10 Smart green industrial policy

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1 Industrial policy is back

Industrial policy is back in vogue. Governments worldwide are turning to it as a way to promote economic growth as their economies transition to climate neutrality. With the Inflation Reduction Act, the United States has sent a clear signal that it intends to pursue climate targets through a strong industrial policy. The European Union focuses more strongly on the use of carbon pricing, but is also responding with its own Net Zero Industry Act, which seeks to protect and expand the EU's clean technology industrial output. Governments are assuming a critical role through industrial policy in smoothly managing the transition from a fossil-fuel to a low carbon energy system. Bordoff and O'Sullivan (2022) predicted a wave of "*government intervention in the energy sector on a scale not seen in recent memory*".

But a European green industrial policy will not work only by throwing more euros at the problem. If the state is to assume a more dominant role in achieving decarbonisation and accelerating green technology innovation and deployment, green policymaking must be rethought. In this chapter we focus on the development of 'smart green industrial policy' focussed on the regional aspect.

1.1 Towards 'smart' green industrial policy

This chapter discusses the targeting of green industrial policy at the regional level. We argue that such targeting is essential for a government to maximise returns.

The logic of our argument is as follows:

1. Governments wish to use industrial policy for the development of priority low-carbon technologies (a policy decision that has already been made).
2. Regions have unique technological, knowledge and institutional capacities, and these are a crucial indicator of the ability of a region to absorb new specific knowledge and innovate (widely documented in literature).
3. It is possible to identify this *comparative advantage* at regional level (documented in literature).
4. Desirable green technological capacities can be mapped against existing comparative advantages by geography, allowing a policymaker to make positive, well-informed decisions about the likelihood of regions being successful in developing a new green technology.
5. By using the above, 'smart' green industrial policy should focus on removing bottlenecks to allow regions to grow their comparative advantage in the direction of new green technologies.

In section 2, we discuss a definition of green industrial policy suitable for today's political climate. In section 3, we provide a brief overview of the fact that governments are today actively in the process of selecting priority green technologies. In section 4, we provide theoretical and empirical evidence that regions have unique capabilities and potential development pathways. In section 5, we discuss metrics widely used in the literature for measuring these regional specialisation and comparative advantages. Existing energy factor inputs have driven regional industrial specialisation, but the advent of zero-carbon energy technologies will reshape the map, as we discuss in section 6. Public policy should utilise the information discussed in sections 3 to 6 to better target regional industrial policy at alleviating broad growth constraints that prevent development into nearby green technologies – which is the focus of section 7.

2 Contemporary green industrial policy

2.1 Defining industrial policy

The main objective of industrial policy is to increase the welfare of the population sustainably. This can be pursued by ensuring that a country can generate high value added. That is, a country should try to export many goods with a substantial mark-up on top of the initial production cost. This only works if a country is very efficient at producing desirable goods that competing exporters are unable/unwilling to offer more cheaply to global markets. The country is then said to have some form of market power. At the same time the welfare of the population depends on the cost of imports. If essential import goods are monopolised by certain exporters, the importing country's terms of trade will deteriorate.

Hence, industrial policy is both about generating own market power (eg supporting a highly efficient offshore wind industry) and breaking foreign market power (eg setting up Airbus to rival Boeing).

2.2 Defining green industrial policy

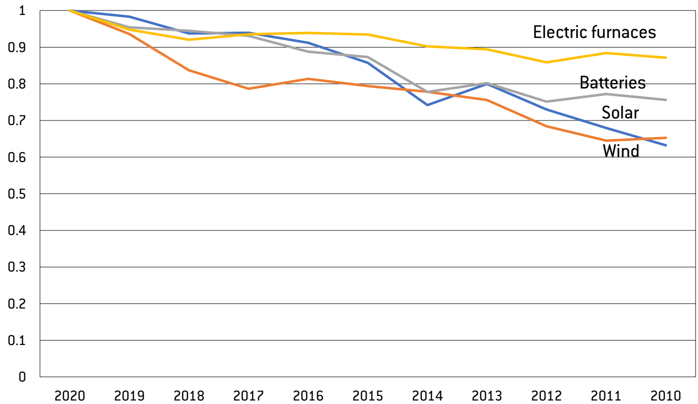
A future-proof industrial policy almost inevitably needs to have strong 'green' elements. Investments in production processes that lock in substantial carbon emissions are likely to become sunk, and the clusters around those investments, including the human skills, will lose value. Supporting this cannot be good industrial policy. By contrast, investments in low-carbon alternatives may be the first steps towards development of sustainable comparative advantages in relatively new fields – developing new skills that will see high demand in the future and pulling entire new value chains.

