QUANTITATIVE EVALUATION OF CHINA'S CARBON EMISSION REDUCTION POLICIES UNDER THE "DUAL CARBON" TARGETS

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Abstract. At the 75th United Nations General Assembly in 2020, China unveiled its "dual carbon" objectives— to peak carbon emissions by 2030 and achieve carbon neutrality by 2060— signalling a pivotal shift towards sustainable, low-carbon development. In this context, the effectiveness of carbon emission reduction policies has become a critical determinant of China's transition pathway. The objective of this study is to employ the Policy Modeling Consistency (PMC) Index Model to quantitatively assess the design quality and implementation potential of China's carbon reduction policies. The study utilised a systematic analytical approach, encompassing the text mining and multi-dimensional scoring of ten exemplary policy documents. This methodical process led to the identification of salient strengths, including policy comprehensiveness, transparency, and alignment with national strategic objectives. However, the report also reveals persistent weaknesses, particularly in cross-sectoral coordination, stakeholder inclusiveness, and incentive mechanisms at the local level. The results of the PMC evaluation indicate that five policies achieve a "Good" rating, while the remaining five are "Qualified". These results reflect structural imbalances in policy frameworks across administrative tiers. The study proposes targeted recommendations, including enhancing multi-agency collaboration, broadening policy scope, reinforcing safeguard mechanisms, and establishing adaptive feedback systems to improve policy effectiveness. These insights provide valuable guidance for the refinement of China's carbon reduction strategies and the acceleration of the country's progress towards its dual carbon targets.
Keywords: *energy revolution, energy reform, policy quantification, PMC index model, "dual carbon" goals, carbon neutrality*

Introduction

On September 22, 2020, at the 75th United Nations General Assembly, President Xi Jinping announced that China would aim to achieve peak carbon emissions by 2030 and carbon neutrality by 2060. Carbon neutrality involves offsetting greenhouse gas emissions through various mitigation activities such as afforestation, renewable energy adoption, and energy conservation measures, ultimately reaching a net-zero emissions. These "dual carbon" objectives underscore China's commitment to global climate governance and signal a significant shift in the nation's approach toward sustainable and low-carbon development (Xi, 2022). The period of the "14th Five-Year Plan" is of critical importance in China's pursuit of ecological civilisation, with carbon reduction efforts receiving increased policy attention and strategic significance. This transition not only propels improvements in environmental quality but also fosters innovation-driven industrial upgrading and sustainable economic transformation.

Carbon emission reduction policies typically encompass administrative command approaches, market-oriented carbon trading systems, and carbon taxation mechanisms.

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Administrative commands, despite their straightforward implementation, tend to lack flexibility and adaptability. In contrast, carbon trading systems leverage market forces to optimize carbon emission reductions, enhancing efficiency and flexibility. Carbon taxes provide a stable and continuous economic incentive, promoting long-term low-carbon transitions. Each mechanism presents unique strengths in managing carbon emissions and balancing economic development, thereby becoming an integral tool within China's broader strategy to address climate change.

The development of China's carbon emission reduction policies has been gradual, but the path ahead is not without obstacles. These include limited policy coverage, poor coordination among government agencies, and gaps in policy design. In order to address these issues, it is essential to undertake a comprehensive evaluation that extends beyond mere policy outcomes to encompass the internal logic, consistency, and scientific basis of the policies themselves. The Policy Modeling Consistency (PMC) Index Model provides a practical and comprehensive approach to this by assessing key aspects such as completeness, coherence, and feasibility. The PMC model employs data mining and text analysis to provide an objective and repeatable method for the analysis of complex policy documents. In this study, the PMC model is employed to systematically identify the strengths and weaknesses of China's carbon reduction policies, and to offer suggestions for the improvement of future policies that are evidence-based. This work contributes to the advancement of policy evaluation by introducing a rigorous approach, and it also extends the application of the PMC model in the domain of carbon emission reduction, where its utilisation has been limited.

Carbon reduction policies are key instruments in addressing global climate change while striving to balance economic growth and environmental sustainability. Globally, scholars have extensively analysed policy mechanisms such as carbon taxes, emissions trading systems (ETS), and command-and-control regulations (Narassimhan et al., 2018; Green, 2021). Carbon taxes are recognized for their long-term efficacy in internalizing externalities and promoting low-carbon development (Maestre-Andrés et al., 2019; Kuo et al., 2016), though public acceptance remains a challenge due to perceived fairness issues. Conversely, ETS offers flexibility but often faces volatility in price signals and inconsistent reduction outcomes (Narassimhan et al., 2018; Zhang et al., 2020). Studies by Wang et al. (2020) and Lv and Bai (2021) found that higher carbon prices and price volatility under ETS can stimulate corporate innovation, enhancing carbon-reduction technologies. In addition to policy instruments, the phenomenon of carbon leakage through international trade has become a matter of pressing concern. Li et al. (2020) employed network analysis to illustrate the expanding global carbon flow, emphasising the necessity for collective governance. In their 2021 study, Wang and Zhang examined the decoupling of carbon emissions from economic growth across 182 countries. They highlighted trade openness as a factor with divergent impacts on developed and developing economies. Seto et al. (2016) introduced the concept of "carbon lock-in," which explains how infrastructural, institutional and behavioural constraints reinforce emission trajectories. This paper asserts that in order to break these entrenched patterns, policy interventions are necessary.

China's endeavours to reduce its carbon emissions have attracted significant academic scrutiny, particularly in the wake of the declaration of its dual-carbon targets—to peak emissions by 2030 and achieve carbon neutrality by 2060 (Wei et al., 2022). The Chinese government has implemented a variety of policies aimed at reducing emissions, ranging from administrative regulations to market-based

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mechanisms such as carbon trading and taxation. Research conducted by Feng et al. (2022) and Zhang et al. (2020) has demonstrated that China's ETS pilots have been effective in reducing industrial carbon emissions. This reduction has been achieved through the restructuring of regional industries and the promotion of technological advancements. Hao et al. (2015) and Cui et al. (2022) emphasised the necessity of accounting for regional heterogeneity when designing emission reduction targets, as economic structure, industrial composition, and population density significantly influence carbon intensity convergence patterns. The efficacy of the carbon trading market in promoting low-carbon innovation was validated by Lv and Bai (2021), who demonstrated that both high carbon prices and price fluctuations incentivise firms to invest in carbon-reduction technologies. Concurrently, empirical studies by Du and Wang (2022) and Zhao et al. (2020) demonstrated that China's energy-saving and emission reduction policies have yielded substantial carbon mitigation effects, although outcomes exhibited regional and policy design variations. Sector-specific analyses, such as Wang et al. (2020) for aviation and Huang et al. (2017) for urban buildings, have highlighted inefficiencies in emission reduction, suggesting a need for targeted policy interventions. It is increasingly recognised that household consumption patterns play a pivotal role in the achievement of carbon reduction targets. Dubois et al. (2019) posited that behavioural changes in areas such as transportation, diet, and residential energy use are imperative, yet they emphasised the necessity of policy frameworks that are conducive to achieving such changes. This assertion was reiterated by Zhang and Wang (2017), who emphasised the necessity of integrating demand-side policies with supply-side measures to optimise household-level emission reductions.

