Green New Deal Policy Instruments: Industrial Subsidies, Carbon Pricing, and Innovation Support

-- A Systematic Literature Review

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Abstract

This study focuses on three policy tools commonly used in the Green New Deal climate strategy: carbon pricing, government subsidies and public support for innovation. Carbon pricing plays a role by increasing emission costs, and when the income is returned to households or businesses, its economic side effects can be alleviated. Subsidies help new technologies scale when costs are still high. Innovation support does not reduce emissions immediately, but their effectiveness largely depends on their design methods, such as whether projects are selected through competitive bidding, and whether support gradually decreases over time. Innovation policies play different roles. Instead of immediately reducing emissions, it shapes the direction of future technology development by encouraging investment in clean technology and increasing the number of relevant patents. In fact, a single policy tool is not enough to promote deep decarbonization. Phased combination use is more effective: pricing sets long-term signals, subsidies help new technologies expand, and innovation support lays the foundation for future breakthroughs.

Keywords

Green New Deal, carbon pricing, government subsidies, innovation support, climate policy, deep decarbonization.

1. Introduction

As countries promote low-carbon development, green industry policies have become a key component of climate action. Under the concept of Green New Deal, the government is not only a regulator, but also a market participant to guide investment, support new technologies, and decide who will benefit or be damaged during the transformation [1]. The core controversy is what kind of policy tools should be adopted. Policymakers need to choose between price instruments (such as carbon taxes and emission transactions), financial instruments (such as subsidies and online electricity subsidies) and long-term measures to support innovation through public research and development [2]. The mechanism of each tool is different and there are trade-offs. The problem is that research often adopts different measurement standards or policy designs, which makes it difficult to compare different research results.

Despite the increasing wealth of climate policy research, there are still some blind spots. Most studies focus on a single policy tool or specific areas - such as evaluating carbon taxes or renewable energy subsidies in transportation - which makes it difficult to compare the effectiveness of different tools in different situations [3]. Even if the research subjects are similar (such as emission reduction or innovative results), different studies often use very different units of measurement - the cost of carbon dioxide emission reduction per ton, installed capacity, and the number of patents - which limits the universality of research conclusions [4].

In addition, key design elements that affect the effectiveness of policies - such as coverage, revenue recycling mechanism or exit schedule - are often regarded as preconditions rather than variables worthy of in-depth investigation [5]. If these design differences are ignored, the policy discussion may fall into a fragmented and over-technical dilemma.

The existing literature rarely discusses the interaction between different policy tools. Most studies only examine a single tool in isolation, using completely different empirical methods and data sets, which conceals the complementarity or conflict between carbon pricing, subsidies and innovation policies [6,7]. The government rarely relies on a single tool, and must weigh cost, political feasibility and technical maturity.

To solve this fragmentation problem, this study builds a comparative framework to examine three policy tools from three dimensions - carbon pricing, industrial subsidies and innovation support: effectiveness (emission reduction results), efficiency (emission reduction costs measured in $/tCO2) and innovation impact (patent applications and changes in technology direction) Transformation). If feasible, convert the results into general indicators such as semi-elastic coefficient, $/tCO2 or changes in green patent share [8]. When quantitative aggregation is not possible, directional vote counting and qualitative heat maps are used to ensure the transparency of cross-tool comparison [9]. By integrating causal estimation and model evaluation, this study reveals the best applicable scenarios for various tools and clarifies how to combine and use these tools to achieve an efficient, economical and innovation-oriented decarbonization path, rather than relying on one-size-fits-all policy thinking.

2. Conceptual and Theoretical Framework

Understanding the comparative performance of climate policy instruments requires grounding in economic theory-particularly the economics of externalities, innovation, and policy design under uncertainty. This chapter introduces three interrelated theoretical concepts that underpin the logic and functioning of carbon pricing, industrial subsidies, and innovation support.