This implies a race between countries to host the growing sectors of the future. Using the revealed comparative advantage measure (RCA)[62],

62 Revealed comparative advantage is a computed index used in economics to determine the relative competitiveness of a country in a given class of goods or services. It is measured as the share of a class of goods or services in a country's total exports. This share is divided by the proportion of global exports of that class of goods or services.

Figure 1 indicates that current strength in exporting certain low-carbon products is strongly correlated to past strength. That means that developing competitive production and export advantages in new low-carbon products will provide a lasting advantage.

Figure 1: Correlation of the 2020 standardised RCA with the same technology's past standardised RCA



Source: Bruegel based on UN COMTRADE database. Notes: the chart shows the correlation of RCA by country for each sector over time. Each data point shows the correlation of RCA across countries for a given sector and given year compared to the RCA by country in 2020 (the most recent data). All countries for which data is available were included; the exact number of countries for each correlation depends on each year/sector export data availability.

2.3 Goals for contemporary green industrial policy

2.3.1 Reducing greenhouse gas emissions

Traditional academic rationale for government support for the development of green technologies comes from positive societal spillovers that do not directly accrue into profit for investors or entrepreneurs. The first reason for this is a form of late-mover advantage: while pioneer companies take on the risk of failure, some of the valuable side effects, including proving commercial potential, spill over to competitors. Second, falling costs of low-carbon technologies enable society to embark on lower-cost pathways to decarbonisation – think, for example, of government support in the early 2000s for solar PV and wind deployment in Europe and the United States. Third, there remains considerable uncertainty around carbon pricing and the extent of government commitment to climate targets (the Trump administration pulled out of the Paris Climate Accord, for example). Investors do not face a certain environment in which they can make green investments. The final reason is that in many cases, export markets for low-carbon products do not contain any serious climate policy, and hence pure market forces would make EU green-tech producers underinvest in low-carbon solutions (McWilliams and Zachmann, 2021).

2.3.2 As a growth strategy

In 2014, Rodrik proposed that the definition of green industrial policy be limited to only this first goal: developing innovative technologies that have the potential to reduce greenhouse gas emissions.

However, in the current political reality, green industrial policy is also being seen explicitly as a vehicle for growth: the European Green Deal, has been labelled "*our new growth strategy*" by European Commission president Ursula von der Leyen, for example. Domestic content requirements in the US Inflation Reduction Act highlight the US administration's focus on green industrial policy as a vehicle to create domestic jobs. President Biden commented that tax credits will "*create thousands of good-paying jobs*"[63].

2.3.3 To escape import dependencies

Finally, governments are also using green industrial policy as a political lever to position their own countries more strategically in a future

63 See https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/04/remarks-by-president-biden-in-roundtable-with-business-and-labor-leaders-on-the-inflation-reduction-act/.

global energy order. The inevitability of the energy transition sees governments evaluating the potential strategic dependences that may emerge in future. Europe's experience of rapid energy decoupling from Russia in 2022, and the associated challenges, have strengthened the resolve that energy systems should not be overly dependent on external suppliers.

Consequently, a third aim for green industrial policy is identified as contesting or breaking foreign market power. Rhetoric around the US Inflation Reduction Act has clearly focused on competition with China, which is perceived to have excessive power over supply chains that will be critical in a decarbonised system, such as the production of solar cells and lithium-ion batteries. The EU Net Zero Industry Act lays out the context: "*net-zero technologies are at the centre of strong geostrategic interests*", and the "*global technology race*". The word 'strategic' occurs one and half times more often than 'climate' in the document, and three times more than the word 'carbon'.

3 Identifying green sectors for intervention

Beginning in the early 2000s, governments provided substantial support for the deployment of solar photovoltaic and onshore and offshore wind generation. Since then, there has been a clear government focus on supporting specific green technologies. The European Commission in July 2020 proposed a Hydrogen Strategy (European Commission, 2020), which was strengthened in 2022 to set fixed targets for 2030 for the domestic production and import of low-carbon hydrogen. The European Union operates an Innovation Fund that supports certain technologies deemed eligible for support. A Battery Alliance was launched in 2017, aiming to make Europe a global leader in sustainable battery production and use. The draft Net Zero Industry Act now lays out a range of technologies in which the EU aims to achieve 40 percent production capacity relative to deployment by 2030.

