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A New Perspective on Strategic Choices for the Survival and Development of Energy Enterprises: An Analysis of Market Power, Innovation Strategy, and Sustainable Development of Major Multinational Oil Companies

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Abstract: As global economic recession and deterioration of the ecological environment become increasingly prominent, every responsible enterprise, especially the energy enterprises with more environmental controversies, will be faced with the most difficult choice regarding sustainable operation in history: market power expansion strategy, or technological innovation strategy? Most of the literature supports the finding that the former can occupy the market advantage and obtain the current market survival, but the future potential is low, while the latter reduces the firm's negative externality and gains future competitiveness, but current profits are reduced. This paper proposes a new perspective to evaluate the "sustainable development of enterprises" and then constructs a new measurement model, using a linear regression model for empirical analysis, which provides technical support and guidance for energy enterprises facing this decision-making dilemma. For further research, we have proposed more practical business management strategies for the sustainable development of petrochemical companies in developing countries.

Keywords: market power expansive strategy; technological innovation strategy; sustainable development of enterprises; firm sustainable total factor productivity; negative data in DEA

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1. Introduction

Since the Second World War, humanity has long been troubled by global population expansion, energy crisis, over-consumption of resources, serious environmental pollution, climate change, and a sharp decline in biodiversity [1]. Consequently, ecological preservation and environmental protection have attracted the attention of governments and practitioners worldwide, shaping socio-economic development policies and international cooperation agendas, particularly in developed nations [2]. Simultaneously, in response to the global economic downturn, several prominent politicians from various countries have proposed controversial policies sacrificing environmental and other social rights to stimulate economic growth [3]. Consequently, the dichotomy between "realistic survival" and "future development" has emerged as a complex and pressing issue, presenting a challenge to the foundational principles of sustainable development—the theoretical cornerstone of environmentalists. This has prompted introspection: is it viable to ensure future sustainability and intergenerational equity at the expense of the present generation's rights and interests [4]?

In the microeconomic domain, the intricacies surrounding this issue are pronounced. It encompasses not only the dilemma of prioritizing between a company's "current survival" and "future development", but also extends to the broader question of the relative significance between "corporate survival" and "social development". Naturally, this complex inquiry can be distilled into the overarching question, "What constitutes sustainable development for enterprises"?

The above issue poses a decision-making dilemma for corporate management between "technological innovation strategy" and "market power expansion strategy", particularly salient for energy enterprises with more environmental controversies. Existing research suggests that adopting a "market power expansion strategy" yields favorable outcomes in terms of market dominance and immediate market survival, albeit potentially compromising future development prospects [5]. Conversely, embracing a "technological innovation strategy" offers advantages in environmental preservation [6], productivity enhancement and future competitiveness, albeit with potential challenges such as current profit reduction and survival difficulties [7]. However, there is a notable absence of research providing technical support and guidance for companies facing the strategic dilemma between "technological innovation" and "market power expansion".

Addressing this decision-making challenge for enterprises, especially within the energy enterprises, this study introduces a new perspective for evaluating "enterprise sustainable development". This is primarily accomplished through three steps: (1) introducing the concept of "enterprise sustainable development" and traditional evaluation methods; (2) elucidating the limitations of conventional evaluation methods and the theoretical foundation of the new perspective proposed in this paper; (3) discussing the feasibility of employing a comprehensive total factor productivity index, emphasizing the sustainability dimension, to approximate the level of enterprise sustainable development. Additionally, to practically implement the proposed evaluative perspective, a novel measurement model of common and group boundaries is devised. Given that companies facing strategic choices are typically mature, large-scale listed entities, their sample data may contain numerous negative values, rendering conventional total factor productivity measurement methods less suitable. Finally, this study conducts a new empirical procedure, using historical data from large multinational oil companies to examine the impact of technological innovation and market power expansion strategies on the sustainable development of petrochemical companies. Throughout this process, a considerable amount of negative data are encountered. Conventionally, since handling negative data involves either disregarding them or subjecting them to transformation, we construct a new model and put it into practice. This provides technical support and guidance for companies facing strategic choice dilemmas, especially petrochemical companies currently facing greater environmental pressure and financing constraints.

The paper is structured as follows: Section 2 proposes research hypotheses through theoretical analysis; Section 3 constructs a new meta-Malmquist index based on the negatively constrained RDM model; Section 4 describes the research methods and data; Section 5 uses empirical analysis methods to examine the impact of technological innovation and market power expansion strategies on corporate sustainable development; Section 6 conducts a comparative analysis with the research of other scholars; and Section 7 summarizes the main research conclusions and puts forward relevant policy recommendations.

2. Theoretical Analysis and Research Hypothesis

What is "corporate sustainability"? How should we evaluate "corporate sustainability"? Scholars concur that Sustainable development theory is rooted in the principle of sustainable equity, encompassing intergenerational equity and intragenerational equity [8]. Although there is a lack of a widely recognized concept of "corporate sustainability", this concept must follow the principle of sustainable equity. Hence, two distinct evaluation perspectives are generated: the social sustainable development perspective that emphasizes intergenerational equity, and the internal sustainable development perspective of the firm that emphasizes intragenerational equity.

Traditional methods of evaluating corporate sustainability. From the perspective of social sustainable development, the Environmental, Social, and Governance (ESG) assessment stands out as the most widely accepted approach [9]. A notable gap exists in recognized evaluation methods that focusses on the internal sustainable development of businesses. Among them, assessments of enterprise sustainable competitiveness, drawing upon Porter's competitive strategy theory, and evaluations of enterprise performance, utilizing the enterprise financial system, are accepted and acknowledged by some scholars. These two assessment perspectives have evolved independently over time, and are supported by the literature.

A new perspective of evaluating corporate sustainability: corporate survival. Traditional methods for assessing corporate sustainability are inherently limited. Firstly, this is a one-sided evaluation only from the perspective of socially sustainable development, but the sustainable development of enterprises is a prerequisite for the sustainable development of society. To advance sustainable social and economic progress, it is essential to enhance the inherent potential of enterprises. Secondly, it is insufficient to evaluate the sustainable development of enterprises only from the inside of enterprises. Enterprises pay attention to serving the sustainable development of society, which is the premise of the sustainable development of enterprises. High levels of Environmental, Social, and Governance (ESG) performance enable companies to obtain recognition and oversight from stakeholders, while signaling altruism attracts investment and financing opportunities [9,10]. Lastly, whether a firm survives is the core of evaluating its sustainable development. It means the essence of enterprises is avoiding bankruptcy caused by reduced profits, bad investment decisions, and depleted human resources, both now and in the future. Furthermore, enterprise survival is also one of the essence of the sustainable development of the social economy.

Basis of enterprise survival. According to classical economic theory, enterprises function as production entities striving for profit maximization. In contrast, the neoinstitutional economics theory posits that enterprises a substituting market mechanisms and serve as organizations aiming to reduce transaction costs [11]. Additionally, some scholars argue that an enterprise represents a unique contract between human and non-human capital [12]. From this perspective, the factors supporting enterprise survival should encompass at least three dimensions: Degree of enterprise cost saving, Adaptability of product market demand, and Persistence of human capital.

