Improving the quality of public spending in Europe

Green transformation

STUDY

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European Added Value Unit

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Linking national spending on the environment with the effects it has on the environmental performance of EU Member States allows for a better assessment of the effective quality of budgetary interventions. In this analysis, based on the detailed research paper in the Annex, we discuss under what circumstances some public environmental expenditure could be spent more efficiently at EU rather than at national level. We estimate that this transfer towards a more efficient level of governance would allow Member States to save between €20 billion and €26 billion of budgetary spending per year. In the present exacerbated economic, social and environmental crisis, we conclude that reducing budgetary waste and improving the way public money is spent should be fully integrated to achieve more sustainable development.

EPRS | European Parliamentary Research Service

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The annexed study was prepared by Prof. Dr. Samantha Bielen of Hasselt University, Faculty of Business Economics, at the request of the European Added Value Unit (EPRS).

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Executive summary

The European Added Value Unit of the European Parliamentary Research Service (EPRS) has developed a method to estimate the **budgetary waste rate**.[1] By comparing whether public expenses would be spent more efficiently and bring more added value at EU level rather than at national level, the rate of wasted public spending is estimated. Previous EPRS publications have shown that there is a **considerable opportunity for EU governments to generate savings through more efficient public spending**.[2]

This is the third study done using this method. First, we applied it to evaluate more broadly the savings that could be expected by looking at:

- general public environmental expenditure.

The analysis then looks at two subdomains of this spending:

- wastewater expenditure; and
- ambient air, soil and groundwater protection, as well as noise abatement expenditure.[3]

We chose these subdomains of environmental policy and spending due to the availability of data and the fact that we wanted to apply the budgetary waste rate method to the environmental field (we already conducted an analysis of the waste rate in the field of climate mitigation spending related to the European Union Emissions Trading System in the 2020 waste rate study).[4]

This report emphasises that a broader systemic reflection is needed as to the optimal governance level for public spending, especially in times of economic, social and environmental crisis. In particular, more efficient expenditure on environmental purposes could help the EU to achieve its ambitious environmental objectives, called the 'green transformation' in this research.

For this project, we have commissioned an external study – the research paper in the Annex – whose results indicate that moving to the efficiency frontier in that field could achieve between **€20 billion and €26 billion of savings** in public environmental spending per year for the whole EU. The same intermediate output could be achieved by using less inputs – i.e. less environmental spending. This could contribute not only to a better economic situation but also improve the environmental performance of EU Member States. It also means that these savings could be available as additional **investment to improve EU environmental quality and ensure the well-being of EU citizens**.

By analysing in more detail selected environmental policy areas (wastewater management as well as groundwater, soil, air and noise pollution), the study also highlights the need for stronger partnerships between institutional levels and to refrain from top-down and one-size-fits-all approaches. Therefore, the study confirms that the real question should not only focus on budgetary means at EU level or national level, but rather on mobilising more budgetary resources at the level where they help to increase efficiency and maximise added value.

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1 Saulnier J., Improving the quality of public spending in Europe – Budgetary 'waste rates' in EU Member States, EPRS, European Parliament, October 2020.

2 Müller K., Navarra C. and Jančová L., Improving the quality of public spending in Europe – Social policy, EPRS, European Parliament, April 2022.

3 These two groups of government environmental protection expenditure are reported by Eurostat, which uses the Classification of the Functions of Government (COFOG) terminology. What we call the 'ambient air, soil and groundwater protection as well as noise abatement expenditure' is classified in the COFOG under 'pollution abatement'. We use this more descriptive term to avoid any confusion as to what type of pollution abatement is concerned.

4 Saulnier J., Improving the quality of public spending in Europe – Budgetary 'waste rates' in EU Member States, EPRS, European Parliament, October 2020.

More specifically, analysis in the research paper in the Annex on **wastewater management expenditure** by EU Member States reveals that a shift to more efficient governance would be beneficial. The quantitative analysis of EU governments' spending in this category shows a certain level of inefficiency, as the same intermediate output could be achieved with less input, i.e. budgetary resources. A more detailed analysis concludes that there may be potential for both scale effects and cross-border spillover effects. This might be an argument for more EU direct action in this area, although further comprehensive evaluations would naturally need to confirm these tentative sectoral results.

The quantitative analysis of EU Member States' expenditure on **ambient air, soil and groundwater protection as well as noise abatement** also shows that there is a certain level of inefficiency in public spending at national level. However, the partial analysis found no evidence that shifting pollution abatement expenditure to EU level would result in increased scale efficiency or spillover effects that could be internalised. This might be an argument for more EU coordination of action by Member States in this area, although, again, more quantitative evaluations, as well as more in-depth qualitative ones, are needed to confirm these tentative sectoral results.

To conclude, efficiency of public spending needs to move higher up the EU political agenda, the need for financing to ensure a successful green transformation being one of the current priorities. From that point of view, **EU institutions have a central role to play** to ensure that all levels of administration are represented and more fully integrated in the decision-making process. A stronger culture of partnership that links all levels should be pursued to move away from suboptimal allocation of resources and related budgetary waste.

The European Parliament is a strong supporter of ambitious financing of EU climate and environmental policies to help achieve EU carbon neutrality and other environmental objectives. The Parliament is also advocating, in line with the environment action programme to 2020 adopted by EU Member States, for an increase in governments' national environmental spending.

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1. The rationale for efficient environmental budgetary spending in the EU

This study is the third in a series of analyses of national budgetary waste rates. As with the previous publications,[5] it is based on a method developed by the European Added Value Unit (EAVA) of the European Parliamentary Research Service (EPRS). Its goal is to establish whether and under what circumstances budgetary benefits and cost savings can be realised by Member States by shifting spending to the EU level instead of keeping them at national level, and to measure the scale of such benefits and savings. Higher EU added value in environmental expenditure could be achieved through efficiency gains and economies of scale, new public goods, better integration of externalities (key in the environmental field) and lower administrative and public procurement costs delivered by the EU budget. This can also result in savings for national budgets.

Faced with an extremely challenging economic environment where risks are increasing and where large budgetary gaps are identified, the lack of efficient common EU spending in some areas appears unsustainable, particularly if some budgetary resources are wasted (spent inefficiently) at Member State level. A recent EPRS study on budgetary waste rates in EU Member States showed that between €160 billion and €180 billion of public money per year could be saved without compromising the delivery of public goods, if the partnership between all institutional levels was reinforced to arrive at an organisational architecture closer to the efficiency frontier. Reducing budgetary waste could be an important argument in discussions over how to achieve higher levels of solidarity and more efficiency in spending. It could also be used as a strong argument against some resistance to beneficial organisational change and to transferring budgetary resources to the most efficient administrative level.

This question of the optimal allocation of budgetary resources between various spatial levels (local, regional, national and supranational) is not new and has been a recurrent source of debate within the academic community. Regarding the EU, and as already explained more than 40 years ago in the insightful MacDougall report, it appears increasingly difficult to argue that a budget of 1 % of Gross National Income (GNI) makes any rational sense for a zone that shares a common currency and a single market and aims for a role as a global actor. This also raises a question over potential misallocation of budgetary resources within EU Member States, as centralised budgets in Member States (on average around 20 % of GDP) are far higher than the 1 % of GNI currently agreed and allocated to the EU-level budget. This is an even more preoccupying challenge in the field of environmental expenditure, considering that the EU has a unique window of opportunity to address urgent sustainability challenges and the need for large additional investment to achieve the ambitious targets that the EU has set in this field.[6]

The research paper in the Annex looks more precisely at these issues and provides a detailed evaluation of potential room for improvement in national-level public spending on environmental policy (the 'green transformation').[7] It uses the same methodology as the one described in detail in

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[5] Saulnier J., Improving the quality of public spending in Europe – Budgetary 'waste rates' in EU Member States, EPRS, European Parliament, October 2020; Müller K., Navarra C. and Jančová L., Improving the quality of public spending in Europe – Social policy, EPRS, European Parliament, April 2022.

[6] European Environment Agency, The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe.

[7] Data in the research paper in the Annex relies mainly on Eurostat, which defines 'expenditure for environmental protection' as consisting of 'outlays and other transactions related to: inputs for environmental protection activities (energy, raw materials and other intermediate inputs, wages and salaries, taxes linked to production, consumption of fixed capital); capital formation and the buying of land (investment) for environmental protection activities; users' outlays for buying environmental protection products; transfers for environmental protection (subsidies, investment grants, international aid, donations, taxes earmarked for environmental protection, etc.)'.

the previous EPRS waste rate study. The results show that, should the EU exploit potential synergies in this area to the maximum extent possible by moving towards the efficiency frontier, between €20 billion and €26 billion could be saved every year. In other words, between **€20 billion and €26 billion could be available for additional investments directed towards improving environmental quality and the lives of EU citizens.**

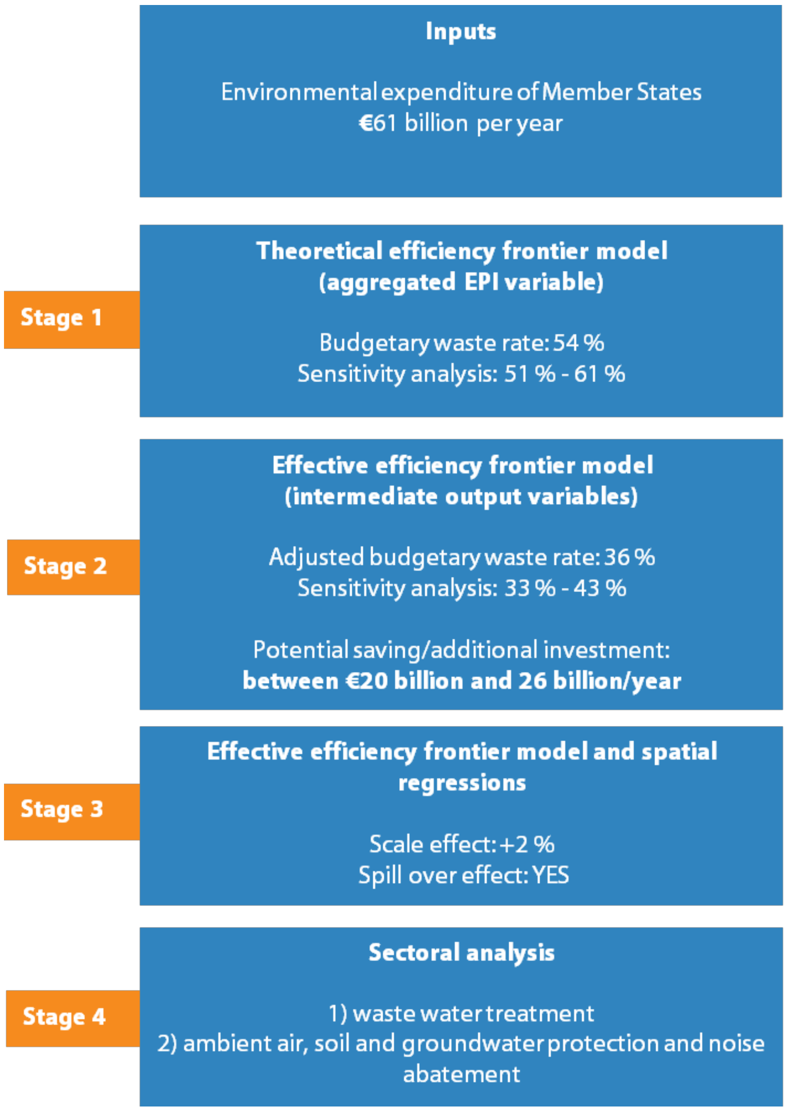
By analysing in more detail selected environmental policy areas (wastewater management as well as groundwater, soil, air and noise pollution), the study also highlights the need for stronger partnerships between institutional levels and to refrain from top-down and one-size-fits-all approaches. Therefore, the study confirms that the real question should not only focus on budgetary means at EU level or national level, but rather on mobilising more budgetary resources at the level where they help to increase efficiency and maximise added value.

From that point of view, **EU institutions have a central role to play** to ensure that all levels of administration are represented and more fully integrated in the decision-making process. A stronger culture of partnership that links all levels should be pursued to move away from suboptimal allocation of resources and related budgetary waste.

2. More efficient organisation of environmental spending would help the EU achieve its green transformation

The research paper presented in the Annex applies the EPRS waste rate methodology to EU Member States' budgetary and fiscal policies related to the green transformation of the European economy. For this purpose, the paper analyses EU Member States' environmental expenditure that helps to achieve the EU's environmental and climate ambitions.[8] The key research question is if and to what extent, in line with the EU subsidiarity and proportionality principle, the aggregation or coordination of budgets, oversight and competences at EU level generates additional added value (or, alternatively, saves resources but maintains constant performance). The analysis follows a four-step approach (see Figure 1).

Figure 1. Budgetary waste rate of EU national environmental expenditure – key selected results



Source: EPRS.

[8] Eurostat data on environmental expenditure used in the research in the Annex is from 2018, which is the latest available year for all Member States.

First, by using data envelopment analysis (DEA) of Member States' production of public services ('environmental protection') the study compares the capability of different Member States to reach the level of desirable environmental output with the lowest use of inputs. This allows us to compute a theoretical efficiency frontier and to derive efficiency scores and budgetary waste for Member States. The inputs are national environmental expenditures[9] based on Eurostat data; the final outcome is the rank in the Environmental Performance Index (EPI).[10] Overall, the quantification results for this first stage of analysis show that, from a theoretical point of view, the same level of environmental protection could be achieved with between 51 % and 61 % less budgetary resources.

Second, the analysis is enriched by comparing this theoretical result to what could be effectively achieved in practice, as it is unlikely that the efficiency materialises to the full extent indicated. For that purpose, a complementary DEA analysis includes intermediate outputs, focusing more specifically on the contribution by green energy generation (wind, solar and hydro) to total net energy generation.[11] This constitutes a good proxy for the current extent of green transformation of the production system in EU Member States; the inputs are still national environmental expenditures based on the Eurostat data, as in the previous step of the analysis. Overall, the quantification results for this second stage of analysis show that the same level of environmental protection could be achieved with between 33 % and 43 % less budgetary resources. This means that, theoretically, there are potential savings in achieving environmental outputs of between €20 billion and €26 billion annually by the Member States if their environmental spending was shifted to the EU level and used in an efficient way.

Third, the analysis goes beyond the DEA to refine the estimates of whether there are any returns-to-scale or cross-border spillover effects that could explain differences in Member States' structural organisation and preferences. For this purpose, the paper uses spatial regression models[12] and incorporates the effect of economic, social, political and geographical variables.[13] This stage of analysis allows us to evaluate potential returns-to-scale and spillover effects. The results indicate that a better allocation of spending at EU level would allow exploitation of scale effects, which results in an increase in efficiency of around 2 %. The results also show the existence of significant spillover effects, which could be internalised by allocating environmental expenditure at EU level.

Fourth, a sectoral analysis is conducted by focusing on two specific sectors of particular interest for EU policy, namely wastewater and ambient air, soil and groundwater protection, as well as noise abatement. The rationale for further decomposing the analysis is that some categories of Member States' environmental expenditure may not necessarily show increased efficiency if moved to spending at EU level.

For **wastewater management**, the input measures are Member States' expenditures for this purpose that are used to operate sewage systems and wastewater treatment.[14] They amount to nearly €20 billion annually for all EU Member States combined.

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9 They amount to a total of over €61 billion combined for all Member States per year.

10 EPI is an index developed by the Yale Center for Environmental Law & Policy. It is composed of performance indicators across 10 issue categories, ranking 180 countries on environmental health and ecosystem vitality. For details, see Wendling Z., Emerson J., Esty D., Levy M., de Sherbinin A. et al., 2018 Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law & Policy.

