Transition to carbon neutrality

Implications for productivity, competitiveness and investments

Natalia Kuosmanen, Ville Kaitila, Olli-Pekka Kuusela, Jussi Lintunen, Terhi Maczulskij, Tarmo Valkonen

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Abstract

In light of Finland's commitment to carbon neutrality, this project examined the implications of the green transition on its economy, outlining the complex relationship between environmental regulations, structural change, and productivity, while emphasizing the crucial role of green investments.

The main findings can be summarized as follows: 1) Environmental regulations have diverse effects on firms and the overall economy, leading to adaptations and triggering changes in market dynamics. 2) The effect of structural change on productivity is complex, highlighting the need to improve the productivity of continuing firms. 3) Finland's carbon intensity aligns closely with the EU average, with improvements in most industries, but challenges persist in certain industries. 4) Financing the green transition is complex due to uncertain future investments, potential government intervention reasons, and sector-specific challenges.

Finland's successful green transition relies on stricter environmental regulations, efficient carbon pricing, and the promotion of green technologies, supported by customized regulations and sustainable consumption. Additionally, it necessitates a consistent environmental policy, a long-term investment strategy, increased green technology R&D, and support for startups to foster innovation and sustainability.

Provision

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Keywords

research, research activities, carbon neutrality, environmental policy, green transition, productivity

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Siirtymä hiilineutraaliuteen
Vaikutukset tuottavuuteen, kilpailukykyyn ja investointeihin

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Tekijä/t	Natalia Kuosmanen, Ville Kaitila, Olli-Pekka Kuusela, Jussi Lintunen, Terhi Maczulskij, Tarmo Valkonen		
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Tiivistelmä

Suomi on sitoutunut hiilineutraalisuustavoitteisiin. Tämä projekti tarkasteli vihreän siirtymän yhteyksiä Suomen talouteen, ottamalla huomioon ympäristömääräyksien, rakenteellisen muutoksen ja tuottavuuden monimutkaiset yhteydet, korostaen samalla vihreiden investointien keskeistä roolia.

Tärkeimmät havainnot voidaan tiivistää seuraavasti: 1) Ympäristömääräyksillä on moninaisia vaikutuksia yrityksiin ja kokonaistalouteen, mikä johtaa markkinadynamiikan muutoksiin. 2) Rakenteellisen muutoksen vaikutus tuottavuuteen on monimutkainen, mikä korostaa tarvetta parantaa jatkavien yritysten tuottavuutta. 3) Suomen hiili-intensiteetti on lähellä EU:n keskiarvoa, vaikkakin useilla toimialoilla havaitaan hiili-intensiteetin parannusta ja toisaalta tietyillä toimialoilla haasteita. 4) Vihreän siirtymän rahoittaminen voi olla haastavaa, koska meidän on vaikea ennustaa tulevia investointeja, toimialakohtaisia haasteita tai valtion asettamia politiikkapäätöksiä.

Suomen menestys vihreässä siirtymässä perustuu tiukempiin ympäristömääräyksiin, tehokkaaseen hiilidioksidin hinnoitteluun ja vihreiden teknologioiden edistämiseen, ottaen samalla huomioon kohdennetut määräykset ja kestävän kulutuksen. Lisäksi vihreä siirtymä edellyttää johdonmukaista ympäristöpolitiikkaa, pitkän aikavälin sijoitusstrategiaa, vihreiden teknologioiden tutkimusta ja kehitystä, sekä uusien yritysten tukemista innovaation ja kestävyyden edistämiseksi.

Klausuuli

Tämä julkaisu on toteutettu osana valtioneuvoston selvitys- ja tutkimussuunnitelman toimeenpanoa.(tietokayttoon.fi) Julkaisun sisällöstä vastaavat tiedon tuottajat, eikä tekstisisältö välttämättä edusta valtioneuvoston näkemystä.

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Övergång till koldioxidneutralitet
Konsekvenser för produktivitet, konkurrenskraft och investeringar

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Finland har åtagit sig att uppnå koldioxidneutralitetsmål. Det här projektet undersökte kopplingarna mellan den gröna övergången och Finlands ekonomi, med beaktande av de komplexa sambanden mellan miljöbestämmelser, strukturell förändring och produktivitet, samtidigt som den betonade den centrala rollen för gröna investeringar.

De viktigaste resultaten kan sammanfattas enligt följande: 1) Miljöbestämmelser har olika effekter på företag och den totala ekonomin, vilket leder till förändringar i marknadens dynamik. 2) Effekten av strukturell förändring på produktiviteten är komplex och understryker behovet av att förbättra produktiviteten för fortsatta företag. 3) Finlands kolintensitet ligger nära EU-genomsnittet, med förbättringar inom flera branscher, men utmaningar kvarstår inom vissa branscher. 4) Finansieringen av den gröna övergången kan vara komplex på grund av osäkra framtida investeringar, potentiella ingripanden från regeringen och branschspecifika utmaningar.

Finlands framgång i den gröna omställningen bygger på skärpta miljöbestämmelser, effektiv prissättning av koldioxid och främjandet av gröna teknologier, samtidigt som skräddarsydda bestämmelser och hållbar konsumtion beaktas. Dessutom krävs en konsekvent miljöpolitik, en långsiktig investeringsstrategi, ökad forskning och utveckling av gröna teknologier samt stöd till startföretag för att främja innovation och hållbarhet.

Nyckelord	forskning, forkningsverksamhet, kolneutralitet, miljöpolitik, grön övergång, produktivitet		
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Contents

1 Implications of the transition to carbon neutrality

1.1 Introduction

Addressing climate change necessitates substantial investments in emissions reduction across all sectors of the economy. The European Union has committed to reducing greenhouse gas (GHG) emissions by 55 percent from 1990 levels by 2030.[1] For Finland, the goal is to achieve carbon neutrality by 2035, striving to become a fossil-free welfare society.[2]

This transition towards carbon neutrality involves both emissions reductions across all sectors and the enhancement of carbon sinks. Consequently, some firms and industries are positioned to gain a competitive advantage from stricter emission standards, especially those that have proactively anticipated tighter regulations, effectively leveraged low-emission technologies, and secured private and public funding for green investments. Conversely, other firms may face market share losses, with a few even forced to cease operations entirely. As a result, the carbon-neutral transition is triggering structural changes in production, distribution, and consumption. Although the transition is already underway, the effects are expected to intensify as emission standards continue to tighten.

These structural changes are closely linked to firms’ productivity and competitiveness. On one hand, changes stemming from the carbon-neutral transition, such as the market share expansion or contraction, the establishment of new enterprises, and the

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[1] European Commission, European Climate Law.

[2] Ministry of the Environment, Climate Act (423/2022).

exit of existing firms from the market, can either enhance or weaken productivity growth of entire industries and the overall business sector. On the other hand, firm productivity and competitiveness shape industry structures. For instance, decisions to invest in profitable ventures within Finland or relocate production to countries with lower emission standards depend on productivity and competitiveness considerations. It is important to note that the relationship between economic structural change and productivity is not one-way; while structural change influences productivity, productivity development also influences structural change.

Although the transition to carbon neutrality is anticipated to bring about significant structural changes, there is a notable lack of prior research in this area. This report's primary aim is to address this research gap.

1.2 Research questions

This report focuses on assessing the implications of structural change resulting from the transition to carbon neutrality on the competitiveness and productivity of firms.

The research questions are as follows:

1. Through which channels does the carbon-neutral transition influence industry structure and subsequently affect firm productivity and competitiveness?
2. What structural changes and productivity outcomes has the carbon-neutral transition induced in Finland's business landscape thus far?
3. What structural productivity and competitiveness effects might arise from the transition to carbon neutrality now and in the future?
4. What investment requirements could emerge due to the transition to carbon neutrality, and how do the financial capabilities of firms and the development of financial markets address these needs?
5. What policy measures can facilitate a carbon-neutral transition while enhancing productivity and competitiveness?

Chapter 2 reviews prior research in environmental economics and firm dynamics to address Question 1, while Chapter 3 conducts an empirical analysis focusing on Question 2, examining structural changes and productivity effects in Finland's energy-intensive sectors using firm-level GHG emissions data. Chapters 4 and 5 tackle Question 4, exploring challenges in Finland's carbon neutrality transition, and Chapter 6 emphasizes the uncertainties and challenges of future green investments in the context of Question 4. Finally, Chapter 7 synthesizes insights from all previous chapters to propose policy recommendations in response to Question 5.

2 Literature review and framework

2.1 Introduction

Anthropogenic climate change, driven by GHG emissions, has been the primary driver of global warming since the Industrial Revolution (IPCC, 2013). Addressing this challenge requires significant efforts and investments. Achieving carbon neutrality,[3] as outlined in the Paris Agreement, is considered a just solution. The European Union's vision, "A Clean Planet for all" (COM, 2018), lays out the path to meet the Paris Agreement and the UN's Sustainable Development Goals. This vision aims for net-zero GHG emissions by 2050 while promoting competitiveness, inclusivity, fairness, and prosperity.

The transition to carbon neutrality necessitates global cooperation. As a member of the European Union, Finland is fully committed to the Paris Agreement on Climate Change and has set an ambitious goal to achieve carbon neutrality by 2035 and go beyond by becoming carbon-negative. To guide the efforts toward the 2035 goal, scenarios have been developed (Koljonen et al., 2020) and the national climate and energy strategies are continuously being updated.

Swift emissions reductions are required across all sectors. The Finnish government has developed together with the industries sector-specific low-carbon roadmaps as part of its climate policy, providing a clear outline of the necessary measures and costs for a low-carbon transition (Paloneva and Takamäki, 2021). Additionally, numerous Finnish cities have set ambitious climate neutrality targets (Huovila et al., 2022). Recognizing that a just carbon-neutral transition varies by region, tailored policies are essential (Iqbal et al., 2021; Salvia et al., 2021; Zhao et al., 2022).

The transition to a carbon-neutral economy is already underway and will intensify as emissions standards become more stringent. This transition will reshape production, distribution, and consumption, impacting productivity and competitiveness. As highlighted by Pisani-Ferry (2021), the accelerated transition has immediate economic

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[3] Carbon neutrality, as defined by the Intergovernmental Panel on Climate Change (https://www.ipcc.ch/sr15/chapter/glossary), refers to achieving a net-zero balance between human-made carbon dioxide (CO_2) emissions and removals, mitigating global warming by reducing atmospheric CO_2.

implications, including asset depreciation, plant closures, workforce reallocation, and increased investment.

Despite its profound impact, limited prior research exists on the connection between carbon neutrality and economic performance. To address this gap, we conduct a review of environmental economics literature, examining firm responses to environmental regulations,[4] including command-and-control instruments and market-based mechanisms. We explore how these responses drive structural changes at the firm, industry, and economy levels. Based on our findings, we propose a framework that explains the indirect effects of the carbon-neutral transition on productivity and economic outcomes.

The remainder of this chapter is organized as follows: Section 2.2 introduces prevailing hypotheses in environmental economics, forming the theoretical foundation for empirical analysis. In Section 2.3, we detail potential firm responses to environmental policies and delve into the structural changes induced by the transition to carbon neutrality. Section 2.4 summarizes key findings and presents our framework. Finally, Section 2.5 offers concluding remarks.

2.2 Theory

The link between environmental regulations and economic performance has sparked ongoing debates since the introduction of environmental regulations in the 1970s. Numerous studies have aimed to explore this connection (e.g., Wagner et al., 2001; Ambec and Lanoie, 2008; Lahouel et al., 2022). Within environmental economics literature, two prevailing perspectives have emerged: the pollution haven hypothesis and the Porter hypothesis.

[4] Environmental regulations are typically classified into three policy approaches: command-and-control measures (e.g., emission standards and enforcement policies), market-based instruments (e.g., environmental taxes, tradable permit systems, and targeted subsidies), and information-based tools (including corporate sustainability reports and corporate social responsibility programs.

The **pollution haven hypothesis**, dating back several decades (McGuire, 1982),[5] suggests that stricter environmental policies[6] increase essential input costs for firms in industries with higher environmental compliance expenses. This can disrupt existing comparative advantages, shifting pollution-intensive production to regions with lower abatement costs, often from developed to developing countries. Such a shift results in the emergence of pollution havens, regions with lax environmental regulations, causing policy-induced pollution leakage (Levinson and Taylor, 2008; Li and Zhou, 2017). According to this view, there is a short-term conflict between firm competitiveness and environmental performance (Walley and Whitehead, 1994).

However, it is important to note that the impact of asymmetric environmental policies on competitiveness is complex. Regulations can vary not only across regions (e.g., climate policies) but also among firms and industries (e.g., Green Industrial Policy). This variation in regulations can lead to changes in individual enterprise's production costs, prompting various responses such as investments in clean technology, pricing adjustments, or production volume changes. These responses can have far-reaching effects on the economy, technology, international trade, and the environment.

The **Porter hypothesis**, on the other hand, suggests that stringent environmental policies can ultimately enhance the competitiveness of regulated firms (Porter, 1991; Porter and van der Linde, 1995). Such policies incentivize investments in innovation and clean technologies, potentially offsetting compliance costs (Porter and Esty, 1998). This approach can lead to first-mover advantages, global technological leadership, and market expansion. Therefore, the Porter hypothesis argues that well-designed environmental regulations can drive innovation increase firm productivity, and boost competitiveness (Porter and van der Linde, 1995).[7]

These opposing views on the environmental-economic performance relationship are rooted in different generalized functional relationships (Wagner et al., 2001). The

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[5] For more recent research, refer to studies by Rubashkina et al. (2015), Ramanathan et al. (2017), and Huiban et al. (2018).

[6] Stringent environmental policies typically focus on addressing climate and air pollution, with 'stringency' denoting the strength of the policy signal –the explicit or implicit cost of engaging in environmentally harmful activities, like pollution (Kozluk and Garsous, 2016). Environmental Policy Stringency (EPS) has various proxies in the literature, such as actual pollution emissions, environmental legislation, and regulatory indices. For example, the OECD's EPC measure is a composite index based on selected environmental policy instruments (Botta and Koźluk, 2014).

[7] For recent reviews on this topic, consult studies by Brännlund and Lundgren (2009) and Petroni et al. (2019).

traditionalist view assumes a consistently negative connection, driven by non-productive environmental investments negatively impacting financial performance. This perspective suggests that increased environmental compliance costs can drain a firm's resources, putting it at a disadvantage compared to less environmentally committed firms (Lahouel et al., 2022).

The revisionist view of the Porter Hypothesis argues for a positive relationship between environmental and economic performance. It implies that environmental efforts are investments in innovative technologies that reduce abatement costs. Well-crafted environmental regulations can lead to mutually beneficial outcomes, including improved competitiveness through innovation, enhanced efficiency, increased productivity, reduced compliance costs, and new market opportunities (Ambec and Lanoie, 2008; Xie et al., 2017).

A synthesis of these two views suggests an inverse U-shaped relationship (Wagner et al., 2001; Pierce and Aguinis, 2013). Initially, environmental regulations and firm performance are positively related, reaching an optimal point where regulations maximize economic performance. However, beyond this point, further investments may lead to the use of inefficient technologies, increasing pollution abatement costs and potentially undermining economic performance (Pekovic et al., 2018).

In summary, the relationship between environmental and economic performance is theorized in three ways: consistently negative (traditional view), consistently positive (revisionist view), and inverse U-shaped (synthesis). The empirical evidence on this relationship varies due to research design, methodology, performance measures, periods, and data quality. In light of this theoretical foundation, we will now examine empirical evidence regarding the environmental and economic performance relationship.

2.3 Empirical evidence

Carbon neutrality has gained significant attention in scientific literature, but research on its realization pathways remains limited (Wu et al., 2022). Literature reviews, such as Wang et al. (2022), indicate that existing research predominantly focuses on topics like energy transformation, technology development, and impact assessment, with an emphasis on reducing biomass and quantifying CO_2 emissions.

Yet, few studies have empirically explored the impact of a carbon-neutral transition on structural changes within firms, industries, and the broader economy, including its effects on productivity and competitiveness. Nonetheless, both theoretical and empirical evidence exists concerning the impacts of environmental regulations. It is important to note that achieving carbon neutrality requires substantial sectoral adjustments guided by carbon-neutrality targets and *environmental regulations.*

We next summarize various responses triggered by environmental regulations and policies, drawing from research on the economic impacts of climate change mitigation. We also examine potential structural changes that the carbon-neutral transition may induce within firms, industries and the overall economy. Finally, we synthesize our findings into a framework for assessing the indirect impacts of the carbon-neutral transition on productivity and other economic outcomes.

2.3.1 Firm responses

Environmental regulations, aimed at safeguarding the environment, *introduce additional costs for firms and trigger responses in terms of pricing, output, and investment* (Dechezleprêtre and Sato, 2017)*.* These responses depend on factors such as business characteristics, sectors involved, the nature and strictness of environmental regulations, and other relevant factors (Iraldo et al., 2011). We categorize potential firm responses into three groups.

I Responses in production

Stricter environmental regulations can affect production costs, including direct and indirect costs (Pasurka, 2020). Firms may respond by adjusting product prices, passing increased costs to consumers, or reducing production volumes to mitigate expenses (Dechezleprêtre and Sato, 2017). Alternatively, some firms may choose to increase production capacity to maximize profits without investing in technological innovation (Cai et al., 2022), potentially conflicting with environmental policy objectives. To mitigate environmental impacts, firms may substitute polluting inputs with cleaner alternatives.[8] Electrification of production processes, capitalizing on lower renewable electricity costs compared to fossil-fuel generation, can lead to cost savings and reduced GHG emissions, as demonstrated by recent studies (Wei and McMillan, 2019).

[8] A significant body of research has been dedicated to investigating the elasticity of substitution between clean and dirty inputs, as evidenced by works such as Acemoglu et al. (2012) and Papageorgiou et al. (2017).

II Responses in location

Stricter environmental policies can raise compliance costs for pollution-intensive industries, leading to the relocation of production or pollution-intensive components to regions with lower abatement costs (Levinson and Taylor, 2008). As domestic pressure to reduce emissions mounts, firms may outsource emissions to overseas suppliers to evade responsibilities, a phenomenon linked to investment location decisions.[9] Developing economies with less stringent environmental regulations may attract foreign direct investment (FDI), resulting in the transfer of pollution-intensive production from developed economies and increased pollution emissions, known as “offshoring pollution” (Hao et al., 2020). Recent global discussions have also explored the intersection of trade and climate change, with proposals like the European Union’s carbon border adjustment tax potentially impacting production, exports, and climate change efforts.

It's worth noting that while environmental regulations can influence firm location decisions, they are just one of many factors considered by firms, alongside factors like capital intensity, proximity to raw materials, agglomeration economies, and transport costs (Cole et al., 2017).

III Responses in investment

Environmental regulations incentivize firms to invest in clean energy production, pollution abatement technology adoption, green innovation, and research and development for pollution reduction. Pollution abatement technologies encompass clean technologies and end-of-pipe solutions (Hammar and Löfgren, 2010). Clean technologies aim to reduce emissions during production, while end-of-pipe solutions (e.g., catalytic converters) mitigate environmental impacts by preventing pollution spread.

The Porter hypothesis suggests that stringent environmental regulations drive innovation in firms striving to comply with them. This leads to the discovery of new technologies that not only reduce emissions but also lower production costs. Studies support this hypothesis, indicating that environmental regulations significantly induce

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[9] Empirical research explores the influence of environmental policies on manufacturing investments. Dechezleprêtre and Sato (2017) provide a detailed review and discussion of this topic, examining whether relaxed policies attract investments and how stringent policies affect investment flows and location decisions.

firms to pursue green innovation (Borsatto and Bazani, 2021; Li and Zhu, 2019).[10] Through cleaner production technology and R&D investment, costs are offset, demand for environmentally friendly products rises, and technological leadership and market share increase, enhancing environmental protection while improving firm productivity and competitiveness (Iraldo et al., 2009; Hille and Möbius, 2019).

2.3.2 Structural change

In this section, we explore how the transition toward carbon neutrality can lead to structural changes at different levels of the economy. Environmental regulations can increase production costs for firms, triggering transformations within industries and impacting the overall industrial landscape.

At the economy level

In the context of carbon neutrality, environmental regulations create opportunities to redirect investments from carbon-intensive industries to clean and modern ones. This transition accelerates industry composition changes, moving away from pollution-intensive sectors and towards cleaner, knowledge- and technology-driven production – a phenomenon known as the “composition effect” (Brunel, 2017), and is closely related to the pollution haven hypothesis discussed earlier. This shift can vary among countries based on their environmental regulations and consumer preferences for eco-friendly products.

The heterogeneity of environmental regulations across countries can result in the alteration of their industrial composition. Less-regulated countries may specialize in the production of pollution-intensive goods, while highly regulated countries may focus on eco-friendly products. It is important to note that consumer preferences for eco-friendly products and services play an important role in determining the growth or decline of certain industries (Krüger, 2008). The empirical literature supports this hypothesis, with evidence of heterogeneous responses to environmental regulation within specific industries (for a review, see Millimet et al., 2009).

[10] Firms’ production technology includes both pollution control-oriented and production-oriented technical advancements.

At the industry level

The transition to carbon neutrality results in a constantly evolving operating environment leading to structural changes at the industry or sector level. Industry structure depends on the number of firms within it and the distribution of market share among these firms. Resources shift from declining to expanding economic activities through creative destruction, involving the entry of new firms and the exit of obsolete ones. Environmental regulation can prompt existing firms in the market to adapt and adjust their operations. Additionally, it may influence the industry structure by modifying opportunities for new firms to enter, the exit of incumbent firms, and the relative competitive advantage of active firms.

The study by Millimet et al. (2009) provides an overview of the theoretical and empirical literature on the impact of environmental regulation on market structure. According to static market theories, there is a negative relationship between the number of firms and the level of regulatory stringency, suggesting that more stringent regulations lead to fewer new firm entries and more firm exits. However, the empirical evidence on this subject is abundant but not straightforward. While many studies suggest that environmental regulation results in reduced entry and increased exit of firms, there are also findings supporting the idea that regulation discourages exit. In a dynamic market setting, stringent regulation provides incentives for firms to invest in technology, innovation, and pollution abatement R&D, influencing firm entry, exit, and size heterogeneity. As the industry evolves, firms that adopt cleaner and larger operations through policy-induced investments are more likely to persist, while smaller, less eco-friendly firms may eventually exit the market (Millimet et al., 2009).