Bringing down the cost of low-carbon technologies and thereby enabling large-scale decarbonisation in the EU and beyond is the most tangible benefit. But mastering the technology, creating new production clusters and gaining a competitive edge in sectors that will become very large global markets certainly contribute to the boldness of interventions. Electric vehicles are expected to dominate the market for new passenger vehicles in less than a decade; renewable power generation investments are already larger than fossil-fuelled investments. For heating installations, energy-intensive industries and heavy road, maritime and air transport, low-carbon alternatives will also have to surpass the often technologically quite different incumbent fossil technologies in the next decade.

This is a real new deal as some incumbent strength (eg in internal combustion engines) will quickly depreciate, making space for entrepreneurial newcomers. As demand for these technologies might initially outpace supply, substantial margins might be available.

Though comparative advantages in green technologies are not as entrenched as those in many conventional technologies, the potential to develop certain sectors is not distributed evenly between regions. Desirable areas for development of green technologies can be mapped against existing regional comparative advantages. A region's existing specialisations can be a predictor of future potential specialisation (Bergamini and Zachmann, 2020).

A better understanding can thus be developed about the suitability of particular regions to develop capacities in any given direction. Such a strategy can build on academic demonstration, such as that by Bergamini and Zachmann (2020). Hausmann *et al* (2021) presented an empirical framework that allows policymakers to estimate potential comparative advantage, including for industries not currently present in a region.

BOX 1: Energy-intensive industries typically have low value-added

European energy prices have increased drastically since 2021. This has put the spotlight on the relatively high share of energy-intensive sectors in some European regions. This leads to the very uncomfortable policy question of whether energy-intensive production should be defended, (in)directly subsidising its energy use? For the most energy-intensive products this is hard to justify if viewed only in terms of value added and jobs. A few European sub-sectors require a lot of natural gas as a feedstock and/or energy to produce a product that has little value added as it is a globally traded commodity. Mertens and Müller (2022) found that if Germany were to import products with high gas intensity and import substitutability, industry could reduce gas demand by 26 percent, while losing only 3 percent of final sales, and less in value added. Hence, strong strategic reasons are needed to justify enabling these sectors to use scarce energy (and thus drive up the energy price for all other European industries) for these processes.

4 Regions are unique and this drives development

4.1 Conceptual consideration

Economic activity is distributed unevenly across geography. Different regions have different industrial and institutional structures, different educational, human and physical capital bases, and different access to production factor inputs, such as primary energy. The result is that agglomerations form, with similar firms co-locating in the same area, enabling knowledge spillovers. Areas evolve to become specialised in certain economic activities and develop location-specific advantages, including in transportation and energy infrastructure, access to particularly skilled labour, knowledge spillovers and economies of scale. Geographic regions develop comparative advantages in particular sectors, which grow over time. These specialisations are best understood at the regional, not national level. Consider Belgium, a small country, but with diverging specialisations between its chemical industry in Antwerp and automotive industry in Ghent and Brussels.

4.2 Uniqueness influences a region's ability to absorb new knowledge

A firm's ability to comprehend and absorb new knowledge is conditional on its own knowledge base (Cohen and Levinthal, 1990). For a given regional domain of knowledge and technical capacity, growth paths are then biased toward economic activities related to the region's existing skill base. This is a result of regions being better able to absorb new knowledge when it is more closely related to an existing domain. Tacit – as opposed to codified – knowledge is particularly important as it cannot be copied easily and is geographically restricted (Balland *et al*, 2018). Where external knowledge is unrelated, the existing industrial base will struggle to learn from it and develop economically. Political attempts to impose knowledge or technological capacity that is deemed strategically important, but unrelated to a given region, has been described as attempting to build "*cathedrals in the desert*" (Balland *et al*, 2018). Todtling and Trippl's (2005) summary of literature showed that knowledge spillovers are often spatially bounded, while knowledge spills over effectively only when complementarities exist among sectors (Boschma and Iammarino, 2009).

4.3 Empirical evidence from the literature

Boschma and Gianelle (2014) summarised the empirical literature, concluding that the ability to develop new growth paths is not equal in all regions, while trade profiles tend to remain constant because of increasing returns to scale and non-transferable tacit knowledge that is accumulated over time. Bergamini and Zachmann (2020) complemented this with regional patent data from the OECD to identify technological clusters at NUTS-2 level in the EU. In a second step, the authors used network proximity between existing technological base and 14 innovative green technologies to estimate the potential advantage regions may have in each tech.