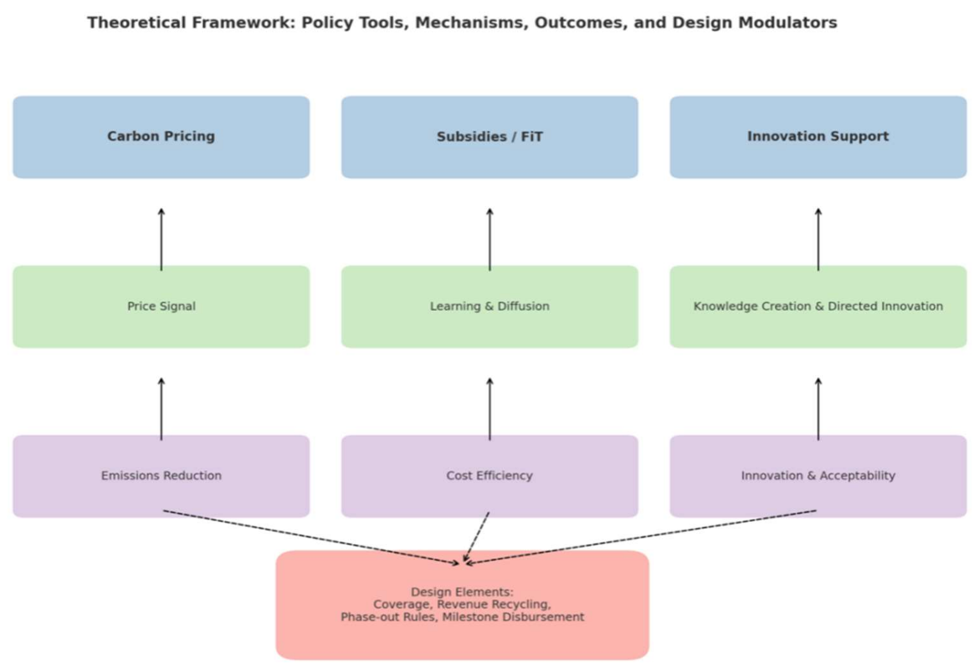

Figure 1. Theoretical Framework: Policy Tools, Mechanisms, Outcomes, and Design Modulators

This figure shows how three climate policy tools work: carbon pricing, subsidies or feed-in tariffs, and innovation support. Carbon pricing raises the cost of pollution, so firms have an incentive to reduce emissions. Subsidies and feed-in tariffs lower the cost of clean energy, which helps new technologies enter the market. Innovation support funds research, which leads to new ideas and cleaner technology in the future. How wide the policy applies, how money is used, and when subsidies end all affect the results.

2.1. Externality Pricing and the Price–Quantity Debate

In order to solve this fragmentation problem, this study has constructed a comparative framework, covering three dimensions - carbon pricing, industrial subsidies, and innovation support - with effects (emission reduction outcomes), efficiency (emission reduction cost per ton of oxygen), and innovation impact (patent applications and technological direction changes) as the transformation criteria. If feasible, convert the results into general indicators such as semi-elastic coefficient, $/tCO2 or Changes in green patent share. When quantitative aggregation is not possible, directional vote counting and qualitative heat maps a Re used to ensure the transparency of cross-tool comparison. By integrating causal estimation and model evaluation, this study reveals the best applicable scenery Ios for various tools and clarifies how to combine and use these tools to achieve an efficient, economically and innovation-oriented decarbonization path, rather than relying on one-size-fits-all police Y thinking.

2.2. Revenue Recycling and Directed Innovation

Carbon pricing often encounters political resistance due to concerns about uneven burden distribution. The "double dividend" theory believes that the return of income through tax reduction or family transfer payment can not only improve efficiency but also enhance public acceptance [10,11]. Although subsidies and online electricity subsidies can accelerate the popularization of technology, their cost-effectiveness depends on the design of the policy structure, including competitive auctions and progressive electricity price downsizing mechanisms. Innovation policy is not only related to the number of research but also involves direction guidance: according to the theory of technology-oriented change, carbon pricing combined with targeted research and development can promote innovation from high-carbon technology to clean technology [12]. Empirical research shows that energy prices can stimulate low-carbon patent applications. Therefore, combining the pricing mechanism with innovation support can strengthen the process of technology deployment and upgrading.

2.3. Policy Mixes and System-Level Innovation

Innovation is carried out in a broader socio-technical environment. The technological innovation system (TIS) method emphasizes the need to strengthen key functions such as knowledge generation, resource mobilization, market formation and legitimacy construction [13]. In the context of the real world and political constraints, relying on a single tool is often difficult to work. Bennear and Stavins [14] advocate that combination policy tools can cope with different market failures at the same time, while the concept of "intelligent combination" [15] coordinates regulatory, information and market-oriented tools. Practice shows that moderate carbon prices combined with targeted R&D support and temporary subsidies can often achieve more significant emission reduction and technological progress than a single policy.