11 The study in the Annex uses the Eurostat data on 'net electricity generation', available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Net_electricity_generation

12 For details see Section 2.3 in the research paper in the Annex.

13 For this, the EPI score of a Member State is correlated with its GDP per capita, GDP growth, population density, country surface area, education and social development levels, industry value added, trade intensity, road length and urban population density. For the sources of this data, see Section 2.4 in the research paper in the Annex.

14 As a percentage of GDP (2018), based on Eurostat data. For details, see Section 4.1 in the research paper in the Annex.

The resulting EPI rank on wastewater treatment is selected as a final outcome. The final results for wastewater management that include the economies of scale and cross-border spillover effects again show that it would be beneficial for all Member States to move towards more efficient organisation of budgetary spending. Quantitative analysis shows that there is a certain level of inefficiency in national spending on these abatement measures, as the theoretical budgetary waste rate is 69 %. Further detailed analysis concludes that there may be potential for both scale effects and cross-border spillover effects. This might be an argument for **more direct EU action** in this area, although further comprehensive evaluations would naturally need to confirm these tentative sectoral results.

For efficiency of national spending on **ambient air, soil and groundwater protection as well as noise abatement**, related expenditure reported by Eurostat was used as an input measure.[15] This expenditure, which, in all EU Member States combined, amounts to almost €16.5 billion annually, serves to construct and deploy different measures such as: monitoring systems and stations (other than weather stations); anti-noise protection; measures to clean water pollution; measures to control or prevent the emissions of greenhouse gases and pollutants that adversely affect the quality of the air; and installations to decontaminate polluted soils, to store pollutant products and transport pollutant products. Several indicators from the EPI are selected as final outcomes; the three main ones are 'PM2.5 exposure', 'PM2.5 exceedance', and 'NOX emissions'.

Quantitative analysis shows that there is a certain level of inefficiency in national spending on these abatement measures, as the theoretical budgetary waste rate is 38 %. However, the partial analysis found no evidence that shifting pollution abatement expenditure to the EU level would result in increased scale efficiency or spillover effects that could be internalised. This might be an argument for **more EU coordination** of action by Member States in this area, although again more evaluations are needed to confirm these tentative sectoral results.

15 For the sources of this data, see Section 5.1 in the research paper in the Annex.

3. Related EU environmental policy positions and ongoing developments

Currently, key EU climate and environment objectives to be achieved by 2050 are defined in the European Green Deal and consist of becoming a carbon-neutral continent, protecting and restoring biodiversity and reducing pollution levels to ones that are no longer considered harmful to health and natural ecosystems. Although these goals were defined in 2019 when the Commission published the European Green Deal, decarbonisation policies, as well as policies to abate and prevent pollution, have been pursued in the European Union for decades. Adequate financing of EU climate and environmental policy is therefore one of the key priorities and challenges in achieving the set goals.

With this research, we aim to contribute with evidence to the discussion on higher effectiveness and efficiency of public spending. Less wasteful environmental expenditure by governments is a not-to-be-missed opportunity for EU Member States. This seems especially important in the context of the current economic, social and environmental crisis, which requires unprecedented investment to ensure social cohesion while transforming to a green economy. In this section, we present a brief overview of relevant EU climate and environmental policy positions and developments.

3.1. European Parliament position

The European Parliament has, for years, been a strong supporter of ambitious climate and environmental action. Since 2019, it has been backing the European Green Deal put forward by the current European Commission and its targets of achieving climate neutrality, mainstreaming biodiversity protection across all policy areas, and achieving zero pollution by mid-century. Recently, the Parliament has been **advocating a high level of EU spending on climate and the environment** in the current EU budget framework (for the period 2021-2027) and for the EU budget mainstreaming target for climate of 30 % and for biodiversity of 10 %. Consequently, in its position on the 2021-2027 EU budget, the Parliament proposed the highest level of spending in the 'natural resources and environment' heading, compared with the Commission and the Council.[16]

The Parliament has also been a strong advocate for increasing EU own resources and linking them with EU priorities such as climate action (e.g. by introducing a carbon border adjustment mechanism). Finally, the Parliament is calling for a strengthening of the tracking methodology in relation to climate and biodiversity mainstreaming in the EU budget, as shortcomings in this area were revealed by the European Court of Auditors in the previous budgetary term. In particular, the Parliament underlined, in its position on the future EU budget, that there should be better monitoring of the impact of EU budget resources on climate mitigation and adaptation.

In addition, the Parliament has been **supportive of more ambitious environmental spending at national level**. In its resolution on the European Green Deal, the Parliament highlighted that significant amounts of resources to achieve the Green Deal objectives will have to come from national budgets. Consequently, it called to pursue sustainable fiscal policies and enable public sustainable investment. In its amendments to the proposal for an 8th environment action programme to 2030,[17] which sets priorities and actions for EU environmental policy up to 2030, the

[16] Kowald K., Natural resources and environment. Heading 3 of the 2021-2027 MFF, EPRS, European Parliament, April 2021.

[17] Position of the European Parliament adopted at first reading on 10 March 2022 with a view to the adoption of Decision (EU) 2022/… of the European Parliament and of the Council on a General Union Environment Action Programme to 2030. At the time of writing, the decision has not yet been published in the Official Journal, but the position adopted by the European Parliament reflects the compromise agreement reached between the co-legislators.

Parliament underlined that spending at Member State level should remain constant throughout the years (at around 2 % of GDP), despite an EU objective set in the previous environment action programme to 2020 to increase public and private sector funding for the environment and climate.[18] It also pointed out the Commission's estimate of an annual cost of €55 billion due to non-implementation of EU environmental policies, and stressed that monitoring, assessment and reporting of environmental indicators should be strengthened and should allow performance to be measured against targets. In its amendments, the Parliament proposed fixed deadlines for phasing out fossil fuel subsidies (by 2025) and other harmful subsidies (by 2027).

In the current term, the Parliament has also expressed its **concerns and recommendations regarding financial resources needed to tackle water, soil and air pollution** in Europe. In a 2020 resolution, the Parliament expressed the importance of adequate financing in the EU water sector to achieve compliance with relevant water legislation and to address the existing investment gap in this sector. In 2021, while calling to establish an EU legal framework ensuring protection and sustainable use of soil, the Parliament stressed the need for adequate financial resources for this purpose.

When it comes to air pollution, in 2021 the Parliament expressed its concern about non-compliance by Member States with some relevant legislation, and of significant implementation and enforcement gaps at Member State level resulting in increases of some air pollutants. Consequently, it called for further strict EU measures to reduce pollution levels in all sectors, and particularly in industrial installations, road and maritime transport, aviation, buildings, agriculture and energy production. Moreover, the Parliament recommended supporting Member States in their actions by dedicating existing EU funds to clean air objectives.

3.2. EU governments and European Commission

In 2019, European leaders set a direction for the EU strategic agenda for 2019-2024. One of the four strategic priorities calls for 'building a climate-neutral, green, fair and social Europe'. It acknowledges that **succeeding in the green transition will depend, among other efforts, 'on significant mobilisation of private and public investments'** and that climate action will need to be pursued in parallel with environmental protection and reduction of pollution levels. Moreover, by adopting the current EU budget and the EAP by 2030, EU governments committed themselves to mainstreaming climate and the environment in EU spending and to making the best use of green budgeting and financing tools.

By presenting a new growth strategy – the European Green Deal – among its key political priorities for 2019-2024, the European Commission went a step further compared to previous political programmes, as it envisages **mainstreaming climate and environmental protection throughout EU policies and action**. One of the European Green Deal's aims, relevant for this research, is to help EU Member States adopt and implement green budgeting practices. Consequently, the European Commission is supporting EU governments in pursuing budgetary reforms that will **improve national budget practices to align them to deliver on climate and environmental policies**.[19]

Also, when presenting the new EU budget for 2021-2027, the Commission proposed an increased ambition (to 25 % from the previous 20 %) for climate mainstreaming, in line with the EU political

[18] National environmental expenditure is one of the indicators introduced in the 7th EAP to monitor Member States' progress in environmental policy. The evaluation of the 7th EAP mentions that this expenditure has remained constant since 2000.

[19] European Commission, Supporting the Implementation of Green Budgeting Practices among the EU Member States.

commitments.[20] The agreed budget envisages an unprecedented 30 % climate mainstreaming commitment, in line with the target advocated by the Parliament.[21] In absolute terms, the **EU budget resources for climate and environmental protection under the current budget period (2021-2027) amount to a record €326 billion**. This means around €47 billion per year. Moreover, a target for biodiversity mainstreaming in the EU budget was agreed between the EU institutions (7.5 % in 2024 and 10 % from 2026).

Importantly, and in relation to the effectiveness of public spending on environmental purposes, the new EU budget agreement also envisages improvements in the methodology for tracking climate- and environment-related expenditure, also in line with the Parliament's position. In addition, with a view to greening the EU budget, an interinstitutional agreement on budgetary matters between the Parliament, the Council and the Commission envisages several mechanisms to ensure the money is contributing to the achievement of climate and environmental targets.

3.3. EU citizens

EU citizens are very supportive of more public action on climate and environmental protection, as an EU-wide opinion poll revealed that they think more could still be done in this field.[22]

- **Over half of respondents replied that local governments are not doing enough to protect the environment,**
- **over 70 % answered that their national governments are not doing enough, and**
- **68 % said that the EU is not doing enough.**

Interestingly, analysis of other public surveys revealed that there is a notable discrepancy between the EU budgetary means that Europeans think are spent on climate change and the desired level of EU spending in this area.[23] In the previous budgetary period from 2014 to 2020, EU citizens' willingness to spend more on climate and the environment increased rapidly up to 40 %. In 2020, citizens' perception of how much is actually spent on these areas at EU level was even higher (22 %) than the planned level of spending (20 %). This shows wide support among citizens for more ambitious budgetary spending at EU level in this area.

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20 As this paper and the research in the Annex analyse the possibility of shifting public environmental spending from national to EU level, i.e. to the EU budget, we do not focus here on other financial instruments that are designed to facilitate the EU green transformation – such as Next Generation EU, InvestEU and the Just Transition Fund – as well as revenue generated through the EU Emissions Trading System (EU ETS), which finances the Innovation Fund and the Modernisation Fund.

21 Council Regulation (EU, Euratom) 2020/2093 of 17 December 2020 laying down the multiannual financial framework for the years 2021 to 2027.

22 European Commission, Special Eurobarometer 501: Attitudes of European citizens towards the environment, December 2019.

23 D'Alfonso A., Matching priorities and resources in the EU budget: Climate action, migration and borders, EPRS, European Parliament, May 2021.

4. Conclusion – More, better and fairer environmental protection through efficient EU involvement

To achieve the objectives of the green transformation, large budgetary resources have been mobilised. The EU budget will also be complemented by the new Next Generation EU instrument, worth €750 billion, that will be spent through Member States' budgets; 37 % of it is planned for addressing climate change and the environment. These resources will be indispensable, for example, to scale-up and deploy emerging low carbon technologies and their enabling infrastructure, to invest in processes and technologies that help to reduce pollution, and also to support research, development and innovation to keep the EU green economy competitive. At the same time, fossil fuel subsidies and other budgetary instruments harmful to the environment will need to be phased out and the polluter-pays principle enforced. In parallel, new support schemes helping low-income households and other vulnerable groups in society will have to be envisaged to ensure that the green transition is socially just and leaves no one behind. Despite this planned mobilisation of resources, many risks prevail.

- First, without necessary EU ambition and leadership, there is no certainty that all the necessary resources will be mobilised on time and that the investment gap will be closed to achieve the European Green Deal's climate and environmental objectives by 2050.
- Second, without EU assessment of potential budgetary waste, the risk of non-efficient allocation of resources (at EU and national levels) could hamper the EU's ability to ensure a just green transformation coupled with sustainable economic growth.
- Third, without EU surveillance and coordination, there is no certainty that all Member States will align budgetary resources with policies to succeed in the green transformation. The current crisis in fossil fuel prices, as well as the risk of Russia further cutting off gas supplies to the EU, have led to calls by some Member States to postpone planned national phase-outs of fossil fuels.
- Fourth, without proper EU guidance and stronger technical assistance, a risk of under-using available budgetary resources could also occur. Indeed, some Member States have a recurrent low rate of absorption of funds from EU budgets.[24] For these worst-performing countries, absorbing new resources in the next seven years might be a difficult task if improvements are not made,[25] especially since the new 2021-2027 EU budget, together with the recovery funds, amounts to unprecedentedly high levels of public resources.

To conclude, in light of the above, the discussion on efficiency and effectiveness of budgetary environmental spending is even more timely and necessary. In particular, if the EU aims to remain competitive, ensure a green transformation and successfully decarbonise its economy, ambitious spending both at EU and national level would need to continue at least until 2050. The recently agreed reinforcement of monitoring, verification and reporting on the progress of EU environmental policy is an opportunity to keep track and reflect on the quality of EU- and national-level climate and environment spending.[26]

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24 The latest available data (up to 31/12/2021) on financial implementation of resources from the previous EU budget for 2014-2020 show that some laggards have absorption rates below 55 %, compared with the EU average of 63 % (https://cohesiondata.ec.europa.eu/overview, accessed on 14/04/2022).

25 Darvas Z., Will European Union countries be able to absorb and spend well the bloc's recovery funding?, Bruegel Blog, 24 September 2020.

26 Article 4 of the General Union Environment Action Programme to 2030 (8th EAP) strengthens the monitoring framework and governance.

Annex

Identifying and computing EU Member States' budgetary waste rate in spending on green transformation

Research paper

As attention towards the environment in the EU has increased significantly in recent decades, local, regional, national and supranational policy makers are increasingly establishing environmental policy. This research paper aims to answer the question of whether and at which administrative level, from an efficiency standpoint, it could be beneficial to shift environmental policies with EU added value. To answer this question, this paper calculates and analyzes, for environmental spending, potential budgetary waste by EU Member States, economies of scale, and cross-border spill-over effects. We find evidence that some, but not all, subdomains of environmental spending have a positive budgetary saving ratio if shifted to the EU level.

AUTHOR

This research paper has been written by Prof. Dr. Samantha Bielen of Hasselt University, Faculty of Business Economics at the request of the European Added Value Unit of the Directorate for Impact Assessment and European Added Value, within the Directorate-General for Parliamentary Research Services (EPRS) of the Secretariat of the European Parliament.

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Executive summary

The purpose of this research paper is to analyze whether, from an efficiency standpoint, it would be desirable to shift environmental expenditures from the Member State level to the EU level based on three criteria: (1) budgetary waste, (2) economies of scale, and (3) cross-border spill-over effects. We follow the empirical approach of the EPRS study 'Improving the quality of public spending in Europe – budgetary 'waste rates' in EU Member States'.[1]

More specifically, from an economic point of view, if resources were allocated to the EU level and the EU would operate on the efficient production function as estimated using actual production by Member States, **budgetary waste** in public environmental expenditures could be avoided. Furthermore, if Member States operated under increasing returns to scale, shifting environmental spending to the EU level would allow the EU to exploit these **scale effects.** Both Member States' budgetary waste and scale effects are calculated using Data Envelopment Analysis (DEA). Spatial regression analysis is used to assess the existence of **cross-border spill-over effects**, which could be internalized and further increase efficiency in case of common EU action.

The analyses are conducted for total public environmental protection expenditures in EU27 and, subsequently, for two of its subdomains: (1) wastewater management and (2) ambient air, soil and groundwater protection and noise abatement.[2] We find that not all subdomains of national environmental spending have a positive budgetary savings ratio if shifted to EU level. The most important conclusions are presented briefly below.

