Green Industrial Policy and Technology Neutrality:

Odd Couple or Unholy Marriage?

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Abstract: Green industrial policy (GIP) first emerged following the Global Financial Crisis and is a central pillar of the responses of many governments to the twin challenges of climate change and COVID19-induced recession. Our survey of the small but growing literature on the concept highlights its roots in neoclassical welfare economics, with an emphasis on addressing market failures; while its branches intertwine with concepts such as sustainability transitions and strategic niche management. The principle of technology neutrality is often referenced explicitly in GIP. The centrality of technology-specific market failures, a need for policy learning, and the importance of reducing uncertainty for market participants all speak strongly against applying this principle in GIP.

What is Green Industrial Policy; and should it be Technology Neutral?

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1 Introduction

Green industrial policy (GIP) emerged in many countries as a central pillar of government response to the twin crises of COVID19 and climate change. The European Union and South Korea are among those who have announced a New Green Deal in 2020, and Democratic US President Joe Biden also recently announced a $US2trillion version (European Commission, 2019; Greenpeace International, 2020; Nelson & Moore, 2021). GIP for specific industries is even more wide-spread; no less than 20 countries have developed hydrogen strategies or have entered the substantive stage of development. Another 17 hydrogen strategies are at the initial stage of policy discussion (Uwe Albrecht et al., 2020). Rapid technological development is a central pillar of many of these same programs.

GIP was originally seen as a more politically feasible approach to emissions mitigation than carbon pricing. Increasingly, however, its popularity of GIP is due to recognition that emissions pricing alone is not sufficient to bring about the rate of transition toward zero emissions that is required to keep temperature rises below 2C (Karp and Stevenson, 2012). The speed and magnitude of current GIP can also be understood as part of the historically unprecedented fiscal stimulus measures being implemented to combat the economic downturn brought on by the COVID19 pandemic. Given the amount of public money being spent on GIP currently, it is crucial we understand what GIP and how to get it right. The current paper contributes to this goal.

We begin with a structured review of the literature on GIP. Our review focusses on four questions: What is GIP? What are the goals/purpose of GIP? What market failures does it address? What are the challenges in GIP? And how does it compare to related concepts? Reflecting the bulk of the literature on GIP, the organizing framework for the structured review is primarily neoclassical economics, especially welfare economics. Our assessment of the “largest common denominator” of definitions in the literature is that green industrial policy comprises sector-targeted policies that support the growth and development of certain industries and technologies, with the aim of furthering both economic and environmental goals. Our reading of the relevant literatures is that GIP is one of the outputs of government transition management, including strategic niche management; and that best-practice GIP development reflects the recommendations of these literatures.

The second half of the paper applies insights derived from the literature review to revisit the question of the application of the principle of technology neutrality in GIP. Technology neutrality is sometimes suggested as a means of minimizing "government failure" in GIP (Hallegatte et al., 2013; Schwarzer, 2013) and many instances of GIP invoke the principle. On the other hand, technology neutrality has been widely criticized for being counter-productive (i.e. leading to technology bias) and for undermining the achievement of the goals of GIP to which it is applied (Azar and Sandén, 2011; Greenberg, 2016; Thompson, 2011).

Considering technology neutrality through the lens of neoclassical welfare economics, we argue that "first-best" policy will sometimes display technology neutrality – for example the targeted response to the external costs of carbon emissions is an economy-wide carbon price. On the other hand, when the market failure being addressed by the policy is technology-specific, the first-best policy will also be technology specific. Since many of the market failures which are the focus of GIP are technology-specific, technology neutrality is not a feature of optimal policy in most cases.

Considering arguments about technology neutrality (TN) from the legal literature in light of our review findings also speaks against its application in GIP. A key legal motivation for TN is increasing the longevity of law and policy. Meanwhile, the literature on GIP unanimously emphasizes the need for systematic policy evolution through processes of learning, experimentation and development. A key legal criticism of TN is that it results in vagueness and ambiguity. Meanwhile, the literature on GIP unanimously emphasizes the reduction in uncertainty for market participants as a key goal. We conclude that the principle of technology neutrality is not constructive in GIP.

2 Method and Conceptual Framework

2.1 Structured Literature Review of Green Industrial Policy

GIP is a rapidly evolving field in which many key publications are in the so-called grey literature. In order to ensure we had the most up to date literature and captured important policy publications, we used Google Scholar for our search.

We searched research containing "Green Industrial Policy(ies)" in their title. In total 49 unique papers were found. We filtered further and deleted 15 country-specific case studies that only explain the practice without further theoretical implications for GIP, as well as 12 research the intersection of GIP and WTO, climate finance, or economic geography. One paper has the citation detail but the full text is not available, and another is not available in English. Therefore, a total of 20 papers/books/reports were reviewed.

Six individual contributions to the literature which were important for their originality are discussed briefly in Section 3.1. An overview of key trends and findings from the literature is presented in Section 3.2. Key features from the remainder of the papers are summarized in Table 1 in the Appendix.

Our central purpose was to examine what the literature thinks GIP actually is, and what it is for. Reflecting the bulk of the literature on GIP, the organizing framework for the structured review is primarily neoclassical economics, especially welfare economics. The dominant theoretical motivation for GIP in the literature is to address market failures.

The welfare economic approach to policy – widely espoused by organizations such as the OECD Best Practice Principles for the Governance of Regulators (OECD, 2014, p. 10) – follows from the first welfare theorem. Namely, in the absence of market failures, the most efficient outcome (including all forms of social and environmental costs and benefits) is achieved when the government does not intervene. The presence of one or more market failures, however, means that the market alone will not achieve the optimal outcome. Market failures, therefore, provide a potential efficiency justification for government policy or regulatory intervention.

