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Research on the High-Quality Development Path of Gas Enterprises from the Perspective of Industry Efficiency Evaluation

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Abstract: Against the backdrop of global energy transition and the advancement of the "Dual Carbon" strategy, the gas industry is under multiple pressures such as shrinking traditional profit margins and accelerating substitution by clean energy. This paper selects 24 listed gas companies as analysis samples, and systematically explores the current situation of high-quality development and its core influencing factors in the gas industry by integrating the DEA-BCC model and the Malmquist index method. The results show that:(1)The overall industrial efficiency is characterized by weak technical support and gradually declining returns to scale.(2)Leading enterprises in the industry have significant advantages in technical efficiency, while some enterprises have low operational efficiency due to slow technological innovation and unreasonable scale structure.(3)Technological innovation is the key engine driving the growth of total factor productivity of enterprises, and low-carbon transition and cross-border collaborative cooperation will become important directions for the future development of the industry.(4)Gas enterprises should build an intelligent gas operation system, promote the complementary development of multiple types of energy, layout a low-carbon transformation path, enhance comprehensive competitiveness by relying on industrial collaboration alliances and foreign exchanges and cooperation.

Keywords: Efficiency evaluation, DEA model, Gas enterprises, High-quality development.

1. Introduction

Under the trend of accelerating reform of the world's energy structure, natural gas, as a low-carbon fossil energy, undertakes a key connection mission in building a clean, stable and efficient modern energy system. However, with the continuous implementation of the "Dual Carbon" strategy, gas-related enterprises are facing a series of development pressures such as tightened policy control, accelerated substitution of clean energy, and narrowing of traditional revenue channels. Especially in China, the traditional model of the gas industry relying on connection benefits and purchase-sales price differentials for profits is unsustainable, and enterprises in the industry are urgent to explore a high-quality development path to adapt to the profound changes in the energy pattern and market ecology.

In recent years, the overall domestic gas industry has shown the characteristics of gradual slowdown in development growth and widening differences in operational benefits. First, guided by the "one city, one enterprise" policy, the degree of industrial resource integration has been continuously improved, and leading enterprises have expanded market coverage through mergers and acquisitions. Second, problems such as imperfect gas price transmission mechanism, strict distribution price supervision, and lack of investment in scientific and technological research and development have continuously restricted enterprises' profit space and long-term development capacity. Taking the Sichuan-Chongqing region as an example, even though the region is rich in natural gas reserves, local gas enterprises still face practical problems such as inverted residential gas prices, huge investment in pipeline network upgrading and transformation, and low popularity of additional services. How to complete the transformation from relying on scale expansion to relying on efficiency improvement through technological innovation, operational management improvement and profit model innovation has become a core issue to promote the high-quality development of the industry.

Based on this, this paper selects listed gas companies as analysis samples, comprehensively adopts the DEA-BCC model and Malmquist index method to measure the high-quality development effect of the industry from both static effect and dynamic change levels, and disassembles the key cruxes restricting the high-quality development of the industry combined with representative cases and the current policy environment. Under this research framework, targeted transformation and development strategies are proposed to strive to provide theoretical support and practical directions for gas enterprises to cope with the challenges of energy transition. All manuscripts must be in English, also the table and figure texts, otherwise, we cannot publish your paper.

2. Theoretical Basis and Literature Review

2.1. Analysis of the Connotation of High-Quality Development

The concept of high-quality development originates from the practical needs of China's economic transformation and upgrading, aiming to break through the traditional extensive growth model and shift to a development path that pays more attention to efficiency, sustainability and inclusiveness. Since this important concept was officially put forward in 2017, relevant arrangements have been carried out around the five connotations of innovation, coordination, green, openness and sharing, striving to promote the steady improvement of economic development quality and reasonable expansion of scale.

For gas enterprises, high-quality development means building a safe, efficient and clean energy supply system guided by the new development concept. Specifically, enterprises should take innovation as the key driving force, improve operational efficiency by means of smart pipeline networks and low-carbon technologies, adjust the business layout structure, coordinate the needs of civil and industrial gas consumption, traditional businesses and emerging sectors, increase carbon reduction and consumption reduction in production and operation, actively lay out clean energy such as bio-natural gas and hydrogen energy, strengthen the collaboration of the upstream and downstream industrial chains, extend business fields, strike a balance between ensuring people's livelihood needs and improving operating benefits, and optimize service levels to achieve mutual benefit among all parties. It can be seen that the diversified system of high-quality development provides an overall guidance for the transformation and upgrading of the gas industry.

