GREEN INDUSTRY POLICY: WHERE FROM, WHERE TO?

Wilson Peres

João Carlos Ferraz

Julia Torracca

Tatiana Fleming

Carolina Dias

DECARBONIZATION AND INDUSTRIAL POLICY: CHALLENGES FOR BRAZIL

About the Project DIP-BR

"Decarbonization and Industrial Policy: Challenges for Brazil" (DIP-BR) is a policy-oriented research-action project aimed at influencing public debate on industrial, innovation, and trade policies in Brazil and selected Latin American countries that promote decarbonization and energy transition in the region. The initiative seeks to inform and induce efficacy, efficiency, effectiveness, and innovativeness in policy design and implementation. The methodology encompasses critical benchmarking analyses of past and present policy experiences from an international comparative perspective, regional trade studies, and economic analyses of productive sectors and chains, combining structural analysis of traditional production, employment, and trade statistics and simulation models of sectoral impacts using input-output approach.

Funded by the Open Society Foundations (OSF), Project DIP-BR is executed by the Research Group of Industry and Competitiveness at the Institute of Economics, Federal University of Rio de Janeiro (GIC/IE-UFRJ, **https://www.ie.ufrj.br/gic**) and is currently managed through José Bonifácio University Foundation (**https://www.fujb.ufrj.br/**).

Project DIP-BR Team

Head Investigator
Carlos Frederico Leão Rocha,
Professor at IE-UFRJ

Research Team
João Carlos Ferraz,
Professor at IE-UFRJ

Marta Castilho,
Professor at IE-UFRJ

Fabio Freitas,
Professor at IE-UFRJ

Kaio Vital,
Professor at IE-UFRJ

Julia Torracca,
Professor at IE-UFRJ

Wilson Peres,
Research Fellow at
GIC/IE-UFRJ

Research Assistants
Bruna Ribeiro,
Ph.D. student at IE-UFRJ

Gabriel Pessanha,
Ph.D. student at IE-UFRJ

Tatiana Fleming,
Ph.D. student at IE-UFRJ

Nilo Bezerra Neto,
Undergraduate student
at IE-UFRJ

Project Manager
Carolina Dias,
Ph.D. student at ECO-UFRJ

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Wilson Peres[a]

João Carlos Ferraz[b]

Julia Torracca[c]

Tatiana Fleming[d]

Carolina Dias[e]

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[a] Associated research fellow at the Research Group on Industry and Competitiveness, Federal University of Rio de Janeiro (GIC/IE-UFRJ). Santiago, Chile. ORCID: http://orcid.org/0009-0006-5279-8730. E-mail address: wilsonpn@me.com.

[b] Professor at the Institute of Economics, Federal University of Rio de Janeiro (IE-UFRJ), and researcher at the Research Group on Industry and Competitiveness (GIC/IE-UFRJ). Rio de Janeiro, Brazil. ORCID: http://orcid.org/0000-0001-5980-2591. E-mail address: jcferraz@ie.ufrj.br.

[c] Professor at the Institute of Economics, Federal University of Rio de Janeiro (IE-UFRJ), and researcher at the Research Group on Industry and Competitiveness (GIC/IE-UFRJ). Rio de Janeiro, Brazil. ORCID: https://orcid.org/0000-0002-0958-858X. E-mail address: julia.torracca@ie.ufrj.br.

[d] Ph.D. student at the Institute of Economics, Federal University of Rio de Janeiro (IE-UFRJ), and research assistant at the Research Group on Industry and Competitiveness (GIC/IE-UFRJ). Rio de Janeiro, Brazil. ORCID: https://orcid.org/0000-0003-0861-806X. E-mail address: tvasconcelosflem@worldbank.org.

[e] Ph.D. student at the Post-Graduate Program in Information Science, Federal University of Rio de Janeiro (PPGCI/IBICT-UFRJ), and research project manager at Research Group on Industry and Competitiveness (GIC/IE-UFRJ). ORCID: https://orcid.org/0000-0002-0478-8777. E-mail address: diascarolina@ie.ufrj.br.

GREEN INDUSTRY POLICY: WHERE FROM, WHERE TO?

ABSTRACT

Systematic knowledge about how the literature has dealt with the different dimensions of sustainability-bound industrial policies is still limited. The purpose of this article is to investigate the nature of this body of literature to suggest a frame of reference for further research on climate policy experiments. For that, a quantitative bibliometric analysis is combined with a narrative literature review. The quantitative study covers co-citation and keyword co-occurrence patterns from 1,660 articles published in Scopus and Web of Science from 1976 to 2023. The qualitative in-depth analysis covers 33 top-cited works. The quantitative study indicates three patterns: (1) a discussion about green industrial policies from a broad development perspective, (2) a focus on thematic specialization to investigate the role of industry and the State, and (3) contributions concerned with sustainable industrial development in a specific national context (mainly China). The qualitative analysis reveals a consensus on the importance of proactive State interventions. The most cited and discussed instruments are of a regulatory nature (carbon pricing) and tax incentives, but with strong differences in the breadth and scope of State intervention. The article concludes that effective decarbonization industrial policies demand concerted State capabilities strictly and pertinently aligned to the peculiar features of different sustainability challenges.

KEYWORDS

Green industrial policy. Sustainability. Decarbonization. Bibliometric analysis.

POLÍTICA INDUSTRIAL VERDE: DE ONDE E PARA ONDE?

RESUMO

O conhecimento sistemático sobre como a literatura tem lidado com as diferentes dimensões das políticas industriais vinculadas à sustentabilidade ainda é limitado. O objetivo deste artigo é investigar a natureza desse corpo de literatura a fim de sugerir um quadro de referência para futuras pesquisas. Para tanto, combina-se uma análise bibliométrica quantitativa com uma revisão narrativa da literatura. O estudo quantitativo abrange padrões de cocitação e co-ocorrência de palavras-chave de 1.660 artigos publicados na Scopus e Web of Science de 1976 a 2023. A análise qualitativa aprofundada abrange 33 trabalhos bem citados. O estudo quantitativo indica três possíveis padrões: (1) discussão sobre políticas industriais verdes a partir de uma perspectiva ampla de desenvolvimento, (2) foco em um tema específico para investigar o papel da indústria e do Estado e (3) artigos focados no desenvolvimento industrial sustentável em um contexto nacional específico (principalmente a China). A análise qualitativa revela um consenso sobre a importância de intervenções proativas do Estado. Os instrumentos mais citados e discutidos são de natureza regulatória (precificação de carbono) e incentivos fiscais, mas com fortes diferenças na amplitude e fôlego da intervenção estatal. O artigo conclui que as políticas industriais efetivas para a descarbonização exigem capacidades estatais concertadas e pertinentemente alinhadas às características peculiares dos diferentes desafios de sustentabilidade.

PALAVRAS-CHAVE

Política industrial verde. Sustentabilidade. Descarbonização. Análise bibliométrica.

Introduction

The re-emergence of proactive industrial policies in countries around the world, regardless of their political orientation, is a phenomenon not registered for quite a long time. Several impelling factors lie behind it: escalating international competition, the pandemic, harsh geopolitical conflicts, the emergence of disruptive technologies, and the threats from climate change. Political decisions and policy directives are taken up by perceptions and visions of political leaders in view of societal needs, interests, and aspirations that press State actions in multiple directions. Notwithstanding, academic research play a key supporting role to organize conceptual pillars under proper frameworks of reference with a narrative to justify the different modes of State intervention.

Since the late 1970s, a sizeable amount of scholarly work has analyzed the relations between industrial policy and (broadly defined) sustainability associated to State actions; moreover, recent trends indicate we should expect a high rate of growth of that literature in the years to **come**[1]. Research on green industrial policy is particularly concerned with the different roles the State may have to play in dealing with a broader development perspective (e.g., the environment), a specific theme (such as climate change), a subject of concern (energy transition), and/or a locational specification (the challenges of an urban milieu)

However, many open questions still need to be answered concerning how the specialized literature has dealt with the different dimensions of a sustainability-bound industrial policy. Do the questions posed, the analytical frameworks, the objects of analysis, and the nature of policy instruments examined converge or diverge in the literature? Are there any "empty policy spaces" left in the "green" industrial policy research? Do the related policy suggestions converge or diverge from one another? In a historical moment when countries try to position themselves in face of climate and energy challenges by means of explicit industrial policies, the higher the convergence of concepts, modes of intervention, and instruments, the more apparent the horizon for the emergence of consensual and sound propositions of policy designs. And vice versa.