Hidalgo *et al* (2007) showed that countries expand their mixes of exports around products in which they have already established a comparative advantage. Neffke (2011) found that Swedish regions diversify into industries that are related to their current portfolio of industries, and that industries which leave the region are typically located at the periphery of the existing technology portfolio.

On green technology specifically, Montresor and Quatraro (2020) performed patent-based empirical analysis for 240 NUTS regions, to show that relatedness to pre-existing knowledge makes a new green-tech specialisation more probable. An important contribution is the clarification that non-green tech specialisation is still important, and perhaps even more so, for developing green tech capabilities. To develop capacities for building hydrogen pipelines, it is helpful to have existing skills building natural-gas pipelines.

Boschma and Iammarino (2009) related the import and export structure of Italian provinces, to show that regions benefit particularly from extra regional knowledge when that knowledge originates from sectors that are related, but not too similar, to those present in the region. If cognitive proximity is too close, nothing is learned.

Box 2: Problems with picking winners

The key problem of industrial policy is the risk of 'picking winners': governments trying to decide in favour of which sectors/technologies/companies they are tilting the playing field. It is already intrinsically difficult to beat the market (where equity and finance providers should have a strong incentive to bet on the right horse). But governments not only typically lack the resources to make good choices, they are also politically more accountable to incumbent interests than to those unborn sectors and jobs. Moreover (hidden) distributional motives to favour specific regions/stake-holder groups over others can even inefficiently bias 'horizontal industrial policies'.

Following intervention, there is a risk of evaluating support given to incumbents overly positively, as the high indirect cost of withholding resources (skilled people, energy, finance) from new sectors is not properly accounted for.

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5 Identifying regional comparative advantage

Regions typically do not become active in all industrial sectors at once. They specialise in several sectors in which they are particularly successful. Thereby, sectoral success in a region is driven by a complex combination of local knowledge, specific human capital, infrastructure, geography, input factor cost/availability, economic, industrial and institutional organisation. Some of these factors are relatively rigid, some are endogenous to past development and some can be shaped by policy. The combination of these factors can be said to determine a region's *comparative advantage*[64]. Every region, by definition, has a comparative advantage. It is a challenge to identify in which sectors this not directly observable advantage lies.

Bottom-up approaches mapping out specific regional factor endowments (eg based on regional labour surveys, energy cost and infrastructure statistics, etc) are possible. But as so many drivers determine a comparative advantage in a specific sector, and some factors are rather difficult to measure directly (and in an internationally comparable way), reliable bottom-up approaches are extremely challenging.

An alternative and/or complement is indirect approaches based on current outputs, rather than available inputs. Here, identifying comparative advantages can be approached empirically, in two steps:

1. Identifying the economic activities, and innovation efforts, currently present in a region;
2. Using known technological and knowledge linkages to project potential future specialisation.

64 The ability of a firm, region or country to produce a particular good or service at a lower opportunity cost than competitors. Opportunity cost is key to *comparative* rather than *absolute* advantage, and the idea that every economic actor in a system has *comparative* advantage at producing something.

5.1 Identifying current regional specialisation

Where market data is available, a typical step for translating this into comparative advantage is assessing export and import structure. The logic is that trade brings a region into direct competition with neighbouring and competitors further afield. Therefore, if a region is particularly successful at exporting a particular good, it is likely to be competitive in that sector. Export data has often been used to map national comparative advantage (eg by calculating the Balassa (1965) revealed comparative advantage index), for example by Hidalgo (2007), Boschma and Iammarino (2009), Zachmann (2016) and Hausmann (2021). However, trade data is typically not available at regional level[65] and so alternative indicators should be used to explore current regional specialisation.

Identifying current economic activities present in a region is relatively straightforward. For Europe, regional economic data is widely available for industrial output, employment, production and value added, but much of the data has only a (very) limited sectoral/product resolution. To have not only regional, but also sectoral and temporal granularity, more indirect sources might be needed.

Regional specialisation can be explored using labour-market data. For example, text mining of job vacancy descriptions and using artificial intelligence methods to develop up-to-date classifications can offer granular insights into regional specialisation trends (even slightly forward-looking).