2.2. Research Status of High-Quality Development of Gas Enterprises

In terms of research status of high-quality development, as the core theme of economic development in the new era, the academic community has carried out systematic research on its connotation, influencing factors and realization paths. In terms of connotation interpretation, high-quality development is generally defined as a development model guided by the new development concept of innovation, coordination, green, openness and sharing, taking into account efficiency improvement, structural optimization and sustainability. Nie (2022) systematically sorted out the theoretical evolution of high-quality development, pointing out that it is an inevitable choice for the economy to transform from high-speed growth to high-efficiency and high-quality development. In the research of influencing factors, scholars generally believe that technological innovation, industrial upgrading, institutional reform and green transformation are the key driving forces [1]. Ma(2023) found through empirical analysis that innovation investment and total factor productivity improvement have a significant positive effect on high-quality development. Existing studies have laid a solid theoretical foundation for the analysis of high-quality development at the industrial level, but special research on the energy industry, especially gas enterprises, still needs to be deepened [2].

In terms of research status of gas industry development, as an important part of the energy system, the research on the development of the gas industry focuses on industrial characteristics, transformation challenges and strategic directions. In terms of industrial status, Lv (2021) pointed out that China's gas industry has entered a period of steady growth, with the continuous expansion of natural gas consumption scale and continuous improvement of infrastructure, but it is facing multiple pressures such as single profit model, new energy substitution and strict supervision [3]. Zhang et al. (2024) inferred that the gas industry is shifting from high-speed expansion to quality and efficiency improvement, and smart gas and integrated energy services have become new directions for transformation [4]. In the research of transformation challenges, Yang (2024) analyzed that under the "Dual Carbon" goal, gas enterprises need to balance energy supply guarantee and low-carbon emission reduction, and accelerate the transformation to clean and intelligent [5]. In terms of development paths, scholars have put forward diverse countermeasures: Chi et al. (2024) advocated building a smart gas system to improve operational efficiency and service quality [6]; Dong et al. (2025) suggested strengthening industrial collaboration and expanding development space through international cooperation. Most existing studies focus on the macro level of the industry, and there is a relative lack of micro empirical research on enterprise efficiency evaluation and high-quality development paths [7].

In terms of research status of high-quality development level measurement, it is the core link of empirical research, and the measurement methods and index systems are constantly improving. Mainstream measurement methods are divided into two categories: single index method and comprehensive index system method. Among single indicators, total factor productivity is widely used in measuring development quality because it can reflect input-output efficiency, and the DEA-Malmquist index is a mainstream tool for calculating TFP. Liu (2020) used this method to measure the high-quality development efficiency of Chinese industrial enterprises and verified its applicability [8]. In terms of comprehensive index systems, scholars mostly build frameworks based on the new development concept. Li (2020) constructed an evaluation system including five dimensions: economic vitality, innovation efficiency, green development, people's lives and social harmony [9]. In industrial applications, Cao (2024) used the entropy method and coupling coordination degree model to measure the high-quality economic development level of western ethnic regions [10]; Wang (2025) incorporated the concept of green development into the system and constructed a high-quality development evaluation model for the energy industry [11]. Although the existing measurement system is becoming increasingly mature, there is a lack of industry-specific indicators for gas enterprises, the integration of efficiency measurement and high-quality development connotation needs to be improved, and there is a lack of an integrated measurement framework taking into account technology, scale, green, innovation and other dimensions.

3. Efficiency Evaluation of High-Quality Development of the Gas Industry

3.1. Efficiency Evaluation Methods

To scientifically measure the high-quality development level of China's gas enterprises, this paper uses the DEA model and Malmquist index to measure the high-quality development efficiency of each gas enterprise, providing a data basis for subsequent suggestions.