Recent research has also explored macro-level strategies for achieving carbon neutrality. Wei et al. (2022) conducted a systematic review of over 1100 publications, with a view to identifying research priorities and policy actions for carbon peaking and neutrality. In their 2022 study, Huang et al. (2022) utilised the STIRPAT and LEAP models to map sectoral pathways in Beijing, with the objective of achieving the dual-carbon targets. Li et al. (2021) utilised system dynamics to predict carbon emissions in the construction industry, emphasising the significance of multi-scenario policy simulations.

From a methodological perspective, quantitative evaluation models have become pivotal in the assessment of policies. The evaluation of policies has evolved from descriptive, outcome-focused approaches to more structured and quantitative models that assess policy design consistency and effectiveness. The Policy Modeling Consistency (PMC) Index Model was introduced by Estrada (2011), and subsequently localized for application in China's policy evaluation research by Zhang and Geng (2015). PMC has been employed as a tool to assess policy coherence and identify structural strengths and weaknesses across diverse policy domains (Wei et al., 2015).

Despite the increased utilisation of the PMC Index Model in the domain of environmental policy research, its systematic application to evaluate the design logic and internal coherence of China's carbon reduction policies remains limited. The majority of extant studies concentrate on policy outcomes such as emission reductions, technological innovation, or economic impacts, while neglecting comprehensive assessments of policy structure, consistency, and implementation readiness. In order to address this gap, the present study employs the PMC Index Model to conduct a quantitative analysis of key carbon reduction policy texts in China. By focusing on the policy design process rather than merely the outcomes, the model helps to identify structural weaknesses, logical inconsistencies, and areas for improvement. This

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approach facilitates the development of targeted recommendations to enhance policy effectiveness and coherence. The present study makes a significant contribution to the existing body of knowledge in this field, both from a methodological perspective and in terms of its practical applications. Methodologically, it serves to expand the scope of the Policy Marker (PMC) in the context of carbon policy evaluation. In terms of its practical applications, it provides a robust analytical foundation that will facilitate the refinement of China’s carbon governance strategies in line with the “dual carbon” goals.

Current status of China’s carbon emission reduction policies

The trajectory of China’s climate policy has undergone a notable shift, transitioning from a conventional emphasis on reducing energy consumption and emissions to a more strategic, system-wide approach that is aligned with the objectives of the “dual carbon” initiative.

Evolution of carbon emission reduction policies

Initial formation stage (1980-1994)

During this period, China began prioritizing energy conservation primarily through administrative measures. In 1980, the government issued *“the Report on Strengthening Energy Conservation Work”*, which incorporated energy conservation into national macroeconomic management as a dedicated policy objective. This was followed by the enactment of the *“Interim Regulations on Energy Conservation Management”*, providing systematic guidance for energy efficiency efforts. In response to rising environmental pressures, China gradually established a legal framework for ecological protection, introducing key regulations such as the *“Implementation Rules of the Water Pollution Prevention and Control Law of the People’s Republic of China”* and the *“Implementation Rules of the Air Pollution Prevention and Control Law of the People’s Republic of China”,* laying the foundation for pollution control policies. The 1994 *“China Agenda for the 21st Century”* emphasized that sustainable progress requires balancing economic goals with the protection of environmental and resource systems.

Development and transformation stage (1995-2007)

With increasing energy shortages and mounting pressure on energy security, energy conservation became an urgent priority. *“The Energy Conservation Law”*, enacted in 1997, established energy conservation as a national strategic policy aimed at optimizing industrial and energy structures while fostering an energy conservation market. This law positioned energy efficiency as a fundamental requirement for sustainable economic development. In 2004, the *“Outline of the Medium- and Long-Term Energy Development Plan (2004-2020)”* (Draft for Comments) further emphasized energy as a key strategic component of economic growth and provided policy support for sustainable economic and social development.

Comprehensive improvement stage (2007-2020)

During this period, China’s energy conservation policy system underwent substantial enhancement, transitioning toward explicit advocacy for low-carbon development. The revision of the *“Energy Conservation Law”* in 2008 introduced more detailed guidance

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on energy management, clarifying enforcement responsibilities and compliance obligations for energy-intensive enterprises. In 2011, the *“Twelfth Five-Year Plan for Controlling Greenhouse Gas Emissions”* set clear objectives and implementation pathways for greenhouse gas emission control, with a strong emphasis on low-carbon technology research, development, and deployment. Further policy advancements were made with the 2016 *“Comprehensive Work Plan for Energy Conservation and Emission Reduction during the 13th Five-Year Plan”*, which set strategic directions for reducing energy use and emissions, and marked a step forward in institutionalizing support for ecological civilization goals.

“Dual carbon” stage (2020-Present)

In his address to the 75th United Nations General Assembly on 22 September 2020, President Xi Jinping expounded China’s *“dual carbon”* vision, which aims to cap carbon emissions by 2030 and pursue carbon neutrality by 2060. This declaration marked a pivotal transition, ushering China into a new phase of comprehensively promoting low-carbon development. The adoption of the “dual carbon” strategy has accelerated the integration of regulatory, market-based, and technological measures, establishing a clear trajectory for China’s long-term sustainable transformation toward a low-carbon economy.

Carbon emission reduction policies in typical provinces

Given China’s vast economic, industrial, and geographic diversity, carbon reduction strategies and their implementation effectiveness vary significantly across regions. To illustrate these regional disparities, this study examines policies from three representative areas: Beijing, Shanxi Province and Shandong Province.

Beijing, as a frontrunner in low-carbon development, has successfully reduced coal consumption through stringent environmental policies and targeted interventions. Its key achievements include the widespread adoption of electric mobility, the large-scale deployment of clean energy heating systems, and the implementation of smart energy management technologies. These measures have positioned Beijing as a model city for urban carbon neutrality initiatives.

