POLITECNICO DI TORINO

Master’s Degree in Management Engineering

Graduation Session of November 2025

The Role and Impact of Business R&D Expenditure in Shaping Cleantech Firm Revenues and Growth

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Academic Year 2024/2025

Abstract

The industrial sector now depends heavily on cleantech because it unites technological progress with goals to boost operational performance and decrease reliance on conventional resources while creating fresh development prospects. The field delivers environmental advantages while creating industrial transformations that create employment opportunities and strengthen business sustainability. Research efforts need identification of sustaining factors for cleantech firm development and success measurement to understand which nations and industries excel at turning research into tangible outcomes.

This thesis focuses on the role of research and development, with particular emphasis on Business Enterprise Expenditure on R&D (BERD), as a driver of firm performance. The analysis takes a comparative perspective across five European economies – Italy, France, Germany, Denmark and the Netherlands – highlighting how differences in spending levels, financing structures and sectoral priorities influence outcomes such as sales growth and employment creation. Business expenditure is considered alongside Gross Domestic Expenditure on R&D (GERD), enabling a distinction between the roles played by governments and private enterprises. In parallel, the financing composition is assessed to clarify whether innovation is primarily supported by internal corporate resources or relies more heavily on public co-funding.

The evidence shows that the trajectory of R&D investment varies significantly across countries. In Germany, for instance, BERD has grown consistently and is heavily concentrated in manufacturing, reflecting the industrial structure of the country and the strong role of enterprises in financing their own innovation. France and Italy, by contrast, display lower shares of BERD relative to GDP, with a more visible role for government in sustaining expenditure. Denmark and the Netherlands present intermediate but distinctive patterns: the former experienced substantial fluctuations in private expenditure, while the latter has shown relatively smaller levels of business investment but with important sectoral diversification. These contrasts underline that aggregate R&D figures do not fully capture the dynamics at play and that the balance between public and private contributions has a material impact on outcomes.

Beyond aggregate levels, the thesis also investigates sectoral allocations, with a particular focus on manufacturing and pharmaceuticals. The data indicate that manufacturing absorbs

the majority of BERD in all five countries, often exceeding three quarters of total expenditure, suggesting its role as the backbone of business-led innovation. Pharmaceuticals, while smaller in scale, exhibit distinct dynamics, often linked to higher knowledge intensity and stronger effects on firm revenues. These differences raise the question of whether sectoral composition matters more than overall volume when evaluating the effectiveness of R&D in supporting cleantech development.

The study's foundation is rooted in an examination of numbers focusing on how business research and development spending affects a company's sales over time. To get an understanding researchers looked at whether pouring money into R&D actually leads to lasting growth, in revenue. What they found was a bag. In some countries like Germany and Denmark the link between R&D spending and sales growth was clear but, in others it was weaker or uneven. They also explored how R&D spending impacts employment changing their focus to this area of inquiry. The picture gets more complicated; sometimes a higher budget, for research and development actually goes hand in hand with jobs especially when companies are setting up new factories.. In cases the two don't seem to be related or even move in opposite directions. This suggests that pouring money into research that relies heavily on brainpower can make a company more efficient without needing to hire people.

This thesis offers a look, at how cleantech innovation develops in settings by looking at trends and testing them with economic data. What is key here is that it's not just how much research and development is done but who is doing it who is paying for it and which areas are getting the attention. The results give us an idea of what helps cleantech companies grow and what gets in their way. They show that it's the specifics. Like who's, behind the innovation and where the money is going. That can make or break a company's ability to scale up. It is clear that each country has its path to follow. What works in one place may not work in another, so it doesn't make sense to try to use the approach. When it comes to things, like policy and planning, for companies an individualized approach is needed, one that takes into account the specific circumstances and needs of each country.

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1. Introduction

The world now acknowledges climate change as a major worldwide emergency which affects human existence through environmental and social consequences. The world experiences increasing severity of climate change effects which include rising ocean heights and more destructive natural disasters and water contamination and biodiversity changes. The solution to these environmental problems needs international collaboration and unified efforts across all organizational levels.

The cleantech industry functions as a vital tool to fight environmental problems while enabling sustainable economic development. Human activities require cleantech technologies to reduce environmental harm while these solutions create economic expansion and employment opportunities and draw investment capital. The technology sector includes modern solutions which focus on renewable energy systems and energy efficiency measures and waste management techniques and sustainable transportation methods.

The European Union established the European Green Deal as a comprehensive policy framework to make Europe the world's first climate-neutral region by 2050. The initiative represents a groundbreaking sustainability pledge which establishes precise environmental targets and drives innovation throughout the cleantech industry.

Cleantech company success depends heavily on the policies and regulatory systems which support their growth. The expansion of cleantech businesses depends on three essential elements which include regulatory stability and financial support and sufficient funding opportunities. The research needs to examine essential elements which will boost European cleantech company growth.

This research investigates the enabling elements that support cleantech sector development through an examination of individual nations. The research design uses a country-based method to study cleantech sectors while it seeks to discover new knowledge gaps and apply European-wide research outcomes to national market characteristics. The European Union together with its member states has developed multiple green policies to establish sustainable economic growth which protects all stakeholders during the transition process. The research draws its core elements from the CLEU project which received EIBURS funding from the European Investment Bank (EIB) to study Cleantech in the European Green Deal and its policy obstacles and financial support systems for small and medium enterprises. The project delivers essential frameworks to distinguish between two types of cleantech businesses which include innovators and ecosystem participants. The research will use Orbis database by Bureau van Dijk to identify cleantech firms while combining their financial records with patent data and technological advancement information. The research design allows for complete sector analysis through which researchers can study national patterns and cleantech firm expansion trends.

The research investigates how different indicators of cleantech businesses affect their sales performance and workforce growth through specific change drivers across different countries and time periods. The research examines how national policies together with financial support systems and additional enabling elements affect the market value of cleantech companies. The research provides evidence to create better strategies for supporting innovative technologies. The research investigates major countries and industries which drive the European cleantech industry. The research investigates how different national elements affect the emergence and expansion of cleantech businesses and startups through detailed country-level assessments. The research investigates key elements which drive innovation and expansion in the cleantech sector to provide essential knowledge about successful conditions for growth. The research aims to help achieve sustainable climate neutrality by studying national and sector-specific best practices and challenges that exist in each area. The research aims to enhance knowledge about European national cleantech sector operations which will help develop specific policies for sustainable technology promotion throughout Europe.

Keywords: Cleantech, Environmental Innovation, National Policies, Venture Capital Investments, Country-Level Analysis.

2. The Cleantech Sector

The global economy now experiences rapid transformation through the emerging Cleantech industry which shows exceptional dynamism. The rising environmental awareness and sustainable solution requirements have established cleantech companies as leaders who drive innovation throughout different market segments. The companies in this sector create environmental solutions through technological advancements which simultaneously generate economic value. The transition to a sustainable low-carbon economy depends heavily on cleantech solutions which include renewable energy systems and waste management technologies. This chapter investigates how the cleantech industry developed through time while analyzing the elements that accelerated its fast growth and the essential part that new sustainable businesses play in creating a sustainable future.

2.1 Diving into the Cleantech startup sector

The increasing global emphasis on sustainability and environmental responsibility has led to the birth and rapid growth of the Cleantech sector, made up of cleantech companies. The most commonly used definition of cleantech comes from Pernick and Wilder (2007), who state in their article that "cleantech refers to any product, service, or process that delivers value using limited or zero non-renewable resources." This definition captures the essence of the sector, emphasizing the innovative use of resources that minimize or eliminate environmental impact while promoting sustainability. The cleantech sector is a diverse and dynamic area that spans multiple industries, including renewable energy, energy storage, water purification, waste management, and sustainable transportation. These companies focus on creating solutions that are economically viable while also addressing global environmental challenges. The innovations within the sector often leverage cutting-edge technologies, digital platforms, and novel engineering solutions to improve resource efficiency, reduce emissions, and create sustainable alternatives to traditional processes.

As the global economy transitions toward a low-carbon future, cleantech startups have become increasingly central to driving the transformation. These startups are innovating in ways that align with international climate goals, pushing the boundaries of what is possible in green technologies and practices. The rapid growth of cleantech companies reflects the increasing recognition of their potential to address not only environmental issues but also economic and social challenges. Several key elements are fuelling the expansion of cleantech startups:

- **Increasing Investment**: the inflow of venture capital and private equity funding into the cleantech sector has been substantial, with venture capital serving as the primary funding source for early-stage startups. Investors are increasingly aware of the significant market potential of cleantech solutions, recognizing their capacity to generate returns while contributing to sustainability efforts. For example, a report by the Cleantech Group indicated that global cleantech investments reached $46 billion in 2022, signalling strong investor interest in green technologies (Cleantech Group, 2023). As expected, energy and energy efficiency technologies represent the lion's share of this funding, accounting for roughly 70 percent of total cleantech investments (PWC, 2015). Furthermore, new forms of financing, such as crowdfunding, have also emerged to support cleantech ventures, democratizing access to capital for smaller companies.

- **Supportive Policies**: government policies and international agreements, such as the Paris Agreement and the European Green Deal, have played a significant role in creating a favourable regulatory environment for cleantech innovations. These policies provide financial incentives, subsidies, and regulatory frameworks that encourage the adoption of clean technologies and support the transition to renewable energy sources. They also set ambitious targets for reducing greenhouse gas emissions and achieving carbon neutrality by 2050 (European Commission, 2019). Such policies not only drive demand for sustainable solutions but also help cleantech startups secure funding and market access by reducing the barriers to entry.

- **Technological Advancements**: the rapid evolution of technologies such as artificial intelligence, blockchain, and advanced materials has accelerated the development of cleantech solutions. These technologies enable more efficient, scalable, and cost-effective solutions for managing resources and reducing environmental impacts. The integration of digital tools and artificial intelligence, for instance, has allowed cleantech companies to optimize processes, increase energy efficiency, and automate complex tasks, significantly enhancing the scalability and affordability of green technologies (International Energy Agency, 2022).

- **Consumer Demand**: growing consumer awareness of environmental issues and the desire for sustainable products and services have contributed to a surge in demand for cleantech solutions. As sustainability becomes an integral part of consumer behaviour, businesses are under increasing pressure to adopt environmentally friendly technologies. This shift in consumer preferences is driving companies across various industries to incorporate cleantech solutions into their operations, helping them meet market expectations and achieve their sustainability goals. The adoption of sustainable practices, driven by consumer demand, is transforming traditional industries, making cleantech solutions integral to corporate strategies (McKinsey & Company, 2023).

The growth of technology-based startups, such as cleantech ventures, can be influenced by various factors. These factors can be classified into three broad categories: individual, firm-specific, and external. Individual factors refer to the personal characteristics of entrepreneurs, such as their skills, knowledge, and experiences, which influence their ability to innovate and manage new ventures. Firm-specific factors include the resources and networks that firms can leverage, such as partnerships, access to capital, and organizational capabilities. External factors, on the other hand, encompass the broader regulatory environment, market conditions, and government policies that can either facilitate or hinder the growth of startups. The interplay between these factors is critical to understanding the success and challenges faced by cleantech startups, which are constantly navigating the complexities of a rapidly evolving market. In this context, government regulations, which play a vital role in shaping the landscape for cleantech innovations, will be a focus of investigation in this thesis.

2.2 Cleantech Segmentation

The cleantech sector is multifaceted, encompassing a wide range of technologies and industries aimed at achieving environmental sustainability. This diversity allows cleantech companies to address numerous environmental challenges, such as reducing carbon emissions, conserving resources, improving energy efficiency, and minimizing pollution. The sector spans industries like renewable energy, water purification, energy storage, waste management, and sustainable transportation. It is often driven by a sense of urgency to combat climate change and to transition towards a more sustainable, low-carbon global economy. The increasing demand for sustainable solutions, coupled with advances in technology, has led to the rapid expansion of this sector globally.

In their research, Ambrois et al. (2023) address a significant gap in the understanding of the cleantech sector by providing a segmentation of European cleantech companies. Prior to this study, no comprehensive and systematic list of cleantech firms existed, making it difficult to assess their contributions or track their progress. The segmentation process is essential as it allows for a more in-depth analysis of the different types of companies within the sector and provides a clearer understanding of their roles in driving innovation and adoption of clean technologies. By categorizing cleantech companies, researchers and policymakers can more accurately target interventions, investments, and regulatory efforts to support the sector's growth.

The segmentation method employed by Ambrois et al. is both innovative and thorough, combining advanced data science techniques with traditional classification methods. The first step in this process involved using a supervised machine learning (ML) algorithm, which was trained to recognize cleantech companies based on their extended business descriptions extracted from the Orbis database. These descriptions contain valuable keywords and information related to cleantech activities, such as sustainability practices, renewable energy, energy efficiency, waste management, and pollution reduction. By manually labelling a sample dataset of companies as either cleantech or non-cleantech, the algorithm was able to learn patterns in the data and build a model capable of classifying a larger dataset. This initial classification helped to identify a broad set of companies with potential cleantech characteristics.

Following this automated classification, computer-aided filters were applied to further refine the results. These filters cross-referenced additional criteria and datasets to eliminate any false positives and improve the accuracy of the classification. This two-step approach of ML and automated filtering ensured that the dataset was both comprehensive and reliable, minimizing the risk of misclassification. The final step in the segmentation process involved manual verification and categorization of the companies. This was necessary to ensure the accuracy of the classification and to assign each company to one of two main categories: **Cleantech Innovators** and the **Cleantech Ecosystem**.

Cleantech Innovators are companies that focus on developing new clean technologies and solutions that have the potential to significantly reduce environmental impact. These include firms working on next-generation renewable energy technologies, energy storage solutions, green chemistry, and sustainable materials. For instance, companies engaged in the development of advanced solar panels, hydrogen fuel cells, or next-generation recycling technologies fall into this category.

On the other hand, the **Cleantech Ecosystem** encompasses companies that are involved in the adoption, commercialization, or supporting activities related to cleantech solutions. These companies play crucial roles in enabling the scaling and distribution of clean technologies. They are further subdivided into the following categories:

- **Experimenters**: these are companies involved in experimental activities that contribute to the development and refinement of cleantech solutions. They often engage in early-stage research and development, pushing the boundaries of cleantech science.

- **Manufacturers**: these firms are responsible for producing the components, materials, and equipment required for clean technologies. Their work is fundamental to ensuring the availability of the necessary inputs for large-scale production and adoption.

- **Distributors**: companies in this category are involved in the distribution and commercial provision of cleantech products or services, ensuring that these technologies reach the market and are accessible to end users.

- **Integrators**: integrators focus on engineering, installation, and the design of systems that make cleantech solutions operational. Their work ensures that clean technologies are ready for use by consumers and businesses.

- **Operators**: these firms are involved in the construction, operation, and maintenance of facilities that utilize cleantech. They may also include adopters, such as energy production companies, that incorporate clean technologies into their operations to reduce their environmental footprint.

This meticulous process of segmentation reduced the initial dataset of over 537.000 companies to a refined list of 23.858 cleantech companies, of which 2.990 were classified as innovators, while 20.868 were categorized as part of the broader cleantech ecosystem. By narrowing down the dataset in this way, researchers can now focus on analyzing the specific needs, contributions, and challenges faced by different groups within the sector.

This segmentation serves multiple purposes in the research, particularly in understanding how different categories of cleantech companies respond to regulatory changes, investment patterns, and market dynamics. It also allows for a more targeted analysis of the financial performance and growth trajectories of cleantech firms, which is critical for evaluating the effectiveness of policies and incentives aimed at fostering sustainability. Moreover, the segmentation enables detailed geographical analysis, which can highlight regional strengths and weaknesses within the cleantech sector, thus helping policymakers tailor interventions that support the development of cleantech hubs across Europe.

2.2.1 Database Utility

The segmented database plays a crucial role in providing valuable insights for this research, offering a multifaceted approach to understanding the dynamics of the cleantech sector in Europe. The comprehensive database serves several critical functions that are instrumental in analyzing the sector's growth and identifying the factors influencing cleantech companies.

1. **Policy Impact Analysis**: the segmentation of cleantech companies into innovators and ecosystem participants enables a more granular analysis of how different types of companies respond to varying policies and regulations. This distinction allows researchers to explore how innovations are fostered in response to supportive policies, such as financial incentives, subsidies, or market access programs. By tracking the regulatory environments in which these companies operate, it becomes possible to assess whether policy changes stimulate innovation, accelerate the adoption of clean technologies, or lead to industry consolidation. For example, analyzing the impact of the European Green Deal could reveal whether it accelerates technological advancements or changes the competitive landscape among cleantech firms.

2. **Financial Performance and Investment Trends**: segmentation of the cleantech sector also facilitates the tracking of key financial performance indicators (KPIs) and venture capital (VC) investment patterns, providing deeper insights into how investment flows correlate with sector performance. The database enables the identification of investment trends, such as whether cleantech innovators experience

a greater influx of venture capital following the introduction of supportive policies. This information is critical in understanding the financial health of the sector, determining which sub-sectors attract the most attention from investors, and evaluating the effectiveness of government initiatives in promoting the financial sustainability of cleantech firms. Tracking these patterns over time allows for more informed decisions regarding resource allocation, as well as the identification of high-potential investment opportunities.

3. **Geographical and Sectoral Insights**: the database offers detailed geographical analysis, which is essential for identifying regions with high concentrations of cleantech activities. By examining these regional clusters, it becomes clear which areas in Europe are most active in cleantech innovation and adoption. For instance, the concentration of cleantech innovators in Northern Europe, driven by favourable policies and investment climates, could be identified. This geographical insight also aids in understanding sectoral trends, such as which specific industries within the cleantech sector - like renewable energy, sustainable transportation, or waste-to-energy technologies - are thriving and which are lagging. With this knowledge, policymakers can design more targeted interventions, such as increased funding or tax incentives for underdeveloped sectors, thereby ensuring more balanced growth and fostering innovation across the entire sector.

4. **Mapping Cleantech in Europe**: one of the most valuable aspects of the database is its ability to map the distribution of cleantech companies across Europe. The geographical mapping of cleantech activities allows for the visualization of clusters of innovation and adoption, identifying areas of growth and potential for further development. For example, specific countries or regions may emerge as hubs of cleantech development due to favourable investment conditions, policies, or technological expertise. By pinpointing these regional hubs, it is possible to focus policy efforts on areas with high potential for growth or to address disparities in cleantech development. The visual representation of this data helps inform strategic decisions for industry stakeholders, guiding efforts to support lagging regions, stimulate local economies, and promote the widespread adoption of cleantech solutions.

5. **Innovation and Patent Activity**: the focus on cleantech innovators in the database allows for an in-depth examination of technological advancements and patent activity within the sector. By analyzing the rate of patent filings and the emergence of new technologies, this research can identify which technologies are gaining traction and have the potential to transform the cleantech landscape. For example, an uptick in patents related to battery storage technology could indicate that this area is poised for significant growth, highlighting a promising opportunity for further investment and policy support. This focus on innovation and patent activity provides a critical indicator of the sector's technological trajectory and can guide decisions regarding research funding and public-private partnerships.

6. **Support Scheme Design**: a well-segmented database offers policymakers the necessary insights to design more effective support schemes for cleantech companies. Understanding the financial needs and operational challenges faced by both cleantech innovators and ecosystem participants enables the creation of more tailored funding programs and incentives. For example, early-stage innovators may require grants and subsidies to support research and development, while companies in the cleantech ecosystem may benefit from tax incentives or access to low-cost capital for scaling technologies. The database helps pinpoint the specific requirements of different types of companies, allowing for the development of more effective policies that cater to the diverse needs of the sector.

The segmentation and creation of a detailed database are foundational to this research. This approach offers a nuanced understanding of the cleantech sector, allowing for the analysis of how policies, investment trends, and technological advancements influence the growth and development of cleantech companies across Europe. By leveraging statistical tools like Stata, it is possible to analyze the relationship between regulatory changes and the financial performance of cleantech firms, providing valuable insights for policymakers, investors, and industry stakeholders. Furthermore, the geographical mapping of cleantech companies highlights regional strengths and weaknesses in sectoral development, contributing to a more targeted and informed policy approach that supports sustainable innovation across Europe.

3. Literature Review

Before proceeding with data collection and analysis, a comprehensive literature review was conducted to understand the existing body of knowledge surrounding the cleantech sector. This phase was crucial for framing the research questions and identifying the key factors influencing the growth and development of cleantech companies. The review focused on understanding the state of the cleantech sector, examining current trends, and exploring the factors that have been identified as significant drivers for the emergence and expansion of cleantech enterprises.

The Cleantech sector has become an increasingly important part of global economic and environmental strategies. As countries strive to meet international climate goals and reduce their carbon footprints, Cleantech technologies have emerged as essential for mitigating the environmental impact of human activity. These technologies span across a range of industries including renewable energy, waste management, energy efficiency, sustainable mobility, and more. Cleantech companies are often seen as critical players in addressing the global challenges posed by climate change, offering solutions that not only reduce environmental harm but also promote economic growth and job creation.

The rise of Cleantech is not a mere trend, but part of a larger, more profound shift toward sustainable development. As defined by the European Union and other international bodies, Cleantech represents innovations designed to address the world's most pressing environmental challenges through new products, services, or processes that reduce the use of natural resources or minimize negative environmental impacts. Companies operating in this sector typically engage in the development of renewable energy solutions, pollution reduction methods, and the enhancement of energy efficiency across various sectors of the economy.

In the past few decades, Cleantech has seen significant growth, fuelled by governmental policies, public-private partnerships, and increasing consumer demand for sustainable products. This growth is not only relevant for environmental protection but is also seen as a potential driver of economic prosperity and competitive advantage.

3.1 Purpose of the Literature Review

The primary objective of the literature review was to:

1. Identify the most relevant **indicators and variables** that affect the cleantech sector, with particular emphasis on **environmental factors** (e.g., CO2 emissions, R&D expenditure, patent activity, venture capital availability).
2. Examine **policies and regulations** implemented by governments and their direct or indirect impact on cleantech company formation and growth.
3. Understand **current trends** within the cleantech industry, including market shifts, technological innovations, and the global transition towards sustainability.
4. Provide a **theoretical framework** that links **national environmental indicators** with cleantech growth metrics, helping to form the foundation for the quantitative analysis that follows.

3.2 Sources and Scope of the Literature Review

The literature review encompassed a variety of sources, ranging from academic papers to industry reports.

In order to select the relevant literature to be reviewed we proceeded with the following steps: first, we conducted an extensive search in the titles and abstracts of published, peer-reviewed articles, using a series of keywords that cover the topics under scrutiny. The selected keywords have been the following ones: Cleantech, Cleantech sector, Cleantech startups. We then selected all the relevant research published from various sources, such as academic journals, industry reports, and government publications, including those from the European Commission, OECD, and World Bank, along a proper time frame (from 2000 to 2023). We then read all those articles by choosing the ones that fit the most with the main topic and finally reviewed extensively and included them in our literature review.

- **Policy and Regulatory Analysis**: papers and reports discussing the role of government policies in fostering clean technology innovation and the broader regulatory environment shaping the cleantech sector.

- **Technological Trends**: papers that examine technological advancements, including renewable energy solutions, energy efficiency technologies, sustainable mobility, and waste management systems.
- **Economic and Financial Aspects**: articles exploring the role of financial mechanisms such as venture capital (VC), public funding, and private investment in supporting cleantech innovation.
- **Geographic and Market Insights**: research that analyses how different regions, especially Europe, have approached the cleantech sector and the varying levels of success and challenges encountered.

This diverse collection of sources helped to create a comprehensive understanding of the sector, including insights into policies, technological innovations, market conditions, and financial dynamics that have shaped cleantech development.

3.2.1 The Role of Policies and Regulations in Cleantech Growth

Environmental policies play a key role in determining the growth trajectory of Cleantech companies. At both the national and international levels, regulatory frameworks shape the incentives and barriers faced by firms in the Cleantech sector. The European Green Deal, for instance, outlines the European Union's commitment to achieving climate neutrality by 2050, with specific policies to promote renewable energy and energy efficiency, curb carbon emissions, and foster green innovation. Policies such as carbon pricing, tax incentives for sustainable practices, and funding for research and development in clean technologies are some of the tools being used to drive Cleantech adoption across Europe.

The economics literature argues that since environmental problems arise from market failures, government interventions such as taxes and/or regulations are the best way to deal with these problems (Crifo and Forget, 2014), creating a need for policies.

These policies impact Cleantech firms in several ways. First, they create a market environment where clean technologies are incentivized through financial and regulatory benefits. Second, such policies help to increase the long-term predictability of environmental markets, providing firms with the certainty needed to make substantial investments in clean technologies.

While there aren't many studies in the literature regarding this topic, some studied provided by the European Commission, the IEA (International Energy Agency) and the IMF (International Monetary Fund) analyze the impact of policies in supporting Cleantech startups in different fields.

A study of the European Commission done in 2021 provides a selective review of policies that can help to foster a transition towards green technologies, focusing on policies that support the supply of clean technologies, such as R&D funding, as well as those supporting demand, such as carbon pricing and clean technology standards (Science, research and innovation performance of the EU 2022, Chapter 10, Dugoua).

The study highlighted how technology is important to the transition into green economy, however some critical points should be highlighted: solutions to problems typically do not fall from the sky, or from market economies when markets are blinded to the problems, or by waiting for cleaner technologies to come about, but instead in designing government interventions that will tackle the various market failures at different points of the technological change pipeline. Solar power is an example of this, where multiple policies in different markets led to a strong support of demand of solar panels, which eventually led to impressive cost reductions (Science, research and innovation performance of the EU 2022, Chapter 10, Dugoua).

