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Jakob Hafele[1], Laure-Alizée Le Lannou[1], Nils Rochowicz[2,3,4], Sonia Kuhls[1,5], Claudius Gräbner-Radkowitsch[1,6,7]

1: ZOE Institute for Future-fit Economies
2: Institute for New Economic Thinking, University of Oxford
3: Department of Economics, Chemnitz University of Technology
4: Mathematical Institute, University of Oxford
5: Business and Economics, Berlin School of Economics and Law
6: Institute for the Comprehensive Analysis of the Economy, Johannes Kepler University Linz
7: Europe University of Flensburg

Abstract: Achieving compatibility between economies and planetary boundaries poses a momentous challenge. It requires a fundamental restructuring of current industrial systems, with a dual focus on the creation and protection of green technologies and firms, as well as the redirection of workers and technologies from ecologically harmful activities to support sustainable production patterns. This paper acknowledges that during the process of green industrial restructuring, certain non-future fit sectors will inevitably decline due to regulatory requirements or reduced competitiveness. Allowing market forces to solely determine the decline of these sectors would result in extensive economic and social consequences. Instead, this paper advocates for the implementation of active industrial policies to facilitate the phasing out of non-future-fit sectors and to ensure a just transition for the workers affected.

To this end, the paper introduces a data-driven political framework with two objectives: 1) identify emission-intensive sectors with limited potential to stay competitive (non-future-fit sectors) and 2) identify sectors capable of absorbing workers from declining sectors while presenting better economic potential (complementary future-fit sectors). Despite the data limitations, applying this framework in Germany and Hungary reveals two significant challenges. First, the results indicate a limited number of skill-related sectors able to absorb workers from declining industries, highlighting the reluctance of workers to adapt to the changing landscape due to the costs associated with retraining and relocation. Second, a market-driven approach to the green transformation is likely to result in gradual shifts, requiring ongoing worker retraining as other problematic sectors decline. These preliminary findings underscore the need to anticipate these challenges and prioritise worker retraining and skill development, particularly in cases where there are limited complementary future-fit sectors.

Keywords: Green Transformation, Industrial Policy, Competitiveness, Emission Intensity, Economic Complexity

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ZOE Discussion Papers present economic and socio-scientific analyses of potentials and barriers for a future-fit economic system.

1. Introduction

In contemporary economic discourse, industrial policy has made a resurgence as a driver of the green transformation. This marks a departure from the laissez-faire approach of the 1980s which advocated for the best industrial policy being "no industrial policy at all" (Chang, 2015: 30).[1] Scholars and policymakers now go beyond questioning whether industrial policy makes sense (Gray, 2013; Ocampo, 2019; Stein, 1992) to focus on how it can be carried out (Lin and Chang, 2009; Mazzucato, 2013; Rodrik, 2008; Stiglitz et al., 2013). The failure of unfettered markets to internalise environmental costs at the necessary scale and speed underscores the integral role of industrial policy in preventing catastrophic climate breakdown (Mazzucato et al., 2020; Rodrik, 2008). The recognition of this fact has contributed to this shift in focus.

As a result, major powers are deploying their industrial plans and taking advantage of the opportunity to embrace a proactive approach to economic policy. As one such player, the European Union (EU) recently launched its "Green Deal Industrial Plan" (01/2023) with the aim of achieving climate neutrality by 2050. The industrial plan aims to position the continent as a green economy powerhouse by providing financial support to scale up green industries. At present, the plan's funding is primarily at the national level of member states, with the relaxation of state aid rules in the Temporary Crisis and Transition Framework (TCTF; 03/2023).

However, achieving climate targets requires not only scaling up green industries but also redirecting technologies and workers from ecologically harmful activities to facilitate sustainable production patterns. This necessitates a fundamental restructuring of the industrial ecosystem (Andreoni, 2022). Such industrial restructuring can be motivated by diverse reasons, including regulatory compliance with international laws such as the Paris Agreement, exposure to price increases and energy input volatility, and potential competition from environmentally friendly competitors emerging in new market ecosystems.

Regardless of the reason, the implication remains the same: the most ecologically harmful sectors must either adopt sustainable production structures or risk market exit. If governments were addressing this challenge by relying primarily on market-based mechanisms, such as the EU Emissions Trading Scheme (ETS), this would have drastic economic and social consequences. For instance, even the existing emissions regulations are estimated to affect around 137,000 workers in the German automotive industry alone (Ifo Institute, 2021).

In this context, this paper advocates for the implementation of proactive industrial policies to guide the inevitable scaling-back of non-future-fit industries and ensure a just transition for affected workers. By identifying potential green industries with similar skill requirements, policies can facilitate a just transition by either promoting the growth of these industries or, in cases where options are limited, investing in worker retraining and skill development. This is based on the acknowledgment of the fact that certain non-future-fit sectors will inevitably be reduced due to regulatory compliance or loss of competitiveness during the transformation to a green economy. The German Energiewende, despite its undeniable drawbacks, exemplifies this approach as it proactively scales back sub-sectors such as coal mining to facilitate a socially just process, rather than leaving the decline of this industry to market forces alone.

To achieve this goal, we propose a policy framework encompassing two major steps: first, identifying emission-intensive sectors with limited potential to stay competitive (non-future-fit sectors) and, second, identifying sectors that present strong economic potential and can absorb workers from declining sectors (complementary future-fit sectors). Given the complexity of identifying complementary sectors, we also outline general industrial policy strategies to address possible tensions between conflicting goals.

[1] This paper uses the standard definition of industrial policy as "any policy that attempts to affect the evolution of specific industries through state intervention" (Chang, 1993)

To this end, the paper is structured as follows. After providing a concise review of the relevant literature on industrial policy in section 2, section 3 describes the methodology used to identify non-future-fit and complementary future-fit sectors. Section 4 then outlines some general industrial policy strategies to deal with trade-offs when identifying the latter. This methodology is then illustrated by its application to two case studies: Germany and Hungary in section 5. Finally, section 6 discusses the policy implications of the results, and section 7 summarises the findings and points to avenues for future work.

2. Literature review

In the following, we first provide a historical analysis of industrial policy, pointing to the need to leverage targeted industrial policy to address contemporary social and ecological challenges (section 2.1). We then argue that industrial policy should not only be understood from a phasing-in perspective but should also anticipate and mitigate the impending and necessary restructuring of ecosystems to meet such challenges, emphasising the need to offer a just transition for workers in sectors that need to be phased out (section 2.2).

2.1. Historical approaches to industrial policy

2.1.1. 19th century to post World War II: infant-industry promotion and the appraisal of industrial policy

The first stage of the debate on industrial policy dates back to the late 18th century (Andreoni and Chang, 2019). At that time, economists supported immediate government promotion of the manufacturing sector to facilitate catch-up economies in climbing up the industrial ladder (Andreoni and Chang, 2019; Chang, 2002; Reinert, 1995). At the core of the argument was the idea of protecting infant industries (List, 1856): the state needs to safeguard its nascent industries and provide them with the opportunity to develop before they can compete in international markets (Chang et al., 2016; Hauge, 2020). Common policy tools included import tariffs, capital flow controls, and export subsidies (Hauge, 2020). These government measures aimed to push infant industries towards higher productivity, higher-skilled activities, which were expected to drive production and innovation (Andreoni and Chang, 2019; Cohen and DeLong, 2016). Indeed, most of today's advanced economies implemented infant-industry measures during the early stages of their development (Allen, 2011; Chang, 2002).

In the post-World War II period, structuralist economists further reinforced the initial phase of the industrial policy debate by developing various concepts to provide a more systemic explanation of the infant-industry argument (Furtado, 1965; Prebisch, 1950; Singer, 1996; Sunkel and Paz, 1970).[2] This understanding of industrial policy continued to influence policymakers and played a crucial role in the economic policies that facilitated the remarkable development of East Asian economies in the late 20th century (Chang, 2002).

2.1.2. 1980s onwards: the laissez-faire approach and critiques of industrial policy

The second phase of the debate dates back to the beginning of the 1980s. The dominant narrative shifted to the delegitimisation of state intervention in economic policy. This fundamental shift arose from the perceived failure of Keynesian deficit spending as a tool to drive growth in response to the drastic shocks of the joint oil crises in 1973 and 1979 (Barro, 1979). The laissez-faire approach to industrial policy argues that the "best industrial policy is none at all" (Chang, 2015: 30).

An important concept upholding the laissez-faire approach is the theory of comparative ad-

[2] Another well-acknowledged concept is Hirschman's "big push" argument (1958), which states that when per capita income is low, demand can be lacking, leading firms to lack the revenue needed for upgrading their production. This underscores the importance of state intervention and protection (Murphy et al., 1989).

vantage (Ricardo, 1817). It suggests that countries should specialise and export in industries in which they are comparatively more productive (Bajona and Kehoe, 2006). According to the updated interpretations of Ricardo's work, the removal of industrial policies frees the space for market signals that can direct investment into comparative-advantage-conforming industries and away from unproductive and inefficient structures (Lin and Chang, 2009; Stein, 1992). This work was meant to refute the infant-industry argument and argued instead that free trade would incentivise technological innovation by providing an enabling environment based on market rationality for the private sector (Weiss, 2020).

2.1.3. At present: industrial policy only to fix market failures

Today, the laissez-faire view on industrial policy has 'lost its dominance' (Chang, 2015). At present, the debate is not focused on whether industrial policy should be used, but on how (Lin and Chang, 2009; Chang, 1993; Greenwald and Stiglitz, 2013; Hausmann and Rodrik, 2003; Pianta et al., 2020; Rodrik, 2008; Wade, 2012).[3] This changed consensus is mainly due to a growing agreement on the universal presence of market failures, which requires governments to do more than a pure laissez-faire approach (Lin and Chang, 2009).

The consensus is, however, not universal, and two main lines of argument can be distinguished. First, the market-espousing approach, which is rooted in the laissez-faire approach to industrial policy. It argues that industrial policy should limit itself to fixing market failures whether they be static (monopoly, provision of public good – under-provided RD) or dynamic (path dependency, lack of international cooperation, see Aiginger and Rodrik, 2020). The need to fix market failures is exemplified with the information-externality argument, whereby investments are not made in industries because the initial entrepreneurial firm is afraid of providing a free experiment to competitors who could then imitate it and deprive it of its profit (Hausmann and Rodrik, 2003; Rodrik, 2004, 2008).