Shanxi Province, as China’s leading coal-producing region, faces significant structural challenges in transitioning to a low-carbon economy. The province has implemented a series of measures, including the transformation of coal-dependent industries, the promotion of clean coal utilization, and the expansion of renewable energy projects. However, its heavy reliance on fossil fuels and the economic implications of energy sector reforms pose considerable obstacles to achieving long-term carbon neutrality.

Shandong Province, an industrial hub with high energy consumption and carbon emissions, has adopted an aggressive carbon reduction strategy. Key measures include optimizing its energy structure, expanding nuclear and renewable energy capacity, and enforcing stricter regulatory oversight on high-carbon industries. Despite these efforts, the province faces persistent challenges in balancing economic growth with stringent emission reduction targets.

Policy implementation challenges

Despite significant progress, China’s carbon emission reduction policies face several critical challenges. First, there is an uneven distribution of policy effectiveness across

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regions due to disparities in economic development levels and industrial structures. Coastal provinces, with advanced technological capabilities and economic resources, generally exhibit more effective carbon reduction measures compared to inland and resource-dependent regions. Second, the integration of administrative, market-based, and fiscal policy instruments remains incomplete, necessitating a more coordinated and synergistic approach. Third, enforcement and compliance mechanisms require further strengthening, particularly in historically high-emission industries, to ensure the effective realization of carbon reduction targets.

To address these challenges, future policy efforts should prioritize enhancing cross-regional collaboration, refining carbon pricing mechanisms, and expanding incentive-based policies to support technological innovation and industrial upgrading. By adopting a more holistic, adaptive, and regionally inclusive policy framework, China can accelerate its transition toward carbon neutrality while maintaining economic stability and fostering sustainable growth.

Materials and methods

Data source

In the construction of the PMC index model, policy documents serve as the core data source. The accuracy and completeness of these texts are vital to ensuring the rigor of quantitative policy research. This study focuses on evaluating the effectiveness of carbon reduction policies in China. Therefore, during the data collection process, three key criteria were prioritized: authority, public availability, and relevance. To ensure the credibility and validity of the research, the official website of the Peking University Law Database was selected as the primary source of policy documents. As a highly authoritative and reputable platform, it offers a wide array of official and normative policy texts, greatly facilitating the collection and screening of relevant documents. During the selection process, priority was given to formal and directive policy documents issued after the announcement of the “dual-carbon” goals, such as notices, opinions, decisions, and action plans. These documents typically include essential information such as policy background, objectives, measures, and anticipated outcomes, and thus provide significant analytical value for quantitative evaluation. To maintain consistency and avoid potential bias, informal documents—such as replies, letters, and internal communications—were excluded from the sample. Following this selection process, ten representative policy documents were identified for analysis. These are listed in *Table 1*.

Moreover, to ensure a comprehensive and representative analysis, the selected ten policy documents were screened based on three criteria: Firstly, geographical coverage must be ensured to guarantee the inclusion of policies at both national and sub-national levels. Secondly, the administrative level must be taken into consideration, encompassing central government-issued policies, provincial-level plans, and municipal-level implementation schemes. Thirdly, policy type must be considered, including strategic planning documents, implementation guidelines, and sector-specific regulatory measures. In the ten documents selected for analysis, four are national-level strategic frameworks (P1–P4), addressing overarching goals and action plans; four are provincial-level policies (P5–P9), representing key regional initiatives from Shanxi, Beijing, Shandong, Jiangsu, and Shanghai; and one municipal-level implementation plan (P10), illustrating localized governance practices

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at the city level. This multi-tiered selection strategy enables a balanced evaluation of policy design logic across different administrative hierarchies and geographical contexts, thus ensuring that the analysis reflects both top-down strategic planning and bottom-up implementation dynamics.

Table 1. *Selected carbon reduction policy documents*

Serial No.	Policy title	Date of issue
P1	Notice of the State Council on Issuing the “14th Five-Year” Comprehensive Work Plan for Energy Conservation and Emission Reduction	2021.12.28
P2	Implementation Plan for Coordinated Pollution and Carbon Reduction	2022.06.10
P3	State Council Guidelines on Accelerating the Establishment of a Green, Low-Carbon, and Circular Economic System	2021.02.22
P4	Notice of the State Council on Issuing the Action Plan for Carbon Peaking by 2030	2021.10.24
P5	Opinions of the Shanxi Provincial Government on Promoting Green and Low-Carbon Development in the Coal Chemical Industry	2022.07.01
P6	Guiding Opinions of the Beijing Landscaping Bureau on Achieving the Dual-Carbon Goals in the Landscaping Sector During the 14th Five-Year Plan	2022.06.15
P7	Notice of the Shandong Provincial Government on Issuing the 14th Five-Year Plan for Energy Conservation and Emission Reduction	2022.10.27
P8	Notice of the Shanghai Municipal Government on Issuing the Carbon Peaking Implementation Plan	2022.07.08
P9	Decision of the Jiangsu Provincial People’s Congress on Advancing Carbon Peaking and Carbon Neutrality	2022.11.25
P10	Notice of the Chengdu Municipal Government on Issuing the Carbon Peaking Implementation Plan	2024.03.13

Source: Peking University Law Database

Variable selection and parameter identification

Based on the collected policy texts, this study selected representative samples to explore their intrinsic features. Text segmentation was conducted using ROSTCM6.0 software, followed by word frequency analysis. The segmented terms were ranked by frequency, and 60 high-frequency keywords were identified for in-depth analysis (*Table 2*).

Based on these word frequency statistics, a high-frequency keyword network graph (*Fig. 1*) was developed to visually illustrate the interconnections and underlying logic among key policy terms. This facilitated a deeper understanding of policy focus areas and strategic priorities.

Drawing on the frequency data and previous studies, this research constructed a carbon reduction policy evaluation framework, consisting of 10 primary variables, each with corresponding secondary variables, totalling 38 indicators. The final structure is detailed in *Table 3*.

After determining the variables, parameter assignment was carried out. In this study, all secondary variables were considered equally important and were given equal weight in the multi-input-output matrix. This study employed a binary coding system, where a variable was marked as 1 if the policy text explicitly covered it, and 0 if there was no indication or mention, allowing a straightforward assessment of policy content.