Patent data is another source of information. A patent offers legal protection for new and innovative products or processes. Such data therefore can provide a very granular indication of technological and scientific data on a sectoral basis (see for example, Bergamini and Zachmann, 2020; Montresor and Quatraro, 2020). Data is publicly available for very specific locations and narrowly defined technological

65 Customs data might be in principle available at the zip-code level – but we have not seen them made accessible to research.

domains. Making them comparable internationally is not easy[66], but using relative frequency of technologies in specific regions gives an indication of a region's specialisation.

5.2 Exploiting linkages between sectors

Consistent with Hidalgo and Hausmann (2009), we can view the product space as a representation of the underlying economic factors that influence competitiveness. If a region specialises in producing semi-conductors, condensers and photovoltaic cells, this indicates the presence of economic factors that are conducive for such activities. There are relatively strong (and typically intuitive) linkages between specialisations. Turning this around, a region that specialises in a certain sector indicates that certain economic conditions are present, which also increase the likelihood of successfully specialising in related economic activities.

For export data, establishing the links between specialisations can be done relatively directly by exploiting the coincidence of revealed comparative advantages, eg through correlation or some regression analysis. Boschma and Gianelle (2014) proposed that relatedness between industries can be measured in different ways, including: industry classification codes, co-occurrence of products, input-output linkages and the intensity of labour reallocations between industries. As patent data classifications are much more granular and patents typically have more than one classification, Zachmann (2016) used the relative frequency with which two industry codes appear for the same patent to establish linkages between specialisations.

Building on the above, one approach to identify regional potential is to use predictive algorithms trained with historical data. That is, current specialisation on a regional level is regressed on past

66 Patents are still not a perfect indicator of innovative activity. They measure only specific steps in the innovation process, and only apply in case entrepreneurs do apply for legal protection. Their quality can vary significantly, with some sectors, such as photovoltaic cells, being characterised by wider patent categories than others (Zachmann, 2016).

specialisation in the corresponding product space. The obtained coefficients allow extrapolation for any region of which technologies are more or less likely to emerge, based on past specialisation trends.

Box 3: From official statistics to big data

Pre-defined industrial and geographical classifications will not necessarily map well to a dynamic reality. For example, the 'Modifiable Areal Unit Problem' refers to the fact that clustering does not always take place at the geographic scale of available data (eg NUTS-2), and working at inappropriate scales can distort results. Second, industrial classifications are backward-looking and may constrain understanding of emergent sectors, including low-carbon tech applications, which may sit across multiple industries. Stich *et al* (2023) cited the fact that the NACE classification is over a decade old.

Recent, innovative attempts in the literature have been made to utilise big data and web scraping techniques for better identification of regional clusters. Stich *et al* (2023) scraped a dataset of archived webpages, which they interrogated using natural language processing techniques, to build a bottom-up classification of economic activities, alongside physical trading addresses that businesses report on their websites. They argued that their novel methodology can overcome traditional limitations, and successfully applied the methodology to the postcode region of Shoreditch, London. Papagiannidis *et al* (2017) applied a big-data mining methodology to identify regional clusters, applied to the northeast of England.

Making approaches based on very granular big data productive for industrial policy-making should allow for better targeting.

5.3 Interacting with industry

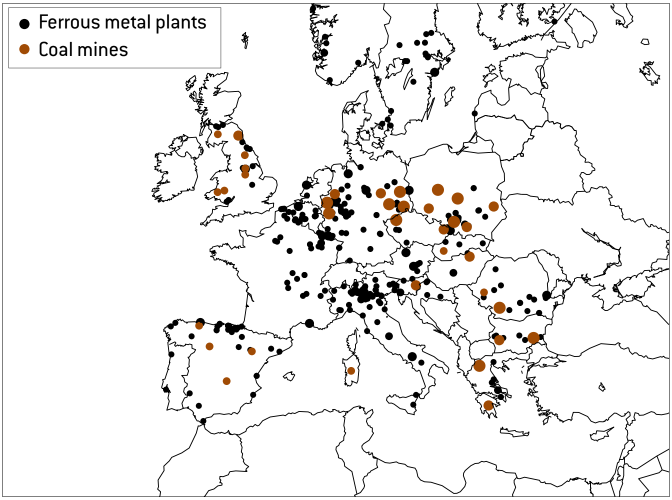
Finally, for all the quantitative and innovative analysis, having people on the ground engaging with local stakeholders will remain fundamental for regional policymakers to understand community specialisations and needs. In seminal work, Rodrik (2014) argued that the state should build on knowledge that resides in the private sector, in a pragmatic way. This requires significant communication between public and private sectors, with the state embedded but not 'in bed' with private interests (Tagliapietra and Veugelers, 2020). The challenge is for forums to be established in which policymakers can learn from entrepreneurs, but not fall prey to lobbying attempts and vested interests when designing policy.