The second line argues that rather than facilitating the exploitation of a country's comparative advantage, state intervention should be about defying comparative advantage to facilitate industrial upgrading (Lin and Chang, 2009; 490).[4] This is because, given the process of factor accumulation and technological capacity-building, it is not possible for developing economies to accumulate capabilities in new industries without defying their current comparative advantage (Lin and Chang, 2009; 491). While the two lines of argument agree on the relevance of industrial policy in general, they disagree on the kind of industrial policy that is adequate.

In this context, scholars differentiate between vertical and horizontal industrial policies. Vertical policies are selective, or targeted, in that they explicitly favour some activities over others (Chang, 1993). Horizontal policies, on the other hand, are general in that they supposedly benefit all industries equally. These include policies focused on education, research and development (RD), or infrastructure. Horizontal policies are usually favoured by scholars following the market-espousing approach (Little, 1982). This is because horizontal policies limit themselves to providing public goods that are under-provided by the market but that benefit all industries equally. As such, horizontal policies mean to ensure that governments do not involve themselves in selecting industries to protect over others, and that the market thus remains the primary force in selecting which industries become competitive. Conversely, scholars following the market-defying approach to industrial policy usually call for targeted industrial policy to facilitate industrial upgrading (Chang et al., 2016).

[3] See Lin and Chang (2009) for a comprehensive overview of the debate.

[4] This is founded on the empirical fact that developed, rich, countries export almost all products while developing, poor, countries solely export a small subset of these products (Hidalgo et al., 2007).

2.1.4. Towards the future: industrial policy to 'govern the market'

Today, humanity faces the challenge of transforming industries to achieve environmental goals and prevent climate and ecological collapse (Chang and Andreoni, 2020). The past decades have shown that the approach of fixing market failures is unable to deliver such transformations in the time and scale needed. In fact, it is possible that countries with comparative advantages in unsustainable industries, and hence no market-based incentives to transform their economic growth model, might block further international climate agreements and policies if they are unable to actively transform their economies (Gräbner and Hafele, 2022).[5]

In this light, the mission-oriented approach to industrial policy has garnered significant attention (Mazzucato et al., 2020). This approach recognises that relying on the private sector alone cannot achieve the necessary market-defying transformations to shift from current comparative advantages and create a new green development model. This is because, without sufficient incentives to invest in uncertain ventures, the private sector tends to focus on static output growth rather than dynamic skills upgrading (Hauge, 2020).

Consequently, the state should act as an 'entrepreneurial agent' able to catalyse activities and boost expectations about future growth areas by harnessing the private sector's competitive assets (Mazzucato, 2013; Mazzucato et al., 2020).[6] Indeed, with its exceptional fiscal abilities, the state can take on the risks associated with market-defying investments that private investors lack (Andreoni and Chang, 2016; Crespi and Guarascio, 2019; Mazzucato, 2013; McKelvey and Saemundsson, 2018). China's solar panel industry exemplifies the potential of green sectors that rely on latent comparative advantages requiring initial state support for growth.[7]

2.2. Industrial policies for deep industrial restructuring

The energy transition is a complex process that requires not only the expansion of green sectors and technological solutions but also the contraction of industries that lack the potential to become sustainable in the future. Deep industrial restructuring of global production and consumption patterns is necessary to facilitate a just transition away from fossil fuels (Andreoni, 2022). Despite a significant increase in renewable energy generation since 2000, fossil fuels still account for 80% of global energy demand (Davidson, 2019).[8]

To mitigate negative social and economic impacts, governments need to anticipate the costs associated with the transition for individual sec-

[5] For instance, Eastern European countries have followed a very emissions-dependent growth model to develop (Gräbner and Hafele, 2022). As such, their socio-economic development rests substantially on non-sustainable activities. These countries will impede the implementation of required progressive climate policies if they are not able to develop other green development models that make it realistic for them to achieve similar economic benefits compared to their current fossil fuel-driven model (Gräbner and Hafele, 2022).

[6] Numerous real-world examples exist (see Rodrik, 2014, for an overview). For instance, Steer (2013) notes that more than 50 developing countries have now instituted practices such as feed-in tariffs or renewable energy standards to increase green technologies (Steer, 2013).

[7] Failure is an inherent part of success and should be managed (Hallegatte et al., 2013). The Plan Calcul, a 1960s French initiative to promote a national or European computer industry, failed despite the creation of an agency, a manufacturing company, and a research institute which cost over $100 million to the government in the first five years. The program was gradually disbanded between 1975 and 1978 and ultimately considered a failure.

[8] These alarming figures, or alternatively, a more skeptical view on the potential of environmental innovations, have led many scholars to argue that efficiency strategies and strategies promoting the shift to renewable energy sources and resources must be complemented by sufficiency (or, sometimes more broadly, degrowth) strategies. These strategies aim to reduce environmental stressors through the immediate reduction of production and consumption activities. Although not advocated in this paper, the policy framework proposed here could, in principle, also be used to complement such sufficiency strategies. For more details on the latter, see, for example, Jungell-Michelsson and Heikkurinen (2022) and Wiese et al. (2022).

tors.[9] While the energy sector, responsible for approximately three-quarters of global greenhouse gas emissions, plays a central role in this restructuring (Andreoni, 2022; IEA, 2021), all industrial sectors are closely linked to harmful energy consumption. Some sectors are already adapting to the changing landscape and benefitting from favorable market conditions, including regulations, relative energy prices, and shifting demand. For example, the heating and cooling sector in buildings has shown a clear downward trend in emissions (from 2005 to 2018) due to increased energy efficiency and the transition to less carbon-intensive fuels (EEA, 2020). On the other hand, certain sectors face challenges in reducing emissions through energy efficiency improvements or the adoption of renewable energy sources. Heavy industries like steel and cement, for instance, have made limited progress in reducing emissions due to technical and economic difficulties in decarbonization (Gross, 2021).

This paper focuses on the challenge of scaling down non-future-fit sectors that need to comply with regulations or face loss of competitiveness during the transition to a green economy. The active downsizing of these industries (as opposed to passively observing their decline) requires careful management to ensure a just transition for workers.[10] In many cases, leading economic activities tend to be concentrated in specific regions, creating a path dependence that makes it difficult to reverse the spatial pattern (Arthur, 1989, 1990; Malmberg and Maskell, 2002). Phasing out certain economic activities can have a significant impact on the local economy of entire regions. For example, Ziouzios et al. (2021) found that the planned phase-out of lignite in Western Macedonia, Greece, by 2025 is expected to result in the loss of 21,000 direct and indirect jobs and a total income loss of €9 billion between 2018 and 2028 without appropriate mitigation measures.

To facilitate regional diversification, particularly in regions locked into unsustainable activities, policymakers can draw on insights from academic disciplines such as evolutionary economic geography (EEG; Boschma et al., 2014, 2015) and transition studies (Bergek et al., 2008; Geels, 2002; Rip and Kemp, 1998). These approaches offer valuable and often complementary frameworks for understanding the region-specific potential for diversification into new industries and the development of new growth paths. For instance, EEG research suggests that regions often diversify into related activities that leverage existing local capabilities, which can reduce the uncertainty of diversification (Boschma et al., 2015). Therefore, any active transition policy must consider the relatedness of existing regional capabilities and the capabilities required by potential sustainable activities that would replace the non-future-fit activities in the current status quo.

Furthermore, successful transition planning requires considering not only economic factors but also the politics and power dynamics of industry incumbency (Geels, 2014; Scoones et al., 2015). Understanding the interests and networks of actors involved can shed light on why certain sectors persist in specific places and help identify pathways for change (Brauers and Oei, 2020). Additionally, involving all relevant stakeholders in the restructuring process, promoting participatory processes, and creating shared understanding are crucial to prevent social backlash against environmental action. For example, Brauers and Oei (2020) attribute the persistence of the coal industry in Poland to supportive government policies, indicating the need to challenge core beliefs and values associated with coal production through changes in media communication about climate change in order to successfully phase out coal.

In the next section, we will develop an indus-

[9] The need to identify economically non-viable sectors in advance, before the adverse impacts of policies lead to their uncoordinated decline, builds on similar works such as those of Brinkmann (2022) and Südekum (2021), which assess which regions are at risk considering the energy crisis.

[10] In the latter case, this refers to the concept of exnovation, the purposeful 'exit from non-sustainable infrastructures, technologies, products, and practices' (Heyen, 2016, p. 5) in transformation studies (Antes et al., 2012; Arnold, 2015; Davidson, 2019; Jacob et al., 2016).

trial policy framework that incorporates these insights and aims to anticipate the social impacts of the green transformation.

3. Developing an industrial policy framework for a just transition

To effectively utilise industrial policies for industrial restructuring amidst the green transformation, policymakers must overcome four main challenges:

1. To identify industries at risk of decline during the green transformation.
2. To decide on a mitigation strategy that addresses the threats facing these sectors, which may involve protecting them from market forces or proactively scaling them down. This decision requires careful consideration of potential negative side effects on the wider economy resulting from scaling down one sector. Policymakers may choose to safeguard the sector if the consequences were significant, for example, for reasons of input-output linkages or national security considerations, but if scaling down was necessary, they would need to anticipate and mitigate these effects.
3. To identify potential new employment opportunities in future-fit sectors that align with workers' skills.
4. To develop strategies to mitigate social costs associated with job losses in declining sectors, such as facilitating the transition to new employment opportunities identified, providing universal basic services, or offering active retraining programmes.

Below we propose a framework that addresses the first and third challenges by first identifying non-future fit sectors and then identifying complementary future-fit sectors to which worker flows could be directed. While we acknowledge that the second step requires a very nuanced analysis, for example, into the role of sectors within the input-output network of the economy, we here focus on how to deal sectors for which the decision of scaling-down has been made. This must be considered if one wished to put the framework into immediate use for designing concrete policy measures. After describing the steps in more detail below, section 4 demonstrates the application of the framework to case studies of Germany and Hungary.