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Table 2. *Word frequency statistics from carbon reduction policy texts*

Keywords	Frequency	Keywords	Frequency	Keywords	Frequency
Green	658	Environment	172	Reinforce	119
Development	534	Building	170	Fields	118
Energy	419	Enterprises	163	Foundation	118
Low-carbon	391	Emission	162	Coordination	117
Promote	371	Nation	161	Reform	116
Construction	358	Resources	158	Policy	115
Ecology	352	Level	147	Industry	115
Energy-saving	300	Facilities	146	Circular	112
Drive	286	Improve	137	Energy consumption	112
Utilization	280	Promotion	137	Clean	112
Technology	251	Projects	136	Transportation	111
Accelerate	243	Transformation	136	Capacity	110
Strengthen	223	Application	131	Target	106
Carbon peaking	220	Establish	130	Optimize	103
Enhance	213	Innovation	130	Encourage	103
System	203	Unit	125	Standards	101
Key areas	202	Emission reduction	125	Improve	101
Launch	197	Action	123	Protection	100
Management	179	Mechanism	123	Comprehensive	100
Carbon neutrality	177	System	122	Integrated	99

Source: Compiled by the authors

Table 3. *Indicator variable correspondence table*

Primary variable	Secondary variable
Policy Nature (X1)	X1-1: National-level, X1-2: Local-level
Policy Duration (X2)	X2-1: Short-term (<3 years), X2-2: Medium-term (3–5 years), X2-3: Long-term (>5 years)
Issuing Authority (X3)	X3-1: State Council, X3-2: Local Government, X3-3: People's Congress and its Standing Committee, X3-4: Other Departments
Policy Domain (X4)	X4-1: Economic, X4-2: Social, X4-3: Technological, X4-4: Environmental, X4-5: Political
Policy Target Group (X5)	X5-1: Province/Municipality, X5-2: Ministry, X5-3: Subordinate Agency, X5-4: Enterprise, X5-5: Collective, X5-6: Individual
Industry Coverage (X6)	X6-1: Individuals, X6-2: Domestic Enterprises, X6-3: Multinational Enterprises
Level of Policy Impact (X7)	X7-1: National Innovation, X7-2: Regional Economy, X7-3: Industrial Development, X7-4: Enterprise Innovation
Policy Function (X8)	X8-1: Carbon Emission Reduction, X8-2: Technological Innovation, X8-3: Economic Efficiency, X8-4: Environmental Awareness, X8-5: Implementation and Supervision
Safeguards and Incentives (X9)	X9-1: Legal Guarantee, X9-2: Tax Incentive, X9-3: Technical Guidance, X9-4: Investment Subsidy, X9-5: Talent Support
Policy Transparency (X10)	(No secondary variable)

Source: Compiled by the authors

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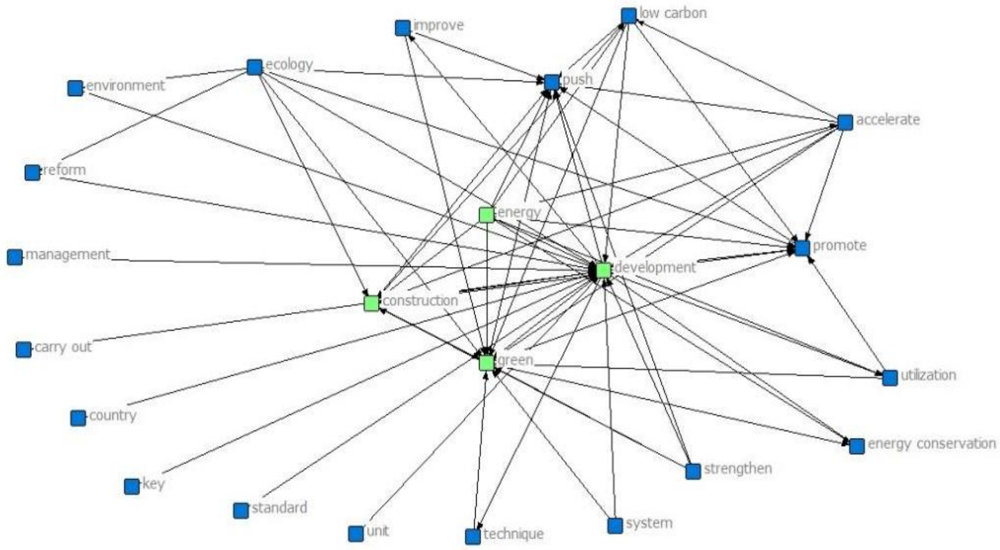

Figure 1. *High-frequency keyword co-occurrence network. (Source: compiled by the authors)*

Multi-input output table

The assessment utilized a structured matrix to support PMC index measurement, enabling comprehensive analysis across various aspects of policy content. Each indicator, regardless of level, was given the same weight to preserve neutrality (*Table 4*).

Table 4. *Multi-input output table*

Primary variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Secondary variable	X_{1-1} X_{1-2}	X_{2-1} X_{2-2} X_{2-3}	X_{3-1} X_{3-2} X_{3-3} X_{3-4}	X_{4-1} X_{4-2} X_{4-3} X_{4-4} X_{4-5}	X_{5-1} X_{5-2} X_{5-3} X_{5-4} X_{5-5} X_{5-6}	X_{6-1} X_{6-2} X_{6-3}	X_{7-1} X_{7-2} X_{7-3} X_{7-4}	X_{8-1} X_{8-2} X_{8-3} X_{8-4} X_{8-5}	X_{9-1} X_{9-2} X_{9-3} X_{9-4} X_{9-5}	X_{10}

Source: Compiled by the author

PMC index calculation and surface plotting

The calculation of the PMC index followed a three-step process:

(1) Scoring of Secondary Indicators: A binary value (1 or 0) was assigned to each secondary indicator, depending on whether it was reflected in the policy content.

$$X \sim N[0,1] \qquad \text{(Eq.1)}$$

$$X = \{XR: [0 \sim 1]\} \qquad \text{(Eq.2)}$$

(2) Aggregation at the Primary Level: The values of related secondary indicators were summed to compute the score for each primary category.