Degree of enterprise cost saving. The operating cost of an economy is defined as a broad transaction cost, and the cost expense of an enterprise belongs to the transaction cost of an enterprise [13]. We can infer that enterprises not only need to participate in environmental protection to maintain good public relations and save external transaction costs, but, in addition, it is necessary to minimize the cost of the production process to save the internal transaction cost. However, in the two perspectives of the traditional approaches to assessing corporate sustainable development, each addresses this fundamental element, yet exhibits shortcomings. On the one hand, ESG evaluations examine the extent to which companies engage in environmental protection, thereby fostering positive public relations and consequently reducing transaction costs. On the other hand, internal corporate evaluations focus on profit maximization, thereby exploring cost-saving measures from the standpoint of minimizing expenses. Presently, most indicators evaluated directly or indirectly from these two perspectives consider this foundational factor. However, the former lacks intuitiveness, while the latter lacks comprehensiveness.

Adaptability of product market demand. In the information age, characterized by competition and changes in the market environment, comprehending market demand characteristics, fostering market adaptability, and responding to consumer preferences can more accurately reflect the sustainable development capabilities of enterprises [14]. Meanwhile, when subjected to the intervention of an external regulatory environment, those products that are more in line with the requirements of environmental regulation have more market competitive advantages. Therefore, the operating income of enterprises will be more stable and the survival of operations will be stronger; otherwise, it will be weaker. However, in the two perspectives of the traditional methods of assessing corporate sustainable development, each addresses this fundamental element, yet exhibits shortcomings. Both evaluation methods have assumptions. On the one hand, ESG evaluations presuppose a public preference for environmentally friendly products; on the other hand, internal corporate evaluations assume that profit maximization stems from market equilibrium driven by consumer preferences. The assumptions mentioned above are limitations.

Persistence of human capital. As the basic condition of enterprise operation, human capital includes not only the core entrepreneurs or enterprise decision-makers, but also the core management and technical personnel of the enterprise [15]. In the two perspectives of the traditional methods of assessing corporate sustainable development, ESG evaluation did not consider this factor, and the internal evaluation perspective of the enterprise only focuses on the entrepreneur's ability.

The implementation methods of this paper's new perspective. Traditional evaluation methods have limitations: traditional ESG indicators prioritize environmental and social factors, failing to directly reflect corporate cost savings and the sustainability of human capital. The traditional internal evaluation perspective of enterprises considers three fundamental elements crucial for sustained survival. However, it primarily concentrates on result evaluation, thus neglecting process evaluation [16,17]. This paper posits the rationality of a new perspective for assessing the sustainable development of enterprises. Hence, utilizing the DEA method can facilitate this endeavor. Firstly, this approach obviates the need for predefined production functions. Secondly, this approach enables the consideration of the three fundamental elements of enterprise sustainable development by controlling the selection of input and output indicators. Thirdly, by incorporating a dynamic Malmquist measurement, it can encompass both the process and result evaluation aspects. Based on the above analysis, this paper puts forward the following hypothesis.

H1. *The stronger the enterprise's sustainable total factor productivity, which encompasses the examination of the three fundamental elements of enterprise sustainable development, the higher its sustainable development ability.*

What is market power? Can enterprises adopt a "market power expansion strategy" to achieve sustainable development? According to the theory of industrial organization, market power refers to the ability of enterprises to influence market prices or monopolize the market [18]. It is comprised of cost advantages and demand advantages. One approach to acquiring cost or demand advantages involves enhancing the uniqueness of products or the comparative competitive advantage of enterprises, which is typically short-term and not detrimental to the social economy. The second approach involves obtaining cost or demand advantages through government support and resource monopolization, which is typically long-term and detrimental to the social economy [19]. For sustainable development, firms should focus on adopting the first approach to market power expansion, as it helps mitigate the negative externalities of firms. Therefore, enterprises can lower production and transaction costs and attain cost advantages by modifying product structure, refining market positioning, and optimizing supply channels [20]. Similarly, enterprises can achieve demand advantages through strategies such as market segmentation, innovative product design, and sales models [21]. In this process, enterprises can comprehensively improve sustainable total factor productivity and enterprise sustainable development capacity by realizing the optimization of the three fundamental elements of sustainable development. Based on the above analysis, this paper puts forward the following hypothesis.

H2. *Market power expansion strategy can promote the enterprise's sustainable total factor productivity and enhance the sustainability of enterprises.*

What is innovation? Can enterprises adopt an "innovation strategy" to achieve sustainable development? Innovation represents a long-term, high-cost, and high-risk economic endeavor. However, due to the inherent principal-agent problem within the "separation of powers" management mechanism, companies often lack incentives for innovative projects [22]. Furthermore, the allocation of corporate innovation funds faces constraints arising from principal-agent conflicts between investors and insiders, exacerbating the reluctance of firms to invest in innovation [23]. Nevertheless, innovation yields benefits for businesses. Corporate innovation can mitigate corporate carbon emissions, enhance environmental performance, develop safer and more reliable products, bolster consumer trust and corporate reputation [24], elevate product quality, reduce operating costs, and enhance market competitiveness [25]. In this process, by optimizing the three fundamental elements of sustainable development, enterprises can comprehensively improve sustainable TFP and sustainable development capacity. Based on the above analysis, this paper puts forward the following hypothesis.

H3. *Technological innovation strategy can promote an enterprise's sustainable total factor productivity and enhance the sustainable development ability of enterprises.*

Enterprises can attain sustainable development objectives through various strategies, including technological innovation and market power expansion, among others [26]. In contrast to the market power expansion strategy, the optimization effect of technological innovation strategies on the three fundamental elements of enterprise sustainable development has a longer-lasting duration. Hence, innovation strategies that lead to better sustainability adhere more closely to the Pareto optimality principle under numerous conditions of uncertainty. Based on the above analysis, this paper puts forward the following hypothesis.

H4. *When confronted with the decision between market power expansion and technological innovation strategies, opting for the technological innovation strategy is more conducive to promoting the sustainable improvement of the enterprise's total factor productivity, thereby enhancing the enterprise's overall sustainable development capability.*

3. The RDM Model for a New Perspective of Evaluating Corporate Sustainability

Common measurement methods of Total Factor Productivity (TFP) include parametric methods (such as the stochastic frontier method) and non-parametric methods (such as Data Envelopment Analysis (DEA)). However, stochastic frontier analysis is only applicable for measuring output per unit with multiple inputs, and requires setting the specific form of the production function, leading to potential errors in the results. Additionally, index methods have stringent assumptions, such as constant marginal productivity and safe substitution of capital and labor, making them unsuitable for the measurement in this paper. This study opts for the Malmquist index, which is suitable for dynamically examining multi-input and multi-output scenarios, to conduct a comprehensive evaluation of the process and outcome regarding the three fundamental supporting elements of enterprise sustainable development [27].

Furthermore, recognizing that the sample data of the petrochemical industry may include a significant number of negative values, this paper selects the Negative Value Constrained Range Directional Model (RDM) based on Data Envelopment Analysis (DEA) and adapts it accordingly to suit the measurement process. Certainly, the examination of environmental regulation's impact on total factor productivity through Luenberger indices is more appropriate. However, this is not the main focus of our study, and there is already ample literature on this topic. Moreover, it is not suitable for our paper due to the significant presence of negative values in the data.

3.1. The RDM Model

In the DEA method, processing negative values typically involves leveraging two key characteristics, unit invariance and transformation invariance, through appropriate preprocessing methods. These methods include employing fixed-value direction vectors, converting input–output indicators to positive by augmenting them with the negative value of the positive vector, and averaging input and output vectors [28,29]. However, these approaches have limitations. The selection of fixed-value direction vectors is subjective and speculative. Conversely, directly adding positive vectors or averaging them can potentially lead to data deviations from their actual values.