3.1. Identify non-future-fit sectors

To identify non-future-fit sectors, we require data on both the ecological impacts as well as the economic benefits of a sector. Here, we propose to combine data on emission intensity as a measure for the ecological impacts with data on economic complexity as a measure for economic benefits.[11] Economic complexity measures an economy's "sophistication" in terms of its capabilities, such as technologies, production know-how, infrastructure, and institutions (Boleti et al, 2021; Hausmann and Hidalgo, 2011; Hausmann and Rodrik, 2003; Mealy and Teytelboym, 2020; Sutton and Trefler, 2016).[12] The scientific community continuously broadens the object of analysis for this measure. For instance, economic complexity makes it possible to uncover emergent technology patterns across different scales of analysis (Napolitano et al., 2018; Pugliese et al., 2019). Also, insights from the economic complexity literature have been promisingly applied

[11] Economic complexity is preferred over production space for two reasons (the production space of a country reflects its current technological capabilities and the range of products it can produce using these capabilities (Hidalgo et al., 2007). First, it identifies sectors that are more competitive for diversification. Second, using production space for less developed economies risks keeping them in a low-production capabilities trap. Economic complexity highlights sectors that can increase competitiveness in international markets, and the state can use targeted industrial policies to build up industrial capabilities where necessary (Hidalgo et al., 2007).

[12] This concept acknowledges the fact that a country's productive structure not only requires capital and labor, as the 'traditional production approach' suggests, but also capabilities.

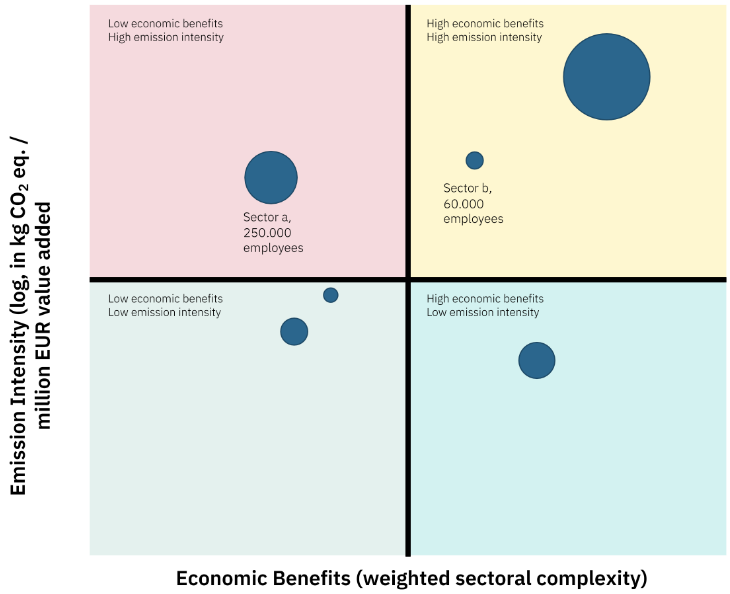


Figure 1: Emission intensity and economic benefits matrix to identify non-future fit sectors in an economy, bubble size reflects the proportion of employees in a sector

to environmental issues, with a particular emphasis on environmental products (Fankhauser et al., 2013; Hamwey et al., 2013; Mealy and Teytelboym, 2020). This forms the basis for studying the productive or technological capabilities relevant to the green economy.[13] In this context, we define non-future-fit sectors as those currently having high emissions while also lacking the necessary capabilities to transition their production structures towards sustainable targets.

To aid in decision-making, both measures can be correlated into a decision-making matrix exemplified in Figure 1. For more details on the data used in this step, see Appendix A. In Figure 1, the size of each sector represents its proportion of employees in the country under consideration. Non-future-fit sectors are in the upper left quadrant of Figure 1, whereas future-fit sectors, which have high economic benefits and low emission intensity, are in the lower right quadrant.

While this paper aims to identify non-future-fit sectors that require government attention, the decision on the most effective industrial strategy to address the impact of green transformations on these sectors is left with policymakers. Above all, there might be compelling reasons for why a thus defined non-future-fit sector must nevertheless be supported to be kept alive: for instance, a sector might play a crucial input-output linkage role in the economy or for national security or independence. In these cases, rather than managing the scaling-down of these sectors, policymakers must think of strategies of how to make these sectors more energy-efficient or even how to protect these sectors from incumbents to survive the

[13] It is important to note that higher economic complexity does not necessarily lead to lower emission intensity. The relationship depends on industries' energy mix and environmental considerations, leading to conflicting findings in the literature. Some scholars argue that it can improve environmental quality by shifting towards knowledge-intensive activities, while others suggest it can increase emissions due to its correlation with GDP per capita. Studies by Can and Gozgor (2017) and Neagu, (2019) support both views.

changing landscape.[14]

More commonly, however, the sectors in the upper left are found to be less essential sunset industries that are not economically justifiable to protect due to a lack of significance, excessive emission intensity, or the availability of environmentally superior alternatives. These sectors will require active management of their scaling-down to ensure a just transition for workers before market forces cause severe disruption and unemployment.

3.2. Identify complementary future-fit sectors

To identify complementary future-fit sectors, the remaining sectors are assessed based on three criteria: a) low emissions intensity; b) high competitiveness and economic development prospects; and c) sufficient similarity to the non-future-fit sector in terms of skills and capabilities demanded from potential employees.

For the latter, we draw on tools developed in the literature on "relatedness" (e.g., Hidalgo et al., 2018). Generally, relatedness refers to the similarity between industries, conceptualized in terms of technological, product, or competence relatedness. Previously, the notion has been used to identify regional strengths (e.g., technological knowledge), thus providing a direction for further economic growth via targeted investments. It indicates where synergies between related industries can be exploited, i.e., where innovations and spill-over effects are most likely to occur (D'Adda et al., 2020; Foray et al., 2012; McCann and Ortega-Argilés, 2013). For the purpose of this paper, we focus on one particular dimension of relatedness, i.e., "skill relatedness," which quantifies the similarity of capabilities required to work in different sectors.[15] This is essential because for workers to be able to move from one sector to another, the requirements in terms of skills and competencies must be sufficiently similar (Yi et al., 2015).

Complementary sectors can only be identified for one pre-specified vantage sector. This means that policymakers must first identify a non-future-fit sector to scale down, and then determine complementary future-fit sectors. To do so, they can refer to the data underlying the Figure of the previous step and complement it with data on skill relatedness (for more details on the underlying methodology, see Appendix B.1).

Table 1: Matrix of emission intensity, economic complexity, and skill-relatedness: Identifying complementary future-fit sectors for potential replacement of sector X

Replacement sectors	Emission intensity	Economic complexity	Skill related-ness
Sector a			
Sector b			
Sector c			
Sector d			

One can integrate sectoral information on emission intensity, economic complexity, and potential worker transitions into a sector-specific replacement analysis for future-fit sectors, as illustrated in Table 1. The replacement sectors are selected based on their compatibility with workers from sector X, allowing for a maximum of three job transitions. As such, all replacement sectors listed in the table are considered "complementary." These replacement sectors have above-average economic complexity relative to the economy and are less emission-intensive than the current sector under consideration, making them relatively "future-fit." When choosing a replacement sector, the significance

[14] A viable goal for future research is, however, the provision of information that can facilitate the classification choice of policymakers, for example, by providing information on the sectors' relevance within the input-output network or for national security and independence.

[15] Thus far, the transfer of the skill relatedness concept to transition research has been limited. While it is sometimes mentioned in the broader context of industrial restructuring, it is seldomly connected to the ecological transformation. A noteworthy exception to the neglect of this research area is the study conducted by Capasso et al. (2019) who assess regional capabilities for a green economic restructuring based on skill relatedness.

of each dimension can be adjusted depending on whether the focus is on emission intensity, economic complexity, or skill relatedness.

4. Industrial strategies to deal with trade-offs and tensions

Before describing an exemplary application of the framework, this section discusses some of the challenges that regularly emerge in the context of identifying non-future-fit sectors and their complements. This is because the process of identifying complementary future-fit sectors is not without its challenges, and tensions or trade-offs often arise when balancing the three objectives of this framework: complexity, low emissions, and skill-relatedness.[16]

Challenge 1: Replacement sectors have low levels of emission intensity and demand similar skills but have low levels of complexity.

A potential challenge is that envisioned replacement sectors for a given non-future fit sector are low in emission intensity and demand similar skills but have low levels of economic complexity. Low levels of economic complexity make these sectors less future-fit in terms of competitiveness and future production capabilities. To address this challenge, the government can use targeted industrial policy to build up the production capabilities (knowledge, skills, technology) of that specific sector through de-risking experimentation and crowding-in private investments (Andreoni, 2022; Crespi and Guarascio, 2019; Mazzucato, 2013; McKelvey and Saemundsson, 2018).[17]

[16] A trade-off occurs when there is a deterministic relationship between two objectives, meaning that the enhancement of one objective inevitably leads to the decline of the other. On the other hand, a tension arises when the enhancement of one objective may lead to the decline of another, but this outcome is contingent upon various contextual factors and policy measures (Hafele et al., 2021).

[17] Section 2.1.4 in the literature review provides an overview of a targeted approach to industrial policy.

To drive the green transition, countries can draw from the "carrot" and "sticks" incentives and regulations used in East Asia (Evans, 1995). For instance, Korea's Economic Planning Board partnered with the state-owned Korea Development Bank to provide credit subsidies to targeted firms with strict conditionalities. Export subsidies and loan guarantees were removed if firms did not generate sufficient investments for exports, stimulating export-led industrialisation (Amsden, 1989; Chang et al., 2016).

However, it is also important to recognise that low economic complexity does not necessarily represent an ultimate hindrance. In the context of the green transformation, the emphasis should be on identifying and prioritising sectors that can serve as effective replacements for unsustainable industries, rather than focusing solely on economic complexity. Ultimately, it is preferable for workers to be employed in low-complexity, environmentally sustainable sectors rather than facing unemployment. Also, some low-complexity sectors might be important for other reasons, e.g., because of their central place within the input-output network. In this context, low-complexity industries should be provided with some degree of protection from international competition, which could be achieved through measures such as import tariffs, capital flow controls, and export subsidies (Chang et al., 2016; Hauge, 2020).

Challenge 2: Replacement sectors have high levels of economic complexity and demand similar skills but are emission intense.

A potential challenge is that envisioned replacement sectors for a given non-future fit sector have high levels of economic complexity and demand similar skills, however, have high levels of emission intensity (although being lower in emission intensity than the non-future fit sector under consideration). To address this challenge, governments can provide targeted support to transition a given replacement sector to less emission-intensive structures, linking subsidies to specific targets like reducing emissions and promoting innovation (following the "carrot" and "stick" approach highlighted above).

Additionally, mitigation strategies can also involve transformative changes across the value chain, such as implementing circular economy concepts, that can help achieve emission reduction targets. An example of this is the German steel industry, which was able to lower its material content through transformative policy that required repurposing, reuse, and recycling activities (Mazzucato, 2018; 6).