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$$X_i = \left[\sum_{j=1}^{n} \frac{X_{ij}}{n(X_{ij})}\right] \qquad i = 1,2,3,\dots,n \tag{Eq.3}$$

(3) PMC Index Derivation: The overall score, obtained by summing all primary-level scores, was then used to derive the PMC index for each policy document.

$$PMC = \begin{bmatrix} X_1\left(\sum_{a=1}^{2}\frac{X_{1a}}{2}\right) + X_2\left(\sum_{a=1}^{3}\frac{X_{2a}}{3}\right) + X_3\left(\sum_{a=1}^{4}\frac{X_{3a}}{4}\right) + \\ X_4\left(\sum_{a=1}^{5}\frac{X_{4a}}{5}\right) + X_5\left(\sum_{a=1}^{6}\frac{X_{5a}}{6}\right) + X_6\left(\sum_{a=1}^{3}\frac{X_{6a}}{3}\right) + \\ X_7\left(\sum_{a=1}^{4}\frac{X_{7a}}{4}\right) + X_8\left(\sum_{a=1}^{5}\frac{X_{8a}}{5}\right) + X_9\left(\sum_{a=1}^{5}\frac{X_{9a}}{5}\right) + X_{10} \end{bmatrix} \tag{Eq.4}$$

With ten primary variables, the PMC index ranged from 0 to 10, and scores were categorized into qualitative levels as shown in *Table 5.*

Table 5. *PMC policy grading criteria*

PMC score interval	Literal translation	Interpretation
0–4	Unqualified	Indicates major structural flaws; the policy lacks the foundation for effective implementation
4–6	Qualified	Meets minimum requirements; considerable improvements are needed for policy effectiveness
6–8	Good	Generally well-structured and implementable with moderate optimization
8–10	Excellent	Highly integrated and well-designed policy; exemplary in scope and strategic coherence

Source: Compiled by the authors

This study conducted a PMC index evaluation of ten selected carbon emission reduction policies (*Table 6*). The results indicate that the PMC indices range from 5.28 to 6.63, with an average score of 6.12. The policies, ranked in descending order of PMC index, are as follows: P1, P2, P9, P7, P8, P4, P6, P10, P3, and P5. According to the predefined grading criteria, the policies were classified into two main categories: P1, P2, P9, P7, and P8 were rated as Satisfactory, while P4, P6, P10, P3, and P5 were considered Basic.

Among these, Policy P1 achieved the highest score (6.63) and stood out as the top-performing policy. The *"Comprehensive Work Plan for Energy Conservation and Emission Reduction during the 14th Five-Year Plan"* released by the State Council, reflects notable policy effectiveness in driving carbon mitigation efforts and presents a coherent framework across various evaluation aspects. In contrast, Policy P5, titled "Opinions of the General Office of the Shanxi Provincial Government on Promoting the Green and Low-Carbon Development of the Coal Chemical Industry", received the lowest score (5.28), placing it slightly below the overall average. Although it meets the basic threshold for policy quality, the result suggests there remains considerable room for improvement in its design and implementation mechanisms.

Notably, the analysis is based solely on publicly disclosed policy texts, which can be accessed without restriction. As a result, they each scored 1.00 on dimension X10 (Policy Transparency). Given this uniformity, X10 is excluded from further comparative analysis in subsequent discussions.

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***Table 6.** Summary of PMC indexes for carbon reduction policies*

Primary variable	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Sum	Mean
X_1	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	5.00	0.50
X_2	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	3.30	0.33
X_3	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2.50	0.25
X_4	1.00	0.80	0.80	1.00	1.00	0.80	1.00	1.00	0.80	0.80	9.00	0.90
X_5	0.83	0.83	0.67	0.67	0.67	0.67	0.83	0.67	0.83	0.67	7.34	0.73
X_6	0.67	0.67	0.67	0.67	0.33	0.33	0.67	0.67	0.67	0.67	6.02	0.60
X_7	0.75	0.75	0.50	0.50	0.50	0.50	0.50	0.50	0.75	0.75	6.00	0.60
X_8	0.80	0.80	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.40	6.20	0.62
X_9	0.60	0.40	0.40	0.60	0.40	0.80	0.60	0.60	0.80	0.60	5.80	0.58
X_{10}	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.00	1.00
PMC score	6.63	6.43	5.62	6.02	5.48	5.68	6.18	6.02	6.23	5.65	61.16	6.12
Grade	Good	Good	Qualified	Good	Qualified	Qualified	Good	Good	Good	Qualified		
Ranking	1	2	9	6	10	7	4	5	3	8		

Source: Calculated by the authors

This research employed three-dimensional PMC surface diagrams to visually represent the internal structure of each policy. These visualizations play a crucial role in identifying structural strengths and potential deficiencies by offering an intuitive depiction of policy completeness and balance across key dimensions. Specifically: Series 1 illustrates scores on X1 (Nature), X2 (Duration), and X3 (Issuing Authority); Series 2 corresponds to X4 (Policy Domain), X5 (Target Groups), and X6 (Industry Coverage); Series 3 reflects X7 (Policy Impact Level), X8 (Policy Function), and X9 (Safeguards and Incentives).

While the detailed PMC surface diagrams for each of the ten evaluated policies have been moved to the *Appendix* (*Figs. A1–A10*) to streamline the main text, the subsequent analysis directly references the structural patterns and findings observed from these visualizations. Key observations regarding concavity, dimensional balance, and structural completeness will be discussed in the following sections, ensuring that readers can clearly follow the analytical narrative while referring to the corresponding diagrams in the appendix when necessary.

Evaluation of China's carbon reduction policies

In this work, we evaluate ten representative carbon reduction policies in China using the PMC index model and the three-dimensional PMC surface plots derived in Chapter 3. By analysing the PMC indices and corresponding surface features, we provide a comprehensive comparison of policy design quality, multidimensional integration, and implementation potential at both national and local levels.

Overall evaluation based on PMC index and surface plot

Table 6 and *Figures A1–A10* present the PMC index scores and surface plots for each of the ten selected policies. The scores range from 5.48 to 6.63, with a mean value of 6.12, indicating that all policies meet at least a basic level of design adequacy: Five policies (P1, P2, P7, P8, P9) were rated as "Good" (PMC index between 6 and 8); Five

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policies (P3, P4, P5, P6, P10) were rated as “Qualified” (PMC index between 4 and 6); No policy was found to be either “Excellent” (>8) or “Unqualified” (<4), reflecting a relatively stable but not yet optimal policy structure across the board.

Among them, Policy P1—*”the 14th Five-Year Comprehensive Work Plan for Energy Conservation and Emission Reduction”*, issued by the State Council—achieved the highest PMC index (6.63) and displayed a well-balanced PMC surface, with no significant structural depressions. Its high performance can be attributed to three key structural strengths: comprehensive coverage of policy domains and target groups, strong multi-agency coordination mechanisms, and well-defined safeguard measures including fiscal incentives and regulatory enforcement.