Another cornerstone of neoclassical welfare economics is the principle of targeting – the most efficient government intervention will be one that is directly targeted at fixing a given market failure. For example, if the market failure is an externality associated with carbon emissions, the "first-best", targeted policy will be to make market participants internalize the social cost of their actions, by putting a price on carbon. If the market failure is credit constraint for developers of projects relying on new, high-risk technologies, a first-best response is the provision of credit via, for example, a government green bank.

Economists are aware that it is not always possible to implement the first-best policy intervention to address a given market failure. In this case, a "second-best" policy may (or may not) be worthwhile[1]. For example, if it is politically infeasible to put a sufficient price on carbon emissions, a subsidy for supply of renewable energy is a second-best approach.

An important distinction in the literature on GIP is the extent to which it is seen as primarily aimed at addressing environmental market failures (primarily greenhouse gas externalities) or industry-related market failures (such as knowledge spillovers, credit constraints and coordination failures). A related distinction is whether GIP instruments are considered first- or second-best responses to the market failures in question. We note both of these dimensions for each of the papers reviewed.

Grossman and Krueger's (1991) scale, composition and technique effects of trade policy provide an additional conceptual frame through which to understand the literature on GIP. Of particular relevance are the composition and technique effects. The composition effect of a policy on the environment is that which occurs through changing the composition of activities in the economy – that is – the structure of the economy. GIP could have a composition effect through speeding the decline of the coal industry and the rise of the wind energy industry. The technique effect of a policy on the environment is that which occurs through changing how much environmental damage is incurred by a given activity. For example, GIP could have a technique effect by increasing the availability of technologies that lower the environmental impact of the activities of both industry and households.

2.2 Critical review of Technology Neutrality and its application in GIP

In order to understand the definitions, motivations and critiques of technology neutrality, a targeted review of the legal and economic literature and key policy grey literature was undertaken. Priority was given to sources discussing technology neutrality in the context of industry policy in

[1] "worthwhile" = "welfare improving" in the language of neoclassical economics.

general, or GIP in particular. Notably, much of the literature on TN is in the context of the regulation of information and communication technologies. This literature was included where relevant to our context.

It was found that technology neutrality is rarely mentioned in the economic literature. Where it is mentioned, it is not motivated theoretically. The current paper therefore provides a novel contribution by considering the case for TN from the perspective of welfare economic theory. In doing so, it aligns the theoretical framework for TN with that of the dominant literature on GIP.

Our primary assessment of the suitability of TN as a principle for GIP follows from the welfare economic perspective. However, we also consider key legal and political-economic arguments for TN on their merits from their own disciplinary perspective.

3 Green Industrial Policy

The following section provides a structured review of the literature on GIP, focusing on definition, examples, and purpose of GIP. We begin by presenting short summaries of several influential or original papers, followed by a summary of the literature overall.

3.1 Summary of Key Papers

3.1.1 Harrison et al.'s view

According to Harrison et al. (2017, p. 253), green industrial policies "promote industries that produce green technologies and encourage traditional industries to produce goods and services in greener ways." Examples of GIP according to this view include economy-wide carbon pricing as well as command-and-control pollution regulation. Hence Harrison et al.'s concept of GIP focusses on environmental externalities from industry. It may be economy-wide and technology neutral (as in the case of carbon pricing) or highly industry and technology specific (as in the case of command-and-control regulation). In the language of Grossman and Krueger (1991), Harrison's version of GIP may aim to achieve a composition effect by targeting the structure of the economy (e.g. carbon pricing or green-technology support programs), or to achieve a technique effect by targeting the emissions per unit (e.g. carbon-pricing or command-and-control regulation).

The motivation for GIP in Harrison et al.'s view may be inferred from the definition as addressing (efficiency-limiting) market failures which affect industry composition and technique and have negative environmental consequences. Harrison tend to position GIP as a set of first-best responses to these overlapping market failures.

3.1.2 Pegels' view

Pegels (2014, p.5) defines GIP as "government intervention to hasten the restructuring of the economy towards environmental sustainability." As such, Pegel's view is similar to that of Harrison et al. in that the focus is squarely on environmental motivations for GIP: "'Greening' the economy, transforming it to ensure environmental sustainability, is becoming increasingly urgent at current rates of natural resource depletion."(p.1)

Pegels motivates GIP in the neoclassical welfare economic tradition, listing relevant market failures including externalized environmental, decision-making under uncertainty, co-ordination failures, network externalities, economies of scale, and credit constraints. Because of the speed of disruption required, Pegels suggests GIP will need to have a greater focus on innovation than traditional industry policy. She also argues explicitly for technology-specific policies.

Pegels' approach to GIP goes well beyond optimal policy to address market failures. She draws on ideas from strategic niche management to suggest that creation, reduction and management of rents is at the heart of GIP. Demand-side policies are an integral part of this rent management approach.

3.1.3 Rodrik's view

In Rodrik (2014), GIP is implicitly defined as industry policy to facilitate green growth. In particular, GIP should increase the availability of "green technologies: production techniques that economize on exhaustible resources and emit fewer greenhouse gases" (p. 469) by ensuring that investments in such take place at an appropriate scale. Green growth is inherently desirable according to Rodrik as it entails "a trajectory of economic development that is based on sustainable use of non-renewable resources and that fully internalizes environmental costs, including most critically those related to climate change." (p. 469) The focus on availability of green technologies is desirable because it "both lowers social costs in the transition to a green growth path and helps achieve a satisfactory rate of material progress under that path." (p. 469) While Harrison et al.'s definition of GIP can be summarized as environmental policy targeted at industry, Rodrik's is industry and innovation policy targeted at green technologies. Rodrik's examples of GIP include core industry policy instruments such as tax credits, concessional loans, training subsidies and R&D grants; as well as instruments more often considered environmental policies such as feed-in tariffs, vehicle, fuel and appliance standards. Notably several of these examples are not technology neutral.