However, if the sector's necessary emissions reduction is difficult to achieve in the timeframe required, policymakers may have limited options. In such cases, a genuine trade-off emerges, necessitating a decision on priorities. Policymakers must determine whether the priority is to reduce CO2 emissions or preserve competitiveness and jobs (to differentiate between trade-offs and tensions, see Hafele et al., 2021).

Challenge 3: Economy has complex and green sectors but none of them are skill-related to the non-future fit sector under consideration.

A potential challenge is that even though the overall economy has complex and green industries, none of them are really connected to the non-future fit sector under consideration. In this case, governments can actively offer retraining of the workforce of the scaled-back sector. In so doing, this process should respect the principles of a just transition (see box 1, ILO, 2016). Indeed, respecting the notion of a just transition is not only a moral consideration, but it also ensures the political viability of phasing-out efforts.

To address this challenge, the state should prioritize social dialogue with relevant stakeholders, including under-represented groups such as women and youth, to develop a context-specific just transition strategy. This can include offering appropriate compensation and social protection for affected groups. Moreover, the state can also fund effective programs for retraining and redeployment of the workforce, which would not only provide social insurance for actively scaled-back workers but would also achieve structural change while making the process inclusive (Chang and Andreoni, 2020).

Box 1: Summary of the Guiding Principles to guide the transition to environmentally sustainable economies and societies (ILO, 2016)

1. Strong social consensus and social dialogue with all relevant stakeholders are fundamental for policymaking and implementation.
2. Policies must respect and promote fundamental principles and rights at work.
3. Gender policies should be considered to promote equitable outcomes.
4. Coherent policies across the economic, environmental, social, education/training, and labour portfolios are needed to enable a just transition.
5. Just transition policies must anticipate impacts on employment, provide adequate and sustainable social protection for job losses and displacement, provide skill development and social dialogue, including the effective exercise of the right to organize and bargain collectively.
6. There is no "one-size-fits-all". Policies must be designed based on country-specific conditions.
7. International cooperation among countries is important for implementing sustainable development strategies.

For instance, Japanese and Korean governments implemented 'retraining programs' for the workers of written-off industries to limit opposition to structural transformation processes (Chang, 2003). Similarly, Sweden recently adopted a new agreement to make the Swedish labor market more fit with respect to social and ecological goals, which includes significant funding for retraining workers (CEDEFOP, 2021).

Challenge 4: Economy lacks green and complex sectors/niches.

A potential challenge is that the overall economy lacks green and complex sectors/niches in general. In this case, the state can actively create a new green and complex sector that can either be skill-related to the scaled-back sector or retrain workers for the new sector. Building on section 2.1.4, the state can act as an entrepreneurial agent by stimulating innovation in future market opportunities and leveraging the competitive assets of the private sector through horizontal support for RD, public planning, and skill-formation policies (Mazzucato, 2013).

According to the "deepest pocket" argument, the government is more capable than the private sector in taking on high-uncertainty but potentially high-return investment opportunities. By investing in a new sector that aligns with the transition to a green economy, the economy will make a long-term investment in the future. This new sector can offer opportunities for innovation and entrepreneurship, which can have a ripple effect throughout the economy, generating positive spillovers between firms. Examples include the state-owned Costa Rican Institute of Electricity (ICE), which has invested massively in hydro, wind, and geothermal power plants to create a strong renewable energy sector for the economy. Once again, creating a new sector that is related to the declining non-future fit sector can also be applied as a viable strategy for the other challenges.

5. Pathways for future-fit development in Germany and Hungary

In this section, we explore the framework using case studies of Germany and Hungary. Industrial policy faces specific challenges in the European context. The Single Market, the cornerstone of the EU, was argued to be incompatible with national industrial policies that could hinder competition among member states (Landesmann and Stöllinger, 2020). However, recent developments like technological advancements, emerging economies, EU convergence, and the climate crisis have sparked interest in industrial policy (Landesmann and Stöllinger, 2020). To address these issues, the EU introduced the 'Green Deal Industrial Plan' in January 2023.

While the EU provides funds and initiatives like REPowerEU (05/2022) to support industrial policy, the main responsibility still lies with member states. To promote industries with net-zero emissions, the European Commission relaxed state aid rules through the Temporary Crisis and Transition Framework (TCTF), encouraging strategic projects and partnerships.

However, depending too much on relaxed state aid rules may give an advantage to wealthier states, decreasing cohesion in the Union. Some member states lack the necessary abilities and funds to implement a green industrial strategy effectively (Gräbner and Hafele, 2022).

In this context, we focus on Germany as a "core" EU member state and Hungary as a "catch-up" member state. "Core" countries have superior political and economic resources for immediate action and could therefore take the lead in meeting social and ecological objectives, while "catch-up" countries may require guidance in navigating climate regulations that might conflict with their current emission-intensive development models.

5.1. Germany

Germany wields considerable influence over the global political economy due to its sheer economic size, boasting the largest economy in Europe and the fourth largest worldwide (Prittwitz, 2023). Three features of its economy are particularly relevant to keep in mind when discussing the space for industrial policy in Germany:

- **Manufacturing focus:** Germany has an export-led economy, with a strong focus on manufacturing (Hassel, 2017; Hein and Martschin, 2020; World Bank, 2023). Indeed, the manufacturing sector has accounted for around 20% of GDP over the last 20 years (World Bank, 2021).
- **Thriving SMEs:** The German economy is characterized by a thriving innovation-focused small and medium enterprises (SMEs) sector, which accounts for 99% of all enterprises in the country. Even in the pandemic year 2020, SMEs created 207 billion EUR in export revenues, which amounted to 16% of the German total export revenues (IfM, 2022). Employing 55% of the workforce, SMEs can be considered an essential cornerstone

of the German economy (IfM, 2022) and are hailed as economic innovators that "drive the success behind the 'Made in Germany' trademark" (BMWK, 2023).

- **Export-led economy:** Germany's growth model is highly export-oriented. Indeed, goods and service exports amounted to 47% of GDP in 2021 (World Bank, 2023). Exports largely rely on Germany's strong manufacturing sector and its technological competitiveness.

In sum, Germany can be considered a "core" economy in the EU (Gräbner et al., 2020). Core countries are characterised by a strong industrial base and high living standards. The firms in these countries have accumulated a lot of "capabilities" and technological knowledge that allows them to produce and export sophisticated products few others can provide on the world market (Gräbner and Hafele, 2022).

Recognising the need for sustainable development in the country, the Federal Ministry of Economic Affairs and Energy has recognised the need for an industrial policy framework to support industries in their transition to sustainable production (BMWK, 2021). This initiative is aligned with Germany's Sustainability Strategy and its national implementation of the Agenda 2030, as the country aims to reorganize its industrial production to address the climate and ecological crisis (Rammer, 2023).

5.1.1. Decision-making matrix: assessing the future-fitness of Germany's industrial sectors

The first step is to analyze the future-fitness of Germany's industrial sectors. To do so, Figure 2 plots its economic sectors based on their sectoral economic complexity[18] and emission-intensity[19], with the bubble size being proportional to the total employment share in each sector.

The overall number of workers in our dataset stands at 46,385,790 for Germany. Among those, 7,133,518 are employed in non-future fit sectors found in the upper-left corner of Figure 2. This means that based on our data, 15.4% of the workforce is currently employed in sectors that are likely to undergo fundamental changes in the process of decarbonisation. Figure 3 provides an overview of the inter-industry mobility of workers in Germany (explained in Appendix B.3), revealing significant disparities across different sectors. There seems to be job immobility in agriculture and transport, whereas industries like food and agri-products and manufacturing demonstrate greater mobility.

[18] The method used to determine economic complexity is only applicable to tradable sectors in the economy. Therefore, non-tradable sectors, such as services, are not represented in this analysis. The measure used is sectoral measured as a weighted average of the product complexity of products the sector produces.

[19] Emission-intensity is divided by value-added to account for the economic value created per unit of greenhouse gas emissions produced. It, therefore, assesses the environmental efficiency of an economy or industry. The measure is the Kg CO2 equivalent by million € of value added.

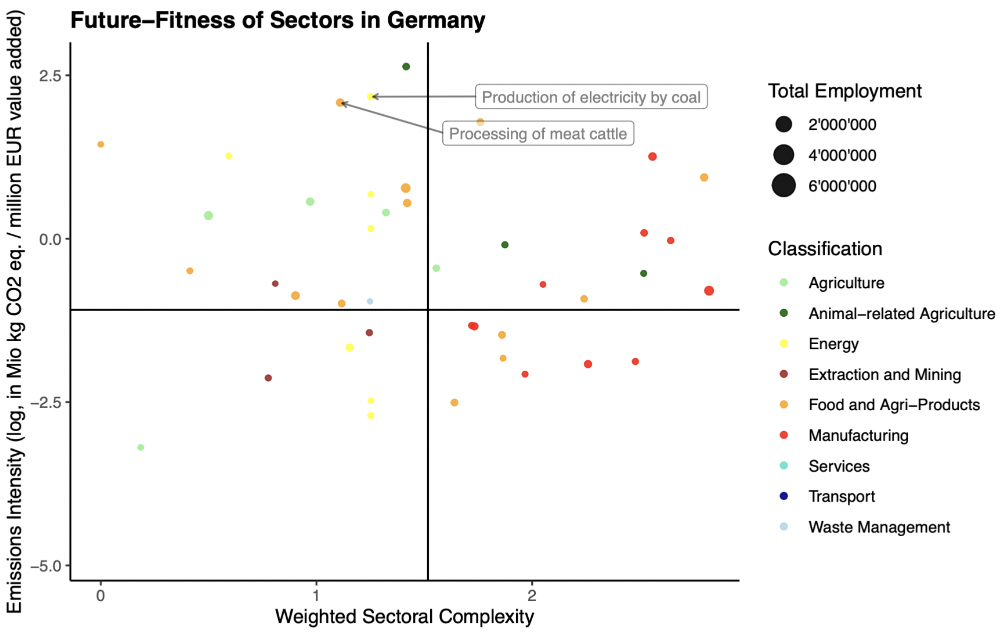


Figure 2: Overview of Germany's economic sectors based on sectoral complexity, and emission-intensity; bubble size proportional to overall employment