At the firm level

The shift towards carbon neutrality is expected to lead to significant product renewals in the near future. Companies are anticipated to transition their production lines by incorporating eco-friendly products and discontinuing unsustainable ones – a process referred to as “product switching” (see Bernard et al., 2010; Bernard and Okubo, 2016). This realignment of economic activity is driven by a shift away from unsustainable products and towards eco-friendly ones. Product switching facilitates the internal reallocation of resources within firms towards the most efficient use. Recent studies (Maliranta and Valmari, 2017; Kuosmanen et al., 2022) indicate that product switching is prevalent in Finnish manufacturing industries.[11] Companies that

[11] While there is extensive research on resource reallocation due to firm entry and exit, limited attention has been given to the causes and consequences of reallocation within surviving firms.

successfully adopt can remain competitive and grow, while those unable to adjust may decline or exit the market.

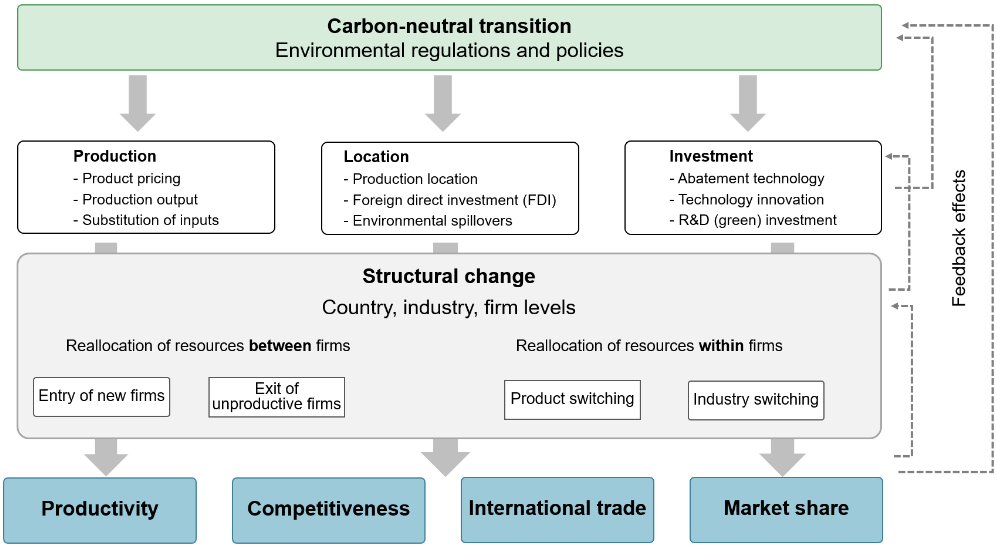
2.4 Framework

Figure 1 provides a summary of the discussed findings, illustrating the channels of the transition toward carbon neutrality on various economic outcomes. The top part of the figure outlines potential firm responses to environmental regulations, drawing from environmental economics literature. These responses involve changes in production methods, production location, and investment choices. These actions induce structural changes within firms, industries, and the broader economy.

The bottom part of the figure represents the consequences of these responses. They lead to product renewal and transformations in production processes, which in turn, affect market structure, competitiveness, productivity, and international trade. Firms that anticipate stringent emissions legislation may gain a competitive advantage, while others may face declines or closure. Some industries may shrink, while others can expand by adopting environmental technologies and enhancing competitiveness. At the economy level, achieving carbon neutrality necessitates efforts such as decarbonization, investment in energy efficiency, renewable energy, and green technology R&D, especially for carbon-intensive industries.

It is important to note that this framework simplifies the complex dynamics involved in the transition to carbon neutrality and its impacts on economic growth. It does not distinguish between different types of environmental regulations or specific measures of economic growth. Instead, it serves as a flexible tool for understanding the broad relationships between these concepts.

Figure 1. Indirect impacts of carbon-neutral transition on economic growth.



Additionally, the interconnections depicted in Figure 1 are not one-way. The effects of the transition to a carbon-neutral economy, including changes in market share, firm entry and exit, and shifts in productivity, can also influence industry and sector-level productivity growth. Likewise, a firm's productivity and competitiveness can shape industry structures. For example, a firm's productivity and competitiveness can influence its decision to invest domestically or abroad in countries with different emissions standards. Therefore, the relationship between structural changes and productivity is bidirectional, with each factor influencing the other.[12]

2.5 Conclusions

Addressing climate change through achieving carbon neutrality is essential due to the adverse impact of GHG emissions on global warming. Finland has set an ambitious target to attain carbon neutrality by 2035 and even surpass it by becoming carbon-negative. This transition necessitates substantial global efforts and investments, along with decarbonization across all economic sectors (Huttunen et al., 2022). Guiding this

[12] Growing awareness acknowledges the circular causality between economic growth and structural change. Dietrich (2012) found that structural change stimulates overall economic growth, and vice versa. Although initial economic growth temporarily slows structural change, it eventually advances it with a time delay.

transition are environmental regulations such as emissions trading system and long-term climate and energy policies.

The shift towards a carbon-neutral economy is already in progress and will accelerate with the implementation of stricter emissions standards. This transformation will lead to significant alterations in production, distribution, and consumption patterns, with notable consequences for productivity and competitiveness.

Despite its importance, there is a lack of prior research on the intricate connection between the transition to carbon neutrality and economic performance. To address this gap, this chapter reviews previous research in the fields of environmental economics and firm dynamics. Our review focuses on how firms respond to environmental regulations and how these responses trigger structural changes at the levels of individual firms, entire industries, and the broader economy.

Based on our findings, we propose a conceptual framework that explains the channels and indirect impacts of the transition toward carbon neutrality on productivity and broader economic outcomes. This framework offers insights into the complex interplay between environmental regulations, firm responses, and overall economic performance.

3 Structural change decomposition of green total factor productivity

3.1 Introduction

Finland has committed to achieving carbon neutrality by 2035. Prior research on the impact of this transition on productivity has primarily focused on the examination of carbon productivity (or its inverse carbon intensity) at the country, regional, or sector level (e.g., Meng and Niu, 2012; Wang et al., 2016). At the national level, changes in production structure and technology have been identified as key factors in reducing carbon intensity (Su and Ang, 2015), while at regional and sector levels, changes in economic structure, energy efficiency, and fuel usage have played similar roles (Greening et al., 1998; Liu et al., 2019). Furthermore, technological innovation has been recognized as an important driver of carbon productivity improvement (Zhengnan et al., 2014).

While substantial research exists at the aggregate level, there is limited evidence about how structural change contributes to productivity at the firm level. Recent studies, focusing on Finland's manufacturing and electricity generation sectors, suggest that in manufacturing, continuing firms are the primary drivers of carbon productivity growth, whereas new entrants and exiting firms have a negative contribution (Kuosmanen et al., 2022; Kuosmanen and Maczulskij, 2023). Additionally, Kuosmanen and Maczulskij (2023) found a positive link between carbon productivity and labor productivity in energy-intensive manufacturing. Similarly, the electricity generation sector experienced significant carbon productivity growth, attributed to radical structural changes including firm entries/exits, industry switching, and GHG emission reallocation.

While the carbon productivity measure is informative, it primarily assesses output about carbon emissions, overlooking other inputs such as labor and capital.

Therefore, in this chapter, we shift our focus to a more comprehensive metric: green total factor productivity (Green TFP),[13] which incorporates carbon emissions.[14]

More specifically, we estimate firms' Green TFPs in two sectors: energy-intensive manufacturing and electricity generation by employing a fixed effects model.[15] We utilize unique firm-level GHG emissions data from Statistics Finland and other register-based firm data for the period 2000–2019. Subsequently, we apply the structural change decomposition of productivity proposed by Kuosmanen and Kuosmanen (2021) to break down Green TFP growth into components, including contributions of continuing firms, and effects of entry and exit, resource allocation, and industry switching. This approach allows us to gain a better understanding of the factors driving Green TFP growth in these sectors.

The rest of this chapter is structured as follows. Section 3.2 presents an overview of aggregate Green TFP in Finland from 1995 to 2019. Section 3.3 details our data sources and methodology. Section 3.4 presents decomposition results for Green TFP growth in the examined sectors. Section 5 summarizes our key findings.

3.2 Green TFP in Finland

To assess Green TFP at the national level in Finland, we adopt a growth accounting approach akin to Brandt et al. (2014; 2017).[16] We utilize the EUKLEMS datasets to

[13] Further insights on greening productivity measurement are available on the OECD's website at https://www.oecd.org/environment/indicators-modelling-outlooks/greening-productivity-measurement.htm.

[14] Zhang et al. (2021) provide an overview of the prevailing trends and influencing factors in Green TFP research.

[15] Energy-intensive manufacturing refers to industrial processes with high energy demands for producing goods and materials. This includes industries such as Manufacture of pulp and paper products (TOL 2008 code C17), Manufacture of basic metals (C24), Manufacture of coke and refined petroleum products (C19), Manufacture of other non-metallic mineral products (C23), and Manufacture of chemicals and chemical products (C20).

[16] Green TFP methodology vary depending on the approach used. Similar to TFP, growth accounting and econometric methods can be used to measure Green TFP. For details and applications, refer to Chen (1997).

obtain TFP indices for the period 1995–2019[17] and Statistics Finland's data on value added and GHG emissions. To account for carbon pricing, we use the OECD carbon pricing benchmarks (OECD, 2021). Specifically, we consider three scenarios: low prices of 30 and 60 euros per tonne of CO_2, and a high price of 120 euros per tonne.

TFP is expressed as the ratio of value added (*VA*) to aggregate input (*Inputs*):

(1) $$TFP = VA/Inputs.$$

While value added represents the output or value generated by the production process, *Inputs* refer to aggregated inputs of labor, capital, and other production factors.

The calculation of Green TFP involves an adjustment to the conventional TFP measure, achieved by subtracting the product of the carbon price and GHG emissions from the value added, as follows:

(2) $$GreenTFP = (VA - Price \cdot GHG)/Aggregate\ Input.$$

Here, *Price* denotes the carbon pricing benchmarks, mentioned above. By incorporating emission costs into the TFP calculation, Green TFP offers an environmentally conscious perspective on productivity.

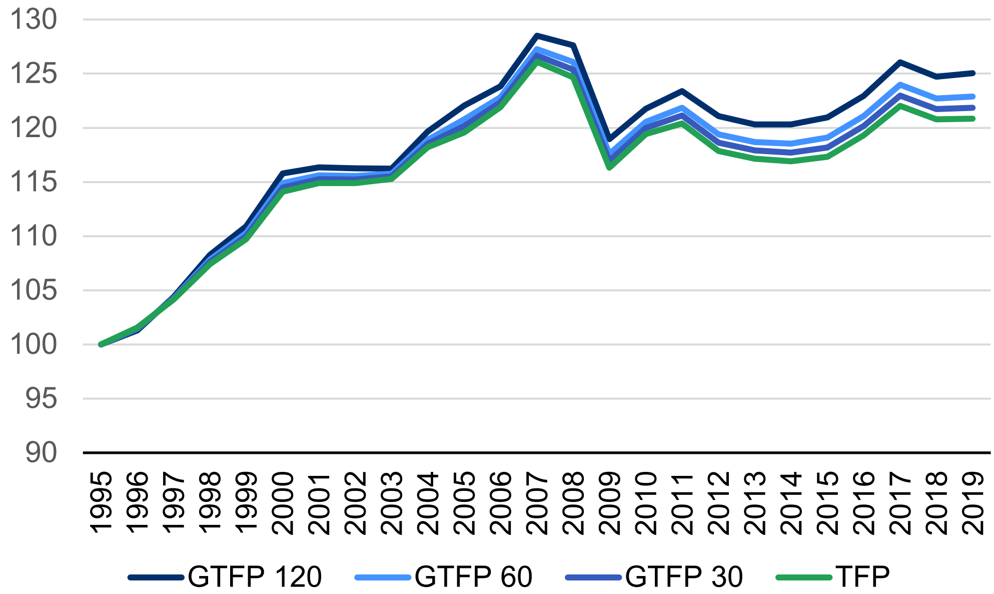
Figure 2 illustrates the changes in the TFP and Green TFP in Finland during 1995–2019, with an index of 100 set for 1995. The black line represents TFP change without considering emission reduction, while the three green lines of varying shades depict Green TFP change calculated using three different carbon prices. When accounting for emission reductions, Green TFP change closely aligns with TFP change, even under the highest carbon price of 120 euros per tonne of CO_2. Thus, this specific approach reveals only a small gap between Green TFP and TFP at the

[17] The EU KLEMS growth accounts rely on the growth accounting methodology established by Jorgenson and Griliches (1967) and extended into a broader input-output framework by Jorgenson et al. (1987, 2005). This approach assesses the relative importance of labor, capital, and intermediate inputs to growth, and calculates total factor productivity growth measures.

national level, suggesting that the costs associated with emission reductions have not significantly impacted overall productivity and economic growth.[18]

To gain deeper insights into the effects of GHG emission reduction efforts on specific industries in Finland, we proceed to analyze the Green TFP of two energy-intensive sectors: energy-intensive manufacturing and electricity generation. Through a decomposition of Green TFP change within these sectors, we aim to explain the structural transformations in these sectors and their influence on sectors' productivity growth.

Figure 2. TFP and Green TFP change in Finland in 1995–2019, Index (100=1995). Source: Calculations by the authors using data from Statistics Finland and EUKLEMS. The TFP and Green TFP calculations for Finland encompass all NACE activities.



[18] A recent study by Dai et al. (2023) examines whether accounting for GHG emissions can explain productivity stagnation in OECD countries revealing that measured productivity growth increases when GHG emissions are considered, potentially doubling conventional TFP growth.

3.3 Green TFP in energy-intensive sectors

3.3.1 Data and methods

In the present analysis, we use a dataset that combines firm-level GHG emissions data from Statistics Finland's Greenhouse Gas Inventory[19] for the period 2000–2019 with other firm-level register data, including financial statement information.[20] Our merged dataset allows us to calculate Green TFP for each firm and explore the role of structural change in the productivity growth of these sectors while considering emission reduction.

Figure 3 illustrates the trends in GHG emissions, measured in carbon dioxide equivalent (CO_2 eq., Mt), within the energy-intensive manufacturing and electricity generation sectors in Finland in 2000–2019.

In 2019, the manufacturing sector accounted for approximately 10.9 million tonnes of CO_2 eq., while the electricity generation sector emitted around 11.6 million tonnes. Over the study period, emissions from the manufacturing sector showed a decreasing trend. In contrast, emissions from the electricity generation displayed year-to-year fluctuations but generally remained consistent. These fluctuations in the electricity generation sector's emissions can be attributed to various factors, including changes in energy consumption influenced by weather conditions, especially during cold winters, and fluctuations in the overall business cycle.

To estimate Green TFP at the firm level, we employ a fixed effects model with a Cobb-Douglas production function, as represented by the following equation:

(3) $$ln(GO_{it}) = \alpha + \beta ln(L_{it}) + \gamma ln(K_{it}) + \delta \ln(M_{it}) + \theta ln(GHG_{it}) + \mu_i + \varepsilon_{it}.$$

In Equation (3), the variables are defined as follows: GO_{it} represents the gross output (turnover) of firm i in period t, L_{it} represents the labor input measured in full-time equivalent, K_{it} represents the capital input, M_{it} represents the intermediate inputs, and GHG_{it} represents the GHG emissions. All variables are expressed in their natural

[19] Greenhouse gas inventory, https://www.stat.fi/tup/khkinv/index_en.html.

[20] For details on the Financial Statement Data Panel and its data description, see https://taika.stat.fi/en/aineistokuvaus.html#!?dataid=FIRM_19862020_jua_FSSpaneeli_001.xml.

logarithmic form. Additionally, specific parameters include α, β, γ, δ, θ as coefficients, μ_i represents firm-specific fixed effects, and ε_{it} is the error term capturing unexplained factors. We present the coefficient estimates along with their standard errors and statistical significance in Table 1.

By estimating the output elasticities of labor (β), capital (γ), intermediates (δ), and GHG emissions (δ) inputs, we capture the portion of output that cannot be explained by these factors, as represented by the residuals (ε) in Equation (3).

We can rewrite Equation 3 as follows:

(4) $$\exp(\varepsilon_{it}) = GO_{it}\left(GHG_{it}^{-\theta}\right)/[\exp(\alpha + \mu_i)\left(L_{it}^{\beta}\right)\left(K_{it}^{\gamma}\right)\left(M_{it}^{\delta}\right)].$$

These residuals reflect firm-level Green TFPs, which measure the efficiency with which firms transform inputs into output while accounting for the impact of GHG emissions. We next use these firm-level Green TFP estimates to examine the link between emission reduction efforts and productivity growth of the two analyzed industries.

Figure 3. GHG emissions (in CO_2 eq.) of the Finnish energy-intensive manufacturing and electricity generation industry in 2000–2019. Source: Authors' calculations based on Statistics Finland's firm-level emission data.

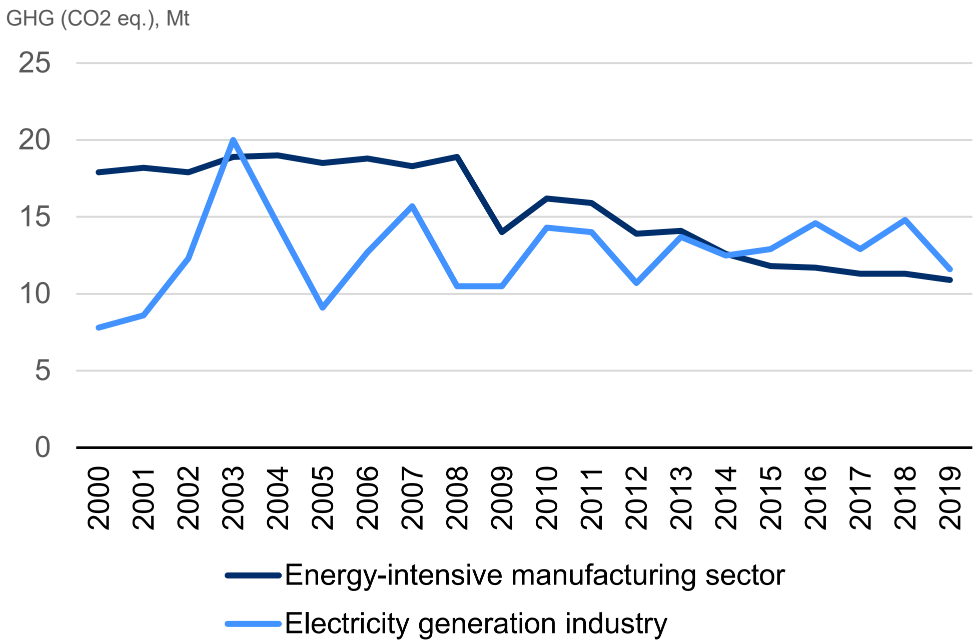


Table 1. Results of fixed-effects regression analysis.

Manufacturing

Variable	Coefficient	Std. Error
ln (Labor)	0.144***	(0.006)
ln (Capital)	0.032***	(0.003)
ln (Intermediates)	0.776***	(0.005)
ln (Emissions)	0.012***	(0.002)
Constant	2.889***	(0.076)
Observations	5,083	-
Number of firms	589	-
R^2	0.921	-

Electricity generation

Variable	Coefficient	Std. Error
ln (Labor)	0.027***	(0.005)
ln (Capital)	0.035***	(0.008)
ln (Intermediates)	0.801***	(0.013)
ln (Emissions)	0.039***	(0.007)
Constant	2.553***	(0.252)
Observations	627	-
Number of firms	73	-
R^2	0.893	-

Note: Standard errors are shown in parentheses. The significance levels are indicated as follows: *p < 0.1, **p < 0.05, ***p < 0.01.

3.3.2 Structural change decomposition

To analyze the factors contributing to the sector’s Green TFP, we apply the structural change productivity decomposition method proposed by Kuosmanen and Kuosmanen

(2021). We categorize the firms in our sample into four distinct and mutually exclusive sub-groups:

i. Non-switching continuing firms: Firms that remain within the same industry within the examined sector during a specific period.
ii. Industry-switching continuing firms: Firms that transition to another industry within the examined sector during the same period.
iii. Exiting firms: Firms that were observed in the initial period but were absent in the last period.
iv. New entrants: Firms that were absent in the initial period but are observed in the last period.

Considering a sector with N_t firms in period t, where each firm's Green TFP is denoted as p_{it}, define the sector's aggregate Green TFP, P_t, as the sum of four distinct components as follows:

Industry Green TFP (P_t)

= Green TFP of non-switching continuing firms ($\bar{p}_{Sn,t}$)

+ Industry switching effect ($\bar{p}_{S,t} - \bar{p}_{Sn,t}$)

+ Entry and exit effect ($\bar{p}_t - \bar{p}_{S,t}$)

+ Resource allocation effect ($P_t - \bar{p}_t$)

or equivalently:

(5) $$P_t = \bar{p}_{Sn,t} + \left(\bar{p}_{S,t} - \bar{p}_{Sn,t}\right) + \left(\bar{p}_t - \bar{p}_{S,t}\right) + (P_t - \bar{p}_t).$$

In Equation (5), P_t represents the sector's aggregate Green TFP in period t, calculated using aggregated inputs and output data. The first component on the right side represents the average Green TFP of non-switching continuing firms. The second component captures the impact of industry switching by comparing the mean productivity of all continuing firms with that of non-switching continuing firms. The third component reflects the productivity effects resulting from the entry and exit of firms, calculated by comparing the average productivity of all firms with that of continuing firms. The fourth component captures the allocation of resources among all firms in the sample, calculated as the difference between the sector-level productivity and the average productivity of all firms.