Following the work of [30], we proposed the evaluation concept of directional distance function to enhance the DEA method. Consider a set of unit j (j = 1, ..., n) and a vector x_{ij}^t reflecting m inputs consumed for producing a vector of s outputs y_{ij}^t in time period t. Consider the technology of time period t as $T^t = \{(x^t, y^t),\ x^t\ can\ produce\ y^t\}$. Following [31], we consider (g_x, g_y) as the directional vector results in the directional distance function, generally defined as:

$$\vec{D}^t(x_k^t, y_k^t, g_x, g_y) = sup\{\beta | x_k^t - \beta g_x, y_k^t + \beta g_y\} \quad (1)$$

The directional distance function can be used with any directional vector. The above problems can be solved through linear programming using the model in (2):

$$\begin{cases} max\beta_0 \\ s.t.\sum_{j=1}^n \lambda_j y_{rj}^t \geq y_{r0}^t + \beta_0 g_{yr}^t \\ \sum_{j=1}^n \lambda_j x_{ij}^t \geq x_0^t - \beta_0 g_{xi}^t \\ \lambda_j, \beta_0, g_{xi}^t, g_{yr}^t \geq 0 \end{cases} \quad (r = 1, 2, \cdots, s; i = 1, 2, \cdots, m) \quad (2)$$

In model (2), the condition for satisfying the direction vector is that its variable values should be greater than 0. Considering an ideal point as $I = \left(max_J y_j^t, r = 1, 2, \cdots, s; min_J x_j^t, i = 1, 2, \cdots, m\right)$, we can define the directional victors P_{r0} and P_{i0} in (3), which we define as the range of possible improvement of unit o.

$$\begin{cases} p_{r0} = max_J\left(y_{rj}^t\right) - y_{r0}^t\ r = 1, 2, \cdots, s \\ p_{i0} = x_0^t - min_J\left(x_{ij}^t\right)\ i = 1, 2, \cdots, m \end{cases} \quad (3)$$

Thus, we can obtain the directional distance function in (4):

$$\vec{DP}^t\left(x_k^t, y_k^t, P_{x_k^t}, P_{y_k^t}\right) = sup\{\beta | x_k^t - \beta P_x, y_k^t + \beta P_y\} \quad (4)$$

Based on the notion of the range of possible improvement in (2) and (3), the linear programming of the model is as follows:

$$\begin{cases} max\beta_0 \\ s.t.\sum_{j=1}^n \lambda_j y_{rj}^t \geq y_{r0}^t + \beta_0 p_{r0}^t \\ \sum_{j=1}^n \lambda_j x_{ij}^t \geq x_0^t - \beta_0 p_{i0}^t \\ e\lambda = 1 \\ \lambda_j, \beta_0, p_{xi}^t, p_{yr}^t \geq 0 \end{cases} \quad (r = 1, 2, \cdots, s; i = 1, 2, \cdots, m) \quad (5)$$

We can obtain an inefficiency measure equal to $\vec{DP}^t\left(x_k^t, y_k^t, 0, P_{y_k^t}\right) = \beta^* = y^{t*} - y_{r0}^t / p_{r0}^t$, which is provided by the optimal solution to model (5). Moreover, we define $\vec{RDM}^t\left(x_k^t, y_k^t, 0, P_{y_k^t}\right) = 1 - \vec{DP}^t\left(x_k^t, y_k^t, 0, P_{y_k^t}\right) = 1 - \beta^*$ as the RDM output 'meta-efficiency' of unit j in period t. Note that we have $1 - \beta^* = \left(max\left(y_{rj}^t\right) - y^{t*}\right) / \left(max\left(y_{rj}^t\right) - y_{r0}^t\right)$ for each output r.

3.2. Meta-Malmquist Indices

As mentioned earlier, we will utilize a meta-frontier approach, which involves aggregating data from a panel spanning multiple time periods, referred to as the meta-period, to calculate our productivity change index and indicators.

Following the work of [31], let $\overrightarrow{DP}^t\left(x_j^t, y_j^t, 0, P_{y_j^t}\right)$ be expressed as $\overrightarrow{DP}^{mf}\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right)$ when the meta-frontier is the technology employed to determine the directional distance function of DMU j in period t. The term $\overrightarrow{DP}^{mf}$ indicates the distance function is concerning the meta-frontier, and $P_{y_j^t}^{mf}$ denotes the maximum increase in output under the meta-frontier. We obtain the ideal point as $I = \left(max_T max_J y_j^t, r = 1, 2, \cdots, s; min_J x_j^t, i = 1, 2, \cdots, m\right)$.

We define $\overrightarrow{RDM}^{mf}\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right) = 1 - \overrightarrow{DP}^{mf}\left(x_j^t, y_j^t, 0, P_{y_k^t}^{mf}\right)$ as the RDM output '*meta-efficiency*' of unit j in period t. Then, $\overrightarrow{RDM}^t\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right) = 1 - \overrightarrow{DP}^t\left(x_j^t, y_j^t, 0, P_{y_k^t}^{mf}\right)$ can be the RDM '*within-period-efficiency*' of unit j in period t. Because within-period efficiencies maintain the same ideal point as meta-efficiencies, collinearity between the directional distance from the observation point to the target under the meta-frontier and the directional distance from the ideal point under the group frontier to the target value under the meta-frontier is preserved. This enables the calculation of various Range Directional Model (RDM) efficiencies.

$$\overrightarrow{RDM}^{mf}\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right) = \overrightarrow{RDM}^t\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right) \times RE_j^f \quad (6)$$

where RE_j^f is retrieved residually as in (7):

$$RE_j^f = \overrightarrow{RDM}^{mf}\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right) / \overrightarrow{RDM}^t\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right) \quad (7)$$

Using the aforementioned definitions where efficiency measures are computed through the RDM model, a Meta-Malmquist index can be followed, as in (8):

$$MM_j^{t,t+1} = \frac{\overrightarrow{RDM}^{mf}\left(x_j^{t+1}, y_j^{t+1}, 0, P_{y_j^{t+1}}^{mf}\right)}{\overrightarrow{RDM}^{mf}\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right)} \quad (8)$$

By substituting (8), we can decompose the Meta-Malmquist index, as shown in (9):

$$MM_j^{t,t+1} = \frac{\overrightarrow{RDM}^{mf}\left(x_j^{t+1}, y_j^{t+1}, 0, P_{y_j^{t+1}}^{mf}\right)}{\overrightarrow{RDM}^{mf}\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right)} = \frac{\overrightarrow{RDM}^t\left(x_j^{t+1}, y_j^{t+1}, 0, P_{y_j^{t+1}}^{mf}\right)}{\overrightarrow{RDM}^t\left(x_j^t, y_j^t, 0, P_{y_j^t}^{mf}\right)} \times \frac{RE_j^{t+1}}{RE_j^t} \quad (9)$$

The pure technical efficiency change of unit j from year t to year $t+1$ is captured by the first term in Equation (9). The second term captures the pure technical progress change between the VRS frontiers of periods t and $t+1$ in (9).

3.3. Group-Malmquist Indices

To circumvent the occurrence of varying frontiers across different periods within the model, the previous section introduced the construction of the Meta-Malmquist index, incorporating the global idea of establishing a unified frontier. The Meta Frontier Malmquist method was then employed for calculation, effectively mitigating the issue of solution scarcity in Range Directional Models (RDM). Nonetheless, disparities exist in the characteristics between developed and developing countries within the sample group, potentially imposing limitations on the common frontier hypothesis.

3.4. Model Practical Design

Firstly, the above new RDM model is constructed to realize the evaluation process of adapting to negative values, processes, and outcomes by using the Meta-Malmquist index and Group-Malmquist index.