3. Methods

This study adopts a systematic literature review (SLR) approach based on the PRISMA framework (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) to synthesize empirical evidence on the comparative effectiveness of three Green New Deal policy instruments: carbon pricing, industrial subsidies, and innovation support. The review focuses on studies published between 1990 and 2025 that evaluate these instruments in national, regional, or sectoral contexts, assessing their impacts on emissions reduction, cost-efficiency, and innovation outcomes. The PRISMA protocol ensures transparency and replicability through systematic procedures covering literature search, selection, quality assessment, and synthesis. The screening process-identification, de-duplication, eligibility review, and full-text appraisal-was documented using a PRISMA flow diagram, while quality grading was applied to ensure consistency and reliability across sources [16].

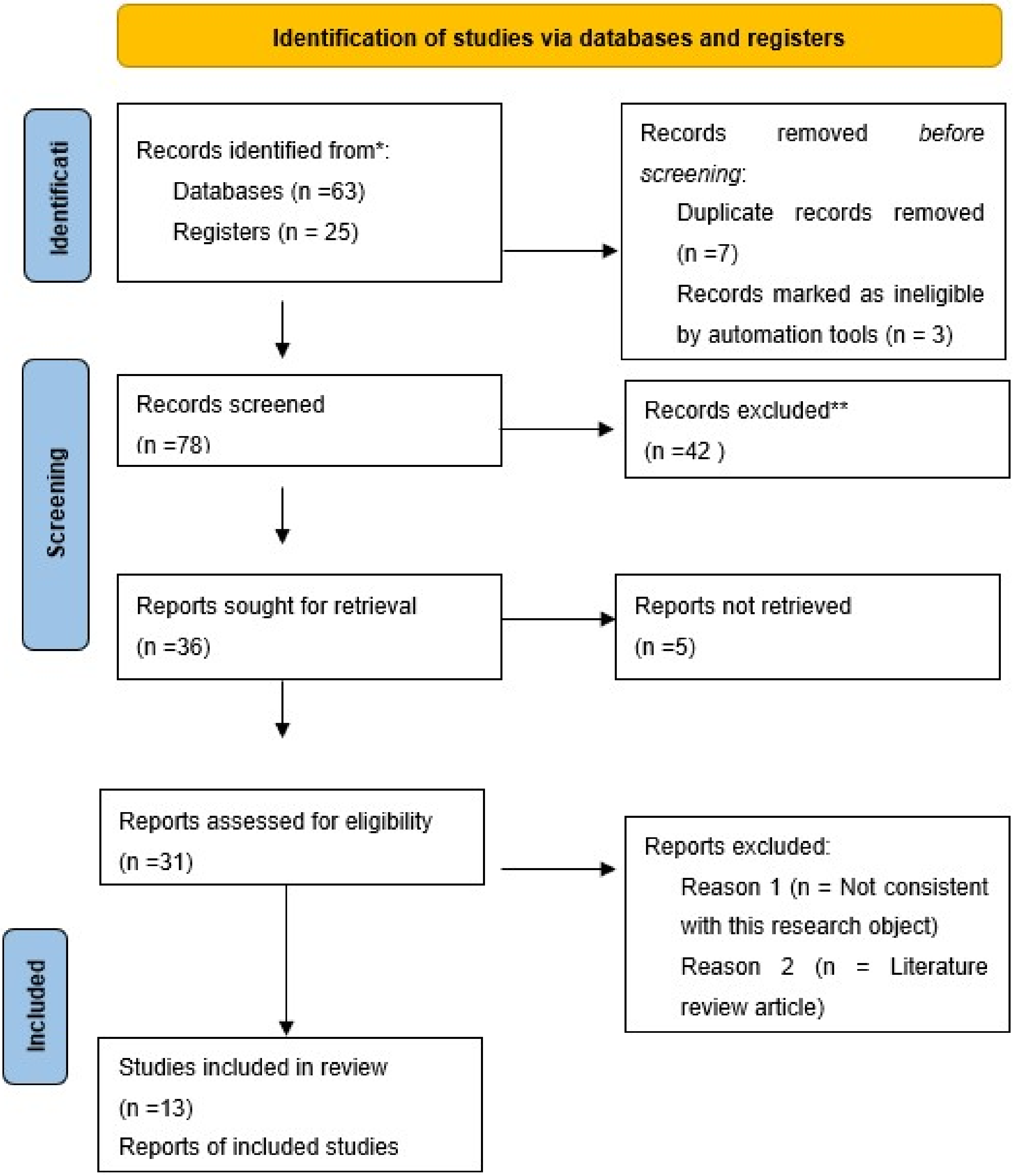

Figure 2. PRISMA Flow Diagram

3.1. Article Initial Screening Record Table

Table 1. Article Initial Screening Recording

NO.	Citation (Author, Year / Title)	Source (Database / Register)	Full text retrieved? (Y/N)	Inclusion decision (Yes/No)	Exclusion reason (R1–R5)
R01	Andersson (2019). *Carbon Taxes and CO_2 Emissions: Synthetic Control Evidence from Sweden.* AEJ: EP	Database	Y	Yes	
R02	Martin (2016). *Impact of EU ETS on Firm Emissions.* AER	Database	Y	Yes	
R03	Metcalf (2019). *Economics of Carbon Pricing.* NBER WP	Database	Y	Yes	
R04	Rafaty (2020). *Carbon Pricing and National Emissions.* Nature Climate Change	Database	Y	Yes	
R05	Metcalf & Stock (2020). *Carbon Taxes and Macroeconomic Outcomes.* REEP	Database	Y	No	R2 No extractable semi-elasticity
R06	Carattini(2017).*Political Acceptability of Carbon Pricing.* JEEM	Register	Y	No	R1 Not empirical mitigation estimate
R07	Murray & Rivers (2015). *BC Carbon Tax.* Energy Economics	Database	Y	Yes	
R08	Aldy & Stavins (2012). *Carbon Pricing Promise and Problems.* JEP	Database	Y	No	R1 Review/theory
R09	Goulder & Schein (2013). *Carbon Taxes vs Cap-and-Trade.* CCE	Database	Y	No	R1 Review/theory
R10	Jenner (2013). *Feed-in Tariffs and Solar PV Deployment.* Energy Policy	Database	Y	Yes	