3.1.1. Static Measurement Model of High-Quality Development Level

Combined with input-output theory and the characteristics of high-quality development, the high-quality developmentof gas enterprises can be regarded as a multi-input and multi-output problem, and the data envelopment analysis method (DEA) with variable returns to scale is used to test its efficiency level. This method was proposed by A. Charnes and W.W. Cooper et al. in 1978. By calculating and comparing the input-output efficiency of decision-making units (DMUs), the production frontier is determined to judge whether DEA is effective and the relative efficiency value. Its mathematical expression is as follows:

$$s.t.\begin{cases} min\theta \\ \sum_{j=1}^{n}\lambda_j x_{jm} + S^- = \theta x_0 \\ \sum_{j=1}^{n}\lambda_j y_{jr} - S^+ = y_0 \\ S^-, S^+, \lambda_j \geq 0 \\ \sum_{j=1}^{n}\lambda_j = 1 \end{cases}$$

Where θ is the comprehensive efficiency value of the j_0th DMU, x_{jm} is the mth input of the j_0th decision-making unit; y_{jr} is the rth output of the j_0th decision-making unit; S- and S+ are the input slack variable and output slack variable of the j_0th DMU respectively, and λ_j is the input-output weight value of the j_0th DMU. When $\theta < 1$, the DMU is in an inefficient state; when $\theta \geq 1$, the DMU is effective, and the larger the θ value, the higher the efficiency.

3.1.2. Dynamic Measurement Model of High-Quality Development Level

Considering that the DEA model is only used to evaluate the static efficiency of each decision-making unit and cannot measure the degree of efficiency change, scholars often introduce the Malmquist index model to measure the dynamic evolution of decision-making unit efficiency, so as to conduct a longitudinal comparative analysis of efficiency in the time dimension. The total factor productivity change index (Tfpch) calculated by the model is equal to the product of the technical efficiency change index (Effch) and the technical progress change index (Techch); among them, the technical efficiency change index (Effch) is equal to the product of the pure technical efficiency change index (Pech) and the scale efficiency index (Sech). The values of each efficiency less than 1, equal to 1 and greater than 1 correspond to efficiency reduction, unchanged and improvement respectively.

3.2. Index Selection

Combined with the connotation of high-quality development of gas enterprises and typical measurement indicators of high-quality development, this paper selects appropriate input and output indicators from the five dimensions of innovation, coordination, green, openness and sharing to construct an evaluation index system for the high-quality development level of gas enterprises, as shown in Table 1.

Input indicators. Referring to the studies of Chen Junlong (2023), Xiao Xiaoyu (2024), Suo Ruixia (2025) et al., this paper selects total assets, total foreign investment, employee compensation, operating costs, sales and management expenses, and R&D expenses as the input index system for high-quality development of gas enterprises from the perspectives of capital input, external input, labor input, resource input and innovation input [12, 13, 14]. Among them, total assets can better reflect the overall asset input; total foreign investment quantifies the external expansion capacity and resource integration expenditure; employee compensation directly measures the scale and quality of labor input; resource input is divided into operating costs, representing direct resource and indirect resource input respectively; R&D expenses represent innovation input.

Output indicators. Referring to the studies of Fang Qi (2022), Yan Xing (2022), Cao Chunfang (2024) et al., this paper selects net intangible assets, operating income, ESG rating score, investment income and total tax payment as output indicators for high-quality development of gas enterprises from the five perspectives of innovation, coordination, green, openness and sharing[15,16,17]. Among them, operating income reflects the enterprise's revenue generation, profitability and operational capacity, and indirectly reflects its competitive strength and development potential; net intangible assets directly quantify the value of intellectual property rights and technological achievements accumulated by enterprise R&D and innovation; ESG rating score scientifically evaluates the enterprise's sustainable performance in the environmental dimension; investment income quantifies the economic results obtained by the enterprise through external investment and cooperation, reflecting the degree of openness; total tax payment reflects the enterprise's direct contribution to public finance and social feedback capacity.