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[1] See, for example, Criscuolo and Lalanne (2024), Furceri, Ganslmeier, and Ostry (2023), Harris (2023), Juhász and Lane (2024), Karltorp and Maltais (2024), Kastelli, Mamica, and Lee (2023), Lebdioui (2024), Lewis (2024), Rodrik and Stiglitz (2024), Schen, Ayele, and Worako (2023); Stern and Stiglitz (2023), Veugelers et al. (2024), Wang and Wang (2024).

To address some of these issues, the present study examines the academic literature published in peer reviewed journals from 1976-2023, combining quantitative bibliometric analyses with a narrative literature review. The purpose is twofold: characterize this body of literature and suggest a framework for the analysis of climate/energy policy experiments, assuming that sustainability-related challenges are specific to economic activities (or sectors), technologies, locations, and moments of time.

Bibliometric analysis encompasses different quantitative techniques, such as co-citation and co-occurrence analyses (Zupic; Cater, 2015) that examine bibliographic elements contained in documents such as authorship, title, keywords, journal, publication year, and citations. This approach serves varied purposes, including discerning patterns and trends in scientific output (Young, 1983), understanding knowledge dynamics and research development (Osareh, 1996) and thus supporting research evaluation and informing policy design.

Exercises of this nature have been done before. For example, Tamasiga et al. (2023) identified key themes and research gaps through a bibliometric approach, providing insights into how publications on green industrialization in developing countries have progressed. The present study attempts to add to this literature by examining the concepts and analytical framework underpinning industrial policy in a context of low-carbon emission initiatives.

This paper is structured as follows. After this introduction, Section 1 presents the bibliometric study that investigates the scope and structure of the academic literature on green industrial policy. Section 2 conducts an in-depth analysis of top-cited papers using narrative literature review. Section 3 synthetizes the essential themes addressed by green industrial policies according to the reviewed literature and brings the concluding remarks. The appendix describes the database and the methodological procedures employed in the study.

1. What is what and who is who in the green industrial policy literature

What is what and who is who in the academic literature on "green" industrial policy? These are the basic research questions driving the exercise presented in this section. To address them, a bibliometric study has been conducted of the academic literature on green industrial policy published in Scopus and Web of Science (WoS). The purpose is to investigate and describe the key features of such body of literature.

For that, the following successive steps were implemented: setting-up the bibliometric database, characterizing the body of literature by identifying clusters of most recurring keywords and top-cited authors, and defining a sample of top-cited papers for a qualitative, narrative review. A complete description of the methodological procedures is provided in the Appendix.
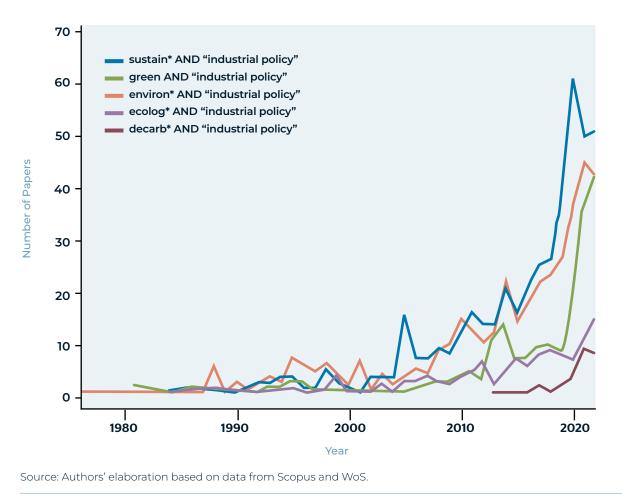
1.1. Setting up the database

The expression "green industrial policy" has gained traction in the specialized literature and policy documents issued by governments and national and international organizations, to shelter different approaches and policy stands. In that, many words can be used in addition to "green" to refer to sustainability-bound industrial policies, such as sustainable, ecological, environmental, decarbonization (or decarbonisation), and so forth. Giving that, this study chose four root words in addition to "green" to be combined with "industrial policy" to capture the phenomena of interest: sustain*, ecolog*, decarb*, and environ*. Hence, the empirical strategy to screen the literature published in Scopus and WoS searched for publications (papers, reviews, book chapters) that feature the expression "industrial policy" combined with each term (green, sustain*, ecolog*, environ*, or decarb*) in their title, keywords, or **abstract** [2].

After merging the search results from each database, processing them, and removing duplicates, a body of 1,660 documents was included for analysis. **Figure 1** shows the number of documents featuring each combination of terms. The combination of "industrial

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[2] See the complete methodological procedures in the Appendix.

policy" with sustain* has yielded the most articles per year since 2011, but the combination with environ* appears the earliest in the literature and has grown consistently over the years. The oldest results come from the combination with environ*, dating back to 1976. The first document featuring "industrial policy" and ecolog* appeared in 1984, whereas green and industrial policy combined did not appear until 1993 but experienced exponential increase after 2014, coinciding with the publication of Rodrik's (2014) paper. Works referring to decarb* and industrial policy are the most recent but peaked in 2021 and continued to grow thereafter.

Figure 1 – Documents featuring "industrial policy" combined with each root word, 1976–2023

Source: Authors' elaboration based on data from Scopus and WoS.

Since more than one combination of terms can appear in each included document, the degree of overlapping offers additional data to understand the convergence between the areas of study concerning industrial policy associated with sustainability issues.

Figure 2 shows the results for such an analysis. More than two thirds (76.96%) of the included documents contained only one combination of terms, with "industrial policy" combined with sustain* taking the lead (32.55% of the total database), follow by environ* (23.45%). As much as 9.83% of the included documents mentioned green combined with "industrial policy." The least recurring combination is with decarb*, present in 2.29% of the included documents. One can see that the more generic the term combined with "industrial policy," the larger is the number of documents retrieved in the database. Sustainability is a large umbrella concept that encompasses the environmental dimension and other adjacent aspects such as the social ones, which can influence and are influenced by environmental issues.
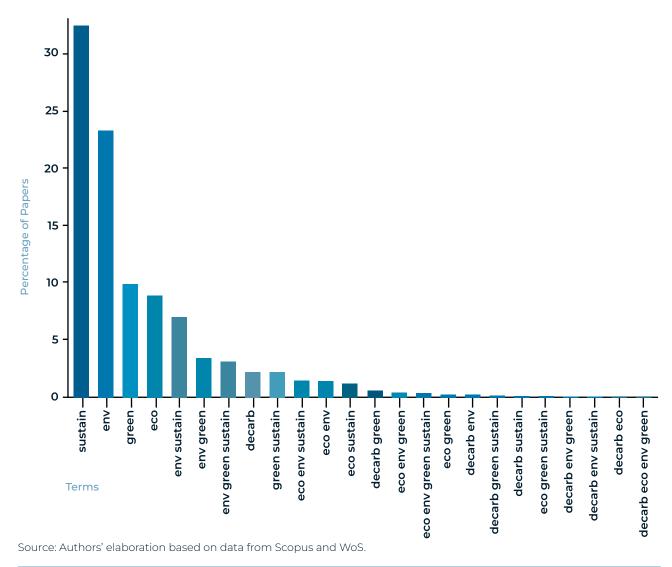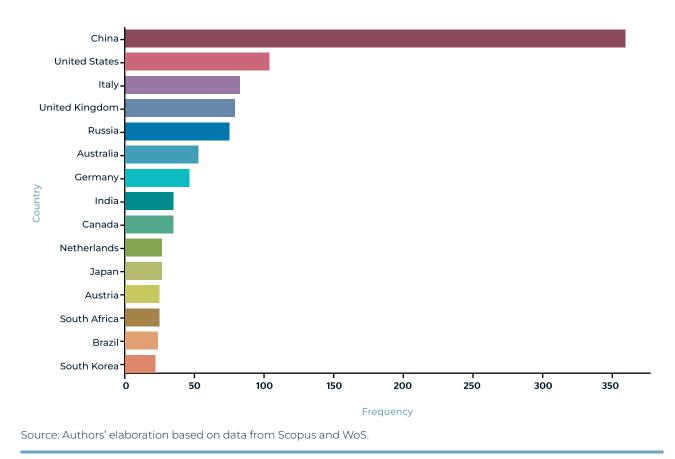
Figure 2 – Results featuring each and all terms combined with "industrial policy", 1976-2023

Source: Authors' elaboration based on data from Scopus and WoS.