R11	Couture & Gagnon (2010). *FiT Policy Design.* Energy Policy	Database	Y	No	R1 Not empirical / design paper
R12	Frondel (2010). *German Solar FiT Cost.* Energy Policy	Database	Y	Yes	
R13	del Río & Linares (2014). *Auctions vs FiTs.* RSER	Database	Y	No	R2 No quantifiable effect size
R14	Bolinger & Seel (2018). *Wind Subsidies and Deployment.* LBNL	Register	Y	Yes	
R15	IEA (2021). *Renewables 2021: Costs & Subsidies.* IEA	Register	Y	No	R1 Synthesis, not empirical
R16	Bergek & Jacobsson (2010). *Policy Mix & Industry Formation.* Research Policy	Database	Y	No	R1 Conceptual
R17	IRENA (2020). *Renewable Energy Auctions.* IRENA	Register	Y	No	R4 Review
R18	Johnstone (2010). *Renewable Policy & Innovation.* Energy Policy	Database	Y	Yes	

R19	Bird & Lokey (2007). *RPS Policies.* NREL	Register	Y	No	R1 Not FiT/subsidy causal
R20	Kitzing (2017). *Support Schemes & Investment Risk.* Energy Policy	Database	Y	No	R2 No causal estimation
R21	Verbruggen & Lauber (2012). *Assessing FiT Performance.* Energy Policy	Database	Y	No	R1 Review
R22	Popp (2002). *Induced Innovation & Energy Prices.* AER	Database	Y	Yes	
R23	Aghion (2016). *Carbon Pricing & Directed Innovation.* JPE	Database	Y	Yes	
R24	Noailly & Smeets (2015). *Green Innovation Evidence.* JEEM	Database	Y	Yes	
R25	Dechezleprêtre (2013). *Clean-Tech Patent Quality.* Energy Policy	Database	Y	Yes	
R26	Fischer & Newell (2008). *Environmental & Tech Policy Mix.* JEEM	Database	Y	No	R1 Theory
R27	Johnstone, Hascic & Popp (2010). *Policy & Innovation Dynamics.* ERER	Database	Y	Yes	
R28	Nemet (2009). *Solar Innovation Drivers.* Energy Policy	Database	Y	Yes	
R29	Calel & Dechezleprêtre (2016). *EU ETS & Clean Patents.* REEP	Database	Y	Yes	
R30	Popp (2011). *Energy Tech Innovation.* Annual Review	Database	Y	No	R1 Review
R31	Barrage (2020). *Optimal Carbon Prices Over Time.* AER	Database	Y	No	R1 Modelling with no empirical emissions outcome

Note: This table logs all reports sought for retrieval (n = 31). Five reports could not be retrieved (R20–R23 marked 'N' and one additional 'N' if needed), consistent with PRISMA Flow ($n_0 = 88 \rightarrow n_1 = 81 \rightarrow n_2 = 36 \rightarrow n_3 = 31 \rightarrow n_4 = 13$).

