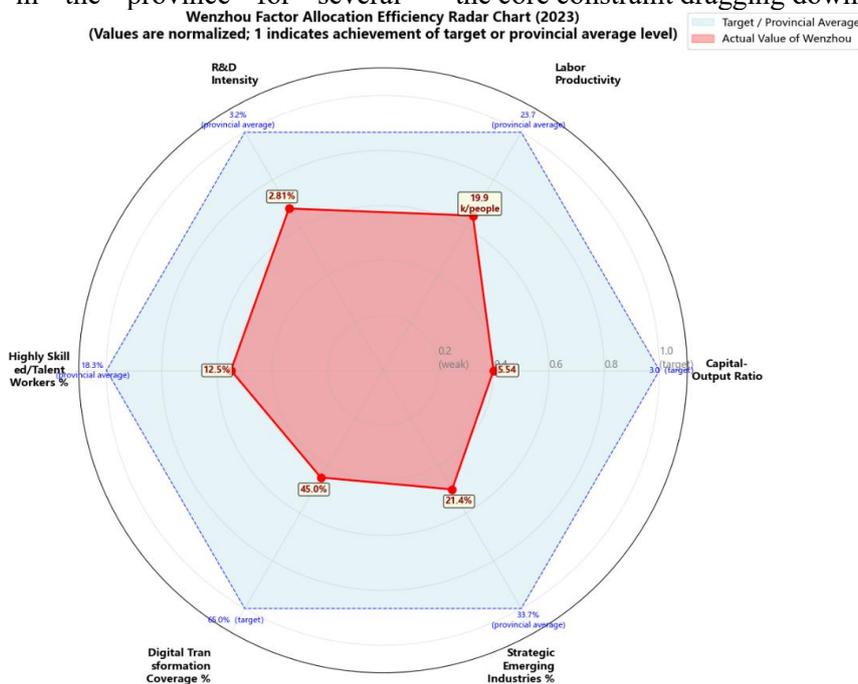

Figure 6. Radar Chart of Wenzhou Factor Allocation Efficiency Radar Chart (2023)

6. Policy Recommendations

6.1 Accelerating Technology-Driven Development

If Wenzhou is to reverse the inertia of negative TFP growth, it must follow a core trajectory of leapfrogging R&D intensity–breakthroughs in frontier technologies–smooth transformation of research outcomes, thereby achieving a fundamental shift from factor-driven to innovation-driven growth.

In the short term, rigid growth requirements for R&D expenditure should be institutionalized through legislation, mandating that above-scale industrial enterprises increase R&D intensity by no less than 0.15 percentage points annually, ensuring that the citywide average exceeds 3.2% by 2025 and rises above the national mean. Concurrently, a 'R&D reserve fund' mechanism should be established, allowing enterprises to accrue up to 3% of sales revenue as a pre-tax provision, with unused balances carried forward for up to five years, thereby smoothing intertemporal volatility in R&D spending. A complementary ex post R&D subsidy scheme should be implemented: manufacturing firms with annual incremental R&D expenditure exceeding RMB 5 million and an increment ratio above the citywide average should receive a fiscal subsidy equal to 15% of the incremental amount, capped at RMB 10 million, generating a compounded effect of government interest subsidies plus market leverage.

In the medium term, relying on local universities and research institutions-such as Wenzhou University, Wenzhou-Kean University, and the Zhejiang University Wenzhou Research Institute-Wenzhou should establish tripartite innovation consortia integrating leading enterprises, universities, and new-type R&D institutions. Priority should be given to three strategic tracks: intelligent sensing in electrical equipment, advanced materials for footwear and apparel, and electronic control systems for new-energy vehicles. Open competitive lists for key technological breakthroughs should be introduced, with fiscal funds matching firms' actual investment at a 1:1 ratio and a maximum support of RMB 30 million per project, ensuring seamless linkage between basic research, applied research, and industrial demonstration.