For **total environmental protection expenditures**, budgetary waste rates are large, both in terms of final outcomes[3] and intermediate outputs[4] (Table 1 below summarizes the results). The results of the analyses indicate that the same amount of outputs and the same level of environmental protection could be achieved with 36 percent and 54 percent fewer resources, respectively, **a saving of almost €22 billion per year**. Furthermore, spending at the EU level would allow the exploitation of scale effects, which results in a further increase of efficiency of 2.1 percent (in terms of the production of green energy and circular material use). Finally, we found evidence for the existence of significant spill-over effects, which could be internalized by allocating environmental expenditures to the EU level. In sum, there is evidence in favor of shifting environmental expenditures to the EU level when considering efficiency.

Looking at more disaggregated results by sector, budgetary waste rates are also large regarding **wastewater management expenditures** (Table 2 below summarizes the results). Assuming that, if resources would be allocated to the EU level, the EU would operate on the efficient production function as estimated using actual production by Member States, the same amount of wastewater could be treated and the same share of resident population could be connected to a wastewater collecting system with 69 percent and 82 percent fewer resources, respectively. However, results in terms of economies of scale and spill-over effects are mixed. When focusing on the share of the population connected to wastewater treatment plants, we found both scale effects and cross-border spillover effects, which could be exploited and internalized in case of common EU action. However, there is no empirical evidence of (positive) scale effects or spill-over effects when considering the final outcome (that is, wastewater treatment). These results are not completely

[1] EPRS. (2020). *Improving the quality of public spending in Europe - Budgetary 'waste rates' in EU Member States.*

[2] We focus on wastewater management and ambient air, soil and groundwater protection and noise abatement because these subdomains are important parts of the European Green Deal. Furthermore, they have a cross-border dimension and an important impact on human health.

[3] An environmental performance indicator.

[4] The percentage of solar, wind, and hydro energy generation contributing to the total net energy generated, and circular material use.

surprising given the ongoing debate on the appropriate level of governance in the domain of (waste) water management.

The benchmarking analysis on **ambient air, soil and groundwater protection and noise abatement expenditures** shows that 38 percent of budgetary waste could be avoided if resources were allocated to the EU level (Table 2 below summarizes the results). Nevertheless, we found no evidence that shifting ambient air, soil and groundwater protection and noise abatement expenditures to the EU level would result in increased scale efficiency or for spill-over effects that could be internalized. Again, these results raise the question of the most appropriate level of budgetary governance in the domain of ambient air, soil and groundwater protection and noise abatement. They also confirm that the benefits that could be expected from the application of an optimal economic calculation should be considered as an upper limit of what could effectively be achieved in practice

Table 1: Summary results - general model

Model	Budgetary waste rate	Efficiency change if increase in scale	Spill-overs?
	Environmental protection		
Model A: Final outcome	54%	-8.87%	Yes
Model B: Intermediate outputs	36%	2.10%	Yes

Environmental protection: INPUT: Environmental protection expenditures; OUTCOME: Environmental performance index; INTERMEDIATE OUTPUT: Solar energy, wind energy, hydro energy, circular material use

Table 2: Summary results - sectoral model

Model	Budgetary waste rate	Efficiency change if increase in scale	Spill-overs?
	Wastewater management		
Model A: Final outcome	69%	-52.86%	No
Model B: Intermediate outputs	82%	5.08%	Yes
	Ambient air, soil and groundwater protection and noise abatement		
Final outcome	38%	-54.37%	No

Wastewater management: INPUT: Wastewater management expenditures; OUTCOME: Wastewater treatment (EPI); INTERMEDIATE OUTPUT: Population connected to wastewater treatment plant

Ambient air, soil and groundwater protection and noise abatement: INPUT: Ambient air, soil and groundwater protection and noise abatement expenditures; OUTCOME: PM2.5 Exposure (EPI), PM2.5 Exceedance (EPI), NOX Emissions (EPI)

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1. Introduction

In 1985, Jacques Delors defined the European Union (EU) as an "*Objet politique non-identifié (OPNI)*". The EU is still not a fully-fledged federation because Member States share sovereignty only for a small selection of issues (Blackley, 2011). However, the creation of the single market, and more importantly, the creation of the EMU, have been key milestones towards more integration, moving the EU away from simply a collection of interdependent individual regions.

The incompleteness of this framework, and the relative lack of corresponding substantial EU budgetary powers, however raise the following question: **What is the best organizational approach between various levels of governance, competences, and institutions** for an entity as the EU? Moreover, the goal of the EU is more than just a purely economic one. For example, Member States share a set of projects and values, such as democracy and human rights. An important ongoing debate concerns the discussion of **which policy areas should be assigned to the EU level, and to what extent, and which should remain at the Member State level or at another most appropriate level of governance (regional, local, or individual).**

In this report, **we focus on environmental expenditures** because, particularly in the last three decades (after the 1992 Rio conference and the 1997 Kyoto conference), the environment has received significantly increased attention. The Eurobarometer (2019) and the Eurobarometer (2021) show that citizens consider environmental issues (especially air pollution, marine pollution and pollution of rivers, lakes and groundwater) as the second-most important EU challenge. Furthermore, the majority of respondents indicate that citizens, companies, local and national governments, and the EU are not doing enough to protect the environment (Eurobarometer, 2019).

As a result, local, regional, national, and supranational policy makers are increasingly establishing environmental policies. An example is the European Green Deal, which aims to counter climate change and steer Europe towards being the first climate-neutral continent by 2050, as well as achieving zero pollution by 2050 (which is in line with the "do no significant harm" principle, which means achieving a toxic-free environment) (European Commission, 2021c).

However, ambitious goals such as the latter require sufficient and efficient environmental expenditures. One of the relevant issues in this regard is closely related to the **subsidiarity principle**, and raises the question of whether a budgetary intervention at the EU level when it comes to environmental expenditure could be beneficial. To allow such evidence-based decision-making, this report more specifically analyzes **whether, *from an efficiency standpoint*, it would be desirable to shift (certain) environmental expenditures**[5] **from the Member State to the EU level**. In trying to reply to this question, we follow the empirical approach of the EPRS study 'Improving the quality of public spending in Europe – budgetary 'waste rates' in EU Member States' to evaluate whether and under what circumstances Member States can realize budgetary benefits through shifting environmental expenditure from the national to the EU level.

We used a two-step approach. In the first step, we performed a Data Envelopment Analysis (DEA), which uses "linear programming methods to construct a non-parametric[6] piece-wise surface (or frontier) over the data" (Coelli et al., 2005). DEA allowed us to **compute the budgetary waste** rate of Member States' environmental spending and provided insights into potential efficiency gains due

[5] In Chapter 3, we focus on total environmental expenditures. In Chapters 4 and 5, we focus on specific subcategories; wastewater management and ambient air, soil and groundwater protection and noise abatement expenditures, respectively.

[6] A non-parametric method does not make assumptions about characteristics of the sample. Therefore, it does not require the parameterization of the production set.

to **increasing returns to scale** (Coelli et al., 2005). That is, we aim to answer the question of whether resources could have been saved (and, if so, how many) if spending was assigned to the EU level rather than retained at the Member State level and environmental spending was fully efficient. In our analyses, the productive units were the 27 EU Member States.[7] To start, in Chapter 3, we used Member States' total environmental expenditures[8, 9] as inputs. In Chapters 4 and 5, we further decomposed these expenditures and focus specifically on expenditures related to respectively **wastewater management** and **ambient air, soil and groundwater protection and noise abatement**, respectively. In the second step, we used the obtained efficiency scores to determine whether there are **cross-border spill-over effects** across Member States. The presence of such spill-overs provides a strong argument for common environmental expenditures at the EU level as well.

Increased scale efficiency (which is the focus of this research paper) is only one argument in favor of common spending. There are obviously other important matters to consider, such as differences in preferences across Member States. Furthermore, shifting the competencies at hand to the EU level could lead to a different level of output for environmental quality compared to what DEA results suggest. When a policy area is allocated to the EU level, European institutions will decide on how money is spent and this might differ from how it was spent at the Member State level, resulting in different output levels. For that reason, the results of our DEA cannot be interpreted as a prediction of the production function when competences are shifted to the EU level. Instead, they provide an **empirical estimate and evidence of the potential benefits of this shift**.

The remainder of this report is organized as follows. The methodology is discussed in Chapter 2. In Chapter 3 we analyze potential benefits of shifting environmental expenditures from the Member States to the EU level based on budgetary waste, returns to scale, and cross-border spill-over effects. We conduct the same analyses in Chapter 4 and 5, but examine two specific subdomains of environmental protection (wastewater management and ambient air, soil and groundwater protection and noise abatement).

[7] Depending on data availability, some analyses include all or only a subset of the 27 Member States.

[8] Expenditures on all goods and services used for environmental protection, including expenditure on environmental protection specific services (environmental protection services produced by economic units for sale or own use), environmental protection connected products (products whose use directly serves environmental protection purposes but which are not environmental protection specific services or inputs into characteristic activities) and adapted goods (goods that have been specifically modified to be more "environmentally friendly" or "cleaner" and whose use is therefore beneficial for environmental protection). The expenditure may relate to intermediate consumption, final consumption and gross fixed capital formation (United Nations, 2014).

[9] In this report, we use public expenditures. However, it is important to emphasize that there are private ones as well (e.g. industry and household expenditures).

2. Methodological approach

2.1. Measuring potential budgetary waste in MS environmental expenditures

This research paper uses the methodology introduced in the EPRS study 'Improving the quality of public spending in Europe – budgetary 'waste rates' in EU Member States' and applies it to environmental expenditures. First, budgetary waste and returns to scale are computed. Second, we examine whether cross-border spill-over effects are present. Such effects would be an important economic argument for shifting environmental expenditures to the EU level because resources could be saved by exploiting/internalizing them.

Budgetary waste indicates the saving in resources that could be achieved if some environmental expenditure is shifted from Member States to the EU level, which implies an economic argument for a shift to the EU budget. However, budgetary waste is not a sufficient argument to allocate environmental expenditure to the EU level. Additionally, two EU principles have to be fulfilled. First, the **principle of subsidiarity** states that the EU should only act when it is not possible to achieve an objective effectively at the Member State level. When budgetary waste can be avoided by shifting environmental expenditures from the Member State level to the EU level, we conclude that, following the principle of subsidiarity, the EU level is the most appropriate level of governance. Second, according to the **principle of proportionality,** the EU is only allowed to act to achieve the goals set up in EU legislation (European Commission, 2021a). According to Articles 11 and 191–193 of the Treaty on the Functioning of the European Union (TFEU), the EU has the competence to act in all areas of environmental policy. This competence is shared with each of the individual Member States. However, Member States may only enact laws if similar laws have not yet been enacted by the EU itself. One could say **Member States and the EU complement each other** (European Parliament, 2021b). In sum, the goal of the EU is not to shift all competences (or even all expenditures related to a particular competence) to the EU level, but rigorous analysis is required to verify which expenditures such a shift would be beneficial for. The present paper aims to contribute to provide **evidence-based answers** to the overarching question of what is the best organizational approach among various levels of governance, competences, and institutions for an entity as the EU, applied to environmental expenditures. However, the exercise should not stop there. For example, although it is beyond the scope of this research paper, it would also be relevant to analyze whether some expenditures would be spent more efficiently at the local and regional level.

To compute the budgetary waste rate of each Member State, parametric methods (such as Stochastic Frontier Analysis, SFA[10]) and non-parametric methods (such as Data Envelopment Analysis (DEA)) can be used. In this research paper, we employed **DEA** (as defined in Chapter 1). The main advantage of DEA is that, unlike parametric methods, a specification of the production function, which is particularly difficult to determine in case of government production, is unnecessary (Li et al., 2020). Furthermore, DEA does not require the use of weights on inputs and outputs, nor is the analysis restricted to single inputs and outputs. Finally, DEA enables comparisons to the best operating unit instead of average performance (Vyas & Jha, 2017). However, DEA is more sensitive to data errors and variable selection and it is difficult to implement statistical hypothesis tests (Kalirajan & Shand, 1999; Sarkis & Weinrach, 2001). Fortunately, there are several approaches to overcome these disadvantages, such as Simar and Wilson's (2007) parametric bootstrap procedure or semi-parametric two-stage procedures, which combine DEA with regression analysis.

[10] A parametric method for frontier estimation that assumes a given functional form for the relationship between inputs and outputs (Coelli et al., 2005).

Our approach assumes that if resources were allocated to the EU level, the EU would (1) operate on the same **efficient production function** as estimated using actual production by Member States, (2) **internalize spill-over effects**, and (3) **fully exploit returns to scale**. This is a perfectly rational and plausible assumption, but a rather optimistic one that can be seen by some as a limitation of our research paper. However, producing an artificial counterfactual by trying to guess how environmental expenditures would be spent once the competence has shifted to the EU level seems even more problematic. Furthermore, our aim is to provide some empirical basis for the potential financial advantages of shifting environmental expenditures to the EU level, not to predict the resulting production function.

2.2. Using DEA for the analysis of budgetary waste

We adopted **an input-oriented DEA approach**, which provides a measure of budgetary waste (that is, how many resources could be saved if Member States act efficiently?).

DEA identifies a production frontier based on the current production of different productive units. When the production frontier is identified, we can calculate **budgetary waste** that could be avoided if all productive units produce at this frontier. In our analysis, productive units are the EU Member States, inputs are the resources needed to produce a specific output, and outputs are indicators to assess the performance of the government policies. Outputs are represented by intermediate outputs (more specific outputs needed to produce outcomes) and outcomes (more general outputs, such as public goods).

Determining budgetary waste is not sufficient to decide whether environmental expenditures should be shifted to the EU level. We also need information on economies of scale and spill-overs. To estimate **economies of scale**, we require information about the scale efficiency (SE). To obtain an estimate, we adapt DEA to different specifications of returns to scale: the Charnes-Cooper-Rhodes model, which assumes constant returns to scale (Charnes et al., 1978), and the Banker-Cooper-Charnes model, which extends the former model to variable returns to scale (Banker et al., 1984). To verify for each Member State whether there are increasing returns to scale, we compared the Charnes-Cooper-Rhodes model (CRS) (which computes Pure Technical Efficiency (PTE)) with the Banker-Cooper-Charnes model (VRS) (which computes Technical Efficiency (TE)) (Banker et al., 1984; Charnes et al., 1978; Ji & Lee, 2010). To compare these models, we used the following formulas:

$TE = PTE * SE$
$SE = TE / PTE$

Increasing returns to scale would provide an important theoretical argument for common spending at the EU level. By assigning environmental expenditures to the EU level, returns to scale could be exploited, which would result in efficiency gains (assuming that the efficient production frontier of Member States and the EU is the same).

Using the calculated SE, we created a new measure (percentage change) that indicates whether a shift of environmental expenditures to the EU level will result in:

1. No changes of the SE if the production function of a Member State has constant returns to scale
2. An increase of the SE to one if the production function of a Member State has increasing returns to scale
3. An equivalent decrease of the SE if the production function of a Member State has decreasing returns to scale.

By calculating the mean of 'percentage change', we estimate the efficiency gains/losses of allocating environmental expenditures to the EU level (larger scale).

2.3. Spill-over effects

The presence of **spill-overs** across Member States is another argument for assigning environmental expenditures to the EU level. A more efficient organization of spending means that it is more likely that spill-overs are internalized. To investigate the role of spill-over effects, we perform a spatial regression analysis (Ramajo et al., 2017).