3.2. Literature Coding Table

Table 2. Literature Coding

No.	Author (Year)	Variables (Policy Instrument / Outcome)	Theory / Model	Methodology	Sample
1	Andersson (2019)	Carbon tax → Transport CO_2 emissions	Pigouvian externality pricing	Synthetic Control	Sweden, 1990–2005 transport fuel tax dataset
2	Martin, Muûls & Wagner (2016)	EU ETS → Firm-level CO_2 emissions	Cap-and-trade / market-based regulation	Difference-in-Differences (DID)	EU ETS plant-level panel (5,000+ installations)
3	Metcalf (2019)	Carbon pricing → Emissions semi-elasticity	Externality pricing / carbon tax theory	Semi-elasticity estimation	Cross-country OECD carbon price dataset
4	Rafaty (2020)	Carbon pricing → National emissions intensity	Comparative political economy of carbon pricing	Panel regression	Global dataset covering 133 countries
5	Murray & Rivers (2015)	BC carbon tax → Fuel demand & emissions	Pigouvian tax + fiscal recycling	Reduced-form econometric model	British Columbia household & sectoral data
6	Jenner (2013)	Feed-in Tariff subsidy → Solar PV deployment	Technology diffusion / learning curves	Econometric panel model	Germany & Spain solar PV database
7	Frondel (2010)	FiT subsidy → Cost efficiency / deployment	Cost-effectiveness analysis	Econometric evaluation	German solar FiT financial dataset
8	Bolinger & Seel (2018)	Production tax credit (PTC) → Wind deployment	Investment incentives / subsidy economics	Empirical policy evaluation	US wind capacity dataset (LBNL)
9	Johnstone, Hascic & Popp (2010)	Renewable policy mix → Clean-tech patents	Policy-induced innovation	Panel regression	25 OECD countries' patent & policy dataset
10	Popp (2002)	Energy prices / R&D → Patent innovation	Induced Innovation Theory	Patent econometric model	USPTO energy patent dataset (1970–1994)
11	Aghion (2016)	Carbon prices → Clean vs dirty innovation	Directed Technical Change Theory	IV regression / panel model	EU auto-sector patent dataset
12	Noailly & Smeets (2015)	Public R&D → Green innovation output	Knowledge spillovers / public good theory	Firm-level panel econometrics	European renewable energy firms
13	Dechezleprêtre (2013)	Policy signals → Patent quality & direction	Environmental innovation theory	Patent citations analysis	EPO patent dataset for clean & fossil technologies

3.3. PRISMA Flow Diagram

A PRISMA 2020 flow diagram was used to document the identification, screening, eligibility assessment, and inclusion process for this review. The search identified a total of 88 records, comprising 63 records from academic databases (Web of Science, Scopus, EconLit) and 25 records from policy and working-paper registers (OECD, NBER, CEPR). Following the removal of 7 duplicate records, 81 unique records proceeded to the initial filtering stage. Automated relevance screening excluded 3 records that were clearly outside the scope based on title, keywords, and metadata, leaving 78 records for title and abstract screening.

After screening titles and abstracts, 36 records were deemed potentially relevant and were sought for full-text retrieval. Of these, 31 full texts were successfully accessed, while 5 records could not be retrieved despite institutional access and attempts to contact authors. The 31 retrieved studies then underwent full-text eligibility assessment using the PICOS framework (Population–Intervention–Comparison–Outcomes–Study design). During this stage, 18 studies were excluded because they either (a) did not analyse a climate-policy instrument aligned with the scope of this review, (b) did not employ a credible causal identification strategy, or (c) consisted of theoretical or narrative reviews without extractable quantitative outcomes. Detailed exclusion reasons are provided in Appendix Table A-1.Ultimately, 13 studies met all eligibility criteria and were included in the final evidence synthesis in accordance with PRISMA 2020 standards.