This study also highlights the importance of the direction of technological change, and that should be evaluated not in absolute terms, but relative to dirtier solutions.

Economists have identified several market failures that contribute to clean technologies being under-provided (Jaffe et al., 2005; Popp et al., 2010). The two most important ones are the environmental market failure, where pollutants are emitted as a side effect of economic activities and impose a cost on society overall, and the public-good characteristics of knowledge. When knowledge is created, it can often be acquired and used by others for free.

The variety of market failures in green technological change establishes the need for a mix of policies that go from carbon pricing and R&D subsidies to technology standards and adoption subsidies.

On the supply side, the industry's typical high capital intensity and long payback periods require patient investment with very deep pockets, which private-sector firms may not be able to provide easily. As a result, the public sector has a complementary role to play by having high er tolerance to risk and payback time, which is also critical when supporting the development of early-stage and more radical innovations (Science, research and innovation performance of the EU 2022, Chapter 10, Dugoua).

Another study from the IEA (International Energy Agency) highlighted how important policies and programmes are in order to help gaps in early stages. This study has yet to produce a consolidated catalogue of agreed best practices, however it has shown the numerous ways taxpayer resources can be used to significantly boost innovation, beyond what conventional public and private sector support can do. In fact, the value of some services governments provide directly to start-ups far outweighs the financial cost to the taxpayer. This is especially true for granting access to laboratory infrastructure and using the government's brand to unite stakeholders. All those factors, driven by governments, can help cleantech startups in their growth and success. (How Governments Support Clean Energy Start-ups, IEA, 2022).

Policies in different countries can also lead to different levels of investments, both from the private and public sectors, which are vital for cleantech startups in order to survive. As R. Bianchini and A. Croce states in their study, environmental policies can help promoting venture capital investments in companies involved in the development of clean technologies. Given this peculiar risk profile of cleantech companies, governments can play a crucial role in designing environmental policies for both demand or supply aimed at reducing the risk profile of these technologies and fostering financial investments by VC investors.

The study highlights that GVCs' (Governments Venture Capital) and IVCs' (Independent Venture Capital) investment in the cleantech sector are driven by different environmental policies. IVC investments react positively to mechanisms able to increase revenues and, with non-monotone behavior, to instruments that impose a pollution cost on companies. On the contrary, GVCs and indirect support mechanisms, such as subsidies and tariffs, result in substitutes and GVCs seem to support cleantech initiatives in countries where the implementation of environmental policies is more stringent (Bianchini and A. Croce, Review of Corporate Finance, 2022, 2: 587–616). The financial part of cleantech startups will be discussed in more detail later in the literature review.

3.2.2 Innovation as a Driver of Cleantech Growth

Innovation is often seen as the backbone of the Cleantech sector. The rapid pace of technological advancement in renewable energy, waste management, energy storage, and other Cleantech solutions is essential for addressing environmental challenges. However, the creation of new, sustainable technologies requires significant investment in research and development (R&D), a process that can be hindered without adequate financial support. The role of national governments and the private sector in fostering innovation through funding, policy, and infrastructure is therefore crucial.

Innovative technologies in Cleantech encompass a wide range of solution, ranging from next-generation solar panels, advanced wind turbines, and energy-efficient systems for both residential and industrial use. One area where innovation has been particularly promising is in the development of energy storage technologies, which are crucial for integrating renewable energy sources into the grid. This is because energy generation from renewable sources like wind and solar is intermittent, and efficient storage technologies are needed to smooth out supply-demand imbalances.

The innovation against policy indicators is studied by some papers, which highlight the importance of stronger policies. A study of Eugster analyses the impact of environmental policy on innovation in clean technologies, underlining the positive impact over the cleantech sector. The paper's main conclusions are three-fold. First, tightening environmental policies made a statistically and economically significant contribution to increased innovation in clean technologies, with effects of such a tightening materializing rather quickly, becoming statistically significant almost immediately and strengthen over the first 2 to 3 years after the policy change. Second, distinguishing between different technologies, the paper finds that both market policies (including trading schemes and feed-in tariffs) as well as non-market policies (including emission limits (e.g. on power plants) and R&D subsidies) made positive, statistically significant and roughly comparable contributions to clean innovation, making the result encouraging in two ways. It first confirms that market mechanisms are effective at stimulating innovation, consistent with models of endogenous technological change, where the expected future demand for a product can incentivize research into producing it more efficiently. Finally, the paper looks at whether environmental policies induce additional innovations or merely change its composition towards cleaner alternatives. Focusing on electricity related technologies only, the paper finds that policies contributed to a shift in the composition of innovation away from dirty towards clean as well as "grey" technologies. This suggests that the technological improvements necessary to curb climate change will not only come from entirely new green technologies, but also from increased carbon efficiency of *a priori* dirty technologies (The Impact of Environmental Policy on Innovation in Clean Technologies, Eugster,2021, IMF).

These, as well as Johnstone et al. (2010), generally provide support for the idea that clean innovation can be "induced" by environmental policies.

In addition to technological innovation, policy-driven innovation is also vital for Cleantech development. Countries that provide financial incentives for R&D in sustainable technologies tend to see more innovation in the sector. For instance, nations with robust patenting systems and strong intellectual property protection offer a better environment for Cleantech firms to protect and commercialize their innovations (Smith & Raven, 2012; Johnstone et al., 2020). Moreover, policies that promote cross-sectoral collaboration between private firms, universities, and government agencies have been instrumental in accelerating the pace of innovation within the Cleantech space.

3.2.3 Venture Capital and Financial Support in Cleantech

Literature has extensively analysed the impact of venture Capital in the cleantech sector, given the importance of financing research and development of new technologies, and how those funds can influence and drive this sector.

Access to capital is a critical factor for the development and growth of Cleantech companies. Given the capital-intensive nature of many Cleantech innovations, venture capital (VC) plays an essential role in financing the early-stage growth of startups. The Cleantech industry, however, faces particular challenges related to the riskiness and long-time horizon of these investments. Venture capital funds are essential for bridging the financing gap between early-stage concept development and commercialization.

Firstly, we should wonder why Corporate Venture Capitalists invest in the cleantech sector. A study from Hegeman and Sørheim tries to highlight why this is the case, despite the riskier nature of this type of investment: in general, CVCIs invest for more than purely financial gain, balancing a mix of financial and strategic reasons as well (Gompers and Lerner, 1998), which can be as important as the financial return itself. The goal of strategic investments is to benefit the companies' own businesses, which can take different forms. Investing in a startup can provide the CVCI with insights into new technologies and practices (Siegel et al., 1988; Maula et al., 2009; Sahaym et al., 2010; Wadhwa et al., 2016; Rossi et al., 2020). Companies can also invest because of the early window on new markets or on government development that these investments provide (Rind,1981). In all these cases, CVC is associated with explorative learning (March 1991), which requires the investment target to have a certain distance from the investor's existing knowledge base (Schildt et al., 2005). In other cases, a CVCI contributes to a startup that is developing a complementary product, as it may increase the demand for the CVCI's own products (Sykes, 1990; Dushnitsky and Lenox, 2006). By making CVC investments, a company will also be exposed to entrepreneurial knowledge, culture and thinking, which may again enhance its innovative capabilities (Dushnitsky and Lenox, 2005b; Basu et al., 2011). Even if the investment fails, the learning provided to the investing firm can be such that the endeavor is still regarded as a success because of strategic returns (Keil et al., 2010; Titus and Anderson, 2018).

There are also substantial differences between cleantech venture capital and typical venture capital investment: it tends to be very capital intensive and faces greater technological risks associated with the functioning of technology, scalability and exit requirements than the typical venture capital investment. Moreover, unlike the typical venture capital investment, the benefits arising from cleantech cannot be totally captured by the venture capitalist as many of its benefits accrue to society via reduced environmental degradation and better health and quality of life outcomes, for example cleantech investments that improve air/water quality, will benefit everyone, including competitors. ('Cleantech' Venture Capital around the world, Douglas Cumming, Irene Henriques, Perry Sadorsk, 2016). This study concludes that there are several factors that can influence VC investments in the cleantech sector: government effectiveness and rule of the law each have positive and statistically significant impacts on cleantech VC deals; media coverage is found to be an important explanatory variable of cleantech VC deals, helping to build image, reputation, and legitimacy and these factors help to increase the growth of new markets; oil price also have an influence on VC investment, increasing the rate of investments with a slowing rate of increase (this could be done to the fact that higher oil prices can lead to exploitation of more expensive and polluting oil deposits).

However, the type of venture capital available and the geographical distribution of this funding can significantly influence the success of Cleantech ventures. Countries with higher levels of VC funding, especially in Cleantech and sustainability-focused sectors, tend to have a more vibrant Cleantech ecosystem. Conversely, a lack of adequate VC resources in countries with high demand for Cleantech solutions can slow the growth of new companies in these regions (Cohen & Levinthal, 1990; Hall et al., 2009).

Beyond venture capital, governments also play a role in funding Cleantech through grants, subsidies, and research collaborations. These mechanisms help offset the risks associated with the initial stages of Cleantech innovation, providing firms with the financial resources necessary to scale their technologies. Financial tools such as carbon credits, green bonds, and subsidies for energy efficiency improvements have become increasingly important for both private and public sector players in the Cleantech market.

However, VC investments cannot always be profitable, as the lesson from the boom-and-bust cycle from 2006 to 2011 teaches. The cleantech sector gained considerable investor attention in the years before the investment peak of 2008. A number of factors contributed to increased investor appetite for the sector, which rose sharply starting in 2006, such as the increase in oil and energy prices in the US.

Venture capital (VC) firms spent over $25 billion funding clean energy technology (cleantech) start-ups from 2006 to 2011. Less than half of that capital was returned; as a result, funding has dried up in the cleantech sector.

The cleantech boom-and-bust demonstrated that cleantech investment are poorly suited to the VC investment model for many reasons, some of them are explained earlier in the paragraph. The study proposes that broader support from policymakers, corporations, and investors is needed to underpin new innovation pathways for cleantech, with the support of R&D, incubators and encouraging policies that increases participation in cleantech innovation, both from corporations and institutional investors (Venture Capital and Cleantech: The wrong model for energy innovation, Gaddy et al, Energy Policy, Volume 102, March 2017, Pages 385-395).

Another method of cleantech financing is crowdfunding, a method of raising capital from a large number of people, typically via online platforms. It allows individuals, startups, and businesses to gather small contributions from a broad audience instead of relying solely on traditional funding sources like banks or venture capital. Crowd funding has recently emerged as an effective alternative to traditional entrepreneurial finance, with the potential of transforming the financial landscape for young innovative ventures (Ralcheva and Roosenboom, 2016). The study examines the relationship between risk and returns in crowdfunding. The authors find that, on average, project returns are negatively related to risk; however, projects offering better risk-adjusted returns tend to attract larger average contributions. Behavioral factors like bounded rationality or altruism may explain this apparent mispricing of risks. The study provides important lessons for policymakers, that should improve the technological risk-adjusted returns of emerging technologies in order to attract larger investors that provide higher average investments, that could make this form of investment viable and sustainable for this sector, even for projects with high risks, by unlocking the potential of investments by a large number of micro funders (Do crowdfunding returns reward risk? Evidences from clean-tech projects, Bento et al. , Technological Forecasting and Social Change, Volume 141, April 2019, Pages 107-116).

All of these studies highlight how different and complex the financing of the cleantech startup sector could be, given the uncertain and complex nature of it, while remarking the importance of the sector for the future of the environment and our planet, thus inviting policymakers to be more effective in their critical role.

3.2.4 Environmental and Technological Indicators Affecting Cleantech Growth

Several environmental and technological indicators are critical in assessing the potential growth of Cleantech companies. Among these, CO2 emissions levels, national R&D spending, patent activity, and the concentration of venture capital are key factors that influence Cleantech entrepreneurship. Countries with lower levels of CO2 emissions, higher spending on R&D, and strong patenting activity often see higher levels of Cleantech innovation and entrepreneurship.

The correlation between environmental performance (e.g., emission reductions) and innovation is an essential topic in environmental economics. Studies have shown that countries with stringent emissions reduction policies tend to foster greater technological innovation, particularly in sectors that are most affected by environmental regulations. For instance, carbon-intensive industries like energy and transportation often require major innovations to meet regulatory standards, creating opportunities for Cleantech firms to develop disruptive technologies (Mazzucato & Semieniuk, 2018; Polzin et al., 2019).

Similarly, the availability of venture capital and other financial mechanisms is crucial for the scalability of Cleantech firms. Countries with a high concentration of venture capital dedicated to green technologies are better equipped to support the rapid growth of Cleantech startups. In contrast, nations with limited financial resources for innovation often experience slower development in the Cleantech sector. This highlights the need for integrated policies that not only support innovation but also ensure that financial resources are available to scale successful technologies.

3.3 Conclusion & Implications for the Current Research

The literature on Cleantech growth emphasizes the critical role of environmental policies, innovation, financial support, and regulatory frameworks in fostering the development of Cleantech companies. However, while significant work has been done on the effects of these factors at the global level, there remains a need for more detailed research on the interaction between country-level indicators and Cleantech entrepreneurship. The literature review provided essential insights that directly inform the design and focus of the current study. The following implications were drawn:

- **Policy Impact**: national and European-level policies significantly influence the cleantech sector. Thus, understanding how policies interact with environmental and economic variables will be a central focus of the analysis.
- **Financial Support Mechanisms**: the role of venture capital and government funding is crucial for cleantech startups. It will be important to explore how access to financial resources impacts firm growth, particularly in different national contexts.
- **Technological Innovation**: R&D expenditure and patent activity will serve as critical indicators for analyzing innovation within cleantech firms.
- **Geographic Variability**: the research will analyze how cleantech growth varies by region, identifying countries that are outliers or leaders in cleantech development.

By addressing these points, the literature review has helped establish the foundational knowledge required to evaluate the relationship between environmental indicators, national policies, and cleantech firm growth. The next step in the research will involve applying this knowledge through **statistical analysis** and **policy comparison** encompassing all those indicators in order to empirically test the hypotheses related to the growth of cleantech firms in different countries, and which factors can contribute the most to this sector.

4. Research Methodology

In this study, an accurate and well-structured methodology is essential to explore the enabling factors that influence the development of cleantech companies in Europe. The methodology adopted in this research is divided into several phases, each contributing to a comprehensive and detailed understanding of the phenomenon under examination.

4.1 Research Objectives

The cleantech sector is essential for addressing the world's most pressing environmental challenges, including climate change, resource depletion, and pollution. The expansion of this sector has the potential to drive both environmental and economic transformation by fostering the development of new technologies and solutions aimed at reducing environmental impacts. However, the success and growth of cleantech companies are significantly influenced by the regulatory and policy environment in which they operate. Therefore, understanding the factors that drive the growth of these companies, particularly the influence of national and European policies, is crucial for ensuring the continued success of the sector. The objective of this research is to investigate these key factors, with a particular focus on policies and regulations at both the European and national levels, as well as the trend of investments in the sector and how these influence the creation and development of cleantech companies in different European countries.

4.1.1 Specific Objectives

Analyze the European Regulatory Framework

A key objective of this research is to analyze in detail the policies and regulations introduced by the European Union, particularly the European Green Deal. This analysis will involve reviewing key directives, regulations, and initiatives that regulate the environmental impact of human activities and support the cleantech industry. Understanding the impact of these EU policies is essential to assess how effectively they are fostering a favourable environment for cleantech technologies. For instance, the European Green Deal outlines ambitious objectives, including carbon neutrality by 2050, which has the potential to significantly influence the cleantech sector by creating long-term demand for sustainable solutions. It will also be important to evaluate whether EU funding programs, such as Horizon Europe, are adequately supporting cleantech innovation across the region. By analyzing these frameworks, the research aims to assess whether they sufficiently address the needs of cleantech firms and the challenges they face in terms of market access, regulation, and financing (Bassi et al., 2020; European Commission, 2021).

Evaluate National Policies

In addition to the EU-wide regulatory framework, individual member states have implemented specific policies designed to support cleantech industries. The research will explore how these national policies differ across countries and examine the outcomes of their implementation. This analysis will provide valuable insights into the varying effectiveness of these policies in different contexts, as some countries may offer more robust support for cleantech companies, while others may face barriers to their growth. For example, certain countries may prioritize market-based policies, while others may implement more direct interventions like subsidies, grants, or tax incentives. By comparing these national policies, the research aims to identify best practices and highlight the most effective policy mechanisms that could be replicated across other national contexts to further accelerate cleantech innovation and adoption (Smith & Raven, 2012; Johnstone et al., 2020). Furthermore, the research will also consider the interaction between these national policies and other country-level factors, such as economic development, infrastructure, and innovation capacity, which can influence the success of cleantech firms. By examining how policies work in synergy with these factors, the study aims to provide a deeper understanding of the conditions that foster a thriving cleantech ecosystem in various countries.

Identify Financial Support Mechanisms

An essential aspect of this research is to explore the financial support mechanisms available for cleantech companies at both the European and national levels. The availability of funding, particularly for early stage firms, plays a critical role in the development and scaling of cleantech innovations. The research will examine how government funding programs, tax incentives, and grants are structured to support cleantech startups, as well as the role of venture capital in funding these companies. VC investment has become increasingly important in supporting cleantech firms, especially in the early stages of their development, as it provides the necessary capital to drive innovation and scale operations.

The study will also explore how the presence of venture capital in specific countries influences the growth of cleantech companies. By comparing the amount of VC funding available in countries with strong cleantech sectors versus those with less developed industries, the research aims to identify the relationship between financial support and the success of cleantech enterprises. Additionally, it will examine how financial tools, including green bonds, green loans, and other alternative financing mechanisms, can be leveraged to further promote the cleantech sector (Lerner, 2012; Mazzucato, 2013; Mazzucato & Semieniuk, 2018; Polzin et al., 2019).

Analyze the Relationship Between Policies and Company Value Using Statistical Analysis

A key objective of this research is to evaluate the relationship between the introduction of new environmental policies and the financial performance of cleantech companies. This will be done through statistical analysis using software such as Stata, allowing for the empirical testing of whether new laws and regulations lead to tangible economic outcomes for cleantech firms. The analysis will focus on the average value of cleantech companies across countries, correlating the implementation of policy changes with metrics such as company growth, sales, employee numbers, and overall market value. In particular, the research will investigate whether countries that have introduced more stringent environmental regulations, higher levels of funding, or more robust financial support mechanisms see better economic outcomes for their cleantech firms. This quantitative analysis will provide critical insights into how policies and regulatory changes impact the growth trajectory of cleantech companies and whether these effects differ across national contexts (Cohen & Levinthal, 1990; Hall et al., 2009; Cecere et al., 2018; Cumming et al., 2016).

4.2 Research Design and Approach

This research is based on a mixed-methods approach, integrating both quantitative and qualitative techniques to ensure a comprehensive understanding of the factors affecting cleantech companies. The aim is to determine how environmental indicators, such as CO2 emissions, research and development (R&D) expenditures, and venture capital funding, interact with policies and regulations to shape the emergence and growth of cleantech startups across Europe. Specifically, the study uses secondary data analysis, regression modelling, and qualitative insights from industry stakeholders to explore these relationships.

The research design is divided into two main stages:

1. **Data Collection and Pre-Processing**: this includes gathering data from various sources such as OECD, Eurostat, national regulatory databases, and Orbis to provide a holistic picture of environmental indicators and cleantech firm performance.
2. **Data Analysis and Interpretation**: this phase involves applying statistical techniques (such as regression analysis and correlation analysis) to identify relationships between country-level environmental factors and the growth metrics of cleantech firms.

4.3 Data Collection

4.3.1 Data Sources

The primary source of data for this research will come from secondary data obtained from various databases and industry reports. These sources are invaluable for understanding both the environmental context and firm-level performance.

- **OECD Database**: The OECD provides a comprehensive set of environmental and economic indicators, including carbon emissions, energy consumption, research and development (R&D) spending, and innovation activity across different countries. These variables will be critical for understanding how national policies and environmental factors influence the growth of cleantech companies.
- **Eurostat**: Data from Eurostat will complement the OECD data, offering more granular insights into country-specific economic and environmental trends. This data

includes information on renewable energy adoption, waste management practices, and investment in clean technologies.

- **Orbis Database**: This database contains information about the financial performance and structure of millions of companies worldwide. The data from Orbis will be used to assess the performance of cleantech firms, such as annual sales, growth in the number of employees, patent activity, and more. By cross-referencing this with environmental data, it will be possible to evaluate the correlation between environmental indicators and company performance in the cleantech sector.
- **National Policy and Regulatory Databases**: National policy data, including climate change policies, subsidies, tax incentives, and environmental regulations, will be sourced from country-specific governmental and international organizations. This data is essential for understanding the regulatory environment in which cleantech companies operate.
- **Venture Capital and Innovation Data**: The role of venture capital (VC) in the cleantech sector is critical for assessing firm growth. Data on VC investments in cleantech companies will be obtained from databases such as Crunchbase or PitchBook. Additionally, patent data will be analyzed to assess the level of technological innovation within the sector.

4.4 Statistical Analysis

The statistical analysis is the backbone of this research, enabling the exploration of the relationship between environmental indicators and the growth of cleantech companies. Various statistical techniques will be employed to test the hypotheses and investigate how policy measures and other environmental factors influence the performance of cleantech firms. The analysis will primarily involve regression models, correlation analysis, and time-series analysis, each contributing to different aspects of the research questions.

4.4.1 Regression Analysis

A key component of the methodology is the use of regression analysis to examine how various environmental indicators impact the growth of cleantech companies, allowing the identification and quantification of relationships between dependent and independent variables, providing insight into which factors most significantly affect firm performance.

The dependent variables in this analysis will be the growth metrics of cleantech firms, including:

- **Sales growth**: The percentage change in the annual revenue of cleantech companies, which is a direct indicator of financial performance.
- **Number of employees**: The growth in the number of employees within cleantech firms, which serves as a proxy for the expansion of business activities and market presence.
- **Firm age**: The length of time since a firm was established, used to analyze how the age of a firm influences its ability to scale and adapt to market conditions.

The independent variables will include a range of environmental indicators, such as:

- **CO2 emissions reduction targets**: the goals set by countries to reduce greenhouse gas emissions, which could directly affect cleantech innovation and firm growth by increasing demand for clean technologies.
- **R&D expenditure by country**: national investments in research and development, which drive innovation and technological advancement within cleantech sectors.
- **Venture capital investment levels**: the amount of venture capital funding available for cleantech startups, which can significantly impact their ability to scale and commercialize new technologies.
- **Government policy incentives related to cleantech**: policies and financial incentives such as subsidies, tax breaks, or grants that aim to promote the growth of the cleantech sector.

Multiple linear regression models will be used to estimate the relationships between these variables, allowing for the testing of hypotheses about how environmental factors and policies influence firm growth in the cleantech sector. The regression model will help answer key questions about the role of policy support, innovation, and financial backing in fostering the development of cleantech companies.

4.4.2 Correlation Analysis

In addition to regression analysis, correlation analysis will be employed to explore the strength and direction of relationships between key variables. Correlation analysis provides a useful means of understanding how variables move in relation to one another, helping to identify patterns that might not be immediately apparent through regression alone.

For example, one of the key relationships to explore is the correlation between the level of **venture capital investment** and the number of **cleantech startups** in a given country. It is expected that higher levels of venture capital funding will correlate with a greater number of startups entering the cleantech market, as access to financial resources is a significant enabler of new business formation.

Another relationship to explore is the correlation between national **CO2 emissions** and **cleantech innovation** (measured through patent filings). This analysis will provide insight into whether countries with higher emissions are investing more in cleantech innovation, as part of their efforts to mitigate climate change and meet their emissions reduction targets.

4.4.3 Time-Series Analysis

Time-series analysis will be used to examine trends over time and assess how the introduction of new environmental policies correlates with changes in cleantech company growth metrics. This method is particularly useful for understanding the long-term effects of policy interventions, as it allows for the analysis of trends in data over multiple years.

For example, one key area of focus will be the **European Green Deal** and its impact on cleantech firms. Time-series analysis will allow us to track how the implementation of this policy has influenced the growth metrics of cleantech companies across Europe over time. By analyzing trends before and after the introduction of specific policies, we can gain insight into the effectiveness of these regulations in promoting innovation and firm expansion within the cleantech sector.

Overall, the combination of regression analysis, correlation analysis, and time-series analysis provides a comprehensive approach to investigating the impact of environmental policies and indicators on cleantech company growth. This methodology will help identify key drivers of success in the cleantech sector and inform future policy recommendations aimed at fostering the growth of this critical industry

5. Dataset Description

The dataset utilized in this research serves as the central tool for analyzing the growth and performance of cleantech companies, focusing on various critical business and economic metrics. This comprehensive dataset provides a broad view of cleantech firms operating across multiple European countries (as well as the United States), with data organized by year. The primary focus is on understanding the growth trajectories of cleantech companies, measured through sales, employee numbers, and firm creation, along with the factors that influence these dynamics.

5.1 Data Segmentation

The data is segmented into several important attributes, allowing for detailed tracking of each firm's performance over time, both in terms of absolute values and growth rates. The dataset includes metrics on sales, employee growth, and the emergence of new firms in the cleantech sector, each broken down by country and categorized by different cleantech segments, such as innovators, distributors, and ecosystem players.