The bibliometric analysis also aimed at determining the countries contributing to the literature. For that, descriptive metadata on main authors' affiliation (country-wise) were analyzed for the whole set of documents included in the literature review. As shown in **Figure 3**, China is the most prolific country in this literature, having published the highest number of documents (n=361), followed by the United States (n=105), Italy (n=83), and the United Kingdom (n=80). It is noteworthy that while Latin American countries do not often appear at the top of the traditional citation rankings, Brazil ranks the highest in the examined literature (n=24), followed by Mexico (n=12) and Chile (n=5).

Figure 3 – Top 15 countries contributing to the "green" industrial policy literature

Source: Authors' elaboration based on data from Scopus and WoS.
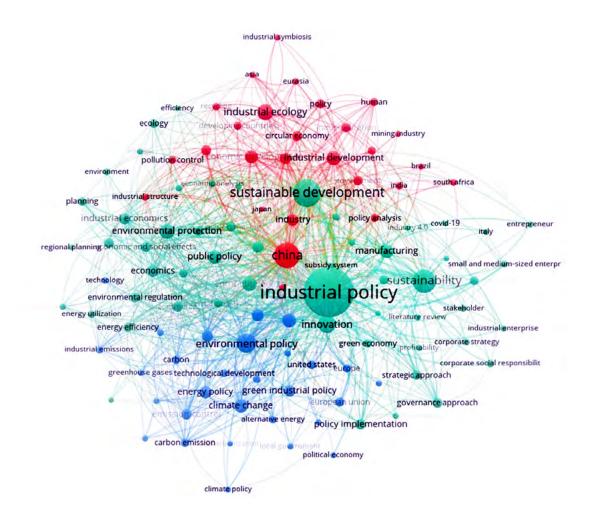
1.2. Cluster analysis: keywords and authors

After setting up the database, a bibliometric analysis combining co-citation and co-occurrence analyses was conducted to identify the most prolific authors and examine the most recurring keywords to understand how key concepts are organized and connected. While co-occurrence analysis identifies the frequency of specific terms appearing together in

scholarly documents, co-citation analysis examines references that are frequently cited together and reference a third work (Boyack; Klavans, 2010). The latter reveals relationships and networks of influence among works and authors (Osareh, 1996), while the former identifies patterns and relationships in papers' subjects and concepts. The methods have been chosen due to their ability to provide complementary insights into the structure, patters, and evolution of the "green" industrial policy literature.

The co-occurrence analysis considered the keywords extracted from the whole set of documents included in the database to identify the most frequently ones appearing together. The analysis revealed a network with three clusters, which are depicted in **Figure 4**. They were build retaining only the strongest couplings between pairs of keywords, meaning those that frequently appear together in various documents (Boyack; Klavans, 2010). The Appendix describes the technique in detail, including the clustering algorithm employed.

Figure 4 - Clusters of strongest keywords, 1976–2023

Source: Authors' elaboration based on data from Scopus and WoS.

In the green cluster, the strongest centroid corresponds to the keyword "industrial policy." A common feature in this cluster is the exploration of specific industrial policies and development strategies that promote economic, environmental, and social sustainability from an industrial perspective. In addition to "sustainable development," this group also includes terms such as "innovation," "competitiveness," and "manufacturing." The red cluster has "China" as a prominent keyword. This group of papers focuses more on "industrial development," "industrial ecology," and "economic development," specially on the Chinese context. Overall, this cluster suggests a more detailed analysis of innovation and economic development policies in China, with an emphasis on environmental sustainability. The blue cluster revolves around topics such as "environmental policies," "climate change," and "green industrial policy," with a particular emphasis on the European Union (EU). Unlike the green and red clusters, more broadly focused on industrial policies, innovation, and economic development, the blue cluster is more concerned with environmental and energy issues, highlighting the EU as a significant setting for climate mitigation efforts.

It is noteworthy that the type and relevance of the keywords contained in the literature addressing "green industrial policy" have changed over the years. Between the 1990s and the 2010s, "industrial policy" was the most prominent term, followed by "sustainable development" and "environmental protection." However, since 2020, "industrial policy" has become increasingly linked with "sustainability" and "manufacturing," while "China" has emerged as a central theme, forming its own distinct cluster due to its significant influence. This result suggests an important analytical movement: the merging of industrial policy – a term typical associated with the improvement of productive activities – and sustainability – a term that embraces not only the "green" aspect but also other economic dimensions such as the social one.

The next bibliometric exercise was a co-citation analysis to search for connections among cited authors. Co-citation patterns within the comprehensive dataset reveal which papers are most strongly connected to one another, both within their respective clusters and across the entire database. It is worth noting that some authors have more than one document in the database, which impacts their position and strength within the co-citation network. As a result, five clusters and one outlier have been identified **(Figure 5 and Table 1).**
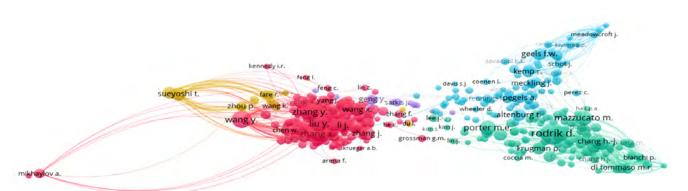
Figure 5 - Clusters of authors with strong co-citation ties, 1976-2023

Source: Authors' elaboration based on data from Scopus and WoS.

These five clusters provide a comprehensive overview of the key authors and thematic focuses within the field of "green industrial policy." With the highest cumulative link strength, the dominating green cluster features Rodrik (2014) as its central node. Mazzucato (2018) and Krugman (1979) are also notable members, with a broad influence across the literature on economic development. This group primarily consists of economists, sociologists, and experts in economic development, with significant contributions in economic theory, industrial policy, innovation, international trade, globalization, institutional economics, evolutionary economics, and regional development case studies. Following closely is the red cluster is centered around Zhang (2017). This set also includes impactful works by Liu (2010) and Wang (2018). Focused on practical green policies tailored to the Chinese context, authors in this cluster commonly utilize methodological approaches to analyze and assess energy transitions. The third set, the yellow one, although smaller in publication volume, has strong links and features Sueyoshi and Goto (2011) as its centroid. It also includes authors affiliated with Chinese institutions who focus on operational research, production economics, and efficiency analysis, often overlapping in topics related to operations and efficiency within the Chinese setting. The fourth and most robust cluster is the blue one led by Geels (2004). With significant contributions from Kemp and Never (2017) and Meckling *et al.* (2015), this cluster engages in both theoretical and applied discussions on sustainability, energy transitions, environmental policies, and green innovation. Authors in this group are deeply involved in research and debates concerning the future of sustainable industrial practices. Finally, the fifth cluster depicted in purple is the smallest and least interconnected one. Anchored by Côté and Cohen-Rosenthal (1998), this group comprises a diverse array of authors who are specialized in urban studies, environmental management, and sustainability. Due to its varied composition and weaker connections, discerning a clear thematic pattern within this group is challenging.