To decompose productivity changes, we can rewrite Equation (5) as

$$(6) \qquad \frac{P_t}{P_{t-1}} = \frac{\bar{p}_{Sn,t}}{\bar{p}_{Sn,t-1}} + \left[\frac{\bar{p}_{S,t}}{\bar{p}_{S,t-1}} - \frac{\bar{p}_{Sn,t}}{\bar{p}_{Sn,t-1}}\right] + \left[\frac{\bar{p}_t}{\bar{p}_{t-1}} - \frac{\bar{p}_{S,t}}{\bar{p}_{S,t-1}}\right] + \left[\frac{P_t}{P_{t-1}} - \frac{\bar{p}_t}{\bar{p}_{t-1}}\right].$$

This decomposition allows us to examine the specific contributions of each component to the sector’s Green TFP growth, providing a better understanding of its productivity dynamics.

3.4 Decomposition results

3.4.1 Energy-intensive manufacturing

Table 2 presents the results of the productivity decomposition (Equation 6) for the energy-intensive manufacturing sector, focusing on its Green TFP growth. The values represent average growth during specific periods, expressed as a percentage per year.

The first row of Table 2 reports the average Green TFP growth of the continuing firms that remained in the same industry throughout the examined periods. The following three components are industry switching, entry and exit, and reallocation, capturing the structural changes within the sector resulting from various changes in the economic environment, including the transition toward carbon neutrality. The sum of these three components, combined with the average Green TFP growth of the continuing non-switching firms, equals the average productivity growth of the sector, as reported in the bottom row of the table.

The average productivity growth of continuing firms in the same industry showed modest growth of only 0.08% per year during the first period (2000–2006), followed by an average decrease (-0.88%) during the second period (2007–2012). However, the average productivity growth of continuing firms reached 0.38% per year in the last period (2013–2019).

The decline in the second period (2007–2012) can be attributed to various factors, including the financial crisis and a broader economic downturn, which negatively impacted productivity across industries. Additionally, the implementation of new environmental regulations and policies focused on energy efficiency and carbon emissions may have necessitated adjustments by firms, temporarily affecting productivity. Moreover, this period witnessed significant technological disruptions and changes within the industry, potentially causing initial productivity disruptions before leading to long-term benefits.

Table 2. Average Green TFP growth of the Finnish manufacturing sector and its components (% per year).

	2000–2006	2007–2012	2013–2019
Continuing firms, same industry	0.08	-0.96	0.25
+ Effect of industry switching	0.01	0.03	-0.03
+ Effect of entry and exit	2.15	-0.17	0.21
+ Resource allocation effect	-1.93	0.22	-0.05
= Green TFP of the sector	0.30	-0.88	0.38

The contribution of firms that changed industries to sector’s productivity growth was relatively small. During the first two periods, the contribution was positive but turned negative in the third period. In contrast, the contribution of firms' entry and exit was positive in the first and third periods but negative in the second period. Notably, in the period 2000–2006, entry and exit contributed as much as 2% per year, suggesting that the exit of less productive firms and the entry of more productive firms contributed to overall Green TFP growth.

The resource allocation component in our decomposition is based on the productivity decomposition of Olley and Pakes (1996) and captures changes in the allocation of resources. A positive sign of this component indicates resource allocation to more productive firms, resulting in higher sector productivity. Conversely, a negative sign of this component indicates allocation to less productive firms, reducing sector productivity. Our results reveal a relatively large negative allocation (-1.93% per year) during the first period, an improved allocation contribution (0.22%) in the second period, and a slight decrease in the third period (-0.05%).

In the context of Green TFP in energy-intensive manufacturing, resource allocation primarily involves redirecting investments, technologies, and production processes toward more environmentally friendly practices. Finland's active pursuit of sustainability, adoption of cleaner energy sources, implementation of energy efficiency policies, and stricter environmental regulations have likely influenced resource reallocation in this sector.

3.4.2 Electricity generation

Table 3 summarizes the productivity decomposition results for Finland's electricity generation sector. The first row in Table 3 presents the average Green TFP growth of firms that remained in the same industry during the specific periods. The subsequent three rows highlight the contributions of industry switching, entry and exit, and resource allocation. The final row presents the average overall productivity growth of the sector.

During 2000–2006, continuing firms in electricity generation experienced substantial productivity growth of 2.2% per year. However, this growth declined in the period 2007–2012 and rebounded to 0.4% per year in the most recent period during 2013–2019. Industry switching, though relatively small, had a positive impact on the sector's productivity growth in the first two periods but turned negative in the last period. Entry and exit of firms played a pivotal role in the sector's productivity growth, with a notable negative contribution during the first period, followed by positive contributions in the subsequent periods. The resource allocation effect showed fluctuations, contributing negatively in the first and second periods but positively in the last period.

Taking into account the performance of continuing firms and the various productivity-influencing factors, the sector's average Green TFP change amounted to -0.3% per year in the first period, about 0.6% in the second period, and nearly 1% in the last period. These results illustrate that many factors affect the productivity growth of the sector.

Table 3. Average Green TFP growth of the Finnish electricity generation industry and its components (% per year).

	2000–2006	2007–2012	2013–2019
Continuing firms, same industry	2.20	-0.08	0.41
+ Effect of industry switching	0.01	0.01	-0.04
+ Effect of entry and exit	-2.40	0.76	0.58
+ Resource allocation effect	-0.11	-0.11	0.04
= Green TFP of the sector	-0.30	0.58	0.98

3.5 Conclusions

Our analysis of structural changes and productivity effects in Finland's energy-intensive manufacturing and electricity generation sectors reveals both opportunities and challenges. Using unique firm-level data on GHG emissions and a novel structural change decomposition approach, we have uncovered several key insights.

Firstly, we have observed relatively weak productivity growth of continuing firms in both sectors during the most recent period of our analysis (2013–2019). This indicates the need for further efforts to enhance productivity while concurrently reducing emissions.

Secondly, in the latest period of our analysis (2013–2019), we found that the entry and exit of firms had positive impacts on the Green TFP growth of both sectors. This implies that firm dynamism resulting from firm entry and exit contributed positively to productivity growth in both sectors.

Lastly, our findings suggest that there is room for improvement in resource allocation to enhance productivity growth, particularly in the manufacturing sector.

However, it is essential to recognize the challenges associated with the transition to a carbon-neutral economy, especially for firms with high GHG emissions. Addressing these challenges requires policymakers to consider implementing policies that incentivize emission reduction while providing support for innovation and investment in low-carbon technologies. This dual approach can facilitate the necessary transformation towards a more sustainable and environmentally friendly economic landscape.

4 Industry-level carbon intensity in Finland and other EU countries

4.1 Background

The transition to carbon neutrality is a significant challenge, especially for energy-intensive industries which account for a substantial proportion of GHG emissions. The EU has set ambitious targets for reducing its carbon footprint, and various policies have been implemented to support the transition to a low-carbon economy.

In this section, we examine the carbon intensity of production at the level of industries in Finland and other EU countries over the period 2008–2021. We interpret a lower carbon intensity (CO_2-equivalent emissions relative to value added produced) as evidence of higher carbon competitiveness. We compare the development of industries' carbon intensity in Finland to the EU27 average, Germany, Sweden, and Denmark. Additionally, we analyze the current levels of carbon intensity across the EU countries, while taking into account the importance of each industry in their respective national economies.

In addition to more traditional drivers of competitiveness, such as production processes, costs, supply chains, and customer relations, carbon competitiveness is a new piece of the jigsaw puzzle that firms need to tackle in their operations and planning.

GHG emissions have become an increasing cost for firms today, either directly through expenses such as fuel costs, carbon permits, or environmental taxes, or indirectly by affecting the firms' image among their customers, or even their access to financial markets.

The EU has established extensive GHG emission regulations for manufacturing industries. The EU plans to extend the European Emissions Trading System (ETS) to include additional industries in the near future, including transportation, and will no longer provide free carbon allowances. To complement these policies, the EU will implement a carbon border adjustment mechanism (CBAM) to level the playing field vis-à-vis third countries. This will likely encourage other nations to adopt similar types of carbon-reducing policies.[21]

Technological advances and their integration into the production process are the key to reducing GHG intensities (or increasing carbon productivity). It is important to phase out fossil fuels in both production processes and household consumption, such as private car transportation. The supply of energy currently produced with fossil fuels then needs to be produced with clean energy sources. Studies by Levinson (2009, 2015), Shapiro and Walker (2018), and Ghosh et al. (2020) emphasize that technological advancements drive emissions reduction. As suggested by Acemoglu et al. (2012, 2016), a combination of (temporary) carbon taxes and research subsidies can facilitate the development and adoption of new clean technologies.

A recent industry study by Kaitila (2023) finds that the level and development of GHG intensities in Europe after 2008 have been negatively associated with the level and development of the industries' labor productivity. The level of productivity is a proxy for the industry's distance from the technological frontier. If productivity is high, the distance is small. Also the level of the firms' know-how is high and therefore the capability to develop, absorb, and implement modern technological solutions is probably higher than when productivity is lower, and the distance is thus larger. Possibly also the financial opportunities and capabilities are higher in industries that have higher productivity.

According to the results, lower GHG intensity is also associated with higher investments, higher ETS carbon prices, an expansion of the ETS to cover a larger share of the economy, and higher environmental taxes on energy, pollution, and transportation. Consequently, financial incentives are effective in lowering emissions.

4.2 Carbon competitiveness in Europe

This section reviews the development of carbon competitiveness, measured by the GHG intensity of production in European industries since 2008. Intensity is measured as the amount of CO_2-equivalent GHG emissions emitted by firms within an industry relative to their combined value added. The LULUCF (land use, land-use change, and forestry) sector is not included in the analysis.

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[21] On the impact of CBAM on European industries and its potential legal challenges, refer to Kuusi et al. (2020).

We concentrate on the industries that are the biggest emitters of GHGs and the ones in manufacturing that are otherwise particularly important for the Finnish economy. These are mostly primary and secondary sectors, and the transport sector. Other service industries than the transport sector emit quite little GHGs. However, emissions in one sector affect costs in other sectors through value chains. Transportation is an obvious example of an industry that directly services most if not all other industries. Indeed, input-output tables reveal that all industries are interconnected. Consequently, an improvement in an industry's carbon competitiveness radiates to other industries.

Figure 4 illustrates GHG intensities in selected industries in 2008–2021 in the current EU27, Denmark, Finland, Germany, and Sweden. Several general observations can be drawn from the data. First, there is a consistent declining trend in intensities, most notably evident in the first graph depicting the development of the aggregate economies. This trend is crucial for climate considerations and overall carbon competitiveness. However, it is also important to analyze individual industries. The aggregate is summed over the industries, so on average the industries also present a declining trend. Second, despite the average downward trend, there are industries where intensities remain stable or even increase, at least in some countries. Third, there are considerable intra-industry differences between the countries.

The intra-industry differences between the countries arise partly from differences in production structure. These would become more apparent with more granular data. The available manufacturing industry data at the two-digit level remains relatively aggregated. For example, the manufacture of other non-metallic mineral products includes a variety of products, with cement production especially having high GHG emission intensity. If cement production accounts for a large share of the total production of other non-metallic mineral products, then the overall intensity is likely to be relatively high.[22]

Additionally, the degree of outsourcing services and intermediate products to firms in other industries affects the firms' value added produced and their CO_2 emissions. These business choices are likely to vary between industries and countries in ways that cannot be controlled in this analysis. We rely on official industrial statistics.

[22] According to data from the Finnish Energy Authority, 64 per cent of the GHG emissions in the manufacture of non-metallic mineral products originated from the production of cement clinkers and 22 per cent from the production of lime or the calcining of dolomite or magnesite in 2022.

Another factor that affects an industry's GHG intensity is its reliance on fossil fuels. This is most evident in power-generating electricity, gas, steam, and air conditioning industries. There are large differences in this respect between countries. For example, the possibilities to produce hydro, solar, and wind power vary depending on many natural elements that cannot be modified. Previous decisions on whether to build nuclear power or to rely on gas, coal, or oil-burning technologies in power generation have long-term implications for GHG emissions.

Various manufacturing industries may also rely on fossil fuels to different degrees. In the transport sector, lorries and vans are starting to use electric motors for propulsion during this decade, and the speed of this development is likely to differ between countries depending on financial and investment resources and charging infrastructure, among other things. The importance of rail vs. road transportation also affects average GHG intensities.

Lastly, certain manufacturing industries emit GHGs in their production processes regardless of their use of fossil fuels. Examples of such industries include cement and basic metals production. However, ongoing efforts are directed toward developing new technologies that can fundamentally reduce or even achieve (near-)zero emissions in production. The pace of these advancements will vary among firms and countries in specific industries, consequently affecting the development of relative carbon productivity.

At the national level, Finland's carbon competitiveness is approximately the same as that of the EU27 average. Finland's emission intensity has declined slightly faster than the average after 2008. The industries, where Finland's carbon competitiveness is relatively weak are crop and animal production (agriculture), paper and paper products, construction, and land transport (Figure 4). Otherwise, competitiveness is, by and large, either similar to the EU27 average or better. Thus, based on publicly available data, Finland's emission intensity is pushed up to the average EU27 level by just a handful of industries.

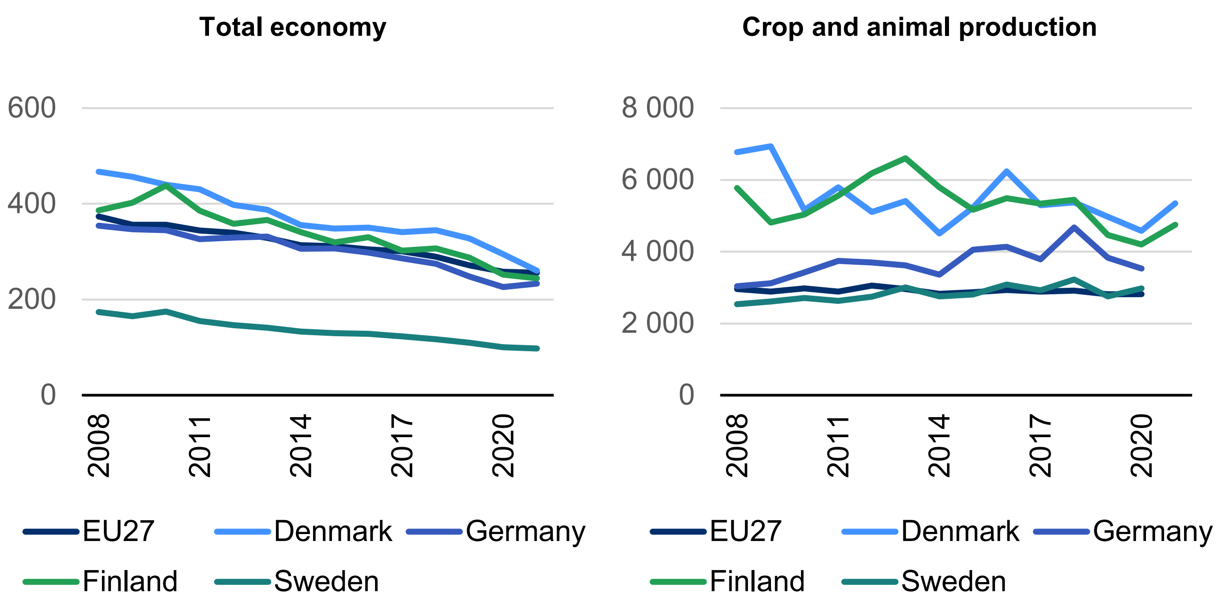
Denmark and Germany have aggregate emission intensities similar to those of Finland and the EU27 average. In contrast, Sweden has a considerably lower aggregate emission intensity, primarily due to its local power generation industries, which rely more on nuclear and hydropower compared to the EU countries on average.

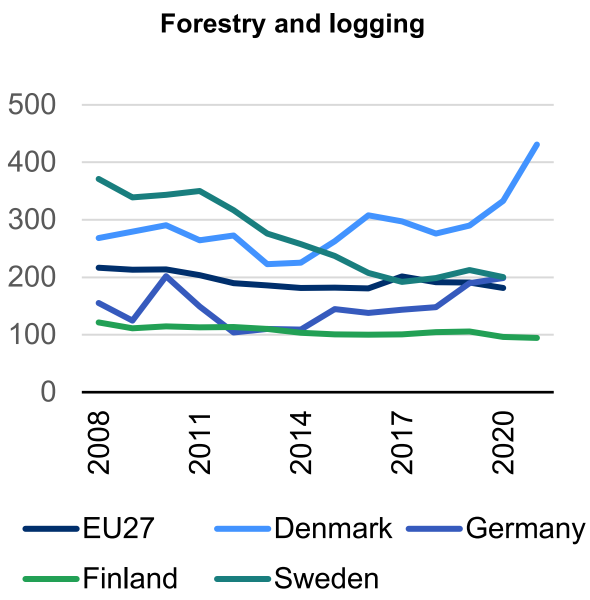
In addition to the above-mentioned four industries, Finland's carbon competitiveness is also weaker than that of Sweden in the power industry (electricity, etc.), sewerage and waste management, and water transport. Additionally, it is weaker than that of Germany in sewerage and waste management.

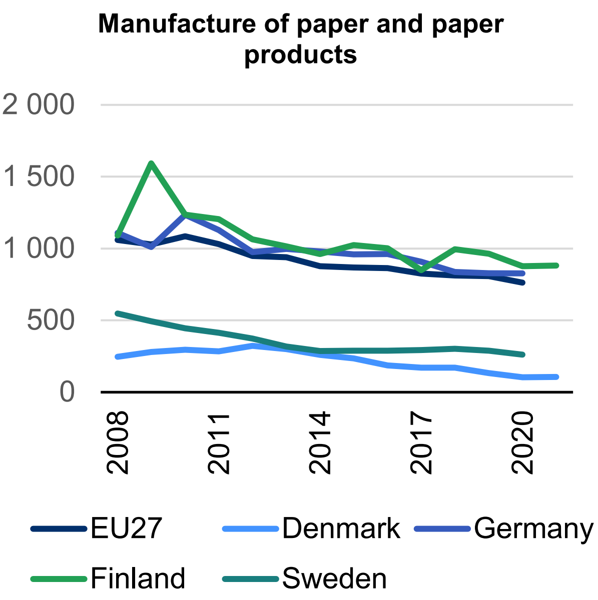
Compared to the EU27 average, emission intensity is much lower in Finland in forestry and logging, various manufacturing sectors (food products and beverages; textiles, wearing apparel, and leather products; wood and products of wood; other non-metallic mineral products; fabricated metal products; electrical equipment; and motor vehicles and trailers), wholesale and retail trade, information and communication, professional, scientific and technical activities, education, human health, and social work activities, and other services.

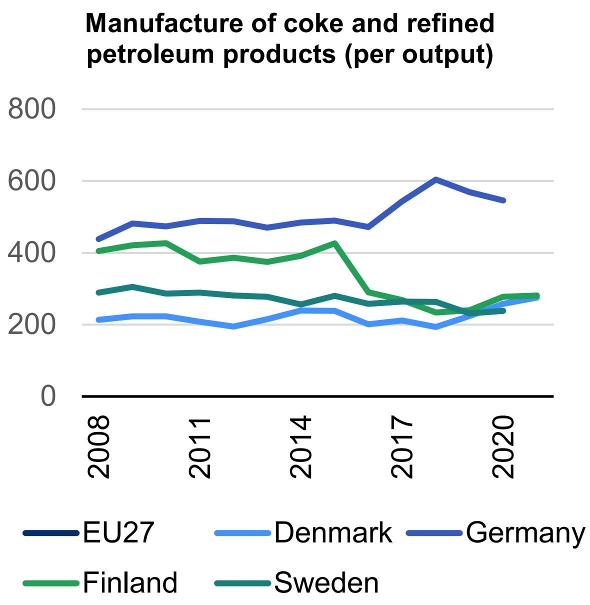
Some manufacturing industries, such as the manufacture of chemicals and chemical products, basic pharmaceutical products and preparations, computer, electronic and optical products, machinery and equipment, other transport equipment, and furniture and other manufacturing, lack recent aggregate EU27 data from Eurostat for comparison. Nonetheless, a comparison with individual EU countries indicates that the carbon competitiveness of Finnish manufacturing is relatively good in these industries.

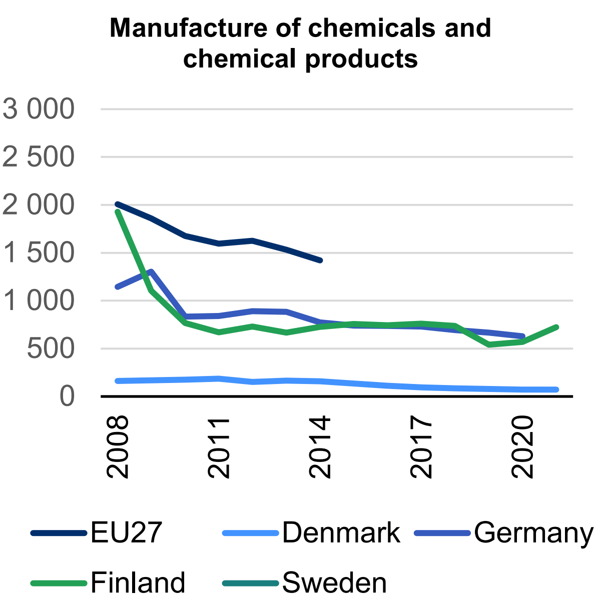
Figure 4. Carbon (CO_2 equiv.) intensity of production (value added). Note: GHG (CO_2, N2O, CH4, HFC, PFC, SF6, and NF3, all CO_2 equivalent) emission intensities, grams per euro of value added (except output for the manufacture of coke and refined petroleum products), chain-linked volumes (2010). Output was used when the value added was very volatile. Some data are missing from Eurostat and are therefore not shown in the graphs. The COVID-19 pandemic disrupted air transport so the value added was negative in some countries. These observations have been removed from the graphs. See Kaitila (2023) for more data. Source: Eurostat.