5.1.1 Sales Data

The sales data provides a detailed analysis of the revenue generation of cleantech firms over multiple years, with specific metrics focusing on both average sales and the growth rates of those sales in the years following the founding of each firm. These variables are essential for understanding the financial trajectory of cleantech companies, as they reflect how well these firms are scaling their operations and capturing market share. The specific metrics include:

Table 1. Description of Sales Data from the DB Cleantech (1/3)

Ysales3YafterFY	Average value of sales in the 3 years following their founding
Ysales5YafterFY	Average value of sales in the 5 years following their founding
Ysalesg3YafterFY	Average growth of sales in the 3 years following their founding

Ysalesg5YafterFY	Average growth of sales in the 5 years following their founding
Ysales3Yafter	Average value of sales in the 3 years following the year
Ysales5Yafter	Average value of sales in the 5 years following the year
Ysalesg3Yafter	Average growth of sales in the 3 years following the year of the table
Ysalesg5Yafter	Average growth of sales in the 5 years following the year of the table

These sales metrics are categorized across the cleantech sector as a whole and further divided into specific subcategories, such as Innovators, Distributors, and Ecosystem companies. This segmentation allows for a more nuanced analysis of how different types of cleantech companies perform and scale over time, offering valuable insights into which segments are leading in sales growth and which ones require more support or investment.

5.1.2 Employee Data

Another key component of the dataset is the employee data, which provides a snapshot of how cleantech firms grow in terms of workforce size. Employee growth is an important indicator of a firm's expansion, as it reflects how companies are scaling their operations to meet growing demand. The employee-related variables are structured similarly to the sales data, with focus on both the average number of employees and the growth in employee numbers over time:

Table 2. Description of Sales Data from DB Cleantech (2/3)

YEmp3YafterFY	Average number of the employees in the 3 years following their founding
YEmp5YafterFY	Average number of the employees in the 5 years following their founding
YEmpg3YafterFY	Average growth of employees in the 3 years following their founding

YEmpg5YafterFY	Average growth of employees in the 5 years following their founding
YEmp3Yafter	Average number of employees in the 3 years following the year
YEmp5Yafter	Average number of employees in the 5 years following the year
YEmpg3Yafter	Average growth of employees in the 3 years following the year of the table
YEmpg5Yafter	Average growth of employees in the 5 years following the year of the table

These metrics allow for a detailed longitudinal analysis of how workforce expansion correlates with company performance, and they are also segmented by the cleantech sectors to identify specific trends within each industry. By analyzing employee growth alongside sales data, the research can offer deeper insights into the operational scaling of cleantech firms.

5.1.3 Firm Birth and Growth Data

The dataset also includes data on the birth and growth of cleantech firms across the selected countries. This is crucial for understanding how the cleantech sector is evolving over time, particularly regarding the number of new firms entering the market each year. The specific variables in this category are as follows:

Table 3. Description of Sales Data from DB Cleantech (3/3)

Y n comp born	Number of new cleantech firms that were born in each country in a given year
perc n comp born	Percentage of new cleantech firms born in each country in a given year

These variables are crucial for understanding the dynamics of firm entry into the cleantech sector, helping to analyze how favourable environmental policies, financial conditions, and market opportunities influence the birth rate of cleantech companies. In addition, the data is further segmented into specific categories such as cleantech ecosystem firms, which helps to track not only the total number of firms but also the breakdown of firms across various subcategories, such as Innovators, Manufacturers, Distributors, and Integrators.

5.1.4 Categorization of Firms

A critical element of this dataset is the categorization of cleantech companies into different types, as this allows for a deeper understanding of the sector's dynamics. Firms are categorized into **Cleantech Innovators** and the **Cleantech Ecosystem** (which are subdivided into *distributors, experimenters, integrators, manufacturers, operators* as explained in chapter 2).

The categorization allows the research to focus on how different types of firms contribute to the overall growth of the cleantech sector. By breaking down data across these categories, it is possible to assess how different factors, such as policy interventions, R&D investment, or venture capital funding, have varying effects on the growth of each segment within the cleantech ecosystem.

5.2 Data Analysis

Below is a detailed comparative analysis of the data provided in the pivot tables for ***Italy, France, Germany, the Netherlands,*** and ***Denmark***. The countries focused on in this research have been selected due to their significant roles in the European cleantech sector. Each of these countries exhibits unique characteristics in terms of regulatory frameworks, government policies, and cleantech investments. The focus on these nations allows for a comparative analysis of how different national contexts shape the emergence and performance of cleantech companies. Therefore, this analysis focuses on the birth of new enterprises, sales generated five years after their establishment, and employment levels five years after establishment. The goal is to provide an extensive descriptive assessment of the economic dynamics in the selected countries.

5.2.1 Analysis of New Enterprise Births

The number of new enterprises created annually in the five countries is given by the variable “Y_n_comp_born”. This metric provides insights into the entrepreneurial activity and market dynamism within each country.

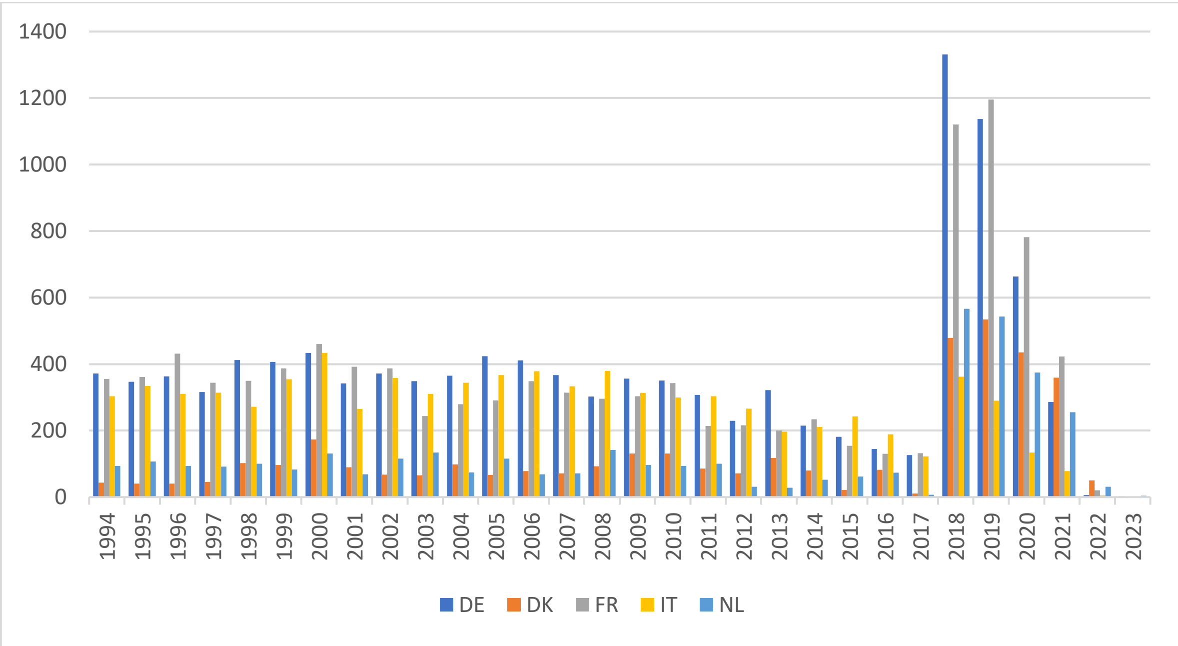

Figure 1. Number of Cleantech companies established in the last thirty years

The provided chart and table illustrate the number of new enterprises born annually from 1994 to 2023 for five countries: Germany (DE), Denmark (DK), France (FR), Italy (IT), and the Netherlands (NL). Below is an in-depth analysis of the data trends and patterns:

The total number of new enterprises shows a steady trend from 1994 until approximately 2017, with notable peaks around specific years (e.g., 2018-2019). After 2019, there is a significant decline in the number of new enterprises across all countries, likely due to external factors such as the global pandemic and its economic repercussions.

Germany consistently exhibits the highest number of new enterprises annually, reflecting its strong and stable entrepreneurial ecosystem. For example, in 1994, Germany reported 372 new enterprises, while Denmark had only 44, emphasizing the disparity in scale. On the other hand, **France and Italy** generally follow Germany, showing competitive but smaller numbers of new enterprises. Italy shows slightly higher figures than France in earlier years, but both countries remain significantly below Germany. Finally, **Netherlands and Denmark** have the lowest counts among the five. Denmark shows particularly low figures, consistent with its smaller population and focus on high-quality rather than high-quantity entrepreneurship.

Country Breakdown:

- **Denmark:** Denmark's entrepreneurial activity shows moderate but steady growth. For example, in 1994, 120 new enterprises were established. The number remained consistent, with 128 in 1995 and 130 in 1996. These figures highlight Denmark's focus on quality-driven startups rather than sheer volume. Denmark's policies, which emphasize sustainable growth and innovation, likely play a role in fostering a steady pipeline of new businesses.
- **Germany:** Germany remains a leader in new enterprise births. In 1994, 372 enterprises were established. The figures slightly declined in subsequent years, with 347 in 1995 and 363 in 1996. The high numbers reflect Germany's robust market infrastructure and strong support systems for entrepreneurship. However, the slight dip suggests potential challenges such as market saturation or increasing competition.
- **France:** France also demonstrates strong entrepreneurial activity. In 1994, 355 new businesses were established. This number grew to 361 in 1995 and peaked at 431 in

1996. France's upward trend highlights its dynamic business environment, likely supported by government incentives and access to international markets.

- **Italy:** Italy's performance is stable but lags behind Germany and France. In 1994, 303 new enterprises were established. This increased to 334 in 1995 before slightly decreasing to 310 in 1996. Structural challenges, such as bureaucratic hurdles and limited access to credit, might be hindering higher growth rates in entrepreneurial activity.
- **Netherlands:** The Netherlands reports consistently lower figures compared to the larger economies. In 1994, 94 new enterprises were established. This number remained stable in 1995 and 1996. Despite the lower volume, the Netherlands excels in fostering high-quality, niche-focused startups, reflecting its emphasis on innovation and specialization.

During the analyzed period, the cleantech sector – both in terms of ecosystem participation (**perc_n_comp_born_cleaneco**) and innovation-focused enterprises (**perc_n_comp_born_clean**) – shows distinct trends across the five countries. Denmark stands out as a leader, maintaining high percentages in the cleantech ecosystem metric throughout the late 1990s and early 2000s, with peaks such as **44.91% in 2001**, indicating a sustained focus on eco-friendly and sustainable industries. Similarly, its leadership in cleantech innovation becomes more evident after 2000, with percentages steadily increasing and reaching a significant **14.23% in 2017**, suggesting a strong national emphasis on cutting-edge clean technology. Germany also shows substantial engagement in the cleantech ecosystem in the earlier years, with percentages hovering around 30-40% during the 1990s. However, a gradual decline after 2008, coupled with a reduced presence in cleantech innovation (dropping to **0.79% in 2017**), suggests a potential shift in focus or market dynamics.

France and Italy exhibit comparatively lower percentages across both metrics, with France consistently contributing minimal figures in cleantech innovation (often below 2%) and showing limited alignment with cleantech ecosystem efforts. Italy, while relatively consistent, does not surpass the mid-20% range in cleantech ecosystem metrics and shows sporadic engagement in innovation, with occasional peaks such as **4.47% in 2008**. The Netherlands displays significant early contributions to the cleantech ecosystem, with percentages comparable to Denmark in years like **2001 (49.11%)**, but its engagement diminishes over time. However, it occasionally demonstrates stronger contributions to innovation (e.g., **7.38% in 2009**), reflecting a more niche, high-value focus. Across all countries, the years 2000-2001 and 2018-2019 appear to mark pivotal moments, characterized by surges in cleantech ecosystem activity, while the period after 2020 highlights a stark drop, likely due to external economic pressures or global challenges such as the COVID-19 pandemic.

5.2.2 Analysis of Sales Five Years After Establishment

The dataset provides data on the revenue generated by enterprises five years after their establishment. This metric offers insights into the economic impact and scalability of startups in each country. In particular, the data analyzed highlights the performance of enterprises in terms of their average sales (**Ysales5YafterFY**) and their average sales growth (**Ysalesg5YafterFY**) during the five years following their establishment. Across the analyzed countries there are notable disparities in both metrics, reflecting differences in entrepreneurial ecosystems and economic environments. Germany and France dominate in terms of absolute sales, consistently leading in **Ysales5YafterFY** values across the period. Denmark and the Netherlands, while trailing in overall sales, showcase unique patterns of growth, with Denmark exhibiting significant negative spikes, suggesting potential instability or challenges in scaling. Italy's performance remains consistently modest, struggling to match the sales levels or growth trajectories of its counterparts.

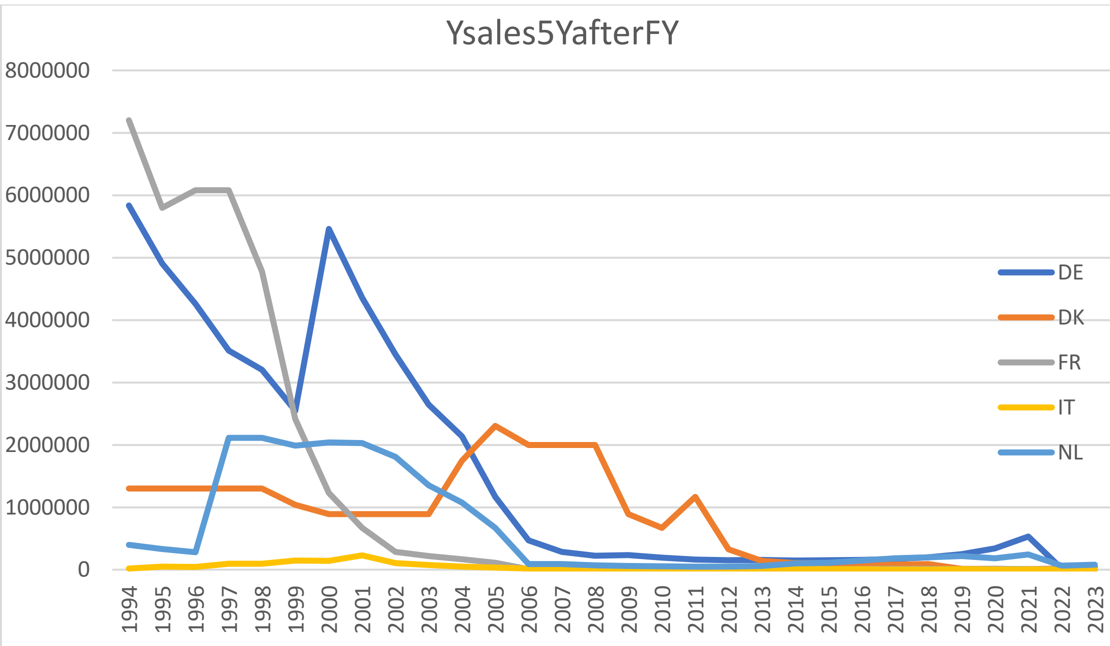

Figure 2. Sales Five Years After Establishment

Country Breakdown:

- **Germany:** demonstrates the highest absolute sales values (**Ysales5YafterFY**) across the years, totalling over **47 million monetary units** by the end of the period. This reflects Germany's robust market infrastructure and the scalability of its enterprises. Despite its strong sales figures, Germany's growth rates (**Ysalesg5YafterFY**) exhibit a gradual decline post-2000, suggesting a maturing entrepreneurial ecosystem with limited room for rapid expansion in established markets.
- **Denmark:** presents an intriguing case, with **Ysales5YafterFY** values significantly lower than Germany and France but still showing consistent performance in earlier years (e.g., **~12 million monetary units in 1994-1996**). However, the growth metric (**Ysalesg5YafterFY**) reveals stark volatility, with notable negative dips around 1999 and 2009. This pattern indicates potential challenges in maintaining growth or the susceptibility of Danish enterprises to external economic pressures.
- **France:** closely trails Germany in terms of **Ysales5YafterFY**, achieving a total of **35 million monetary units** over the analyzed years. The data reflects a steady sales performance, particularly during the mid-1990s. In contrast, France's growth rates show relative stability without significant volatility, suggesting a balanced but conservative entrepreneurial environment where enterprises grow at a steady pace without major fluctuations.
- **Italy:** performance is consistently modest, with **Ysales5YafterFY** values totalling just **12 million monetary units** by the end of the period. Growth metrics are similarly subdued, averaging **~0.2 growth rates** in most years. This underperformance highlights structural challenges such as limited scalability and constrained market opportunities for Italian enterprises, which lag behind their European counterparts.
- **Netherlands:** displays a mixed profile, with **Ysales5YafterFY** values reaching **18 million monetary units**, placing it ahead of Denmark and Italy but behind Germany and France. The growth metric (**Ysalesg5YafterFY**) shows more positive performance, particularly in years like 2009, where spikes suggest moments of rapid expansion for specific sectors or enterprises. This indicates that while Dutch enterprises may not achieve the highest sales, they are capable of significant growth under favourable conditions.

5.2.3 Analysis of Employment Five Years After Establishment

From the dataset the average number of employees (**YEmp5YafterFY**) and the average growth in employees (**YEmpg5YafterFY**) over five years following the establishment of enterprises have been analyzed. The data and graphs reveal disparities in enterprise employment contributions across countries and years, with distinct trends and outliers.

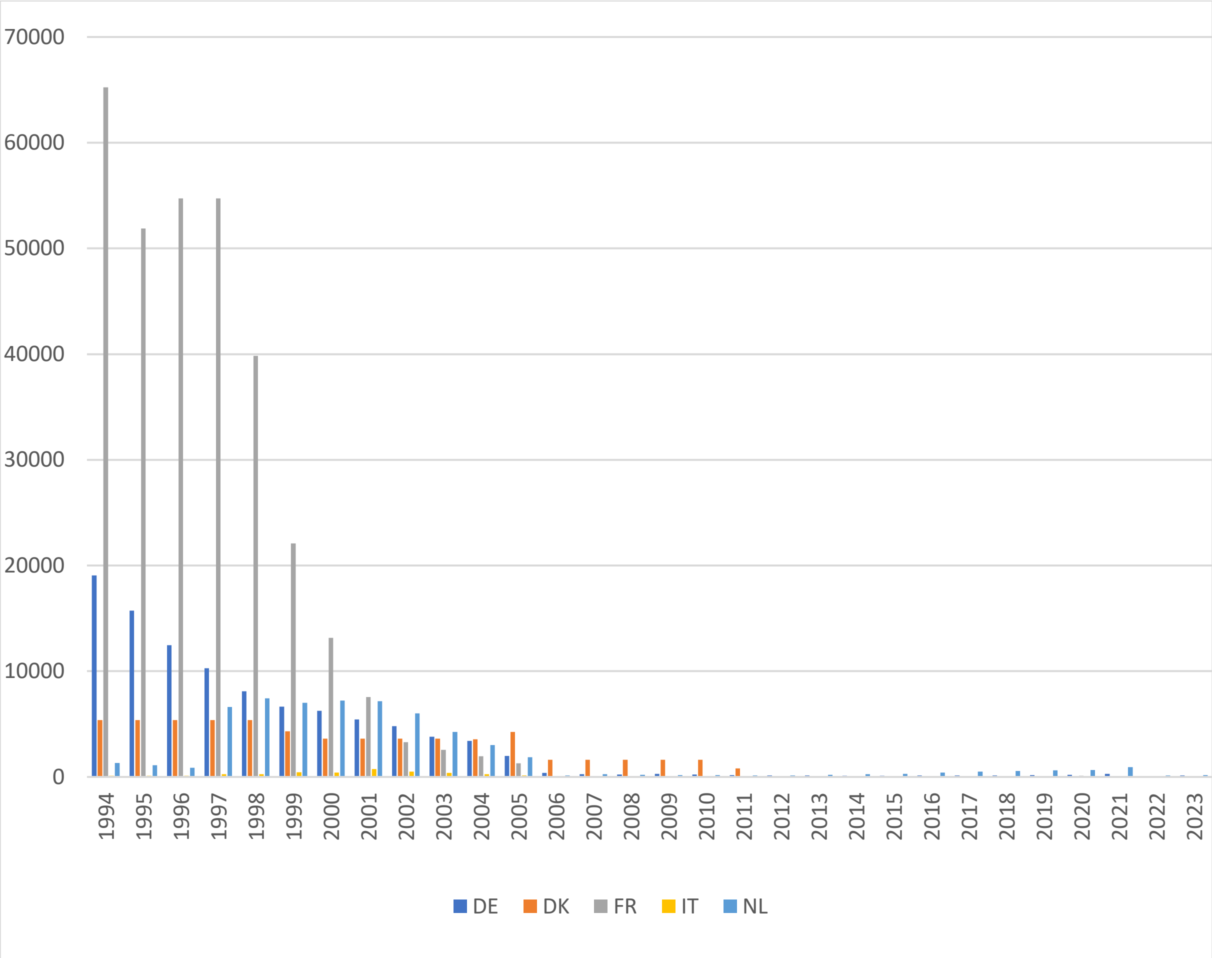

Figure 3. Employment Five Years After Establishment

General Trends and Country Comparisons

The **YEmp5YafterFY** data highlights significant differences in enterprise employment contributions. France consistently outpaces other countries in terms of absolute employee counts, with a peak in 1994 (**65,222 employees**) and significant totals throughout the analyzed period. Germany follows with consistently high employee figures, particularly in earlier years (e.g., **19,054 employees in 1994**) before declining steadily. Italy, the Netherlands, and Denmark lag behind, with Denmark showing particularly modest numbers, rarely exceeding **5,000 employees** annually. The data indicates that larger economies like France and Germany are able to scale businesses more effectively to contribute to higher employment.

In terms of growth (**YEmpg5YafterFY**), trends are more volatile across countries. Denmark shows sharp fluctuations, with notable growth peaks in the late 1990s (e.g., **~0.15 growth in 1998**) and then steady declines post-2010. France and Germany show relatively stable growth rates, typically in the range of **0.1 - 0.15**, but both countries exhibit diminishing returns over time. Italy and the Netherlands exhibit sporadic increases, with occasional spikes suggesting sector-specific or policy-driven growth moments, but they generally remain below France and Germany.

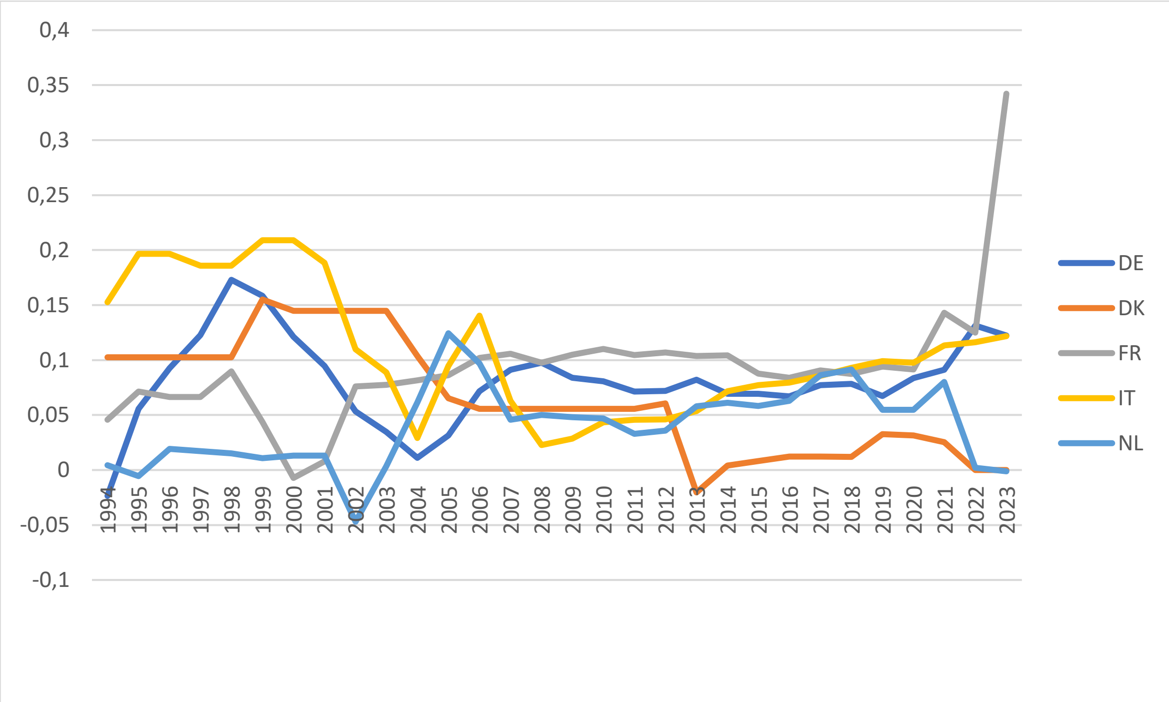

Figure 4. Differences in enterprise employment contributions

Country Breakdown:

- **France**: France dominates in terms of absolute employment contribution, with the highest employee averages across nearly all years, particularly in the 1990s. This is indicative of large-scale enterprises with a significant capacity to employ. Growth, while steady, exhibits no major peaks, highlighting a stable but mature market with consistent employment trends.

- **Germany**: Germany ranks second in employment contributions, with strong performance in earlier years (e.g., **19,054 employees in 1994**) but a steady decline thereafter. Growth rates remain stable, suggesting Germany's enterprises maintain consistent scaling without significant spikes or volatility.
- **Italy**: Italy exhibits modest employment figures, rarely exceeding **40,000 employees** annually, even in its peak years. Growth rates remain relatively subdued but consistent, reflecting the country's smaller market size and challenges in scaling enterprises.
- **Netherlands**: The Netherlands performs similarly to Italy in absolute employee counts, with occasional growth rate spikes (e.g., **0.14 growth in 2001**) but no sustained periods of significant employment expansion. This suggests niche enterprises that may not scale widely but contribute positively in certain years.
- **Denmark**: Denmark consistently reports the lowest employment contributions, with employee figures rarely exceeding **5,000 annually** and volatile growth rates. Sharp declines in post-2010 growth highlight challenges in sustaining enterprise scaling within a smaller market.