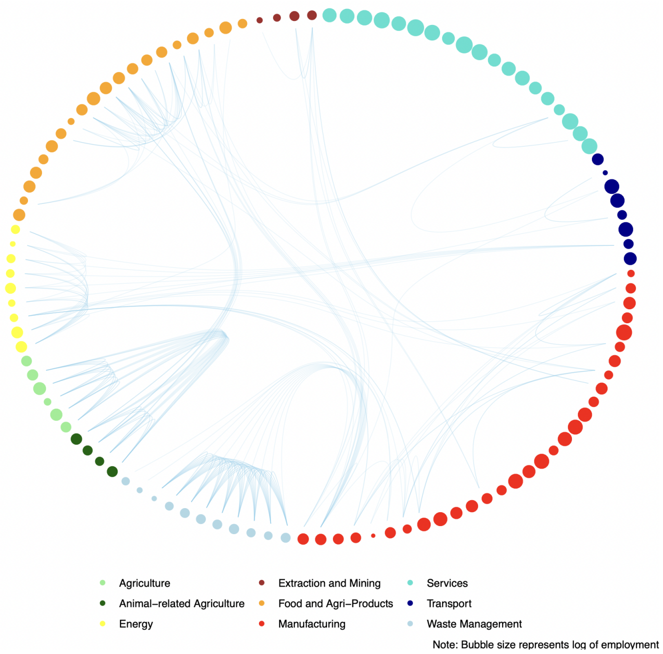


Figure 3: Network of workers moving between sectors in Germany

Table 2: Highest employment non-future-fit sectors in Germany

Sectors	Employment	Emissions_cba	Emissions Intensity	Sectoral Complexity
Processing of Food products	226456	37592832318	2.17	-0.47
Cultivation of vegetables, fruit, nuts	150017	7924945364	1.42	-1.39
Sugar refining	116537	1214440779	0.42	-0.98
Processing of meat cattle	101909	12197355938	8.03	-0.78
Manufacture of beverages	96071	9730675165	1.73	-0.47

Table 3: Highest emissions non-future-fit sectors in Germany

Sectors	Employment	Emissions_cba	Emissions Intensity	Sectoral Complexity
Production of electricity by coal	42516	85429889444	8.78	-0.63
Petroleum Refinery	13032	46033396318	3.55	-1.29
Processing of Food products	226456	37592832318	2.17	-0.47
Processing of meat cattle	101909	12197355938	8.03	-0.78
Manufacture of beverages	96071	9730675165	1.73	-0.47

Table 4: Lowest complexity non-future-fit sectors in Germany

Sectors	Employment	Emissions_cba	Emissions Intensity	Sectoral Complexity
Processed rice	8281	524156642.2	4.24	-1.89
Manufacture of fish products	12462	208527568.5	0.61	-1.47
Cultivation of vegetables, fruit, nuts	150017	7924945364	1.42	-1.39
Petroleum Refinery	13032	46033396318	3.55	-1.29
Mining of chemical and fertilizer minerals, production of salt, other mining, and quarrying	7103	282665989.7	0.5	-1.08

Table 2, 3, and 4 provide a brief overview of the different non-future fit sectors in the German economy, classified by prioritizing three variables of interest: the 5 most employment-intensive, 5 most emission-intensive non-future fit sectors, and the 5 least economically complex non-future fit sectors.

As previously stated, this analysis aims to draw attention to non-future fit sectors that require attention. The subsequent strategy employed to address these sectors remains the responsibility of policymakers and is not within the scope of this analysis.

5.1.2. Replacement analysis

The second step is to identify complementary future-fit sectors that can offer employment prospects for workers in non-future fit sectors. We exemplify this approach by analyzing Germany's most emission-intensive non-future fit sector: 'Production of Electricity by Coal.' Additionally, we also analyze replacement options for Germany's non-future fit sector with the 4th largest employment, "Processing of meat cattle," as the first three largest non-future fit sectors are agricultural sectors for which one might focus on reducing emissions rather than scaling them down.

The comprehensive results for any replacement analysis are available from the authors upon request. Here we focus on the key implications only. But before, two points are important to note. First, the labor flow data used in this analysis is rather aggregated. Before delineating concrete policy implications, one should use more disaggregated data (which, however, is not publicly available). Second, the economic complexity index can only be computed for tradable sectors. As a result, all service sectors in the economy are not included as potential replacement sectors in our methodology. It is important to bear this in mind as service sectors can serve as viable and green replacement options. Further studies could use alternative measures for economic benefit to complement the results below.

Replacement analysis for the sector "Production of electricity by coal":

The decline of coal production in Germany is driven by both non-competitiveness and environmental concerns. The National Energy and Climate Plan aims to phase out coal-fired power generation by 2038 at the latest. With the government ending subsidies in 2018, the coal industry is already disappearing without adequate diversification into sustainable industries, as exemplified with Ruhr and Saarland's 50-year-long experiences with a predominantly economically driven coal decline (Oei et al., 2019). To ensure a just transition, it is crucial to identify transferable sectors for workers in this declining industry.

Figure 4: Replacement sectors for "Production of electricity by coal" in Germany

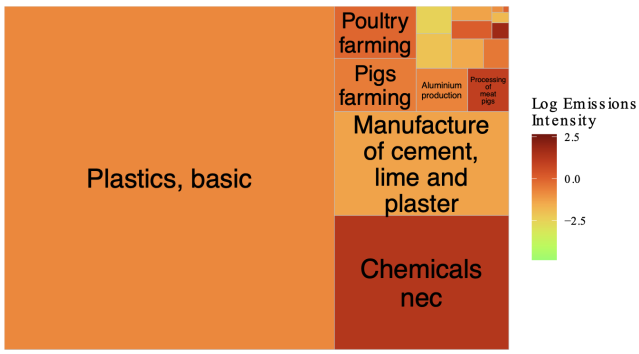


Figure 4 illustrates sectors with transferable skills to coal, determined by higher-than-average economic complexity and lower emission intensity. In these figures, the size of the box corresponds to the level of skill-relatedness between the replacement sector and the non-future fit sector, weighted by the employment size. Meanwhile, the color of the box indicates the degree of emission intensity of the replacement sector, with only those sectors being considered which are less emission-intense than the non-future fit sector. Furthermore, the figure only displays the replacement sectors that are higher than average in terms of complexity (more explanation in Appendix B.2).

In our dataset, 42,516 individuals are currently employed in the "Production of electricity by coal." At first glance, the results show that these individuals are not stuck in their employment, having over 100 complementary sectors. Additionally, most complementary sectors can be categorized as economically complex manufacturing sectors, which builds on the country's current economic model (section 5.1). The plastic industry clearly emerges as the most skill-related weighted by employment. In fact, the plastic industry is one of Germany's most important industrial sectors, being one of the most competitive plastic sectors in global markets and generating an annual turnover of over EUR 97 billion (Plastics Industry, 2023).

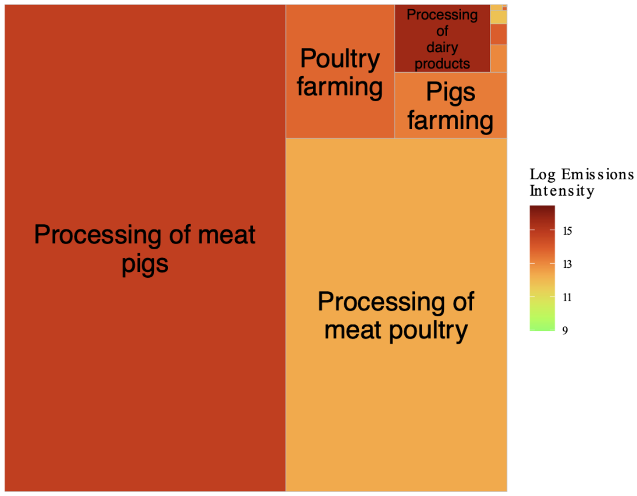
However, these complementary sectors face the second trade-off in section 4, whereby even though they are skill-related and economically complex, they are still emission-intensive. For the plastics industry, even though the government is implementing transformative measures in the plastic industry aimed at promoting circular practices to reduce the sector's emissions (Plastics Industry, 2023), the trade-off between emission-intensity, competitiveness, and jobs still exists. As such, the complementary sector of "Manufacture of fabricated metal products" might be a less emission-intensive replacement option.

Replacement analysis for the sector "Processing of meat cattle":

The German cattle industry, which is the EU's second-largest and a substantial employer in Germany with 101,909 workers in our dataset, must downsize by at least 50% to fulfill greenhouse gas emissions targets (CEW, 2021). Furthermore, the EU's Farm to Fork strategy (2020) highlights the necessity of transitioning toward plant-based diets in general to mitigate environmental and climate impacts, a move that will have significant consequences for the meat sector.

Our results, however, reveal a stark lack of complementary future-fit green sectors for the many workers in the "Processing of meat cattle" industry in Germany, highlighting an important need for government attention. To address this, the government must choose between retraining the workforce for a just transition to other green and complex sectors in the economy or creating a new green and complex sector that aligns with their current skills, as highlighted in section 2.3.

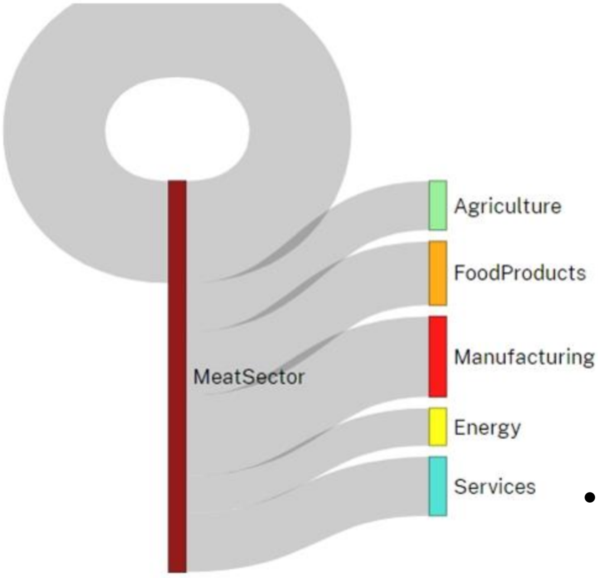
Figure 5: Replacement sectors for "Processing of meat cattle" in Germany



To obtain a comprehensive understanding of whether employees in the meat industry more broadly are limited in their career options, we aggregated their employment data and presented the results in Figure 6 (more explanation in Appendix B.4).

The figure clearly illustrates that although some workers transition into other sectors, the majority tend to remain within the meat industry. However, it's important to note that the situation might not be as bleak as the figure suggests since the lack of labor flows to other sectors in the past might well be due to the absence of such policies at that time.