Secondly, input and output indicators are controlled. To achieve the theoretical core of this paper, the measurement of sustainable total factor productivity contains three fundamental elements. The input indicators are as follows: (1) Total assets, which are used to assess the enterprise's capital investment and resource allocation effectiveness. (2) Main business costs and various period expenses, which are used to examine the degree of cost savings, are one of the three fundamental elements proposed by the theoretical analysis. (3) The number of employees, which is used to examine the stability of labor input, is one of the three fundamental elements proposed in the theoretical analysis. Similarly, the output indicators are specifically chosen: (1) Main business income, employed to assess the adaptability of the company's current product market demand, future development prospects, and security. (2) Net profit, utilized to evaluate the company's current profitability. Two output indicators jointly examine the adaptability of product market demand, one of the three fundamental elements proposed in theoretical analysis.

Thirdly, we prepare and collate the sample data. Our sample is comprised of approximately 20 large multinational oil companies that have consistently ranked in the Fortune 500 list in recent years. However, Saudi Aramco was excluded due to the unavailability of pre-2019 data before its initial public offering, and ExxonMobil was omitted due to significant missing data on intangible fixed assets. The distribution of samples between developed and developing countries is relatively balanced. The primary data for this study is sourced from the BvD Osiris global listed company analysis database, covering the period from 2009 to 2018. We specifically selected data from listed petroleum companies such as Royal Dutch Shell, BP, Exxon Mobil, Total, Chevron, Rosneft, Valero Energy, Lukoil, Petrobras, Eni, Indian Oil, PTT PCL, Oil & Natural Gas, Repsol, ConocoPhillips, and Suncor Energy. Additionally, these data are adjusted to constant GDP levels in 2000.

Lastly, the process of the model is implemented. This paper constructs the new RDM model to measure the sample data and obtain the measurement results of enterprise sustainable development, including the total factor productivity (MI_MM, MI_GM) of the Meta-Malmquist index and Group-Malmquist index, technical efficiency (EC_MM, EC_GM), and technological progress (TC_MM, TC_GM) of oil companies. The above results can, respectively, examine the sustainable development ability, realistic viability, and future development potential of enterprises under the global and group frontier.

4. Research Design

Building upon the findings of [30], we designate the total factor productivity of oil companies' sustainable development, the technical efficiency, and technological progress of oil companies as the dependent variables. Additionally, we identify market power and innovation strategy as the independent variables in our analysis. The model is constructed as follows:

$$\begin{aligned} Y_{it} &= \alpha_0 + \alpha_1 markpow_{it} + \alpha_2 innov_{it} + \alpha_3 ownstr_{it} + \alpha_4 propstr_{it} \\ &+ \alpha_5 assstr_{it} + \alpha_6 liqrat_{it} + \alpha_7 assgrow_{it} + \alpha_8 shock_{it} + \varepsilon_{it} \end{aligned} \tag{10}$$

where i and t represent enterprise and time, respectively; Y examines the sustainable development of total factor productivity, technical efficiency, and technological progress of each sample enterprise; *markpow* and *innov* are market power and innovation strategy, respectively; *ownstr*, *propstr*, *assstr*, *liqrat*, *assgrow*, and *shock* are ownership structure, property structure, asset structure, liquidity ratio, asset growth rate, and international financial crisis, respectively, where international financial crisis is a dummy variable; α_0 is the constant term, and $\alpha 1$ to $\alpha 8$ are the coefficients to be estimated; and ε is the error term.

Explained variable: We designate the total factor productivity (MI_MM), technical efficiency (EC_MM), and technological progress (TC_MM) of the MM model (Meta-Malmquist's RDM model), along with the total factor productivity (MI_GM), technical efficiency (EC_GM), and technological progress (TC_GM) of the GM model (Group-Malmquist's RDM model) as the explanatory variables, respectively.

Explanatory variables: (1) Market power (*markpow*). Market power is used to measure the ability of enterprises to control the market and the competitiveness of their products in the market, which can be measured using the Lerner index. In this paper, we use the formula (main business income—main business cost)/main business income for measurement [32]. (2) Innovation strategy (*innov*), which is expressed as the strategic decision used to measure enterprises' treatment of innovation. As a high-risk long-term investment, R&D investment needs to be supported by the company's strategic decision-making level to maintain the consistency of decision-making and the sustainable development of innovation. In this paper, it is measured using the ratio of intangible assets to total assets.

Control variables: (1) Shareholding structure (*ownstr*), which refers to the shareholding ratio of the largest shareholder. (2) Property rights structure (*propstr*): the ultimate owner of the property rights of the enterprise is a dummy variable with 0 for state ownership and 1 for others. (3) Asset structure (*assstr*) is used to measure the asset allocation of enterprises, which is measured using (fixed assets + inventory)/total assets regarding [33]. (4) Current ratio (*liqrat*), which measures the ability of an enterprise to use cash for debt repayment, which is measured using current assets/short-term liabilities. (5) Asset growth rate (*assgrow*), which is used to measure the growth of assets, and is expressed as (total assets of the current period—total assets of the previous period)/total assets of the previous period. (6) International financial crisis (*shock*) is a dummy variable with a value of 1 for the occurrence of an economic crisis and 0 for the absence of an economic crisis. The definitions and description of variables are, respectively, shown in Tables 1 and 2.

Table 1. List of variable definitions.

	Variable Name	Variable Symbol	Description of Variables
Explained Variables	Total factor productivity of the MM model	*MI_MM*	These are the measurement result of Meta-Malmquist's RDM model and Group-Malmquist's RDM model, which will, respectively, examine the sustainable development ability, realistic viability, and future development potential of enterprises under the global and group frontier.
	Technical efficiency of the MM model	*EC_MM*	
	Technological progress of the MM model	*TC_MM*	
	Total factor productivity of the GM model	*MI_GM*	
	Technical efficiency of the GM model	*EC_GM*	
	Technological progress of the GM model	*TC_GM*	
Explanatory variable	Market power	*markpow*	(Main business income—main business cost)/main business income.
	Innovation strategy	*innov*	The ratio of intangible assets to total assets.
Control variable	Shareholding structure	*ownstr*	Refers to the shareholding ratio of the largest shareholder.
	Property rights structure	*propstr*	A dummy variable with 0 for state ownership and 1 for others.
	Asset structure	*assstr*	(Fixed assets + inventory)/Total assets regarding.
	Current ratio	*liqrat*	Current assets/short-term liabilities.
	Asset growth rate	*assgrow*	(Total assets of the current period—total assets of the previous period)/total assets of the previous period.
	International financial crisis	*shock*	A dummy variable with a value of 1 for the occurrence of an economic crisis and 0 for the absence of an economic crisis.

Table 2. Summary statistics.

Variable	Mean	St. Dev	Min	Max	Skewness	Kurtosis	JB	Number
MI_MM	1.041	0.460	0.051	2.132	8.617	93.924	96,000 ***	270
EC_MM	1.001	0.050	0.759	1.254	0.568	11.343	797.6 ***	270
TC_MM	1.038	0.456	0.051	2.132	8.835	97.206	100,000 ***	270
MI_GM	1.048	0.472	0.051	2.516	8.027	84.591	78,000 ***	270
EC_GM	1.001	0.037	0.847	1.223	0.872	13.290	1225 ***	270
TC_GM	1.047	0.469	0.051	2.441	8.150	86.512	81,000 ***	270
markpow	0.399	0.240	0.078	0.100	0.862	2.865	33.65 ***	270
innov	0.046	0.050	0.001	0.350	2.682	12.422	1322 ***	270
ownstr	0.376	0.294	0.001	1.000	0.355	1.536	29.78 ***	270
propstr	0.611	0.488	0.000	1.000	−0.456	1.208	45.49 ***	270
assstr	0.800	0.072	0.598	0.938	−0.117	2.300	6.128 **	270
liqrat	1.326	0.469	0.600	3.390	1.457	6.807	258.6 ***	270
assgrow	0.144	0.653	−0.878	10.008	13.103	195.245	420,000 ***	270
shock	0.067	0.249	0.000	1.000	3.474	13.071	1684 ***	270

Note: **, and *** indicate significance levels at 5%, and 1%, respectively.