In a nutshell, it comes to sight that France dominates in total employee contributions, reflecting its ability to support large-scale enterprises. Despite strong early performance, Germany's decline in employment contributions suggests a shift in market dynamics or challenges in scaling enterprises post-2000. Denmark and the Netherlands show greater volatility in growth rates, indicative of smaller markets that are more sensitive to policy or economic changes. Italy's consistent, albeit modest, performance underscores structural challenges in scaling enterprises for significant employment impact.

5.2.4 Comparisons and Key Insights

The analysis across Germany, Denmark, France, Italy, and the Netherlands reveals notable trends that shed light on the dynamics of economic contributions, innovation, and scalability. A general trend observed across the five nations is the steady decline in the number of new enterprises and their performance metrics, particularly after 2019. This is likely linked to global challenges such as the COVID-19 pandemic and its associated economic disruptions. Between 1994 and 2017, all countries experienced relatively stable or growing entrepreneurial activity, with marked peaks in enterprise births, sales, and employment contributions around the early 2000s and 2018-2019. These surges can be attributed to favourable market conditions, policy incentives, and increased focus on sustainability and cleantech innovation. However, the period post-2020 highlights significant declines across metrics, particularly in growth rates for smaller markets like Denmark and the Netherlands.

When comparing the five countries, Germany and France dominate both in scale and economic impact. Germany exhibits a robust market presence with consistently high absolute values in sales and employment metrics. However, its growth rates indicate a maturing entrepreneurial ecosystem with reduced room for rapid expansion in established markets. France, on the other hand, excels in employment contributions, reflecting its ability to support large-scale enterprises and stable, steady growth trends, particularly in the 1990s. Denmark and the Netherlands, despite their smaller markets, emphasize quality over quantity. Denmark maintains leadership in cleantech ecosystem engagement, focusing on sustainability-driven startups, while the Netherlands demonstrates high potential for growth in niche, high-value sectors. Italy's performance, while steady, underscores structural challenges, with consistently lower figures in enterprise scalability and growth. Its modest contributions in both sales and employment highlight the need for structural reforms to improve competitiveness. Overall, Germany and France lead the cleantech entrepreneurial landscape, while Denmark and the Netherlands stand out for innovation and specialization. Italy, despite lagging behind, shows promise if systemic issues are addressed. This analysis underscores how varied economic and policy contexts shape the cleantech landscape, offering insights for fostering a balanced, innovation-driven ecosystem across Europe.

6. Policy and Regulatory Framework

The cleantech sector in Europe is shaped by a complex web of policies and regulations at both the European Union (EU) and national levels. These policies play a crucial role in fostering the development of clean technologies by providing a supportive framework that encourages innovation, investment, and adoption of sustainable practices. This section delves into the various policies and regulations influencing the cleantech sector, analysing their impact on the growth and sustainability of cleantech companies.

6.1 European Policies and Regulations

The EU has established a robust policy framework aimed at promoting environmental sustainability and accelerating the transition to a low-carbon economy. Key policies and regulatory instruments include:

- **European Green Deal:** launched in December 2019, the European Green Deal is a comprehensive roadmap aimed at making the EU climate-neutral by 2050. It encompasses a wide range of initiatives targeting climate change, biodiversity, clean energy, sustainable industry, and pollution reduction. The Green Deal sets ambitious targets, such as reducing greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. This overarching strategy provides a significant boost to cleantech companies by creating a favourable environment for green innovations and investments.
- **EU Taxonomy for Sustainable Activities:** the EU Taxonomy Regulation, effective from July 2020, establishes a classification system for sustainable economic activities. It aims to guide investors towards environmentally sustainable projects, thereby channelling financial flows into cleantech and other green sectors. The taxonomy defines criteria for activities to be considered environmentally sustainable, covering six environmental objectives, including climate change mitigation and adaptation. This regulation enhances transparency and fosters investor confidence in the cleantech sector.
- **Horizon Europe:** as the EU's research and innovation program for 2021-2027, Horizon Europe allocates €95.5 billion to support research and development in

various fields, including cleantech. The program includes specific missions and partnerships aimed at addressing global challenges such as climate change and sustainable energy. Funding from Horizon Europe provides critical support for cleantech innovators, enabling them to advance their technologies and bring them to market.

- **Renewable Energy Directive (RED II):** the Renewable Energy Directive, revised in 2018 (RED II), sets binding targets for renewable energy use within the EU. It aims for at least 32% of the EU's energy consumption to come from renewable sources by 2030. RED II includes measures to simplify administrative procedures for renewable energy projects, improve grid integration, and enhance cross-border cooperation. These provisions directly benefit cleantech companies involved in renewable energy technologies by creating a more favorable regulatory environment.

6.2 National Policies and Regulations

In addition to EU-wide policies, individual member states implement their own regulations and initiatives to support the cleantech sector. These national policies often complement EU directives and can vary significantly between countries, reflecting local priorities and resources. Some examples of European nations are provided:

- *Germany:* Germany's Energiewende (Energy Transition) policy aims to transform the country's energy system towards renewable energy and increased energy efficiency. The Renewable Energy Sources Act (EEG) provides financial incentives for renewable energy projects through feed-in tariffs and auction schemes. Germany also supports cleantech innovation through funding programs like the Climate Initiative, which finances research and development in energy efficiency, sustainable mobility, and green technologies.
- *France:* France's Energy and Climate Law sets ambitious targets for carbon neutrality by 2050 and includes measures to phase out coal, promote renewable energy, and enhance energy efficiency. The law supports cleantech development through subsidies, tax incentives, and regulatory measures aimed at reducing carbon emissions. France also has specific initiatives like the GreenTech Innovation program, which provides support for startups and SMEs in the cleantech sector. For

example, the BPIfrance program offers financing solutions tailored to the needs of cleantech companies, facilitating their access to capital.

- *United Kingdom:* Although no longer an EU member, the UK continues to implement robust policies supporting the cleantech sector. The Clean Growth Strategy outlines measures to cut emissions, promote renewable energy, and support green innovation. The UK government offers grants and incentives through programs like the Industrial Strategy Challenge Fund and the Green Investment Group, which focus on advancing low-carbon technologies and sustainable practices. The Contracts for Difference (CfD) scheme has been particularly effective in supporting the deployment of renewable energy projects by providing price stability to investors.

6.3 OECD PINE Dataset: description and introduction

In recent years several datasets which collect information about environmental policies have been gathered by different organizations around the world, which contain different subsets of information with different levels of details. We chose to analyze the following dataset: the PINE.

The PINE database (Policy Instruments for the Environment) is a powerful tool provided by the OECD (Organization for Economic Cooperation and Development) which gathers data from all countries and territories (regardless of if they a are part of the OECD or not) about their environmental policy instruments, with their issuing dates starting from 1980 up to 2024. The dataset provides a deep insight into the policies, classifying them with different categories, ranging from a classification of the instrument type itself, the geographic scope, the domain to which it applies, the targeted payer of the policy itself.

Starting the analysis from the classification of the different tools the governments have and can use. The various policy alternatives all have different levels of efficiency and target different users. All of those can be categorized into two main types of policies: market-based and non-market based, as De Serres et al. (2010) clearly explain.

The main purpose of market-based policies is to manipulate the market equilibrium by artificially modifying prices in markets that may have failures. The basis from which they are implemented is that many aspects of the natural environment are public goods. Public goods are goods that are **non-excludable** (everyone can access them, even without paying) and **non-rival** (one person's use doesn't reduce their availability for others). Examples of public goods include national defence, public transportation and public parks. These goods are typically provided by governments because private markets often struggle to supply them efficiently. This strongly applies to the environment, due to the difficulty of assigning property rights for environmental resources and the impossibility to exclude people from benefitting them. Without government intervention, decentralized market economies tend to generate an inefficient balance between the "supply" of environmental goods and services (that is, the levels of environmental quality) and the supply of other goods and services. Pigou's classic contribution showed that taxes could be employed to account for environmental externalities. (A. Lans Bovenberg, Lawrence H. Goulder, 2002).

Non-market-based policies instead rely on direct regulations or measures without involving market mechanisms. They set strict rules, limits, or mandates that must be followed, but they do not put a cost on negative externalities, hence failing to modify market rules.

The subset of policies analyzed in this dataset are:

- **Taxes and fees**: These economic instruments are used to penalize behaviours or practices that harm the environment. The taxes aimed at this purpose are called Pigouvian taxes: they serve to eliminate the cost wedge, raising private costs to a level that corresponds to social cost. The goal is to encourage behavioural changes toward more sustainable practices by increasing the cost of environmentally damaging activities. In this way, the Pigouvian tax internalizes the social cost from pollution, borne by society. Governments impose taxes or fees on activities or products that negatively impact the environment (e.g., CO_2 emissions or fossil fuel usage).
  Taxing sources of environmental pollution and greenhouse gas emissions is an efficient and effective way to combat climate change, biodiversity loss and pollution. Environmental taxes can also contribute to revenue mobilization and redistribution (OECD, Tax and the Environment). Some examples of taxes and fees are the Carbon Tax, a tax on CO_2 emissions; the Plastic Bag Fee, which is present in many countries, especially in the European Union, which consists in a fee for single-use plastic bags to reduce plastic waste; the Congestion Charges, which are fees applied to vehicles entering urban areas, such as London's congestion charge, to reduce traffic and air pollution.

- **Deposit-Refund Systems**: These systems combine an upfront deposit, with similar effects of a tax, with a refund upon the return of an item, incentivizing proper disposal or recycling. They work as follows: consumers pay a deposit when purchasing a product (e.g., bottles or batteries) and receive a refund when they return the item to a designated collection point. Some examples of these policies are Bottle Deposit Schemes, which are widely used in countries like Germany and Norway, where consumers pay a deposit on beverage containers and receive a refund when they return the empty bottles and E-Waste Programs, where some regions have deposit-refund systems for electronic waste, encouraging the recycling of old devices like smartphones and batteries.
- **Environmentally Beneficial Subsidies and Payments:** Governments provide financial incentives to support environmentally friendly practices or technologies. These incentives aim to reduce the cost barrier to adopting green solutions. They are redacted in the forms of subsidies or payments that are given to individuals, companies, or organizations that invest in sustainable practices or technologies. Examples of this category are the Renewable Energy Subsidies, which are Grants or tax breaks for installing solar panels, wind turbines, or other renewable energy systems (e.g., the U.S. Investment Tax Credit for solar energy); Conservation Payments: which are payments to farmers to adopt sustainable agriculture practices, such as the EU's agri-environmental schemes; Electric Vehicle (EV) Incentives, which are present in many countries, where the government provides money directly for the purchase of EV, lowering their actual cost to consumers and pushing demand.
- **Tradable Permits and Offsets:** These tools are market-based instruments that create a system where environmental rights or responsibilities can be bought and sold in a free market. Governments usually set a limit (cap) on the total allowable environmental impact (e.g., CO2 emissions). Companies are allocated permits, which they can trade if they emit less or need more than their allowance. Examples of these policies are the Cap-and-Trade Systems, like the EU Emissions Trading System (EU ETS) that caps CO2 emissions and allows companies to trade emission permits if they need more or are emitting less, creating a competitive advantage for those who can emit less and sell their permits, and Carbon Offsets, which allows companies to invest in projects like reforestation to offset their emissions. For example, airlines may offer customers the option to offset the carbon footprint of their flights.

- **Voluntary Approaches:** These involve initiatives where companies or individuals voluntarily commit to environmental goals, often driven by consumer demand, brand reputation, or corporate social responsibility. Organizations can adopt sustainable practices without legal obligation, often encouraged by public awareness campaigns or certification programs. Examples of those are the Corporate Sustainability Programs, where many companies, like Patagonia, adopt voluntary environmental goals, such as using 100% renewable energy or reducing waste; Certification Schemes, like LEED (Leadership in Energy and Environmental Design) for green buildings or Fair Trade for sustainable farming; Voluntary Carbon Neutrality Pledges: where companies, like Microsoft, have committed to becoming carbon negative through voluntary initiatives.

The **geographic scope** of a policy refers to the physical area or regions where the policy is applicable and enforced. It defines the boundaries within which the policy's rules, regulations, and effects are intended to operate. There are different levels of scope at which a policy can be enforced, ranging from a very specific geographic area to the whole country. The levels can be divided as follows:

- Local: Policies that apply within a city, town, or specific local jurisdiction (e.g., municipal recycling programs, city-specific congestion charges).
- Regional: Policies targeting a broader area, such as a province, state, or economic region (e.g., California's cap-and-trade program or EU regional environmental directives).
- National: Policies implemented at the country level, applying to all citizens and businesses within national borders (e.g., national carbon taxes or renewable energy incentives).
- International and supranational: Policies that apply across multiple countries, often established through treaties or agreements (e.g., the Paris Agreement on climate change).

The environmental policies contained in this dataset aim to regulate and manage various domains. Several domains are hence included, ranging from air pollution to noise reduction to renewable energy. For instance, air pollution addresses the emission of harmful substances like greenhouse gases and particulate matter into the atmosphere, while water pollution focuses on contaminants in water bodies that affect aquatic life and human health. Similarly, soil pollution concerns the degradation of land due to chemicals and waste, which impacts agriculture and biodiversity. Solid waste management seeks to reduce and responsibly dispose of waste materials, minimizing their environmental footprint. Sustainable use of natural resources is another key aspect, with domains like fisheries aiming to prevent overfishing, and forests focusing on preserving biodiversity and reducing deforestation. Freshwater management ensures the availability of clean water for consumption, agriculture, and ecosystems. In the energy sector, policies address both production and consumption. Renewable energy initiatives promote the use of sustainable energy sources like solar and wind, while regulations on fossil fuels aim to curb their environmental impact. Similarly, minerals extraction is monitored to minimize ecological damage, and energy efficiency policies encourage reducing energy consumption through better technologies. The circular economy concept supports reusing and recycling resources to limit waste, complementing efforts in chemical management to safely handle hazardous substances and mitigate their impact on the environment. Altogether, these domains highlight the interconnected nature of environmental issues and the need for comprehensive policies to address them effectively, with policies usually not targeting only one, but many.

The dataset lastly provides information about the targeted payer of the policy, so the entity that will be directly affected by this policy will pay the monetary cost. They can be the households, which are the end consumers, the firms or the government. From a general perspective however, even if the policy applies to firms, the final price will almost certainly be paid by the end consumers, since the firms will charge the amount of the tax to the final price of the goods, and households will absorb the cost of the policy.

The scope of our analysis will be limited to the European Countries, focusing on the ones with the most policies and the most affected by those policies in helping (or not helping) the cleantech sector in its formation, growth and sustainment.

6.3.1 Policy Instruments by Number & Continent

Over time, the number of environmental policies has shown a steady increase, reflecting growing global awareness and action to address environmental challenges. As the PINE dataset shows, the commitment from governments to the environment has become stronger and stronger, whit the constant introduction of policies, year over year. Among the various policy instruments, taxes and fees have consistently represented the largest share. These tools are favoured for their ability to generate revenue while incentivizing behavioural change, making them an efficient and widely adopted approach across both OECD and non-OECD countries.

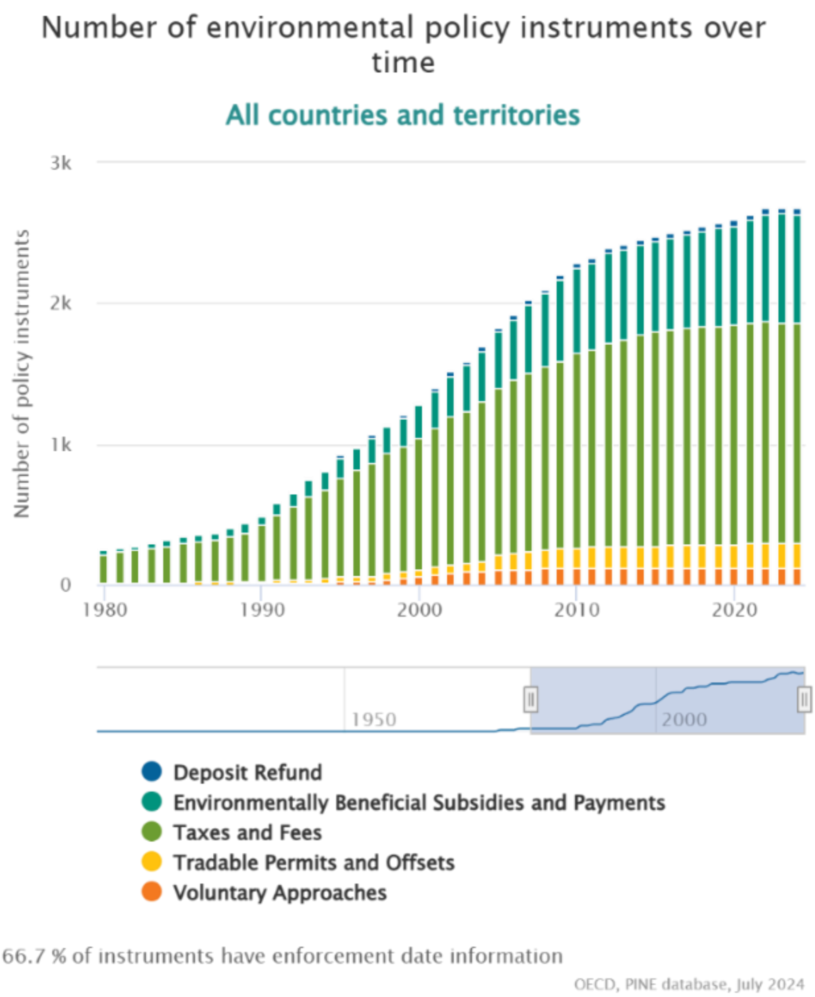

Figure 5. Number of environmental policy instruments over time

The distribution of those policies around the world is not uniform, with notable differences across regions, with OECD countries leading in both the number and diversity of policies implemented. According to the PINE database Europe, in particular, accounts for the largest share of policies issued, surpassing all other continents combined. This reflects Europe's long-standing commitment to environmental regulation: since the early 1990s, the European Union (EU) has presented itself as a leader on climate change (Kilian and Elgström 2010), driven by strong institutional frameworks, international agreements, and public demand for action and is now setting some of the world's most comprehensive and ambitious environmental regulations, including frameworks like the European Green Deal, the Emissions Trading System (ETS), and the Circular Economy Action Plan.

In contrast, non-OECD countries tend to rely more heavily on simpler tools, such as taxes and fees, due to resource and capacity constraints. This geographical disparity highlights the role of economic development and institutional strength in shaping the scale and sophistication of environmental policymaking worldwide.

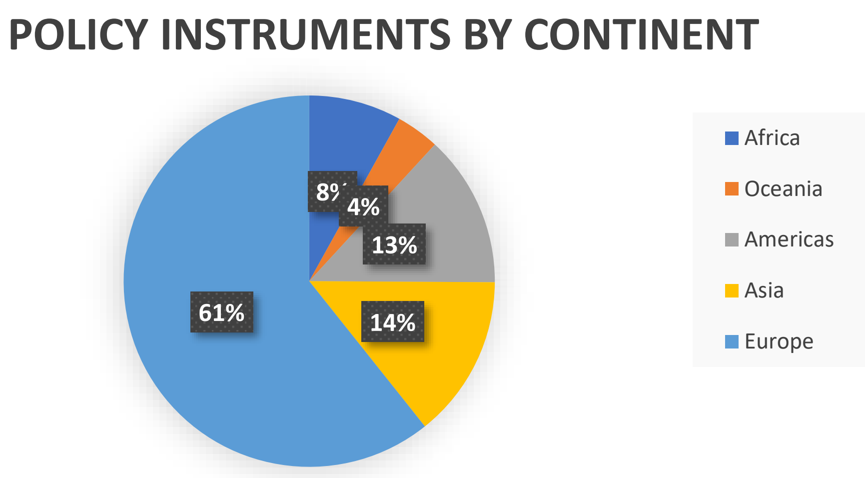

Figure 6. Percentage of government incentives in different continents

6.3.2 Policy Instruments by Type & Subtype

Countries can choose between different types of policies; however, the dataset clearly shows that taxes and fees constitute the largest share of instruments adopted by governments to implement environmental policies, accounting for over 60% of all policies. This predominance can be attributed to their cost-effectiveness, flexibility, and ability to achieve multiple objectives simultaneously: mitigating environmental damage while generating public revenue. Their widespread use, as reflected in the PINE database, highlights their central role in contemporary environmental policymaking, where balancing economic growth with sustainability remains a priority.

The second-largest category consists of subsidies and payments, emphasizing the critical role of financial support in promoting green energy projects, sustainable technologies, and environmentally friendly practices. By providing economic incentives, governments encourage key sectors to adopt greener commitments and technologies.

The remaining portion of the graph represents other types of policies, which occupy a significantly smaller share. This suggests their comparatively lower relevance in governmental decision-making processes, likely due to perceived limitations in their effectiveness relative to taxes, fees, and subsidies. These aspects, including their efficacy, will be examined further in the subsequent sections of this document.

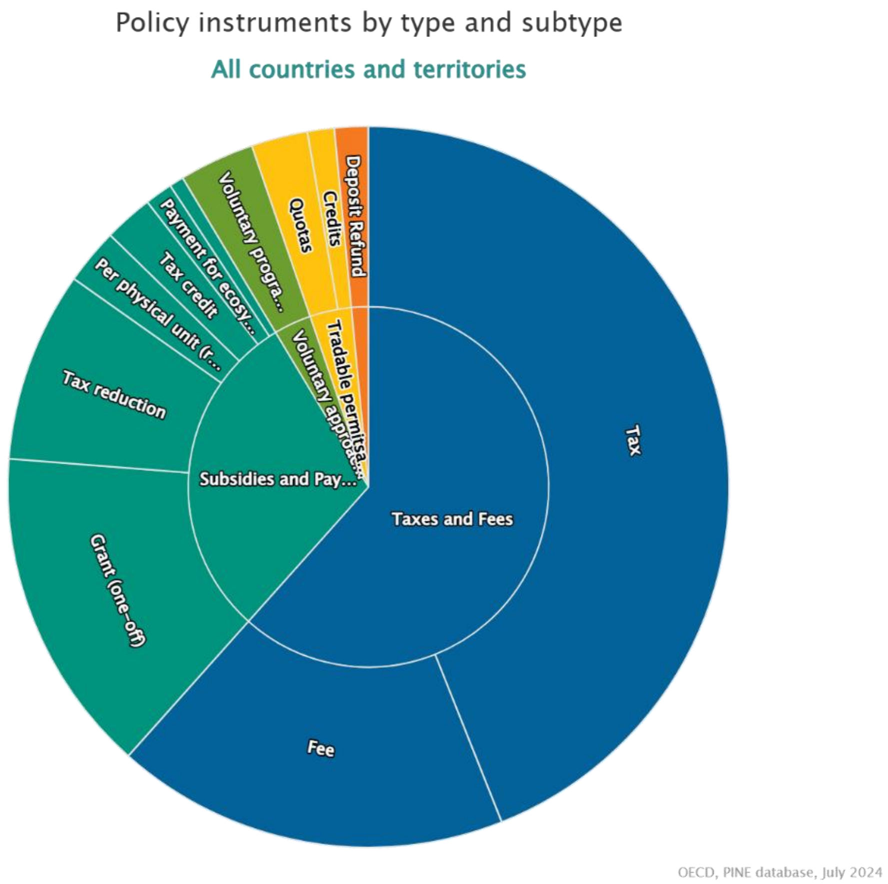

Figure 7. distribution of policy instruments by type and subtype (OECD, PINE database, July 2024)

The dataset also displays a significant distinction between OECD and non-OECD countries: by analyzing the distribution of those policies in those countries, some interesting patterns could be described. The pictures below will show the different distributions.