In our **spatial regression models**, the dependent variable is the efficiency score of country i (θ_i) resulting from DEA. There are two independent variables of interest. The first is the level of environmental expenditure of country j (S_j). The coefficient of this variable (δ_1) measures the average effect of the level of spending of Member State j on the efficiency score of Member State i. The second independent variable is the interaction term between the level of spending of country j and a dummy variable indicating whether country i and j are contiguous ($S_j \times \text{contig}_{ij}$). The coefficient of this interaction term (δ_2) indicates the differential effect of spending by contiguous countries compared to the average effect of spending in other Member States. In addition to the independent variables of interest, a set of control variables[11] for both countries is included (Z_i, Z_j) (see Section 2.4 on the importance of these variables in related empirical studies and Section 3.1.4 for the introduction of the data used in this paper).

$$\theta_i = \delta_0 + \delta_1 S_j + \delta_2 S_j \times \text{contig}_{ij} + \delta_3 Z_i + \delta_4 Z_j + \varepsilon_{ij}$$

The presence of spill-over effects is indicated by statistically significant coefficients of the independent variables of interest (S_j and $S_j \times \text{contig}_{ij}$).

2.4. Second-stage models

We need to be aware that the outcomes not only depend on environmental expenditures, but also on other factors such as the economic, social, political, and other geographical characteristics of a country. To identify the impact of these factors, we run a **second-stage regression analysis**. The dependent variable in this model is the efficiency score of EU countries resulting from the DEA model that models the final outcome(s) as a function of input. Explanatory variables are based on a literature review. Table A.3.1 in the Appendix provides an overview of a selection of studies that assess the impact of these explanatory variables on environmental quality.

First, most studies found a negative impact of **GDP per capita** on environmental quality, which could be explained by the fact that greater level of economic activity is related to more pollution (Andrée et al., 2019; Awan & Azam, 2021; Gassebner et al., 2011; Lamla, 2009; Neumayer, 2003). On the other hand, most studies found that **GDP growth** could contribute to improve environmental quality if a decoupling between economic development and environmental deterioration is realised and as sufficient capital input would then improve environmental governance. This hypothesized relationship is also known as the environmental Kuznets curve (Chang et al., 2019; Gassebner et al., 2011; Grossman & Krueger, 1991; Lamla, 2009).

Surface area is expected to have a negative impact on environmental quality, as larger countries generally have more fossil fuel reserves. Since extraction of fossil fuels is responsible for corresponding emissions, this may harm environmental quality (Congleton, 1992; Lamla, 2009). Most scholars found that **population density** is negatively correlated with environmental pollution

[11] We always control for GDP per capita, GDP growth, surface area, population density, urban population, and industry value added. In Chapter 4, where we focus on wastewater management spending, we also include nitrogen and phosphorus consumption. In Chapters 3 and 5, where we focus on total environmental spending and ambient air, soil and groundwater protection and noise abatement spending, we also include tertiary education, Social Progress Index (SPI), trade intensity, and road length.

because heavily populated countries tend to put more pressure on the available resources (Borghesi, 2006; Chang et al., 2019). There is also ample empirical evidence of a negative effect of **urban population** on environmental quality (because, among other things, food and consumer goods are imported into cities) (Cole, 2004; Gassebner et al., 2011; Lamla, 2009; Panayotou, 1997).

When it comes to **education level**, most studies showed that a better educated population which is expected to be more aware of the importance of a clean environment, is associated with better environmental quality (Gassebner et al., 2011; Lamla, 2009; Zafar et al., 2020). **Social development level** has a positive impact on environmental quality, which is explained by the fact that a more economical and socially developed population tends to have more pro-environmental attitudes (Gassebner et al., 2011; Giannakitsidou et al., 2020).

Most studies found that a large **industrial sector** is expected to have a negative impact on environmental quality. This can be explained by the fact that industry is naturally more resource intensive than other sectors (such as the service sector) (Chang et al., 2019; Cherniwchan, 2012; Neumayer, 2003). **Trade intensity** increases the market size, which increases production and, in turn may be expected to contribute to higher level of pollution (Birdsall & Wheeler, 1993; Gassebner et al., 2011; Kellenberg, 2009; Lamla, 2009; Managi & Kumar, 2009). **The transport sector**, which is responsible for the consumption of a large amount of fossil-fuel based energy, is expected to have a negative impact on environmental quality as well (European Environment Agency, 2021c; Neumayer, 2003).

In Section 3.1.4, we introduce the data used in this research paper for the above-mentioned variables.

3. Total environmental expenditures

3.1. Data

3.1.1. Data on environmental expenditure

One of the most ambitious EU environmental policy initiatives is the European Green Deal, which aims to achieve a green transformation that will steer Europe towards being the first climate-neutral and pollution-free continent by 2050. With sufficient political will, and assuming that the necessary capacity to act is reinforced, this should transform the EU into a competitive but sustainable economy that will improve the health and well-being of current and future generations by providing clean energy, unpolluted air, water and soil, energy-efficient buildings, healthy and affordable food, green transport and sustainable goods and services. (European Commission, 2021c).

To reach these ambitious goals, financial resources are indispensable. For that reason, the EU has decided to allocate 30 percent of total expenditures of the Multiannual Financial Framework (MFF, €1,074.30 billion for the period 2021–2027) and the Next Generation EU recovery package (NGEU, €750 billion) to green investments. This results in a European budget of around €547 billion for 2021–2027 to achieve the goals set by the European Green Deal (European Commission, 2021d). **This represents €78 billion per year, or 0.5 percent of GDP in environmental protection per year at the EU level**. However, an additional investment of €260 billion per year is still required solely to achieve the greenhouse gases reduction targets by 2030 (European Parliament, 2021c).

In addition to environmental expenditures of the EU, Member States themselves invest in environmental protection as well. National environmental expenditures are defined by the United Nations (2014) as "Expenditures on all goods and services used for environmental protection, including expenditure on environmental protection specific services[12], expenditure on environmental protection connected products[13] and expenditure on adapted goods."[14] We identify inputs, intermediate outputs, and outcomes to determine the "environmental protection" production function. With inputs, intermediate environmental protection services (intermediate outputs) are produced and these services are used to improve environmental quality (outcome).

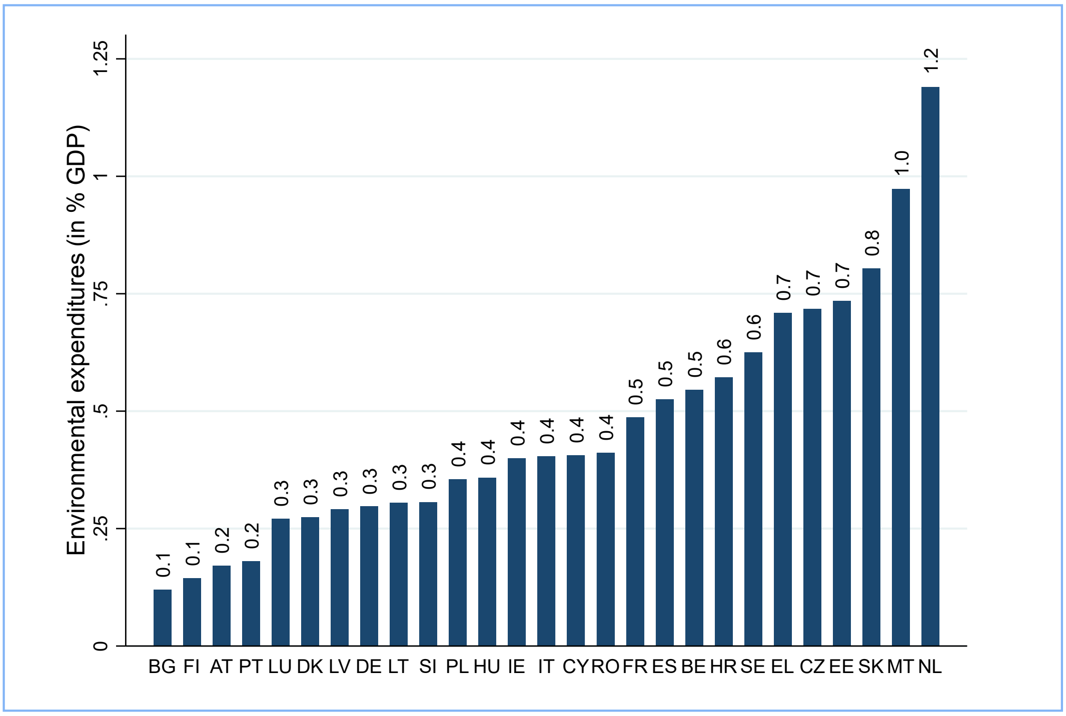
As an **input measure**, we use national environmental expenditures for the most recent available year (2018). The latter expenditures are relatively stable over time. Nevertheless, in Section 3.3 we use averaged data for multiple years to assess the robustness of the results. Following the EPRS study entitled 'Improving the quality of public spending in Europe – budgetary 'waste rates' in EU member states', we express these public expenditures as a percentage of GDP. Figure 3.1 shows significant heterogeneity among countries. For example, environmental expenditures of Bulgaria and Finland are only 0.1 percent of GDP, compared to 1.2 percent in the Netherlands. **The total annual environmental expenditures of all EU Member States combined are more than €61 billion or 0.45 percent of GDP.**

[12] Environmental protection services produced by economic units for sale or own use (United Nations, 2014).

[13] Products whose use directly serves environmental protection purposes, but which are not environmental protection-specific services or inputs into characteristic activities. An example is a septic tank (United Nations, 2014).

[14] Goods that have been specifically modified to be more "environmentally friendly" or "cleaner" and whose use is therefore beneficial for environmental protection. An example is desulphurized fuel (United Nations, 2014).

Figure 3.1: National environmental expenditures 2018 (% GDP)



Source: Eurostat

3.1.2. Data on environmental quality – final outcome

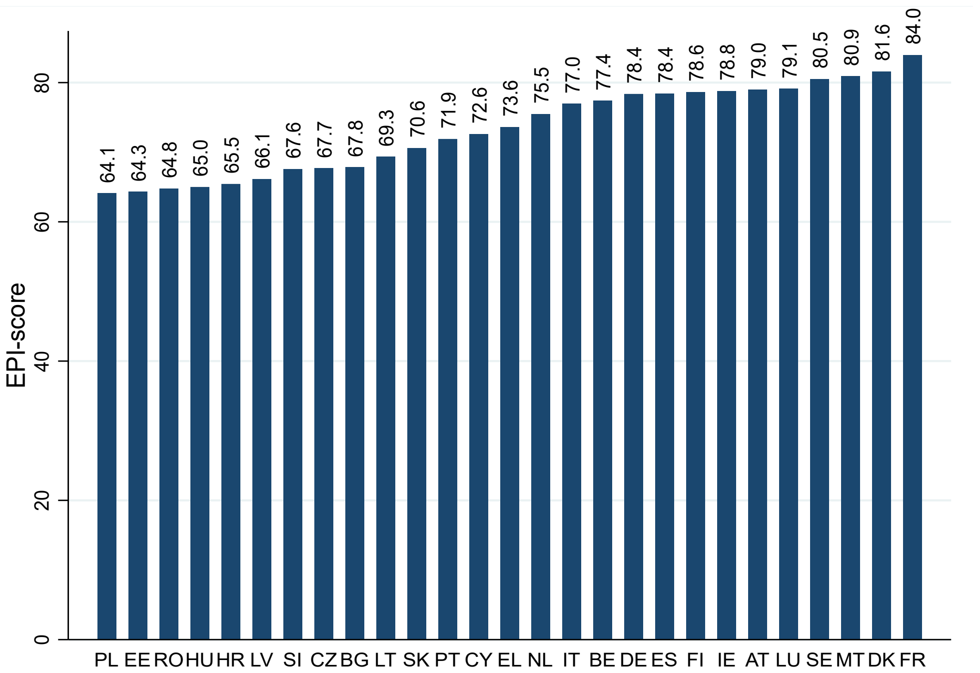
The goal of environmental policy is to improve environmental quality. Therefore, we use a **measure for environmental quality** as our **final outcome**. More specifically, we use the Environmental Performance Indicator (EPI), developed by the Yale Center for Environmental Law & Policy and the Center for International Earth Science Information Network.[15] EPI, measured on a scale ranging from 0 (worst performance) to 100 (best performance), summarizes the state of sustainability of a country based on 24 performance indicators (Wendling et al., 2018). Figure A.3.1 in the Appendix shows the composition of the EPI.

Figure 3.2 displays the EPI score for each Member State in 2018.[16] There is a difference of almost 20 points between the best- (France; 84.0) and the worst- (Poland; 64.1) performing Member States. **The average and median Member State EPI scores are 73.3 and 73.6, respectively.**

[15] https://epi.yale.edu/

[16] We only use 2018 data because it is not appropriate to assemble scores into time series due to changes in underlying methodology and data between EPI versions.

Figure 3.2: Environmental Performance Index (EPI) 2018



Source: EPI

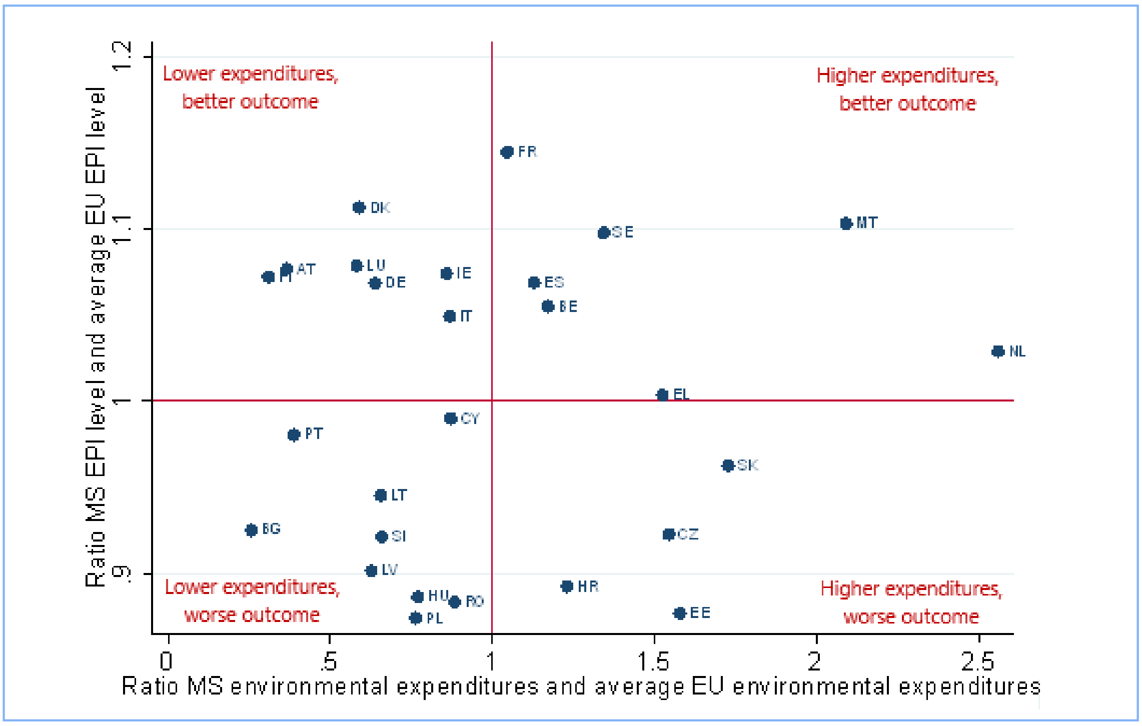
Figure 3.3 shows the **relationship between national environmental expenditures and the final outcome EPI**, both expressed as the ratio between the Member State level and the average EU level. Countries in the upper-right quadrant have spending and EPI levels that are higher than the EU average, while countries in the lower-left quadrant have spending and EPI levels that are lower than the EU average. Countries in the upper-left quadrant are the most efficient.[17] They spend less than the EU average, but their EPI is higher. Efficiency is lowest in the lower-right quadrant.[18] These countries spend more than the EU average, but their EPI is lower.