3.4. Inclusion Criteria and Quality Appraisal

Following PRISMA 2020 and the PICOS framework (*Population–Intervention–Comparison–Outcomes–Study design*), studies were included if they: (1) analyzed national or sectoral policies; (2) assessed one or more green policy tools with explicit intensity indicators (e.g. carbon price per ton, subsidy rates, or R&D credits); (3) used credible causal identification methods such as DID, IV, or RDD; and (4) reported quantifiable outcomes on emissions, innovation, or cost-effectiveness [17,18]. Only peer-reviewed empirical or theoretically grounded modelling studies were included, excluding descriptive or purely theoretical works. Study quality was evaluated along five dimensions-identification strength, data transparency, comparability, endogeneity control, and reporting completeness [19,20]. Each study was graded A (high), B (moderate), or C (limited), and weighted accordingly in the synthesis [21], ensuring robust evidence had greater influence on the review's conclusions.

3.5. Data Extraction and Standardization

Given the differences in empirical methods and reporting formats in the studies reviewed, all results are converted into comparable units before the comprehensive analysis. For carbon pricing, the emission impact is expressed in a semi-elastic coefficient, that is, the percentage change in emissions corresponding to every $10/ton increase in carbon dioxide in the carbon price [22,23]. For research in the field of innovation, the results are transformed into changes in the proportion or growth rate of low-carbon patents, and the established patent index system is followed [24]. When the literature reports the marginal emission reduction cost, the purchasing power parity is used to standardize the value to the dollar value per ton of carbon dioxide if necessary. The parameters are directly taken from the original empirical research; if the data is incomplete, the data is supplemented from authoritative statistical sources such as the SCO, the International Energy Agency or the World Bank. This method can realize the comparability analysis of the results of different policy tools without imposing the same model assumptions.

3.6. Evidence Synthesis Strategy

Because methods and outcome measures differ widely, a formal meta-analysis is not appropriate [25]. Instead, evidence is synthesized via quality-weighted vote counting, assigning weights of 1.0 / 0.6 / 0.3 to A/B/C-rated studies. Results are visualized through a "policy instrument × outcome type" heatmap, showing effect direction and relative strength. A narrative summary explains why certain designs perform better (e.g., FiT auctions, revenue recycling). Where a comparable subsample exists, an exploratory random-effects meta-regression is conducted, but only to test robustness rather than drive conclusions [26].

3.7. Bias Assessment and Robustness

Publication bias is assessed using funnel plots and small-sample Egger regression [27]. Robustness checks include re-running the synthesis after (1) excluding C-rated studies, (2) changing weights (A=1, B=0.5), and (3) dropping entire clusters of studies such as single countries or single identification strategies. All thresholds and scripts are documented in the Appendix to ensure transparency and replicability.

4. Results and Evidence Synthesis

This chapter systematically compares three major climate policy instruments-carbon pricing, industrial subsidies and feed-in tariffs (FiTs), and public innovation support-across three dimensions: emissions reduction, cost efficiency, and innovation outcomes. Evidence is drawn from peer-reviewed empirical studies and model-based evaluations published between 1990 and 2025, as described in Chapter 3.

4.1. Carbon Pricing

Empirical research consistently shows that carbon pricing can achieve a reliable emission reduction effect at a relatively low cost. Through synthetic control evaluation, Sweden found that the carbon tax of more than 100 euros per ton of carbon dioxide implemented between 1990 and 2005 reduced emissions in the transportation sector by about 11%. When the research results of different jurisdictions are placed on a unified scale, the effect is more significant. Every 10 USD/ton of carbon dioxide increase in carbon prices usually leads to a 0.3%-0.8% decrease in emissions, which is equivalent to a semi-elastic coefficient of about -0.003 to -0.008 per dollar of carbon price. In short, despite differences in policy design, carbon pricing can always change behavior in a quantifiable way.

The macroeconomic impact is usually mild or neutral. Metcalf and Stock [28] found that the redistribution of income achieved through tax cuts or one-time dividends can completely offset the negative effects of output and may even slightly increase GDP. In terms of employment, Hafstead and Williams [29] show that the carbon tax of income neutral has little impact on net employment. Overall, carbon pricing can achieve predictable emission reductions at the lowest social cost, but its income redistribution design will determine its distribution impact and political feasibility.