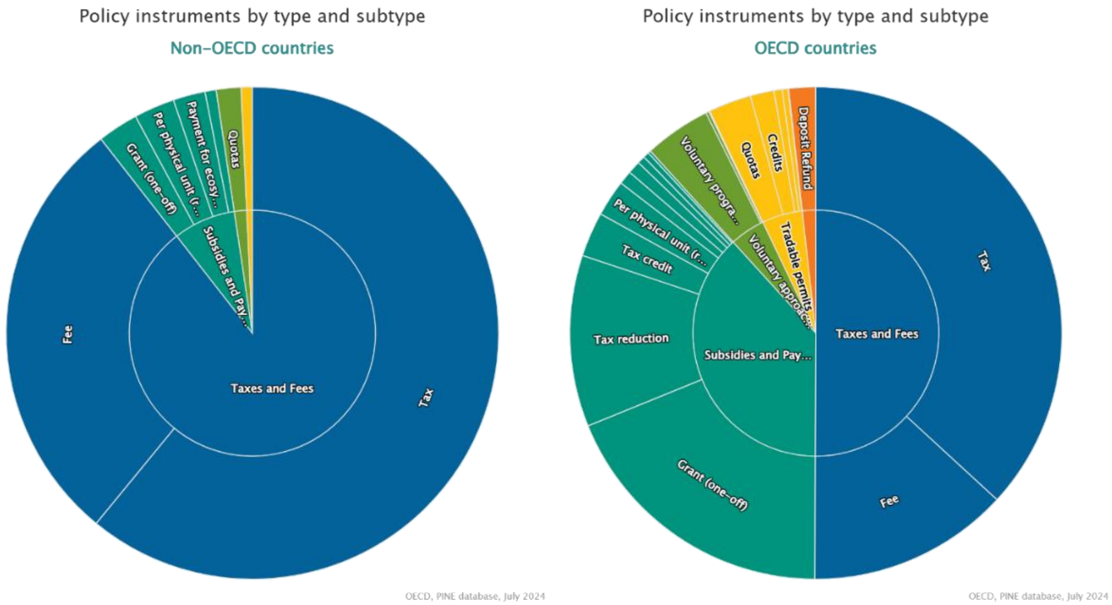

Figure 8. Policy Instruments differences among OECD & Non-OECD Countries (OECD, PINE database, July 2024)

While the prevalent type of policies remains the same between those clusters of countries, OECD countries rely on a much broader use of subsidies and payments. This could be explained by several economic, institutional, and developmental factors:

- OECD countries generally have higher fiscal capacity and stronger economies, enabling them to allocate substantial public funds to subsidies and incentives. Subsidies – such as grants, tax reductions, and credits – require significant financial resources to implement and maintain OECD governments can absorb the fiscal burden of incentives more easily due to larger tax bases and more efficient financial systems. In contrast, many non-OECD countries face budgetary constraints and may prioritize policies that generate revenue (e.g., taxes and fees) over those that require expenditure
- OECD countries often use subsidies to promote green innovation and accelerate the transition to sustainable economies. They prioritize incentives to encourage investment in clean technologies, energy efficiency, and environmental conservation. Non-OECD countries, on the other hand, may prioritize more

immediate challenges, such as infrastructure development, poverty alleviation, and resource management

- Implementing subsidies and payments often requires strong administrative capacity to ensure transparency, proper allocation, and monitoring. OECD countries typically have well-developed institutions and regulatory frameworks, which enable them to efficiently manage complex subsidy programs. In contrast, non-OECD countries may face institutional limitations, such as weaker governance, corruption risks, or challenges in program implementation
- Subsidies in OECD countries are often designed to drive private sector investment in green technologies and sustainable practices. By lowering costs or providing financial incentives, governments can encourage businesses to adopt cleaner technologies and innovate. This aligns with OECD countries' goals of decarbonizing their economies and meeting international climate commitments, while non-OECD countries can be focused more on economic development, rather than decarbonization.

6.3.3 Policy Instruments by Geographical Scope

The **geographical scope** of policies in the PINE database reveals that most environmental policies have national coverage, rather than referring to a smaller portion of the territory of the country, whether provincial, regional or state. This trend can be explained by several factors:

- **Centralized Decision-Making**: National governments typically have the authority and responsibility to design and implement broad environmental strategies. Issues like climate change, air pollution, and energy use often require coordinated, large-scale action that goes beyond regional or local boundaries.
- **Uniformity and Consistency**: National policies ensure a consistent approach across the entire country. This avoids regional disparities and ensures that environmental regulations, taxes, or incentives are applied evenly, which is crucial for issues like emissions standards, taxation, or resource management.
- **International Commitments**: Many national policies stem from international agreements, such as the **Paris Agreement** or other global climate frameworks.

To meet these commitments, governments often implement nationwide policies that align with global targets.

- **Resource Allocation**: National governments have greater fiscal and administrative capacity to implement policies compared to provincial or regional authorities. They can mobilize resources, coordinate across sectors, and enforce compliance more effectively.

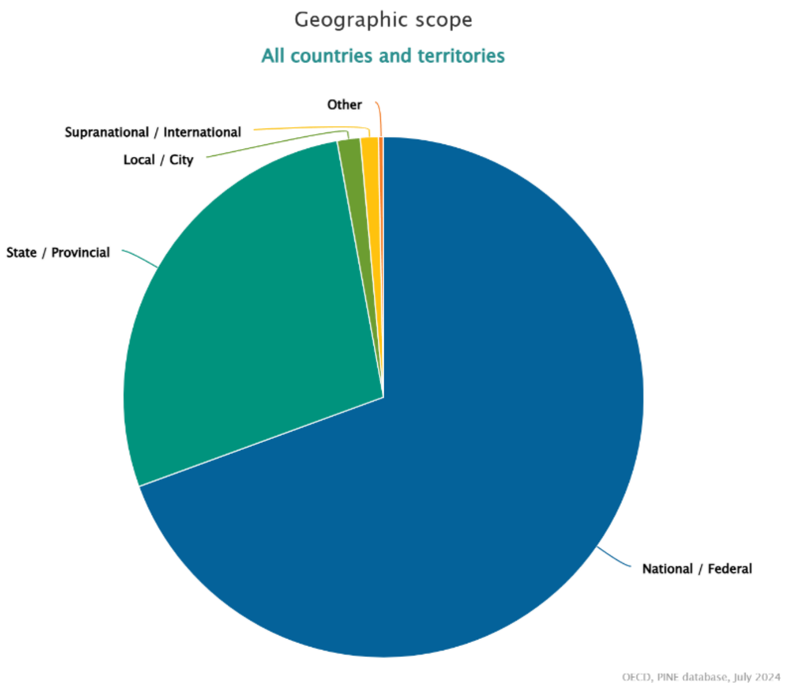

Figure 9. Policy Instruments by Geographical Scope (OECD, PINE database, July 2024)

6.3.4 Policy Instruments by Type & Environmental Domain

Policies adopted by governments can target a wide range of domains, however some of them are the more regulated. The domains with the highest number of policies are climate change mitigation, air pollution, biodiversity, circular economy, fossil fuels, solid waste and energy efficiency, because they address the **most pressing environmental and economic challenges** faced by governments today. There are many reasons why those are the most targeted: **climate change mitigation** is a global priority, as it directly impacts ecosystems, economies, and societies. Governments focus on this domain to meet international commitments, such as the Paris Agreement, and to reduce greenhouse gas emissions. **Air pollution** is a critical public health issue, causing millions of premature deaths annually, especially is certain areas, for example Northern Italy. Policies targeting this domain aim to improve air quality and reduce related healthcare costs; **Circular economy** policies address resource efficiency and waste reduction, promoting sustainable production and consumption practices while reducing environmental degradation. **Fossil fuels** are the major contributor to greenhouse gas emissions, inducing governments to regulate the sector, while transitioning to more sustainable sources of energy. **Solid waste** management is vital for reducing pollution, minimizing landfill use, and supporting recycling initiatives, which align with sustainable development goals. **Energy efficiency** is targeted as it offers a cost-effective way to reduce energy consumption, lower emissions, and improve energy security. All these domains also represent issues that are widespread in all the world, and not related to specific areas, thus they represent the biggest stake in the dataset.

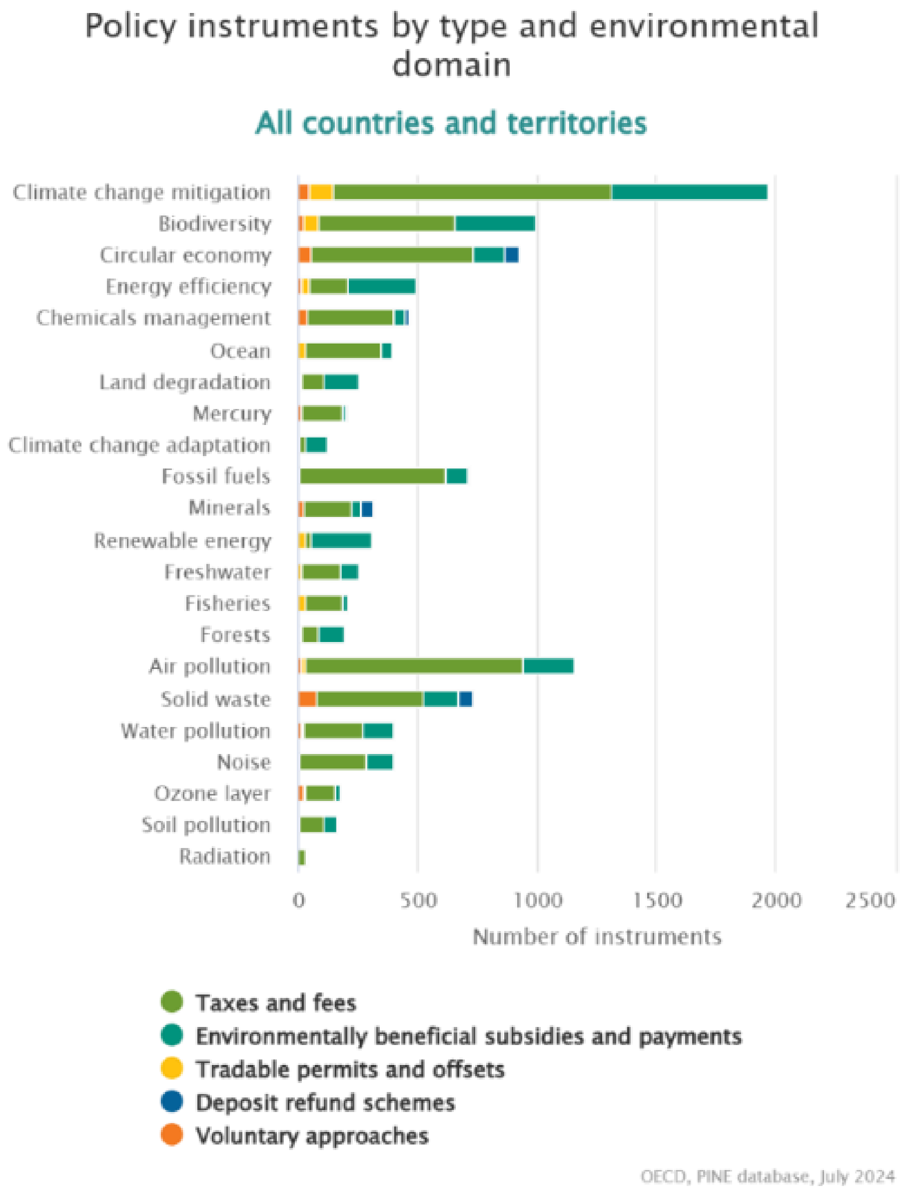

Figure 10. Policy Instruments by Type & Environmental Domain ((OECD, PINE database, July 2024)

7. CO2 Emission and R&D Expenses

7.1 Dataset: CO2 Emissions

Global greenhouse gas (GHG) emissions, primarily driven by human activities such as fossil fuel combustion, deforestation, industrial processes, and agriculture, are the leading contributors to climate change. Over the past century, emissions have risen exponentially, with CO_2, methane (CH_4), and nitrous oxide (N_2O) being the most prevalent. These emissions have far-reaching consequences, including rising global temperatures, extreme weather events, biodiversity loss, and disruptions to ecosystems and economies worldwide. According to the latest data, global GHG emissions in 2023 reached 53.0 Gt CO_{2eq} (without Land Use, land Use Change and Forestry). The 2023 data represent the highest level recorded and experienced an increase of 1.9% or 994 Mt CO_{2eq} compared to the levels in 2022. (European Commission, JRC. (2024). *EDGAR - Emissions Database for Global Atmospheric Research*)

In this framework, cleantech startups have emerged as critical drivers of innovation and change, developing cutting-edge technologies such as renewable energy systems, carbon capture and storage (CCS), energy-efficient products, waste-to-energy solutions, and digital tools for monitoring and optimizing emissions. Without innovation driven by those, reducing emissions could be an impossible mission. Analyzing the correlation between cleantech startups and GHG emissions could lead to interesting findings.

The EDGAR is a multipurpose, independent, global database of anthropogenic emissions of greenhouse gases and air pollution on Earth. EDGAR provides independent emission estimates using international statistics and a consistent IPCC methodology [Crippa, M., et al. (2024). *GHG Emissions of All World Countries - 2024*. Publications Office of the EU (JRC138862)].

This dataset helps tracking GHG emission with different level of details, starting from the total national amount, diving deeper by dividing emissions into the following sectors: Power Industry, Industrial Combustion and Processes, Buildings, Transport, Fuel Exploitation, Agriculture and Waste. The dataset also provides GHG divided by each country’s GDP and population, highlighting the carbon intensity of each country, which means how much of GHG is necessary to produce a unit of GDP, and the per-capita GHG emissions. Those indicators are useful because carbon intensity helps countries assess their progress toward climate goals (such as the Paris Agreement's target to limit global temperature rise) and formulate strategies for further reducing emissions while maintaining economic growth and can help assessing whether innovation by cleantech startups can improve those indicators, while still helping growth.

7.2 Dataset: Investment and R&D

Investments in Research and Development (R&D) play a critical role in creating a favourable environment for startups by enabling innovation that can drive economic growth. As countries face increasing pressure to address climate change and transition to sustainable energy sources, R&D investments become essential for developing advanced technologies that reduce carbon emissions, enhance energy efficiency, and promote renewable energy solutions.

Governments, private enterprises, and academic institutions that prioritize R&D contribute to building a robust ecosystem where startups can thrive, attract investors, and scale their solutions globally. By examining the level of investment in R&D across countries and various indicator, we can gain insights into which regions are better positioned to support cleantech innovation and economic development in the transition to a sustainable future.

The OECD Main Science and Technology Indicators (MSTI) is a database provided by the OECD which focuses principally on tracking financial and human resources devoted to research and experimental development (R&D), as defined in the OECD Frascati Manual (OECD. (2015). *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on R&D)* complemented by additional indicators of outputs and potential outcomes of S&T activities, namely patent data and international trade in R&D-intensive industries (OECD. (2024). Main Science and Technology Indicators (MSTI)).

The key main indicators of this dataset are:

- **Gross Domestic Expenditure on R&D (GERD)**, which measures the total expenditure on research and development activities carried out within a country's borders, regardless of the funding source. GERD can be expressed as an absolute value in monetary term, or as percentage of GDP (known as R&D intensity), allowing for comparison of a country's R&D commitment relative to its economic output.

- **Business Enterprise Expenditure on R&D (BERD)**, which measures the total expenditure on research and development performed by the business sector within a country. It is a subset of the Gross Domestic Expenditure on R&D (GERD) and focuses specifically on R&D activities carried out by private enterprises, regardless of the source of funding.
- **Higher Education Expenditure on R&D (HERD),** which measures the total expenditure on research and development performed within the higher education sector of a country. This includes R&D activities carried out by universities, colleges, and other tertiary education institutions, regardless of the source of funding.
- **Government Expenditure on R&D (GOVERD)** measures the total expenditure on research and development performed directly by the government sector. This includes R&D activities carried out in government-owned research institutions, laboratories, and agencies, regardless of the source of funding.
- **R&D personnel,** which refers to the individuals directly involved in Research and Development (R&D) activities, including researchers, technicians, and supporting staff. These personnel are a critical component of the innovation ecosystem, as they are the driving force behind the creation, development, and application of new knowledge, technologies, and solutions. In this dataset there is the same distinction as mentioned before, with separation of personnel active in business enterprise, higher education and government sectors.

Analyzing this dataset, along with the other dataset mentioned above, can help analyzing factors that can influence the birth, growth and consolidation of cleantech startups, by using statistical methods for analyzing all the data.

8. VC Investments in the Cleantech Sector

Venture Capital (VC) is a form of private equity financing provided to early-stage, high-growth startups and businesses with strong potential for innovation and scalability. Venture capitalists are the primary source of early-stage funding targeted at young companies with the potential for rapid growth and high returns (Metrick and Yasuda, 2021). VC firms invest in these companies in exchange for equity, aiming to generate significant financial returns when the businesses succeed and either go public or are acquired.

Investment in sustainable startups drives the transition to cleaner production (Bocken, 2015; De Lange, 2019). In this context, Venture Capitalists (VCs) are increasingly interested in cleantech startups due to the growing demand for sustainable solutions, the acceleration of global climate change initiatives, and the economic potential of innovative clean technologies. VC funding is particularly suited for startups in sectors like technology, biotechnology, and cleantech, where high risk and capital requirements often deter traditional financing options. At the start of the century, VC investments in clean energy experienced a boom-and-bust cycle. From 2005 to 2008, the share of VC investments going to clean energy technologies more than tripled, spurred by growing societal interest in environmental issues.

However, the returns on these investments proved quite poor, with investors losing more than half of the money they invested in cleantech startups between 2006 and 2011 (Gaddy et al., 2017). After a boom-and-bust cycle in the early 2010s, venture capital (VC) investments have, once again, been flowing towards some green businesses since 2015 (Popp & van den Heuvel, 2023). In recent years, VC investments have grown exponentially. 2022, for example, was an enormous year for Climate Tech VC. The US alone invested more Climate Tech VC in 2022 than the entire 2006-2011 Clean Tech 1.0 Boom and overall the world delivered $70.1B of investment, defying gravity in a broader market that had fallen significantly. While it is still very early in the year, based on Q1 2023 deal activity and the broader economy, we're forecasting around $36B of full year 2023 Climate Tech VC investment, a little over half of the record levels of 2022. (HolonIQ, 2023, $11.2B of Climate Tech Venture Funding for Q1 2023. Forecasting a $36B full year.), while 2023 has seen a decrease in VC investments.

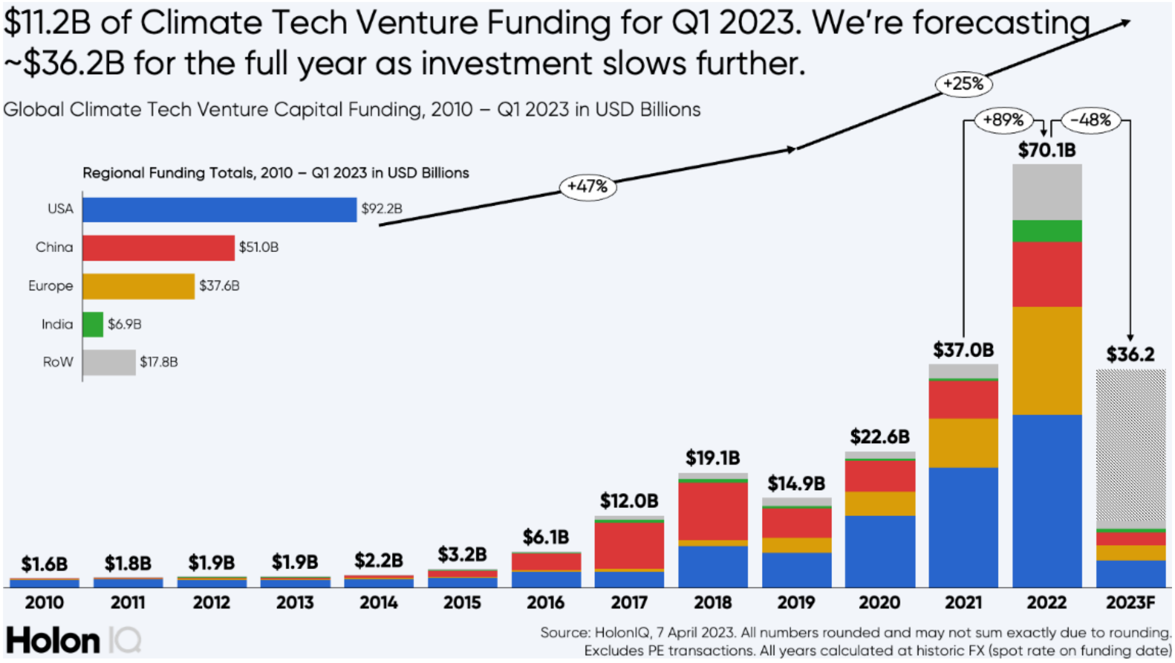

Figure 11. The growth of VC investments in the Cleantech sector

However, Venture capital (VC) remains crucial in the cleantech sector because it provides the funding and support needed to develop and scale innovative solutions that address environmental challenges.

9. Empirical Analysis: Impact of Business R&D Expenditure on Cleantech Firms

The empirical research section expands on the previous descriptive findings by uniting firm-level cleantech performance metrics with national research investment data and personnel statistics. The research investigates how business R&D expenditure (BERD) affects economic performance of cleantech enterprises through revenue generation and job creation. The research begins by showing GERD and BERD development in Italy and France and Germany and the Netherlands and Denmark through absolute values and GDP percentages while separating research funding between government and enterprise sectors. The research establishes fundamental knowledge about how different institutional systems that direct innovation funding resources.

The research examines BERD distribution between manufacturing and pharmaceuticals which represent major innovation funding sectors with separate operational approaches. The two sectors differ in their R&D expenditure patterns because manufacturing investments focus on general industrial progress and incremental development yet pharmaceutical research requires focused knowledge-based funding. The analysis of sectoral patterns throughout different countries reveals which industries lead national innovation paths and what role private and public entities play in these developments.

Finally, the research transitions from descriptive analysis to relationship testing in its final section. The research uses linear regression models to determine if higher business R&D spending leads to increased sales performance and employment expansion in newly established companies. The research investigates whether R&D spending results in actual market performance or remains a financial obligation. The research evaluates business-led research investment effects on cleantech firm development through time by comparing results between five countries while showing general patterns and individual national characteristics.

9.1 GERD and BERD Dynamics Across Countries

The initial assessment of national research funding distribution between **Gross Domestic Expenditure on R&D (GERD) and Business Expenditure on R&D (BERD)** shows how different national innovation systems allocate their resources for research activities. GERD shows the total economic research investment through public and private sector funding, but BERD shows only business sector funding for research activities. The combined analysis of these two metrics enables researchers to track changes in government-enterprise funding distribution patterns throughout time and between different nations. The distribution between enterprise and government funding percentages in national innovation systems provides essential information about their strategic priorities. Countries with business-led R&D funding demonstrate better private sector innovation capabilities while government-led funding indicates attempts to support businesses that lack innovation capacity. The analysis of these funding dynamics reveals both the total investment amount and the distribution of innovation funding responsibilities between different entities.

DENAMRK

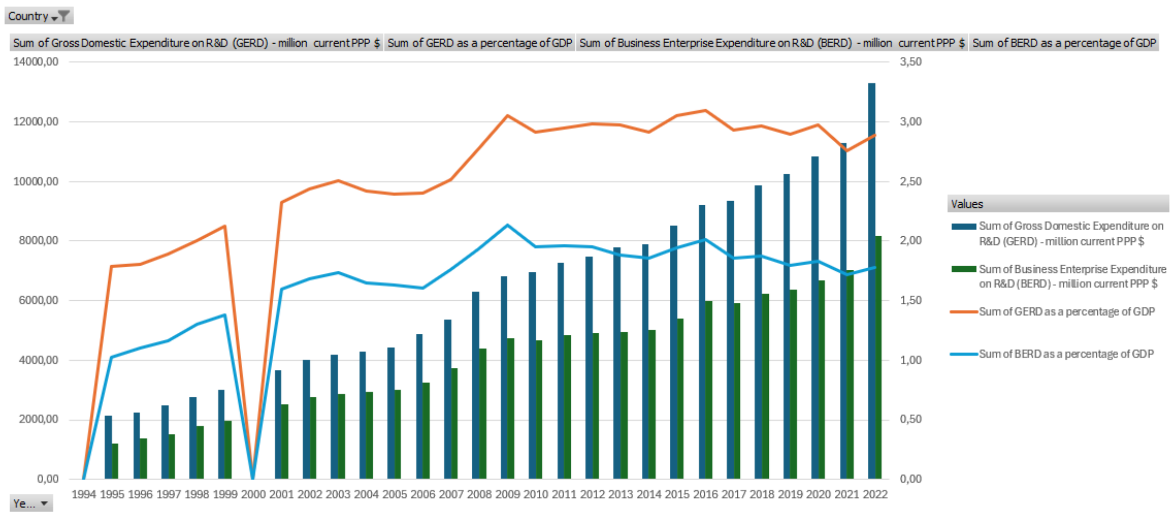

Figure 12. Country Trends of GERD & BERD – Denmark

The research and development (R&D) spending trends in Denmark demonstrate ongoing innovation support through continuous growth of both gross domestic expenditure on R&D (GERD) and business enterprise expenditure on R&D (BERD) throughout the years. The data shows that both GERD and BERD have consistently increased since 1994 while business enterprise R&D spending has become the dominant portion of total research investments. The private sector drives innovation through its R&D investments because business R&D spending reached more than €11 billion in 2022 while total R&D spending reached €17.6 billion.

The percentage of R&D spending in relation to GDP (GERD and BERD) demonstrates a rising trend during the years even though it shows occasional variations which indicates Denmark's growing investment in research and development activities. The graph shows a significant increase in BERD as a percentage of GDP during 2022 because of focused initiatives for innovation and technological advancement across different sectors. The economic data indicates that Denmark has dedicated resources to implement green technology integration and digital transformation within its national economy.

FRANCE

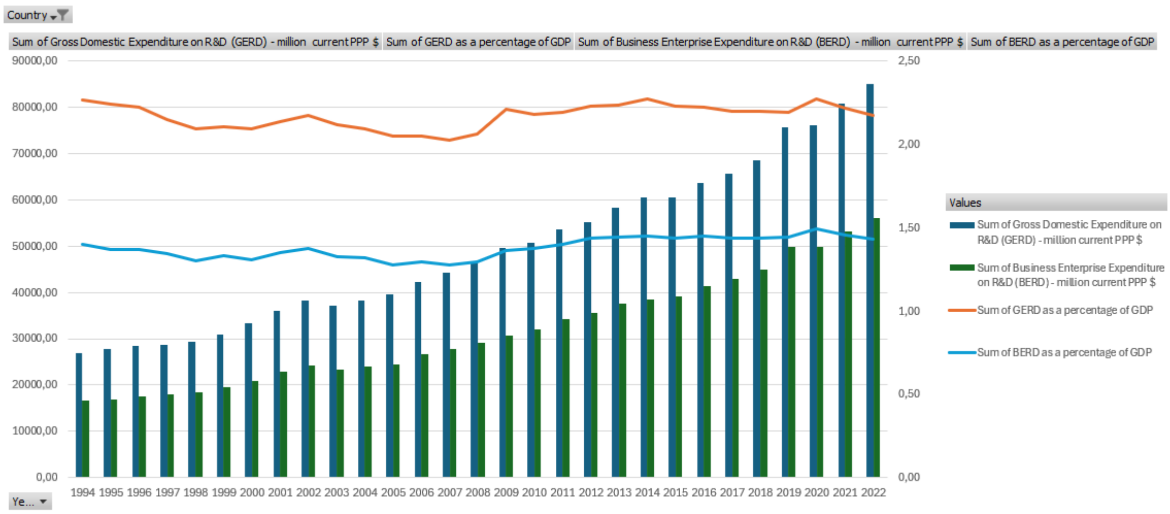

Figure 13. Country Trends of GERD & BERD - France

The data from France shows a strong and continuous upward pattern in both GERD and BERD. The last twenty years have brought substantial growth to French R&D spending because GERD reached €85 billion in 2022. The percentage of R&D spending in relation to GDP has continuously increased to exceed 1.4% in current years. The upward trend in French R&D spending demonstrates the country's rising dedication to innovation which matches the EU's goal to make R&D a key economic growth driver.