6 The new energy map: evolving factors of production

Regions have unique comparative advantages, and empirical methods can reliably identify these. Maps of least resistance can be designed which plot the likely ability of any region to diversify into a desirable green technology.

One specific extension must be added to include the evolution of energy as a relative input cost. Europe's existing heavy industrial base has developed on the back of location-specific access to cheap fossil fuel-based energy. Bridge *et al* (2013) found that Europe's geographical pattern of industrialisation "*closely coincided with the geological distribution of coal beneath the ground*".

Figure 2: Historically, ferrous metal facilities were built close to coal deposits



Source: Bruegel and Alves Dias *et al* (2018).

The energy transition implies that access to cheap fossil-fuel energy will no longer be a relevant factor for locational decisions. Instead, access to cheap, low-carbon energy will become important. McWilliams and Zachmann (2021) used the following framework to evaluate the extent to which the low-carbon evolution will change economic geographies, comprising three elements:

1. Location-specific differences in the cost of capturing clean energy;
2. The technological ability to cheaply transport this energy;
3. Existing 'sticky' agglomeration effects where investments, and policy support are drawn to existing capital and human investments.

Consequently, *maps of least resistance* must be adapted to include information about anticipated access to cheap, green energy, and the impact this will have on future competitiveness. The necessity of energy transformation can be considered an exogenous shock to a region's initial endowment. All else being equal, it will impact the comparative advantage and subsequent innovative capacity of a region.

Geography and endowments of renewable capacities (wind, sun, flowing water) are important, but government policy will also be heavily influential. Local regulations concerning land availability are fundamentally important for factor (1): *costs of capturing clean energy*. Policymakers play a central role in infrastructure development of electricity grids, and potentially hydrogen grids, which determine factor (2): *the ability to cheaply transport energy to a given region*. Policy may also choose to artificially reduce energy input costs through preferential industry tariffs or by flattening electricity costs across a country irrespective of location.

Existing and proven approaches can and should be used by policymakers to produce detailed *comparative advantage* maps. Onto this, desirable innovations can be contrasted against existing *comparative advantage*, as along with information on low-carbon energy input costs. Ideally, the industrial classification for calculating this *comparative advantage* should adapt over time as new low-carbon industrial processes develop that will not necessarily fit neatly into existing classifications. The use of more than one classification based on different techniques can provide a more holistic picture. The first steps toward such an approach have been undertaken by European governments under the Research and Innovation Strategies for Smart Specialisation (RIS3), as part of EU Cohesion Policy (Gianelle *et al*, 2020a), including initial priority visualisation[67].

Such information could be used as a tool for regional bottom-up approaches to identify relevant sectors to approach, and for national top-down approaches through which the most suitable regions are identified for supporting priority technologies.

67 See https://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-tool.

7 'Smart' green industrial policy

7.1 One size-fits-all is not suitable

The primary consequence of regional uniqueness is that a one-size-fits-all industrial policy is not appropriate and should rather be tailored to regional needs. This follows from the fact that the leveraging of structural economic factors that are typically considered to drive growth will have different impacts in different areas. What matters for regional economic growth is the interaction of structural factors, not simply their aggregate volume (Zachmann, 2012).

7.2 Truly horizontal industrial policy is impossible

A regional economy cannot reach 'critical mass' in every domain, but must specialise. A local government cannot achieve all the specific capacities and infrastructure needed for all economic activity, so must specialise (Foray, 2017). Moreover, truly horizontal industrial policy is impossible. Each unique economic activity requires a set of specific inputs for success, many of which are influenced by public intervention. Public intervention, by definition, therefore, will not be neutral, but will have different impacts on different industrial bases (Hausmann and Rodrik, 2006). With information on regional *comparative advantage*, industrial policy can be tailored to put in place specific support that will best grow local knowledge.