In the long run, the innovation ecosystem must be systematically optimized. This includes full

implementation of combined tax and fee policies such as enhanced tax deductions for R&D expenses, corporate income tax reductions for high-tech enterprises, and VAT refunds for registered technology contracts. Rigid assessment of R&D investment should be incorporated into the performance evaluation of municipally owned state-owned enterprises, with R&D intensity accounting for no less than 30% of managerial performance metrics. In addition, central bank tools for share buybacks and capital-increase relending should be flexibly applied to provide low-interest financing support to listed firms that disclose clear targets for improving R&D intensity, leveraging social capital to expand investment in original innovation. Ultimately, a vertically integrated policy loop encompassing fiscal subsidies–tax incentives–financial liquidity should be formed to continuously push the production frontier outward.

6.2 Deepening Industrial Structure Optimization and Upgrading

Breaking the grip of traditional path dependence requires reshaping Wenzhou's industrial core through the integrated advancement of digitalization, greening, and servitization.

For traditional industries, a second phase of the Thousand-Enterprise Intelligent Transformation initiative should be launched. Municipal and county governments should jointly allocate RMB 5 billion in dedicated funds to subsidize 20% of equipment investment-up to a maximum of RMB 20 million for electrical equipment, footwear and apparel, and pump-and-valve firms implementing full-plant intelligent upgrading. In parallel, industry-level industrial internet platforms should be developed to eliminate data silos across design, production scheduling, quality inspection, and logistics. By 2025, the city should aim to establish 30 provincial-level 'future factories' and 300 digital workshops, raising labor productivity in above-scale traditional manufacturing by 25%.

For emerging industries, a strategic emerging industry doubling plan should be implemented, focusing on five priority areas: the digital economy, new energy, new materials, intelligent equipment, and life and health industries. A RMB 10 billion 'Wenzhou Emerging Industries Fund' should be established under a fund of funds plus sector sub-funds and direct investment model. Major projects located in Ojiangkou and the Southern Zhejiang Industrial Cluster Zone should receive equity investment support equivalent to 10% of fixed asset investment, capped at RMB 5 billion per project. The construction of digital economy clusters and large-scale incubation platforms should be accelerated, with the goal that manufacturing value added in core digital economy industries exceeds 15% of above-scale industrial output by 2027.

For modern service industries, leveraging Wenzhou's role as a node city along the Digital Silk Road, the city should develop a new trade hub integrating a cross-border e-commerce comprehensive pilot zone, a market procurement trade pilot, and a comprehensive bonded zone. Digital trade platforms with annual transaction volumes exceeding RMB 1 billion should receive rewards of up to RMB 10 million. At the same time, new consumption scenarios-such as cultural tourism performances, sports events, and first-store and first-launch economies-should be expanded, cultivating performance agencies, ticketing platforms, and copyright operation entities. This will promote the extension of producer services toward the high end of the value chain and form a modern industrial system driven by the dual engines of manufacturing plus services.

6.3 Optimizing Factor Allocation Efficiency

The core of factor market-oriented reform lies in activating land use, guiding capital accurately, and unleashing data value.

With respect to land, the 'output per mu' evaluation system should be iteratively upgraded by incorporating R&D intensity, value added per unit of energy consumption, tax revenue per mu, and carbon emission intensity into a tiered assessment framework. Category-A enterprises should receive a 20% discount on base prices for newly supplied industrial land, while Category-D enterprises should be required to rectify deficiencies within a specified period or face land withdrawal. A full life-cycle performance evaluation mechanism for industrial land should be established, with rolling assessments every three years after project completion. Projects failing to meet agreed tax revenue or energy consumption standards should exit as stipulated, ensuring a transition from controlling output through land to controlling efficiency through land.

Regarding capital, a RMB 5 billion science and

technology innovation relending fund pool should be created to provide interest subsidies equivalent to 40% of benchmark lending rates for enterprises undertaking major national or provincial R&D projects, with an annual cap of RMB 20 million per project. A unified municipal technology property rights exchange should be established to facilitate the trading of patents, software copyrights, and data-related intellectual property, forming a closed loop linking technology, capital, and industry.