The research funding data shows strong dependence on government support because private sector R&D investment has not experienced equivalent growth. The widening difference between GERD and BERD indicates France dedicates more resources to government-led innovation through public research and strategic sectors including pharmaceuticals and aerospace and energy. The private sector in France shows limited enthusiasm for R&D spending because public R&D investments have not led to equivalent growth in private sector research funding. The economic output would experience significant increase if private sector R&D investment rates accelerated because research spending creates employment opportunities and enables technological advancements that transform industries.

GERMANY

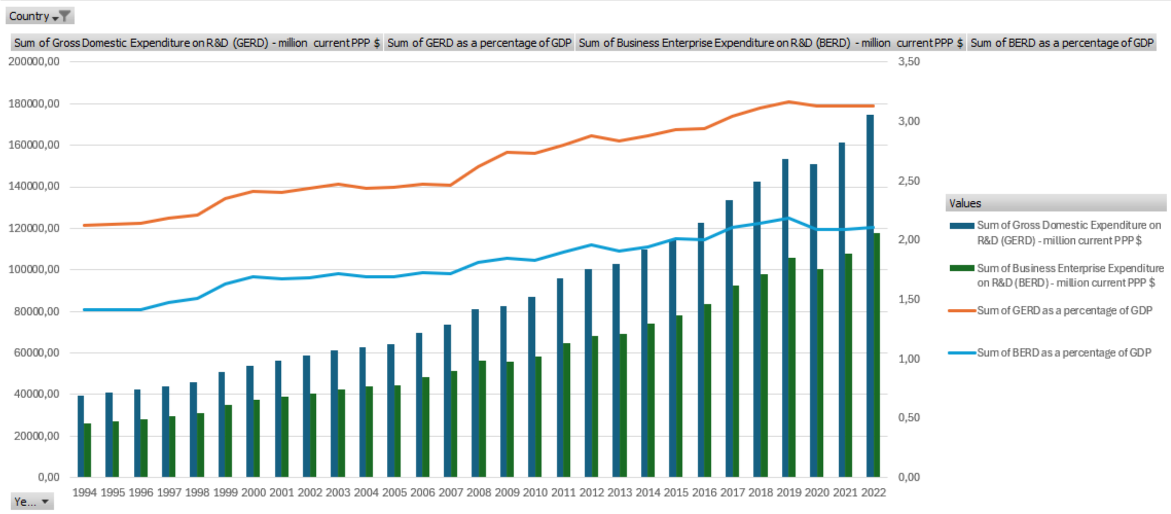

Figure 14. Country Trends of GERD & BERD – Germany

The data from Germany demonstrates a continuous growth pattern for both GERD and BERD throughout the last twenty years. The economy demonstrates rising research activity through the continuous growth of R&D spending as a percentage of GDP for both GERD and BERD. The private sector now bears greater responsibility for innovation because BERD shows a significant increase in its contribution to total R&D efforts. The European R&D intensity ranking places Germany among its top members because its business R&D spending reached more than 2% of GDP in 2022. The millions invested in Denmark and France were significantly lower than Germany's during the last ten years.

Business R&D spending has increased steadily since 2007/2008 while government R&D funding through GERD has shown a more controlled growth pattern although the government maintains its essential role in supporting research activities. The R&D growth rate experienced a significant boost during the time period following the global financial crisis of 2007/2008 which indicates that Germany joined other countries used this period to initiate structural changes and innovation initiatives.

ITALY

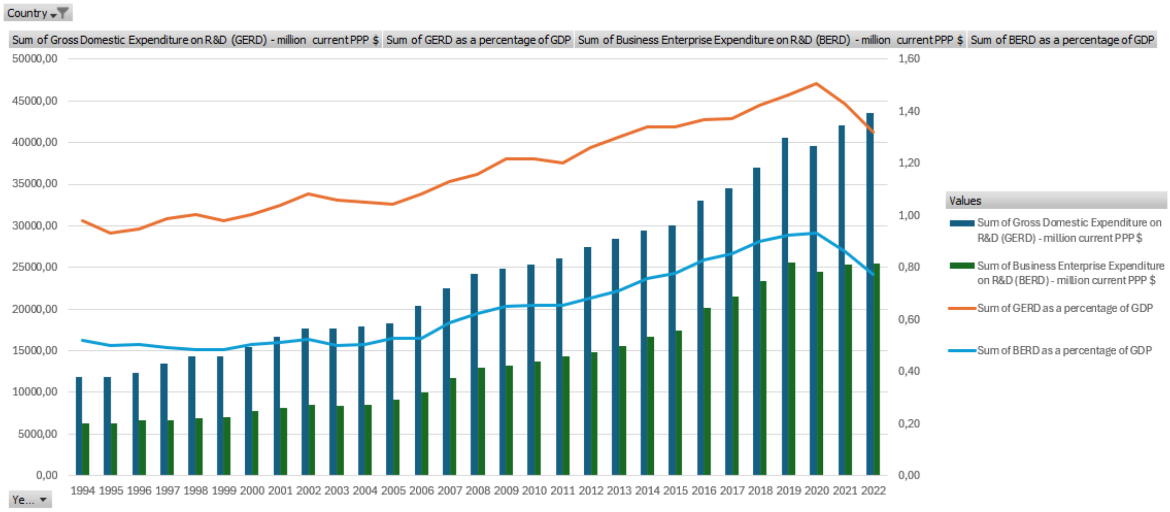

Figure 15. Country Trends of GERD & BERD – Italy

The research and development expenditure in Italy demonstrates a continuous yet moderate growth pattern for both domestic and business enterprise spending throughout the years. The two figures demonstrate continuous growth since the past years but at a moderate pace. The GERD numbers rose from €11.88 billion in 1994 to reach €43.5 billion in 2022 while R&D spending as a percentage of GDP exceeded 1% starting in the early 2000s. The R&D spending in Italy shows lower levels compared to other European countries when measured against its national economic performance. The GERD percentage of GDP started at 0.60% during the early 2000s before increasing to 0.70% by 2022. The entire period saw Business expenditure in R&D increase, yet it maintained a minimal share of GDP which stayed under 1%.

The financial crisis of 2008 did not stop Italy from expanding its BERD spending which reached €25.5 billion in 2022 while businesses took on more responsibility for R&D expenses. The private sector participation in R&D through BERD shows rising involvement but its share of total R&D funding remains lower than government funding levels in Italy. The percentage of GERD and BERD relative to GDP experienced a substantial decline after 2020 because of the economic instability caused by the Covid-19 pandemic in Italy.

NETHERLANDS

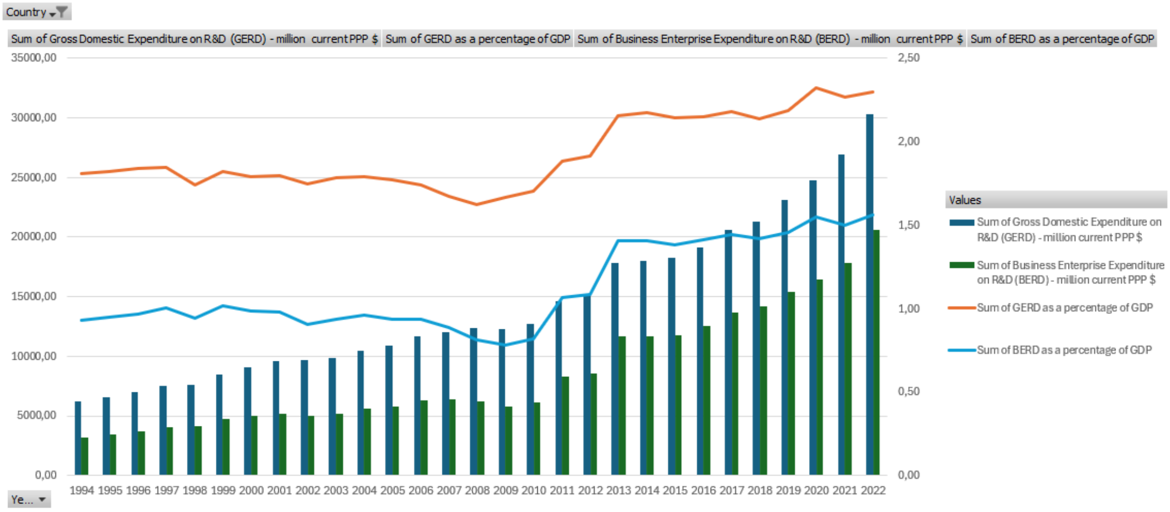

Figure 16. Country Trends of GERD & BERD - Netherlands

The Netherlands has experienced rising research and development spending during recent decades as business enterprise research and development (BERD) has become more prominent. The business sector spent about €20 billion on R&D during 2022 which represented a major portion of total research and development funding. The total research and development spending has increased yet the business sector's share of total R&D funding remains at a moderate level according to the chart.

The percentages of GERD and BERD relative to GDP have shown more variability since the late 1990s among the different countries. The growth rate of BERD as a percentage of GDP has matched the growth rate of the other countries. The Netherlands dedicates a large portion of its R&D funding to government initiatives because the country maintains strong support for scientific research and innovation.

9.2 BERD Expenditure and Sectoral Patterns

The economic priorities of each nation become clearer through studying how Business Enterprise Research and Development (BERD) distributes across major industrial sectors. The innovation landscape depends heavily on two essential sectors which are manufacturing and pharmaceuticals. The two sectors operate within high-technology knowledge-intensive domains yet show distinct characteristics. The analysis tracks sector-specific BERD development patterns to show how enterprise and government funding proportions reveal national priorities and technological capabilities. The dominance of manufacturing R&D spending in certain areas indicates established industrial practices but pharmaceutical research takes center stage in other regions. The analysis shows whether governments actively support vital sectors through funding or if businesses must fund innovation expenses in these fields.

DENMARK

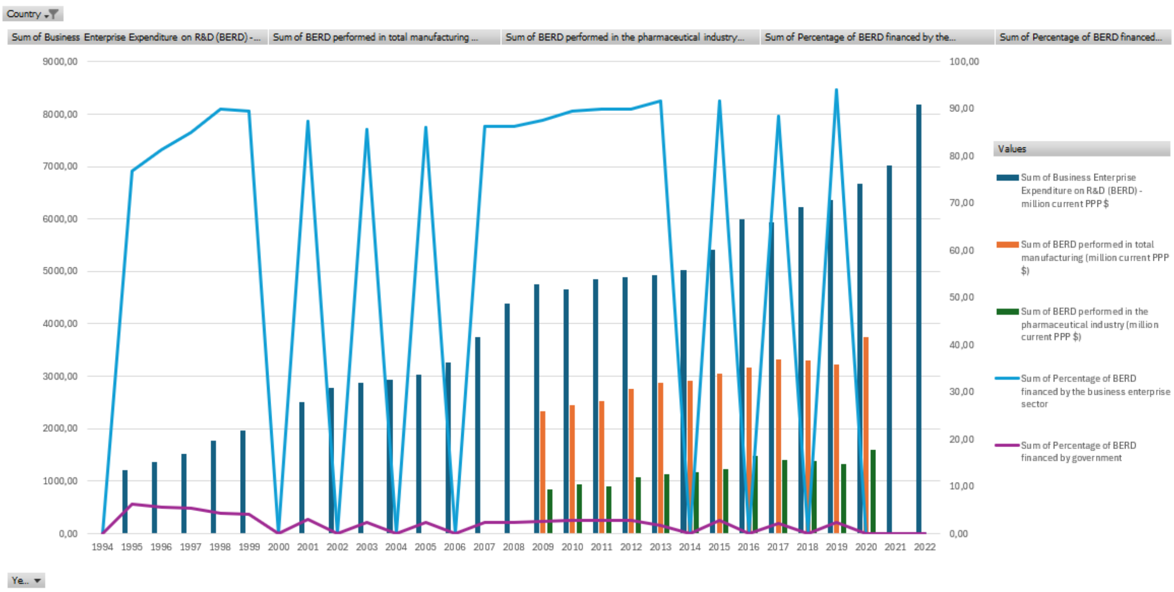

Figure 17. BERD and sectors deep dive – Denmark

The business enterprise expenditure on R&D (BERD) in Denmark has grown continuously since 2000 but the distribution of this investment between sectors and funding sources stands out as the most significant factor. The manufacturing sector leads private R&D investments because its spending increased steadily since 2009 to reach 3,700 million current PPP dollars in 2020 while becoming the primary sector for business innovation funding. The pharmaceutical industry maintained a smaller size compared to manufacturing throughout the period with its highest point reaching 1,500 million PPP dollars in 2020. The structural dominance of manufacturing in Danish private R&D activities becomes evident through this financial data because pharmaceuticals maintain a smaller yet increasing position.

The way funding sources distribute their investments throughout the period reveals important information. The entire period shows that enterprises funded 75% to 94% of their R&D expenses through internal resources because government support remained minimal at less than 5% of total funding. The innovation system of Denmark operates mainly through private funding because businesses lead innovation efforts while public institutions provide minimal supplementary support. The funding pattern between Denmark and other countries demonstrates how business-led innovation drives the country's innovation capacity because government support for R&D remains minimal.

FRANCE

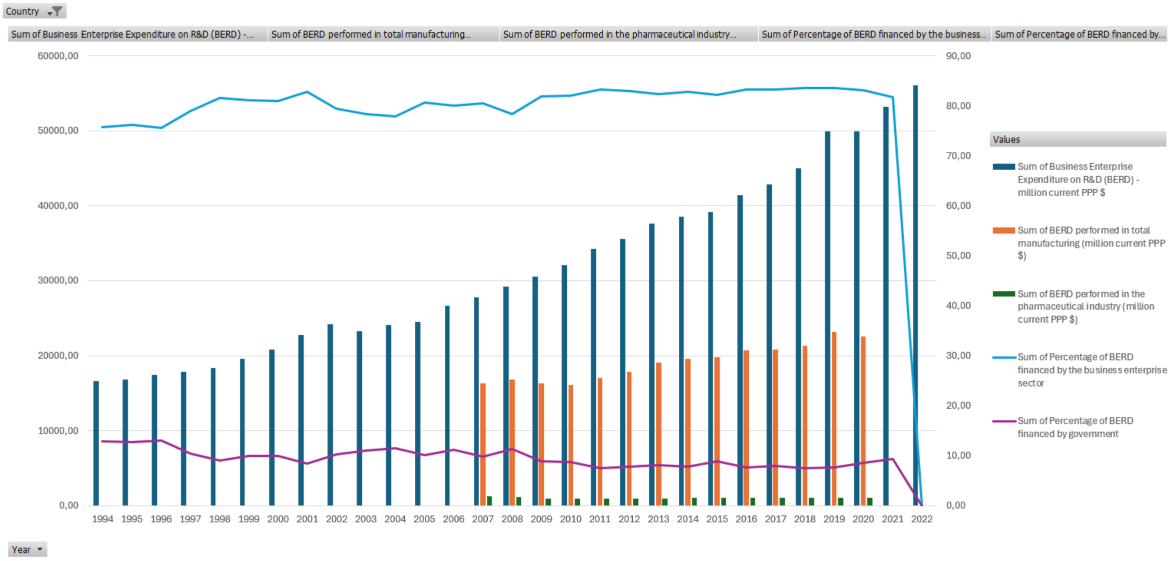

Figure 18. BERD and sectors deep dive – France

The French business sector dedicated more money to R&D through enterprise spending which rose from 16,600 million PPP dollars in 1994 to 56,000 million PPP dollars by 2022. The most significant aspect of this data set emerges from its sectoral distribution which becomes accessible starting from 2007. The data shows that manufacturing takes the lead in business R&D spending because it exceeds 20,000 million PPP dollars at the end of the period. The pharmaceutical industry maintains a minimal position in the sector because its funding levels stay between 1,000 million and slightly above this amount. The substantial difference in size between manufacturing and pharmaceuticals demonstrates that manufacturing functions as the main pillar of French private R&D while pharmaceuticals maintain a minimal contribution to the overall picture.

The financial structure demonstrates that private sector entities maintain control over most funding sources. The enterprises maintained a stable funding pattern for BERD between 75% and 83% throughout the entire period while government support remained within a limited range below 10%. The state guides industrial policy through its increased involvement but provides limited direct funding for R&D activities. The system operates with private companies taking the main financial burden for R&D expenses in manufacturing while public institutions function as support organizations. The data shows France operates with expanding business R&D activities that focus on manufacturing while receiving most of their funding from private enterprises with pharmaceuticals starting to show growth as a smaller but noticeable sector after 2016.

GERMANY

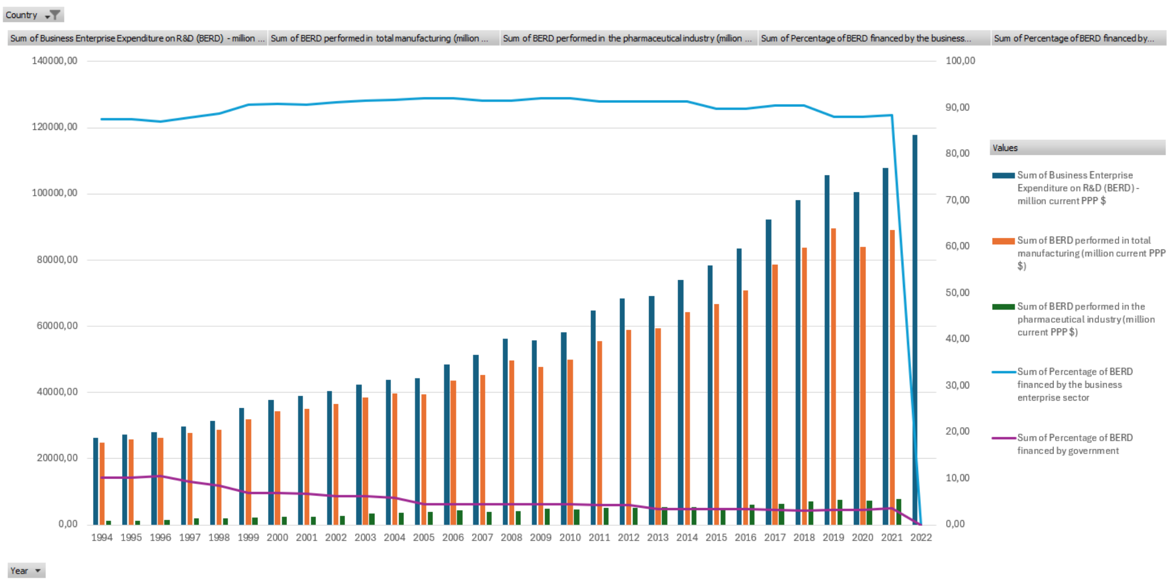

Figure 19. BERD and sectors deep dive – Germany

The business R&D expenditures in Germany demonstrate both significant scale and distinct organizational patterns. The business expenditure on research and development (BERD) in Germany grew from 26,000 million PPP$ in 1994 to exceed 100,000 million PPP$ during the period from 1994 to 2021 which established Germany as a leading technological power in Europe. The dominant role of manufacturing emerges as the most noticeable characteristic in Germany's research and development spending. The manufacturing sector received more than 1400 billion PPP$ in cumulative funding throughout nearly three decades because Germany depends heavily on its industrial sector to drive innovation. The pharmaceutical industry experienced continuous growth yet maintained a minimal market share which reached 8,000 million in 2021. The system demonstrates a manufacturing-centric structure because manufacturing functions as the fundamental pillar which supports the entire research and development framework of the country.

The financing patterns support the existence of a business-oriented innovation system. Enterprises maintained their position as the primary funders of BERD throughout most of the period because their contribution ranged from 87% to 92%. The government funding for research decreased progressively from 10% in the mid-1990s to less than 3% during the 2010s. The research investment responsibility has shifted toward private entities because Germany follows an industrial policy which supports firm-driven development and competitive market strategies.

ITALY

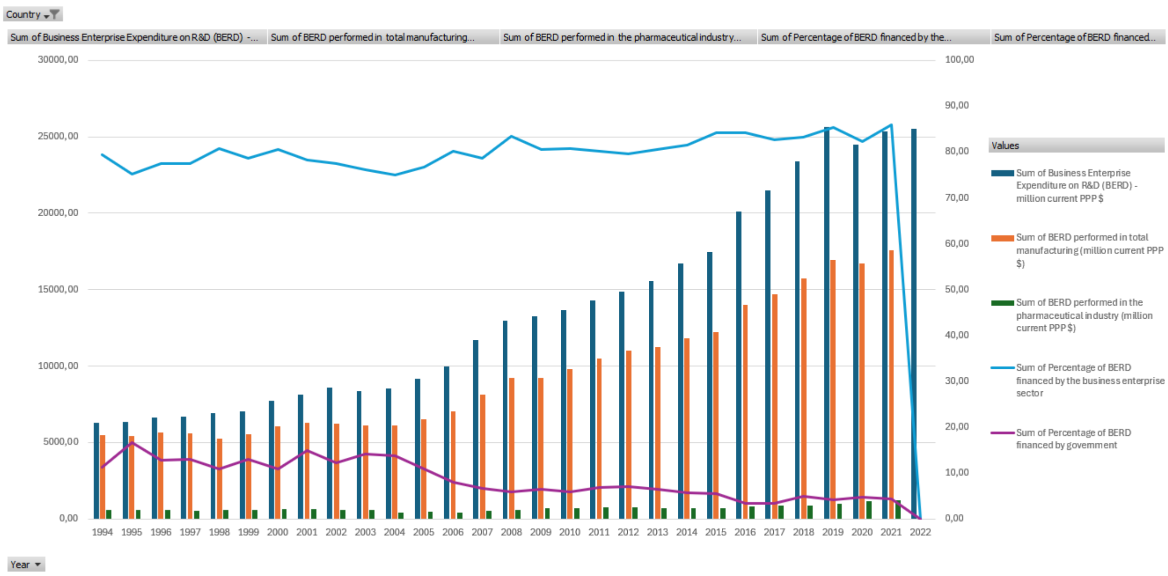

Figure 20. BERD and sectors deep dive – Italy

The BERD profile of Italy shows that manufacturing sector has maintained its position as the main recipient of private R&D funding throughout the entire period. The manufacturing sector received more than 5,000 million PPP$ in BERD during the mid-1990s before reaching above 17,000 million PPP$ in 2021 while accounting for most of the total BERD spending. The pharmaceutical sector maintained a small position in R&D spending because annual investments stayed below 1,000 million PPP$ and total spending reached 20 billion while manufacturing spent more than 266 billion during the same period. The uneven distribution between traditional industrial sectors and life sciences research in Italian R&D activities shows that the country has not achieved the same level of knowledge-intensive sector development as other advanced nations.

The business sector maintained control over funding operations through the entire period. The business sector maintained a consistent funding level of 75-85% of BERD throughout the entire period while their funding share reached 80% during the 2010s. The government support for BERD funding decreased from more than 15% in the 1990s to less than 5% during the mid-2010s. The business sector took on a more important position in funding R&D initiatives because Italy faced budget limitations. The system effectively directs private funds toward industrial development but faces two major challenges because it lacks sufficient support for new industries and depends on Italian industrial market fluctuations.

NETHERLANDS

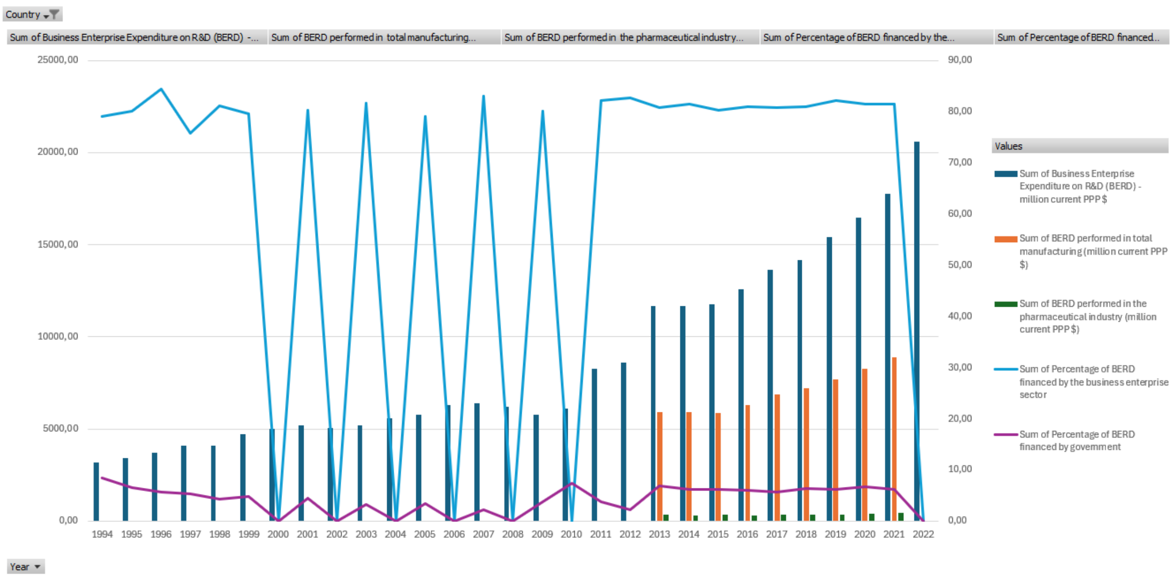

Figure 21. BERD and sectors deep dive – Netherlands

The Netherlands shows a distinct structural change in BERD composition starting from 2012 when sectoral data becomes available. The manufacturing sector became the main focus of

R&D investment in 2013 when it received more than €5,800 million PPP$ and continued to grow until 2020 when it reached more than €8,800 million before declining in the last years of the series. The pharmaceutical sector maintains a small position in the total BERD figures because it stays between €300–400 million PPP$ annually while representing a tiny fraction of the total R&D investments. The industrial focus of Dutch private R&D becomes evident through this data because manufacturing technologies receive more funding than life sciences despite their worldwide significance.