Table 1. Input and Output Indicators for High-Quality Development of Gas Enterprises

Variable Type	Variable Name	Variable Description	Unit
Input Indicators	Capital Input	Total Assets	Ten Thousand Yuan
	External Input	Total Foreign Investment	Ten Thousand Yuan
	Labor Input	Employee Compensation	Ten Thousand Yuan
	Resource Input	Operating Costs	Ten Thousand Yuan
		Sales and Management Expenses	Ten Thousand Yuan
	Innovation Input	R&D Expenses	Ten Thousand Yuan
Output Indicators	Coordinated Development	Total Operating Income	Ten Thousand Yuan
	Innovation Development	Net Intangible Assets	Ten Thousand Yuan
	Green Development	ESG Rating Score	Score
	Open Development	Investment Income	Ten Thousand Yuan
	Shared Development	Total Tax Payment	Ten Thousand Yuan

3.3. Data Sources and Processing

According to the industry classification principles of the *Guidelines for Industry Classification of Listed Companies* by the China Association of Listed Companies, this paper eliminates listed gas enterprises with "ST" marks and abnormal data, and screens out 24 gas enterprises for this evaluation, which are anonymized. The sample data are mainly from the CSMAR Database, Wind Information Database, listed enterprise annual reports, *China Energy Statistical Yearbook*, and the patent database of the State Intellectual Property Office. The data period is 2022-2024.

3.4. Analysis of Evaluation Results of High-Quality Development Level

3.4.1. Static Evaluation Result Analysis

This paper uses the Dearun software and adopts the input-oriented DEA-BCC model with variable returns to scale to conduct a static measurement analysis of 24 listed gas enterprises from 2022 to 2024. The evaluation results of technical efficiency (TE), pure technical efficiency (PTE) and scale efficiency (SE) of each enterprise are shown in Table 2.

Table 2. Static Evaluation Results of High-Quality Development Level of Listed Gas Enterprises

Enterprise Name	2022	2022	2022	2023	2023	2023	2024	2024	2024
	TE	PTE	SE	TE	PTE	SE	TE	PTE	SE
HR	1	1	1	1	1	1	1	1	1
FR	1	1	1	1	1	1	1	1	1
CN	1	1	1	1	1	1	1	1	1
DZ	1	1	1	1	1	1	1	1	1
CT	1	1	1	1	1	1	1	1	1
BC	1	1	1	1	1	1	1	1	1
ST	1	1	1	1	1	1	1	1	1
XT	1	1	1	1	1	1	0.995	1	0.995
KT	1	1	1	1	1	1	0.99	1	0.99
XA	1	1	1	0.991	1	0.991	0.991	1	0.991
CD	0.993	0.999	0.994	0.989	0.99	0.999	0.987	0.987	0.999
ZT	1	1	1	0.985	0.989	0.997	0.965	0.969	0.997
WT	0.999	1	0.999	0.979	0.993	0.986	0.971	0.979	0.993
GZ	1	1	1	1	1	1	0.949	0.955	0.994
SF	1	1	1	0.975	0.976	1	0.967	0.97	0.996
CQ	0.981	1	0.981	0.969	1	0.969	0.968	1	0.968
TH	1	1	1	1	1	1	0.886	0.886	1
SZ	0.955	0.955	1	0.976	1	0.976	0.95	0.957	0.993
ST	0.961	1	0.961	0.943	0.96	0.982	0.956	1	0.956
SL	0.952	0.953	0.999	0.954	0.954	1	0.945	0.947	0.998
GX	0.959	1	0.959	0.916	1	0.916	0.899	1	0.899
NJ	0.906	0.936	0.968	0.938	1	0.938	0.898	0.903	0.994
CC	0.863	0.875	0.985	0.846	0.849	0.998	0.849	0.853	0.995
DL	0.688	0.932	0.739	0.811	0.933	0.869	1	1	1

It can be found from the data in Table 2 that the high-quality development level of China's gas enterprises presents a differentiated pattern. In terms of technical efficiency, 7 enterprises including HR and FR have an efficiency measurement value of 1 for three consecutive years, stably at the optimal level, showing their excellent capabilities in management level, technological innovation and resource allocation. At the same time, 13 enterprises including XT, KT and XA have a technical efficiency between 0.95 and 1, and some enterprises still have room for development and optimization in the production and operation process. Enterprises such as GX and NJ have been in the efficiency depression of the industry in recent three years, and their efficiency values show a downward trend.