Like Harrison et al, and Pegels, Rodrik's central theoretical motivation for GIP is addressing market failures such as knowledge spillovers and environmental externalities. In contrast, to Harrison et al., his focus is less clearly on shifting industry composition and technique, and more on ensuring sufficient development, investment in, and adoption of green technologies which can lower the environmental impact of industry and households alike.

Rodrik is wide-eyed about the political and national competitiveness motivations for GIP. According to him "Even though full pricing of carbon would be a far better way to address climate change, it appears most governments would rather deal with the problem through subsidies and regulations that increase the profitability of investments in renewable energy sources." (p. 473) Hence, although generally a champion of industry policy, Rodrik positions GIP as largely a politically-feasible, second-best approach to pernicious environmental externalities.

3.1.4 Altenburg & Assman's view

Altenburg and Assmann (2017, p. xii) define GIP as "policy options for managing structural change that accounts for both the productivity and the environmental challenges in a harmonized way." They use the term 'industrial policy' to describe sets of measures that governments use to influence a country's economic structure in the pursuit of a desired objective. Green industrial policy then arises when environmental and Sustainable Development Goals (United Nations,

2015) are injected into industry policies. This requires aligning productivity-enhancing economic development with environmental objectives and national interests to be compatible with the protection of global commons (Altenburg and Assmann, 2017). In language of Grossman and Kreuger (1991), Altenburg & Assman's version of GIP is very much focused on achieving composition effects – shrinking environmentally damaging industries and growing more benign or beneficial ones.

Examples of GIP presented in the Altenburg & Assman volume differ from those in previous literature. Their case studies are the bioethanol industry in Brazil (Veiga and Rios, 2017), electric vehicles in China (Altenburg et al., 2017), solar energy in Morocco (Auktor, 2017)and the Energiewende (energy transition) in Germany (Pegels, 2017). In contrast to the GIP instruments discussed in the earlier references, all of these are policy packages driven by an overarching strategy for the industry in question. Hence they look very much like traditional industry policy applied to industries which can provide both environmental and other benefits.

Although both and Altenburg & Assman acknowledge the dual motivations of governments for GIP, there is a subtle normative difference between them. Rodrik positions GIP as the second-best choice of a politically constrained government, unable to adopt first-best environmental policies. Whereas Altenburg & Assman's portrayal is closer to the choice of a benevolent dictator, focusing bureaucratic resources on first-best industry policies that target market failures which have both environmental and productivity implications.

3.1.5 Hallegatte et al.'s view

Hallegatte et al. (2013)'s view of GIP is closest to that of Altenburg and Assmann (2017). Hallegatte et al (2013, p.3) define GIP as "industrial policies with an environmental goal—or more precisely, as sector-targeted policies that affect the economic production structure with the aim of generating environmental benefits." Unlike some authors, especially Harrison et al, Hallegatte et al. distinctly carve-out pricing of environmental market failures from their definition of GIP. In the view of Hallegatte et al, GIP encompasses both a first and second-best approach. It is encompasses a first-best approach to market failures (other than prices for environmental costs and benefits) which would otherwise limit green growth – the authors refer to these as Sunrise policies. It encompasses a second-best approach because it can help make pricing of environmental externalities more politically palatable – especially through Sunset policies. GIP also represents a second-best approach in so far as it can help compensate for the inevitable mispricing of environmental costs and benefits in the economy. Similarly to Altenburg & Assman, the emphasis of Hallegatte et al.'s version of GIP is distinctly on environmental improvements via composition effects.

According to Hallegatte et al. (2013, p.8), examples of GIP include "subsidies to green R&D, access to cheaper capital for green projects (notably through government direct participation and subsidized loans), feed-in tariff policies for renewable energy, consumer mandates and green public procurement rules."

3.1.6 Karp & Stevenson's view

According to Karp and Stevenson (2012), green industrial policy "refers to government attempts to hasten the development of low-carbon alternatives to fossil fuels." GIP in their view is industry policy applied to the energy transition, and industry policy is used "to promote the development of new industries and the creation and adoption of new technologies." Examples of industrial policy include tax credits, input, output and R&D subsidies, minimum use requirements, standards, and trade restrictions."

As such, Karp & Stevenson's view encompasses the sunrise policies for Hallegatte et al. and the technology policies of Rodrik. Karp & Stevenson position GIP as a first best response to the typical market failures that motivate industry policy more generally, as well as two additional market failures specific to GIP: commitment problems about future climate policy, and endogeneity of future policy. Hence the major contribution of this paper is to describe topics generally considered the domain of transition literature in a neoclassical welfare-economic framework.

3.2 Summary of Literature Review Findings

3.2.1 What is GIP?

The "largest common denominator" of definitions in the literature surveyed suggests that ***green industrial policy comprises sector-targeted policies that support the growth and development of certain industries and technologies with the aim of furthering both economic and environmental goals.*** This definition includes first-best policies aimed at addressing industry- or technology-specific market failures (such as knowledge spillovers, external economies of scale, and information asymmetry) for industries which are believed to have potential to bring environmental benefits relative to current industries in the economy. In other words, it encompasses traditional industry and innovation policy for green industries. The broad consensus of GIP in the literature reviewed also includes second-best policies aimed at encouraging supply from specific industries, but targeting widespread environment-related market failures such as emissions externalities. In other words, it encompasses supply-side environmental policy carrots. Government-funded long-term supply contracts for renewable energy (for example via reverse auctions) are an example of this sort of supply-side GIP.