The financial structure of R&D activities shows significant patterns through its funding distribution. Business enterprises maintain control of more than 80% of R&D funding throughout the period with peaks reaching 85% in certain years while government support remains steady at 5-7%. The system depends heavily on corporate leadership because public sector involvement remains minimal. The Dutch model demonstrates both strong industrial R&D growth potential and weak points because manufacturing R&D shows fast expansion but pharmaceuticals remain underfunded and government support remains low.

9.3 Linear Correlations: BERD and Firms' Sales

The connection between research and development spending and commercial success of new businesses stands as a fundamental issue in innovation economics. The relationship between Business Enterprise Research and Development (BERD) and sales expansion can be evaluated through regression analysis to determine if R&D investments lead to improved market results for new businesses. The empirical findings about R&D spending effects on product development and market competitiveness and sales performance vary between different economic systems.

The analysis examines how well Business Enterprise Research and Development (BERD) predicts sales expansion in the chosen countries. The analysis of correlation strength and direction together with significance levels helps explain how different R&D investment approaches perform. Research spending shows a direct positive relationship with commercial success in certain economies yet produces weak or negative results in other economies because of inefficient operations and sector-specific challenges and delayed market effects.

DENMARK

Table 4. Correlation between BERD and Firms' Sales value 5 years after the observation period – Denmark

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,453304816							
R Square	0,205485256							
Adjusted R Square	0,176058784							
Standard Error	412,7668593							
Observations	29							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	1189740,132	1189740,132	6,983006872	0,013526496			
Residual	27	4600164,965	170376,4802					
Total	28	5789905,096						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	995,3195484	162,9613675	6,107702479	1,59368E-06	660,9504415	1329,688655	660,9504415	1329,688655
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,096398555	0,036479535	-2,64253796	0,013526496	-0,171248377	-0,021548733	-0,171248377	-0,021548733

The statistical analysis between Ysales5Yafter and Business Enterprise Expenditure on R&D (BERD) in Denmark shows both statistical significance and meaningful results. The model shows an R^2 value of 0.20 which indicates that BERD explains 20% of the sales variation after five years and this relationship stands as a significant finding in comparative terms. The estimated coefficient of -0.096 shows that higher business R&D spending leads to decreased average sales performance in subsequent years. The observed relationship between R&D spending and sales performance seems contradictory because Danish R&D spending patterns during late 2000s and 2010s led to market adjustments and firm cohort reductions.

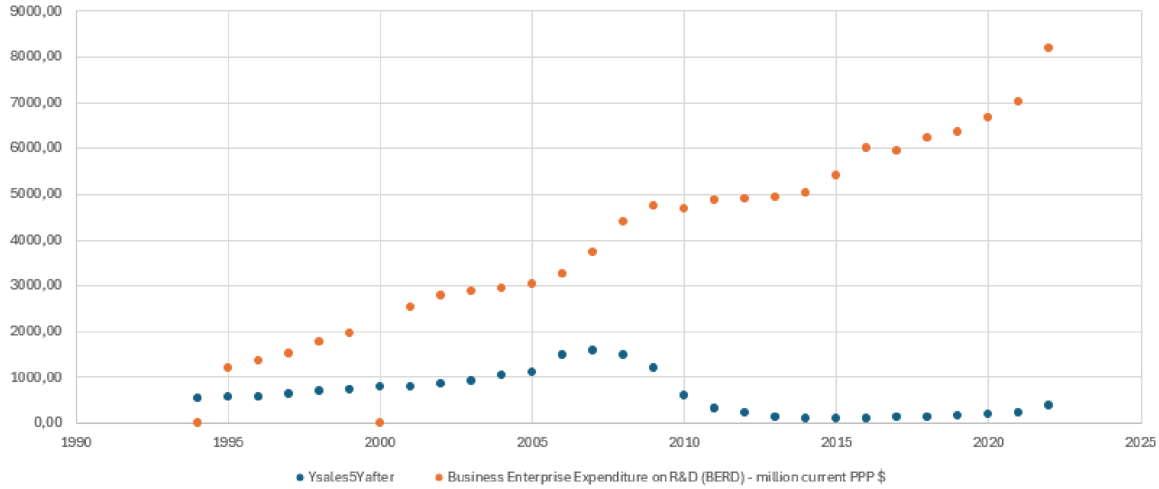

Figure 22. Graphic view of the statistical regression model – Denmark

The time-based pattern of variables supports this interpretation because BERD increased from 1.2 billion PPP$ in 1995 to 8.1 billion PPP$ in 2022 while post-foundation sales followed a distinct pattern of growth during the 1990s followed by a steep decline until 2010 before reaching stable lower levels. The ANOVA analysis validates this difference through its F-statistic of 6.98 and its p-value that approaches 0.013 which shows the observed relationship is statistically significant. The results indicate that Danish business R&D growth does not directly result in higher medium-term firm revenues and that how and when companies spend their funds appears more important than the total amount of expenditure.

FRANCE

Table 5. Correlation between BERD and Firms' Sales value 5 years after the observation period – France

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,544842682							
R Square	0,296853548							
Adjusted R Square	0,270811087							
Standard Error	934,822447							
Observations	29							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	9961356,509	9961356,509	11,39882849	0,002242235			
Residual	27	23595111,2	873893,0074					
Total	28	33556467,71						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	2284,273308	502,8841837	4,542344702	0,000104161	1252,440193	3316,106422	1252,440193	3316,106422
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,050406827	0,014929981	-3,376215113	0,002242235	-0,081040618	-0,019773037	-0,081040618	-0,019773037

The regression analysis between post-foundation sales averages and R&D expenditure in France shows a comparable pattern to Denmark. The model explains 30% of sales outcome changes through BERD fluctuations because it generates an R^2 value of 0.30. The model shows better explanatory power than Denmark because it explains 30% of sales variations through a negative relationship between BERD and future sales performance. The negative coefficient of -0.05 indicates that higher BERD spending during a period leads to lower average sales performance for subsequent years. The t-statistic value of -3.38 along with a p-value approaching 0.002 indicates that the observed effect is not caused by random events.

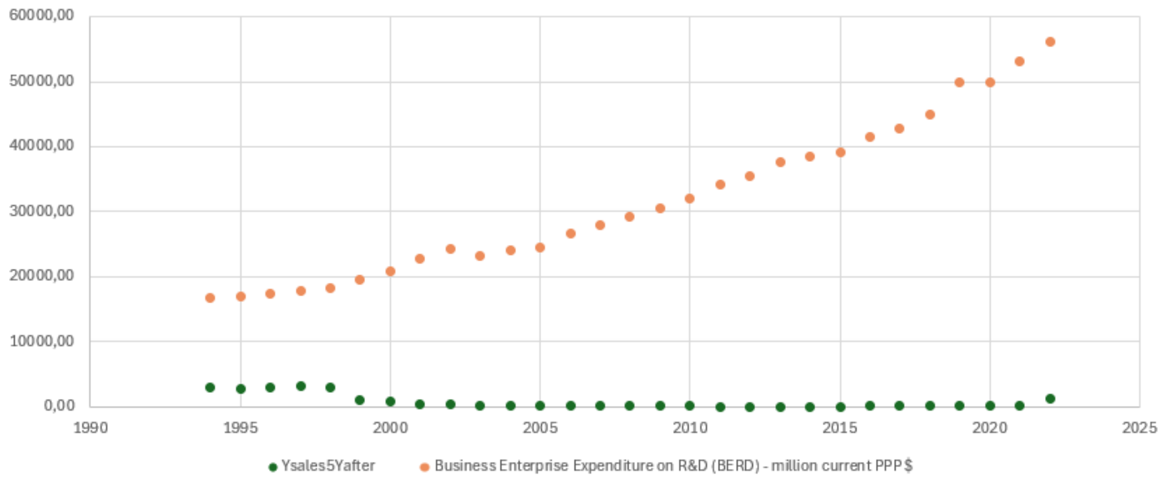

Figure 23. Graphic view of the statistical regression model – France

The time series data provides context to this discovery. The French business enterprise research and development (BERD) expenditures rose steadily from 16.6 billion PPP$ in 1994 until they reached more than 56 billion PPP$ in 2022 while showing minimal interruptions throughout the period. The average sales performance of firms five years after market entry declined dramatically starting from the early 2000s until they reached below

100 in most years between 2007 and 2020 before showing a minor increase in the last recorded observations. The rising business R&D expenditures in France have not led to equivalent sales growth for new cleantech companies during the studied five-year period. The expansion of French R&D spending through financial means might focus on projects with extended development times and delayed market entry which reduces its short-term effect on revenue generation for new cleantech businesses.

GERMANY

Table 6. Correlation between BERD and Firms' Sales value 5 years after the observation period – Germany

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,139562636							
R Square	0,019477729							
Adjusted R Square	-0,01683791							
Standard Error	2564,809086							
Observations	29							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	3528212,337	3528212,337	0,536345483	0,470261398			
Residual	27	177612632,4	6578245,646					
Total	28	181140844,8						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	2600,769613	1171,166857	2,22066531	0,034954876	197,7337148	5003,80551	197,7337148	5003,80551
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,012939401	0,017668182	-0,732356117	0,470261398	-0,049191515	0,023312713	-0,049191515	0,023312713

The regression analysis shows Germany has a weak relationship between its variables. The coefficient of -0.0129 shows a small negative relationship between BERD growth and medium-term sales performance but the high p-value (0.47) indicates this relationship is not statistically significant. The model shows low explanatory power because the R^2 value reaches only 0.02 which indicates BERD dynamics explain less than 2% of sales outcome variations. The relationship between BERD and sales performance in France shows a more defined negative pattern than the weak connection found in Germany.

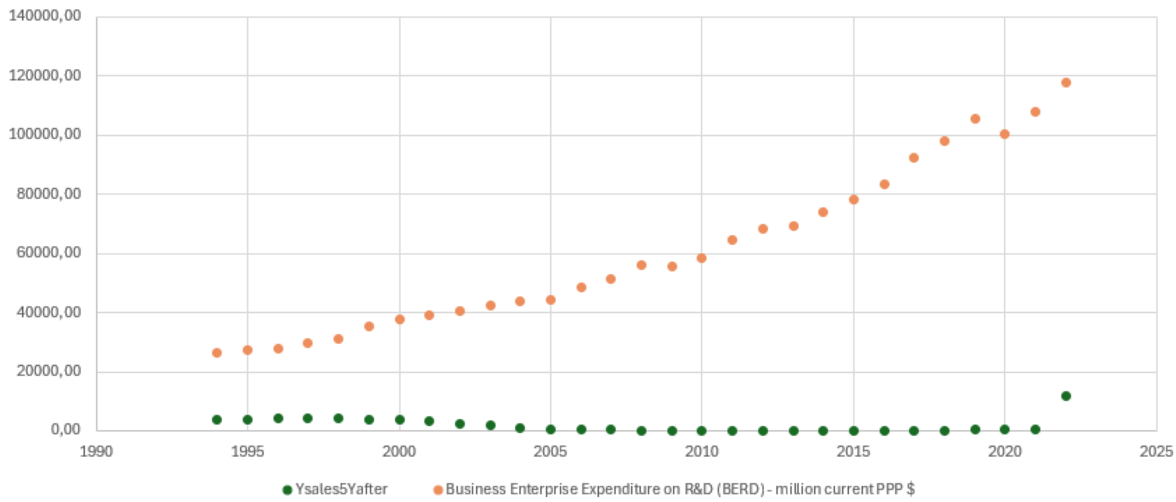

Figure 24. Graphic view of the statistical regression model – Germany

The trend data offer additional information about the situation. The German business enterprise research and development (BERD) expenditures grew substantially from 26 billion PPP$ in 1994 to reach 118 billion PPP$ in 2022 which demonstrates Germany's position as a major European research and development investor. The Ysales5Yafter indicator showed a significant downward trend since its peak above 3,900 in the mid-1990s until it reached below 200 in 2010 before experiencing a limited recovery during the most recent period. The significant increase in R&D spending does not match the prolonged sales stagnation which indicates a fundamental problem in the system. The German firms dedicate substantial funds to research yet their post-establishment sales performance remains weak because returns occur late or focus on particular industries that escape the overall measurement or face market-related counterbalances.

ITALY

Table 7. Correlation between BERD and Firms' Sales value 5 years after the observation period – Italy

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,665219948							
R Square	0,442517579							
Adjusted R Square	0,421870082							
Standard Error	391,3643699							
Observations	29							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	3282658,339	3282658,339	21,43202041	8,24395E-05			
Residual	27	4135483,891	153166,07					
Total	28	7418142,231						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	1079,825603	168,4835673	6,409085586	7,25313E-07	734,1258777	1425,525327	734,1258777	1425,525327
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,051419191	0,011106921	-4,629473016	8,24395E-05	-0,07420871	-0,028629671	-0,07420871	-0,028629671

The Italian regression analysis demonstrates a powerful negative relationship between R&D spending and sales performance. The medium-term analysis shows that R&D spending increases lead to decreased sales performance according to the -0.051 coefficient. The R^2 value of 0.44 demonstrates that BERD levels explain 44% of sales outcome changes and the p-value below 0.001 proves the statistical significance of this relationship. The Italian case demonstrates the most direct and strongest negative relationship between R&D spending and sales performance when compared to Germany and Denmark.

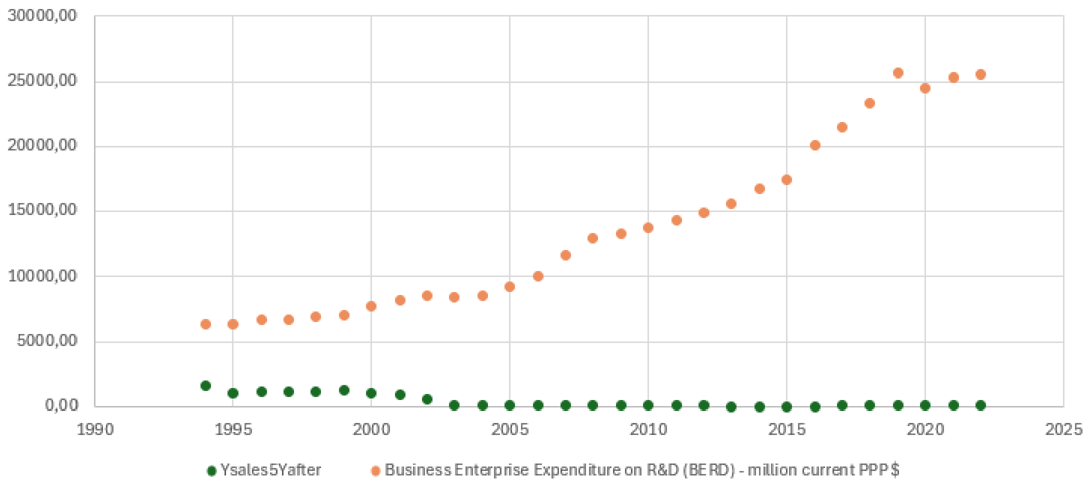

Figure 25. Graphic view of the statistical regression model – Italy

The time-series data demonstrate this divergence. The business sector maintained its R&D investment through steady growth of BERD from 6 billion PPP$ in 1994 to 25 billion PPP$ in 2022. The sales performance of the company declined after 2000 when it dropped from 1,600 in 1994 to less than 100 by the late 2000s before showing a limited recovery to 140 in 2022. The increasing R&D spending in Italy has not led to better commercial results for businesses because of resource allocation problems and market expansion obstacles that prevent innovation from reaching its full potential. The Italian case demonstrates the largest difference between R&D investment and commercial output among European countries which challenges the effectiveness of its innovation system for supporting cleantech businesses.

NETHERLANDS

Table 8. Correlation between BERD and Firms' Sales value 5 years after the observation period – Netherlands

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,154836668							
R Square	0,023974394							
Adjusted R Square	-0,012174703							
Standard Error	1218,564811							
Observations	29							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	984798,6694	984798,6694	0,663208659	0,422554399			
Residual	27	40092305,35	1484900,198					
Total	28	41077104,02						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	1597,995514	462,4986378	3,455135611	0,001832863	649,0266947	2546,964333	649,0266947	2546,964333
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,038347859	0,047088627	-0,814376239	0,422554399	-0,13496574	0,058270022	-0,13496574	0,058270022

The Netherlands shows a non-significant weak relationship between R&D expenditure and sales performance. The R^2 value of 0.02 indicates that R&D expenditure changes explain less than 2% of the total sales performance variation. The negative coefficient of -0.038 indicates a weak negative relationship but the p-value of 0.42 makes this association statistically insignificant. The regression results for Italy and France produced significant negative coefficients but Germany showed a weak relationship that still maintained statistical significance.

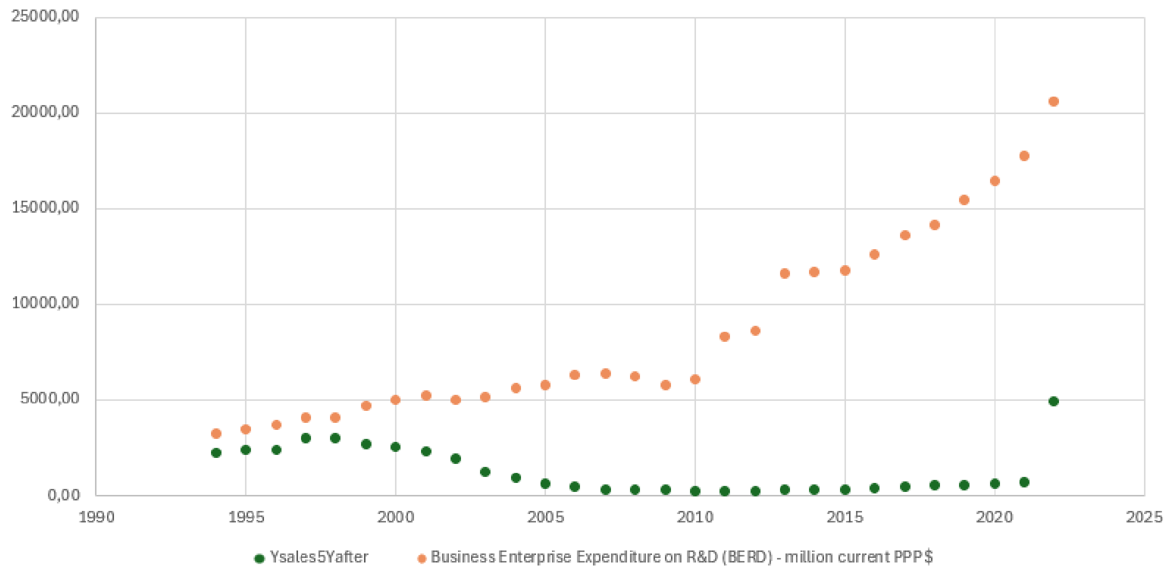

Figure 26. Graphic view of the statistical regression model – Netherlands

The descriptive patterns support this analysis. The business R&D expenditure of the Netherlands (BERD) increased progressively from 3 billion PPP$ in 1994 to reach more than 20 billion PPP$ in 2022. The average sales figures followed a different pattern by maintaining low values throughout the 2000s before showing a recent increase in 2022 when they reached nearly 5,000. The Netherlands shows business R&D spending growth without corresponding stable revenue increases at the firm level. The Dutch case shows no negative structural relationship between spending and sales but instead demonstrates a spending-sales mismatch which could stem from business cycle fluctuations and investment timing and sector-specific characteristics that extend the time before R&D activities produce commercial benefits.

9.4 Linear Correlations: BERD and Employment Dynamics

The relationship between R&D spending and employment results stands equally important to sales performance metrics. The number of employees in the workforce reveals how R&D investments create job opportunities in society. The research evaluates the relationship between BERD spending and new firm employee numbers. The analysis of BERD and employee-related variables through linear regression models reveals a detailed pattern of their connection. The relationship between R&D spending and new business employment rates shows different patterns across different settings because sectors and innovation approaches and labour market systems vary between locations. The assessment of R&D policies becomes more complete through employment analysis because it demonstrates how innovation creates social benefits.

DENMARK

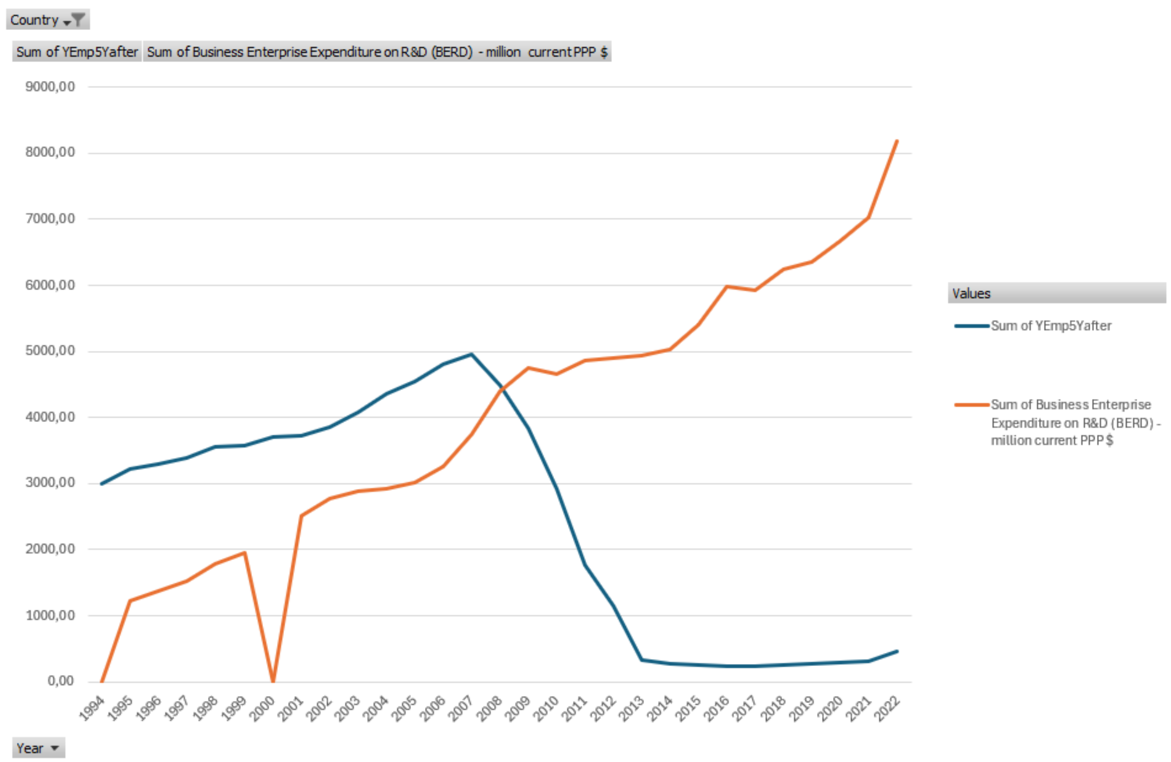

Figure 27. Graphic view of the following statistical regression model – Denmark

Denmark demonstrates an unbalanced relationship between research and development spending and subsequent job market expansion. The country strengthened its innovation capabilities through BERD which rose from 1,200 million PPP$ in 1995 to more than 8,000 million by 2022. The number of employees in firms during the five years after the period started at 3,000 to 4,000 in late 1990s before reaching 5,000 in 2007 but then plummeted to minimal numbers in the mid-2010s before showing small signs of recovery in recent times.

The rising business R&D investments in Denmark have not generated corresponding employment growth in new businesses. The data indicates that productivity growth and automation and capital-intensive sector development have caused R&D spending to lose its ability to create new jobs directly. The current situation reveals a contradictory pattern because companies dedicate record amounts to innovation yet these investments fail to generate substantial job creation which indicates a separation between research funding and workforce growth.

Table 9. Correlation between BERD and average number of employees in cleantech firms – Denmark

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,724295292							
R Square	0,52460367							
Adjusted R Square	0,506996399							
Standard Error	1244,09066							
Observations	29							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	46115117,92	46115117,92	29,794717	8,90988E-06			
Residual	27	41789562,4	1547761,57					
Total	28	87904680,32						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	4818,00134	491,1700412	9,809232926	2,1429E-10	3810,203661	5825,799019	3810,203661	5825,799019
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,60015873	0,10995032	-5,45845372	8,9099E-06	-0,82575816	-0,37455931	-0,82575816	-0,37455931

The regression model between business R&D spending and firm employee numbers in Danish companies shows a strong and highly significant relationship during the five-year period following the initial measurement. The model successfully explains more than 50% of employment growth changes which represents a significant improvement from the sales-based regression models. The Danish data shows that R&D investments directly affect labor market dynamics in the country. The regression model shows that business R&D spending leads to decreased employment growth rates during the medium-term period.