Figure 6: Analysis of flow of workers from the meat sector in Germany



5.2. Hungary

Hungary is a medium-sized economy that has grown considerably since becoming an EU member state in the early 2000s. To gain insights into the space for industrial policy in Hungary, it is important to first consider the distinct features of its economy that have contributed to its success in the last 20 years:

- **Attraction of foreign direct investments (FDIs)**: Hungary is one of the top destinations for foreign direct investment in Europe, which has been a key factor driving its remarkable economic growth. Indeed, in 2020, despite the COVID-19 pandemic, FDIs reached EUR 4,078 million (HIPA, 2020). The country primarily attracted FDIs due to its price competitiveness, tax incentives, grants, and subsidies.
- **Manufacturing-focus**: The manufacturing sector, particularly the automotive production, chemical production, information technology, electrical goods, and food industry, has been particularly successful in Hungary, accounting for around 17% of Hungary's GDP in 2021 (World Bank, 2021). Hungary's manufacturing sector has been a key driver of innovation, with a strong focus on automotive manufacturing, electronics, and IT (OEC, 2020). The manufacturing sector was able to develop so strongly from the attraction of FDIs from international companies. Nonetheless, Hungary's development model is regionally concentrated resulting in a considerable number of regions being left behind in terms of economic progress (Eurostat, 2022).
- **Export-oriented economy:** Hungary's economy relies strongly on exports, with over 80% of the country's GDP coming from exports in goods and services (World Bank, 2021).

Hungary is considered a "catch-up" economy within the EU, typically located in Eastern Europe, with lower living standards but a robust manufacturing sector established by attracting international firms through low factor costs, especially wages (Gräbner et al. 2020, Gräbner and Hafele, 2022).

The country, however, faces challenges in transitioning to a greener economy. This is because Hungary's development model for catching up with richer countries, such as Germany, is based on industrialization that comes with considerable ecological costs (Gräbner and Hafele, 2022). The country is highly dependent on fossil fuels, accounting for approximately 78% of its primary energy supply in 2021 (Ritchie et al., 2022). As a result, Hungary ranks eighth among the most carbon-intensive economies in the EU, with emissions that exceed the EU average by 201 grams of CO2 per euro of GDP (European Parliament, 2021). Despite these challenges, it is crucial that member countries accelerate rather than slow down the European Green Deal.[20] The Hungarian government has launched efforts to transition to a greener economy, following the guidance of the National Energy and Climate Plan (NECP) of 2020 and the National Clean Development Strategy (NCDS) of 2021.

5.2.1. Decision-making matrix: assessing the future-fitness of Hungary's industrial sectors

Figure 7 represents the decision-making matrix for Hungary. The upper-left quadrant contains sectors with above-average emission intensity (in terms of value added) and below-average economic complexity; these sectors can be considered non-future fit.

The dataset for tradable sectors in Hungary comprises 4'599'346 workers. Of these workers, 1'111'976 are currently employed in non-future fit sectors, representing approximately 24.17% of the total. Figure 8 presents a comprehensive overview of the patterns of worker movement in Hungary (explanation in Appendix B.3). Particularly striking is the comparatively low volume of worker flows between sectors in Hungary as compared to Germany, suggesting a higher degree of employment immobility among Hungarian workers.

Table 5, 6, and 7 give a brief overview of the different non-future fit sectors in the Hungarian economy, classified prioritizing respectively three variables of interest: the 5 most emission-intensive non-future fit sectors, the 5 most employment-intensive non-future fit sectors, and the 5 least economically complex non-future fit sectors.

[20] The current prime minister of Hungary, Orban, has already urged the European Commission to withdraw from its Fit For 55 initiative and was critical of the revision of the EU ETS that would impact tax housing and transport.

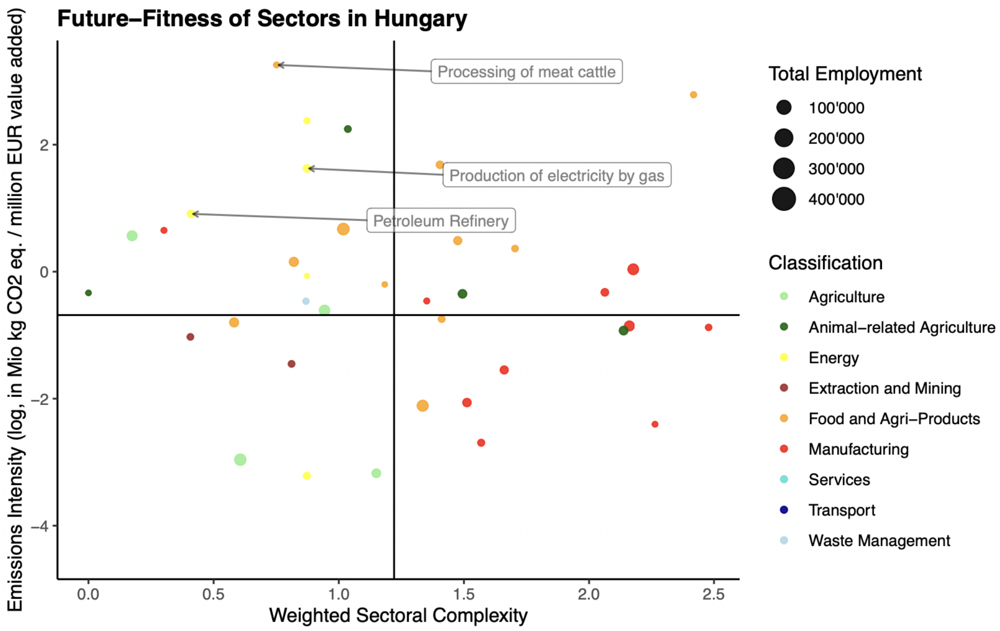


Figure 7: Overview of Hungary's economic sectors based on sectoral complexity, and emission-intensity; bubble size proportional to overall employment

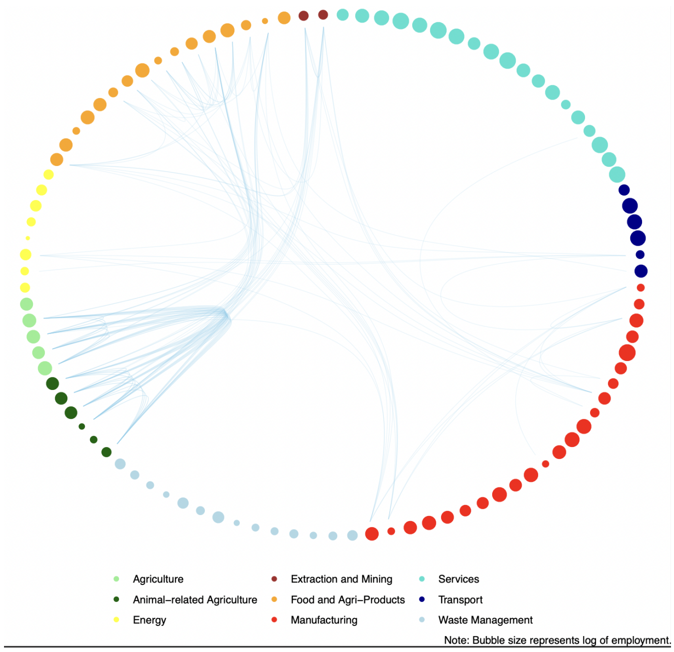


Figure 8: Network of workers moving between sectors in Hungary

Table 5: Highest employment non-future-fit sectors in Hungary

Sectors	Employment	Emissions_cba	Emissions Intensity	Sectoral Complexity
Processing of Food products nec	53094.22	2253402027	1.96	-0.49
Cultivation of wheat	36676.84	397305980.1	0.54	-0.56
Cultivation of vegetables, fruit, nuts	29815.96	798242547.5	1.76	-1.33
Manufacture of beverages	20632.92	682793677.2	1.17	-0.69
Production of electricity by gas	8584.83	2326165243	5.08	-0.63

Table 6: Highest emissions non-future-fit sectors in Hungary

Sectors	Employment	Emissions_cba	Emissions Intensity	Sectoral Complexity
Petroleum Refinery	8216.40	3656805908	2.48	-1.10
Production of electricity by gas	8584.83	2326165243	5.08	-0.63
Processing of Food products nec	53094.22	2253402027	1.96	-0.49
Production of electricity by coal	2842.87	2178910673	10.76	-0.63
Cultivation of vegetables, fruit, nuts	29815.96	798242547.5	1.76	-1.33

Table 7: Lowest complexity non-future-fit sectors in Hungary

Sectors	Employment	Emissions_cba	Emissions Intensity	Sectoral Complexity
Meat animals nec	1348.31	188088648	0.72	-1.51
Cultivation of vegetables, fruit, nuts	29815.96	798242547.5	1.76	-1.33
P- and other fertiliser	1753.46	18353473.71	1.92	-1.21
Petroleum Refinery	8216.40	3656805908	2.48	-1.10
Processing of meat cattle	1829.46	271093396.4	25.94	-0.76

5.2.2. Replacement analysis

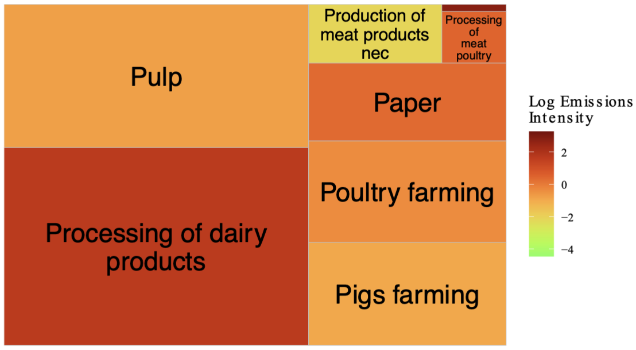
We illustrate our methodology by focusing on Hungary's most emission-intensive non-future-fit sectors, 'Petroleum Refinery' and 'Production of Electricity by Gas', and, for comparison with Germany, the sector "Processing of meat cattle". We do not analyze the most employment-intensive non-future fit sectors because, as seen in Table 5, they are all important agricultural sectors that may be prioritized for protection and emission reduction measures rather than scaling down.

We discuss the results briefly below. Once again, it is important to stress that, first, the labor flow data used in this analysis is aggregated, and further examination is necessary to draw policy conclusions, and second, that we do not include service sectors as potential replacement sectors due to our use of economic complexity.