Regarding data, Wenzhou should pioneer pathways for data value realization by constructing a municipal data factor circulation service platform. Data service providers should receive support in the form of computing power vouchers, scenario access, and subsidies for first-edition insurance products. Pilot programs

for data asset capitalization plus pledge-based financing should be implemented in the electrical equipment and footwear clusters, encouraging banks to issue credit loans equal to up to 30% of assessed data asset value, thereby releasing the multiplier effects of new production factors on the real economy and ultimately enhancing total factor productivity.

6.4 Strengthening Education Upgrading and Talent Attraction

Human capital upgrading constitutes the critical fulcrum for turning TFP growth from negative to positive in figure 7, requiring the construction of a vertically integrated system encompassing basic education, vocational education, higher education, and lifelong learning.
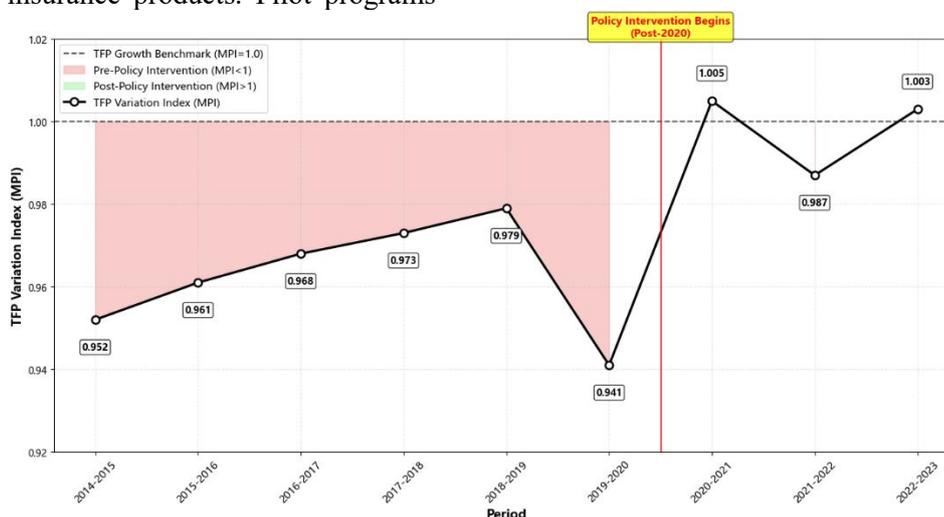

Figure 7. Wenzhou TFP Trends: Pre- vs. Post-Policy Intervention(2014-2023)

At the basic education level, an action plan for improving county-level general high schools should be implemented through a three-unification mechanism covering enrollment management, teacher staffing, and fiscal investment, stabilizing student sources and faculty quality. The municipal government should allocate RMB 1 billion annually to support standardized laboratories, smart classrooms, and academic competition bases in county high schools, ensuring that by 2025 the proportion of students achieving first-tier university admission increases by more than 10 percentage points.

In vocational education, reforms toward integrated secondary-to-tertiary vocational training should be advanced. Institutions such as Wenzhou Polytechnic and Zhejiang Industry & Trade Vocational College should be supported in jointly establishing industrial colleges with

leading enterprises and implementing modern apprenticeship systems under which enrollment equals employment and enrollment equals enterprise entry. Enterprises retaining vocational graduates in Wenzhou should receive subsidies of RMB 10,000 per graduate, with the aim that by 2027 the local retention rate of vocational graduates exceeds 60%.

In higher education and high-end talent development, construction of the Binhai Campus of Wenzhou Medical University and the transformation of Oujiang College of Wenzhou University into an application-oriented university should be accelerated, with university R&D expenditure growing at an annual rate exceeding 15%. The 'Ouyue Talent' program should be implemented, providing housing subsidies of RMB 300,000 for full-time recruited young PhDs and RMB 500,000 for postdoctoral researchers, while Wenzhou offering up to RMB

100 million in funding for top-tier talent (teams). Through a combination of talent housing, preferential access to education for children, and 'green channel' medical services, the city should aim to attract and cultivate more than 120,000 university graduates and over 5,000 PhDs within five years, forming a virtuous cycle of industry attracting talent and talent upgrading industry and providing sustained human capital support for efficiency-driven growth.