7.3 Geographically targeted 'green bets'

Governments do not, and cannot, 'pick winners'. Instead, green industrial policy is built on the principle of making informed 'green bets', which at the individual level may or may not turn out profitable. What is desirable is that the aggregation of these green bets creates a portfolio which generates positive societal return. The public nature of industrial policy means intervention is centred on areas that lack private investment due to the largely socially externalised returns involved (see section 1).

To this understanding, smart green industrial policy adds the notion that policymakers target 'green bets' geographically. After the smart gambler picks a horse, he walks the length of the track to find the bookmaker offering the best odds on his choice. In similar fashion, when making green bets, governments should scour the range of geographically specific *comparative advantages*, to find the best odds of success. Alternatively, regional governments operating within a given *comparative advantage* should optimise public intervention to leverage domestic capacities.

7.4 Removing specific bottlenecks

Based on an evaluation of a regions *comparative advantage*, policymakers should look to remove and address bottlenecks that are slowing evolution into nearby green technologies. This does not entail simply providing subsidies to incumbent firms, which should only be a last-resort policy measure.

Instead, the goal for industrial policy is to facilitate organic growth toward green, innovative sectors. With defined technologies in mind, policies attempt to use industrial policy measures to smoothe the transition of industries and knowledge into said areas. This should be focused on bottlenecks that have public-good characteristics, which individual companies cannot solve, such as the provision of infrastructure. Regulatory measures, public spending on R&D, specific curricula at universities and colleges, public-private partnerships, support for commercialisation of research ideas, specific training of local workforces and encouragement of knowledge exchange between similar regions, can all be tailored to fit this design.

It is a challenge to identify bottlenecks that hold up development of individual technologies in certain regions. It is another challenge to implement smart policies to alleviate these bottlenecks. Smart specialisation has been a target for EU Cohesion Policy since 2014. In their review, Gianelle *et al* (2020a) concluded that regions put significant effort into defining priority areas for development, but then did not use this information to orient policy implementation. That is quite possibly because regional authorities lack the capacity, and know-how to do so. Bergamini and Zachmann (2020) provided a first step in this regard by empirically associating a variety of economic indicators with regional specialisation. Determining causality is an area for future policy-relevant academic research.

One temptation will be to subsidise an individual factor input cost. For example, policy could design industrial tariffs for electricity prices that provide lower prices for industries in a certain region. Governments might also consider subsidising the imports of new green fuels, such as hydrogen toward existing hubs. This approach only creates *artificial* specialisations in a region, dependent on government support, and are therefore not desirable. They will likely be driven for political reasons and are hence at risk of rent seeking. In cases where policymakers want to use such a tool, they should be explicitly limited in time.

7.5 Policy learning

The decision to embark on a revolutionary industrial policy programme of green technology development, that will reach into the billions of euros, must be accompanied by a rethink of, and improvements to, policy functioning. Significantly increased resources must also be made available to the public sector for more efficient distribution of the increased funds.

Government analytical capabilities should be developed for mapping out both regional *comparative advantage*, and *maps of least resistance*. Gianelle *et al* (2020b) argued that this will require the establishment of stable and accountable policy teams at the regional level, which are not vulnerable to political cycles, but accountable for the implementation of smart green industrial policy design.

The innovative and experimental nature of smart green industrial policy means active learning is important. Failures can be celebrated, but the public sector must learn from them. Built-in *ex-ante* and *ex-post* evaluation of policy is key. Each intervention should be accompanied by clear guidelines that will be used to evaluate its success at predefined time periods.

8 Conclusion

Industrial policy is set to play a critical role in the decarbonisation efforts of the next decade, providing billions of euros in public support. The challenge of stimulating innovative green technological development, whilst boosting domestic growth and reducing strategic import dependences, is significant. It is imperative that the public sector develops better competences for more efficient distribution of limited funds.

In this chapter, we have focused on one element: the idea that industrial policy should be focused on alleviating constraints, thus allowing regional *comparative advantages* to flourish and grow into nearby desirable green technologies. A wide literature base has shown that regions have unique potential growth pathways, and emerging analysis is demonstrating proven techniques for identifying these specialisations at decomposed granularities.

An area for future research remains the type of policy intervention that can best alleviate bottlenecks at regional level. We warn against firm-specific support, or artificially lowering the prices of certain energy inputs. Instead, support should focus on removing bottlenecks which have some public good nature, such as infrastructure provision. The targeting of this support to regional specificities will ensure that public support is efficient and provides the best chance for countries to successfully develop competences in the green technologies of the future.

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