Most authors also include demand-side policies in the definition of GIP, but the reason behind this varies. Demand-side policies include government procurement policies, local content requirements and import barriers. While these policies were the mainstay of traditional industry policy, these days any of them which restrict trade can be (and often are) challenged under trade and investment treaties. This leaves only non-discriminatory policies at the disposal of policy-makers. Non-discriminatory demand-side policies include tax-breaks and subsidies for the purchase of goods and services with environmental benefits – electric vehicles, rooftop solar and household batteries for example. In a highly globalized economy, non-discriminatory practices of this type can prove an expensive way of supporting domestic industry – since much of the subsidy falls to foreign producers. Indeed, non-discriminatory demand-side policies are also found for industries-jurisdiction pairs in which there is no local production. In these cases, then, demand-side policies for tradeable goods may arguably best understood as environmental or energy policy rather than

GIP.[2] Demand-side policies fall clearly into the definition of GIP only when there is a clear pathway to local economic benefit such as jobs, technological advancement or improved global competitiveness for local producers. Hence Chinese, South Korean, Japanese, U.S. and German demand-side electric vehicle policy may uncontroversially be considered industry policy. In places such as Australia[3], it is better understood as green transport policy or climate policy.

Another grey area on the boundary of GIP and climate/energy policies is programs which incentivize (e.g. through subsidies) household and commercial infrastructure investments such as rooftop solar, batteries and building efficiency improvements. As per the above discussion, in many cases these will not classify as GIP for the industries producing the goods being installed, however, they may classify as GIP insofar as they support the development of high-employment industries installing the goods.

Feed-in-tariffs which pay fixed, above market rate for solar energy exported to the grid from rooftop solar installations are worth a separate mention. These are one of the most common green energy policy instruments in the world. They are also mentioned in the majority of reviewed papers on GIP. This is appropriate as, unlike the instruments discussed in the previous two paragraphs, feed-in-tariffs are directly incentivizing supply by solar “prosumers”. As such, they are a supply-side policy for the “industry” of distributed renewable energy generation and fall squarely within our largest common denominator definition of GIP, even in countries which do not produce solar panels themselves.

Other potential components of GIP were either not mentioned by a substantial portion of papers, or were explicitly excluded by one or more. First-best, economy-wide, environmental policy such as carbon pricing is a case in point. “Sunset” policies aimed at speeding the decline of particularly harmful industries such as coal-fired power is another. These sunset policies may help speed the decline of industries through either punitive measures or through measures which provide safety-nets and hence reduce political opposition to the necessary structural change. Industry-specific policies aimed at achieving technique (c.f. composition) improvements are also excluded from our largest common denominator definition of GIP. Examples of this type of policy include vehicle-emission, energy-efficiency and fuel standards.

3.2.2 Relationship to other policy types

GIP has substantial overlaps with other policy domains in the literature. We briefly discuss some of these below.

3.2.2.1 GIP & Green Energy Policy

The discussion above highlights that our interpretation of the literature is that GIP has a very large degree of overlap with green energy policy, but the latter is not a mere subset of GIP. There are some elements of energy transition policy which do not have sufficient direct economic benefit to classify. Similarly, not all GIP is about green energy policy (though the vast majority currently is).

[2] Note several of the reviewed papers, including Pegels (2014), do not require economic benefit as part of the definition of GIP. For these authors, demand-side policies fall into the definition of GIP even when there is no domestic industry benefiting.

[3] Tellingly the Australian government has essentially no support for electric vehicles, although some states and territories are beginning to develop policy approaches.

3.2.2.2 GIP & Innovation Policy

Elder & Fagerberg (2017. P.5) identify three types of innovation policy:

- mission-oriented policies, "aimed at providing new solutions, which work in practice, to specific challenges",
- invention-oriented policies, which "concentrate on the R&D/invention phase, and leave the possible exploitation and diffusion of the invention to the market" and
- system-oriented policies, focusing on "system-level features, such as the degree of interaction between different parts of the system; the extent to which some vital component of the system is in need of improvement; or the capabilities of the actors that take part."

All of the literature surveyed on GIP would include the first two elements of innovation policy, but most do not explicitly include system-oriented policies (Lütkenhorst et al. (2014) and Karp & Stevenson (2012) are notable exceptions). The exclusion of systems approaches is due in part to the neoclassical economic foundations of much of the GIP literature.

3.2.2.3 GIP & Strategic Niche Management, Transitions Management

A focus on systems approaches is at the core of concepts such as strategic niche management and transitions management. For this reason, similarly to innovation policy, they are broader than GIP. Examples of aspects not included in several papers on GIP include objectives of strategic niche management such as:

- "to stimulate changes in social organization that are important to the wider
- diffusion of the new technology;
- to build a constituency behind a product - of firms, researchers, public authorities whose semi-coordinated actions are necessary to bring about a substantial shift in interconnected technologies and practices." (Kemp et al, p.186)

Unlike the bulk of the literature, Hallegatte et al.'s (2013) inclusion of policies toward sunset industries is an example of a definition of GIP that goes some way toward including predominantly political-economic issues reminiscient of Kep et al.'s "constituency building" objective.