Replacement analysis for "Petroleum refinery":

The Hungarian economy heavily relies on imports for its fossil fuel energy needs, which mainly come from Russia, as it does not produce much energy domestically. The Russian war could have been an ideal opportunity for Hungary to advance its climate goals by carefully coordinating the phase-out of its small domestically produced fossil fuel energy, rather than increasing its production of fossil gas and lignite, which would lead to more fossil fuel-related problems in the future, as highlighted in its 7-point energy security action plan (2022). Despite the current lag in the deployment of renewable energy technologies, the country should aim to achieve green and competitive diversification by capitalizing on its significant potential for renewable energy, including untapped sources like wind power and geothermal energy. By doing so, the country will then quickly phase out non-future-fit industries such as "Petroleum Refinery," which will become redundant as the country moves towards renewable energy sources. It is important to anticipate these changes and plan for them accordingly.

Figure 9: Replacement sectors for "Petroleum Refinery" in Hungary

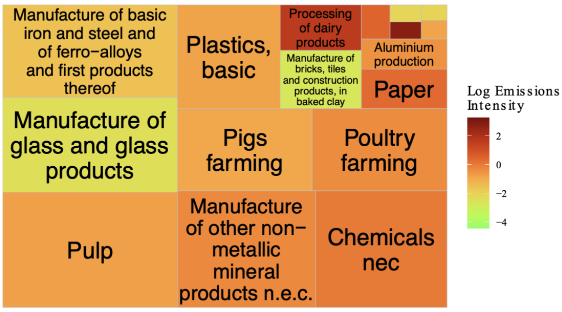


The petroleum refinery industry in Hungary is relatively small, employing 8,216 individuals in our dataset. At first glance, these workers face significant barriers to transitioning to other sectors, as there are only around 20 complementary sectors that they could potentially move into. Moreover, most of these complementary sec-tors are not aligned with Hungary's current economic model, which focuses on manufacturing, and are often carbon-intensive and not future-fit with regards to the green transformation. This dearth of skill-related sectors that could serve as viable complementary and future-fit industries underscores the need for active govern-ment intervention to mitigate the negative impacts of this transition.

Replacement analysis for "Production of electricity by gas":

The petroleum refinery industry in Hungary is relatively small, employing 8,216 individuals in our dataset. At first glance, these workers face significant barriers to transitioning to other sectors, as there are only around 20 complementary sectors that they could potentially move into. Moreover, most of these complementary sectors are not aligned with Hungary's current economic model, which focuses on manufacturing, and are often carbon-intensive and not future-fit with regards to the green transformation. This dearth of skill-related sectors that could serve as viable complementary and future-fit industries underscores the need for active government intervention to mitigate the negative impacts of this transition.

Figure 10: Replacement sectors for “Production of electricity by gas” in Hungary



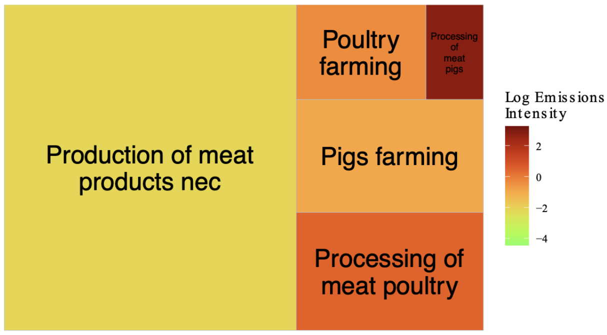
The production of electricity by gas industry is relatively small, employing approximately 8,584 individuals. At first glance, the results highlight that 1) these individuals are not stuck in their employment, as they have over 100 complementary sectors, and 2) some complementary sectors stand out as particularly promising, as they align with Hungary’s economic development model of prioritizing manufacturing (section 5.2) while also being relatively low emission, such as the "Manufacture of electrical machinery and apparatus" and the "Manufacture of machinery and equipment".

Replacement analysis for “Processing of meat cattle”:

The "Processing of meat cattle" sector in Hungary, which employs only 1,829 workers, displays comparable patterns to Germany. Specifically, workers in this sector experience a similar degree of employment immobility, with limited opportunities to transition to other industries beyond meat-related sectors.

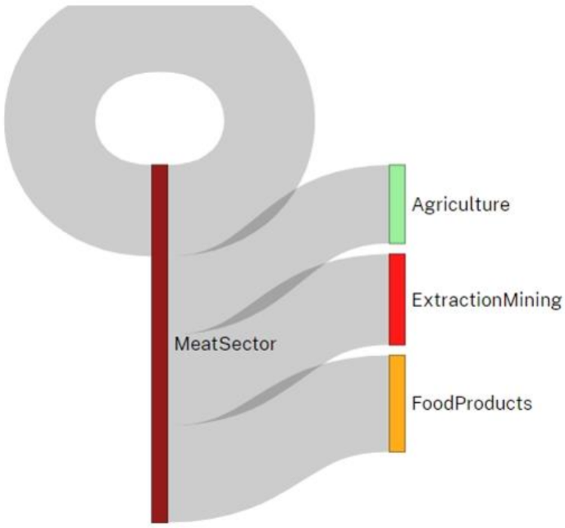
In the same way as for Germany, to get a broader overview of whether employees in the whole meat industry are limited in their career options, we aggregated their employment data

Figure 11: Replacement sectors for “Processing of meat cattle” in Hungary



and presented the results in Figure 12 (more explanation in Appendix B.4).

Figure 12: Analysis of flow of workers from the meat sector in Hungary



The results reveal that most workers in the meat industry are significantly con-strained in terms of career progression, with very limited opportunities to develop new skills. This finding is even more pronounced than in Germany.

6. Discussion and policy implications

Despite the data limitations faced, the analysis of Germany and Hungary produced some findings that deserve further discussion, especially in terms of their relevance for policy. In all, they emphasize the need to consider the skill-relatedness of a country's workforce to position its current capabilities and future opportunities to create future-fit jobs for workers in non-future industries. Our analysis of non-future fit sectors in Germany and Hungary in terms of skill-related replacement sectors revealed that the results were specific to the country and sector, highlighting the need for country-specific policy plans. Moreover, while some sectors presented a wide range of options for workers to transition out of, others showed limited possibilities for workers to move into new fields that align with their development model. For the latter, it is even more critical for governments to anticipate and mitigate these impacts, with strategies such as worker retraining, to ensure a just transition for the necessary green transformation. In general, however, the data suggests that workers in Hungary face more employment barriers, indicating a need for greater involvement in the green transition.

In this context, it is important to recognise that governments face differing fiscal constraints when funding mitigation strategies. For instance, Hungary has less fiscal space than Germany to fund the green transformations (European Commission, 2023). Indeed, while Germany is now in the medium risk bracket in terms of growth outlooks and debt sustainability, Hungary faces a high risk.[21] Although the analysis of the poorest member states was not within the scope of this study, it is worth noting that Hungary's economy is in a better position than others (Gräbner and Hafele, 2022) and has relatively more potential to expand into green sectors based on its existing knowledge (Mealy and Teytelboym, 2020). However, countries with lower levels of income tend to be more emission-intensive, as seen in Figure 13 with the fact that Hungary is twice as emission-intensive as Germany, creating a dual challenge for these countries and underscoring the cost of the transition and its impact on workers.

The EU recognises that its playing field is not level between its member states for industrial policy. The new subsidy framework, the TCTF, differentiates the ceilings for state aid on a per project per member state basis, which varies by region (TCTF, 2023). Although this is a positive step towards steering investments into less developed regions, two important concerns remain. First, this does not address the fact that poorer member states still lack the fiscal space to make use of the higher allowances (Hafele and Barth, 2023). Second, there is still the risk of disproportionately high subsidies within rich countries (Hafele and Barth, 2023). Indeed, since the relaxation of state aid rules in the EU, more than half of the EUR 672 billions of national funding under state aid framework was dished to Germany (Allenbach-Ammann, 2023).

To address these concerns and support green industrial restructuring in member states with less fiscal space and fewer capabilities to invest in the green transition, policymakers can consider several options (Hafele and Barth 2023): First, funds for industrial policy can be made at the EU level so that poorer regions can still support their green industries and retrain their workers. This is why the risk of socio-economic fragmentation will strongly depend on the success of the EU's Sovereignty Fund, which is expected to be negotiated as part of the Multiannual jan Framework (MFF) review throughout 2023. Second,

[21] These risk classifications are based on the Commission's DSA methodology if applied to the most recent Autumn Forecast 2022. https://economy-finance.ec.europa.eu/publications/european-economic-forecast-autumn-2022_en. Defining fiscal space is complicated, as it is typically understood as the amount a government can spend without jeopardising its debt sustainability. However, the Debt Sustainability Monitor used to assess debt sustainability also determines the extent to which the EU grants fiscal leeway to member states through the fiscal rules framework, making it a self-fulfilling prophecy that may accurately reflect a country's fiscal space.

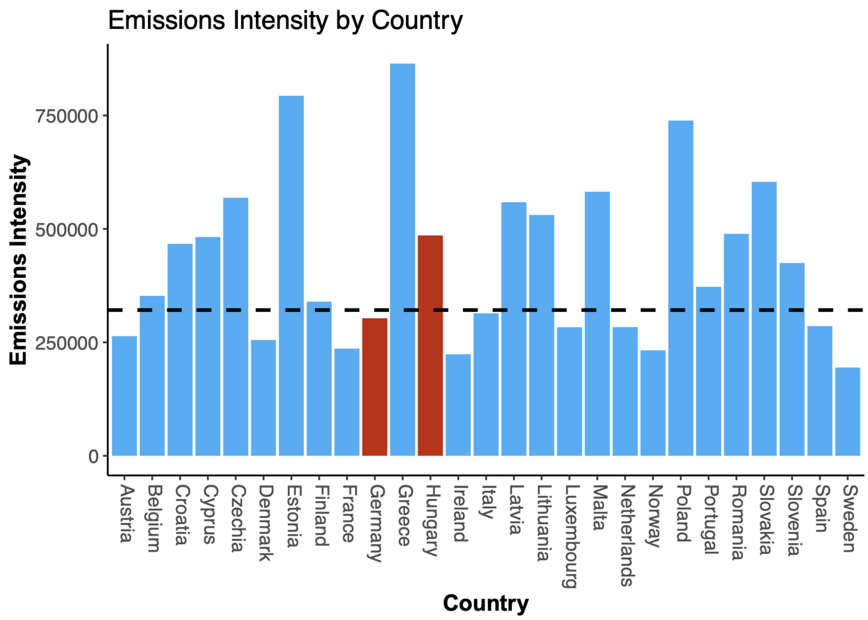


Figure 13: Emission intensity of member states in the Union (data by Exiobase, 2021)

the EU governance framework limits the fiscal leeway of EU member states. The ongoing revision should allow for more green government investments to provide all member states with the necessary fiscal leeway to finance the green transition. Third, for member states with less fiscal space, industrial policy instruments not dependent on fiscal spending, such as tax cuts and regulatory sandboxes, can be used.