EPI is slightly positively related to the level of national environmental expenditures (the correlation coefficient is 0.04). The relatively low correlation coefficient is not surprising, and in line with the literature suggesting that environmental quality (here measured by EPI) also depends on other factors than environmental expenditures (such as economic determinants, social, political, and geographical characteristics) (see, e.g. Lamla (2009) and Gassebner et al. (2011)), and is the reason why we also estimate a second stage model (see Section 3.2.1).

[17] Finland, Austria, Denmark, Luxembourg, Germany, Ireland, Italy.

[18] Croatia, Czechia, Estonia, Slovakia.

Figure 3.3: Outcome and national environmental expenditures



Source: Own estimates based on Eurostat and EPI data

3.1.3. Data on intermediate outputs

The contribution of environmental expenditures to the final outcome (environmental quality) is made through expenditures on intermediate outputs, which are publicly funded services. Our **intermediate output indicators** are the percentage of solar, wind, and hydro energy generation contributing to the total net energy generated.[19] We also include circular material use because the transition from a linear economy to a circular economy has become increasingly important in recent years due to the increasing demand for raw materials (European Parliament, 2021a). Table A.3.2 in the Appendix reports the values of the intermediate outputs for each Member State in 2018 (an aggregate index is added for informative purposes). Bar charts of the intermediate outputs are displayed in Figure A.3.2 to Figure A.3.5 in the Appendix.

Denmark (48.0 percent), Lithuania (35.7 percent), and Ireland (28.6 percent) have a relatively high percentage of **wind energy** to total net energy. The contrast is high with countries such as Slovenia, Slovakia, and Malta, which barely produce any energy using wind (less than 0.1 percent). On average, EU Member States produce 11.3 percent of their energy from wind.

Germany (8.1 percent) produces relatively more **solar energy** than other Member States, as do Italy (8.2 percent) and Greece (7.5 percent). On the other hand, solar energy is less than 0.1 percent of the total energy produced in Sweden, Latvia, Ireland, Estonia, and Austria. On average, 2.7 percent of energy produced by Member States is solar energy.

Luxembourg (61.3 percent), Croatia (57.9 percent), and Austria (56.7 percent) produce the most **hydro energy**, whereas the Netherlands, Denmark, Malta, and Cyprus barely produce any such

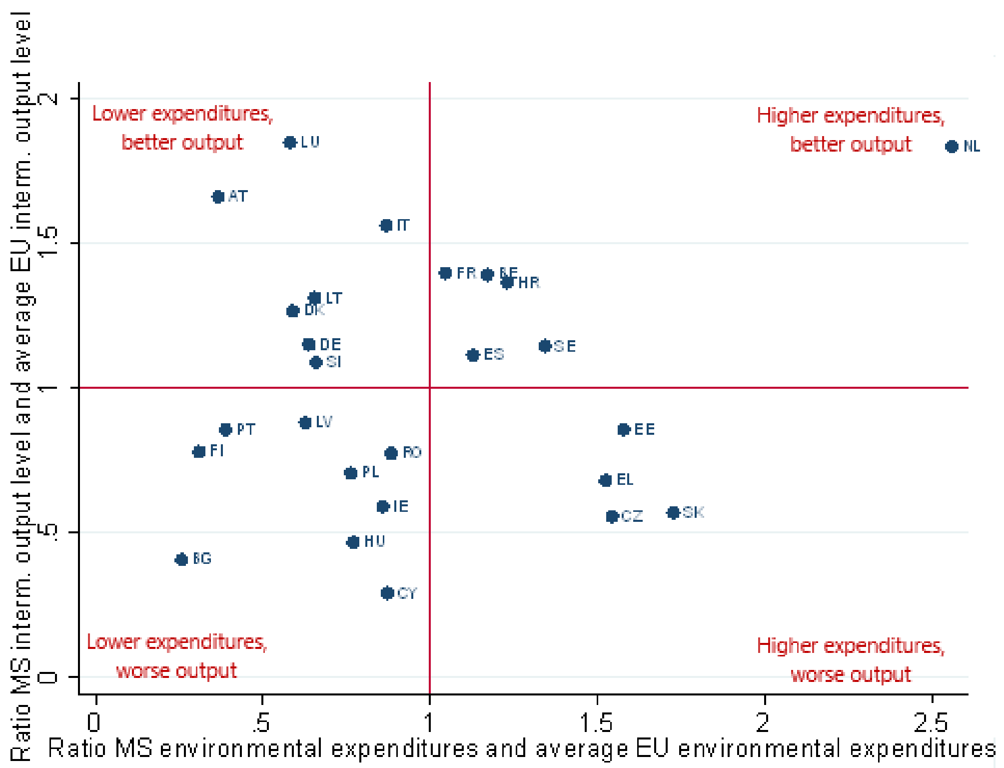
[19] Net electricity generated = gross electricity generation (total amount of electrical energy produced by transforming other forms of energy, for example nuclear or wind power) minus the consumption of power stations' auxiliary services (Eurostat, 2014)

energy (0.1 percent or less). On average, 17.9 percent of the energy produced by Member States is hydro energy.

Finally, Member States on average have a **circular material use rate** of 8.9 percent. The Netherlands (28.9 percent), and to a lesser extent Belgium (19.9 percent), France (19.5 percent), and Italy (18.8 percent), recover the highest amount of material. These numbers stand in stark contrast to the worst-performing countries, such as Ireland (1.6 percent) and Romania (1.5 percent).

Comparable to Figure 3.3, Figure 3.4 shows the **relationship between national environmental expenditures and the intermediate outputs** (all expressed as the ratio between Member State level and the average EU level). The intermediate outputs wind, solar, and hydro energy are combined into one composite indicator, “green energy” (percentage of total net electricity generated by wind, sun, and water). Subsequently, green energy and circular material use are equally weighted. The most efficient Member States are Austria, Luxembourg, Lithuania, Denmark, Germany, Slovenia, and Italy, and the least efficient are Greece, Czechia, Estonia, and Slovakia. Slovakia, Czechia, and Estonia are the least efficient Member States, both in terms of final outcome and in terms of intermediate outputs.

Figure 3.4: Intermediate output and national environmental expenditures



Source: Own estimates based on Eurostat data (environmental expenditures, wind energy, solar energy, hydro energy, circular material use)

3.1.4. Data for second stage and spatial analysis

Table A.3.3 provides the definitions for each explanatory variable included in the second-stage and spatial analyses used in this Chapter. Table A.3.4 provides descriptive statistics. Figure A.3.6 to Figure A.3.15 show values of these variables at the Member State level, and Table A.3.5 provides a correlation analysis for the explanatory variables. All of these tables and figures are in the Appendix.

The correlation coefficients between EPI and the explanatory (control) variables of the second stage and spatial analysis are displayed in Table A.3.6 in the Appendix. The variables GDP per capita, education, SPI, and urban population are positively and statistically significantly correlated with EPI. Countries with a higher GDP per capita have more resources to take action in order to improve environmental quality, and better educated and more socially developed populations generally have more pro-environmental attitudes (Gassebner et al., 2011; Giannakitsidou et al., 2020). Citizens who face more pollution in urban areas often vote in favor of higher environmental quality standards, which explains the positive correlation between EPI and urban population (Cole et al., 2006).

3.2. Results

It is important to understand that intermediate **outputs and outcomes cannot be considered together**. Intermediate outputs measure the technical efficiency (ability to create environmental protection services with the available inputs), while outcomes measure the appropriateness of environmental policy to improve environmental quality. Therefore, we estimated two models: one with the final outcome, and one with intermediate outputs.

We used input-oriented DEA to obtain information about the efficiency of Member States' environmental expenditures and to compute Member States' budgetary waste rates. This approach allowed us to compute how many resources could be saved if Member States act efficiently.

We ran two models:

1. Model A: outcome (EPI) modelled as a function of input (national environmental expenditures)

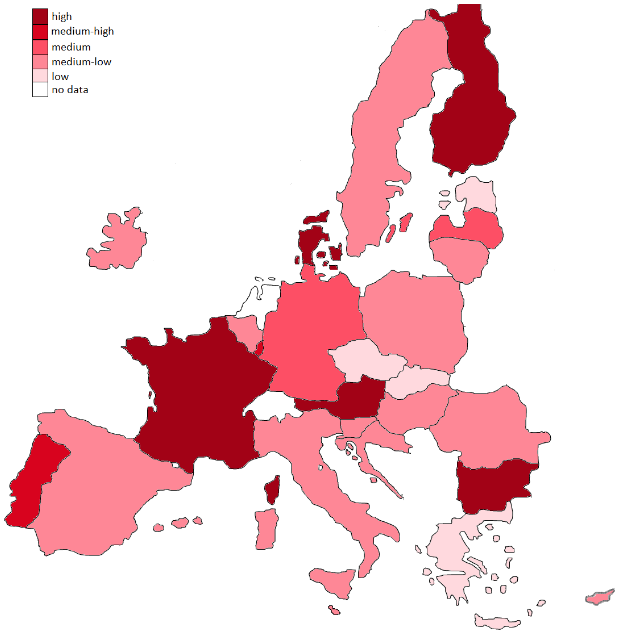
2. Model B: Intermediate outputs (wind energy, solar energy, hydro energy, circular material use) modelled as a function of input (national environmental expenditures)

3.2.1. Budgetary waste in national environmental expenditure

Model A: Final outcome

The estimated efficiency scores for **model A (outcome=f[input])** are shown in Figure 3.5 and Table A.3.7 (in the Appendix). At first sight, we observe a large heterogeneity in efficiency scores among countries. The average Member State efficiency score is equal to 0.46, which corresponds to a **budgetary waste rate of 54 percent**.

Figure 3.5: Efficiency estimations, model A: outcome=f(input)



Source: Own estimates based on EPI and Eurostat data

However, environmental quality depends not only on environmental expenditures, but also on other factors such as the economic, social, political, and geographic characteristics of a country. To identify the impact of these factors on the efficiency scores in the production of environmental outcomes, we ran a **second-stage analysis**. We ran three models,[20] which differ in the number of explanatory variables considered. Table A.3.8 (in the Appendix) shows the regression output. In the most elaborated model, **GDP per capita** has a significant and slightly positive impact on efficiency. This is in line with the findings of Grossman and Krueger (1995) and the hypothesis that a higher GDP per capita implies that more resources are available to invest in environmental protection. Furthermore, **trade intensity** has a significant and negative effect on efficiency in the most elaborated model. This can be explained by the fact that trade intensity increases the market size, which increases production and, in turn, pollution (Birdsall & Wheeler, 1993; Gassebner et al., 2011; Kellenberg, 2009; Lamla, 2009; Managi & Kumar, 2009).[21]

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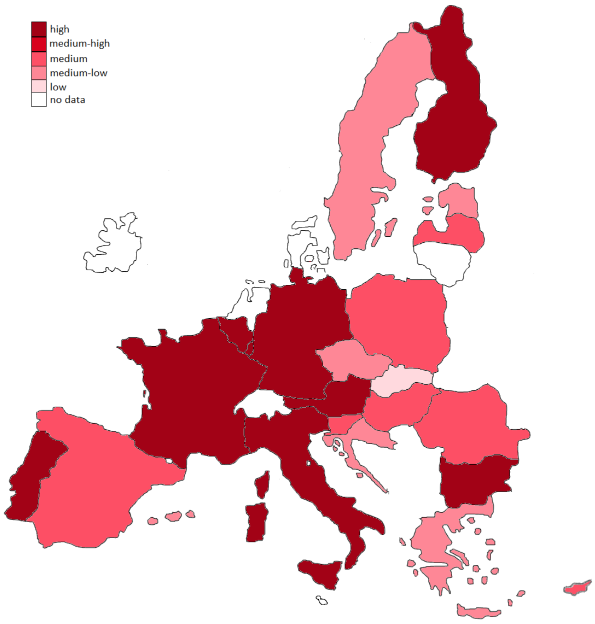
[20] Model 1: GDP per capita, GDP growth, surface area, and population density. Model 2: explanatory variables Model 1 + industry value added and urban population. Model 3: explanatory variables Model 2 + education, SPI, trade intensity, and road length.

[21] None of the remaining explanatory variables have a significant effect on efficiency. This could be at least partly due to a lack of statistical power because the low number of observations used in the regression.

Model B: Intermediate outputs

The estimated efficiency scores of Model B are shown in Figure 3.6 and Table A.3.9 (in the Appendix). We observe a large heterogeneity in efficiency scores among countries in this model too. Moreover, it is noticeable that Member States who are efficient in terms of intermediate outputs (Model B) are not necessarily efficient in terms of outcome (Model A) (such as Belgium, Germany, and Italy). This is in line with the literature suggesting that the outcome (environmental quality) also depends on other factors than environmental expenditures (such as economic determinants and social, political, and geographical characteristics) (Gassebner et al., 2011; Lamla, 2009; Neumayer, 2003). The average Member State efficiency score is equal to 0.64, which corresponds to a budgetary waste rate of 36 percent. **In other words, Member States could reach the same intermediate output with 36 percent fewer resources if they were able to reach the efficiency boundary and the efficient scale. This corresponds to a potential saving of almost €22 billion per year,** which could be used to invest in more goods and services (intermediate outputs). In the long run, this should further improve environmental quality (outcome).

Figure 3.6: Efficiency estimations, model B: output=f(input)



Source: Own estimates based on Eurostat data

3.2.2. Economies of scale and cross-border spill-over effects

Finally, we analyzed whether there are economies of scale and spill-overs in environmental expenditures.

We first discuss economies of scale. Model A (outcome=f[input]) reveals that **moving to a larger scale would be beneficial for eight Member States** (on average, their efficiency would increase with 3.3 percent; see Table A.3.7 in the Appendix). This is a limited increase because the scale efficiency of these countries is already particularly high (0.97). On the other hand, we detect constant returns to scale for one country (its efficiency would not improve nor deteriorate when moving to a larger/smaller scale) and **decreasing returns to scale for 17 Member States,**[22] for whom moving to a larger scale would imply a decrease in efficiency of 15.1 percent (the average scale efficiency of these countries is 0.85). As a result, the total loss in efficiency of the 17 Member States with decreasing returns to scale exceeds the efficiency gains of the eight Member States with increasing returns to scale. These results suggest that, **on an aggregate level, it would not be beneficial to move to a larger scale** (efficiency would decrease by 8.9 percent).

Model B (output=f[input]) (Table A.3.9 in the Appendix) reveals **increasing returns to scale for 12 Member States**. Moving to a larger scale would increase their efficiency by 11.4 percent. **Five countries operate under decreasing returns to scale**; moving to a larger scale implies a decrease in efficiency of 18.0 percent. Finally, five Member States encounter constant returns to scale in Model B (that is, moving to a larger or smaller scale would not affect their efficiency). Overall, the total gains

[22] It appears these are Member States with particularly high EPI scores.

of the Member States with increasing returns to scale exceed the total losses of the Member States with decreasing returns to scale. **Shifting spending to the EU level would result in an efficiency gain of 2.1 percent**, so these potential scale efficiency gains are an argument for shifting spending to the EU level.

Second, we performed a spatial analysis to determine whether national environmental expenditures affect the level of efficiency of other (neighboring) EU countries (that is, whether there are spill-over effects). Because our dependent variable (efficiency scores expressed as a percentage) is bounded between 0 and 100, we apply a Tobit regression model.