The total factor productivity and its decomposition efficiency in the period t~(t + 1) are defined as the explained variables in the period (t + 1). Thus, we finally obtained 18 cross-sectional members, 15 time points, 14 variables, and a total of 3990 data. Furthermore, through the unit root and other correlation tests on the variables, it is shown that the sample data are in a stationary state; thus, we can conduct a regression analysis.

5. Empirical Results and Analysis

5.1. Results of Corporate Sustainability Operational Efficiency Assessment

In the analysis of the overall and disaggregated indicators of the sample enterprises (see Tables 3 and 4), we observed the following trends and results:

Table 3. Mean value of sustainable development ability index of sample enterprises (MM model).

Year Period	MM Model								
	Totality			Developed Country			Developing Country		
	MI	EC	TC	MI	EC	TC	MI	EC	TC
2003~2004	1.065	1.007	1.058	1.051	1.009	1.041	1.082	1.006	1.077
2004~2005	1.085	0.98	1.106	1.038	0.97	1.069	1.137	0.991	1.147
2005~2006	1.005	1.015	0.99	1.026	1.028	0.996	0.982	0.999	0.983
2006~2007	1.03	1.005	1.025	0.965	1.005	0.96	1.102	1.005	1.097
2007~2008	1.045	0.984	1.062	1.077	0.986	1.092	1.009	0.981	1.028
2008~2009	0.803	1.004	0.801	0.753	0.985	0.766	0.859	1.026	0.839
2009~2010	1.079	1.022	1.054	1.099	1.034	1.064	1.056	1.009	1.044
2010~2011	1.029	0.994	1.035	1.071	0.999	1.071	0.982	0.988	0.994
2011~2012	0.981	0.997	0.984	1.01	0.995	1.014	0.949	0.999	0.95
2012~2013	0.946	1.004	0.943	0.966	1.005	0.962	0.924	1.004	0.921
2013~2014	0.942	0.991	0.95	0.954	1	0.954	0.928	0.982	0.945
2014~2015	0.842	0.983	0.856	0.815	0.97	0.838	0.873	0.997	0.876
2015~2016	0.95	1.036	0.915	0.958	1.039	0.919	0.941	1.033	0.909
2016~2017	1.236	1.001	1.234	1.238	0.998	1.238	1.234	1.004	1.23
2017~2018	1.156	1.002	1.152	1.177	1.01	1.16	1.133	0.993	1.142
Mean value	1.013	1.002	1.011	1.013	1.002	1.01	1.013	1.001	1.012

Note: The MM model is the value measured by the Meta-Malmquist method in the RDM model. MI is the value of total factor productivity. EC is the value of technical efficiency. TC is the value of technological progress.

Table 4. Mean value of indicators of sustainable development capacity of sample enterprises (GM model).

Year Period	GM Model								
	Totality			Developed Country			Developing Country		
	MI	EC	TC	MI	EC	TC	MI	EC	TC
2003~2004	1.092	1.008	1.084	1.111	1.003	1.107	1.071	1.014	1.057
2004~2005	1.099	0.997	1.103	1.059	0.997	1.062	1.143	0.996	1.148
2005~2006	1.017	0.997	1.02	1.029	0.994	1.035	1.004	1.001	1.003
2006~2007	1.025	1.002	1.023	0.951	1.006	0.945	1.108	0.997	1.111
2007~2008	1.008	0.989	1.019	1.009	0.994	1.014	1.006	0.983	1.024
2008~2009	0.805	1.011	0.796	0.756	1.008	0.749	0.859	1.014	0.849
2009~2010	1.107	1.003	1.103	1.162	0.997	1.164	1.047	1.009	1.034
2010~2011	1.037	0.995	1.041	1.106	0.993	1.111	0.96	0.997	0.964
2011~2012	0.984	1.001	0.983	1.02	0.995	1.024	0.945	1.006	0.938
2012~2013	0.944	0.998	0.946	0.971	1.002	0.969	0.914	0.994	0.92
2013~2014	0.915	0.995	0.919	0.941	1.001	0.939	0.886	0.988	0.897
2014~2015	0.834	0.983	0.848	0.845	0.97	0.869	0.822	0.997	0.825
2015~2016	0.957	1.029	0.929	0.957	1.031	0.926	0.957	1.027	0.932
2016~2017	1.325	0.998	1.327	1.408	0.996	1.413	1.232	1	1.232
2017~2018	1.172	1.004	1.165	1.199	1.017	1.175	1.143	0.99	1.154
Mean value	1.092	1.008	1.084	1.111	1.003	1.107	1.071	1.014	1.057

Note: The GM model is the value calculated using the Group-Malmquist method in the RDM model, MI is the value of total factor productivity, EC is the value of technical efficiency, and TC is the value of technological progress.

Firstly, upon evaluating the average growth rates of various indicators, it is observed that the sustainable Total Factor Productivity (TFP) of enterprises exhibited an overall upward trend during the sample period. Although there are slight discrepancies in the calculation results between the MM and GM models, possibly attributable to variations in the production frontier between developing and developed countries, this disparity does not compromise the reliability of the comparative conclusions regarding the sustainable development of enterprises in developed and developing countries.

Secondly, time series analysis reveals that from 2008 to 2009, both overall indicators and sub-indicators exhibited abnormal fluctuations, which can be attributed to the financial and real economic turmoil stemming from the 2008 global economic crisis. Specifically, there was a significant decline from 2008 to 2009, followed by a rebound from 2009 to 2011, a slight downturn post-2011, and a notable upsurge in 2016.

Lastly, the measurement of the average value of each decomposition index indicates that there is no significant disparity in the technical efficiency (EC) of enterprises between developed and developing countries. However, a difference is observed in technical progress (TC), particularly evident after the 2008 economic crisis. Under the GM model, the technological progress of developed countries significantly outpaced that of developing countries, subsequently influencing the performance of aggregate indicators. This illustrates the role of technological progress in shaping the sustainable development capability of enterprises and their ability to navigate economic crises. Moreover, the GM model effectively reveals the heterogeneity stemming from technological progress among enterprises, a factor not fully captured by the previous literature that solely considers the common frontier.

As depicted in Table 5, the overall and classification efficiency measurements of the sample enterprises are as follows. The total index (MI) of each enterprise is significantly influenced by the technological progress index (TC). Specifically, companies such as Rosneft, ConocoPhillips, and Eni exhibit higher values of both technical progress and technical efficiency indicators across different models, resulting in elevated overall index values. This suggests that these enterprises possess superior sustainability. Conversely, companies like Valero Energy, Suncor Energy, and CNOOC also demonstrate high sustainable Total Factor Productivity (TFP) due to their elevated technological progress index values.

Table 5. Total index and decomposition index value of sustainable development ability of sample enterprises.