Table 1 - Top authors within each co-citation cluster, 1976–2023

Author	Citations	Total link strength	Cluster
Rodrik (2014)	364	10852	green
Di Tommaso et al. (2013)	92	6189	green
Mazzucato (2018)	171	5405	green
Andreoni and Chang (2016)	124	4948	green
Tassinari(2019)	67	4487	green
Porter (1991)	165	3913	green
Lin (2012)	95	3654	green
TOTAL: 46 authors			

Author	Citations	Total link strength	Cluster
Zhang (2017)	238	9723	red
Hu, Wand, and Wang (2021)	236	9464	red
Liu (2010)	204	8267	red
Zhang and Cheng (2009)	164	7455	red
Liu et al. (2018)	160	6867	red
Ren et al. (2018)	147	6477	red
Zhou, Zhang, and Li (2013)	139	5368	red
TOTAL: 29 authors			

Author	Citations	Total link strength	Cluster
Sueyoshi and Goto (2011)	143	7951	yellow
Goto, Otsuka, and Sueyoshi (2014)	112	7044	yellow
Färe et al. (1989)	61	2992	yellow
Wang and Wei (2014)	63	2815	yellow
Färe, Grosskopf, and Pasurka (2007)	53	2531	yellow
Wei and Ewing (2018)	33	1566	yellow
Aghion et al. (2015)	31	1230	yellow
TOTAL: 7 authors			

Author	Citations	Total link strength	Cluster
Geels(2004)	114	5006	blue
Kern and Howlett (2009)	76	3579	blue
Kemp Never (2017)	92	3169	blue
Meckling et al. (2015)	79	2712	blue
Lewis (2014)	66	2708	blue
Rogger and Johnstone (2017)	54	2620	blue
Schot and Steinmueller (2018)	53	2517	blue
TOTAL: 38 authors			

Author	Citations	Total link strength	Cluster
Cöté and Cohen-Rosenthal (1998)	29	831	purple
Gibbs and Deutz (2007)	30	716	purple
Chertow (2000)	30	608	purple
TOTAL: 3 authors			

Author	Citations	Total link strength	Cluster
Tarasevich (2006)	39	0	outlier
TOTAL: 1 author			

Source: Authors' elaboration based on data from Scopus and WoS.

Considering that the yellow cluster is well connected to the red one, with both focusing on the Chinese experience, and the purple and grey clusters have less strong connections compared to the others, a more in-depth analysis was conducted of keywords pertaining to the green, blue, and red groups, which discuss development themes (green cluster), issues related to energy transition and sector-specific cases (blue cluster), and Chinese perspectives (red cluster). Examining the relevant keywords of the most prolific groups of authors in the literature provides crucial information for understanding the semantics of papers that primarily deal with "green industrial policy," while giving us some insight into the conceptual basis of such a literature. **Table 2** brings the results of this exercise.

Table 2 - Keywords from the most relevant clusters of the co-cited papers, 1976-2023

Keyword	Citations	Cluster	Keyword	Citations	Cluster	Keyword	Citations	Cluster
Industrial policy	805	green	Environmental policy	140	blue	China	224	red
Sustainable development	262	green	Climate change	74	blue	Industrial ecology	102	red
Sustainable	187	green	Environmental economics	73	blue	Industrial development	81	red
Innovation	120	green	Energy policy	62	blue	Economic development	72	red
Environmental protection	88	green	Economics growth	60	blue	Industry	55	red
Competitiveness	80	green	Green industrial policy	53	blue	Environmental impact	45	red
Manufacturing	76	green	Investment	52	blue	Circular economy	43	red
Public policy	74	green	Emission control	46	blue	Government	40	red
Economics	60	green	European Union	39	blue	Industrialization	40	red
Environmental management	53	green	Carbon emission	36	blue	Policy	40	red

Source: Authors' elaboration based on data from Scopus and WoS.

The green cluster (focused on development) mentions keywords deeply connected to the green keyword cluster (where "industrial policy" is the centroid); papers identified as part of the blue cluster (concerning energy transition and sectoral cases) are associated with keywords closely related to the blue keyword cluster (with "environmental policy" as the central node); and papers from the red cluster (focusing on national issues based on authors from Chinese institutions) are related to keywords that belong to the red keyword group (where "China" is the most significant term).

The range of topics is broad, encompassing areas that may stray from the traditional vocabulary of industrial policy to fields more closely aligned with biology or environmental engineering, for example. This diversity in content is apparent in the mismatch between the topics discussed in the articles and the specializations of the journals or publication venues. Such a phenomenon has been examined by Zhang *et al*. (2019) in green finance papers, who have discovered that most green finance articles are published in policy or environmental journals rather than in those directly related to economics.

In summary, when bringing together the clustering exercises, common patterns emerge: there is a group of articles and authors concerned with relating industrial policy to economic, social, and environmental development issues and incorporating industrial issues such as competitiveness and innovation. A second network is formed by authors coming from a thematic specialization (energy, environment) and industrial policy issues that arise from such specialization. The third strongly interrelated group of articles and authors has a primary concern with sustainable industrial development in a specific national (China) context.

1.3. Selected papers to be analyzed

Building on the results of the co-citation exercise, a set of the 27 most cited papers in the reviewed literature has been selected for a qualitative in-depth analysis. This set has been complemented with six papers by highly influential authors **("influencers")** [3]. The final sample comprised 33 papers covering a time span of almost 30 years (1995-2023). These works were grouped according to their scope and issues addressed: i) specific economics activities (sectors, territories or firms), ii) regulation policy, iii) policy packages, sequence and mixes, and iv) a comprehensive development and sustainability approach **(Table 3)**.

Table 3 – Selected papers: authors and main themes

Categories	Selected papers
Specific economic activities: sectors, territories, firms	Zhang *et al.* (2011), Zhang *et al.* (2013), Pegels and Lütkenhorst (2014)*, Chertow (2007), Gibbs and Deutz (2007), Fang, Côté, and Qin (2007), Yu, Han, and Cui (2014), Sueyoshi and Yuan (2015), and Yao *et al.* (2021)
The role of regulation	Porter and van der Linde (1995)*, Simpson and Bradford (1996), Sovacool *et al.* (2021), Yu and Wang (2021), Yang *et al.* (2017), Hu, Pan, and Huang (2020), Yuan and Zhang (2019), Murphy and Gouldson (2000), and Zhu and Tan (2022).
The policy packages, sequence and mixes	del Río, Carrillo-Hermosilla, and Könnölä (2010), Meckling, Sterner, and Wagner (2017), Steurer (2010), Plevin, Delucchi, and Creutzig (2014), Markard, Raven, and Truffen (2012), Rodrik (2014), Kern, Rogge, and Howlett (2019), and Lamperti *et al.* (2019)*.
A comprehensive development and sustainability approach	Stern (2008)*, Acemoglu *et al.* (2012)*, Farberger (2018), Kemp and Never (2017), Mealy and Teytelboym (2022), Stern and Stiglitz (2023)*, and Wieczorek (2018)

Notes: (*) Papers by "influential" authors.
Source: Authors' elaboration based on data from Scopus and WoS.

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[3] An influential author is not only someone who produces impactful work within the academic community, but also someone whose work reaches out to other disciplines and broader audiences, including other policymakers, business leaders, and society. For different reasons, their work on green industrial policy may not present in the top range of citations in the considered databases. The selection was made ad-hoc within the top-cited authors identified in the bibliometric study, based on our understanding of each author's contributions to the literature rather than by predefined criteria or systematic analysis.

2. How do top-cited authors refer to "green" industrial policy?

2.1. An overview of the selected works

An overall review of the 33 selected papers shows that a third of the papers (n=11) are from authors affiliated with Chinese institutions. It is surprising that no papers from India are within the top cited as the country is also populous, but the lack of African, Southeast Asian, Middle Orient, and Latin American works are no surprise. In brief, citations most cited authors and influencers about sustainability-related industrial policy issues are mostly from China and Northern Atlantic ("Western") countries. Chinese works often deliver analyses and proposals for that country, with a strong emphasis on sector or specific policy-oriented studies. Only a few state that their empirical findings and policy implications could be applicable to other industrial and developing nations (e.g., Sueyoshi; Yuan, 2015). "Western" articles are relatively more oriented to considerations about policy packages and economic and sustainable development, sometimes with a global perspective.