As shown in Table A.3.10 (in the Appendix), we observe statistically significant spill-over effects both in Model A (see Column (1)) and Model B (see Column (2)). **A more efficient organization of spending at the EU level could internalize these spill-over effects.**

3.3. Robustness checks

We performed several robustness checks on our main analysis. Table A.3.11 (in the Appendix) provides an overview of the most important results. Summarized, we conducted the following robustness checks:

1. *Alternative period.* In our main analysis we used 2018 data for each input, intermediate output and final outcome. Although the data seem relatively stable over time (and thus the impact of cyclical bias is expected to be negligible), we instead used two-year average (2017–2018) data for inputs and outputs[23] as a robustness check. As shown in Rows (3) and (4) of Table A.3.11 (in the Appendix), the results are robust.
2. *Alternative input.* In our main analysis we used environmental expenditures as a percentage of GDP as our input. As a robustness check, we used environmental expenditures as a percentage of total public expenditures. As shown in Rows (5) and (6) of Table A.3.11 (in the Appendix), the results are robust.
3. *Alternative outputs.* Model B includes each type of green energy (wind, solar, hydro) separately. As a robustness check, we used a composite output indicator: total green energy (percentage of net energy generated by wind, solar and hydro energy). In addition, we kept circular material use as an intermediate output. As shown in row (7) of Table A.3.11 (in the Appendix), the results are robust.
4. *Alternative outcome.* Model A of our main analysis includes the EPI-score as final outcome indicator. As a robustness check, we considered the EPI policy objectives (environmental health and ecosystem vitality) as two separate outcome indicators. Furthermore, as an additional robustness check, we used the EPI scores of 2016 (instead of 2018) as an alternative outcome. As shown in Rows (8) and (9) of Table A.3.11 (in the Appendix), the results are robust.
5. *Keep outliers.* Because DEA models are sensitive to outliers, we dropped them in our main analysis. As a robustness check, we did not drop the outliers. As shown in Rows (10) and (11) of Table A.3.11 (in the Appendix), the results are robust.

[23] Unfortunately, it is not possible to replace our final outcome (EPI) by data averaged over multiple years because EPI scores of different years are not comparable due to changes in underlying methodology. Furthermore, EPI data are not available for 2017.

3.4. Conclusion

In this chapter we performed a benchmarking analysis on **environmental expenditures**. We first estimated Member States' budgetary waste rates. Both in terms of final outcomes and outputs, these waste rates are large. Based on the assumption that if resources would be allocated to the EU level, the EU would operate on the efficient production function as estimated using actual production by Member States, the same amount of outputs and the same level of environmental protection could be achieved with 36 percent and 54 percent fewer resources, respectively. This means, for example, that EU Member States could produce the same level of green energy (solar, wind, and hydro energy) and the same level of circular material use, and **saving almost €22 billion per year**.

Next, we found evidence that shifting environmental spending to the EU level would increase scale efficiency. Because the majority of EU Member States is operating under large increasing returns to scale, shifting environmental spending to the EU level would allow the EU to exploit these **scale effects**, which results in an **efficiency gain** (in terms of the production of green energy and circular material use) of **2.1 percent.**

Environmental issues do not respect international borders (European Environment Agency, 2020b), so it has been argued that these challenges of transboundary nature can only be tackled effectively through international cooperation (European Environment Agency, 2022). For this reason, cross-border spill-overs could provide a strong argument for common environmental expenditures at the EU level as well. We found evidence that there are **significant spill-over effects**. More specifically, if EU Member States invest in environmental protection, this positively affects environmental quality in other Member States. Therefore, allocating environmental expenditures to the EU level could internalize these spill-over effects.

In sum, our findings suggest that technical inefficiency, economies of scale, and cross-border spill-over effects are all arguments for common action in the domain of environmental protection.

4. Wastewater management expenditures

Due to many different uses by a variety of sectors (agriculture, tourism, transport, energy, etc.) and households, the quality of water is under pressure and a considerable amount of wastewater is produced (European Parliament, 2021d). Since wastewater may contain viruses, bacteria, and other pollutants that pose a risk to the environment and human health, it needs to be treated adequately (European Environment Agency, 2021f) and its management transcends national boundaries (European Parliament, 2021d).

According to Articles 191–193 of the Treaty on the Functioning of the European Union (TFEU), the EU has competence to act in all areas of environmental policy, including wastewater management. In 2012, the EU launched the Blueprint to Safeguard Europe's Water Resources. This framework is complemented by more specific legislation. The Water Framework Directive (WFD) and its more targeted directives (such as the urban waste water treatment directive) aim to achieve good environmental status for all waters, by establishing a framework to protect them (European Parliament, 2021d, 2022b). The Marine Strategy Framework Directive (MSFD) specifically targets the EU's marine waters (European Parliament, 2021d).

Although the EU has made significant efforts to improve water quality, only 44 percent of surface water (rivers, lakes, transitional waters and coastal waters) has a good or high ecological status. EU's marine waters specifically are highly contaminated by heavy metals and synthetic chemicals. For that reason, a major focus on water is needed in the European Green Deal's zero pollution action plan (European Environment Agency, 2021b).

Because of the importance of good water quality and the fact that its management transcends national boundaries, this chapter analyzes wastewater management, a specific subdomain of environmental protection. Inputs (public wastewater management expenditures) were used to produce intermediate outputs (population connected to a wastewater collecting system), which should improve the final outcome (wastewater treatment).

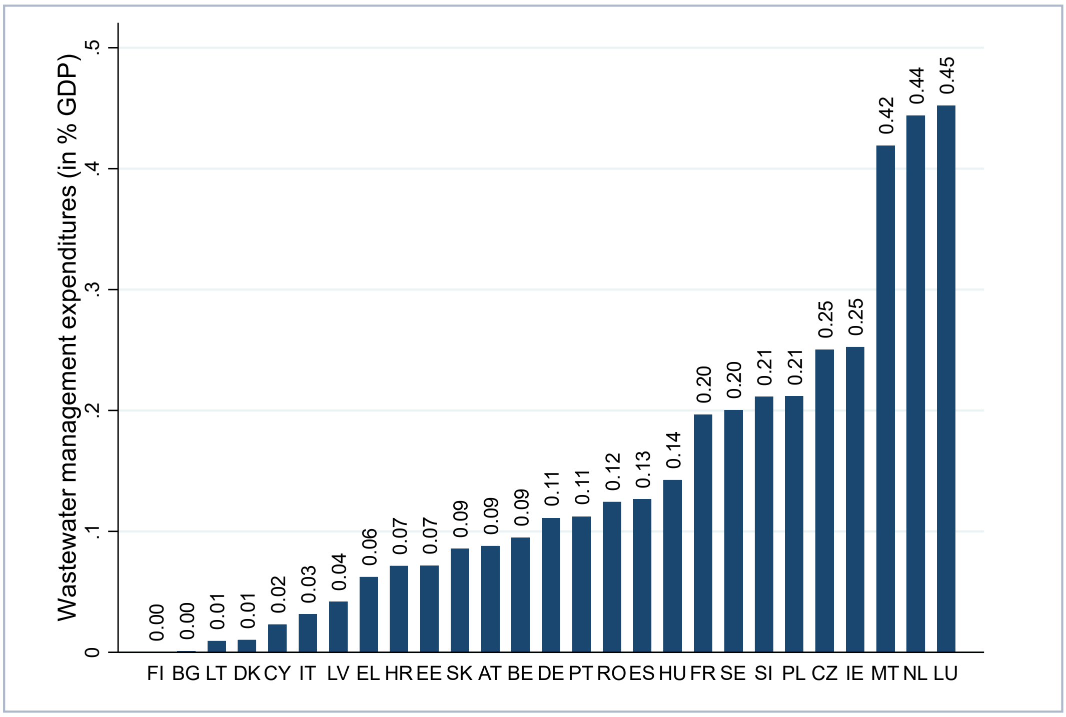
4.1. Data

4.1.1. Data on wastewater management expenditure

As an **input measure,** we use Member States' **wastewater management expenditures** (as a percentage of GDP (2018)). Eurostat (2019) defined wastewater management expenditures as: "Expenditures on sewage system operation and wastewater treatment. Sewage system operation includes management and construction of the system of collectors, pipelines, conduits and pumps to evacuate any wastewater (rainwater, domestic and other available wastewater) from the points of generation to either a sewage treatment plant or to a point where wastewater is discharged to surface water. Wastewater treatment includes any mechanical, biological or advanced process to render wastewater fit to meet applicable environment standards or other quality norms."

Figure 4.1 shows wastewater management expenditures for each Member State. The contrast between the Member States with the lowest wastewater management expenditures (such as Finland, Bulgaria, Lithuania, and Denmark, which have a wastewater management expenditure of 0.01 percent of GDP, or less) and those with the highest expenditures (such as Malta (0.42 percent), the Netherlands (0.44 percent) and Luxembourg (0.45 percent)) is substantial. **The total annual wastewater management expenditures of all EU Member States combined is almost €20 billion or 0.14 percent of GDP.**

Figure 4.1: Wastewater management expenditures 2018 (% GDP)



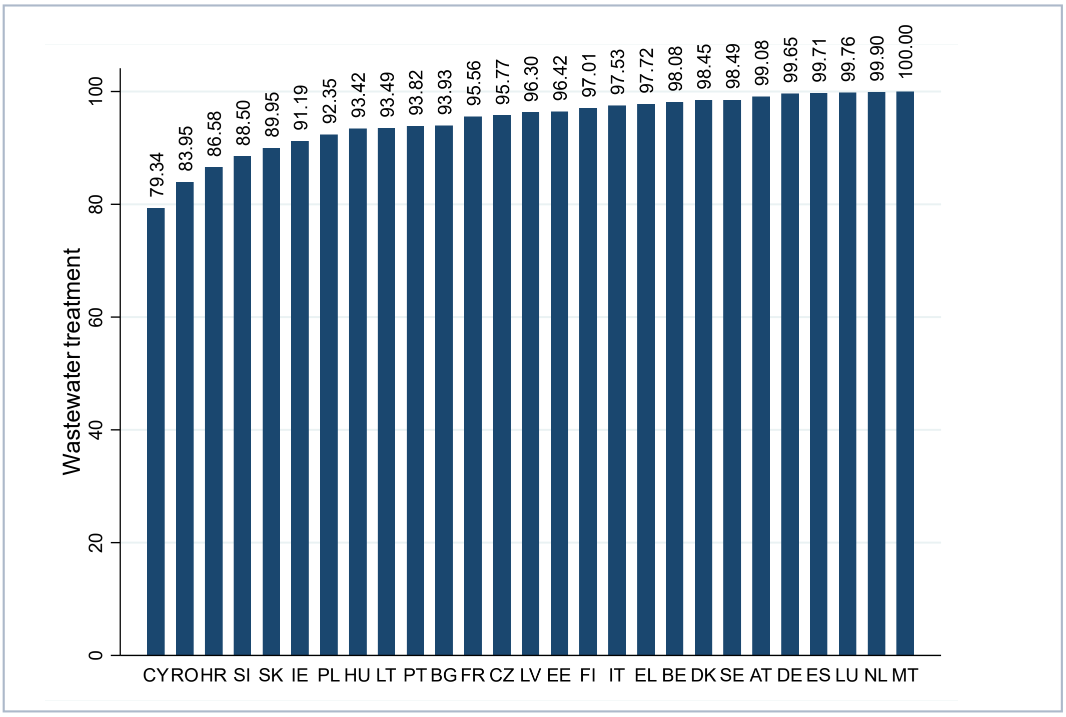
Source: Eurostat

4.1.2. Data on wastewater treatment – final outcome

The goal of wastewater management is to improve water quality by preventing that wastewater is returned into the water cycle. The treatment of wastewater (such as removing contaminants from wastewater) contributes significantly to achieving this objective. For that reason, we use the EPI component "**wastewater treatment**" (measured on a scale from 0 to 100) as our **final outcome**. The latter is defined as "the percentage of wastewater that undergoes at least primary treatment in each country, normalized by the proportion of the population connected to a municipal wastewater collection system" (Wendling et al., 2018).

Figure 4.2 shows a difference of more than 20 points between the best-performing Member State (Malta: 100.0) and the worst-performing one (Cyprus: 79.3). Nevertheless, Member States score relatively high (22 countries score above 90, 16 countries above 95). **The average Member State score is 94.7, the median score is 96.3**.

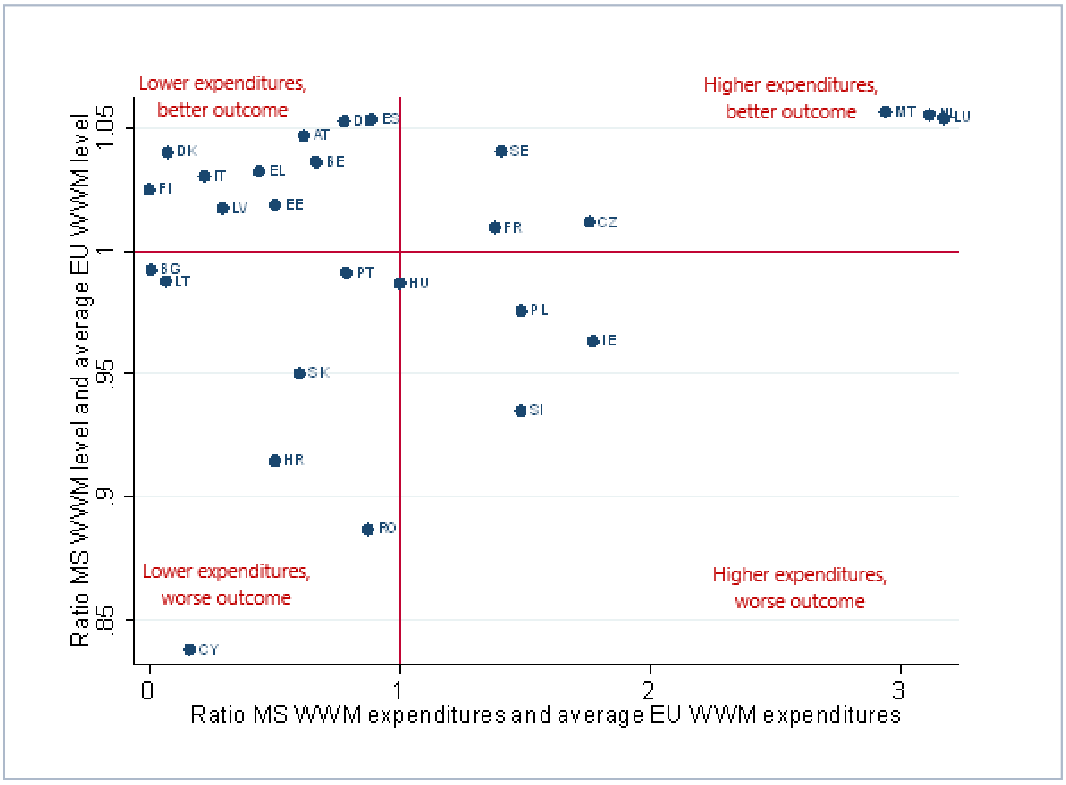
Figure 4.2: Wastewater treatment 2018



Source: EPI

Figure 4.3 shows the **relationship between wastewater management expenditures and the final outcome wastewater treatment**, both expressed as the ratio between Member State level and the average EU level. The most efficient Member States are Finland, Denmark, Italy, Latvia, Greece, Estonia, Austria, Germany, and Spain (upper-left quadrant), while the least efficient are Hungary, Poland, Slovenia, and Ireland (lower-right quadrant).