Similarly, Policy P2, *“the Implementation Plan for Coordinated Pollution and Carbon Reduction”*, ranked second (6.43), with a PMC surface showing strong cross-sectoral coordination and high scores in multi-agency involvement and supervision mechanisms. This indicates that policies emphasizing coordination across departments and explicitly integrating pollution control with carbon reduction objectives tend to achieve higher design quality.

In contrast, policies with narrower scopes or limited stakeholder engagement generally exhibit lower PMC scores. For instance, Policy P5, issued by the Shanxi Provincial Government, received the lowest PMC index (5.48), with its surface plot revealing limited policy target coverage, insufficient innovation support, and relatively weak incentives. This result suggests that while the policy addresses a critical regional industry—coal chemical processing—it lacks multidimensional robustness for broader transformation.

Comparative evaluation of local-level carbon reduction policies

This section conducts an in-depth evaluation of three representative local-level policies—P5, P6, and P7. According to the PMC index results presented in *Table 6,* the scores for these policies are 5.48, 5.68, and 6.18, respectively. Policies P5 and P6 fall within the Basic category, with scores below the overall average, while Policy P7 is rated as Satisfactory, scoring above the average. To further assess the structural integrity and comparative performance of these policies, a radar chart was constructed (*Fig. 2*), and the concavity index was introduced as a supplementary metric. The concavity index, calculated as the number of primary variables minus the PMC score, quantifies the degree of policy incompleteness. A lower concavity index indicates greater structural robustness and fewer design deficiencies.

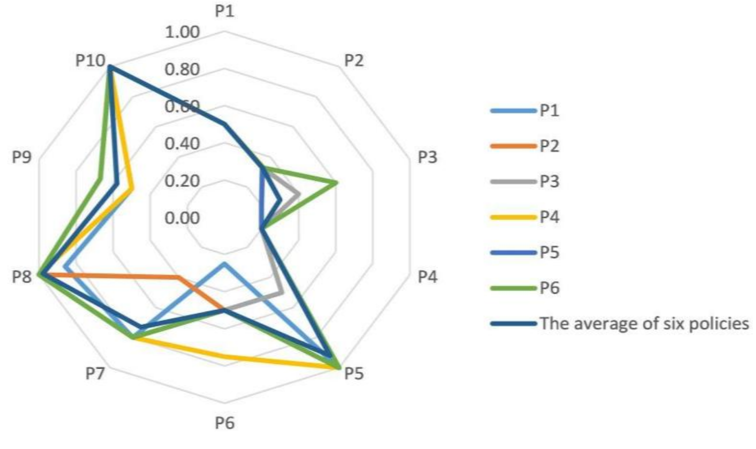

Figure 2. *Radar map of the mean value of policies*

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Policies P1, P2, and P7 share common structural advantages that contribute to their relatively higher PMC scores. These include broad stakeholder coverage, explicit multi-level coordination mechanisms, and the inclusion of safeguard systems such as monitoring, supervision, and fiscal incentives. In contrast, lower-scoring policies (e.g., P5 and P6) tend to have narrower policy domains, limited target group engagement, and insufficient emphasis on technological innovation and capacity-building measures.

As demonstrated in *Figure 2,* the radar chart is likely to reveal distinct patterns in how each policy performs across the ten evaluated PMC dimensions, thus shedding light on both consistent strengths and possible shortcomings. All three policies scored 0.5 on X1 (Policy Nature), confirming their status as local-level initiatives. On X2 (Policy Duration), each policy is designed as a medium-term plan (3–5 years), reflecting relatively stable implementation periods. With a score of 0.33 on X3 (Issuing Authority), Policies P5 and P7 were issued by provincial governments, while P6 was released by a departmental authority—indicating varying degrees of administrative influence and policy reach.

In terms of X7 (Policy Impact Level), all three policies prioritize regional economic and industrial development, but their scores remain below the average of 0.6. This suggests the need to enhance support for national innovation systems and enterprise-level transformation. For X8 (Policy Function), the three policies perform well in areas such as carbon reduction, environmental awareness, and implementation oversight. However, a common design gap is the lack of embedded technological innovation objectives, which limits their capacity to drive long-term structural transformation.

Each policy received a full score (1.0) on X10 (Policy Transparency), demonstrating consistent public disclosure and accessibility across cases. On X4 (Policy Domain), Policy P6 scored slightly below average due to the absence of political components, implying a relatively narrow framing of its operational scope. On X5 (Policy Target Group), Policies P5 and P6 underperformed compared to the average, indicating that they address a limited range of stakeholders. Broader coverage of affected groups should be considered in future revisions. In X6 (Industry Coverage), all three policies mainly target domestic enterprises. While Policy P7 performed relatively better by engaging more stakeholder types, future local policies should aim for broader industry inclusion and multi-sectoral participation. In terms of X9 (Safeguards and Incentives), Policy P5 scored below average, reflecting limited institutional support such as legal guarantees, tax benefits, technical guidance, investment subsidies, and human resource development. Strengthening these components is crucial to ensure effective policy implementation and long-term success.

Summary of strengths, limitations, and implementation challenges

Overall, China's current carbon reduction policies demonstrate consistent strengths in areas such as policy transparency, environmental awareness promotion, and basic implementation oversight mechanisms. It is evident that policies which achieve high scores tend to be distinguished by three key characteristics. Firstly, these policies are noted for their comprehensive stakeholder coverage. Secondly, they are distinguished by robust coordination mechanisms. Thirdly, and finally, they are characterised by well-structured safeguard systems.

Nevertheless, several limitations persist. Common weaknesses include limited emphasis on technological innovation, narrow industry and target group coverage in

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certain local-level policies, and the need for stronger institutional incentives. Moreover, challenges persist in translating policy design into effective on-the-ground implementation, particularly in regions characterised by resource-intensive industries or limited administrative capacity. Addressing these gaps will require enhancing policy integration across sectors, fostering innovation-driven initiatives, and ensuring adequate institutional and fiscal support mechanisms.

Policy recommendations

In light of the preceding findings, the following recommendations are proposed to enhance the effectiveness, fairness, and robustness of China's carbon emission reduction framework.

Promote multi-agency collaborative policy-making

Carbon reduction is inherently a cross-sectoral and cross-regional challenge. To improve coherence, coordination, and policy synergy, the formulation of emission reduction policies should involve multiple government departments—including those responsible for environmental protection, energy, transportation, industry, and science and technology. Establishing inter-ministerial coordination mechanisms or joint task forces can help align emission targets, streamline resource allocation, and prevent policy fragmentation during implementation.