Company	Cluster	MM			GM		
		MI	EC	TC	MI	EC	TC
SINOPEC	2	1.014	1.006	1.008	1.018	1.006	1.012
Royal Dutch Shell	1	0.999	1.002	0.997	1.034	0.999	1.035
PetroChina	2	1.000	1.005	0.996	1.001	1.005	0.997
BP	1	1.001	1.005	0.996	1.008	1.002	1.006
Total	1	0.990	0.997	0.994	1.013	0.998	1.016
Chevron	1	0.988	0.999	0.990	1.013	1.000	1.015
Rosneft	2	1.068	1.003	1.065	1.065	1.001	1.064
Valero Energy	1	1.044	1.000	1.044	1.048	1.000	1.048
Lukoil	2	1.010	1.000	1.010	1.005	1.000	1.005
Petrobras	2	0.983	0.998	0.988	0.971	0.999	0.976
Eni	1	1.019	1.006	1.014	1.065	1.004	1.060
Indian Oil	2	1.011	1.000	1.011	0.988	1.000	0.989
PTT PCL	2	1.004	1.000	1.004	0.983	1.000	0.983
Indian Oil	2	0.989	0.997	0.990	0.989	0.997	0.989
Repsol	1	1.003	1.003	1.002	1.011	0.999	1.014
ConocoPhillips	1	1.051	1.005	1.035	1.071	1.001	1.061
CNOOC	2	1.036	1.000	1.036	1.036	1.000	1.036
Suncor Energy	1	1.037	1.006	1.025	1.059	1.000	1.056

Note: Meta-Malmquist RDM and Group-Malmquist RDM model measures are shown in the table. MI represents the value of total factor productivity, EC is the value of technical efficiency, and TC is the value of technological progress. Cluster 1 is for developed countries and Cluster 2 is for developing countries.

Furthermore, when the total factor productivity value of a firm falls below 1, its technical efficiency and technological progress index values also dip below 1. Indian Oil and Gas Company and Petrobras, for instance, display low technical efficiency and technological progress value indicators, consequently yielding enterprise technical efficiency and technological progress index values below 1, thereby leading to low sustainable TFP efficiency.

It is worth noting that although China National Petroleum Corporation has consistently ranked first in the Forbes 500 petrochemical industry, its technological progress value remains low. This aspect may potentially impact its future development. Enterprises should place increased emphasis on advancing technological progress.

In this paper, the negative constraint Malmquist Range Directional Model (RDM) is utilized to assess the sustainable Total Factor Productivity (MI), technical efficiency (EC), and technological progress (TC) of 18 sample companies operating in both developed and developing countries. The common frontier consists of the Group-Malmquist (GM) model and the Meta-Malmquist (MM) model.

The research findings demonstrate that this method effectively addresses the limitations of conventional Data Envelopment Analysis (DEA) in measuring negative data from listed companies. Additionally, it dynamically isolates the root cause hindering the sustainable development of enterprises, which is identified as either insufficient technological progress (TC) or technical efficiency (EC). This strongly supports H1.

Moreover, the results indicate that developed countries do not exhibit significant advantages over emerging economies in terms of corporate sustainability (MI). All firms with low MI values are located in developing nations. This disparity may be attributed to the incomplete overlap of product markets between developed and developing countries, or it could be attributed to sustainability encompassing both present and future characteristics.

Furthermore, concerning actual viability (EC) and future development potential (TC), developed countries maintain a higher ability to achieve sustainable development compared to developing countries. This holds even when domestic environmental protection pressures constrain their enterprises, thereby equalizing their actual market survival advantage (EC) with that of developing countries. This is largely due to developed countries possessing a stronger potential for future development (TC) than developing countries.

Analyzing the time trend of the calculation results reveals that companies affected by the economic crisis now rely more on the benefits brought by technological progress to mitigate risks and withstand external shocks. This suggests that, in certain aspects, the impact of the economic crisis on the sustainable development capabilities of enterprises is positive rather than negative.

5.2. Benchmark Regression

The benchmark regression of total indicators explores the impact of global competition, market power expansion, and innovation strategies on the sustainable development ability of enterprises (see Table 6).

Table 6. Analysis of influencing factors of sustainable development capacity (MMI) of petroleum enterprises in the total sample.

Variable	FE_MMI	RE_MMI	HTM_MMI	OLS_MMI
markpow	1.28 *** (0.300)	0.256 ** (0.129)	1.028 *** (0.268)	0.256 (0.149)
innov	2.445 *** (0.594)	2.002 *** (0.538)	2.34 *** (0.587)	2.002 (1.842)
ownstr	−0.596 *** (0.226)	−0.433 ** (0.182)	−0.523 ** (0.215)	−0.433 (0.345)
propstr		−0.331 *** (0.119)	−0.241 (0.206)	−0.331 (0.265)
assstr	−2.133 *** (0.625)	−1.517 *** (0.437)	−2.072 *** (0.577)	−1.516 (1.118)
liqrat	0.181 ** (0.088)	0.003 (0.068)	0.12 (0.083)	0.003 (0.042)
assgrow	−0.108 *** (0.039)	−0.093 ** (0.041)	−0.110 *** (0.039)	−0.093 *** (0.009)
shock	0.269 *** (0.099)	0.245 ** (0.105)	0.263 *** (0.099)	0.245 (0.204)
_cons	2.105 *** (0.584)	2.418 *** (0.456)	2.364 (0.582)	2.418 ** (1.039)
N	270	270	270	270
R-sq	0.25	0.16		0.16
F	3.11 ***			
B-PLM test		0.00		
Hausman test	37.58 ***			
Hausman-Taylor Test			7.98 *	
Under-identification test				
Weak identification test				
Sargan statistic				

Note: FE, RE, OLS, and HTM represent the fixed effect, random effect, mixed effect, and Hausman–Taylor model, respectively. _MMI represents the estimation result of the MI index measured by the MM model as the explained variable. Standard errors are in parentheses, and *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively.

The results indicate that both innovation and market power expansion strategies positively contribute to the sustainable development capability of enterprises, thus validating H3. Moreover, the estimation results of the control variables yield additional insights. Firstly, higher cash solvency and the shareholding ratio of the largest shareholder, along with the impact of the economic crisis, all have a positive influence on the sustainable development capability of enterprises.

This study posits that a higher proportion of assets and inventories relative to a company's total assets leads to a higher asset growth rate but lower sustainability (MI). On one hand, increased inventory levels can impact cash flow and impede profit capture, while a faster asset growth rate can diversify shareholders' equity. Adequate inventory reserves and corresponding asset growth rates, essential for augmenting market power, may ultimately diminish the company's future sustainable development capabilities.

This scenario may weaken or even negate the positive effects of the market power expansion path chosen by companies to enhance sustainability in practice, thereby validating H4.

As illustrated in Table 7, market power significantly enhances the actual viability (EC) and future growth potential (TC) of the enterprise. Conversely, the innovation strategy solely exhibits a deterministic positive impact on the future growth potential (TC) of the enterprise, while its effect on the actual survival capability (EC) is characterized by uncertainty. This uncertainty is from the high uncertainty and risk associated with corporate innovation investment. In the short term, technical efficiency may decrease due to innovation, but in the long term, technological progress accelerates, resulting in an eventual increase in technical efficiency.

Table 7. Analysis of influencing factors of technical efficiency (MEC) and technical progress (MTC) of petroleum enterprises in the overall sample.