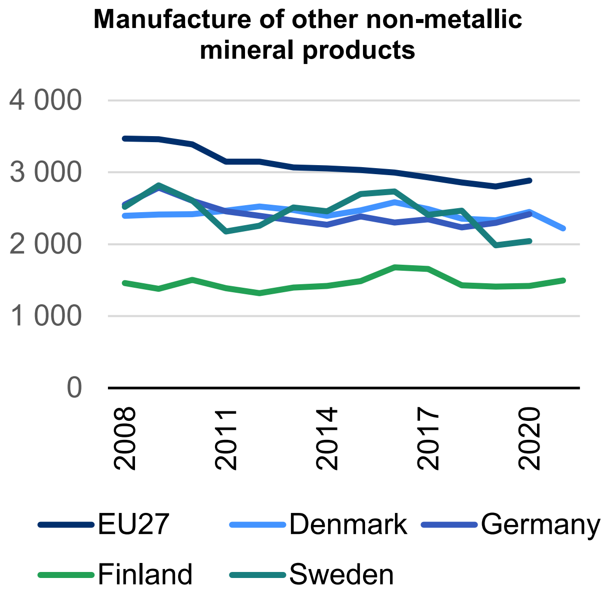


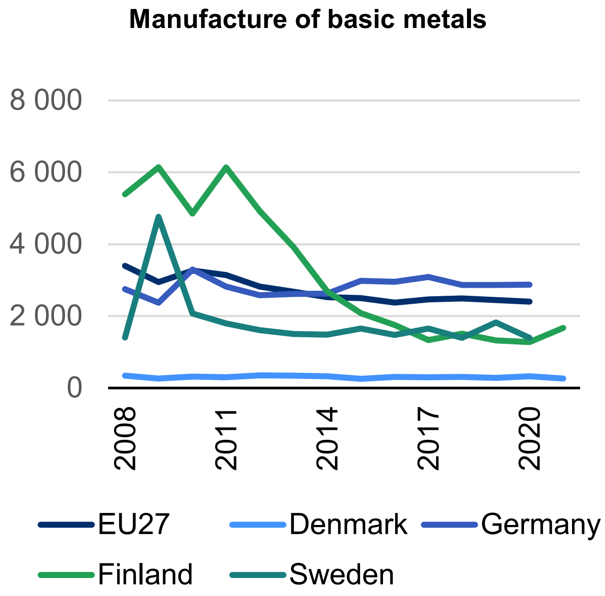

Forestry and logging
500
400
300
200
100
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden

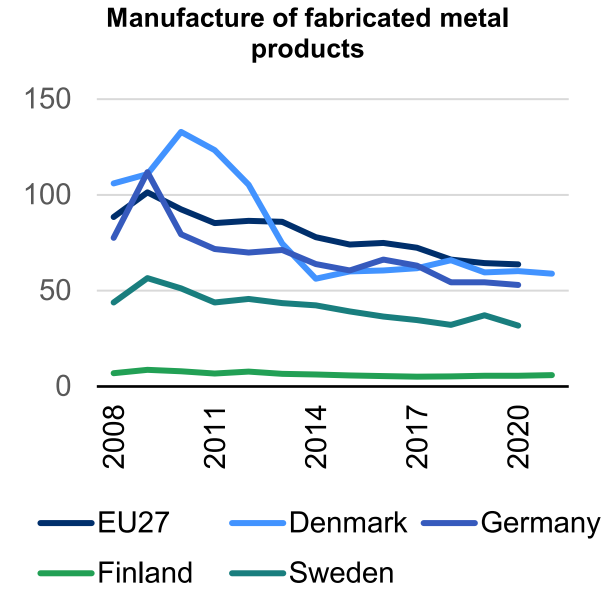

Manufacture of paper and paper products
2 000
1 500
1 000
500
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden

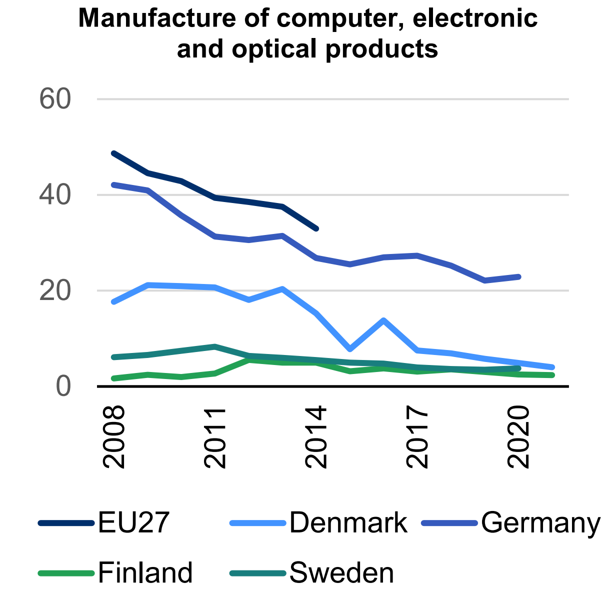

Manufacture of coke and refined petroleum products (per output)
800
600
400
200
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden

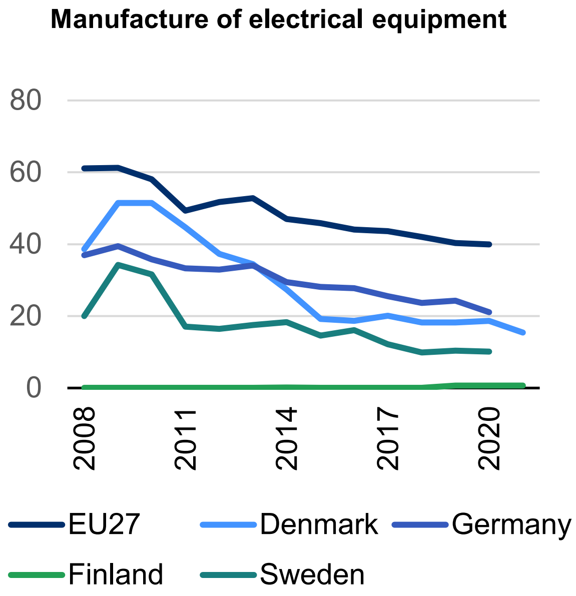

Manufacture of chemicals and chemical products
3 000
2 500
2 000
1 500
1 000
500
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden

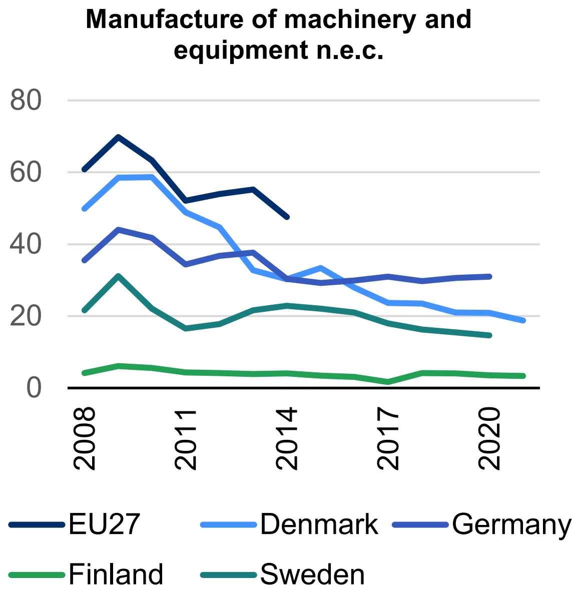

Manufacture of other non-metallic mineral products
4 000
3 000
2 000
1 000
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden

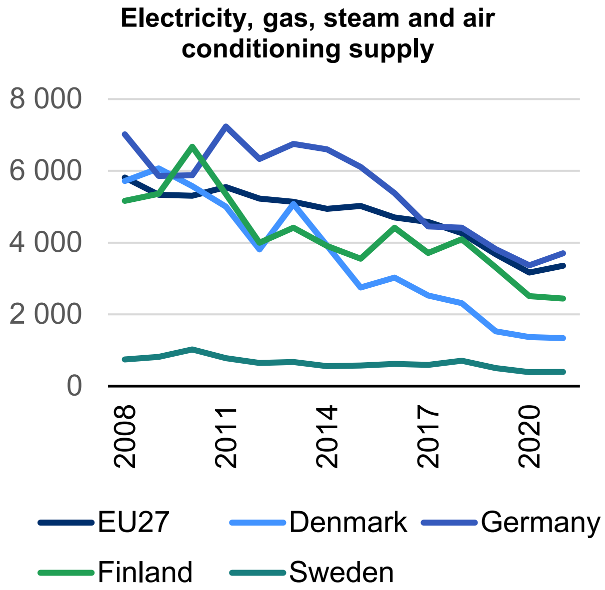

Manufacture of basic metals
8 000
6 000
4 000
2 000
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden

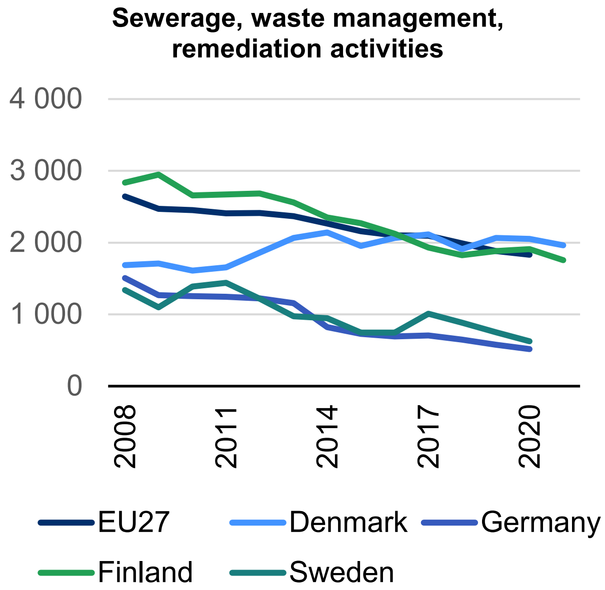

Manufacture of fabricated metal products
150
100
50
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden


Manufacture of computer, electronic and optical products
60
40
20
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden


Manufacture of electrical equipment
80
60
40
20
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden


Manufacture of machinery and equipment n.e.c.
80
60
40
20
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden


Electricity, gas, steam and air conditioning supply
8 000
6 000
4 000
2 000
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden


Sewerage, waste management, remediation activities
4 000
3 000
2 000
1 000
0
2008
2011
2014
2017
2020
EU27
Denmark
Germany
Finland
Sweden

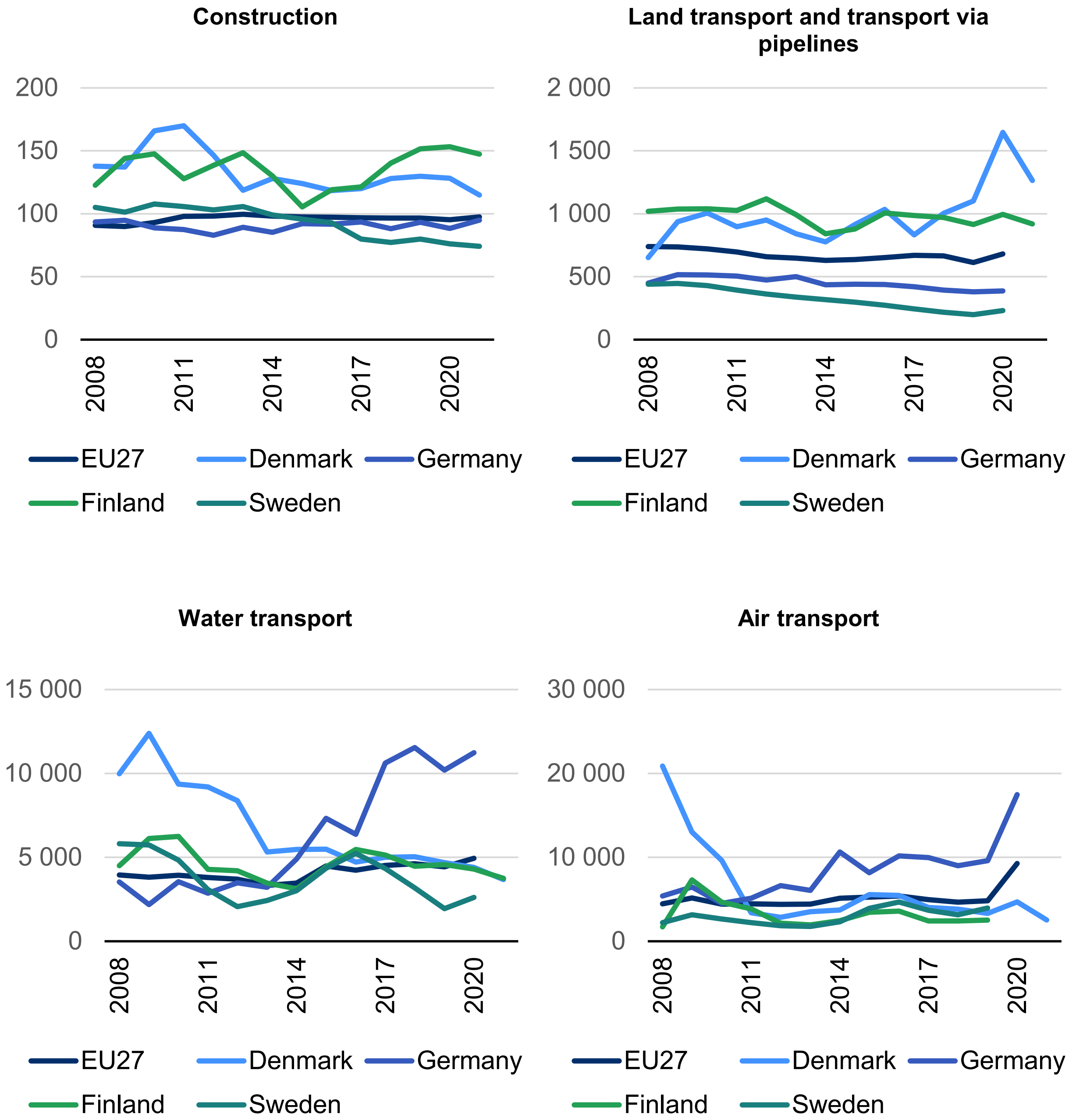
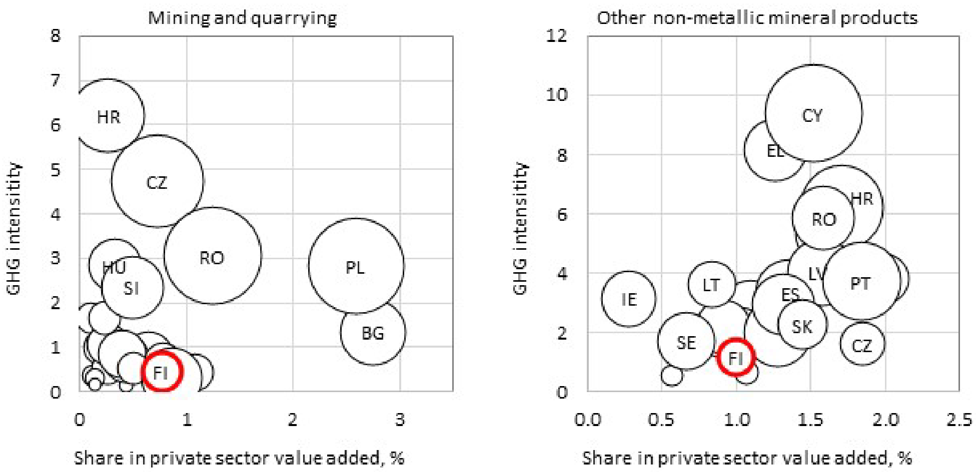


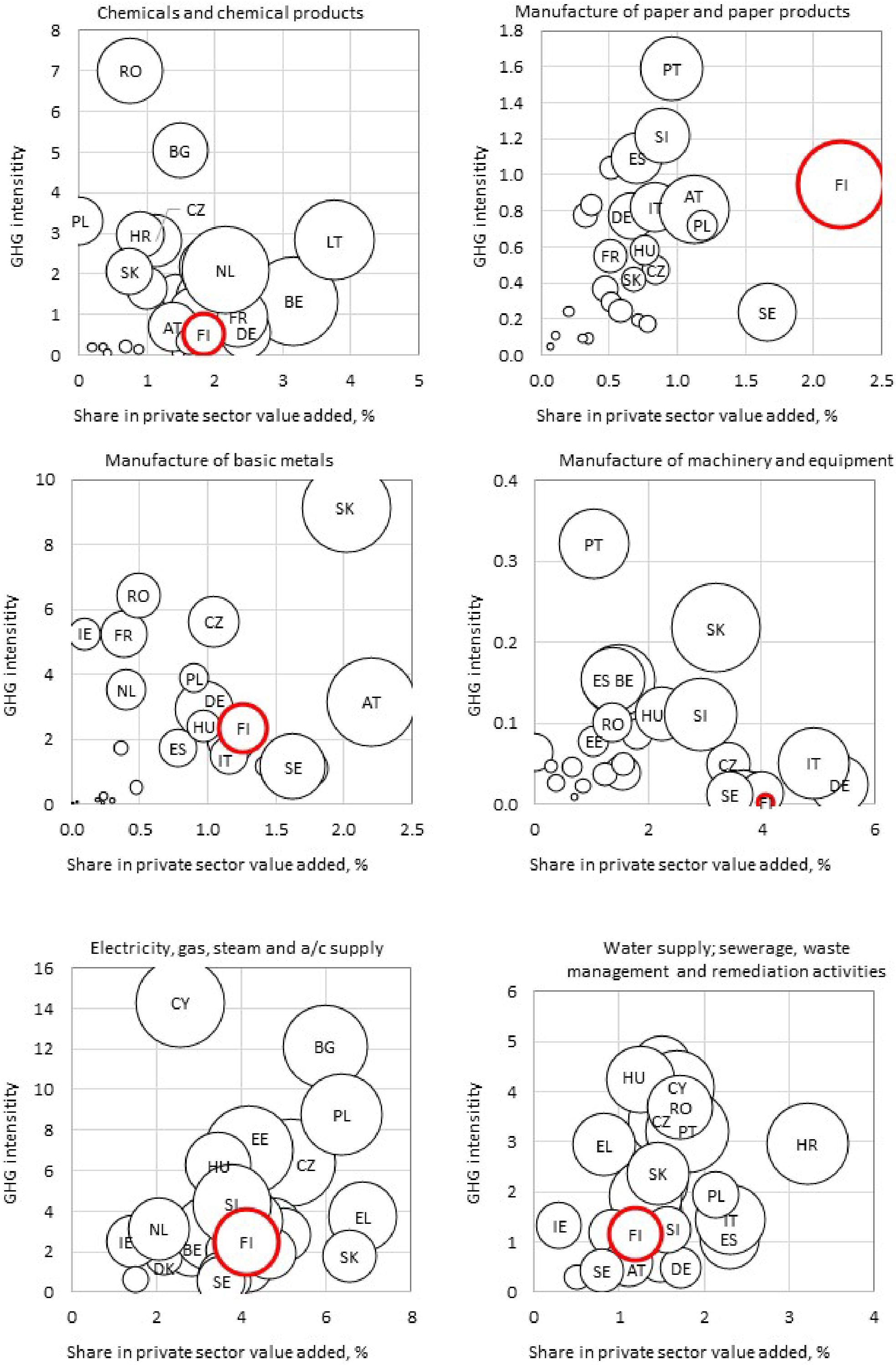
Figure 5 combines three dimensions for one industry per graph with some countries shown separately. The dimensions are GHG-intensity of production (carbon competitiveness) on the vertical axis, the industry's share in private sector value added in each country on the horizontal axis, and the industry's share in national CO_2-equivalent emissions represented by the size of the bubble. Note that the size of the bubble is not comparable across industries, rather it is scaled within the industry in question across the EU countries.

A lower position on the vertical axis relative to other countries indicates that the industry's carbon competitiveness is good. This is the case for example in the manufacture of chemicals and chemical products in Finland. Conversely, industries positioned further to the right along the horizontal axis are more important for the total economy of the country. This is the case for example with the manufacture of paper and paper products in Finland. Then also its carbon competitiveness matters more. We can see that this industry does not have a very good level of carbon competitiveness. A larger bubble size in the graph indicates a relatively larger share of national emissions originating from that sector. If the industry is important for the economy and its carbon competitiveness is poor then the size of its bubble (share in national CO_2 emissions) is likely to be larger than otherwise. Consequently, we tend to find larger bubbles as we move farther away from the origin of the graphs.

As already stated above, Finnish carbon competitiveness is often relatively good, and therefore we tend to find Finland relatively low along the vertical axis. There are some exceptions, as already discussed above.

Figure 5. GHG-intensity of production and the industry's share in private sector value added and in national CO_2-equivalent emissions in 2020. Note: The industry's share in national CO_2-equivalent emissions is represented by the size of the bubble. Sources: Eurostat, ETLA's calculations.




Chemicals and chemical products
GHG intensity
Share in private sector value added, %
RO
BG
PL
HR
CZ
SK
NL
LT
BE
AT
FI
FR
DE
Manufacture of paper and paper products
PT
SI
ES
DE
IT
AT
PL
FI
FR
HU
SK
CZ
SE
Manufacture of basic metals
SK
RO
CZ
IE
FR
PL
NL
DE
HU
FI
AT
ES
IT
SE
Manufacture of machinery and equipment
PT
SK
ES BE
RO
HU
SI
EE
CZ
SE
IT
DE
Electricity, gas, steam and a/c supply
CY
BG
PL
EE
CZ
HU
SI
EL
NL
IE
BE
DK
FI
SK
SE
Water supply; sewerage, waste
management and remediation activities
HU
CY
RO
CZ
PT
EL
HR
SK
PL
IE
FI
SI
IT
ES
SE
AT
DE

In conclusion, the analysis highlights the challenges and opportunities for energy-intensive and GHG-emitting industries in Finland and other EU countries as they transition to low-carbon economies. While substantial progress has been made in reducing the carbon intensity of many industries, there is still much work remaining. Firms face increased competition as they seek to reduce their carbon emissions.