The research findings align with the concept that organizations conducting extensive research and innovation projects tend to undergo organizational restructuring. The short-term reduction of staff occurs when companies redirect their resources toward innovation development and automation and efficiency enhancement initiatives. The employment benefits from innovation investments become apparent when market-ready products generate fresh market opportunities. The Danish case demonstrates how R&D creates essential competitiveness but produces short-term job losses which represent a transitional period before achieving positive employment effects.

FRANCE

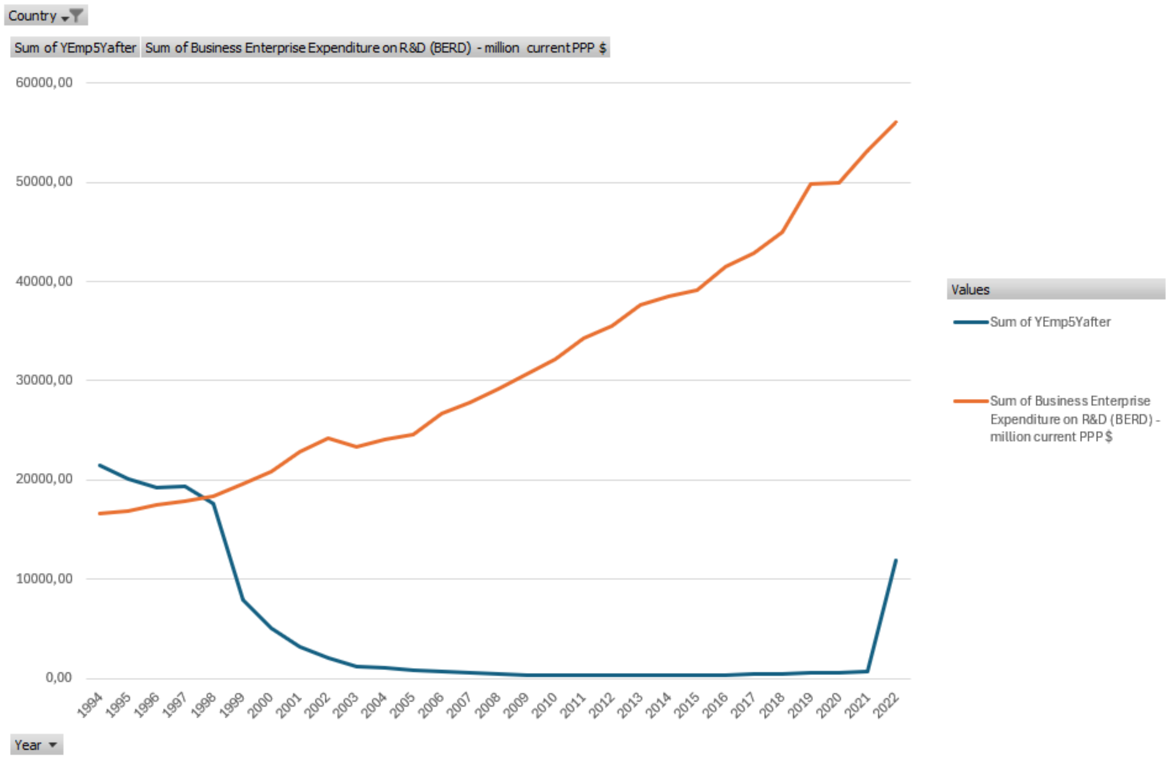

Figure 28. Graphic view of the following statistical regression model – France

The relationship between R&D spending and employment numbers in French businesses demonstrates an extreme separation between these two variables. The financial support for innovation through business enterprise R&D expenditure increased steadily from 16,600 million PPP$ in 1994 until it reached more than 53,000 million in 2022.

The employment numbers of new companies show an opposite trend compared to R&D expenditure. The employment indicator reached above 20,000 in the mid-1990s before experiencing a major decline that brought numbers below 5,000 in the early 2000s and maintained minimal levels throughout the following twenty years. The series indicates a minimal increase in 2022 but remains significantly lower than its previous maximum points..

Table 10. Correlation between BERD and average number of employees in cleantech firms – France

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,518453328
R Square	0,268793853
Adjusted R Square	0,241712144
Standard Error	6396,417895
Observations	29

ANOVA

	df	SS	MS	F	Significance F
Regression	1	406084976,1	406084976,1	9,925291326	0,003960937
Residual	27	1104682371	40914161,89		
Total	28	1510767347			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95,0%	Upper 95,0%
Intercept	14934,72277	3440,928704	4,340317413	0,000178948	7874,520253	21994,92529	7874,520253	21994,92529
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,321838936	0,102156723	-3,150443036	0,003960937	-0,531447217	-0,112230655	-0,531447217	-0,112230655

The regression analysis shows a statistically important relationship exists between the variables. The model explains 27% of employment growth variation which demonstrates a reasonable explanatory power for its basic regression structure. The negative BERD coefficient shows that higher research and development spending leads to decreased employment growth during the medium-term period.

Research investments in France lead to short-term employment decreases because companies restructure their operations. Companies that spend large amounts on innovation tend to move away from labour-based manufacturing toward technological advancements and automation which results in decreased job numbers during the first years. The extended development timelines of numerous French high-tech and pharmaceutical companies indicate that R&D will produce employment benefits only after an extended period of time. The regression results demonstrate that R&D creates positive employment effects in the long run, but these benefits become hidden by short-term negative impacts on employment.

GERMANY

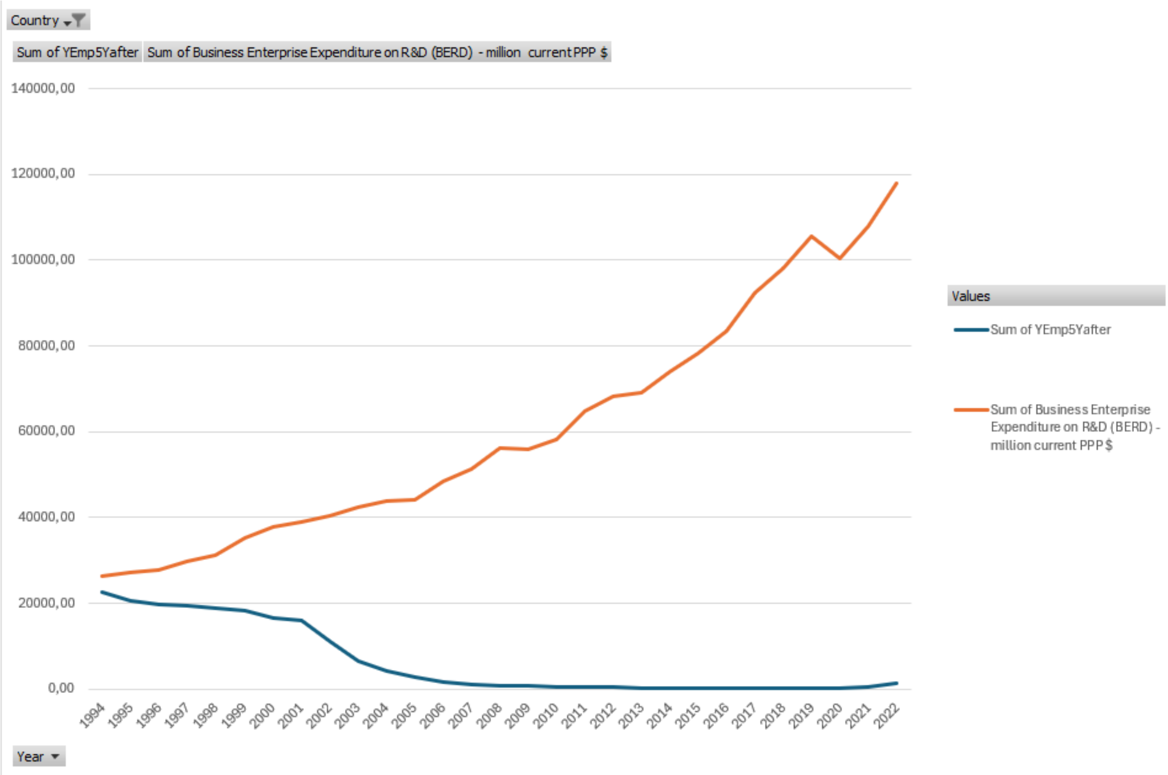

Figure 29. Graphic view of the following statistical regression model – Germany

The German business sector dedicated increasing amounts of money to R&D from 1994 to 2022 as their research and development spending grew from 26,000 million PPP$ to 118,000 million. The increased financial investment in R&D by German firms did not lead to equivalent job market expansion because the number of employees in new businesses decreased from 22,000 in the 1990s to fewer than 300 employees by the late 2010s.

The limited job creation from R&D investments may stem from automation and efficiency improvements and the concentration of funding in high-tech sectors which need specialized workers in smaller numbers. The German economy demonstrates how increased R&D spending can lead to productivity growth but does not necessarily create new employment opportunities for the general workforce.

Table 11. Correlation between BERD and average number of employees in cleantech firms – Germany

SUMMARY OUTPUT									
Regression Statistics									
Multiple R	0,749104999								
R Square	0,561158299								
Adjusted R Square	0,544904903								
Standard Error	5607,957149								
Observations	29								
ANOVA									
	df	*SS*	*MS*	*F*	*Significance F*				
Regression	1	1085802001	1085802001	34,52560238	2,93627E-06				
Residual	27	849127951,5	31449183,39						
Total	28	1934929952							
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*	
Intercept	20186,04631	2560,757285	7,88284248	1,78557E-08	14931,80636	25440,28625	14931,80636	25440,28625	
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,226992825	0,038631493	-5,875849077	2,93627E-06	-0,306258102	-0,147727548	-0,306258102	-0,147727548	

The regression model produces a strong and statistically valid result for Germany. The model successfully explains more than 50% of employment growth variations through its basic framework which demonstrates strong explanatory power. The model shows that business research and development expenses lead to decreased employment growth rates.

The German innovation system demonstrates this result because of its intricate nature. The German economy operates with industrialized foundations that depend on efficiency improvements and technological advancements and automation to stay competitive. The adoption of new processes and technologies through substantial R&D investments leads to temporary labour reduction in industries with industrialized economies. The employment benefits from innovation will emerge through new market opportunities and product development and increased demand which takes time to materialize.

ITALY

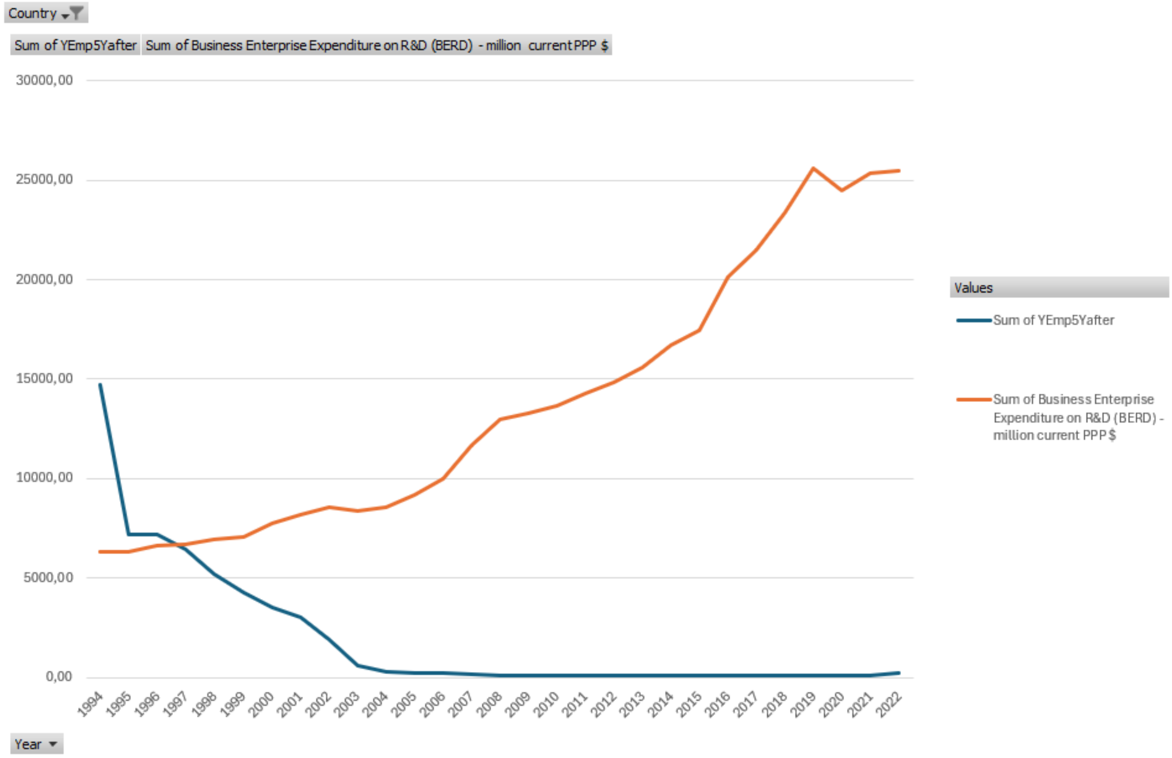

Figure 30. Graphic view of the following statistical regression model – Italy

The employment patterns in Italy diverged from its business research and development spending throughout the analyzed period. The Business Enterprise Research and Development (BERD) data shows continuous growth since 1994 when it reached 6,300 million PPP$ and then exceeded 20,000 million in 2016 before reaching more than 25,000 million in 2022. The financial support for research and innovation from firms has grown continuously since 1994 while the global financial crisis and Eurozone downturn did not stop this trend.

The employment statistics following new business establishment present an opposite trend from the initial numbers. The initial value of average employees five years after firm creation in 1994 reached 15,000 but experienced a significant decline throughout the following years. The employment numbers decreased to less than 3,500 during the early 2000s before remaining at minimal levels below 100 employees per cohort from 2005 until 2022 when they experienced a small increase. The increasing R&D investments in Italy have not led to new job creation because the funds primarily support capital-intensive sectors and large corporations that use technology to minimize their workforce needs. The 2022 employment numbers show potential signs of change, but the overall pattern demonstrates that innovation spending in Italy fails to create substantial job opportunities.

Table 12. Correlation between BERD and average number of employees in cleantech firms – Italy

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,577347408							
R Square	0,33333003							
Adjusted R Square	0,308638549							
Standard Error	2822,1194							
Observations	29							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	107517233,3	107517233,3	13,4997993	0,001040859			
Residual	27	215037663,5	7964357,908					
Total	28	322554896,8						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	5966,705909	1214,931098	4,911147567	3,86705E-05	3473,873205	8459,538612	3473,873205	8459,538612
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,29427369	0,080091749	-3,674207302	0,001040859	-0,458608385	-0,129938995	-0,458608385	-0,129938995

The regression analysis demonstrates a strong and steady relationship between these two variables. The model demonstrates substantial explanatory power because BERD explains about one-third of employment growth variations thus requiring further investigation. The Italian firms show negative employment growth rates following their R&D investment increases during the medium-term period. The strong and statistically significant result indicates that this pattern represents a fundamental characteristic of Italian business operations.

Italian manufacturing companies together with other businesses must handle two essential challenges by implementing modern production methods while maintaining affordable costs. The implementation of more efficient processes through R&D investments leads to higher automation levels which decreases labor requirements during short and medium-term periods. The time between technology development and commercial product launch and market expansion determines when innovation creates new job opportunities. The Italian data shows that R&D investments lead to innovation-driven rationalization because they drive long-term competitiveness yet result in employment reductions during the first few years after investment.

NETHERALNDS

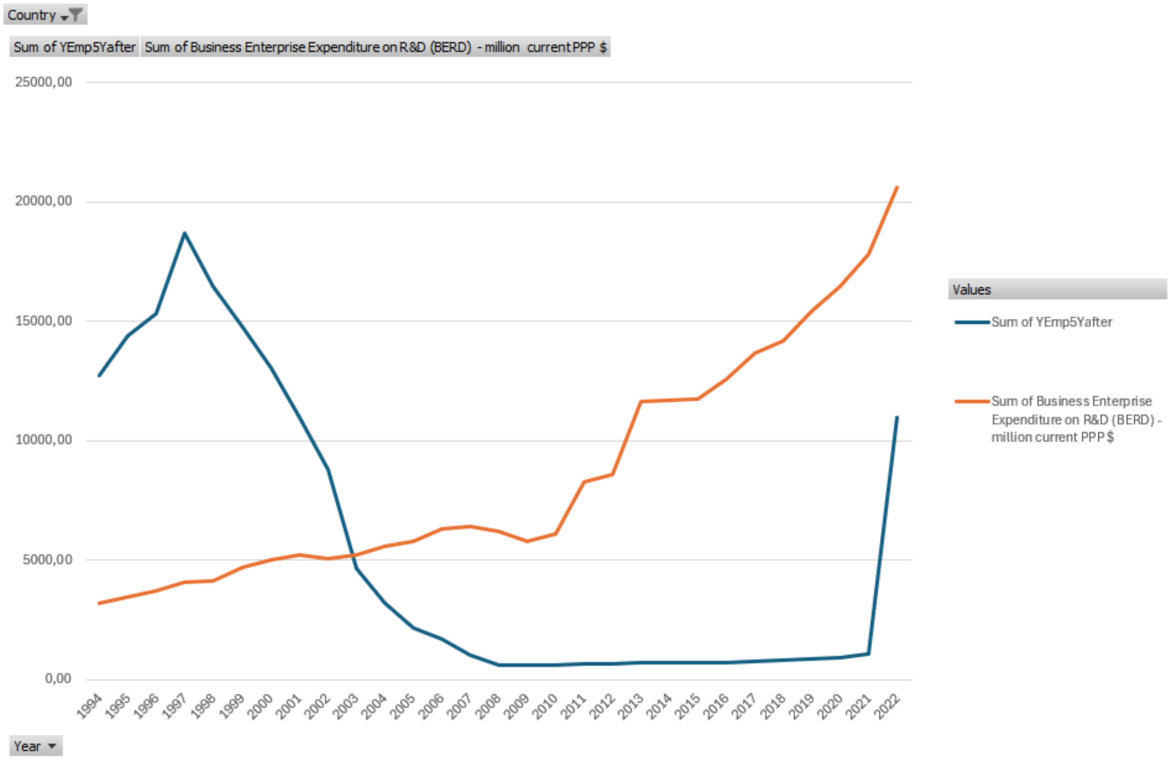

Figure 31. Graphic view of the following statistical regression model – Netherlands

The Netherlands shows a distinct pattern of business R&D expenditure effects on employment patterns throughout different time periods. New18,000 employees in 1997. The indicator experienced a steep decline during the 2000 businesses maintained a substantial number of employees during the late 1990s because their workforce numbers exceeded s until it dropped under 5,000 in 2004 before reaching almost zero in subsequent years. The employment numbers of new businesses started to recover in 2022 when they surpassed 10,000 employees but they remained below their previous peak levels.

Businesses in the Netherlands maintained a steady upward trend in their R&D spending throughout this time period. The business enterprise research and development (BERD) expenditure started at 3,000 million PPP$ in 1994 before reaching 16,000 million by 2020 and then surpassing 20,000 million in 2022. The Dutch economy underwent a fundamental transformation because companies dedicated more funds to innovation, yet these investments failed to produce lasting workforce growth in new business enterprises. The observed pattern indicates Dutch R&D activities now focus on high-tech sectors which deliver better efficiency and technological advancement rather than creating many new jobs thus raising doubts about innovation-driven strategies for social and labour market development.

Table 13. Correlation between BERD and average number of employees in cleantech firms – Netherlands

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0,481453399							
R Square	0,231797376							
Adjusted R Square	0,203345427							
Standard Error	5606,795045							
Observations	29							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	256109597,7	256109597,7	8,146977037	0,008186423			
Residual	27	848776068,2	31436150,67					
Total	28	1104885666						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95,0%*	*Upper 95,0%*
Intercept	10779,70096	2128,023924	5,065591996	2,55349E-05	6413,356531	15146,04539	6413,356531	15146,04539
Business Enterprise Expenditure on R&D (BERD) - million current PPP $	-0,618415431	0,216661663	-2,854290987	0,008186423	-1,062968442	-0,17386242	-1,062968442	-0,17386242

The Dutch case shows a statistically significant negative relationship between BERD and employment outcomes. The BERD coefficient shows a negative value of -0.618 with a p-value of 0.008 which proves that the observed relationship exists beyond random chance at standard confidence levels. The model successfully explains 23% of employment outcome variations through changes in BERD which results in an R^2 value of 0.23. The relationship between business R&D expenditure and employment numbers shows a significant connection even though the explanatory power remains moderate.

The negative coefficient value indicates that R&D resource distribution in the Dutch economy creates structural problems. Business R&D expenditure growth leads to decreased average employee numbers at new firms instead of creating more employment opportunities for employment. The Dutch business R&D focus on capital- and technology-intensive projects leads to short- and medium-term labour demand reduction because of efficiency gains and automation. The concentration of BERD investments in large established companies instead of smaller cleantech businesses restricts job creation through potential workforce spillovers. The model shows that firms sustain more than 10,700 employees when R&D spending is absent which supports the idea that Dutch R&D investments do not directly lead to workforce growth..

Conclusion

The comparison across Italy, France, Germany, Denmark and the Netherlands looks at a simple question: when firms spend more on R&D (BERD), do cleantech companies grow and hire more? The answer is not uniform. Using country trends and a set of straightforward regressions, the work shows where the patterns line up and where they diverge. The goal was to see whether business-led R&D is followed, after a few years, by higher revenues and more jobs, and to what extent national choices on sectors and funding matter.

A first look at totals helps to set the scene. R&D intensity rises in all five countries over the long run, but not in the same way. Germany is the clear outlier on scale and keeps most spending in manufacturing. France and Italy grow more slowly and split R&D across a broader set of activities. Denmark shows bigger swings, with a strong manufacturing push after the late 2000s. The Netherlands increases steadily from a lower base. These paths matter, because similar headline growth in R&D can hide very different mixes of sectors and funding.

Breaking BERD down by sector sharpens the picture. Manufacturing absorbs the bulk of business R&D almost everywhere and remains the anchor of industrial research—especially in Germany and Italy. Pharmaceuticals play a smaller, but distinct, role. Where pharma is more prominent (France and parts of Denmark), revenue effects tend to arrive later and are tied to a few knowledge-intensive players. The Netherlands only reports detailed sector data in recent years; even so, the move towards both manufacturing and pharma is visible, albeit from a modest starting point. In short, the sectoral split helps explain why the same euro of R&D can show up in sales today in one country and only a few years later in another.

The regression results keep the message grounded. The link between BERD and sales growth is mixed. Denmark and France post negative and statistically significant coefficients over the five-year window used, a result that fits with ongoing restructuring and the weight of R&D in knowledge-intensive activities where payoffs are slower. Italy shows a similar pattern, pointing to difficulties in converting spending into market scale. Germany's association is weak and not significant, despite its large volumes, size alone does not guarantee firm-level gains. The Netherlands shows almost no relationship in the period covered, which suggests a disconnect more than an inverse link.

Employment tells a comparable story. Higher BERD does not automatically translate into more jobs. Denmark and Italy show the clearest gap: business R&D climbs while average employment growth in cleantech falls. Germany's jobs decline sharply in the early 2000s and then level off at low rates, even as BERD remains high. France shows some signs of recovery in the most recent years, hinting at a slow re-alignment between spending and hiring. In the Netherlands, employment dynamics remain volatile and do not track the steady rise in BERD. Overall, productivity gains and capital-deepening appear to offset any direct hiring effects in the short to medium term.

Funding structures also differ. In Germany and Denmark, more than nine euros out of ten of BERD are financed by enterprises themselves. France and Italy rely a bit more on public support; the Netherlands sits in the middle with fluctuations over time. This matters for outcomes: privately financed R&D tends to chase projects with a clearer business case, which can narrow spillovers; public co-funding can help close the gap between research and market uptake, but its weight is small in most cases.

Methodologically, combining trend charts with simple regressions proved useful. It separates broad movements from specific links to sales and jobs and allows for lags of three to five years, which is closer to how R&D pays off in practice. The approach is descriptive rather than causal, but it highlights where the signals are consistent and where the numbers push in different directions.

There are limits, and they point to the next steps. Country averages can hide important differences within each economy. Firm-level data would help identify which types of cleantech companies benefit from BERD and which do not. The focus on sales and employment is necessary but not sufficient; innovation outputs (patents, prototypes, time-to-market), adoption metrics, and resource-efficiency indicators would give a fuller picture. Methods could also be extended – panel models with richer controls, policy discontinuities, or matched firm-level designs – to get closer to causality. Finally, it would be useful to track whether public-private mixes in funding shift the timing of returns.

The bottom line is straightforward. Business R&D is **necessary** for cleantech growth, but it is **not sufficient**. What matters is where the money goes (manufacturing vs. pharma and other services), who pays for it, and whether firms and institutions can absorb and scale the resulting knowledge. Germany shows the limits of scale without clear firm-level payoffs; France and Denmark illustrate how knowledge-intensive R&D can raise productivity before it boosts sales or jobs; Italy confirms the challenge of turning spending into market traction; the Netherlands shows steady investment with weak transmission to firm outcomes. For policy and corporate strategy, the implication is practical: increase BERD, yes, but tie it to sector priorities, complementary adoption policies and financing tools that help carry ideas from labs to markets.

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