Further analysis of the pure technical efficiency measurement results shows that 12 enterprises including XA and XT have achieved technical effectiveness for three consecutive years. Among them, FR has realized the forward movement of pipeline risk prevention by virtue of technologies such as smart pipeline networks and digital twins, and XA has deeply researched and innovated LNG technology, effectively reducing energy consumption per ton. At the same time, these enterprises also show a good management level. In addition, some enterprises have low pure technical efficiency, which limits the technological development of enterprises to a certain extent. For example, NJ with a low score has no signs of independent R&D and has not popularized an intelligent monitoring system, and CC still adopts manual meter reading and regular sampling inspection, with a long-term lack of intelligent monitoring.

From the perspective of scale efficiency results, the overall scale efficiency of China's gas enterprises is good, with an industry average of 0.986. Among them, 8 enterprises including CT and ST are continuously in the stage of effective scale. At the same time, DL shows good regulation ability. After decreasing returns to scale in 2022, it quickly adjusted to an effective state. Through expanding receiving stations and optimizing layout, the enterprise scale reached a reasonable state. However, 6 enterprises including GX and CQ still have not achieved effective scale efficiency for three consecutive years, with the risk of decreasing returns to scale, exposing problems such as diseconomies of scale, unbalanced layout and low capacity utilization.

3.4.2. Dynamic Evaluation Analysis

To further understand the dynamic change direction and driving factors of the high-quality development level efficiency of China's gas enterprises, this paper uses the Malmquist index method to decompose the efficiency value of the high-quality development level of gas enterprises, and the results are shown in Table 3.

Table 3. Calculation Results of the Overall Average Total Factor Productivity Change Index and Its Decomposition Indicators of China's Gas Enterprises

Time Span	Effch	Techch	Pech	Sech	Tfpch
2022-2023	1.006	1.072	1.001	1.005	1.079
2023-2024	0.996	0.990	0.999	0.996	0.986

The data in the table show that in the past three years, the total factor productivity reflecting the change in the comprehensive level of high-quality development in the gas industry has fluctuated "rising first and then falling", with the two-cycle indexes being 1.079 and 0.986 respectively. From the perspective of its specific driving factors, 2022-2023 mainly relied on the technical progress change index of 1.072; while in 2023-2024, both technical efficiency and technical progress indexes fell below 1, reflecting the deterioration of management or scale efficiency and industrial technological regression. From the perspective of subdivision indicators, the technical progress change index also became the main reason for the decline of the total factor productivity change index; the pure technical efficiency in technical efficiency decreased slightly, and the scale efficiency change index decreased from 1.005 to 0.996, also showing a certain dexiao'lgree of decline. This also shows that with the gradual popularization of urban gas, the development path of China's gas enterprises relying on scale expansion and internal management efficiency improvement cannot bring significant productivity improvement to enterprises. As mature public enterprises, the key to the high-quality development of China's gas enterprises lies in achieving technological improvement through smart pipeline networks, high-efficiency equipment, low-carbon technologies and so on.

Table 4. Calculation Results of Total Factor Productivity Change Index and Its Decomposition Indicators of Each Gas Enterprise in China

Enterprise Name	Effch	Techch	Pech	Sech	Tfpch
DL	1.045	1.818	1	1.045	1.886
KT	1	1.284	1	1	1.284
CN	1	1.184	1	1	1.184
BC	1	1.161	1	1	1.161
CT	1	1.051	1	1	1.051
FR	1	1.016	1	1	1.016
SZ	1.015	0.99	1.021	0.994	1.005
SL	1.017	0.983	1.021	0.997	1
ST	1	0.998	1	1	0.998
CD	1	0.997	1	1	0.997
XT	1	0.995	1	1	0.995
HR	1	0.995	1	1	0.995
ST	1.02	0.972	1	1.02	0.992
CQ	0.987	1.003	1	0.987	0.99
WT	0.998	0.992	0.999	0.999	0.989
NJ	1.016	0.967	1.005	1.01	0.984
SF	1	0.977	1	1	0.977
CC	0.959	0.999	0.964	0.995	0.956
GX	0.974	0.971	1	0.974	0.946
DZ	1	0.937	1	1	0.937
TH	1	0.937	1	1	0.937
ZT	1	0.925	1	1	0.925
XA	1	0.912	1	1	0.912
GZ	0.985	0.764	0.99	0.995	0.753