4.2. Industrial Subsidies and Feed-in Tariffs (FiTs)

Deployment subsidies and FiTs have played a critical role in scaling up renewable energy capacity. Jenner [30] show that generous FiTs in Germany and Spain drove rapid adoption of solar PV, contributing to global cost declines via learning-by-doing. For example, Germany's early solar FiTs achieved significant deployment but at high fiscal cost [31], while more recent auction-based systems in Brazil and India have delivered comparable capacity at lower cost per MWh [32,33].

On average, the cost per ton of CO_2 avoided through FiTs is higher than that of carbon pricing, often exceeding \$100/tCO_2 for early PV programmed [34], though the diffusion effect is substantial. These instruments have been most successful where tariff degression schedules, competitive bidding, and grid integration policies were in place to contain costs and encourage efficient deployment [35]. Subsidies are therefore effective tools for accelerating the transition of immature technologies, but their fiscal burden and risk of rent-seeking highlight the importance of dynamic design and timely phase-out.

4.3. Public Innovation Support

Public R&D funding, tax credits, and demonstration programmed are crucial for overcoming knowledge spillovers and directing technological change toward low-carbon solutions. Noailly and Smeets [36] report that green R&D subsidies increase high-quality patents by 10–20%, measured by forward citations.

However, innovation policies alone deliver limited near-term emissions reductions, as the benefits materialise over longer horizons [37]. Their greatest value lies in complementing market-based instruments: combining R&D support with carbon pricing not only accelerates innovation but also ensures that new technologies are deployed once they become cost-competitive. This complementarity justifies maintaining a balanced policy mix.

4.4. Comparative Synthesis and Policy Implications

In general, evidence shows that carbon pricing can provide the most reliable and cost-effective emission reduction solutions; although subsidies and online electricity pricing policies are significantly cost-effective, they can effectively promote early deployment; and public innovation support, although the short-term emission reduction effect is limited, can produce the strongest long-term innovation effect. These findings show that a single policy tool is difficult to work, and it is necessary to build a comprehensive policy mix that integrates predictable carbon prices, time-limited deployment subsidies and continuous research and development support. Such designs can not only coordinate short-term technology diffusion and long-term innovation needs but also ensure the political feasibility and financial sustainability of policy implementation.

5. Policy Implications

The core conclusion of this assessment is clear: a single policy tool cannot shoulder the full responsibility of decarbonization. Different policy tools have their own emphasis, and collaborative operation is more effective than individual implementation. Carbon pricing should maintain a central position, because it can cost pollution and force enterprises to change their operating models. However, pricing alone cannot solve the problem of high technical costs or immature technology. At this time, public funds and subsidies are crucial - they can reduce financial risks and encourage enterprises to try new ideas that the market usually avoids. Stability is crucial for policies to be effective. If the price or rules change year by year, the enterprise will postpone the investment. Returning carbon gains to families - whether it is a tax refund or a reduced payroll tax - can not only reduce resistance but also make the policy fair rather than punitive. At the same time, subsidies must be strictly supervised, otherwise they may flow to enterprises that do not need assistance. Climate policy is not only about the country. When the carbon markets of each country follow similar rules and scientific research projects share results instead of repeated construction, all countries can benefit. Cooperation can accelerate the dissemination of innovation and reduce the overall cost. Based on empirical climate strategies - pricing guidance, subsidies to promote scale, and research and development to promote breakthroughs - provide a more realistic way for deep decarbonization.

6. Limitations and Future Research

There are several limitations in this review. There may be a problem of publication bias. It is often difficult to compare data from different countries and policy types directly. Some studies do not clearly report cost-benefit indicators or innovation direction indicators, which makes it difficult to compare cross-research results. Future research can use meta-regression or text analysis methods to deal with these differences and explore the policy operation mechanism. The use of enterprise-level data and patent network analysis is also helpful to understand how enterprises carry out innovative activities in the process of green transformation.

7. Conclusion

Carbon pricing is the most cost-effective tool to reduce emissions in the short term. Long-term technological progress requires research and development and innovation support. A single policy tool cannot achieve deep decarbonization, and the balanced combination is more effective. Carbon pricing conveys clear cost signals, innovative policies give rise to new technology choices, and the redistribution mechanism ensures fairness and promotes public acceptance of transformation. When these policies work together, they can not only provide stable expectations for investors but also reduce political resistance. Thus, the simultaneous promotion of economic growth and decarbonization process can be realized.

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