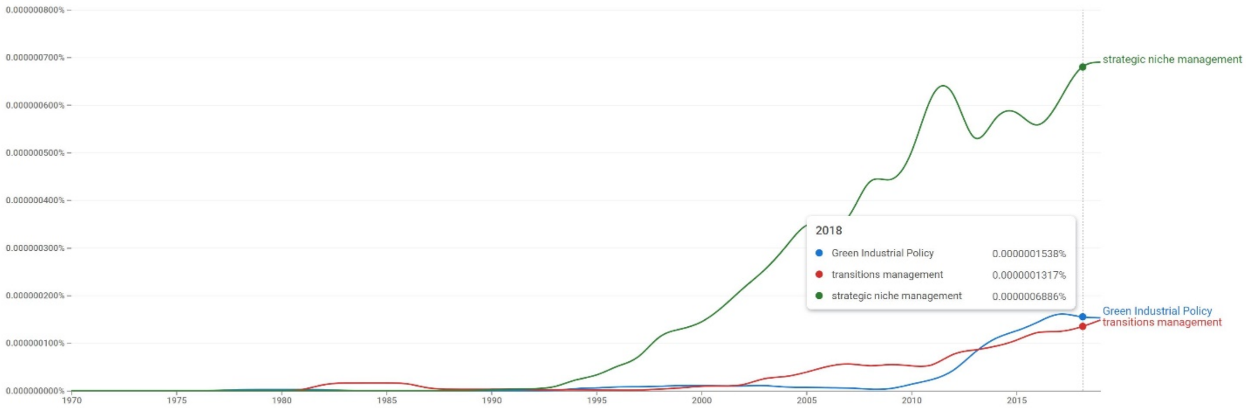
Other elements of strategic niche management are better described as recommended processes for toward GIP, than GIP itself. In particular Kemp's objective of "to articulate the changes in technology and in the institutional framework that are necessary for the economic success of the new technology" is closely related to Rodrik's (2014) emphasis on determining and setting clear objectives for GIP.

These differences notwithstanding, some elements of strategic niche management are squarely within the objectives of GIP. In particular, Kemp et al's objective 2 and part of 3:

- "to learn more about the technical and economical feasibility and environmental gains of different technology options
- to stimulate the further development of these technologies, to achieve cost efficiencies in mass production, to promote the development of complementary technologies and skills."

Finally, figure 1 shows that the concept of GIP is more recent than transitions management or strategic niche management. Indeed, its emergence is suspiciously correlated with the global financial crisis around 2008.

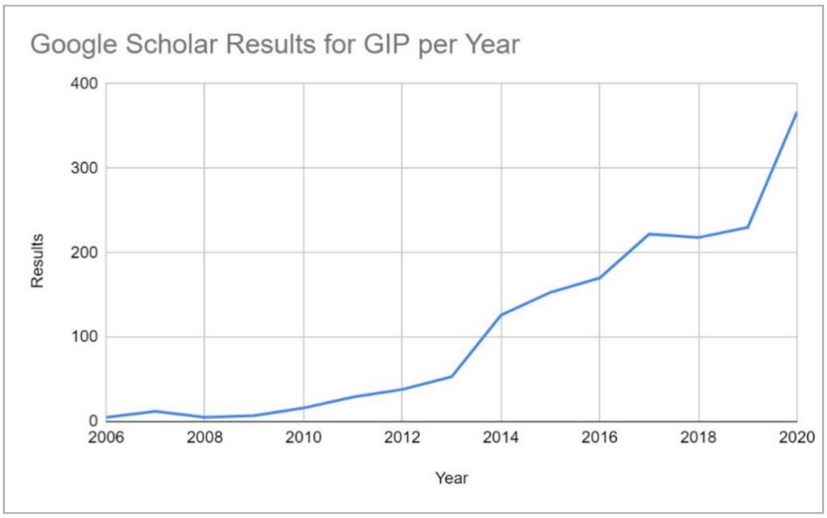
Figure 1: The frequency of the terms' occurrence in Google books. Source: https://books.google.com/ngrams, consulted 2nd May 2021.



3.2.2.4 GIP and Keynesian Fiscal Stimulus

Although not a focus of much of the literature on GIP, there can be no doubt that Keynesian-style fiscal stimulus is a key motivator. The correlation of the rise of the term with the Global Financial Crisis in Figure 1 is telling. Furthermore, Figure 2 shows that the COVID crisis has already spurred another leap in the number of references to GIP (this time in Google Scholar). Last but not least several of the largest GIP packages in the world are part of so-called "New Green Deals" – in explicit reference to the US President Roosevelt's New Deal launched to help stimulate the economy after the Great Depression (Schepelmann, 2012).

Figure 2 Google Scholar search results for "Green Industrial Policy" by year of publication. Source: own graph created using data from Google Scholar.



3.2.2.5 GIP and strategic technological competition

Another motivating factor which receives only passing attention in the GIP is geoeconomics – especially strategic technological competition.[4] Green energy is integral to the priorities of major technology initiatives in Europe, the U.S., China, and Taiwan, and technological leadership is a key motivator in the "New Green Deals" of the EU, Japan and South Korea (Doshi, 2020; Shatz, 2020).

The centrality of economic and competitive motivations for GIP is exemplified by US President Biden's recent executive order which says "this executive order, it's about jobs, good paying union jobs. It's about workers building our economy back better than before. It's a whole of government approach to put climate change at the center of our domestic, national security and foreign policy."[5]

3.3 Challenges of GIP and how to overcome them

Discriminatory trade and investment policies under the guise of infant industry protection are a key example of the traditional approaches that saw industry policy fall out of favour amoung mainstream Western economists for a few decades. Market failures are bad, it was argued, but government failure is worse. Governments either had insufficient information to "pick winners" or they were too prone to capture by vested interests (Rodrik, 2014; Hallegatte et al, 2013). Industry policy was considered a waste of public money at best, and dangerously inefficient and distorting at worst.

Over the last couple of decades, the work of authors like Dani Rodrik, Ha, Joon Chang, Antonio Andreoni, Robert Wade, and Justin Lin has reformed industry policy in the eyes of many (Chang and Andreoni, 2020; Wade, 2012). Careful study of industry policy successes and failures allowed these authors to distill recommendations for approaches to industry policy that tip the balance in favor of the benefits of correcting market failures outweighing the costs of rent-seeking and government failure.