Expand policy scope and coverage

Future policies should move beyond a narrow focus on industrial regulation and adopt a more holistic approach that integrates social, ecological, and behavioural dimensions. This includes creating mechanisms to incentivize green consumption, foster public participation, and mobilize community-level initiatives, thereby embedding low-carbon practices into everyday life and regional development strategies.

Develop a multi-tiered policy time horizon

Most existing policies emphasize medium- to long-term goals, while short-term interventions are relatively underrepresented. It is recommended to design integrated policy packages across short-, medium-, and long-term horizons. In this framework, short-term policies should serve as tactical responses to emerging challenges, while medium- and long-term policies should provide strategic direction for structural transformation and sustained low-carbon development.

Strengthen incentive and safeguard mechanisms

To enhance policy durability and stakeholder engagement, it is critical to reinforce institutional safeguards and incentive structures. These may include: Legal guarantees for emission targets and regulatory enforcement, Tax incentives and green financing instruments to support investment, Subsidies for technology deployment and diffusion, Human capital development programs, including the recruitment and training of professionals in green sectors. Local-level policies, in particular, require stronger institutional backing to address regional disparities in administrative capacity, financial resources, and technical readiness.

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Enhance policy monitoring, evaluation, and adaptive feedback mechanisms

A resilient and adaptive policy system must incorporate continuous performance monitoring and iterative learning. Establishing evaluation frameworks—leveraging tools such as PMC index models, scenario-based simulations, and quantitative impact assessments—can provide timely feedback to inform policy refinement, scaling, or realignment. These mechanisms are essential for maintaining long-term effectiveness and enabling course corrections as conditions evolve.

Conclusions

By constructing a PMC index model and employing a policy text mining approach, this study provides a systematic evaluation of ten representative carbon emission reduction policies in China. The findings offer empirical insights into the structural characteristics, design quality, and implementation readiness of both national and local-level policies. Overall, the results suggest that China's carbon reduction policy system exhibits a moderate to strong level of scientific soundness and practical applicability. Among the ten policies assessed, five were rated as "Good", while the remaining five were categorized as "Qualified", indicating an active yet uneven level of policy engagement across different administrative tiers. Several notable strengths emerged from the analysis. Most policies are well-aligned with national strategic goals, such as carbon peaking and carbon neutrality. Many include clearly defined implementation pathways, sector-specific focus, and compliance mechanisms. In particular, national-level policies demonstrate broader policy coverage, stronger inter-domain integration, and more comprehensive incentive frameworks.

Nonetheless, certain structural deficiencies were also identified. A significant portion of the policies were formulated by a single agency, lacking multi-agency coordination, which may hinder interdepartmental synergy during implementation. Others exhibit a narrow sectoral focus, failing to achieve sufficient cross-sectoral integration. Additionally, limited stakeholder inclusiveness is observed—especially regarding support for enterprise innovation, individual participation, and multilevel governance frameworks. Moreover, safeguards and incentive mechanisms, particularly those related to human capital development and technological innovation, remain underdeveloped in most local-level policies. These findings suggest that while the current policy framework has established a solid foundation for carbon governance, there is still substantial scope for structural refinement, multi-stakeholder integration, and intersectoral coordination to enhance the overall effectiveness of China's carbon reduction efforts.

Beyond the immediate context of China's carbon reduction policies, the evaluation framework proposed in this study—combining PMC Index analysis with policy text mining—holds significant potential for broader applicability. Given its flexibility in variable selection and its capacity to systematically assess policy consistency, completeness, and operability, this approach can be adapted to evaluate policy design quality in other domains, such as renewable energy, air pollution control, ecological conservation, and urban green infrastructure development. Moreover, the structured and quantifiable nature of the PMC Index Model facilitates cross-national policy comparisons, rendering it a valuable instrument for evaluating the internal coherence of environmental policies within diverse governance contexts. The application of this framework to diverse countries or policy sectors has the potential to enhance global knowledge on policy design optimisation and foster international policy learning in the field of sustainable development.

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Conflict of interests. The author declares that there are no conflicts of interest related to this article.

Data availability. The data that support the findings of this study are available upon reasonable request from the author.

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APPENDIX

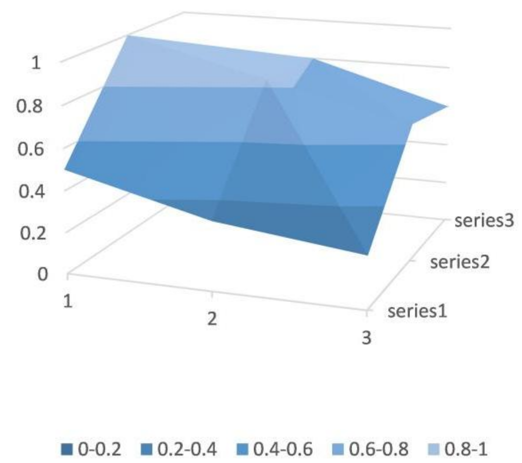
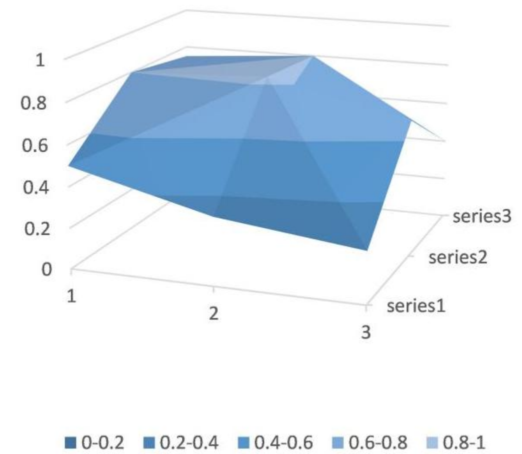


Figure A1. *P1 PMC surface plot. (Source: posted by the author)*



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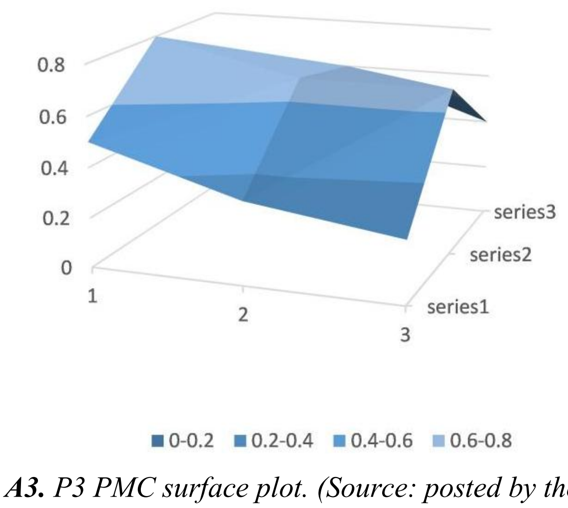