Although most works share an interdisciplinary approach, they exhibit differences in theoretical, referential, and methodological frameworks, as well as diverse policy recommendations, resulting from the complex, multifaceted nature of the issues addressed. Such broad and complex subject matters are approached from different but interrelated theoretical backgrounds: environmental, climate and/or energy economics, industrial organization, management studies, economics of innovation and technical progress, and related policy fields, including political economy, political science, public policy management, and policy analysis.

Most papers (n=26) focus on micro or meso-object of analysis (sector, cluster, location, policy instrument) while a few (n=7) has a comprehensive macro-outlook (development and sustainability). While most micro and meso-level papers define a problem, review the literature, bring their sources of inspirations to the limelight, and, from there, propose their reference for analysis, most macro level studies have an open concern in specifying existing (formal or not) models or criticize them for their limitation to absorb the complex nuances of climate change, particularly the dynamics of carbon emissions and decarbonization policies.

The relevant policy framework, objectives, and instruments used for reducing carbon emissions or fostering of environmental sustainability are the common concern of all works. Many of the frameworks of reference bring together insights from multiple disciplines, reflecting the complex nature of the issues being analyzed. Such interdisciplinary approach is an effort of researchers to come out with a comprehensive understanding of the topics at hand. Sustainability is a recurring theme across the frameworks, whether assessing the environmental impacts of industrial activities, analyzing the effectiveness of environmental policies, or exploring strategies for promoting eco-innovations. Sustainability in opposition to carbon emissions is a central concern of all works.

Just a few works define green industrial policy explicitly. However, each study is grounded on explicit or implicit concepts relevant to its respective knowledge domain (e.g., economics), discipline (e.g., economics of innovation), or specialty (e.g., finance of climate change), which provide the framework for analyzing and interpreting findings. When available, each paper's empirical basis helps validate the frameworks of reference and gives real-world context to understanding the phenomena under study.

All reviewed studies have public policies as the object of analysis or reflection with a view to inform policymaking or propose policy recommendations based on their analysis, which is evidence of the policy-oriented approach all studies take. In such a context, the works deal with environmental, climate, energy, innovation, and industrial policies from the perspective of incentives, regulation, and technical assistance. In this sense, most works are explicitly concerned with the instrumental aspects of and capabilities behind public policies, including whether the State is or should be adequately equipped with the certain political orientations, resources, and instruments to face decarbonization challenges.

While most articles are related to environmental management, sustainability, and industrial development, they employ varied methodologies, including econometric analysis, qualitative case studies, formal modeling, and interdisciplinary synthesis. Such methodological differences reflect the diversity of research methods and tools available within each discipline. Although many frameworks offer policy recommendations, the specific policy implications may vary depending on the analytical focus and findings. Some frameworks advocate for particular policy interventions or regulatory approaches, while others highlight the importance of broader systemic changes or institutional reforms.

In the following sections, the ideas and proposals arising from each group of studies will be reviewed to highlight relevant issues for industrial policy design, policy implementation and future research.

2.2. Specific economic activities: sectors, territories, firms

This group includes nine works focusing on economic activities from different standpoints. Zhang *et al.* (2011) and Zhang *et al.* (2013) study activities related to the automobile industry, in particular, new electrical vehicles (NEVs) and the automotive-component re-manufacturing industry (ACRI) in China. They point out the insufficient development of ACRI (in 2009!) and that financial benefits, performance attributes, environmental awareness, and psychological needs are the most important factors influencing consumers' acceptance of NEVs, with performance attributes being more relevant than financial benefits. Moreover, they argue that "public awareness of government policy" functions as a moderator in the process of acceptance. Whether this paucity of IO sector-based articles is a result of "supply or demand determinants of research" in the academic world remains an open question.

Pegels and Lütkenhorst (2014) focus on the German energy transition as the center piece of the country's green industrial policy and compares wind and solar photo-voltaic electricity promotion along five policy objectives: competitiveness, innovation, jobs, climate change, and cost to consumers. The authors found mixed evidence that the country reached its policy aims at reasonable costs. As the paper was a snapshot of the then current performance, a longer term and systemic perspective required for the energy sector transformation suggests a need for a balanced mix of a variety of clean energy sources.

Four studies analyze the benefits and conditions for industrial symbioses, i.e., physical exchanges of materials, energy, water, and by-products among diversified clusters of firms (Chertow, 2007; Gibbs; Deutz, 2007; Fang; Côté; Côté, 2007; Qin, 2006; Yu; Han; Cui, 2014). In some cases, symbiosis is studied in specific eco-industrial parks (EIP). Research discovered few examples of networking between firms or processes using waste and material recycling. Most EIPs were at an early stage of development, where linkages were potential rather than real. Moreover, "uncovering" existing kernels of symbiosis led to more sustainable industrial development than attempts to design and build EIPs incorporating physical exchanges.

Yao *et al.* (2021) study the effects of green credit policy on firm performance in China and conclude that this policy reduces firm performance in heavily polluting industries. The effect is more prominent in state-owned enterprises, firms with large size, high institutional ownership, high analyst coverage, and during highly uncertain economic-policy

periods. As for Sueyoshi and Yuan (2015), they focus on specific regional firms: heavy polluters in China. Their assessment of regional sustainability of economic development and air pollution management concluded that environmental protection may reduce regional imbalances, increase social sustainability, and enhance the country's international image.

2.3. A one policy focused approach: the role of regulation

This group of works focus on the economic and technological effects of regulation policies, with most of them emphasizing the technological effects of regulation more than other dimensions, such as the industrial structure.

A seminal paper by Porter and van der Linde (1995) provides a conceptual framework suggesting that environmental regulations can enhance competitiveness by stimulating innovation, improving productivity, and fostering comparative advantage in cleaner technologies. They analyze how firms respond to environmental regulations and how these responses influence their competitiveness in domestic and global markets. They suggest that properly designed environmental standards can trigger innovation and may (partially or fully) offset the costs of complying with them because as reducing pollution often coincide with improving the productivity. The Porter and van der Linden hypotheses have been tested for different environments.

Six articles further elaborate on the effects of regulation on innovation. Simpson and Bradford (1996) indicate that environmental regulation should be imposed to control externalities, but while it may not generate industrial advantage, strengthening regulations may sometimes cause profits to shift from foreign to domestic firms. Yuan and Zhang (2019) conclude that a flexible environmental policy can facilitate industrial sustainable development, with a significantly positive impact on technological innovation, and that an environment regulatory enforcement can positively moderate its relationship between flexible environmental policy and technological innovation. Studying the relationship between environmental policy and industrial innovation in England and Wales, Murphy and Gouldson (2000) conclude that regulation can achieve to some extent what is suggested by ecological modernization theory (Hajer, 1995). Yu and Wang (2021) study the impact of environmental regulation policies on industrial structure upgrading and concludes that the positive effects of economic incentives and legislative monitoring of environmental regulation policies on the upgrading of industrial

structure are significant, but there are important differences in their effects across regions. Hu, Pan, and Huang (2020) study the impact of China's carbon emission trading system (CETS) pilot policy on innovation, using the narrow Porter and van der Linden (1995) hypothesis – the induced innovation hypothesis –, and the innovation diffusion theory to assess how environmental regulation affects firms' innovation quantity and quality. They conclude that CETS has had a significantly positive effect on the quantity and quality of innovation, but its impacts on innovation quantity are decreasing. They found that CETS only promotes the innovation quantity and high-quality innovation of state-owned firms, large-size firms, and eastern-region firms. If the government reduces subsidies to "treatment group" firms, it can not only enlarge the direct promotion effect of CETS on the quantity and quality of innovation, but also eliminate the offsetting effect of government subsidies on "compliance costs," thereby indirectly improving the quantity and quality of innovation. In a closely related field, Zhu and Tan (2022) conclude that environmental, social, and corporate governance (ESG) ratings significantly promote the quantity and quality of corporate green innovation and are mediated by alleviating financial constraints and increasing managers' environmental awareness. The higher the ESG rating score, the more apparent is the promotion effect. Furthermore, stricter environmental regulations, increased market competition, and companies in their growth period strengthen the association between ESG ratings and green innovation.