Rodrik (2014) identifies three key institutional design features for successful GIP: embeddedness, discipline, and accountability. Embeddedness helps governments overcome informational asymmetries than can plague GIP, as such, it involves a significant amount of interaction and communication between the public and private sectors. Discipline requires support policies to be reduced or removed if they are not (or no longer) achieving goals. This, turn, requires "clear objectives, measurable targets, close monitoring, proper evaluation, well-designed rules, and professionalism." (Rodrik, 2014, p.487) Finally, accountability towards the public helps to ensure agency-business relationships are not only self-serving and helps legitimize GIP.

Importantly, Rodrik's approach emphasizes industry policy as a process of discovery for the government, and highlights the importance of updating, revising or removing policies as new information is gained. Rodrik's recommendation is elaborated by Hallegatte et al. (2013) who

[4] Fischer (2017) is an exception as she paints strategic trade policy as central to GIP.

[5] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/

recommend iterative policy design. Systematic policy learning is also one of three central requirements for successful GIP according to Pegels et al. (2018).

4 Technology Neutrality

4.1 What is technology neutrality?

Originating in the US in the 1980s,[6] the early development of the principle of technology neutrality was mainly confined to the Information and Communication Technologies sector, and the major policy objective was to promote on-line and off-line equivalence (European Union, 1998).

Since the early 2000s, technology neutrality has also been a popular regulatory and policy principle for environmental and energy policies. In his speech on climate change in 2008, the then US president G.W. Bush stated, "incentive should be technology-neutral because the government should not be picking winners and losers in this emerging market" (Roberts, 2008). The principle of technology neutrality is an important justification for an EU-wide energy roadmap – "the Roadmap does not replace national, regional and local efforts to modernize energy supply, but seeks to develop a long-term European *technology-neutral* framework in which these policies will be more *effective*" (European Commission, 2011, p. 4).

4.1.1 The definition and formulation of technology neutrality

While rarely defined in the policies in which it is invoked, definitions of technology neutrality have proliferated in the academic literature, particularly in law and public policy. In the legal literature, key contributions include Ohm (2010, p. 1685), who defines technology neutrality as the principle that "laws should refer to the effects, functions or general characteristics of technology, but never to a particular type of class of technology". Similarly, according to Selvadurai (2018, p. 18) "a technology-neutral approach to legal drafting involves a description of the result to be achieved without specifying the technology to be employed or regulated". Thompson (2011, p. 303) reflects non-interventionist approach, defining it as "law should not pick technological winners and losers, that law should neither help nor hinder particular types of technological artefacts." Thompson further proposes the criterion of "functional equivalence" (Thompson, 2011, pp. 311–312) be established as a threshold to decide *which technologies* should be taken into consideration under the principle; and the *neutrality* is demonstrated by the practice of non-discrimination among functionally equivalent technologies.

Other particularly relevant definitions of technology neutrality in the context of GIP are Wylly (2015, p. 300), according to whom TN "policy does not favor any particular means of achieving the desired goal. Specifically, a policy must equally support all methods capable of achieving this outcome". Azar and Sandén (2011, p. 135) provide a definition specific to policy for "green"/ "clean" technologies as: "policies that promote technologies with no or low carbon emissions but do not specify which such technologies should be supported".

An important distinction in the above definitions is between those which imply *de juro* that those which imply *de facto* TN. For example, the definitions of Azar and Sandén (2011), Ohm (2010), and

[6] According to (Reed, 2007), the first use of the term was in the description of the US Electronic Communications Privacy Act 1986.

Selvadurai (2018) imply a *de juro* understanding of TN because they require that technologies are not explicitly specified in the law or policy. On the other hand, Wylly (2015) and Thompson (2011) refer to TN in the *de facto* implications of the law or policy. Given the difficulty of determining whether policy is *de facto* TN, or of designing one which is known in advance to be TN, we side with the former authors. For the purposes of this paper, technology neutral policy does not differentiate between functionally equivalent technologies. A feed-in tariff which is equal for all renewable energy sources is, according to our definition, a technology-neutral policy instrument.

4.2 Why technology neutrality?

4.2.1 The political-economic view of TN

One potential motivation for TN in the context of GIP, or indeed industry policy more generally, is to reduce the scope for lobbying and rent-seeking to pervert the policy process (Australian Department of Industry, 2017; Hallegatte et al., 2013; Schwarzer, 2013; Trubnikov, 2017; Warwick, 2013). Some of these authors refer to TN as if it synonymous with non-discrimination and free and fair competition – and hence self-evidently a good principle.

4.2.2 The legal view of technology neutrality

Legal scholarship has also tended to take the wisdom of TN as self-evident, an intrinsic pursuit of law Giannopoulou (2010, p1), and a means of promoting free competition among different technologies (Rios, 2013). Thompson proposes the criterion of "functional equivalence" (Thompson, 2011, pp. 311–312) be established as a threshold to decide *which technologies* should be taken into consideration under the principle; and the *neutrality* is demonstrated by the practice of non-discrimination among functionally equivalent technologies.

An emerging and more specific justification for the principle of technology neutrality in the legal scholarship has been its effects to maintain the longevity of laws. As pointed by Giannopoulou (2010, p1), a steady feature of the law has always been the aim to remain neutral and above technological progress, in order to remain applicable to all issues stemming from technological progress. Constantly changing technologies and established legal frameworks are in continuous conflict with each other, therefore, law reform initiatives must formulate technology neutral, flexible laws that will be able to adapt and evolve with technological change (Selvadurai, 2018). Adopting technology neutrality will also maintain the coherence of the legal framework without creating voluminous and potentially overlapping and inconsistent legislative instruments (Lipinski, 2003).