It can be seen from Table 4 that specifically for enterprises, less than 1/3 of China's gas enterprises have achieved total factor productivity growth in the past three years, indicating that the overall high-quality development efficiency of the industry is weak. Among them, DL and KT perform the most prominently. DL has participated in investing in energy storage companies with scientific research background in recent years, and is currently in the stage of patent industrialization, with certain breakthrough potential in core energy storage technologies; KT has increased R&D investment in the AI gas butler, and improved gas safety management efficiency through an intelligent monitoring and early warning system, driving technological progress. Finally, the technological progress indexes of the two enterprises are as high as 1.818 and 1.284 respectively, and the total factor productivity is improved while the technical efficiency remains stable. This further verifies the effectiveness of gas enterprises driving high-quality development through technological breakthroughs.

In summary, there are still many deficiencies in the overall high-quality development level of China's gas enterprises, and there are also large differences between different enterprises. Under the policy background of "controlling the middle and liberalizing the two ends", gas enterprises should focus on improving internal management efficiency, controlling the speed of scale expansion, and strengthening the improvement of enterprise technical capabilities to strengthen competitive advantages and achieve high-quality enterprise development.

4. Path Suggestions for High-Quality Development of Gas Enterprises

Combined with the enterprise evaluation results and further analysis, this paper puts forward suggestions for the high-quality development of gas enterprises as follows.

4.1. Innovation Leadership: Building a Smart Gas Technology System

The high-quality development evaluation results show that technological progress is the most important driving factor for the high-quality development of gas enterprises. Therefore, gas enterprises should take technological innovation as the core driving force and accelerate the process of intelligent transformation. Focus on developing an intelligent pipeline network management system, and realize real-time monitoring and intelligent early warning of pipeline network operation status by deploying IoT sensors and artificial intelligence algorithms. The practice of a company's "Shenran Core" project shows that intelligent transformation supports pipeline network digital twins and drone inspection, further improving pipeline network operation efficiency. In addition, increase investment in low-carbon technology R&D, focus on breaking through cutting-edge technologies such as hydrogen blending technology, renewable natural gas, and carbon capture and utilization, to further improve the low-carbon level of the industry. On the basis of further popularizing smart gas meters, gas enterprises should integrate big data and AI technologies, use data analysis and APP channels to develop functions such as energy consumption optimization and intelligent interaction to improve user service quality.

4.2. Coordination and Optimization: Promoting Balanced Development of the Entire Industrial Chain

Against the background of slowing new market growth and gradual implementation of the price adjustment mechanism, the business focus of gas enterprises has gradually shifted from scale expansion to internal management efficiency improvement. In terms of natural gas supply, pricing, service and emergency support, balance the demand differences and interest relationships between industrial and commercial users and residential users to ensure that both types of users can obtain stable, economical and efficient gas services and optimize resource allocation. In addition, gas enterprises should, on the basis of in-depth understanding of user needs, coordinate the collaborative development of traditional natural gas business with value-added services (such as gas appliances, energy efficiency management, carbon consulting) and new energy services, and promote the transformation from a single gas supplier to an integrated energy service provider through intelligent scheduling, multi-energy complementarity and customized solutions to achieve multi-energy integration of gas, electricity, heat, hydrogen, etc., to meet the all-round needs of industrial, commercial and civil users for safe, low-carbon and efficient energy. In addition, gas enterprises should balance internal collaboration and external communication, break down departmental barriers in the organizational structure, establish cross-functional project teams to improve collaboration efficiency; at the same time, strengthen communication with the government and users to promote the rationality and implementability of the price adjustment mechanism.