Regulation policies to specifically reduce emissions are considered in two papers. Yang *et al.* (2017) conclude that although China's carbon intensity constraint policy (CICP) was successful on green production performance, it caused a factor substitution effect that hindered the improvement of green production performance **(GPP)**[4]. Thus, CICP was not effective in achieving the double dividend of carbon reduction and industrial growth. Sovacool *et al.* (2021) found that almost 40% of F-gases will fall outside the scope of international agreements such as the Paris Accord, the Montreal Protocol, and the Kigali Amendment.

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[4] The green production performance (GPP), i.e., the environmentally sensitive productivity growth encompassing undesirable output(s), is usually employed to reflect green accounting or sustainable development (see Kumar, 2006; Oh, 2010).

2.4. A policy package approach: sequencing and mixes

This group gathers works focusing on a set of policies and certain policy sequences and mixes to strengthen their effects. In this group and the next one the presence of "Western" studies is overwhelming.

Two works focus on pro-active public policies for environmental transition: Rodrik (2014) and Lamperti *et al.* (2019). Rodrik (2014) examines the concept and practice of green industrial policy and its role in promoting sustainable economic development, focusing on government interventions aimed at fostering green innovation, investment, and industrial transformation. His paper analyzes how government interventions, regulatory measures, and incentives can be designed to support the development and adoption of environmentally friendly technologies, practices, and industries. The practice of industrial policy can be improved by designing institutional frameworks that counter both informational and political risks. As for Lamperti *et al.* (2019), their study analyzes the role of public policy and finance in facilitating the transition to a green economy, with a focus on the active role of the State in driving this transition. It examines dimensions of the green transition, including the decarbonization of industries, renewable energy adoption, sustainable infrastructure development, and the promotion of eco-friendly technologies. It stresses the need for proactive state intervention to steer the economy towards environmental sustainability.

The works by del Río, Carrillo-Hermosilla, and Könnölä (2010), Kern, Rogge, and Howlett (2019), and Meckling, Sterner, and Wagner (2017) focus on policy mixes and sequence of policies. The first one explores policy strategies to promote eco-innovation within industrial sectors and across different stages of the innovation process within the context of industrial ecology and sustainable development. Drawing on evolutionary economics, del Río, Carrillo-Hermosilla, and Könnölä (2010) study combinations of framework conditions and instruments most effective in promoting eco-innovation, considering barriers and eco-innovation types (process/product, mature/immature, and radical/incremental). Kern, Rogge, and Howlett (2019) explore new approaches and insights for designing policy mixes to facilitate sustainability transitions. They suggest bridging the fields of innovation studies and policy studies to develop an understanding of how policy mixes can support transitions towards more sustainable socio-technical systems. Their work identifies components of effective policy mixes and examines their role in fostering innovation and systemic change. It concludes by presenting five significant themes

in the policy mix literature: methodological advances; policy making and implementation; actors and agency; evaluation of policy mixes; and co-evolution of policy mixes and socio-technical systems. Finally, Meckling, Sterner, and Wagner (2017) investigate how different policy instruments and measures can be sequenced over time to achieve decarbonization goals. Their study analyzes the process and impacts of policy sequencing (carbon pricing, renewable energy subsidies, energy efficiency standards) in decarbonization. It concludes that low-carbon leaders such as California and the European Union have followed a policy sequence that helps overcome some of the political challenges low-carbon policy faces by building economic interest groups to support decarbonization and reducing the costs of technologies required for cutting emissions. While politically effective, this policy pathway faces environmental and cost-effectiveness challenges, including excess rent capture and lock-in.

Other policies are addressed by Steurer (2010), Plevin, Delucchi, and Creutzig (2014), and Markard, Raven, and Truffer (2012). Steurer (2010) analyzes the role of governments in promoting corporate social responsibility (CSR) to characterize public policies related to CSR in Europe, including regulatory approaches, incentives, voluntary initiatives, and partnerships with businesses and other stakeholders. Plevin, Delucchi, and Creutzig (2014) evaluate the use of Attributional Life Cycle Assessment (ALCA) as a tool for estimating climate-change mitigation benefits and their implications. Given that ALCA is not predictive of real-world impacts on climate change, a conceptually superior approach, namely consequential LCA (CLCA), avoids many of its limitations. However, because it is meant to model actual changes in the real world, CLCA results are scenario-dependent and uncertain. Markard, Raven, and Truffer (2012) identify the intellectual contours of the emerging field of "sustainability transitions" by reviewing basic conceptual frameworks, together with bibliographical analysis of 540 journal articles in the field. It shows that, more than a decade ago, sustainability transition studies already constituted a field of research of high societal relevance, given the magnitude and pervasiveness of sustainability challenges.

2.5. A comprehensive approach: development and sustainability

Seven papers take a long-term perspective and emphasize economic development and sustainability sometimes incorporating broader considerations about employment and social inclusion, as well as the challenges facing developing countries. They are Stern (2008), Acemoglu *et al.* (2012), Farberger (2018), Kemp and Never (2017), Mealy and Teytelboym (2022), Stern and Stiglitz (2023), and Wieczorek (2018).

Stern's seminal 2008 Richard T. Ely lecture examined the economic dimensions of climate change and its implications for policymaking (Stern, 2008). It offered an economic analysis of climate change, including its causes, impacts, and potential policy responses. Economic analysis of climate change must place at its core: i) the economics of risk and uncertainty; ii) the links between economics and ethics (there are major policy trade-offs both within and between generations), as well as notions of responsibilities and rights in relation to others and the environment; and iii) the role of international economic policy.

Stern and Stiglitz (2023) analyze the interaction between climate change and economic growth and provide insights into policy interventions that could reconcile economic growth with mitigating climate change. It concludes that new technologies, the climate challenge, and the reconfiguration of globalization require a new approach to development emphasizing the green transition and labor-absorbing services.

Within a development perspective, Mealy and Teytelboym (2022) analyze how economic complexity influences the development and diffusion of green technologies, industries, and practices. They conclude that higher ranked countries based on their ability to export complex green products competitively are more likely to have higher environmental patenting rates, lower CO^2 emissions, and more stringent environmental policies even after controlling for per capita GDP. There is a strong path-dependence in the accumulation of green capabilities.

Acemoglu *et al.* (2012) investigate the relationship between environmental concerns and the direction of technological change within the framework of economic growth theory. Their paper analyzes how environmental policies influence the direction of innovation and technological progress, and their impact on economic growth and environmental sustainability. Their conclusions include very specific policy recommendation regarding carbon taxes, research subsidies, and the timing of such policy interventions.

Wieczorek (2018) overviews sustainability transitions in developing countries, highlighting insights from existing research and discussing their implications for both research and policy. The author examines sectors and societal systems in these countries, exploring the dynamics of technological, economic, and institutional change necessary for sustainability transitions. Reviewing publications released in the previous decade, Wieczorek identifies policy implications for international organizations, donors, governments, and civil society organizations.

Kemp and Never (2017) study what governments in developing countries can do to phase in green technologies by learning from more advanced countries. They suggest governments adopt: i) proactive planning, ii) options for support and forms of support, iii) the sequential approach, iv) policy learning, v) policy packages including policy-push and market-pull policies, as well as R&D, institutional capability, skill, and job creation measures, and vi) control mechanisms.

Finally, Farberger (2018) comments on transformative innovation policy and focuses on its role in mobilizing innovation for sustainability transitions. The author examines such a policy's conceptual foundations, practical implications, and potential to facilitate the transition towards more sustainable socio-economic systems. The paper concludes that the existing theorizing and knowledge base in innovation studies may be of relevance when designing policies for dealing with climate change and sustainability transitions.

2.6. An (almost) consensual perspective about policy instruments

The review of policy instruments recommended in the works under consideration shows much less diversity than that found regarding their objectives and conclusions. Although the universe of instruments is more limited than that of objectives, its scope is coherent with the predominance of articles focusing on a micro or meso-level object of analysis (sector, theme, cluster, location, policy framework).