4.3 Conclusions and policy recommendations

The member countries of the European Union have made considerable progress in reducing their carbon emissions since 2007. This progress is largely attributed to active policy measures that have incentivized firms, the public sector, and households to lower their carbon emissions through technological changes in production.

Prior research highlights that technological change is the driving force behind emissions reduction. A combination of regulations, carbon taxes (including tradable carbon emission permits), and research subsidies has been instrumental in fostering the development and adoption of cleaner technologies.

Furthermore, higher levels of productivity are associated with lower emission intensities. Industry’s higher productivity implies that its distance to the technological frontier is smaller. This indicates a higher level of its firms’ know-how, enhancing their capability to develop, absorb, and implement modern technological solutions, likely more effectively than in less productive industries.

While there is an overall decline in carbon emissions and carbon intensity of production in Europe, variations exist between and within industries. Carbon emissions are mostly due to fossil fuel use in production. The pace of transitioning away from fossil fuels varies substantially across industries and countries, contingent on political decisions, particularly concerning energy and electricity production. These decisions may affect the development of emissions for decades.

Lower carbon emission intensity of production equates to better carbon competitiveness of production. Finland’s overall carbon competitiveness is close to the EU average, and it has improved slightly since 2010. Only a few industries, including agriculture, paper and paper products manufacture, construction, and land transport, weaken Finland’s overall carbon competitiveness compared to the EU27 aggregate. In most other cases, Finland’s competitiveness is on par or better than the EU27 average.

Considering these findings and analyses, several policy recommendations emerge as important for fostering sustainable economic growth and reducing GHG emissions:

- Prioritize policies aimed at fostering productivity growth, as evidence suggests that higher productivity is associated with lower emissions and faster productivity growth is associated with a more rapid decline in carbon emissions in Europe. Such policies may involve investments in research and development (R&D), fostering human capital development, and improving market conditions.
- Strengthen environmental legislation and taxation measures as they have been linked to lower emissions and a faster reduction of emissions across Europe. Extending the EU ETS to new sectors is also instrumental in achieving emission reduction targets and facilitating firms' long-term strategic planning.
- Enhance the efficiency and competitiveness of the internal market, stimulating productivity development. Policies promoting healthy competition and eliminating market barriers, when combined with R&D investments, ETS, and other measures, are likely to contribute to emission reduction.
- The EU should further explore possibilities to encourage non-EU countries to adopt similar policies and ambitious CO_2-cutting targets. Diplomatic efforts and collaboration on environmental goals can help address the transboundary nature of climate change.

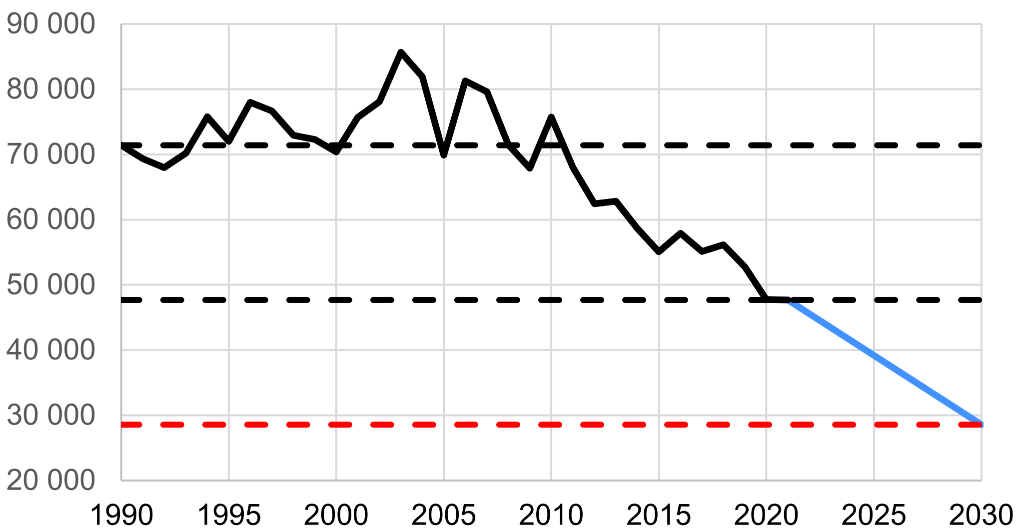
5 A macroeconomic model of green transition in Finland

5.1 Introduction

Finland has committed to an ambitious climate policy to significantly reduce GHG emissions and to achieve the climate neutrality target set by the Paris Agreement. Consequently, this decade and the 2030s will witness a comprehensive energy transformation together with the innovation and expansion of green technologies and products.

Figure 6 shows time series data on GHG emissions in Finland and the linear trajectory to achieve the target for 2030 (60% reduction of emissions compared to 1990). Using the year 2021 as the starting point, this translates to an emissions reduction target of about 40% by 2030. This is an ambitious goal given that during the 30 years from 1990–2020, emissions decreased by about one third. However, the reduction has been significantly larger if one uses the peak year 2003 as the starting point. Note that these emissions exclude emissions from the land use, land-use change, and forestry (LULUCF) sector.

Figure 6. CO_2-eq emissions (1000 tons) in Finland (excluding LULUCF). Source: Statistics Finland and authors' calculations.



Efforts to reduce GHG emissions will also generate structural changes in the economy, as companies invest in new technologies to reduce emissions and new firms enter the market to compete with the incumbents. Given the presence of other major, concurrent trends – such as digitalization and aging populations – the role of carbon-neutral sectors, such as services, will further expand and change the sectoral composition of the economy.

In this chapter, we use a general equilibrium model to analyze how the structure of the economy and productivity may develop given the emission reduction target in Finland for the year 2030. We use a model developed by Finkelstein Shapiro & Metcalf (2023) and calibrate it to describe the Finnish economy. The model captures an endogenous structural change at the level of the whole economy, whereby clean technology firms expand their market share at the expense of emission-intensive firms. It is based on forward-looking saving and investment decisions by households and firms, which are influenced by emission reduction targets set by the regulator.

General equilibrium models, especially computational models, have been widely used to assess the sector-specific impacts of climate change policies (e.g., Böhringer et al., 2012; Kuusi et al., 2021). Less detailed general equilibrium models, on the other hand, are useful in terms of understanding mechanisms behind economic adjustment and gauging their economic relevance. For example, Hafstead & Williams (2018) use a two-sector general equilibrium model to examine the effects of environmental policies on employment in the presence of labor market frictions.

The next section describes the main elements of the model we use. The third section describes the parameterization and calibration of the model. The fourth section presents model results. The last section provides a discussion of the modeling framework, its advantages and limitations, and then offers conclusions.

5.2 Model features

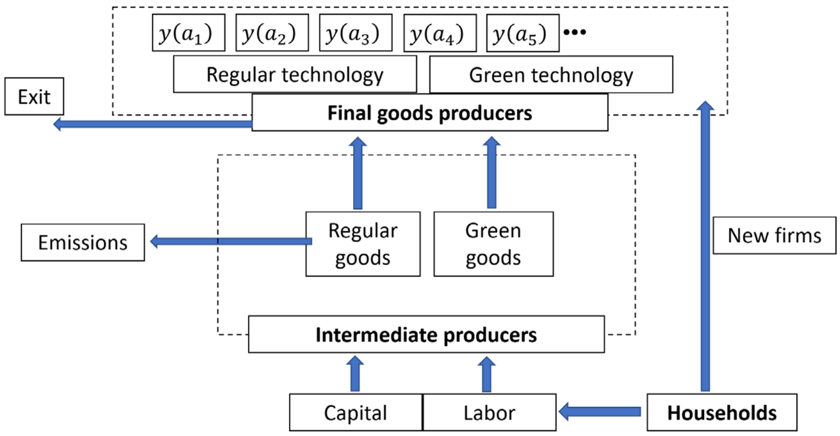
The purpose of this section is to provide a brief overview of the general equilibrium model developed in Finkelstein Shapiro and Metcalf (2023), which is henceforth referred to as the FSM model. The model abstracts from many details of the economy but instead focuses on key mechanisms and markets relevant to the aggregate, economy-wide outcomes of the green transition. It consists of several interconnected markets and decision-makers:

1. Households who supply labor, consume final goods, own all firms, and decide on creating new firms that operate in the final goods markets. Households make distinct labor supply decisions in the two labor markets where labor is hired to produce either clean or regular intermediate goods.
2. Final good producers who decide on which production technology to adopt (clean or regular technology). They purchase technology-specific intermediate inputs from their respective producers. Final producers each produce a specific variety of output and the market for varieties is characterized by monopolistic competition.
3. Intermediate producers who produce either clean or regular products which are sold to the final good producers. Intermediate producers hire product-specific labor and rent technology-specific capital. The market for intermediate goods is characterized by perfect competition.
4. Labor markets where technology-specific (i.e., clean and regular) job vacancies and searchers match and determine wages via bargaining.

Figure 7 shows a stylized depiction of the FSM model with the main model components and points of decision. We next characterize them in more detail.[23]

As a point of departure from the original FSM model, we do not include climate-induced productivity damages in our model. As a justification for this departure, climate damages are expected to be relatively miniscule in the case of Finland during the timescale of the analysis of the next decades (Valkonen et al., 2023).

Figure 7. An overview of the model structure. Notation $y(a_j)$ defines firm-specific output as a function of its productivity.



[23] A reader interested in the full mathematical description of the model should consult the original paper by Finkelstein Shapiro and Metcalf (2023).

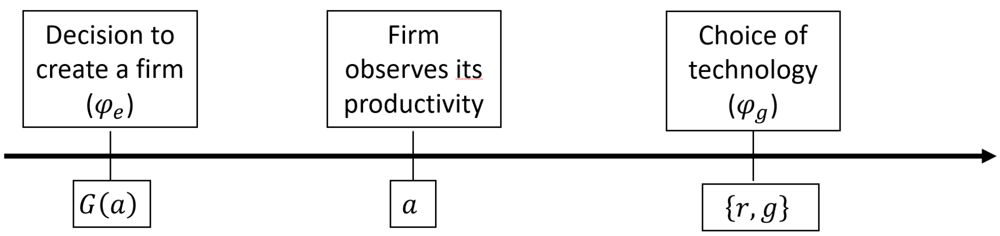
5.2.1 Final producers

Firms in the final goods market produce the final consumption goods purchased by households. Each firm in the final good market produces a single product variety. Which variety the firm chooses to produce is determined by the firm's productivity level. Given the differentiation of products, firms can charge a markup on the product variety they produce. Consequently, the final goods market is characterized by monopolistic competition.

New firms can enter the market subject to a fixed entry cost, and households decide on the creation of new firms. The decision to create new firms is determined in part by the new firm's expected profits which are endogenously determined in the model. Profits are dependent on the level of productivity of the firm. Firms learn their productivity after entering the market. Prior to entry, households who create new firms only know the distribution of productivity. Figure 8 illustrates the sequence of decisions. Existing firms exit the market with an exogenous probability. Hence there is a constant flow of new firms entering the market and a fraction of old firms exiting the market.

Firms can choose between two different technologies to produce the final good. One is labeled as regular technology and the other one as green technology. The technology choice separates the firms into two distinct sectors, and the number of firms in these sectors is endogenously determined in the model. Technologies differ in two ways. First, adopting green technology is associated with a fixed cost whereas regular technology is not. Second, each production technology uses technology-specific inputs that are purchased from intermediate goods producers. Production of intermediate goods for the regular technology causes emissions whereas the inputs for the green technology do not. Hence, climate policies that impose a price on carbon emissions will make adopting green technology a more competitive option.

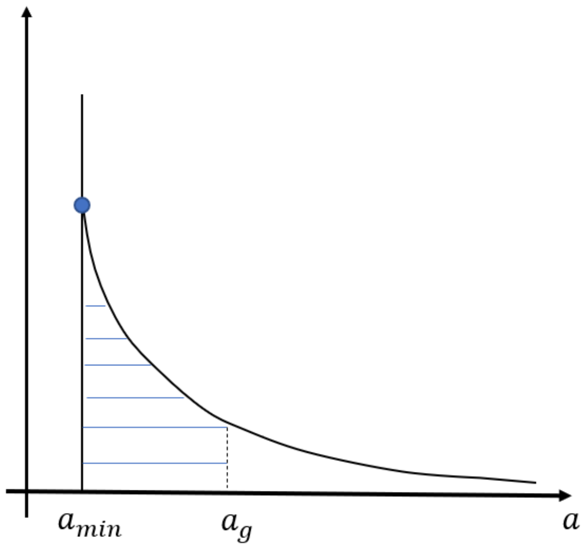
Figure 8. The sequence of events in technology adoption. Function *G* is the cumulative distribution function of productive values, a. Decisions are associated with fixed costs, φ.



Productivity distribution and technology adoption

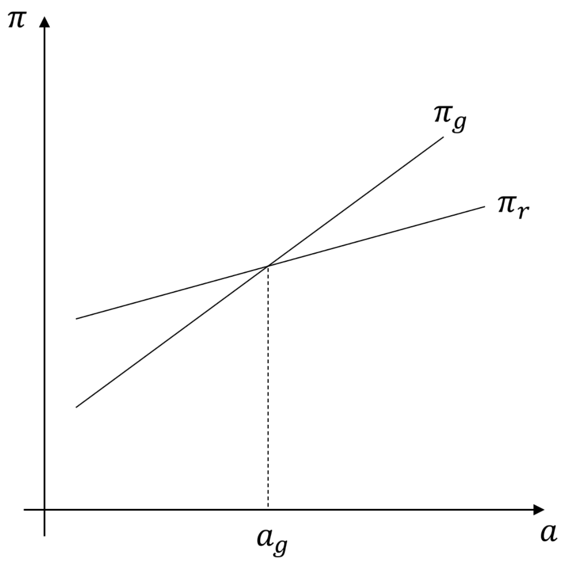
Each new firm draws its productivity from a common distribution of productivity. More productive firms have a lower marginal cost of producing their output variety. Hence, the level of productivity drawn from the distribution also determines whether a new firm adopts the regular or the green technology. An example of a productivity distribution is shown in Figure 9.

Figure 9. An example of productivity distribution with productivity threshold value a_g.



An endogenous productivity threshold divides the set of productivities into two groups. Firms with productivities higher than the threshold adopt green technology since higher profits from adoption justify incurring the fixed cost of adoption. Firms with productivities higher than the threshold adopt green technology since higher profits from adoption justify incurring the fixed cost of adoption (Figure 10). Note that even without a carbon price, there will be some higher productivity firms who still choose to adopt green technology. One reason is that these firms will then be able to use green intermediate goods for which there is less competition than for regular intermediate goods. Hence, the cost of green inputs is lower for green firms. Introducing a price on carbon makes green intermediate goods even more competitive against regular intermediate goods; thus, the effect of a carbon price is to lower the threshold productivity level.

Figure 10. Determination of the productivity threshold value a_g. In the figure, firm profits (y-axis) are sketched as a function of the productivity level (x-axis).



5.2.2 Intermediate producers

Intermediate producers produce both regular and green goods and operate in perfectly competitive markets. The production of the two goods is a distinct process with technology-specific labor and capital required to produce each category of intermediate goods. Firms post technology-specific vacancies to hire labor and determine the level of capital investments and the allocation of capital in each of the production categories. Firms are forward-looking in their investment and vacancy decisions. Technology-specific production functions combine labor and capital to produce intermediate goods which are then sold to the final producers. Producing regular goods causes emissions that are subject to a carbon tax in the climate policy scenario. Firms can reduce emissions generated from a given level of production via expenditures on emissions abatement.

5.2.3 Households

Households consume the final good, decide on the creation of new firms, and supply technology-specific labor by choosing the measure of job searchers. Those searchers who do not find a job become unemployed and receive unemployment benefits which are funded using a lumpsum tax on households. Households are paid technology-specific wages and they also own all the firms in the economy and receive any profits made by the firms. The revenue from carbon taxes is recycled back to the households in a lumpsum fashion.

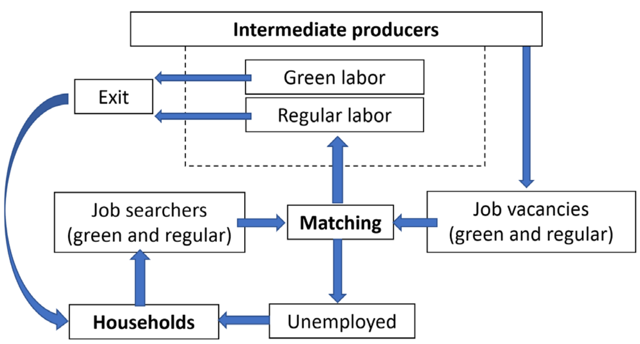
Households are forward-looking in their labor market decisions and when deciding on the number of new firms to create. Creating a new firm is also a form of saving from the perspective of households since they spend resources in the current period in anticipation of dividend payments from the firms in the future. The future also matters in job search decisions since households take into consideration the expected benefit from searching for a job which consists of the wages received from successfully finding a job and then unemployment benefits if the job search fails.

5.2.4 Labor market

A frictional labor market means that some vacancies go unfilled, and some searchers are not able to find a job. Firms can increase the likelihood of finding an employee by posting more vacancies, whereas households can improve the likelihood of finding a job by adding more searchers. In addition to matching employees and employers, the labor market also determines the technology-specific wage rates. Wages are partly determined by the bargaining power of the employees and employers (see Arseneau and Chugh, 2021).

Households choose to search for employment in green and regular technology firms. Correspondingly, intermediate firms hire technology-specific labor. Those who are employed stay employed based on an exogenous probability of keeping the job. Conversely, workers currently employed exit the job by an exogenous probability. Figure 11 illustrates the flows and stocks associated with the technology-specific labor markets in the model.

Figure 11. A closer look at the labor market structure in the model.



5.2.5 Options to reduce emissions

To achieve reductions in aggregate emissions, the regulator can set a price on emissions (through a tax or a cap-and-trade system). As the price of carbon makes the production of regular intermediate goods more expensive relative to green intermediate goods, firms and households respond to this by finding ways to reduce the costs associated with emissions. The model has several options to reduce emissions which operate either at the intensive margin or at the extensive margin.

1. Intermediate firms may spend resources on abatement activities. Such activities reduce emissions associated with producing regular goods.
2. New firms may choose to adopt the green technology instead of the regular technology. Consequently, the number of final producers using green technology increases relative to the number of firms using regular technology. As a result, the demand for green intermediate goods increases while the demand for regular intermediate goods decreases. Such a structural change in the final product industry leads to a decrease in aggregate emissions.
3. Given that abating emissions and choosing green technology can be costly, households can choose to consume less while firms produce less. This also leads to reductions in emissions.

5.3 Quantitative model and calibration

To parameterize the model, we use the same functional forms as in the original FSM paper. Consequently, the model contains several parameter values which need to be determined. As in the original study, we use typical values used in the literature for a set of parameter values, whereas the rest of the parameters are calibrated in such a way that certain outcome variables of interest match the actual data. In our calibration, we use data from Finland whereas in the original FSM paper, the data describes the U.S. economy.

5.3.1 Parameters from the literature

Table 4 shows the parameter values that come directly from the literature or that are best supported by the available data. Most of these values are the same as in the FSM paper. The chosen discount factor implies that the period length in the model best corresponds to a quarter. In the original FSM paper, the authors set the job separation probability to be 0.10. We deem this as a high value and instead use 0.03. This corresponds to an annual rate of about 11.5 percent job destruction.

The productivity distribution takes the form of a Pareto distribution. This means that productivity draws that have a high productivity value occur less frequently than lower productivity draws. The lower bound of the productivity distribution is fixed at a constant level and is represented by the minimum productivity value of one. Firms that enter the market need to incur the fixed cost of entry. However, households consider the entry cost when deciding how many new firms they create. If the entry cost is high enough, some firms with lower productivity may generate losses in the sense that they are not able to recoup the resources spent by the household to create the firm.

Table 4. Parameters from the literature.

Description	Value	Source
Capital share	0.32	Standard value
Discount factor	0.985	Standard value
CRRA parameter	2	Standard value
Elasticity of LFP	0.26	Chetty et al. (2011, 2013)
Elasticity substit. firm output	3.8	Ghironi & Melitz (2005)
Pareto shape parameter	4.2	Ghironi & Melitz (2005)
Min. idiosyncratic productivity	1	Normalization
Job separation probability	0.03	Corresponds to an annual rate of about 11.5%
Worker bargaining power	0.5	FSM (2023)
Elast. of abatement rate	2.8	Nordhaus (2008)
Weight, abate. cost function	1	Hafstead & Williams III (2018)
Elast. parameter emissions	0.304	Heutel (2012)
Capital depreciation rate	0.025	FSM (2023)
Probability of firm exit	0.025	FSM (2023)

5.3.2 Model calibration

To calibrate the model, we use data points from 2019 given the availability of data and the fact that it is the year before the start of the pandemic. The data come from Statistics Finland. Following the FSM paper, we define the regular sector (*r* firms) the aggregation of the following sectors: agriculture, construction, mining, utilities, transportation, chemicals, petroleum manufacturing, and durable goods manufacturing. Consequently, the green sector corresponds mainly to the service sectors. We hence prefer to refer to them as the clean sector instead of the green sector. One problem in defining the two sectors in the model in this way is that now the service sectors are essentially assumed to be more productive than the manufacturing sectors.

In line with the calibration in FSM, we define the labor force participation rate as the share of employed and unemployed from the population of 15–74-year-old people, for which we use a value of 65.8 percent. We next define the value added of the regular sector firms as a share of the total value added. This yields a value of 32 percent. Similarly, we define the share of labor force participants who are employed in the regular sector. This share adds up to 27 percent.

The unemployment rate in 2019 was 6.7 percent. We also need an estimate of the unemployment benefits received by those labor force participants who are unemployed. We use a value of 60 percent relative to the average wages earned. Finally, we set the cost of creating a firm to be 0.7 percent of total output and the total cost of vacancy posting to be 1.75 percent of total output. Table 5 shows the calibrated parameter values and the targets. As a point of comparison, Table 6 shows the original calibrated values for the U.S. economy used in the FSM paper.