Figure A3. *P3 PMC surface plot. (Source: posted by the author)*

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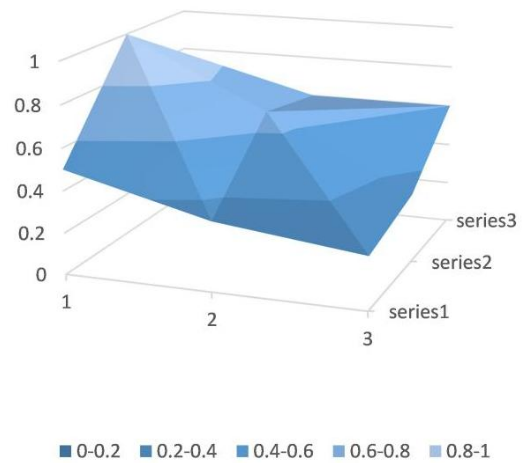

Figure A4. *P4 PMC surface plot. (Source: posted by the author)*

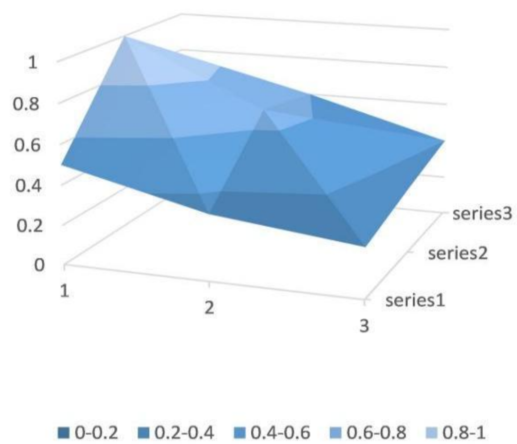

Figure A5. *P5 PMC surface plot. (Source: posted by the author)*

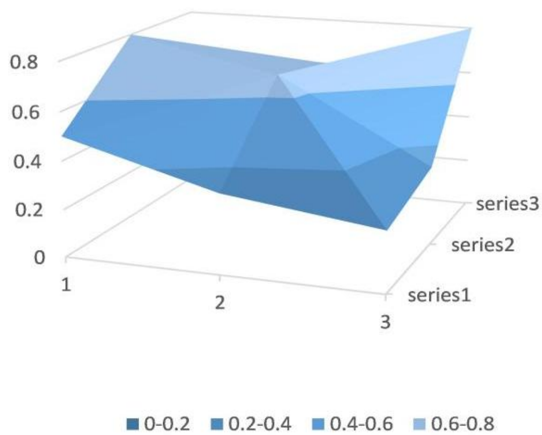

Figure A6. *P6 PMC surface plot. (Source: posted by the author)*

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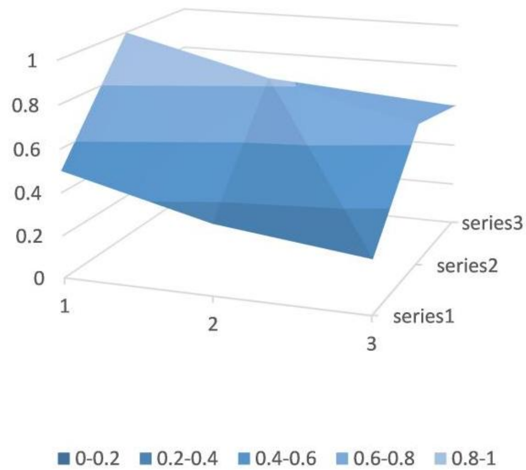

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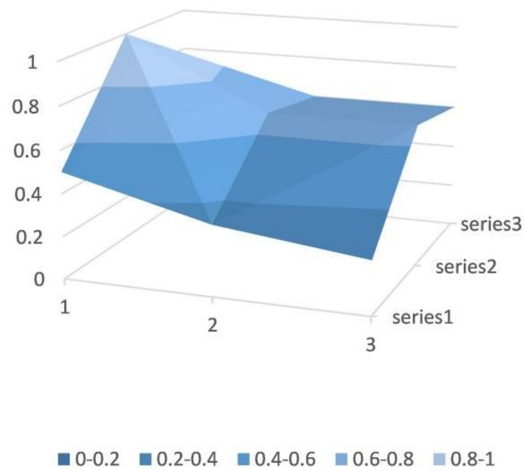

Figure A8. *P8 PMC surface plot. (Source: posted by the author)*

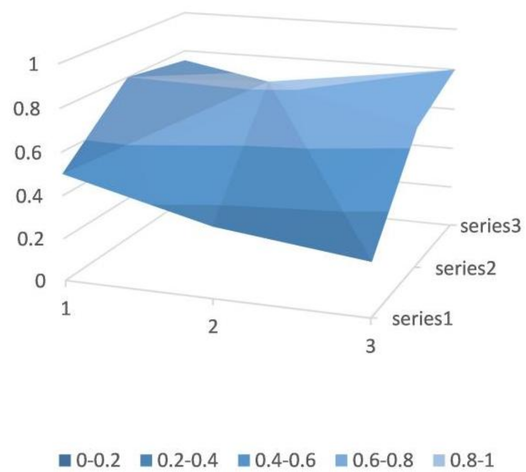

Figure A9. *P9 PMC surface plot. (Source: posted by the author)*

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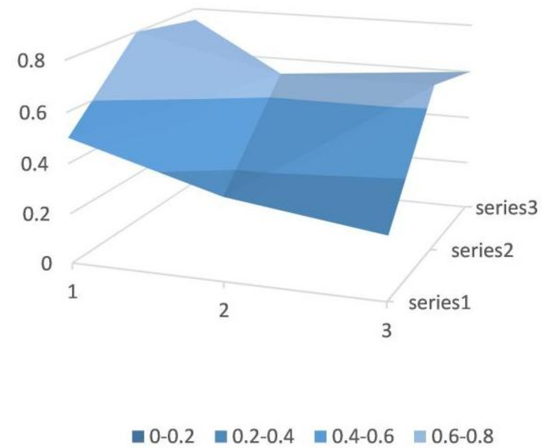

Figure A10. *P10 PMC surface plot. (Source: posted by the author)*

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