Variable	FE_MEC	RE_MEC	HTM_MEC	FE_MTC	RE_MTC	HTM_MTC
markpow	0.107 ***	0.017	0.058 **	1.170 ***	0.236 *	0.921 ***
	(0.037)	(0.015)	(0.029)	(0.299)	(0.128)	(0.263)
innov	−0.038	−0.048	−0.06	2.502 ***	2.061 ***	2.400 ***
	(0.074)	(0.063)	(0.072)	(0.591)	(0.531)	(0.583)
ownstr	−0.016	−0.004	−0.005	−0.579 **	−0.428 **	−0.506 **
	(0.028)	(0.021)	(0.025)	(0.224)	(0.180)	(0.213)
propstr		0.003	0.011		−0.335 ***	−0.257
		(0.014)	(0.019)		(0.118)	(0.197)
assstr	0.012	0.003	−0.002	−2.146 ***	−1.533 ***	−2.067 ***
	(0.078)	(0.051)	(0.064)	(0.621)	(0.432)	(0.569)
liqrat	0.009	−0.001	0.001	0.172 **	0.004	0.109
	(0.011)	(0.008)	(0.010)	(0.087)	(0.067)	(0.082)
assgrow	−0.002	−0.003	−0.003	−0.106 ***	−0.09 **	−0.107 ***
	(0.005)	(0.005)	(0.005)	(0.039)	(0.040)	(0.039)
shock	−0.02	−0.021 *	−0.021 *	0.291 ***	0.268 ***	0.284 ***
	(0.012)	(0.012)	(0.012)	(0.099)	(0.103)	(0.098)
_cons	0.947 ***	0.998 ***	0.978 ***	2.16 ***	2.432 ***	2.414 ***
	(0.073)	(0.053)	(0.065)	(0.580)	(0.450)	(0.572)
N	270	270	270			
R-sq	0.01	0.02		0.24	0.17	
F	0.54			2.94 ***		
B-PLM test		0.00			0.00	
Hausman Test	8.97			35.11 ***		
Hausman Taylor			5.44			7.81 *
Under-identification test						
Weak identification test						
Sargan statistic						

Note: _MEC denotes the estimation results of the explanatory variables using the value of technical efficiency measured using the Meta-Malmquist RDM model; _MTC denotes the estimation results of the explanatory variables using the value of technical progress measured using the Meta-Malmquist RDM model. Standard errors are in parentheses, and *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively.

The estimated results of the control variables also indicate that the effects of equity structure, ownership structure, asset structure, current ratio, asset growth rate, and financial crisis on actual survivability (EC) are inconclusive. However, their effects on future growth potential (TC) align with the previous findings (refer to Table 6). This suggests, to a certain extent, that actual survivability (EC) plays a more dominant role in corporate sustainable development (MI), thus validating H4.

In summary, the benchmark regression of this paper investigates the influence of market power expansion and innovation strategies on firms' sustainability (MI), actual survivability (EC), and future growth potential (TC) in a global competitive environment (MM model). The regression results confirm the validity of H2, H3, and H4, demonstrating that these strategies have distinct impacts on firms' actual survivability and future growth potential.

The managerial insight derived from this analysis suggests that while choosing the path of market power expansion can enhance an enterprise's sustainable development capability, the long-term outcomes may deteriorate or even lead to negative effects. Conversely, technological innovation can boost the future growth potential of an enterprise, which in turn influences its sustainability. For enterprises navigating through uncertainty, opting for a long-term technological innovation strategy aligns with Pareto optimality.

5.3. Further Analysis

Since developed and developing countries possess different first-mover advantages and long-term development prospects, the optimal strategic decisions for firms are likely to vary. Thus, it is crucial to analyze the heterogeneity of optimal decision-making choices among developing country firms in both intra-group and global competitions, while excluding the influence of developed countries' first-mover advantages.

The regression analysis of total indicator heterogeneity explores the impact of market power and innovation strategy on firms' sustainability (MI) within intra-cluster market competition in developing countries (refer to Table 8). The results indicate that, compared to the previous benchmark regression estimates of the total indicator (refer to Table 6), there are no significant differences, but the absolute values of the coefficients are higher. This could be attributed to the tailored market conditions under the cluster approach, leading to a higher degree of improvement. Additionally, the energy market in developing countries may be more promising and opportunistic, granting developing country firms greater access to that market. These findings further support hypotheses H2 and H3.

Table 8. Analysis of influencing factors of sustainable development capacity (GMI) of oil enterprises in developing countries.

Variable	FE_GMI	RE_GMI	HTM_GMI	OLS_GMI
markpow	1.353 ***	0.216	0.956 **	0.216
	(0.503)	(0.199)	(0.441)	(0.184)
innov	4.597 ***	3.68 ***	4.458 ***	3.68
	(1.214)	(1.081)	(1.201)	(3.626)
ownstr	−0.919 **	−0.512	−0.82 **	−0.512
	(0.389)	(0.326)	(0.379)	(0.526)
propstr		−0.358 *	−0.461	−0.358
		(0.197)	(0.455)	(0.322)
assstr	−2.719 **	−2.282 ***	−2.769 ***	−2.282
	(1.078)	(0.883)	(1.041)	(1.700)
liqrat	0.186	−0.069	0.124	−0.069
	(0.127)	(0.108)	(0.123)	(0.064)
assgrow	−0.091 *	−0.085	−0.093 *	−0.085 ***
	(0.053)	(0.056)	(0.053)	(0.015)
shock	0.442 **	0.45 **	0.446 **	0.451
	(0.184)	(0.197)	(0.183)	(0.414)
_cons	2.704 **	3.131 ***	3.074 ***	3.131 *
	(1.062)	(0.887)	(1.052)	(1.632)
N	135	135	135	135
R-sq	0.33	0.27		0.23
F	3.83 ***			
B-PLM test		0.00		
Hausman test	23.14 ***			
Hausman-Taylor test			5.342	
Under-identification test			18.074 ***	
Weak identification test			3.283	
Sargan statistic			1.523	

Note: _GMI denotes estimates with total factor productivity values measured using the Group-Malmquist RDM model as the explanatory variable. Standard errors are in parentheses, and *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively.

Furthermore, the estimation results of the control variables mirror those of the benchmark regression for the aggregate indicator (refer to Table 6), albeit with less significant coefficients on equity structure, asset structure, asset growth rate, and financial crisis. This suggests that developing country firms face fewer constraints on their market power expansion strategy and encounter less environmental pressure compared to their developed counterparts. Consequently, developing country firms are more inclined to adopt market power expansion strategies, providing further validation for H4.

Table 9 examines the impact of market power and innovation strategy on the actual survivability (EC) and future growth potential (TC) of firms in developing countries for sustainable development. The results indicate a lack of significance in the effect of market power on firms' actual survival and future growth while demonstrating a significant positive effect of the innovation strategy on firms' future growth potential, albeit with uncertain effects on actual survivability. This suggests that, given the existence of market and technological first-mover advantages in developed countries, developing countries also need to pursue breakthrough competitive advantages in the field of technological innovation. This further validates H4.

Table 9. Analysis of Factors Affecting the Realistic Survivability (MEC) and Future Growth Potential (MTC) of Oil Enterprises in Developing Countries.