7. Conclusions and Prospects

7.1 Research Conclusions

Using the Solow residual method to estimate absolute levels and the DEA-Malmquist index to decompose dynamic structure, this study conducts cross-validation of total factor productivity in Wenzhou from 2014 to 2023. The results consistently point to a negative cycle characterized by efficiency loss, frontier stagnation, and factor misallocation. Over the decade, the TFP level declined from 0.0321 to 0.0212, representing a cumulative decrease of 34%. The corresponding index fell from 100 to 66, with an average annual negative growth rate of 2.1%. The decline followed a rigid linear trajectory with no annual rebound, indicating that economic growth continues to rely on quantitative expansion of capital and labor rather than outward shifts of the production possibility frontier.

DEA decomposition further shows that an average annual decline of 1.2% in technological progress is the core factor dragging down TFP, while a decline in scale efficiency from 0.954 to 0.834 amplifies diminishing marginal returns to factor inputs. Pure technical efficiency fluctuates narrowly around 1.0, suggesting that under the existing technological paradigm, resource allocation efficiency is approaching its upper bound, leaving limited room for improvement without breakthrough innovation.

In terms of factor misallocation, fixed asset investment growth has consistently exceeded GDP growth by 2.4 percentage points annually, with the capital-output ratio rising by 64 over seven years. Yet strategic emerging industries receive less than 20% of total credit, and the investment share of high-tech industries remains 12 percentage points below the provincial average. On the labor side, employment in the secondary sector accounts for 43.5% of total employment, while high-skilled workers constitute only 12.5%, revealing a pronounced mismatch between human capital structure and industrial upgrading needs. This has slowed technology diffusion and constrained TFP growth.

Regarding policy intervention effects, the technological progress index rebounded briefly to 1.002 during 2021–2023, indicating that digital transformation and R&D subsidies generated pulse-like effects for leading firms. However, insufficient technological adaptability among small and medium-sized enterprises prevented these positive effects from diffusing across the entire economy. As a result, TFP's contribution to growth remained negative, ranging from −5% to −37%, with policy dividend decay occurring faster than expected.

7.2 Future Prospects

Based on observed trends and influencing factors of TFP in Wenzhou, the following outlook is proposed for high-quality economic development.

In the short term (2024–2025), traditional industries will remain the backbone of Wenzhou's economy, with electrical equipment, footwear and apparel, and automobile and motorcycle components expected to account for more than 55% of above-scale industrial value added. Against a backdrop of weakened demand spillovers and declining pricing power, the magnitude of negative TFP growth may narrow but is unlikely to reverse, with an estimated average annual decline of around −1% and a drag on GDP growth of approximately −10% to −20%.

In the medium term (2026–2030), as the Thousand-Enterprise Intelligent Transformation program is completed, the share of manufacturing in core digital economy industries exceeds 15%, and strategic emerging industries reach 35% of total output, the technological progress index is expected to stabilize above 1.005. Scale efficiency should recover with higher capacity utilization, enabling TFP growth to turn positive at an estimated 0.5%–1.5% annually and contribute 5%–10% to economic growth, marking the first efficiency-driven inflection point.

In the long term (2031–2035), if market-oriented reforms of data factors are fully implemented, data asset capitalization and pledge-based financing achieve scale effects, and the share of high-skilled talent exceeds 20%, Wenzhou will

complete its transition from manufacturing to intelligent manufacturing plus services. TFP growth is expected to further rise to 1.5%–2.5% annually, contributing 10%–15% to GDP growth and gradually approaching the national average. Overall, Wenzhou must shift from scale expansion to quality enhancement: advancing the production frontier through higher R&D intensity, correcting capital-labor misallocation via factor market reforms, overcoming technology commercialization bottlenecks through industry–university–research collaboration, and unlocking the dividends of new production factors through data value realization. Only in this way can Wenzhou achieve sustained positive TFP growth by the end of the '15th Five-Year Plan' period, complete the critical transition from factor-driven to efficiency-driven development, and secure sustainable growth momentum as a key node city in the integrated high-quality development of the Yangtze River Delta.