More than two-thirds of the reviewed papers suggest strengthening regulatory frameworks or standards, frequently those related to carbon-intensity constraint policies or general environment protection. Many mention regulations to foster a carbon pricing/market; others point to compulsory measures to curb "ecodelinquent" behaviors. Remarkably, regulation strengthening is predominant in both Chinese and "Western" articles and in those authored by "influencers." It is a practically consensual policy instrument. However, authors do not generally agree on the intensity and characteristics of regulation. For example, while Porter and van der Linde (1995, p. 98) highlight the benefits of "properly crafted environmental regulations" and Stern (2008, p. 25) asserts that "regulation and standards can give greater certainty to industry," Rodrik (2014, p. 473) affirms that "even though full pricing of carbon would be a far better way to address climate change, it appears most governments would prefer deal with the problem through subsidies and regulations that increase the profitability of investment in renewable energy sources."

Present in more than half of the reviewed papers, other widely proposed instruments are fiscal incentives, either under the form of targeted subsidies or grants. In some cases, these instruments are viewed as means to correct market failures; in others, they are considered crucial for a market shaping State intervention. However, very few articles propose specific tax or public procurement programs (about 10% of total each). For example, Acemoglu *et al.* (2012, p. 147, 159) conclude that although an optimal policy involves both carbon taxes and research subsidies, "excessive" use of carbon taxes should be avoided because "relying on only carbon taxes would be excessively distortionary." About a third of the papers propose that fiscal incentives are oriented towards fostering innovation, including technological research and development (R&D), technical assistance or technology transfer programs. In some cases, those incentives should be targeted at investment in innovation projects. Green finance plays a crucial role in some proposals.

Also, about a third of the papers stress the relevance of human and institutional capacity building as a crucial component of policy implementation. Fostering implementation demands other proposed instruments, such as public-private partnerships, including civil society organizations, multi-stakeholder engagement, and industrial symbiosis (a concept close to that of productive clusters). Even so, the reviewed papers tend to be more generic and less detailed when dealing with the implementation of industrial policies. Most articles on the topic stress only the need to improve policy coordination and sequencing within an integrated approach, as well as to enhance monitoring and evaluation systems to ensure transparency of policy goals and outcomes. Finally, a few relevant articles, following Stern (2008), emphasize the need for increased international cooperation to solve transborder problems such as the climate crisis, in general, and decarbonization, in particular.

3. Where to green industrial policies? The need of a political economy approach

3.1. Summary of main findings

The present study has produced a set of insightful evidence on the main features and knowledge structure of the green industrial policy literature published in Scopus and WoS from 1976 to 2023.

The bibliometric analyses revealed i) a group of works/authors associating industrial policy to economic, social, and environmental development issues, and incorporating industrial organization issues such as competitiveness and innovation; ii) a network of works/authors coming from a thematic specialization (e.g., energy, environment) that address issues regarding industrial policy from such a specialized perspective; and iii) a strongly interrelated group of works/ authors primarily concerned with the challenges of industrial policy oriented towards sustainable industrial development in a specific national context (China).

The qualitative review reveals that most papers follow a meso-level approach, with their analytical object being either an economic activity (automobile production), a theme (energy transition, CO_2 emissions), or a particular location (urban, cluster) in a specific moment of time. Nevertheless, very few papers dedicate attention to the embedded forward and backward "environment" related linkages existing in all economic activities. Considering the industrial policy framework, most works cite the importance of "green" or "sustainable" industrial policies combining and incorporating varied policy instruments, but the strategic importance of policy capabilities and coordination is only generically approached. It is practically consensual among the most influential authors that regulation has a prominent role in green industrial policies, although they diverge on the intensity, or the harshness, of the regulations to be implemented in each context. Some mention regulations aimed at fostering a carbon pricing/market; other focus on compulsory measures to curb "ecodelinquent" behaviors. As for the incentive dimension of industrial policy, the most cited and discussed ones are fiscal/tax incentives and very few authors dedicate attention to financial incentives, and almost none of them to issues related to trade policy, such as tariffs or import/export bans. As expected, very wide differences in the width and breath of suggested usage of fiscal incentives mark the authors' propositions.

Taking the above three elements – policy framework, the role of regulation, and policy incentives –, a key issue draws one's attention: the instrumental aspect of industrial policy implementation is seldom considered. Very few studies discuss the operationalization of intervention mechanisms. However, any public policy requires State capabilities in such way that its execution could be efficient, effective, innovative, and accountable. So, it is relevant that research on the topic addresses these issues.

3.2. The nature of the activity, the location, and the moment of time of the related sustainability challenge are of the essence

An evolutionary approach to analyzing the dynamics of sustainability challenges is fundamental to derive pertinent policy implications. Effectiveness in policymaking assumes the adoption of instruments aligned with the policy ambition (in scope and scale), which should address specific challenges and existing demands for State support. Two issues must be considered when analyzing or designing industrial policies for sustainability-associated issues.

Firstly, a place-based approach is required. A country's stage of development defines the contours of potential demand; in more advanced countries, the technological and international competitive frontier can serve as a guide for determining the type of demand for public support. But even in such contexts, less advanced areas may coexist, such as in the field of micro and small firms or population areas with lower purchasing power, each requiring modes of intervention that are conceptually and structurally different from the promotion instruments associated with the demand for more technologically advanced activities.

The objectives of a green industrial policy, the nature of public intervention, and the pertinence of instruments to be implemented must recognize the different stages of development of countries. The more diverse and heterogeneous a country is, the more complex an industrial policy may have to be. Therefore, industrial policies need to be tailored depending on i) each country's level of development of the private sector and the national innovation system, ii) the endowment structure (in terms of resources and institutions), and iii) the actual market structure and competition dynamics in different sectors (and resulting opportunities and challenges for developing countries).

Secondly, although there may be synergy among some policies aimed at sustainability (decarbonization), social inclusion (employment), and industrial structural change, very frequently, one of these goals may only be partially compatible with the others. So, it will be necessary to work within a framework of optimization (one goal) under constraints (the other two goals). This task is of utmost importance. However, the definition of which goal will be prevalent poses major political and policy problems, which is quite clear in predicaments such as "zero growth," "the imperative of employment creation to cope with a huge and increasing informality in the labor market," or "industrialization and technological development at any cost". As there may not be an analytical solution to this trilemma that satisfies all stakeholders, their relative political capabilities will be determinant in the final design and implementation of specific green industrial **policies**[5]. As always policies depend on politics.

3.3. Without State capabilities, no green industrial policy

Any public policy requires State capabilities so that, in the mission of serving the common interest, its execution is efficient, effective, innovative, and accountable (Evans, 1995). Behind the effectiveness of public policy implementation are State capabilities to perform public functions, which increase the likelihood of inducing positive impacts on policy beneficiaries.

The "nuts and bolts" of State intervention must be considered. State policy capabilities depend on the knowledge, skills, and tacit resources that government institutions accumulate over time and are unique assets to each one. It is fundamental that States engage in public policies along their various development stages, from design to negotiation and implementation, investing the knowledge required to read, monitor, and capture opportunities and showing technical autonomy for decision-making under political and policy directives (Ferraz; de Paula; Kupfer, 2020).

The apparatus of any State is rather complex, considering the diversity of ministerial structures and public agencies and organizations, each with its own mandates and hierarchies, and the relations between the different branches of established institutional powers (legislative, executive, judicial). A sustainability-oriented public policy necessarily

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[5] Increasing concerns about security and defense may pose additional objectives that would increase the complexity and trade-offs of green industrial policy design and implementation.

involves substantial efforts to coordinate a multifaceted set of relationships. If different government organizations – individually or coordinated among themselves or with the private sector and social organizations – can move in a common direction, the chances of positive outcomes increase.

3.4. The political economy of a green industrial policy

In Evans (1995) terms, the embedded autonomy of the State matters for a green industrial policy to be effective. On this basis, one must consider the nature of potential beneficiaries, policy priorities, the extent of the due recognition of social and economic representations, and particularly the gaps between announced and implemented policy actions and between expected and observed outcomes (Peres, 2013). For that, the political specification of priority in the face of challenges a country confronts is a necessary first step before considering whether adequate and necessary policy actions are being designed. The reason is quite apparent: it is at the political decision level where challenges are identified and translated into policy directives. From the moment a political orientation is put forward and policy directives are defined, until their impacts can be noted on policy beneficiaries, expectations are created and political commitments are forged. Societal influence and interactions with the public sphere play a crucial role in determining the development avenues to be entered, as public institutions are not insulated from the legitimate pressures exerted by relevant social actors. The political economy of public policies is essential and must be brought into the limelight.