4.3. Green Transformation: Exploring New Paths for Low-Carbon Development

Green transformation is the core content of the high-quality development of gas enterprises and the only way to achieve the "Dual Carbon" goal. On the one hand, gas enterprises should accelerate the low-carbon transformation of pipeline networks, adopt new anti-corrosion materials and energy-saving equipment to reduce transmission and distribution loss rates. On the other hand, vigorously develop the bio-natural gas business, use agricultural and forestry wastes to prepare renewable gas, and build production bases with an annual output of tens of millions of cubic meters around major gas-consuming cities. In the field of hydrogen energy application, it is recommended to give priority to carrying out hydrogen blending demonstrations in parks such as iron and steel and chemical industry and gradually expand the application scope. In the terminal link, implement the gas appliance energy efficiency "leader" plan, promote ultra-low nitrogen combustion technology, and help terminal users save energy and reduce emissions. At the same time, referring to Beijing Gas's "carbon performance" management model, incorporate indicators such as carbon emission intensity and green gas ratio into the KPI system, strongly link with executive compensation, and pilot an internal carbon pricing mechanism to fully stimulate the endogenous power of low-carbon transformation of enterprises.

4.4. Open Cooperation: Building a Win-Win Industrial Ecosystem

Gas enterprises should adhere to the open development concept, build a diversified collaboration network, and create a mutually beneficial and win-win industrial ecosystem. Within the industry, strategic cooperation with peers can be carried out to jointly develop and build infrastructure in disputed areas and realize resource sharing; establish a technology sharing platform to jointly develop common technologies such as smart pipeline networks and energy conservation and carbon reduction. At the cross-industry level, deepen collaborative innovation with other energy enterprises, focus on promoting "gas-electricity complementary" integrated energy projects, explore multi-energy integration models of gas with photovoltaic and energy storage, and jointly develop a "gas + hydrogen" hybrid energy supply system. It is recommended that leading enterprises take the lead in forming a gas industry innovation alliance, integrate the scientific research advantages of universities, the engineering capabilities of design institutes and the industrialization experience of equipment manufacturing enterprises, and focus on joint research on technologies such as hydrogen blending transportation and biomethane purification. In terms of international cooperation, on the one hand, broaden resource channels, establish a diversified LNG procurement system, and deepen long-term cooperation with pipeline gas supplying countries such as Russia and Central Asia; on the other hand, strengthen technical exchanges, introduce European smart gas management experience and Japanese hydrogen energy application technology, promote the integration of China's gas standards with international standards, and enhance the global competitiveness of the industry. Through all-round open cooperation, accelerate the transformation of the gas industry to green, intelligent and international.

4.5. Shared Win-Win: Building a New Benefit Sharing Mechanism

Gas enterprises should establish a shared development mechanism to let all parties share the results of transformation. Explore a carbon inclusive mechanism, share energy-saving benefits with users, launch an "energy-saving benefit sharing" model, and return part of the energy-saving benefits to users. Share development results with employees, strengthen the incentive mechanism, and realize the sharing of enterprise value-added and personal income. Share safety benefits with the community, install intelligent alarm devices in old communities free of charge, and regularly carry out safety publicity. Share data value with the government, provide energy consumption data analysis services, and assist urban refined management. Against the background of "village-to-village connectivity", gas enterprises should actively promote the popularization of gas in rural areas, and reduce farmers' gas costs through the "government subsidy + enterprise profit concession" model. Create a good external environment for enterprise transformation through a multi-win-win benefit distribution mechanism.

5. Conclusion

This paper reveals the key problems and transformation paths in the current development through an in-depth analysis of the high-quality development level of China's gas industry. The study finds that the gas industry as a whole is characterized by efficiency differentiation and insufficient technology-driven development. Leading enterprises maintain their leading position by virtue of technological innovation and management optimization, while some enterprises are stuck in development bottlenecks due to technological lag and diseconomies of scale. Dynamic efficiency analysis shows that the growth of total factor productivity in the industry is weak, technological progress has become the main factor restricting high-quality development, and the traditional development model relying on scale expansion is unsustainable. Faced with this situation, gas enterprises urgently need to build an innovation-driven intelligent development system, focus on breaking through key areas such as smart pipeline networks, low-carbon technologies and multi-energy integration, and at the same time integrate industrial chain resources through open cooperation and establish a shared win-win development mechanism. In the long run, the transformation and upgrading of gas enterprises is not only related to the sustainable development of the industry itself, but also an important support for national energy security and the "Dual Carbon" strategy. It requires the coordinated promotion of the government, enterprises and research institutions to jointly promote the gas industry to develop in an efficient, low-carbon and intelligent direction.

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