Finally, an important principle for successful industrial policy is that subsidies to industries should be linked to the attainment of production-related performance objectives (similar to "carrot" and "sticks" incentives and regulations used in East Asia) (Amsden, 1989; Chang et al., 2016; Evans, 1995). The current Commission proposal, which only considers a price-quality ratio and the sustainability and resilience contribution of tenders, risks repeating past errors in industrial policy, where unproductive companies are subsidised, leading to inefficiencies and profit capture in the economy (Hafele and Barth, 2023). To avoid this, tenders must have time-limited distribution in multiple tranches, and companies that receive subsidies should be evaluated ex-post against their performance goals. Subsidies should only be continued if predetermined performance targets are met. This approach would ensure that public support is directed towards the most productive firms, resulting in a narrowing of the list of companies receiving support to the most efficient and effective ones (Hafele and Barth, 2023).

7. Conclusion

This paper developed a novel data-driven policy framework with two main objectives: 1) identifying non-future fit sectors that are likely to undergo fundamental changes in the process of decarbonization, and 2) finding complementary future fit for workers in these sectors. To accomplish this, we created a methodology that utilizes concepts based on emission-intensity, economic complexity, and skill-relatedness (section 3) and applied it to Germany and Hungary (section 5). Our findings showed that replacement options for workers in non-future industries are highly sector-specific, with some sectors presenting more opportunities for workers than others. However, without proactive government intervention, workers in certain sectors are at risk of being left behind in the green transformation.

There are plenty of avenues for future research. First, while the data matching strategy we used is imperfect, although the best possible with the publicly available data, more detailed and harmonized employment and emission intensity data would improve the accuracy of the analysis. Second, the methodology should be extended to consider the economy-wide negative effects of scaling down activity in one sector due to input-output linkages with other sectors. Third, further analysis could also compare the results of other countries, including peripheral and Jan Froized countries. Finally, our analysis focused on examining worker transitions between sectors at the national level, without factoring in regional geography. Further analysis could consider regional factors which play a crucial role in identifying replacement sectors for workers.

A. Data description and availability

A.1. Exiobase

The main source of data for this study is the Exiobase dataset version 3 by Stadler et al. (2018).[22] It contains data on 163 industries for 44 countries, with detailed data on dif-ferent emissions categories and input-output tables for the years 1995-2019. For simplicity, we use data on the last year for which full data is available, which is 2018. From Exiobase we use sectoral data on total emissions in kg CO2 equivalent, the value added, and employment. Value added and employment are calculated production-based (from the F-matrix), whereas total emissions are calculated consumption-based (from the D-matrix). This is a major advantage of using Exiobase, as it allows us to take into account indirect emissions of a sector beyond the direct production-based emissions. From the total emissions and value added, we calculate the emissions intensity, measuring how many emissions (in million kg CO2 equivalent) are created per million euros value added in a sector.

A.2. Sectoral Complexity Index

This study furthermore uses product complexity from the Atlas of Economic Complexity (Hausmann et al., 2014). This paper uses the normalized complexity index values for 2018. Merging the economic complexity index of 4-digit HS codes (rev 92) to the Exiobase sectors is done via concordance tables supplied on the Exiobase website. This many-to-many matching between products and sectors is resolved by imposing two weighing schemes on the complexity index values: First, the share of product k in the overall country's export basket s_{pk} is used as a weight. Second, the complexity values are weighted by the share of sector i's employment size s_{ei} in the overall employment of the country in the data. The Sectoral Complexity Index of sector i is thus calculated as:

$$\mathrm{SCI}_i^w = \sum_k s_{ei} \cdot s_{pk} \cdot C_k$$

Since some sectors do not produce tradable products, they do not have a sectoral complexity index (e.g., services).

A.3. Skill relatedness

Data on skill relatedness between sectors is taken from the paper by Neffke et al. (2017) for Germany. They estimate relatedness between 288 sectors at the NACE 2.0 4-digit level based on empirically observed job transitions from the IAB employee his-tory between 2008 and 2014. Data for Hungary is taken from Csáfordi et al. (2016), which computes skill relatedness using a similar methodology averaged over 2004-2011.

Relatedness is estimated to be positive for around 11000 binary connections in Ger-many, which occurs if more job transitions occur than are expected at random (for the detailed methodology the reader is referred to the original papers and its appendix). When merging the skill relatedness data with the sectoral employment data of Exiobase, one has to resolve a many-to-one mapping between classification systems from NACE to Exiobase. This is done by keeping only positive skill relatedness val-ues, and an unweighted average is used.[23] Since the data in Hungary contains infor-mation about detailed sectoral employment size and bilateral labour flows, the results could be tested against other ways of calcu-lating and aggregating flows between sec-tors. This paper specifically tested varia-tions using bilateral labour flows directly instead of relatedness values, as well as weighing relatedness by employment size of the outgoing and incoming sector and found that results are qualitatively similar.

To eliminate extreme outlier values in very small sectors, sectors with less than 5000 (1000) employees for Germany (Hungary) are dropped. This results in the final dataset of 111 sectors

[22] The dataset can be accessed on the website https://www.exiobase.eu/.

[23] It would be preferable to use a weighted average like the Sectoral Complexity Index, however con-sistent data for employment numbers in more de-tailed sectoral classifications was not publicly available for Germany.

for Germany (99 for Hunga-ry), out of which we have SCI values for 69 sectors for Germany (62 sectors for Hungary). This set of sectors is plotted in Figures 2 and 6 (and based on this set of sectors the averages of emissions intensity and weighted sectoral complexity is calcu-lated). A table with descriptive statistics of the most emissions-intensive sectors can be found in section 5.1 and 5.2.

B. Methodologies

B.1. Identifying complementary future-fit sectors

The sectors for detailed analysis in the case studies are selected as follows: First, the set of sectors with below-average sectoral complexity and above-average emissions-intensity within each country (these are the sectors in the upper left corner of Figures 2 and 6) is selected. Second, sectors in this set are sorted by their overall emissions, and the top three sectors with the highest overall emissions are selected within each country. This algorithm results in plausible choices for sectors which are non-future-fit for both countries, however, the methodol-ogy is generally applicable, and not restrict-ed to the selection here.

B.2. Treemaps: Replacement sectors

As mentioned above, skill relatedness is a relative measure, a (modified) ratio of observed to expected flows. Thus, by itself, it is not possible to directly infer transition rates of workers between any two sectors.

To identify sectors which could be target sectors for workers from a non-future-fit sector, a network of possible transitions to neighboring sectors is created. Starting from sector i, workers are allowed to only transition to neighboring sectors with a skill relatedness higher than 0: $\mathrm{SR}_{ij} > 0$. This defines a directed network of sectors, where a directed link between two nodes exists if the skill relatedness from i to j is positive. To identify potentially complementary sectors, which are not direct neighbors of sector i, workers can make up to 3 job transitions and gather the set of sectors which can be reached. In network terms, this gathers the set of nodes at an (unweighted) distance of 3 or less from the source node.

The next step is then to determine how to calculate the weighted distance from the source node to a node at path length 2 or 3. This paper chooses the following approach: For each path between node i and k, the product of the skill relatedness distances along the path is calculated. Then, from all the paths of length 3 or less from i to k, the maximum value of weighted distance is taken, resulting in an imputed skill relatedness between i and k of: $\hat{\mathrm{SR}}_{ik} = \max_{\mathrm{paths}(i,k)} \prod_{(j,l) \text{ on paths}(i,k)} \mathrm{SR}_{jl}$.

Finally, calculating the absorptive capacity of sector k with respect to sector i is done as: $\hat{A}_{ik} = \hat{\mathrm{SR}}_{ik} \cdot E_k$, so the (imputed) skill relatedness between sector i and k times the number of employees of sector k. The absorptive capacity balances two considerations when looking at job transitions out of sector i: On the one hand, workers are more likely to transition to sectors with high skill relatedness. On the other hand, smaller sectors cannot absorb inflows of large numbers of workers, limiting the possible flows between sectors. It is assumed that a sector can absorb more workers the more workers are already employed there. The quantity $\hat{A}_{ik}$ is plotted in all the treemaps for a particular origin sector i. Furthermore, to consider sectors with higher economic potential, only sectors with above-average economic complexity are plotted in the treemaps. Finally, the colors of the treemaps show the logarithm of the target sector's emissions intensity, to identify sectors with lower emissions impacts given their economic opportunities.

B.3. Edge-Bundling Plots: Relatedness between sectors

The edge-bundling plots (Figures 3 and 7) plot the network of skill relatedness between sectors, where colors represent the broad industry categories. To avoid over-plotting of all positive values of skill relatedness, a cutoff was chosen as the median skill relatedness value in the German data. Only edges with higher skill relatedness than this value are plotted. Other cutoffs give qualitatively similar results, although at lower cutoffs the skill relatedness network for Hungary appears denser than for Germany. The network reveals a high degree of clustering: Links within broad industry categories are more frequent than links between broad industry categories.

B.4. Sankey Plots: Outflows from the meat sectors

For creating the Sankey plots (flow plots), sectors are aggregated into 8 broad industry categories by hand: Agriculture, Extraction and Mining, Meat Sector, Energy, Manufacturing, Services, Waste Management, Food and Agri-Products, and Transport. The skill relatedness between any pair of broad industry categories is calculated as the unweighted mean of skill relatedness between sectors in this pair, conditional on the pair of sectors having a positive skill relatedness. Pairs of sectors for which the skill relatedness is zero or below are dropped, to focus on positively skill-related sectors. This procedure will tend to over-estimate the extent to which two broad industry categories are skill-related, so the numerical results should be interpreted with caution. Figures 5 and 11 then plot the aggregated skill relatedness between the meat sector and the other broad industry categories, and plot those broad categories to which the meat sector has a positive aggregate skill relatedness. The flow in the Sankey plot directly plots the aggregate skill relatedness, without weighing it by employment (in contrast to the treemaps).

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