Table 5. Our calibrated parameters for the Finnish economy.

Description	Value	Target
Vacancy posting cost	2.0841	Vacancy cost/GDP=0.017
LFP disutility parameter, *r*	0.6791	lfp=0.658
LFP disutility parameter, *g*	0.59198	$n_r/lfp = 0.27$
Unemployment benefits	40.3452	$\chi = 0.6w$
Sunk entry cost	0.6080	$\phi_e/Y = 0.007$
Fixed cost tech. adoption	0.00615	target *r*-output share=0.32

Description	Value	Target
Matching elasticity param.	0.32108	Unempl. rate of 6.7%
Weight of *r* output on emissions	0.72863	Normalization e=1

Table 6. FSM calibrated parameters for the U.S. economy.

Description	Value	Target
Vacancy posting cost	2.1063	Vacancy cost/GDP=0.025
LFP disutility parameter, *r*	0.7723	lfp=0.63
LFP disutility parameter, *g*	0.6618	$n_r/lfp = 0.165$
Unemployment benefits	26.5579	$\chi = 0.5w$
Sunk entry cost	0.6821	$\phi_e/Y = 0.01$
Fixed cost tech. Adoption	0.0051	target *r*-output share=0.20
Matching elasticity parameter	0.5098	Unemployment rate of 6%
Weigth of *r* output on emissions	1.4805	Normalization e=1

5.4 Results

5.4.1 Steady state changes

Table 7 shows the steady state results from our baseline calibration.[24] The initial steady state describes the economy at the start of the current decade, whereas the steady state with a tax represents the end point of the transition where a desired emissions reduction target has been achieved. In our model solutions, we use the target of reducing emissions by 40 % from the initial steady state. This roughly

[24] When presenting the results in this section, all real variables in the model are transformed into their data consistent forms as in Finkelstein and Shapiro (2023). In short, the real variables are converted using a price index calculated from the model whereby the effects from changing varieties are removed.

corresponds to the emissions reduction target set in Finland for 2030. The reduction target is achieved by using a price (tax) on carbon emissions.

Table 7. Steady state comparisons. The emissions tax is set at a level that achieves an overall 40% reduction in emissions.

Variable	Steady state no tax	Steady state w tax 0.081	Percentage change, %
Total output	7.772	7.777	0.1
Consumption	5.2	5.2	-0.1
Employment, *r*	0.18	0.15	-17
Employment, *g*	0.44	0.47	8
Total employment	0.614	0.618	0.73
Real wage, *r*	6.629	6.610	-0.3
Real wage. *g*	5.767	5.750	-0.3
Capital, *r*	14.577	12.078	-17
Capital, *g*	30.975	33.309	8
Firms, total	861.5	845.0	-1.9
Firms, *g*	202.7	246.6	22
Average idiosyncratic productivity, *r*	1.156	1.135	-1.8
Average idiosyncratic productivity, *g*	2.089	1.985	-5
Overall average firm productivity	1.376	1.383	0.54

Variable	Steady state no tax	Steady state w tax 0.081	Pct.-point change
Unemployment rate	6,70%	6,83%	0,13
LFP rate	65,80%	66,37%	0,57
Abatement rate	0%	32%	32

Share of *g*-firm output	68%	73%	5
Share of *g* firms	23,5%	29,2%	5,65

As can be seen from the table, the impacts of reducing emissions on total output and consumption are very modest. Consumption decreases by 0.1 percent, whereas the total output increases by 0.1 percent. The positive effect might seem surprising. However, the results in the FSM paper also show a slight increase in the total output in response to setting a tax on emissions. The positive effect is explained in part by the transformation of the real variables to their data-consistent forms (see footnote 23). On the other hand, the model economy has several avenues to reorganize its production. Hence, given the long adaptation period of steady state analysis, there is no a priori reason to expect notable negative impacts from emission reduction.

The number of clean firms (g firms) increases by 22%, whereas the number of regular firms (r firms) decreases by 9%. The total number of firms also slightly decreases. Correspondingly, employment in the clean sector expands by 8%, whereas employment in the regular sector contracts by 17%. Overall employment slightly increases as well as the labor market participation rate. The unemployment rate also increases slightly. The capital stock in the green sector expands at the expense of the capital stock in the regular sector.

Interestingly, the average productivity of the economy, as defined in the model, slightly increases. This is explained by the fact that overall, slightly more regular firms exit the market than new clean firms enter the market. Hence the remaining stock of firms is slightly more productive than the one at the start of the transition.

5.4.2 Transition path

In this section, we show the transition path from the original steady state to the new steady state where emissions have been reduced by 40% compared to the starting point. We solve a dynamic version of the model and include a linearly increasing emissions tax rate such that the emissions target is achieved by the end of the planning period of 2030. The year 2020 represents the initial steady state.

Figures 12–14 show the dynamic changes in the composition of the economy as measured by the changes in the two sectors in terms of the relative shares of firms, capital stocks, and employment. As can be seen from the figures, the shares of clean firms, capital, and employment are gradually increasing during the transition period towards the new steady state.

Figure 15 illustrates in more detail how emissions are reduced during the transition phase. The role of abatement effort dominates the overall emissions reductions. In other words, most of the emissions reductions are achieved through within-sector reductions in emission intensities. The importance of technology (sector) switching is gradually increasing towards the end of the planning period, reaching a share of 30%.

Figure 12. The share of the two types of firms in a transition path from the original steady state to a new steady with 40% lower emissions.

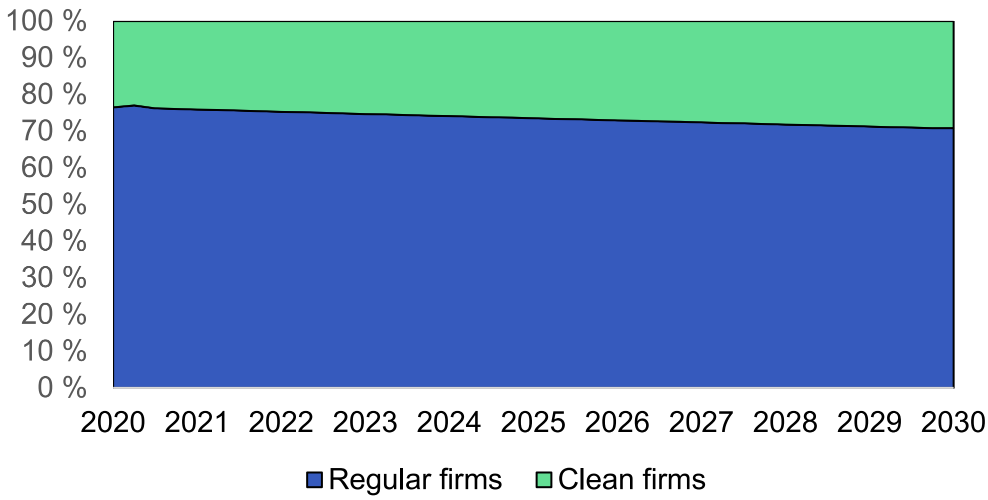


Figure 13. The share of the two types of capital in a transition path from the original steady state to a new steady with 40% lower emissions.

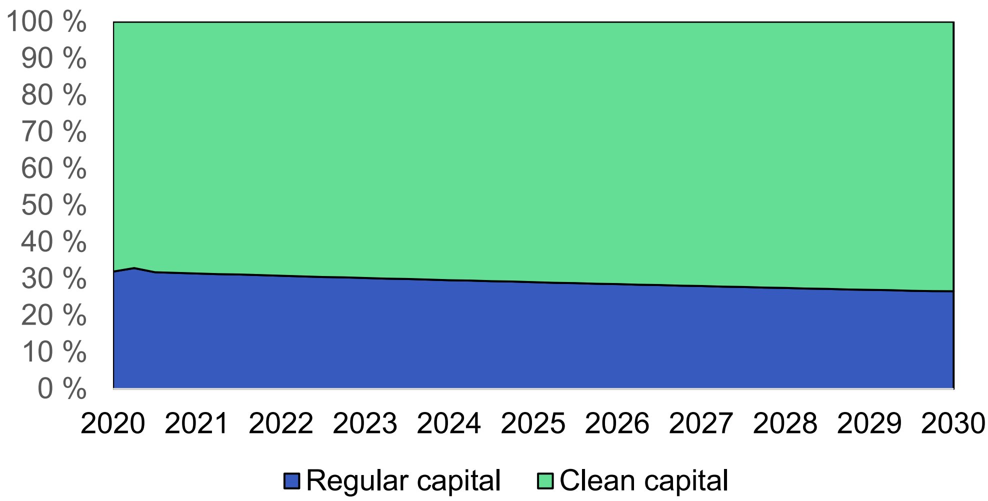


Figure 14. The share of the two types of employment in a transition path from the original steady state to a new steady with 40% lower emissions.

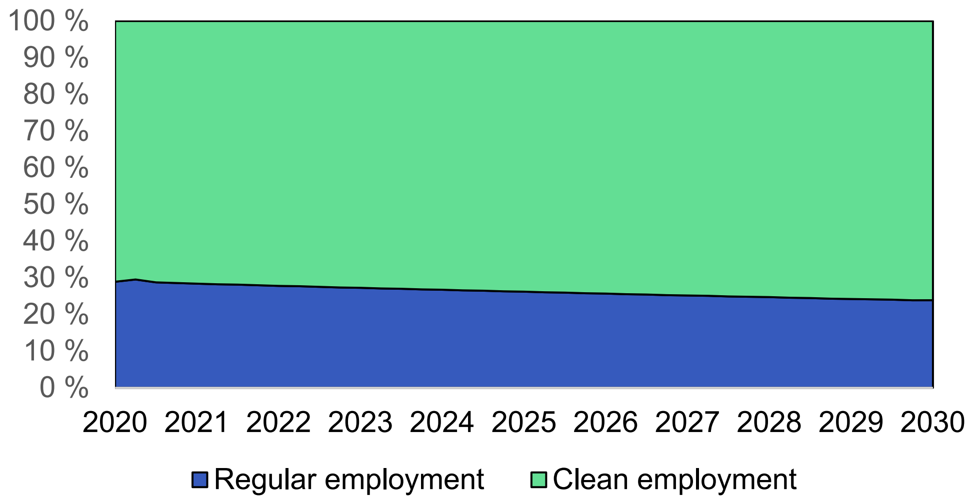
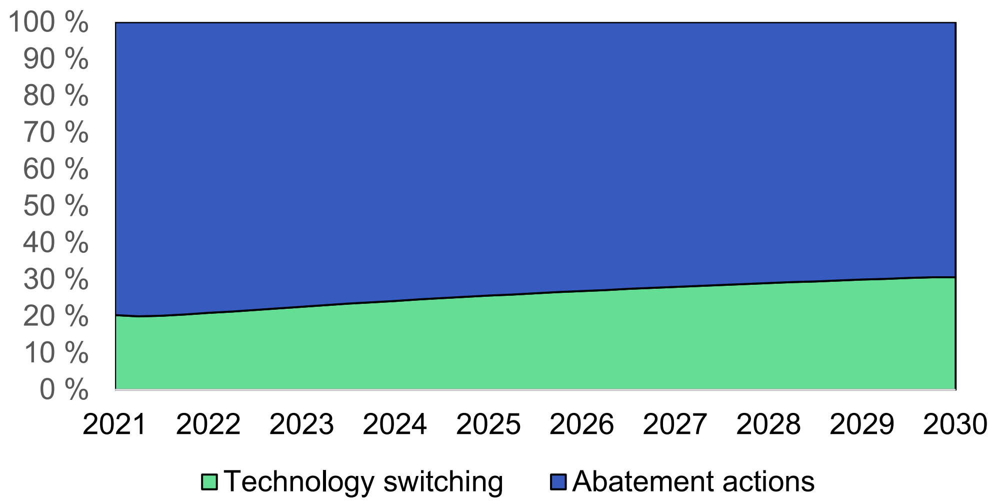


Figure 15. How emissions are reduced in a transition path from the original steady state to a new steady with 40% lower emissions.



5.5 Small open economy

The FSM model represents the case of a closed economy. In other words, the effects of international trade are missing from the model. This assumption is naturally restrictive when analyzing the changes occurring in a small open economy such as

Finland. It is therefore important to consider how the results would change if international trade were introduced in the model.

The FSM model itself builds on the standard macroeconomic model of international trade originally developed by Melitz (2003). Hence, it is possible to use the existing body of research to provide insights into how the introduction of exports and imports might change the results regarding abatement decisions, structural changes, and productivity developments. Several empirical studies have investigated how international trade influences domestic carbon emissions, as well as whether there is evidence of carbon leakage in the context of major climate policy interventions, such as the EU ETS. These findings also shed light on how international trade influences the domestic economy in the context of climate change mitigation policies.

One typical starting point for thinking about the role of international trade in the context of environmental policies is the “pollution haven hypothesis”. According to the hypothesis, emissions-intensive industries should relocate to countries that have more relaxed environmental regulations. Copeland et al. (2022) review the evidence on whether the pollution haven hypothesis holds. Based on empirical findings, there seems to be enough evidence to suggest that environmental regulation is a determinant that influences the location where polluting activities occur, but it is not the main determinant of comparative advantage. Hence, there are usually other, more important factors that determine where production activities occur, such as factor endowments, market access, and technologies.

It has become conventional to differentiate between three main channels that operate in explaining how trade may impact the level of emissions in an economy (Copeland et al., 2022). The first channel is the scale of production. International trade can lead to a larger scale of production and hence to a greater level of emissions. The second channel works through changes in the sectoral composition of the economy. For example, trade and specialization can lead to a reallocation of factors of production between emission-intensive and cleaner sectors and industries. The third channel is the so-called technique channel. It captures changes in industry-level emission intensities that are caused by changes in the available technology or by reallocation of production within an industry. It may also capture abatement efforts done by firms in response to environmental policies.

The question of how these three channels compare to each other in explaining the total effect of international trade on the environment has been investigated in several empirical papers (e.g., Antweiler et al., 2001; Levinson, 2009; Shapiro and Walker, 2018). The scope of these analyses is not limited to GHG emissions, but instead, they focus on the emissions of several air pollutants that are typically more local in their effects. Collectively, these studies suggest that the technique channel explains most of the observed changes in pollution (Copeland et al., 2022). Since the composition channel seems to be less important than the technique channel, these findings seem to suggest that international trade has not considerably contributed to magnifying the effects of stricter environmental policies on the structural transformations in the economy. However, there are still unanswered questions, such as to what extent international trade has led to the substitution of emissions-intensive inputs with imports i.e., to offshoring of emissions-intensive components of the value chain (Copeland et al., 2022).

Given the above observations, the next question is how the results from the FSM model would change if the model economy became an open economy instead of a closed economy. In macroeconomic models with heterogeneous firms, the introduction of international trade typically has two effects on the firms along the productivity distribution. First, some of the least productive firms, which also only serve the domestic market, exit the market due to the increased cost of production caused by the factors of production migrating towards the exporting sector. Second, the more productive firms increase their scale of production in response to export opportunities. Kreickemeier and Richter (2014) show that these effects will lead to a decrease in aggregate emissions if the emission intensities of firms are strongly decreasing in their productivity. In the FSM model, the most productive firms are clean, whereas the dirtiest firms are the least productive. Hence, emissions could decrease.

To start thinking about the interaction of a climate policy and international trade within the FSM setting, it is first useful to make the plausible assumption that the productivity cut-off value which divides the firms into those that export and those that do not export lies somewhere below the other productivity cut off value which divides the firms to those that use a polluting technology and to those that use a clean technology (cf. Figure 9). In other words, some of the firms in the regular sector, namely the most productive ones, also participate in export activities.

If a climate policy were introduced in such a setting, one likely outcome would be that some of the most productive exporting firms in the emissions sector would switch to the clean sector while continuing as exporters. This effect would represent the composition channel. However, the main effect should still work through the technique channel, i.e., firms in the emissions sector invest in abatement efforts. Hence, the introduction of climate policy will cause domestic emissions to decrease, as to be expected, but at the same time, the exports might also become cleaner. This rationale aligns with the results and analysis conducted by Forslid et al. (2018). However, it is also possible that a unilateral climate policy leads to an increase in foreign emissions and imports of carbon-embodied goods. In other words, there could be leakage. To quantify the relative magnitude of all these effects would naturally require a full model analysis.

Several empirical studies have investigated whether there has been leakage caused by the EU ETS (e.g., Joltreau and Sommerfeld, 2019; Venmans et al., 2020; Verde, 2020; Dechezleprêtre et al., 2022). These studies have found that the impacts of the EU ETS on leakage and international competitiveness have been small so far. However, since these studies typically use data from the earlier stages of the EU ETS, it is not evident whether the findings continue to hold in the presence of a considerably higher allowance price regime. Furthermore, one reason for the observed limited effects on leakage and competitiveness could have been caused by the generous free allowance policy which was specifically tailored to shield emission-intensive trade-exposed (EITE) industries against the negative competitiveness effects stemming from the EU ETS (Venmans et al., 2020).

On the other hand, model-based results, using computable general equilibrium models, suggest that the extent of leakage could be more significant. For example, Carbone and Rivers (2017) find that a 20 percent unilateral reduction of emissions in the EITE sector would translate into a 7 percent reduction in exports from that sector on average. Using the same unilateral emission reduction target, Böhringer et al. (2012) compute a 2.8 percent reduction of output from the EITE sector. The introduction of the carbon border adjustment mechanism should help in mitigating these leakage effects (Kaitila et al., 2022).

5.6 Concluding remarks

The model-based results presented in this chapter provide insights into the future of the green transition in Finland. As climate policies are gradually becoming tighter, most of the abatement in emissions is achieved through within sector reductions in emissions intensities. However, changes in the sectoral composition of the economy will also take place and the role of sectoral (technology) switching in achieving emissions reduction grows in importance towards the end of the policy timeline. The average productivity in the economy, as defined in the model, slightly increases, as the relative share of more productive firms increases in the economy. However, real wages are slightly lower in the new steady state.

There are several directions for extending the model to increase the level of detail and the scope of applicability of the model. One of the most obvious ones is to expand the number of sectors. In the current calibration, the clean sector contains different types of service industries. Some of those industries are more productive while others are not. Hence, lumping them all in one sector could potentially yield a positive view on the development of productivity. The other important omitted aspect is the role of international trade.

Another important aspect to consider is the role of different types of friction during the transition periods. Although the model incorporates frictional labor markets and some inertia in the process of re-allocation of labor, there are also potential additional frictions, for example, in the capital markets that are currently missing in the model. The risk of stranded assets has also been acknowledged in the relevant research literature and policy discussions. These types of additional frictions and bottlenecks could mean that the transition period to achieve the new steady becomes longer and more costly than what is suggested by the results presented in this chapter. Additional model development is needed to clarify these issues in the future.

6 Financing of green investments in Finland

6.1 Introduction

Identification and quantification of future green investments and their financing needs in Finland is not an easy task. One starting point in the evaluations is determining the amount and type of investments required to achieve the green transition targets set in national (2035) and EU (2050) legislation. However, due to the high uncertainty and greatly varying outcomes of these evaluations, they can only provide a rough estimate of the scale needed. Additionally, it is important to note that these evaluations may offer a minimum estimate, as climate policy cannot and should not attempt to determine the precise amount and allocation of green investments. One of the benefits of unified carbon pricing is that it allows firms to discover the most effective ways to meet climate targets in the EU area.

Carbon pricing and regulation lower the profits of the companies that currently produce and use fossil fuels. Furthermore, the problem of stranded assets and production processes is likely to be significant, and the costs of the transition are high for those incumbent firms, particularly if the transition is rapid. The weaker financial position limits the possibilities for firms to finance green investments with retained earnings. Consequently, access to and price of external finance will become more important. The position of new innovative firms is not likely to be easy either. They must address the problems created by high political, technological, and market uncertainties involved in green investment activities and the task of convincing the markets of the success of their business ideas when applying for external funding.

In the quantification of the aggregate financing needs, a key issue is whether the new green investments will replace the ones that were associated with the production, transfer, storage, and use of fossil fuels. If they do, the required growth of the aggregate investments and their financing is smaller, even though the investing firms may not be the same. Moreover, if the firms are financially constrained, strong incentives for green investments may lead to a reduction in other investments not related to the green transition. This would harm economic growth, especially if the green investments crowd out the R&D of the constrained firms.

Also, the preferences of the investors matter. Many Finnish institutional investors aim to have carbon-neutral portfolios by 2035 or 2050. This means that they are likely to invest markedly less in brown industries. However, the extent of their role in the green transition of Finland is not obvious. The required green investments to achieve the climate targets are typically much higher in other countries than in Finland. This might create investment opportunities elsewhere with higher returns or improved risk diversification. On the other hand, foreign investors already own a large share of the onshore windmill electricity production in Finland and their plans to invest in windmills, hydrogen production, and green steel are extensive. The realization of these plans would be a key factor in the financing of Finland’s green transition.

The major green investment plans known are tracked rather closely in Finland, but their realization is unclear. Several factors might at least postpone the implementation of the plans. One of them is regulation and slow processing of permissions. Another is a lack of coordination. For instance, a large number of planned windmills cannot be constructed until the new main grids are ready. More generally, the planned investments may be part of a value chain, where the realization of one plan may depend on the progress of the previous and next steps. A third important issue is the availability of a skilled labor force, which is not obvious. Additionally, the known current plans do not encompass all the green investments that will eventually be implemented.

This chapter briefly presents the results provided by the academic green finance literature, assesses the investments needed for green transformation, discusses the known investment plans, and depicts the potential supply of funds and the financial status of Finnish companies.

6.2 Financial constraints and green investments – lessons from the literature

Innovative green investments are known to be riskier than average investments, which implies that, all else being equal, their returns should be higher due to the risk aversion of the investors. On the other hand, if their returns do not correlate fully with the returns of other investments in the investors’ portfolios, they may mitigate the riskiness of the overall portfolios. Other exceptions to this general rule could be preferences of the investors or interventions of the society through subsidies, price control, and regulation. Furthermore, the elevated risk associated with these investments may not be entirely reflected in the observed prices of external financing; in some cases, financing proposals might be declined, or the costs could be prohibitively high.