Variables	FE_GEC	RE_GEC	HTM_GEC	FE_GTC	RE_GTC	HTM_GTC
markpow	0.0637 *	0.0048	0.0263	1.294 **	0.209	0.895 **
	(0.0357)	(0.013)	(0.0257)	(0.504)	(0.198)	(0.438)
innov	−0.0663	−0.0663	−0.0777	4.662 ***	3.747 ***	4.522 ***
	(0.0861)	(0.0706)	(0.0829)	(1.215)	(1.077)	(1.200)
ownstr	−0.0002	0.0058	0.0056	−0.922 **	−0.521	−0.820 **
	(0.0276)	(0.0213)	(0.0254)	(0.389)	(0.325)	(0.378)
propstr		0.0017	0.0043		−0.361 *	−0.467
		(0.0129)	(0.0207)		(0.196)	(0.443)
assstr	0.0214	0.0085	0.0086	−2.731 **	−2.28	−2.774 ***
	(0.0765)	(0.0576)	(0.0687)	(1.079)	(0.880)	(1.039)
liqrat	0.0092	0.0022	0.0047	0.178	−0.070	0.114
	(0.0090)	(0.0071)	(0.0082)	(0.128)	(0.108)	(0.123)
assgrow	0.0001	−0.00005	−0.0002	−0.09 *	−0.084	−0.093 *
	(0.0038)	(0.0036)	(0.0037)	(0.053)	(0.055)	(0.053)
shock	−0.0205	−0.02	−0.0203	0.463 **	0.470 **	0.467 **
	(0.0131)	(0.0129)	(0.0128)	(0.184)	(0.197)	(0.183)
_cons	0.9434 ***	0.9884 ***	0.9743 ***	2.752 **	3.136 ***	3.120 ***
	(0.0753)	(0.0579)	(0.0685)	(1.062)	(0.884)	(1.049)
N						
R-sq	0.12	0.07		0.33	0.23	
F	0.57			3.69 ***		
B-PLM test		0.00		0.00		
Hausman test	4.45					
Hausman Taylor test			5.436			7.812 *
Under-identification test						
Weak identification test						
Sargan statistic						

Note: _GEC denotes the estimation of the explanatory variables using the value of technical efficiency measured using the Group-Malmquist RDM model; _GTC denotes the estimation of the explanatory variables using the value of technological progress measured using the Group-Malmquist RDM model. Standard errors in parentheses, and *, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively.

The heterogeneity regression examines the impact of market power expansion and innovation strategies on firms' sustainability (MI), realistic survivability (EC), and future development potential (TC) when competing within developing country clusters (i.e., the GM model).

Developing countries possess greater access to intra-cluster markets, leading to higher levels of upgrading through strategic decisions. Moreover, they face fewer environmental pressures, resulting in fewer constraints on market power expansion strategies. Consequently, they are more inclined to adopt market power expansion strategies to enhance their firms' sustainability. Compared to developed countries, developing countries could consider the path of technological innovation to break through in market competition.

5.4. Robustness Test and Endogeneity Analysis

To mitigate potential reverse causality and bolster the model's robustness, this paper employs aggregate and decomposition indicators of sustainable development on both common and cluster fronts as explanatory variables for multiple tests. Additionally, lagged terms of explanatory variables that might exhibit reverse causality are selected as instrumental variables to address endogeneity concerns. The findings reveal that only the regression model of MI value measured using the GM model fails the weak identification test, whereas other models indicate that the instrumental variables are appropriately selected. The robustness test results are shown in Table 10.

Table 10. Robustness test results.

Variables	IV_MMI	IV_MEC	IV_MTC	IV_GMI	IV_GEC	IV_GTC
markpow	0.063 *	0.144 *	0.072	0.05	0.0131	0.027
	(0.498)	(0.081)	(0.482)	(0.678)	(0.068)	(0.676)
innov	0.098 *	0.011	0.111 *	2.891 *	−0.4695	2.902 *
	(1.046)	(0.188)	(1.013)	(2.538)	(0.346)	(2.531)
ownstr	−0.896 ***	−0.025	−0.875 ***	−1.518 ***	0.0197	−1.515 ***
	(0.195)	(0.035)	(0.189)	(0.339)	(0.039)	(0.338)
assstr	−0.798	−0.061	−0.732	−1.566	−0.0004	−1.523
	(0.566)	(0.101)	(0.548)	(1.017)	(0.109)	(1.014)
liqrat	0.121	0.008	0.112	0.146	0.0133	0.138
	(0.075)	(0.013)	(0.073)	(0.103)	(0.012)	(0.103)
assgrow	−0.038	0.003	−0.035	−0.02	−0.0131	−0.02
	(0.032)	(0.010)	(0.031)	(0.042)	(0.008)	(0.042)
shock	0.248 ***	−0.023 *	0.273 ***	0.424 ***	−0.0131 *	0.444 ***
	(0.077)	(0.014)	(0.074)	(0.135)	(0.008)	(0.134)
N	270	270		135		
R-sq	0.16	−0.12	0.18	0.26	−0.09	0.26
F						
B-PLM test						
Hausman test						
Hausman Taylor test						
Under-identification test	58.75 ***	64.25 ***	58.75 ***		64.25 ***	35.87 ***
Weak identification test	19.33	14.54	19.34		14.537	12.31
Sargan statistic	2.996	4.796	4.71		4.8	2.88

Note: IV denotes instrumental variable model, _MMI, _MEC, _MTC, _GMI, _GEC, and _GTC explained as before; standard errors in parentheses, *, and ***, denote 10%, and 1% level of significance, respectively.

6. Discussion

This article conducts an empirical study on the relationship between market power expansion, technological innovation, and corporate sustainable development strategies. The study found that both the market power expansion strategy and technological innovation strategy can enhance the sustainable development capabilities of enterprises, but the effect of the technological innovation strategy is better and more lasting.

From the perspective of corporate market power expansion, this is consistent with the finding that a high level of business model innovation can lead to a high level of corporate sustainability [34]. In addition, fierce market competition has reduced the sustainable development performance of enterprises, and enterprises need to adopt necessary market tools to deal with it [35].

From the perspective of corporate technological innovation, formal survival modeling techniques are used to examine the impact of technological innovation on corporate sustainability from the perspective of the duration of the company's listing [36]. This paper also explores the impact of managerial support for innovation on corporate sustainability [37].

From the perspective of corporate market power expansion and technological innovation choices, in the corporate innovation process, whether it is based on technological innovation or market-oriented business model innovation, more attention is paid to the values and expectations of corporate stakeholders. This shows that both technological innovation and market model innovation can promote the sustainable development of enterprises to a certain extent [6].

7. Conclusions

The trading environment deteriorates, amplifying the longstanding challenge of global economic recession. Balancing ecological sustainability with economic recovery is now a big concern not only for national policymakers and the public, but also for enterprises. Specifically, how can enterprises mitigate negative external impacts on society and the environment while ensuring their own sustainable development? In this context, this paper utilizes data from 18 prominent listed petrochemical companies spanning from 2003 to 2018 as research samples to empirically examine the impact of two strategies on the sustainable development ability of enterprises: one is to enhance the current viability through market power expansion, and the other is to enhance the future development potential through technological innovation.

Firstly, a company's sustainable development ability correlates positively with its market control capacity. However, reliance solely on market power expansion may diminish a company's future sustainable development capabilities compared to strategies rooted in technological innovation. While market power expansion offers short-term gains, its long-term implications may prove detrimental. Secondly, an enterprise's future development potential significantly influences its sustainable development capabilities. Thirdly, despite facing lesser environmental pressures, enterprises in developed countries exhibit similar market viability to those in developing countries. However, their stronger future development potential accentuates their sustainable development capabilities. Fourthly, enterprises in developing countries, with fewer environmental constraints, may be inclined towards market power expansion strategies. Yet, such strategies offer limited benefits in global or regional markets. Pursuing technological innovation in market competition appears more feasible for enterprises in developing countries.

In addition, the new measurement model in this paper assumes constant returns to scale. This is mainly because the energy enterprises with strategic choice problems are generally enterprises with little difference in size, and there is no obvious difference in scale benefits among enterprises, so this hypothesis is applicable. Meanwhile, this is also because the high complexity of the negative value model is constructed in this paper when considering the change of scale benefits, and it may be difficult to obtain an effective solution. Therefore, we will continue to explore new models to address the limitations of this article in the future.

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