Figure 4.3: Outcome and wastewater management expenditures



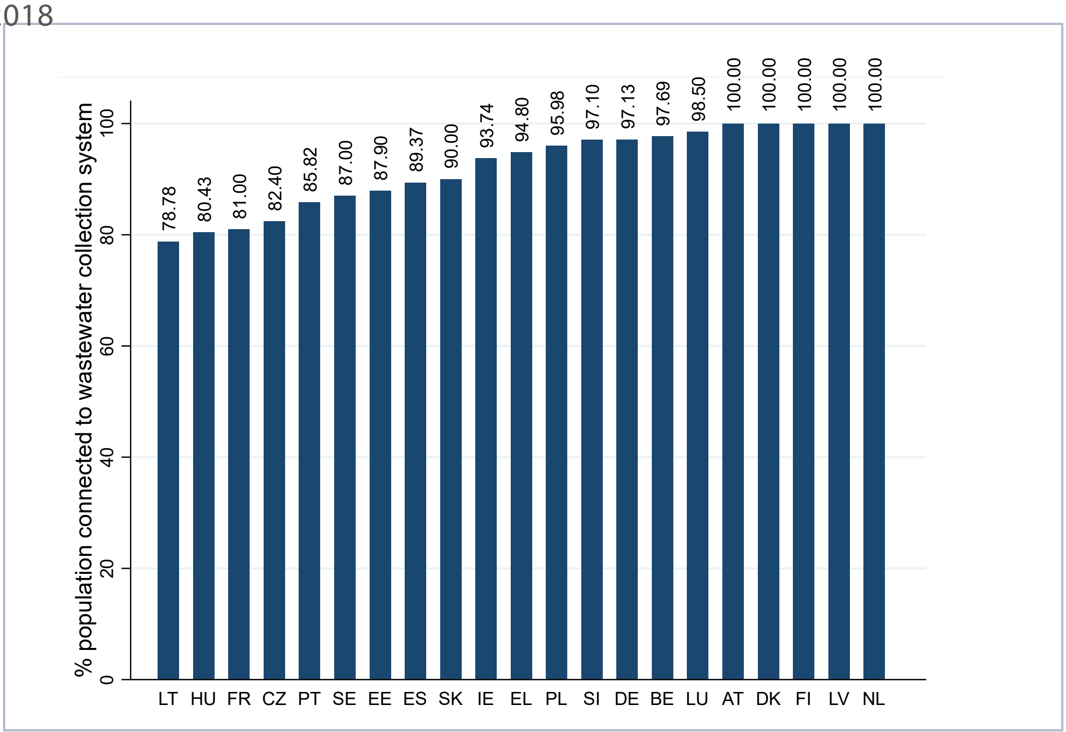
Source: Own estimates based on EPI and Eurostat data

4.1.3. Data on households connected to wastewater collection systems – intermediate output

The contribution of wastewater management expenditures to the final outcome of wastewater treatment is made through expenditures on intermediate outputs. As **intermediate output**, we use the percentage of resident population connected to a wastewater collecting system. Figure 4.4 shows that the worst-performing country is Lithuania with 78.8 percent of its population connected to a wastewater collecting system, while this is 100 percent in the best-performing countries (Austria, Denmark, Finland, Latvia and the Netherlands). **On average, 92.3 percent of the population of EU Member States is connected to a wastewater collecting system.** Unfortunately, we have no data for six Member States (Bulgaria, Croatia, Cyprus, Italy, Malta, and Romania).[24]

[24] Because of missing 2018 data, we use 2017 data for Estonia, Ireland, Portugal and Sweden and 2016 data for Germany and Luxembourg. This is representative because of the stable connection rates of these countries in the previous years.

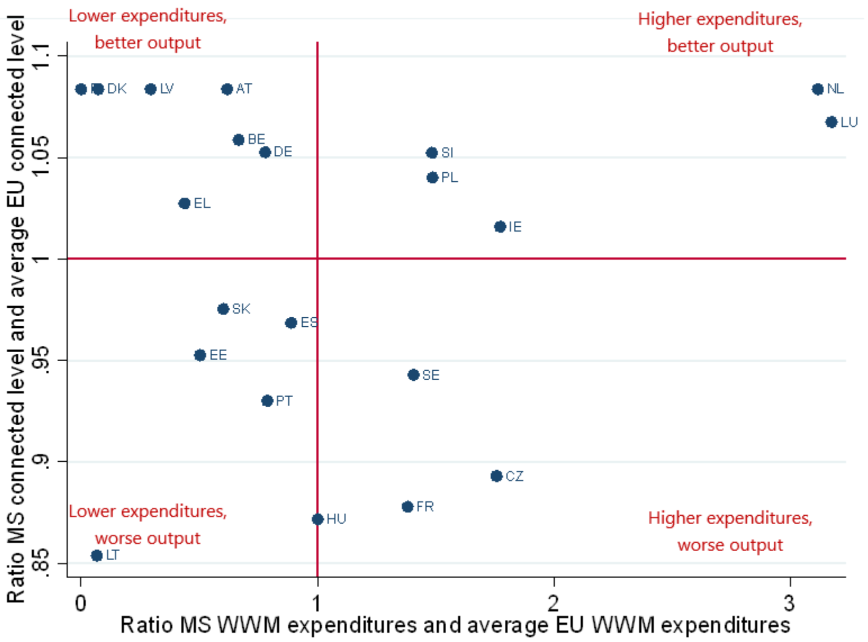
Figure 4.4: Percentage of population connected to wastewater collection system, 2018



Source: OECD

Comparable to Figure 4.3, Figure 4.5 shows the **relationship between wastewater management expenditures and our intermediate output** (both expressed as the ratio between Member State level and the average EU level). The most efficient countries are Finland, Denmark, Latvia, Greece, Austria, Belgium, and Germany. Efficiency is lowest in Hungary, France, Czechia, and Sweden.

Figure 4.5: Intermediate output and wastewater management expenditures



Source: Own estimates based on Eurostat and OECD data

4.1.4. Data for second stage and spatial analysis

Since wastewater management is a subdomain of environmental protection (Eurostat, 2019), we used GDP per capita, GDP growth, surface area, population density, urban population and industry value added as explanatory variables, as we did in Chapter 3 (see section 3.1.4). We also added nitrogen and phosphorus consumption (in 100 tons), both inorganic fertilizers, because the literature has shown that the consumption of fertilizers specifically impacts water quality (see, e.g., Gassebner et al. (2011), Smith and Siciliano (2015) and Chen et al. (2018)).[25] Table A.4.1 provides the definitions of these additional variables, Table A.4.2 provides descriptive statistics, and Figure A.4.1 and Figure A.4.2 show values at the Member State level. All of these tables and figures are in the Appendix.

The correlation coefficients between the EPI wastewater treatment component and the explanatory (control) variables of the second-stage and spatial analysis are displayed in Table A.4.3 in the Appendix. The variables GDP per capita and urban population are positively and statistically significantly correlated with EPI. Countries with a higher GDP per capita have more resources to take action in order to improve environmental quality and citizens who face more pollution in urban areas often vote in favor of higher environmental quality standards, which explains the positive correlation between EPI and urban population (Ali et al., 2017; Cole et al., 2006; Gassebner et al., 2011). GDP growth has a negative and significant impact on EPI because growing countries may overexploit resources to sustain growth, which may be detrimental to the environment (Cai et al., 2020; Carlsson & Lundström, 2003; Gassebner et al., 2011; Lamla, 2009; Wang et al., 2021).

[25] Gassebner et al. (2011) found that a 1 percent increase in fertilizer use results in a statistically significant 0.051 percent increase of Biochemical Oxygen Demand (BOD) (a measure of water pollution).

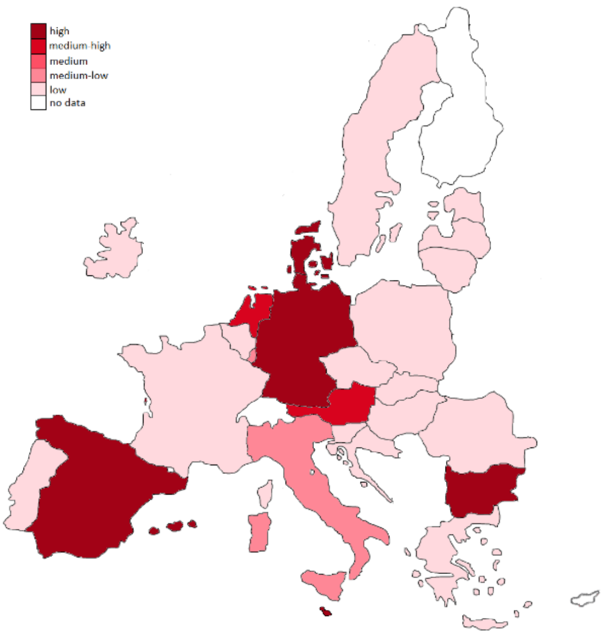
4.2. Results

As explained above, intermediate outputs and outcomes cannot be considered together, as intermediate outputs measure technical efficiency, and outcomes measure the appropriateness of wastewater management to improve water quality. We ran two models to examine budgetary waste, economies of scale, and cross-border spill-over effects:

- Model A: Outcome (EPI wastewater treatment component) modelled as a function of input (Wastewater management expenditures)
- Model B: Intermediate output (percentage of population connected to a wastewater treatment plant) modelled as a function of input (Wastewater management expenditures).

4.2.1. Budgetary waste in wastewater management expenditure

Figure 4.6: Efficiency estimations, Model A: outcome=f(input)



Source: Own estimates based on Eurostat data

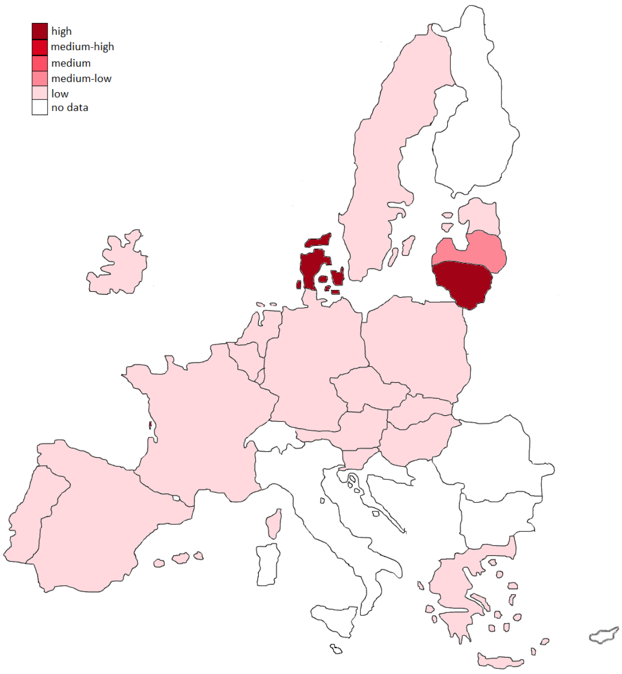
Outcome

The estimated efficiency scores for model A (outcome=f[input]) are shown in Figure 4.6 and Table A.4.4 (in the Appendix). It is striking that most countries have an extremely low efficiency score (< 0.20), resulting in a mean **Member State efficiency score of 0.31. This corresponds to a high budgetary waste rate of 69 percent.**

The impact of factors other than wastewater management expenditure on water quality is analyzed in the **second-stage analysis**. We ran four models, which differ in the number of explanatory variables considered.[26] Table A.4.5 (in the Appendix) shows the regression output. **Population density** has a positive and statistically significant impact on efficiency. This is not in line with the negative effect observed by most scholars (as described in Section 2.4). Nevertheless, according to Stern (2005), environmental policy is more effective when more people are affected and thus population density can positively affect environmental quality. **GDP growth** has a significant and negative impact in the most elaborate model. This negative effect is in line with the explanation that growing countries may overexploit resources by overheating their economy to sustain growth (Carlsson & Lundström, 2003; Gassebner et al., 2011; Lamla, 2009).

[26] Model 1: GDP per capita and GDP growth; Model 2: explanatory variables Model 1 + surface area and population density; Model 3: explanatory variables Model 2 + industry value added and urban population; Model 4: explanatory variables Model 3 + nitrogen and phosphorus consumption.

Figure 4.7: Efficiency estimations, Model B: output=f(input)



Source: Own estimates based on Eurostat data

Intermediate outputs

The estimated efficiency scores of Model B (output=f[input]) are shown in Figure 4.7 and Table A.4.6 (in the Appendix). Again, we observe low efficiency scores for most Member States (< 0.20). **The average Member State efficiency score equals 0.18, which corresponds to a budgetary waste rate of 82 percent.** Hence, Member States could reach the same level of intermediate output with 82 percent fewer resources, which corresponds to an **annual saving of almost €16 billion**. These resources could be used to invest in more intermediate outputs. In the long run, this should further improve water quality.

4.2.2. Economies of scale and cross-border spill-over effects

Finally, we analyze the existence of economies of scale and spill-overs in wastewater management.

Model A (outcome=f[input]) (see Table A.4.4 in the Appendix) shows that **moving to a larger scale would be beneficial for nine Member States** (on average, their efficiency would increase by 3.8 percent). Because the scale efficiency of these countries is particularly high (0.96), this is a limited increase. However, the average efficiency loss of the **15 EU countries operating under decreasing returns to scale** is much larger (-90.4 percent). This can be explained by the fact that their scale efficiency is very low (0.10). As a result, the total loss in efficiency of the 15 Member States with decreasing returns to scale exceeds the efficiency gains of the nine Member States with increasing returns to scale. **At an aggregate level, based on the criterion of scale, it would not be beneficial to move to a larger scale (efficiency for the EU as a whole would decrease with 52.9 percent).**

Model B (output=f[input]) (see Table A.4.6 in the Appendix) reveals **constant returns to scale for four Member States and increasing returns to scale for the remaining 16 Member States** included in the analysis. Moving to a larger scale would increase the efficiency of the countries with increasing returns to scale with 6.4 percent and would not have an impact on the efficiency of the countries with constant returns to scale. Overall, at an aggregate level it would be beneficial to move to a larger scale (**efficiency for the EU as a whole would increase with 5.1 percent**).

To analyze whether wastewater management expenditures affect the level of efficiency of other (neighboring) EU countries, we ran a **spatial analysis**. The dependent variable is the wastewater management efficiency score of Country i. The explanatory variables are wastewater management expenditures of Country j and the interaction term between wastewater management expenditures of Country j and a dummy indicating whether Country i and Country j share a border. As control variables, we use the explanatory variables of the second-stage analysis for both Country i and

Country j (GDP per capita, GDP growth, surface area, population density, urban population, industry value added, nitrogen consumption and phosphorus consumption).

Table A.4.7 (in the Appendix) reveals statistically **significant spill-over effects for Model B**. **These could be internalized if wastewater management expenditures were shifted to the EU level**.

4.3. Robustness checks

To check the robustness of our main analysis, we performed several robustness checks. Table A.4.8 (in the Appendix) provides an overview of the most important results. Summarized, we conducted the following robustness checks:

1. *Alternative period*. In our main analysis we used 2018 data for each input, intermediate output, and final outcome. Although the data seem relatively stable over time (and thus the impact of cyclical bias is expected to be negligible), we instead used two-year average (2017–2018) data for inputs and outputs[27] as a robustness check. The results are quite robust for both models, although spillovers turn statistically significant (at the 10 percent significance level) in Model A and the '% change' becomes *slightly* negative in Model B (see Rows (3) and (4) of Table A.4.8 (in the Appendix)).
2. *Alternative input*. In our main analysis we used wastewater management expenditures as a percentage of GDP as our input. As a robustness check, we used wastewater management expenditures as a percentage of total public expenditures. As shown in Rows (5) and (6) of Table A.4.8 (in the Appendix), the results of both models are robust.
3. *Keep outliers*. Because DEA models are sensitive to outliers, we dropped them in our main analysis. As a robustness check, we did not drop the outliers. As shown in Rows (7) and (8) of Table A.4.8 (in the Appendix), results are robust.

4.4. Conclusion

In this chapter we performed a benchmarking analysis on **wastewater management expenditures**. The estimated Member States' budgetary waste rates are large, both in terms of final outcomes and outputs. Assuming that, if resources would be allocated to the EU level, the EU would operate on the efficient production function as estimated using actual production by Member States, the same amount of wastewater could be treated and the same share of resident population could be connected to a wastewater collecting system with 69 and 82 percent fewer resources, respectively. In other words, EU Member States could connect the same share of the population to wastewater treatment plants, and **save almost €16 billion per year**.