As soon as green investments become standard technology, the risks are more often political. Examples of such risks include government interventions that have affected the profits of companies that produce clean electricity by solar or wind power. In a broader context, the policies should be both consistent with the climate targets and backed by strong political consensus to create a credible investment climate.

The empirical literature does not present a unanimous stance on the presence of the carbon premium (the required rate of return on brown investments is higher) in the bond and stock markets. The premium could be an indication of investor preferences or higher risks attached to the future profitability of brown firms. The majority of the studies suggest that the premium exists in bond markets (Liaw 2020). Correspondingly, firms that have higher carbon emissions pay higher loan spreads to all investors (Kleimeier and Viehs 2021), which suggests that their activities are considered riskier. Bauer et al. (2023) showed, however, that in stock markets, on average, green companies provided higher returns than their brown counterparts. Only during times of energy crises, the brown companies may generate a higher yield.

One potential problem, particularly concerning bank lending to green innovations, is the asset overhang. If the innovations are both disruptive and profitable, they may harm the businesses of the incumbent clients of the bank and diminish the value of the collaterals held by these firms. Degryse et al. (2022) documented that green innovators and diffusers are somewhat less likely to receive bank credit compared to their less disruptive counterparts.

Studies that analyze the demand for green investment financing emphasize the constraints on external funding. Jensen et al. (2019) observed that environmentally innovative firms exhibit higher financial needs and are more likely to have latent financing needs than other innovative firms in Germany. Their policy conclusion is that subsidies may be needed to alleviate these constraints; otherwise, financially constrained firms may need to mitigate their other innovative activities. It is well-recognized that the externalities related to R&D inherently limit the activities to a lower level than is optimal for society, and the crowding out may exacerbate this situation.

A significant body of literature is asking whether a well-designed environmental regulation is good or bad for the productivity and competitiveness of the firms. The regulation restricts the choices of firms. However, several studies claim that the so-called Porter hypothesis is valid. This hypothesis, which dates to the 1990s, suggests that regulation can bring about profitable innovations that compensate for the productivity losses caused by the restriction of choices. Most of the studies show that regulation spurs innovations, but not necessarily enough highly profitable ones to validate the strong version of the hypothesis, which states that the innovations more than adequately compensate for the losses incurred due to the regulation.

A comprehensive meta-analysis of 103 studies shows that the relationship between productivity and environmental regulation is about as likely to be positive as it is negative (Cohen and Tubb 2018). A country-level analysis is more likely to find positive results than a firm-level analysis, especially when the regulation does not generate high compliance costs (Wang et al. 2019). The validity of the strong version would imply that it should be easy to find financing for green innovations spurred by regulation. Zhou et al. (2023) found that stringency of environmental policy lowers the bank lending costs in OECD countries, especially within the energy sector. The result is confirmed by D'Arcangelo et al. (2023), which used global data on syndicated loans.

Government involvement in financing green investments, whether through direct means such as subsidies and loans or indirectly by offering guarantees, can be rationalized based on either externalities (information spillovers and environmental benefits) or the existence of financial market failures. When it comes to funding green innovations, the presence of externalities is evident, yet the literature does not present a unanimous consensus regarding the prevalence of financial constraints.

The most promising findings arise from studies of bank lending and the bond market, which suggest the presence of a carbon premium in historical data. Nonetheless, the magnitude of the financial resources required for completing the green transition is so substantial that financial markets might not be able to manage it without the interventions of governments.

6.3 A medium-term outlook on the investment finances of the Finnish firms

6.3.1 Production growth

The COVID-19 pandemic, collapsed trade with Russia, energy crisis and increasing interest rates have all weakened the overall financial position of Finnish firms, even though with a different strengths in different industries. Especially in manufacturing, the largest firms are highly dependent on exports, which emphasizes the growth of the export markets, market prices, and competitiveness as key factors for the future growth of production and profitability. The medium-term economic outlook for most of the key industries is provided, e.g., by the Spring 2023 projection of the Etla Economic Research (Toimialakatsaus 2023). The average growth rate in value added is expected to remain subdued in all the main industries (see Table 8). The report does not include the development of energy production, which grows strongly because of the deployment of the new nuclear power plant and the large increase in the number of windmills. The recent collapse in building and dwelling production may provide some real resources to the energy sector investments.

Table 8. Medium-term growth of production in key industries: Average yearly value-added growth (%).

Industry	2018–2022	2023–2027
C Manufacturing (10-33)	-0.6	1.1
Forest industry (16-17)	-6.0	1.6
Manufacture of paper and paper products (17)	-5.2	1.8
Chemical industry (19-22)	-4.3	1.0
Manufacture of coke and refined petroleum products (19)	-5.6	-4.4
Metal industry (24-30, 33)	1.3	1.3
Manufacture of basic metals (24)	-6.7	0.8
F Construction (41-43)	0.3	0.0
H Transportation and storage (49-53)	-2.6	1.4

Source: Toimialakatsaus (2023), Etla.

6.3.2 Profitability and indebtedness

The latest information on the profitability and indebtedness of the main industries that are most affected by the green transition is from the year 2022 (Table 9). Energy production stands out as an industry where operating income is high, even though the return on invested aggregate capital is low. The industry primarily finances its large investments with debt, making its net result sensitive to interest rates. The chemical industry is also capital-intensive but more profitable and less indebted. Both the low operating margin and the poor rate of return in the transportation sector indicate that financing their green investments will be challenging. The rapid increase in turnover, driven by high inflation during 2022, has reduced the debt-to-turnover ratios (except for the paper industry).

Table 9. Profitability and indebtedness of the industries exposed to the green transition.

Year 2022	Operating margin	Return on capital invested	Total debt / Turnover	Equity ratio
C Manufacturing (10-33)	9	6	72	50
Forest industry (16-17)	12	7	73	53
Chemical industry (19-22)	13	12	47	55
Manufacture of other non-metallic products (23)	9	3	137	48
Metal industry (24-30, 33)	7	4	82	47
D Electricity, gas, steam, and air conditioning supply (35)	18	3	280	38
F Construction (41-43)	5	7	49	44
H Transportation and storage (49-53)	7	3	54	45

Source: Structural business and financial statement statistics, Enterprises' financial statements (legal unit), Statistics Finland. Operating margin = 100 * EBITDA / Total operating income. Return on capital invested = 100 * (Net result + Financial expenses + Income taxes) / Total Assets. Equity ratio = 100 * Total Equity / Total Assets. Preliminary data from year 2022.

6.3.3 Firm financial position survey

The quarterly Confederation of Finnish Industries' Business Tendency Survey[25] asks for factors that are holding back production in the company. One of the choices is financial difficulties[26]. Figure 16 shows the 4-quarter moving average of the shares of the companies that have answered positively to the question. The shares have increased since the financial crisis to a somewhat higher level, especially in

[25] These surveys are conducted under the European Commission's Joint Harmonised EU Programme of Business and Consumer Surveys. Source: https://ek.fi/en/current/bulletins/companies-estimate-a-weakening-business-cycle/

[26] The question is as follows: What main factors are currently limiting your production?

Construction. The rapidly increased interest rate and the expected low economic growth are likely to weaken the outlook further.

Another relevant survey question is the profitability of the company as a driver for investments[27]. Figure 17 shows a comparison of the manufacturing industry in EU countries and Finland. In both cases, the financial situation of the companies has strongly reacted to the financial crisis and the Covid-19 pandemic. The overall position of the Finnish manufacturing companies is still better, but the drop has been bigger.

A report prepared by the consulting group Afry for the Climate Fund[28] presents a more pessimistic outlook on the financing of green investments. It suggests that access to external funding and its cost have become the primary hindrances to these investments in Finland. According to the report, a reduced willingness to take risks, higher interest rates, shorter payback periods, and slower decision-making processes have impeded financing during the spring of 2023. A significant decline in wind turbine orders had already occurred in Europe in 2022[29]. Higher costs and realization of political risks, such as caps on electricity prices and windfall taxes, are described as factors contributing to the decreased interest.

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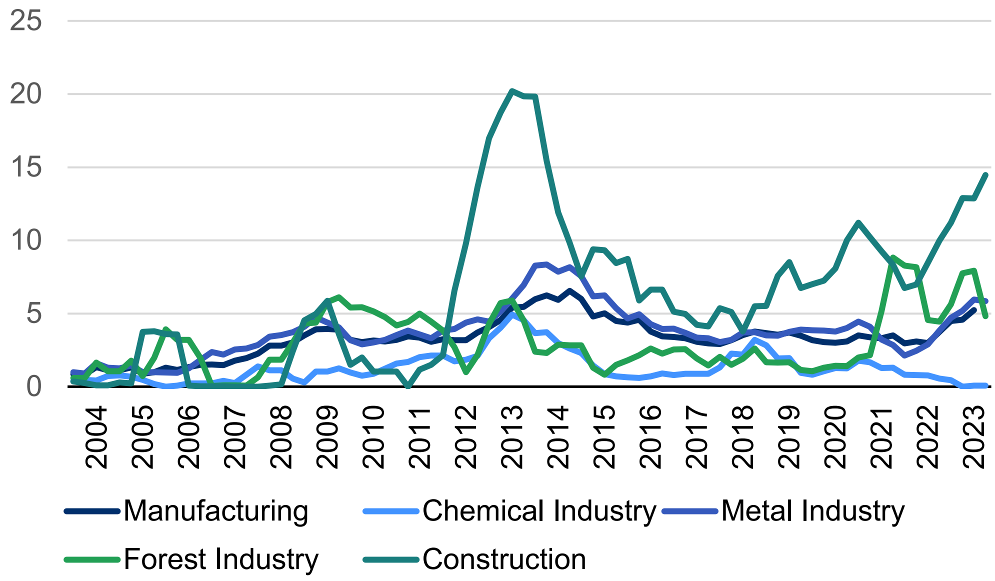
[27] The question is as follows: What main factors are stimulating your investment?

[28] https://www.ilmastorahasto.fi/afry-rahoituksen-saatavuus-ja-hinta-ovat-nousseet-hidasteiksi-vihrean-siirtyman-investointien-toteutumistahdille/

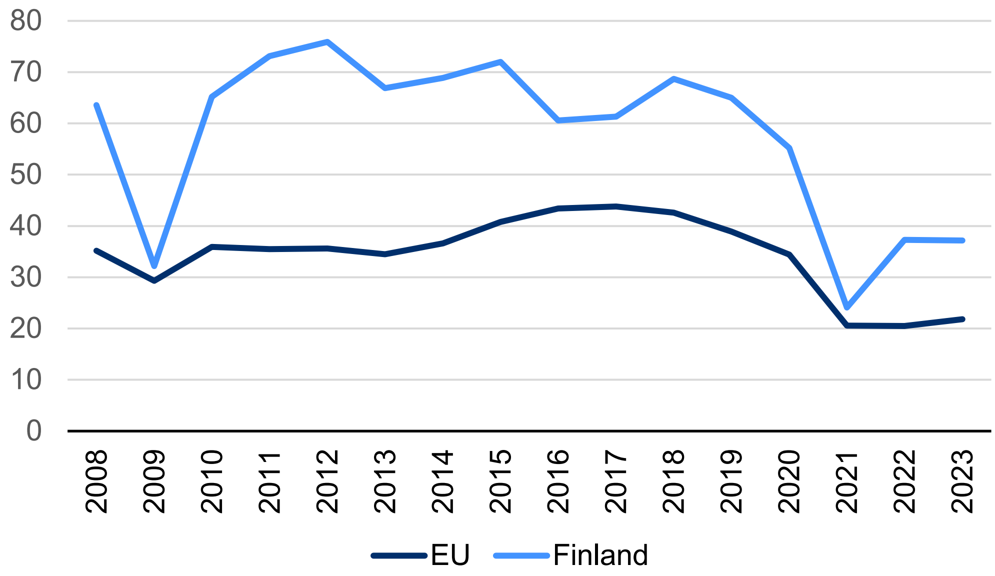
[29] https://windeurope.org/newsroom/press-releases/investments-in-wind-energy-are-down-europe-must-get-market-design-and-green-industrial-policy-right/

Figure 16. Share of firms announcing that financial difficulties hold back production, %.



Source: Business Tendency Survey July 2023.

Figure 17. Factors driving investments in manufacturing: financial conditions.



Source: Business Tendency Survey 2023.

6.3.4 Investment rates in recent years

The average investment rates in the Finnish manufacturing firms are somewhat lower than the averages for non-financial firms in the EU area. Various industrial sectors show, however, large deviations. The energy sector shows very high investment rates, whereas the construction sector invests markedly less than the average (see Table 10). Also, the structure of the investments varies. Intellectual property products dominate in the metal industry but have a minor role in the energy sector.

Table 10. Investment rates in the industries exposed to the green transition.

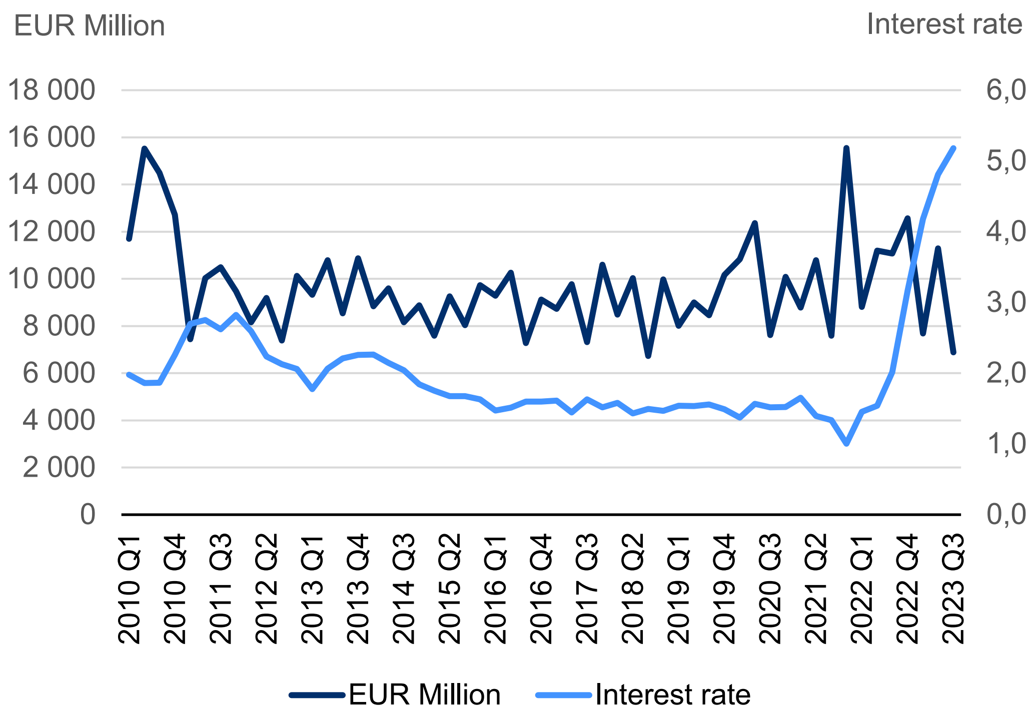
Investment rates, %	2016	2017	2018	2019	2020	2021
C Manufacturing (10-33)	21.1	21.7	20.8	20.2	20.0	21.6
Intellectual property products	10.9	9.5	10.5	10.7	10.9	10.6
Forest industry (16-17)	27.0	29.2	18.0	19.4	20.7	17.2
Intellectual property products	3.8	3.7	3.4	4.3	5.9	3.3
Chemical industry (19-22)	19.6	28.3	21.9	17.2	18.9	33.3
Intellectual property products	9.3	9.5	9.3	7.9	9.3	10.5
Metal industry (24-30, 33)	20.6	18.3	22.0	22.5	20.7	19.8
Intellectual property products	15.2	12.4	14.7	15.3	14.5	14.1
D Electricity, gas, steam, and air conditioning supply (35)	78.9	73.4	58.2	47.8	54.7	54.4
Intellectual property products	3.7	4.1	4.3	4.2	4.1	4.4
F Construction (41-43)	8.1	8.6	8.7	9.4	8.9	10.1
Whereas intellectual property products	1.0	1.4	0.9	1.1	1.0	1.0
H Transportation and storage (49-53)	23.6	21.3	21.5	22.8	22.8	17.8
Intellectual property products	1.6	1.8	1.8	1.8	2.5	2.3

Source: National Accounts, Statistics Finland. Investment rate = 100 * Gross fixed capital formation / Gross value added at basic prices. Intellectual property products include, e.g., R&D investments.

6.3.5 New business loans and their average interest rate

The increase in consumer prices has exceeded the European Central Bank's (ECB) 2% target significantly, leading to a tightening of monetary policy starting in 2022. The period of higher key central bank interest rates is expected to continue at least until 2024, which will dampen economic growth. The interest rate on new business loans has also seen a corresponding increase, as shown in Figure 18. The higher lending rate increases the cost of capital for new investments and, consequently, their required rate of return. A major question is whether companies can pass on these higher costs to customers through higher prices.

Figure 18. New business loans. Source: Bank of Finland.



6.4 Green investment needs in Finland

Various institutions have assessed the green investment requirements in Finland. These evaluations are challenging to compare directly due to differences in definitions and time horizons.

One of the most comprehensive analyses was conducted by the Boston Consulting Group (BCG). According to their report, achieving the stated net emission reduction targets will necessitate investments totaling €242 billion by 2050[30]. The Energy sector, encompassing solar and wind power, storage, electricity grids, and direct heating, requires the most significant investment of €142 billion. Other sectors require the following investments: Industry (€23 billion), Buildings (€45 billion), Transport (€25 billion), Agriculture (€6 billion), and other areas (€1 billion, including waste and LULUCF). In the projections of Sitra (2021), the Energy sector's estimated necessary investments range between €64–70 billion. It's important to note that their analysis employs a more limited definition of the sector.

The BCG report is from 2022 and refers to the Hiisi project[31] results from 2021 as the baseline for required net carbon reductions. However, the Hiisi project's figures regarding the net emission gap have become outdated due to a substantial recent decline in the LULUCF carbon sink. Consequently, it can be inferred that, using the same evaluation methodology, the required investments should be notably higher, or reduce more efficiently emissions in the updated scenario. The same conclusion applies to the estimates of Sitra.

The Finnish Climate Change Panel highlights the urgency of expanding the LULUCF carbon sink. Moreover, the EU's environmental policies have evolved since the BCG report, with a prevailing trend of tightening targets and regulations. Expanding carbon pricing to other sectors would ease the choice of the most cost-efficient policies. Those would also affect the amount and sectoral allocation of green investments.

6.5 Plans for green investments

This section describes the green investment plans of the Finnish firms. We use here three types of information: the roadmaps of the industries, the surveys of the

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[30] Also, the Working group on financing the green transition (2022) used that number.

[31] https://www.hiisi2035.fi/

European Investment Bank, and the firm-specific data collected by the Confederation of Finnish Industries. Also, some other associations, like the Finnish Wind Power Association collect information on future investment plans. It is obvious that the realization of all the plans is unlikely, but also new opportunities, not seen now are likely to emerge during the green transition.

6.5.1 Roadmaps

Several industrial sectors have published their roadmaps for a low-carbon economy. Unfortunately, many key industries have not reported quantitatively the required investments for reaching the goals. The Ministry of Economic Affairs and Employment has compiled an overview of these roadmaps, detailing the required investments for sectors that have provided quantitative assessments. As depicted in Table 11, there are significant variations in the definitions utilized across these sectors.

Table 11. Summary of investments.

Industry	Required Investments (EUR)
Construction industry	Converting the current building stock to be energy-efficient and low-emission: EUR 10–20 billion by 2050
Chemical industry	Additional investments of EUR 16–24 billion between 2015 and 2050
Logistics and transport	Railway network electrification and targeted investments in freight transport (EUR 400 million) Extensive railway projects to increase the market share of railway transport (EUR 5–10 billion) Urgent improvement needs of the core road network, EUR 2–3 billion
Agriculture and forestry	Peatland measures (investments, incentives, and loss of profit): EUR 300–500 million between 2021 and 2050 Poor-quality land afforestation (40,000–80,000 ha): EUR 140–230 million between 2021 and 2050 Sustainable intensification of agriculture (e.g., technological development and field soil fertility): no less than EUR 2.1–3.3 billion between 2021 and 2050 Additional Biogas plant investments EUR 805–1835 by 2050

Industry	Required Investments (EUR)
Sawmill industry (firms represent around half of the production)	Approximately EUR 100 million over the next ten years

Source: Paloneva and Takamäki (2021).

6.5.2 Survey information

The EIB 2021 Survey[32] focused on the readiness of European firms to tackle the green transition. It also provides a possibility to compare the position of the Finnish firms to its competitors in the EU area. A large majority of the Finnish firms, who responded that the transition to the low-carbon economy is expected to have an impact on the demand for their products, considered the effects as positive. Correspondingly, the expected positive effects of the green transition on reputation are more common among Finnish firms than in the other EU or US firms. The firms are also acting: the share of firms currently investing and having plans to invest to tackle climate change is highest in the EU. The superiority compared to the EU average when considering energy efficiency investments is not as large, but this may be explained by the previous investments since the importance of the issue is shown by the high number of implemented energy audits in Finland. The questionnaire also asked about major obstacles to climate-related investments. Access to finance was not considered as important as investment costs and uncertainty about taxation, regulation, and technological change.

The annual Investment Survey of the European Investment Bank (EIBIS) gathers information on the investment activities, their financing requirements, and the difficulties met. The late survey (EIBIS 2022) also describes the plans for green investments. The survey was implemented after the illegal Russian invasion of Ukraine, which accelerated the efforts to limit the dependency on fossil fuels. Also, the Finnish firms increased further the climate-related activities. The share of firms that had already invested in tackling climate change increased to 77 % (62 % in 2020) and the share of those planning to invest over the next three years was 75 % (68 % in

[32] EIB (2021). European Firms and Climate Change 2020/2021 – Evidence from the EIB Investment Survey.
https://www.eib.org/attachments/publications/eibis_2020_report_on_climate_change_en.pdf

2020). Both numbers are markedly higher than the respective EU averages (53 % and 51 %).