4.2.3 The economic view of technology neutrality

The underlying rationales for technology neutrality as a regulatory and policy principle differ between economists and lawyers. From the perspective of neoclassical welfare economics, technology neutrality can sometimes be an emergent property of an efficient policy approach – not a defining characteristic of it.

As discussed in Section 2, an efficient (first-best) policy instrument will be targeted directly at an identified market failure. The vast majority of market failures are not specific to a particular technology, and hence the first-best policy will not be either. A carbon price is a classic example of a technology-neutral policy toward climate mitigation, favored by economists. Notably, technology neutrality arises in this case as a consequence of the underlying neoclassical welfare economic theory – not a fundamental principle of it.

Importantly, there are also situations in which the first-best policy is technology neutral. Namely, when the market failure (or extent thereof) is specific to the technology. Furthermore, this is often the case for industry or innovation related market failures discussed in the literature on GIP. For example, different technologies will exhibit varying degrees of external economies of scale (i.e. agglomeration economies); while technologies at different stages of development diffusion will suffer different levels of knowledge or discovery spillovers. Consequently, the first-best policies will be technology specific.

It is also the case that the second-best policy response may be (superficially at least) technology specific, even when the first best is not. A case in point is when subsidies for renewable energy supply are used as a second-best alternative to carbon pricing. As pointed out by Metcalf (2009), different renewable energy sources have characteristics which mean they displace different types of traditional energy sources. As a result, the abated carbon per supplied kilowatt-hour varies by technology, and consequently any subsidy intended as a second-best approach to the externality from carbon emissions should also vary by technology.[7]

4.2.4 The economic view of the legal view of TN

The legal argument for TN comprises three main elements: supporting competition, non-discrimination, and longevity and parsimony of laws. The former two of these are economic arguments, so it is appropriate to consider them from the perspective of economic theory. The latter point can also be understood from the perspective of economics as an argument about minimizing the transaction costs (alternatively implementation costs) of policy.

It is undoubtedly true that imperfect competition, with resulting market power, is fundamental, efficiency limiting, market failure. However, this is not a sufficient argument for TN in policy. For one, a TN policy will not always increase the competition between technologies. If there is a dominant technology, a TN policy will allow that dominance where a technology biased policy may reduce it. Secondly, a first-best policy aimed at a particular market failure – even a technology specific one - will never induce imperfect competition where it was not already present. A first-best response (technology neutral or not) may, however, exacerbate existing imperfect competition. In this situation, it is an empirical question which must be determined on a case-by-case basis whether the net benefit of a technology neutral or technology biased instrument is higher. Overall, "technology competition" is not a valid justification for applying technology neutral policy when the first-best policy is technology specific.

Non-discrimination is a legal and policy principle that is cherished by lawyers and economists alike. From the perspective of welfare economy theory, discrimination occurs when policy creates artificial advantages for certain actors or technologies. Importantly, the first best policy will never be discriminatory – even if it is *de juro* technology biased. The flip side of this is that deviations from the first-best policy made in the name of technology neutrality, may actually be discriminatory. This

[7] Interestingly Metcalf (2009) is actually arguing that de juro technology neutral policies of this type are not de facto technology neutral.

is essentially the argument made by Metcalf (2009) as well as by several authors discussed in Section 5.

Finally, TN can be motivated as a means of increasing the longevity and parsimony of law and policy. In economic language, this argument is to decrease the implementation costs of interventions aimed at addressing market failures. Indeed, welfare economic theory says that the presence of a market failure may provide an efficiency justification for government intervention. However, the intervention will only be welfare improving if the cost of implementing the intervention is less than the benefit obtained from addressing the market failure. Indeed, lower implementation costs is a leading reason for the adoption of second best rather than first best policy options. Unfortunately, there is no general theoretical argument which allows us to say that parsimony and longevity will always be the dominant consideration. Where the first-best approach is not technology neutral, the assessment as to which is preferred on a net cost-benefit basis needs to be made on a case by case basis.

Overall, through the lens of welfare-economic theory, TN is an emergent principle for efficient policy when the first-best policy can be applied and the market failure in question is not technology-specific. Technology neutrality may also be justifiable on a case-by-case basis when the first-best (technology specific) policy would cause either substantial costs in terms of exacerbating distortions due to imperfect competition or substantial implementation costs.

5 Technology Neutrality as a principle for Green Industrial Policy?

The discussion in Section 4.2 argued that the primary theoretical motivation for TN arises when a policy instrument seeks to address market failures which are not technology specific. In the context of GIP, the most pertinent such market failures are environmental externalities – especially those due to greenhouse gas emissions. However, most definitions of GIP reviewed in Section 2 explicitly excluded first-best policies aimed at environmental externalities form the definition of GIP (Harrison et al. (2017) was the exception). In contrast, the majority of the literature reviewed saw GIP as primarily aimed at either first-best policies towards industry and technology-specific market failures (such as knowledge-spillovers) or second-best policies towards environmental externalities. As pointed out by Metcalf (2009) the second-best policy towards environmental externalities will also generally vary by technology. Hence the primary theoretical motivation for TN does not apply to GIP. Instead, there is a theoretical case for technology specificity in GIP. Section 4.2 also noted secondary theoretical arguments for TN which arise on a case-by-case basis. The very nature of a case-by-case motivation speaks against the wisdom of applying TN as a general principle.

The empirical consequences of applying TN in GIP are well-known, and consistent with the theoretical argument against it. Considering evidence from the clean energy sector, Azar and Sandén (2011) conclude that technology neutrality is often an elusive objective that neither can nor should be prioritized as the main guiding principle. Metcalf (2009) and Popp (2019) also argue that in the clean energy sector, broad-based technology-neutral goals often implicitly favor some technologies over others.