References

[1] Liu, J. C. Research on Chinese total factor productivity: Review and outlook. Technology Economics. 2022, 41 (01): 77-87.

[2] Wang, X. L., Fan, G., & Liu, P. Transformation of Chinese economic growth pattern and growth sustainability. Economic Research Journal. 2009, 44 (01): 4-16.

[3] Meng, X. Y., Xie, H. B., & Zou, M. T. Have government guiding funds improved the total factor productivity of invested enterprises? -- A test based on the perspective of factor input-output efficiency. South China Finance. 2024 (11): 3-18.

[4] Wang, Z. G., Gong, L. T., & Chen, Y. Y. Decomposition of regional production efficiency and total factor productivity growth rate. Social Sciences in China. 2006 (02): 55-66+206.

[5] Shi, F. G. Measurement of TFP in Chinese provinces and analysis of influencing factors. Technology Economics. 2012 (05): 13-16.

[6] Duan, W. B., & Yin, X. F. A review of research on Chinese total factor productivity. Nankai Economic Studies. 2009 (02): 130-140.

[7] Yang, X. L., & Wang, H. Y. Comparative research on total factor productivity of Beijing, Shanghai and Guangdong from the perspective of developing new quality productive forces. Science & Technology Management Research. 2025, 45 (12): 45-57.

[8] Lu, T., & Zhou, J. Malmquist index decomposition method introducing semi-fixed inputs. The Journal of Quantitative & Technological Economics. 2010, 27 (08): 153-161.

[9] Jiang, S. B., Kang, Z., & Cao, S. W. Research on the driving effect of digital economy on high-quality development of circulation industry--Based on DEA-Malmquist index model. Journal of Business Economics. 2025 (21): 5-10.

[10] Wang, B., Wu, Y. R., & Yan, P. F. Chinese regional environmental efficiency and environmental total factor productivity growth. Economic Research Journal. 2010, 45 (05): 95-109.

[11] Du, Y., & Xu, Y. H. Re-measurement of Chinese TFP growth rate under the background of R&D capitalization. Statistical Research. 2024, 41 (01): 33-45.

[12] Xu, Y. H., Deng, M. L., & Liang, P. F. The power of science and technology: Economic growth effect of R&D expenditure. The Journal of Quantitative & Technological Economics. 2025:0.

[13] Wang, W. F., & Zhang, T. Research on the impact of tax competition on total factor productivity. Journal of Finance and Trade Economics. 2022, 33 (09): 57-66.

[14] Wei, S. H., & Wu, T. How local government behavior affects regional total factor productivity--From the perspective of local government platform debt and tax competition level. Finance and Economics. 2024 (03): 134-148.

[15] Wu, M., Cao, J., & Mao, J. Local public debt and corporate total factor productivity: Effects and mechanisms. Economic Research Journal. 2022, 57 (01): 107-121.

[16] Ye, Z. P., Zheng, J. W., & Li, S. Y. Institutional adaptability and the evolution of regional economic development models--Rethinking the transformation of Wenzhou model. Governance Studies. 2022 (04): 101-110.

[17] Yin, Y. Digital finance, industrial agglomeration and total factor productivity. Statistics & Decision. 2022, 38 (07): 131-135.

[18] Zhu, H. M., & Li, Z. H. Digital finance and

cultivation of new quality productive forces: Internal logic and smooth paths. Development Banking Research. 2025:0.

[19]Liu, J. Digital transformation, disruptive innovation and total factor productivity. Technological Economy and Management Research. 2025 (04): 119-126.

[20]Huang, Q. H., & Sheng, F. F. New quality productive force system: Factor characteristics, structural bearing and functional orientation. Reform. 2024 (02): 15-24.