In addition, some general perceptions of Finnish firms are interesting in the EIBIS 2022 survey. They seem to focus on innovations more than the average EU firms. Especially the share of firms that were classified as leading active innovators is higher, since the Finns have invested more often in R&D and developed new products, processes, and services.

As key barriers to future investments, the responded firms mentioned most often the availability of skilled staff and future uncertainty. One in ten Finnish firms was considered financially constrained. A sectoral comparison shows that the availability of finance is most problematic in manufacturing (for 42 % of firms). The investments were financed from internal and intra-group sources more often than on average in the EU countries. External finance comprised only a fifth of the total. More than 40 % of the Finnish firms using external finance received grants from the general government, which is about twice the EU average. The level of dissatisfaction with external finance was typically low. The only exception was the costs of finance.

6.5.3 Information collected by the Confederation of Finnish Industries

The Confederation of Finnish Industries hosts a data window, which lists the values of the known major green investments of the companies. The window also classifies the stage of the investment plans, timetables, and regions.

Table 12. Planned green investments, million euros.

Investment	Sum
Offshore wind power	57 800
Hydrogen	13 179
Steel	6 100
Battery technologies	5 652
Biorefinery	2 580
Energy storage	2 669
Nuclear power	1 000

Investment	Sum
Solar energy	1 802
Circular economy	492
Textile fibers	431
Biogas	369
Bioproducts	320
Waste heat	303
Bioenergy	254
Heat pumps	208
Replacement of fossil fuels	206

Source https://ek.fi/en/green-investments-in-finland/ Extracted 11.9.2023.

Most of the investments on the list are in the stage of planning. For example, more than 90 % of the huge sea wind power investments are in this stage. Also, the timetables are rather long: most of the investments will be completed around the year 2030. Yet another observation is important for the financing: the future sea wind power plants are mainly owned by foreign companies. Finally, it is worth noting that not all the investments represent the creation of new capacity: the nuclear power investments are aimed at keeping the current nuclear power plants in Loviisa running until 2050.

The list does not cover planned investments in onshore wind power (€ 53,7 bill.) and energy networks (€ 8 bill.)[33]. Nor are the required investments in the Transportation sector are in the list, since the single investments are likely to be small, even though their aggregate value is expected to be large. The ILMO45 report (2018) estimated that the cumulative total investment costs to sustainable transport will be 17 billion euros by 2045.

The responsibility of financing is more widespread also in case of the green investments in buildings, encompassing companies, households, and the public sector. It is useful to note in this context, that the Government communication to

[33] Confederation of Finnish Industries, Green investments in Finland: https://ek.fi/en/green-investments-in-finland/.

Parliament (U 48/2021vp) states that the costs of adhering to the suggested energy efficiency directive [COM(2021) 558 final] cannot be reliably estimated.

A comparison of the plans to the required investments to achieve the emission targets shows that the transition to producing emission-free electricity is well underway, and there are also some plans to use it in hydrogen production and transportation. However, much more investment is needed especially on the users' side. Even more worrying information comes from the LULUCF sector, where the large carbon sink has diminished markedly. It may imply tighter emission targets for the companies in the effort-sharing sector.

6.6 Conclusions

Evaluation of the amount of future green investments often begins with the requirements of the green transition dictated by domestic and EU policies. However, even these evaluations are highly uncertain, not least because of the frequent changes in policies. Moreover, the companies in the value chain may decide to invest more, or the transition may need less investments than expected. Of course, the market solution is influenced also by other firms in the value chain. This is well illustrated by the example that a prerequisite for clean hydrogen production is adequate production and low price of green electricity and a well-operating transmission network.

There are essentially three main reasons that potentially justify government intervention in green investment financing: externalities, such as insufficient R&D investments and a too low price for carbon, financial market failures, and unfair competition. It's important to note that advocating for government intervention doesn't necessarily imply providing public funding for investments. Another important point to consider is that financing issues are not the sole concern. The government can also support investments through smoother permission practices, by encouraging labor supply, and by implementing a consistent and credible environmental policy.

Concerning the self-financing of green investments, it is limited by the current indebtedness and the prospects for profitability of the investing firms. In this respect, the overall financial position of the Finnish firms has been good, but the energy production sector is already highly indebted. There are also some sectoral problems in future profitability.

Access to external financing is, in principle, helped by the willingness of many investors to accept a lower yield from green investments. In practice, the literature is not unanimous on the existence of the carbon premium, *i.e.*, the higher required rate of return on brown companies. The most convincing evidence comes from the bank loan markets. Even there, there is a risk that any financial instability may reduce the willingness to finance high-risk investments.

The higher interest rates and more limited access to external financing have started hampering investments recently. In the years ahead some transitory subsidies from the public sector are declining or ceasing. This postpones the green transition. Here the obvious danger is also that the green investments may replace those that would be otherwise beneficial for the firms and the society.

Global competition on green investment financing has become fiercer after the U.S. government decided to support domestic investments with tax breaks. There is a marked risk that this competition will lead to protectionism and efficiency losses that unnecessarily increase the fiscal costs of the transition.

The existing evidence regarding the green investment plans of the Finnish firms shows they are leading the way in the EU. As a large majority of the planned investments are in the early stages, strong conclusions regarding the aggregate numbers should be avoided. From the perspective of the required domestic financing of the investments, two observations are important. First, the companies aiming to invest in offshore windmills are largely from abroad. Secondly, adequate public policies aiming to leverage private investment financing are not in place yet.

7 Conclusions and policy recommendations

The EU's commitment to GHG emissions reduction and Finland's goal to become a carbon-neutral welfare society by 2035 highlights the need for substantial investments in emissions reduction and carbon sink enhancement. This transition triggers structural change in industries, impacting productivity and competitiveness. Despite its importance, there remains a research gap in the growing field of carbon neutrality. This report addresses this gap by exploring the link between structural change, productivity, and competitiveness during this transformation. It also shares insights on the future of the green transition in Finland and highlights the important role of green investments.

The transition to carbon neutrality involves multiple aspects, leading to various implications across different sectors. Understanding these implications and strategically implementing policy measures are important for sustainable economic growth and GHG emissions mitigation. In the following sections, we revisit the report's central research questions posed in the introduction, offering concise answers and specific policy recommendations.

7.1 Implications of transition to carbon neutrality

In addressing our first research question regarding the impact of transitioning to a carbon-neutral economy on productivity and competitiveness, we explored the relationship between firms' responses to stringent environmental regulations and the resulting changes within firms. These changes, in turn, have implications for industry dynamics and the overall economic structure.

Previous research reveals that firms adapt to evolving environmental regulations through adjustments in production methods, location decisions, and investments in clean energy sources and pollution abatement technologies. The nature of these responses varies based on factors such as firm characteristics, sector-specific attributes, and the prevailing environmental regulations.

The implications of these adaptations can extend beyond individual firms, reshaping how entire industries operate. At the industry level, the transition to carbon neutrality can substantially reshape sectors, thus reshaping the whole economy. Moreover, stricter environmental regulations can stimulate increased firm entry and exit, driven by various economic forces.

The transition can facilitate the reallocation of resources from carbon-intensive sectors to cleaner, technology-driven ones, stemming from evolving environmental regulations and changing consumer preferences for eco-friendly products. It is important to recognize that environmental regulations drive not only market adjustments but also investments in technology, innovation, and pollution reduction. This dynamic interaction continually shapes an evolving economic landscape.

In conclusion, the link between the transition to a carbon-neutral economy and productivity and competitiveness reveals complex interactions. Our empirical research aims to clarify these interactions and offer new insights.

7.2 Structural change and green productivity

For our second research question, we explored the role of structural change in Finland's two energy-intensive sectors – manufacturing and electricity generation – in terms of green productivity. Our findings revealed the following key insights:

- *Green productivity trends*: The trends in green productivity growth varied between 2000 and 2019. From 2013 to 2019, both sectors saw growth, with the manufacturing sector experiencing an annual productivity growth of around 0.4%, and the electricity generation sector showing approximately 1% per year.
- *Productivity among continuing firms*: We observed relatively weak productivity growth among continuing firms within these sectors, emphasizing the necessity for targeted efforts to improve the productivity of these firms while concurrently reducing emissions.
- *Role of structural change*: Structural change, including industry switching as well as firm entry and exit, played an important role in the sectors' productivity growth. In 2013–2019, the contribution of industry switching was negative to productivity growth, while entry and exit made a positive contribution.
- *Resource allocation*: In the electricity generation sector, resource allocation positively contributed to productivity growth. Conversely, in the manufacturing sector, its contribution was negative in the recent period (2013–2019), highlighting the need for more strategic resource reallocation toward highly productive firms.

In summary, Finland's commitment to achieving carbon neutrality presents both opportunities and challenges for its business sector. By recognizing the role of structural change in productivity growth and implementing well-informed policies, Finland has the potential to improve its economic growth and advance toward its carbon neutrality goals.

7.3 Finland’s carbon competitiveness

Addressing our third research question regarding the structural productivity and competitiveness effects arising from the transition to carbon neutrality, we analyzed Finland's carbon competitiveness in 2008–2021. We operationalized carbon competitiveness through a carbon intensity measure, calculated as a ratio of industries’ CO_2-equivalent emissions to their value added. A lower carbon intensity implies higher carbon competitiveness, demonstrating the ability of an industry to generate value while reducing carbon emissions. Conversely, industries with higher carbon intensity may confront challenges in balancing economic output with environmental responsibility.

Comparing Finland’s carbon intensities of different industries to the EU27 average, Germany, Sweden, and Denmark, differences primarily come from variations in industries’ structures and the degree of their reliance on fossil fuels. Finland's carbon competitiveness aligns closely with the EU27 average. Since 2008, Finland's emission intensity has decreased slightly faster than the average. Most industries have contributed to this improvement, with specific sectors, such as agriculture, paper manufacturing, construction, and land transport, posing challenges in reducing emissions and potentially undermining Finland's carbon competitiveness.

To improve competitiveness, it is important to address emissions in these specific sectors. In agriculture, the focus should be on sustainable farming practices and advanced technologies. For paper and paper product manufacturing, increased investments in cleaner and more efficient production methods are needed. Within the construction sector, the adoption of sustainable practices and energy-efficient building designs is necessary for emission reduction. Finally, inland transport, encouraging the shift towards low-carbon options such as electric and fuel-efficient vehicles is important, facilitated by supporting clean energy infrastructure and charging stations.

The transition to carbon neutrality has implications for Finland's current and future carbon competitiveness. To improve it, Finland should focus on the mentioned sectors, reinforcing its economic position while reducing its environmental footprint.

7.4 Future implications and prospects for Finland's green transition

Addressing the question of 'What structural productivity and competitiveness effects might arise from the transition to carbon-neutrality now and in the future?' from a forward-looking perspective, we can anticipate several implications for Finland’s green transition in the coming decade:

- *Economic restructuring*: Our model indicates that efforts to reduce GHG emissions will drive notable structural changes in the economy. Driven by emission reduction targets, firms will invest in clean technologies, resulting in the growth of green firms. Simultaneously, parallel trends such as digitalization and an aging population will further stimulate the expansion of carbon-neutral sectors like services. Consequently, a transformation in the sectoral composition of Finland's economy can be expected, with clean technology firms gaining market share at the expense of emission-intensive firms.
- *Increased productivity*: The model forecasts a slight increase in the average productivity of the Finnish economy as cleaner and more productive firms continue to enter the market. This suggests that Finland's commitment to the green transition can yield not only environmental benefits but also economic advantages.
- *Employment dynamics*: As the green sector expands and the emission-intensive sector contracts, shifts in employment dynamics will occur. The model indicates a decrease in employment in emission-intensive sectors while predicting growth in employment in the green sector. Overall, employment is expected to increase slightly.
- *Emissions reduction*: The primary goal of Finland's green transition is to reduce GHG emissions. The model highlights that emissions reduction will primarily occur through within-sector reductions in emission intensity and abatement efforts. Over time, sectoral and technological shifts will play a growing role in achieving emissions reduction.
- *Impact of international trade*: While the model operates under the assumption of a closed economy, it is important to recognize that Finland is part of a global economy. The introduction of international trade could further influence the country's emissions and economic dynamics. Existing research suggests that the technique channel (changes in industry-level emission intensities due to changes in technology and production methods) is the key determinant of pollution changes through international trade.
- *Potential for leakage*: Leakage refers to the phenomenon where GHG emissions are not reduced but merely reallocated from one region to

another due to climate policies' stringency. This is a concern, particularly if the EU's unilateral climate policies lead to an increase in foreign emissions of carbon-intensive imports. Addressing such leakage effects would require careful policy consideration.
- *Role of climate policies*: The effectiveness of climate policies, such as a carbon tax or cap-and-trade system, will be essential in achieving Finland's emissions reduction targets. The model emphasizes the importance of these policies in guiding the transition towards greener technologies and practices.

In summary, the findings from the macroeconomic model suggest the potential for economic growth in Finland, increased productivity, and emissions reduction. However, the role of international trade, the risk of leakage, and the effectiveness of climate policies are key aspects that require further exploration and policy attention.

7.5 Investment requirements and financial capabilities

Considering the investment requirements during the transition to carbon neutrality and the role of financial capabilities and market development, several key points emerge:

- *Financing needs*: This transition requires substantial financial resources across various sectors, including renewable energy (e.g., wind and solar power), green technologies (e.g., hydrogen production, energy storage, and battery technologies), and green infrastructure (e.g., transportation networks and building retrofits), each having specific financial requirements.
- *Financial capabilities of firms*: The financial strength of firms plays an important role in funding green investments. Larger firms with robust balance sheets can utilize retained earnings or capital markets. On the other hand, smaller or financially constrained firms may rely more on external financing.
- *Financial market development*: The development of financial markets offering instruments such as green bonds and investment funds can facilitate the flow of capital into green projects, appealing to a broader range of investors.
- *Investor preferences*: Investor preferences are also important. A growing number of investors express interest in carbon-neutral or sustainable investments. Institutional investors may have specific mandates directing funds towards environmentally responsible projects, thereby contributing to the financing of green initiatives.

- *Government support*: Government policies and incentives, including subsidies, tax incentives, and favorable regulatory frameworks, can stimulate green investments by reducing the cost of capital and mitigating risks. Government support may also encourage private-sector participation.
- *Risks and challenges*: Green investments may carry higher risks, particularly in innovative technologies and sectors with high policy and market uncertainties. These risks may affect the willingness of investors and financiers to participate. Governments and financial institutions play a decisive role in mitigating and sharing these risks.
- *Global competition*: Finland is not operating in isolation. Global competition for green investment financing is intensifying, and factors such as government policies and tax incentives can influence the attractiveness of different markets for green investments.
- *Monitoring and coordination*: Efficient coordination and monitoring of green investment plans are necessary to ensure a smooth and timely transition to a green economy, achieving national carbon neutrality goals. This involves addressing regulatory barriers, ensuring skilled labor availability, implementing a complementary public investment policy, and streamlining permitting processes.

In summary, Finland’s transition to carbon neutrality necessitates substantial green investments across various sectors. Securing financing for these green projects depends on such factors as investor preferences, government support, and firms’ ability to attract investment. Coordination and monitoring are important to ensure alignment with climate goals.

7.6 Policy recommendations

The transition to carbon neutrality involves firms adapting to stricter environmental regulations, restructuring industries, and promoting greener technologies. To ensure a successful transition, implementing carbon pricing mechanisms and expanding the EU ETS to include more sectors are necessary steps. Emphasizing sustainable practices and responsible consumer choices is also important. Additionally, securing the necessary financial resources for the transition and ensuring long-term commitments from both private and public investors depend on maintaining a stable political environment. Moreover, fostering a specially educated workforce with skills and knowledge tailored to the evolving demands of the green transition is needed. To support Finland’s successful transition toward carbon neutrality while simultaneously improving productivity and economic growth, we highlight the following key policy areas:

Climate policy framework for achieving carbon neutrality

- **Strengthening environmental regulations and taxation** is necessary to drive emission reductions. Expanding the EU ETS to new sectors is important for strategic emission reduction planning. Implementing effective carbon pricing and market-based mechanisms is a high-priority action to incentivize emissions reductions, accelerate the adoption of green technologies, and reduce reliance on fossil fuels.
- **Complementing carbon pricing:** Achieving carbon neutrality requires recognizing that carbon pricing alone is not sufficient. Essential to this goal is the implementation of a set of measures, involving a mix of regulatory and incentive-based policies. This includes tailoring environmental regulations to the unique needs of various sectors and firms, promoting sustainability while minimizing adverse economic impacts. For example, supporting the development of sustainable transportation options, such as electric vehicles, and encouraging responsible consumer choices in terms of energy use and resource consumption.
- **Regular evaluation and adjustment of climate policies**: It is important to regularly evaluate and adjust existing climate policies to maximize their effectiveness in reducing emissions. This may involve revisiting carbon pricing mechanisms and regulatory incentives to ensure they remain aligned with evolving environmental and economic conditions.
- Promote market competitiveness and resource allocation for sustainability
- **Foster innovation through competition:** Encouraging competition in emerging green technology sectors is highly relevant as it can promote innovation and accelerate the adoption of green solutions. For instance, creating incentives for startups and established companies to develop and compete in green tech sectors such as renewable energy, electric vehicles, and green infrastructure markets.
- **Streamline regulations:** Simplifying regulatory processes and reducing obstacles to green initiatives is important for accelerating the transition to eco-friendly practices. This can help overcome bureaucratic challenges and facilitate the implementation of sustainable technologies. Moreover, increased R&D investments are essential to drive innovation and develop cutting-edge green solutions, securing Finland's leadership in global green technology.
- **Efficient resource allocation:** Ensuring the efficient allocation of resources is important for promoting productivity growth and sustainability. In this context, resources refer to not only labor and capital but also GHG emissions. Finland should develop policies directing these resources towards high-productive firms. This strategic

allocation is essential because it supports productivity growth and encourages environmentally responsible practices by firms.

Investment strategy for green transition

- **Promote green research and development (R&D):** Investment in R&D for green technologies is the driving force behind innovation and the development of sustainable technologies. This investment is fundamental for the success of green initiatives, aligning with Finland's goal of achieving a carbon-neutral society. For example, fostering collaboration between research institutions and private enterprises can accelerate the development of cutting-edge environmentally friendly technologies.
- **Enhance regulatory certainty:** Finland faces uncertainties in estimating the necessary investments for achieving carbon neutrality. These uncertainties are linked to diverse factors, including future Finnish and EU policies, the timing and outcomes of emerging technologies, the availability and cost of financing, and Finland's competitiveness in attracting investments. To address this challenge, establishing transparent and consistent environmental policies is important. These policies serve as the foundation for all other green investment initiatives and play an important role in reducing business uncertainty. By providing a stable policy environment with clarity and consistency, we can reduce uncertainties for businesses and facilitate private sector engagement.
- **Utilize public support for green investments:** Public support, in its various forms, plays an important role in closing funding gaps. Government initiatives, grants, and incentives should be encouraged to support green projects and startups, especially in areas with positive externalities. This support serves as a driving force, accelerating the transition towards environmentally friendly practices and motivating businesses to invest in green initiatives. Collaboration with the EU can further enhance the impact of these initiatives.

Global collaboration and leakage risk management

- **Foster international collaboration**: International collaboration is important, given the global scale of climate change. Finland should proactively engage in addressing the challenges and opportunities stemming from global trade. This includes establishing cooperative agreements with other nations to harmonize efforts and collectively reduce emissions.
- **Mitigate emissions leakage**: To ensure the effectiveness of Finland's green transition, a proactive stance should be taken in continuously

evaluating and addressing the potential for emissions leakage. International agreements and the introduction of carbon tariffs on imports are effective strategies to safeguard against emissions leakage and ensure progress towards carbon neutrality.

- **Promote international partnerships**: The establishment of international partnerships is important for advancing research, technology development, and the exchange of best practices in the pursuit of achieving carbon neutrality. Collaboration can extend to sharing research findings with international institutions or partnering with international research centers to foster innovation. By doing so, Finland secures its leadership role in green innovation and sustainable business practices.

Workforce development for green transition

- **Fostering green workforce development:** Cultivating a green workforce is a fundamental aspect of green transition strategy. This involves establishing specialized training programs that prioritize skills and knowledge aligned with the evolving green economy, covering areas such as green technologies, sustainability practices, and the changing demands of various sectors. Collaboration with educational institutions is important for delivering tailored courses and degree programs, ensuring that graduates are well-equipped to meet the changing needs of industries. It is also important to promote lifelong learning and provide incentives for continuous skill development within the existing workforce. Furthermore, strengthening partnerships between academia and the private sector ensures that these programs effectively address industry requirements and future workforce demands.
- **Supporting green innovators and startups**: This contributes to addressing the skilled labor shortage by establishing specialized funding programs, grants, and incentives tailored to green-focused businesses. These initiatives should provide comprehensive support for research and development, along with strategies for creating employment opportunities. Additionally, fostering collaboration between research institutions and green technology startups can accelerate the development of cutting-edge environmentally friendly technologies. Such partnerships play a role in cultivating an innovative and competitive workforce, helping bridge skill gaps.
- **Fostering workforce diversity**: To strengthen Finland’s green workforce and address skill shortages, a commitment to diversity and openness to international talent is important. This involves implementing inclusive hiring practices that welcome individuals from diverse backgrounds, promoting equity, and broadening Finland’s talent pool.

Additionally, attracting skilled immigrants who can contribute to the green transition helps fill labor gaps and bring in international expertise. Collaboration with educational institutions and the private sector is essential to ensure the successful integration of international talent into the workforce, ultimately boosting Finland's competitiveness in the green technology sector.

By focusing on these key areas, Finland can enhance its carbon competitiveness and productivity, while contributing to the broader EU goal of a low-carbon economy.

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