3.5. Concluding remarks

Our review and analysis of the literature on green industrial policy shows that sustainability-bound policy challenges are specific to locations, sectors, technologies, and moments of time. While prescriptively generic, the reviewed literature shows that research on industrial policies requires considerable attention to analyzing the peculiar features of different sustainability challenges, the nature of instruments being implemented, and the existing and potential State capabilities. Thus, while sustainability issues must gain preeminence in the political priority agenda of national States, there is not, and cannot be, a "one size fits all" solution, one ideal "green" industrial policy model. A tailor-made suit of concerted policy actions must be designed and implemented according to each complex, multi-dimensional set of sustainability related development challenges.

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APPENDIX: Bibliometric analysis methodology

The database for the quantitative exercise

The body of literature on "green" industrial policy to be examined was selected by searching into Scopus and the Web of Science (Core Collection). Such databases have been chosen due to their broad coverage and high quality of indexed journals, spanning a wide range of relevant disciplines (Singh *et al.*, 2021). In addition, both offer advanced citation analysis and data visualization tools, facilitating the identification of trends and co-authorship networks.

Considering the study goals, the empirical strategy defined five terms (one complete word and four root words) to be combined with the expression "industrial policy" to screen the literature: **green**, **sustain***, **ecolog***, **environ***, and **decarb***. Root words with "*" were used instead of complete words to capture as many documents as possible, considering the existence of related nouns and adjectives and spelling variations in the English language. The search was conducted according to the following criteria: publications (articles, reviews, whole books, book chapters) that feature each term combined with "industrial policy" in the title, keywords, or abstract. The search was conducted in February 2024, set no initial date range, and included only documents published until 2023. **Table A1** show the query strings.

Table A1 – Queries made to databases

Data	Scopus and Web of Science databases
Query	TITLE("industrial policy" AND "decarb*")OR ABS ("industrial policy"AND "decarb*") OR KEY ("industrial policy"AND "decarb*")
	TITLE("industrial policy" AND "ecolog*")OR ABS ("industrial policy"AND "ecolog*") OR KEY ("industrial policy"AND "ecolog*")
	TITLE("industrial policy" AND "environ*")OR ABS ("industrial policy"AND "environ*") OR KEY ("industrial policy"AND "environ*")
	TITLE("industrial policy" AND "green")OR ABS ("industrial policy"AND "green") OR KEY ("industrial policy"AND "green")
	TITLE("industrial policy" AND "sustain*")OR ABS ("industrial policy"AND "sustain*") OR KEY ("industrial policy"AND "sustain*")
Data accessed: February 2024	

Source: Authors' elaboration.

The search identified 1,345 documents in Scopus and 441 documents in the Web of Science. After the queries were made, all descriptive metadata concerning each document's publication date, journal and issue of publication, DOI, country of main author's affiliation, keywords, document title, reference list, and number of citations. After each query was made, all retrieved results were exported for initial processing in an Excel application. As each document can contain more than one term combined with "industrial policy" (green AND/OR ecolog* AND/OR decarb* AND/OR sustain* AND/OR environ*), a column called "label" was introduced in the export spreadsheet to identify from which of the five query strings each result came from. So, each retrieved result was labelled accordingly (green, sustain, decarb, env, eco). Such a label informed whether a document is unique to a query or appears in more than one query.

The results were then merged, processed, and standardized. The document's DOI was the key for identifying duplicates. Ultimately, standardization between the two databases consisted of identifying the columns with the same content match, merging, and labeling them. During processing, 126 duplicates were identified and excluded. The final database held a total of 1,660 documents.

The next two steps in the bibliometric analysis involved analyzing the co-occurrence of keywords and co-citation of authors, based on the keywords and cited references extracted from all documents in the database. All bibliometric data were processed in Python, starting with basic commands using the Pandas library and progressing to the creation of network structures. Visualization of co-citation and co-occurrence structures were performed using the NetworkX library (Rose; Kitchin, 2019). Additionally, the VosViewer software was employed to generate images of the networks (van Eck; Waltman, 2019).

In the keyword co-occurrence analysis, only the strongest couplings were retained and documents weakly coupled or isolated were excluded, a method known as giant component filtering (Lozano *et al.*, 2019). Strong couplings are keywords frequently appearing in the considered documents, while weak couplings are keywords rarely appearing or not at all associated (Boyack; Klavans, 2010). The "Kamada Kawai" method was employed to position nodes in the graph by minimizing distances between them. The clustering algorithm used was the Louvain method, an optimization algorithm that seeks to maximize modularity (Blondel *et al.*, 2008).

After categorizing the groups, the relevance of each paper in the network was analyzed using a link metric based on each paper's weight within its group and in the entire database. A participation coefficient was also calculated, representing the sum of connections from one vertex to others relative to the total number of vertices (Zupic; Cater, 2015). Finally, the networks were analyzed using VosViewer software.

The keyword co-occurrence matrix is presented according to Equation (1)

$$Z_{co-occurrence} = \sum_{d=1}^{D} x_{id} * x_{jd} \qquad (1)$$

In (1), D is the total number of documents in the database, x_{id} is a binary variable that indicates the presence or absence of keyword i in the document d and x_{jd} is a binary variable that indicates the presence or absence of the keyword j in document d.

As for the co-citation analysis, the co-citation matrix is presented according to Equation (2).

$$Z_{cocitation} = X * X' \qquad (2)$$

In (2), X means the co-citation matrix, the rows represent the authors, and the columns represent the cited authors with the corresponding rows. X' is the transpose matrix of X. So, multiplying X by X' results in a new matrix, the $Z_{cocitation}$, representing the weighted co-citation between items. Each element z_{ij} of this new matrix indicates the co-citation strength between items i and j.

The size of each node in a bibliometric graph is proportional to the number of occurrences, and the strength of a node often reflects its relative importance within the network. This importance can indicate a node's centrality in the context of the cluster to which it belongs. In the method used, the centroids are the nodes with the greatest link strength. By selecting these nodes as centroids, elements that exert the most substantial influence and maintain the most significant connections with other nodes within the cluster were prioritized. This approach provides an effective and streamlined representation of each cluster, facilitating clearer interpretation and more accurate identification of key features and trends within the analyzed bibliometric dataset.

The exercise also involved plotting the strongest keywords in the database. The co-occurrence of keywords from the cited papers resulted in a network with three clusters (labelled as green, blue, and red), each represented and organized by the number of occurrences and the total strength of each keyword. According to the cluster technique adopted, inertia was achieved with a division into six clusters. The choice to set the number of analyzed clusters equal to three was the result of experimentation and validation. **Table A2** ahead shows the strongest keywords by cluster.

Table A2 – Strongest keywords by cluster

Keyword	Citations	Link strength	Cluster	Keyword	Citations	Link strength	Cluster	Keyword	Citations	Link strength	Cluster
Industrial policy	805	3123	green	Environmental policy	140	651	blue	China	224	1194	red
Sustainable development	262	1282	green	Climate change	74	346	blue	Industrial ecology	102	168	red
Sustainability	197	846	green	Environmental economics	73	555	blue	Industrial development	81	477	red
Innovation	120	619	green	Energy policy	62	277	blue	Economic development	72	413	red
Environmental protection	88	525	green	Economics growth	60	281	blue	Industry	55	296	red
Competitiveness	80	390	green	Green industrial policy	53	173	blue	Environmental impact	45	280	red
Manufacturing	76	422	green	Investment	52	344	blue	Circular economy	43	189	red
Public policy	74	434	green	Emission control	46	287	blue	Government	40	284	red
Economics	60	375	green	European Union	39	201	blue	Industrialization	40	179	red
Environmental management	53	316	green	Carbon emission	36	243	blue	Policy	40	193	red

Source: Author's elaboration based on data from Scopus and WoS.

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