When TN policy implicitly favours established technologies, technology lock-in leading to dynamic inefficiency can occur. This is probably the most common criticism of technology neutrality in the context of the clean energy sector (see for example Thompson 2011; Azar and Sandén, 2011; Jacobsson et al., 2017). Jacobsson et al. (2017) argue that TN mandate in the EU's energy policy is leading to neglect of policies which focus on stimulating the generation of positive externalities such as R&D investment and fostering innovative capital goods industries. According to Azar and Sandén (2011), TN policies are disadvantaging potentially important, early-stage technologies such as transmitting solar electricity from desert areas and infrastructure for hydrogen and electric vehicles.

Thus far we have considered arguments for TN only through the lens of economics. It would be fair for legal scholars to object to all of their arguments in favour of TN being converted into economic concepts and then dismissed through economic arguments. Probably the strongest legal argument for TN rests on its ability to improve the longevity of law and policy and make them more concise. Let us take consider that argument on its own terms. Two things speak against this being a major advantage in the context of GIP. Firstly, policy, by definition, does not have to go through the same legislative processes as law, and is thus much less time consuming and costly to write and update. Secondly, and more importantly, all of the literature surveyed on GIP highlighted the importance of GIP being monitored, reviewed and updated systematically. GIP should be a process of learning, not a set of static policies.

The final argument in Section 4.2 in favor of TN in was specific to industry policy. Namely, TN was seen as a means of counteracting the (substantial) potential for rent-seeking, lobbying and capture by vested interests. The argument goes that broad-based policies which do not favor particular technologies are less prone to capture by vested interests. The problem with this argument is that TN leads to ambiguity and loss of clarity; and they lead to more opportunity for policy to be captured in a way that is not in the best public interest.

There are two ways in which attempts to apply the principle of technology neutrality in law and policy can cause loss of clarity. The first is through reference to technology neutrality without defining the principle. As discussed in Section 2.1, the concept of technology neutrality can be ambiguous and numerous definitions abound in scholarship and practice. Where the exact definition of technology neutrality is not specified, the resulting vagueness enables policymakers and legislators to adhere to different meanings of technology neutrality (van der Haar, 2007). In particular, a *de juro* definition may be implied, but a *de facto* definition applied.

Moses (2003) and Thompson (2011) highlight the second reason application of the principle of technology neutrality can cause a loss of clarity - namely that drafting law and policy in technology neutral language requires a higher level of abstraction. Ambiguity can be appealing to policy-makers working on sensitive issues because it provides a means to conceal or postpone conflict by leading others to understand something in two or more ways. Ambiguity can also be exploited by powerful groups to achieve certain political purposes (Byers, 2020; Son and Lee, 2018).[8] In this context it is worth noting that established industries and technologies will generally have greater political and lobby power, and it precisely these technologies which tend to benefit most from technology neutral policies. Finally, the ambiguity caused by application of TN works directly

[8] An additional argument against TN is that policy ambiguity and uncertainty suppress investment in a range of settings (Barradale, 2010; Handley and Limão, 2015; Wang et al., 2014).

against the public transparency and accountability that Rodrik (2014) and Hallegatte, Fay & Voigt-Schilb (2013) note is a crucial element of preventing capture of GIP. Even more problematic, ambiguity exacerbates uncertainty; while one of the universally agreed objectives of GIP in the surveyed literature is to reduce uncertainty for market participants.

6 Conclusion

Green industrial policy is an increasingly important component of government responses to twin environmental and economic crises in many countries. A structured review of the literature suggests a largest common denominator definition for green industrial policy comprises sector-targeted policies that support the growth and development of certain industries and technologies, with the aim of furthering both economic and environmental goals. In the language of neoclassical welfare economics, GIP predominantly comprises first-best policies towards innovation- and coordination-related market failures in green industries; and second-best policies towards environmental market failures.

Much of the literature on GIP is based in neoclassical welfare economics. In this component of the literature, GIP is relatively easy to distinguish from concepts such as transitions management and strategic change management. Some authors, however, embrace a broader disciplinary concept of GIP (see for example Pegels (2014) and contributions therein). Their conception of GIP becomes harder to distinguish from related concepts on the basis of content or approach. None-the-less we argue that important differences remain in terms of motivation. The timing of the rise of GIP and direct arguments of governments implementing them suggest growth, fiscal stimulus, technological competition and, above all, jobs, play a much larger role in motivating GIP than they do socio-technical sustainability transitions.

Neoclassical economics is rightfully criticized for its inability to deal with complexity or systems interactions. The reward for this simplicity is analytical clarity. We apply this clarity to the concept of technology neutrality and its applicability to GIP. The neoclassical economic framework allows us to make definitive, first-principles arguments against *de juro* technology neutrality in GIP. The principle of targeting says that if the market failure in question varies by technology, so will optimal policy. In GIP, market failures which vary by technology and industry are ubiquitous. While our theoretical argument does not directly address *de facto* technology neutrality, we concur with previous scholars that this aspirational principle is vague and almost impossible to achieve in practice.

The greatest threat to successful GIP is potential capture by vested interests: “government failure” exceeding “market failure”. Indeed, addressing this threat appears to be a major motivation for proponents of the application of technology neutrality in GIP. However, the need for rules of thumb like technology neutrality is dramatically lessened thanks to the modern literature on both industry policy and GIP being cognizant of the threat of government failure, and replete with recommended approaches to avoid it. Furthermore, governments can also avoid many potential pitfalls by viewing GIP as a component of transitions management, and following recommendations from this literature. Scholars, meanwhile, could support policy-makers better by acknowledging the central role of fiscal stimulus and technology competition in motivating GIP, and adapting their recommendations in this light.

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