In terms of scale efficiency and spill-over effects, the results are mixed. We found evidence that shifting wastewater management expenditures to the EU level would increase the efficiency of the production of intermediate outputs because most Member States are operating under increasing returns to scale (four Member States operate under constant returns to scale). Shifting wastewater management expenditures to the EU level would allow the EU to exploit these **scale effects**, which results in an **efficiency gain** (in terms of connecting population to wastewater treatment plants) of **5.1 percent.** When considering our intermediate output model, we also observed **significant spill-**

[27] Unfortunately, it is not possible to replace our final outcome (EPI) by data averaged over multiple years because EPI scores of different years are not comparable due to changes in underlying methodology. Furthermore, EPI data are not available for 2017.

over effects. These could be internalized by allocating wastewater management expenditures to the EU level.

However, we found no evidence of increased scale efficiency in case of common EU action in the domain of wastewater management when considering final outcomes. In fact, the results suggest that the efficiency of treatment of wastewater would decrease. There is also no convincing evidence of spill-over effects: although the estimated effects seem to suggest there are spill-over effects, they are not precisely estimated (the relevant coefficients are statistically insignificant). The **lack of evidence in favor of shifting wastewater management expenditures to the EU level when considering final outcomes** is not entirely surprising. The appropriate level of governance in the domain of water resources management more generally (that is, regulation of water quantity and quality) has been debated in the EU and beyond (for example in Canada; (Hill et al., 2008)). Although there are arguments for common action (for example, because wastewater can impact downstream states), grounds in favor of Member State competencies have been raised as well (for instance, national legislation is more likely to reflect local circumstances) (Akhmouch et al., 2018; Stoa, 2014).[28]

[28] For a more elaborate overview of the advantages and disadvantages of common action in the domain of water governance, see Akhmouch et al. (2018).

5. Ambient air, soil and groundwater protection and noise abatement expenditures

Exposure to air pollution can cause disease (respiratory illness, stroke, lung cancers, etc.) and is the number-one cause of premature deaths in the EU (over 390,000 per year). Furthermore, it has an important economic impact since the ill health of workers reduces productivity and increases medical costs. Air pollution also damages soil, lakes, rivers, and houses. The greatest harm to human health and the economy is caused by particulate **matter (PM)**[29] and Nitrogen Oxides **(NOx)**[30] (EPRS, 2021; European Commission, 2021b; European Environment Agency, 2021a, 2021d).

Because of the important negative effects of air pollution and its cross-border dimension, the **EU has been working to improve air quality** since the early 1970s[31] (EPRS, 2021; European Commission, 2021b). A recent policy initiative is the European Green Deal, which aims to achieve zero pollution by 2050. To reach this ambition, the EU Action Plan – "Towards Zero Pollution for Air, Water and Soil", which sets out a number of targets for 2030 (such as reducing health impacts of air pollution by more than 55 percent) – was adopted by the European Commission in 2021 (European Commission, 2021f; European Parliament, 2022d).

The EU's air pollution policy is based on three pillars. First, the Ambient Air Quality Directives (AAQDs) define methods to monitor and assess air quality, set standards, provide air quality information to the public, and ensure good air quality (maintain if the quality is already good, improve if quality is not good enough). In 2021, the European Commission announced that a revision of the AAQDs is necessary to align the standards more closely with those recommended by the World Health Organization (WHO) (expected: third quarter 2022) (European Commission, 2021e; European Parliament, 2022a, 2022c). Second, the Directive on the Reduction of National Emissions (NEC Directive) sets up commitments for the reduction of national emissions. Third, legislative acts regulate air pollution in certain sectors (such as industry and transport). An example is the Industrial Emission Directive, which controls pollution from industrial activities (EPRS, 2021).

Thanks to these initiatives, the air quality in the EU has already improved considerably. However, the EEA's annual Air quality in Europe assessment reveals that **air pollution still poses a risk to both human health and the environment** (European Environment Agency, 2020a).Because of the important negative impact of poor air quality and its cross-border dimension, **we analyzed the efficiency of expenditures to reduce pollution levels** (ambient air, soil, groundwater and noise pollution) in this chapter (second specific subdomain of environmental protection). Given the scope of this project, it was only possible to analyze final outcomes. Further research should also focus on efficiency in terms of intermediate outputs.

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29 PM can have many sources. It can be emitted from both natural activities (such as volcanic eruptions) and human activities (industry, motorized vehicles, etc.).

30 NOx is emitted from fuel combustion (power plants, industrial facilities, etc.).

31 Legal basis: Articles 191 to 193 of the Treaty on the Functioning of the European Union (TFEU).

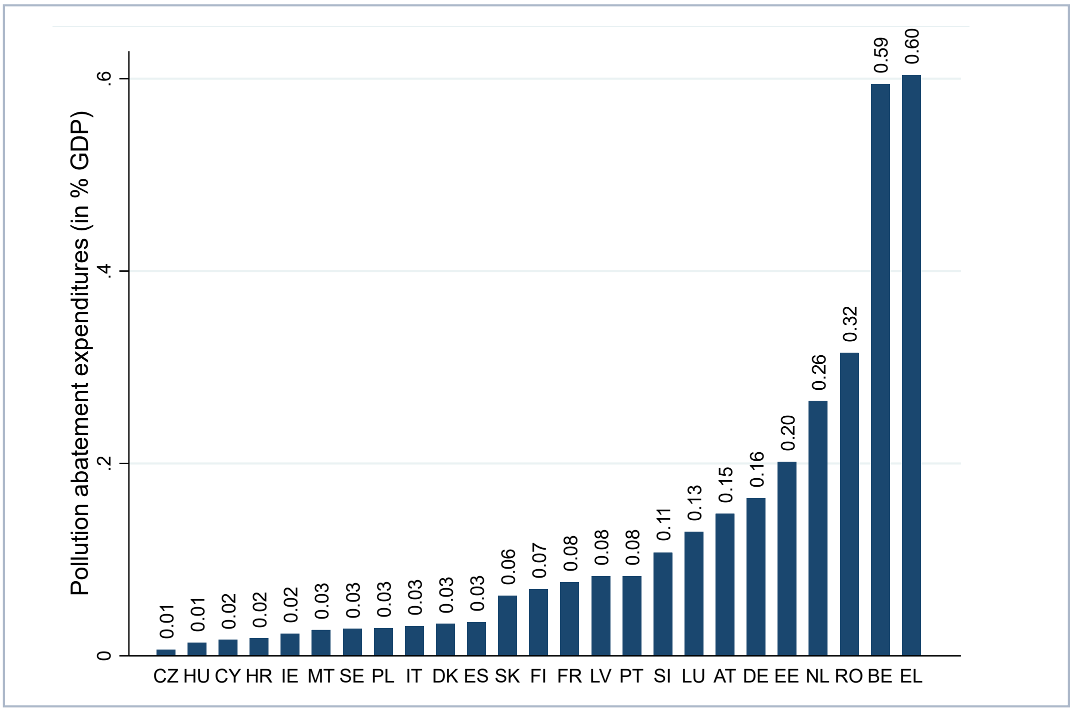
5.1. Data

5.1.1. Data on ambient air, soil and groundwater protection and noise abatement expenditures

We used data on **ambient air, soil and groundwater protection and noise abatement expenditures** (as a percentage of GDP (2018)) as an **input measure**, which Eurostat (2019) defined as: "Expenditures on activities relating to ambient air, soil and groundwater protection and noise abatement. These activities include construction, maintenance and operation of monitoring systems and stations (other than weather stations); construction of noise embankments, hedges and other anti-noise facilities including the resurfacing of sections of urban highways or railways with noise reducing surfaces; measures to clean pollution in water bodies; measures to control or prevent the emissions of greenhouse gases and pollutants that adversely affect the quality of the air; construction, maintenance and operation of installations for the decontamination of polluted soils and for the storage of pollutant products; transportation of pollutant products".

Ambient air, soil and groundwater protection and noise abatement expenditures of each Member State are shown in Figure 5.1. There are large differences among countries. Many countries have very low expenditures (Czechia, Hungary, Cyprus, Croatia, Ireland, Malta, Sweden, Poland, Italy, Denmark and Spain spend 0.03 percent of GDP or less), while two countries have notably higher ambient air, soil and groundwater protection and noise abatement expenditures than the others (Belgium and Greece spend 0.56 percent and 0.60 percent of GDP). **The total annual ambient air, soil and groundwater protection and noise abatement expenditure of all EU Member States combined**[32] **is almost €16.5 billion or 0.13% percent of GDP.**

Figure 5.1: ambient air, soil and groundwater protection and noise abatement expenditures 2018 (% of GDP)



Source: Eurostat

[32] With the exception of Bulgaria and Lithuania, for which data are unavailable.

5.1.2. Data on final outcomes

The goal of ambient air, soil and groundwater protection and noise abatement is to reduce air, soil, groundwater, and noise pollution. Therefore, we use several **final outcome indicators**. Member State data are shown in Table 5.1 and bar charts are provided in Figure A.5.1 to Figure A.5.5 (in the Appendix).

The three main final outcome indicators are the EPI components "PM2.5 exposure", "PM2.5 exceedance", and "NOX emissions". These components, related to local air pollutants, are scores ranging from 0 to 100, where a score of 0 identifies worst performance (high emissions) and a score of 100 best performance (low emissions).[33]

The EPI **PM2.5 exposure** component is calculated rescaling the population-weighted average concentration of PM2.5 in each country into a score from 0 to 100 (Wendling et al., 2018). On average, Member States score 83.2. As shown in Figure A.5.1 (in the Appendix), nine countries have the maximum score of 100 (Denmark, Estonia, Spain, Finland, Ireland, Latvia, Malta, Portugal, Sweden), while the worst-performing country (Poland) has a score of only 46.6.

PM2.5 exceedance is calculated rescaling the proportion of the population in each year that is exposed to ambient PM2.5 concentrations that exceed WHO thresholds of 10, 15, 25, and 35 micrograms per meter cubed (μg/m3) into a 0–100 score (Wendling et al., 2018). Member States have an average score of 85.7. Figure A.5.2 (in the Appendix) shows a difference of more than 40 points between the best-performing countries (Finland, Ireland, and Malta) and the worst-performing one (Poland).

The EPI **NO_X emissions** component is based on the NO_X emission intensity (rescaled into a 0 to 100 score) (Wendling et al., 2018). Member States score worst on this component (average Member State score: 62.6). There is a difference of 74 points between the best-performing (Germany) and worst-performing (Luxembourg) country (see Figure A.5.3 in the Appendix).

[33] These indicators are proxies for air pollution. However, as air pollutants can mix with rain and accumulate on soils and groundwater, they could also be seen as proxies for soil and groundwater pollution (Wendling et al., 2018). Because our input variable consists of expenditures on activities relating to not only ambient air, but also soil protection, groundwater protection, and noise abatement, we also add a measure for drinking water quality and noise pollution as final outcomes. For the former, we use the EPI drinking water component, which measures the disability-adjusted life-years (DALYs) lost per 100,000 persons from unsafe drinking water, and is then rescaled into a score from 0 to 100. Since groundwater covers 40 percent of the need for drinking water, this EPI component could be considered as a proxy for groundwater quality. For the latter, we use the proportion of the population that declares it is not affected by noise pollution. Since the assessment of noise pollution is subjective, an increase/decrease of this variable could be caused by both a change in the level of noise pollution and a change in what people consider acceptable noise.

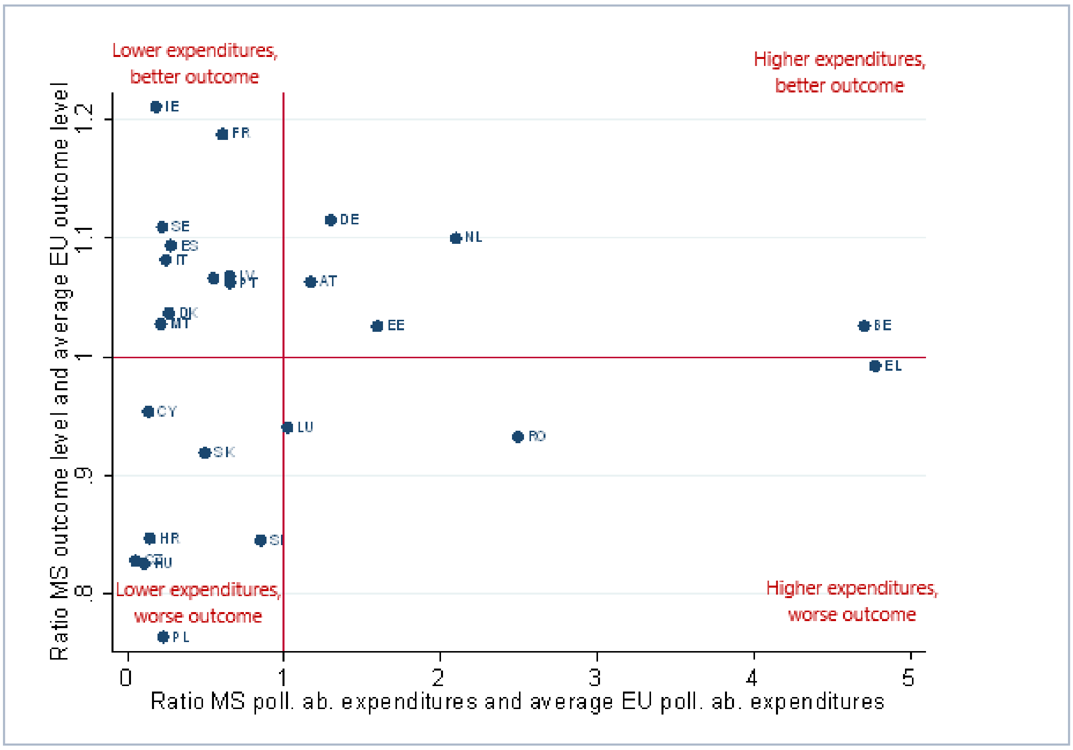
Table 5.1: Values of outcomes related to air pollution

Country	PM2.5 Exposure	PM2.5 Exceedance	NOX Emission
AT	77.05	81.13	80.33
BE	79.83	86.60	64.97
BG	85.44	87.33	56.66
CY	85.49	86.02	42.62
CZ	56.56	65.55	56.64
DE	81.80	85.12	98.44
DK	100.00	97.53	45.21
EE	100.00	99.97	60.31
EL	90.77	89.09	42.50
ES	100.00	97.44	59.51
FI	100.00	100.00	46.32
FR	95.46	92.10	98.01
HR	72.84	75.83	37.14
HU	52.56	64.63	55.26
IE	100.00	100.00	88.45
IT	69.67	75.28	90.12
LT	84.72	86.97	51.89
LU	94.17	89.68	24.35
LV	100.00	97.58	77.07
MT	100.00	100.00	45.37
NL	80.58	85.01	94.40
PL	46.57	56.44	49.21
PT	100.00	99.90	52.87
RO	68.21	72.71	81.63
SE	100.00	99.57	64.20
SI	73.59	79.02	37.94
SK	50.78	62.69	88.81
Total	83.19	85.67	62.60

All variables are EPI scores and measured on a scale from 0 to 100.
Source: EPI (PM2.5 exposure, PM2.5 exceedance, NOX emission)

Figure 5.2 shows the **relationship between ambient air, soil and groundwater protection and noise abatement expenditures and the outcomes**. All outcomes are equally weighted and expressed as the ratio between the Member State level and the average EU level. The correlation coefficient is 0.08. The most efficient Member States are Ireland, Sweden, Spain, Italy, Denmark, Malta, Finland, France, Latvia, and Portugal, and the least efficient are Luxembourg, Romania, and Greece.

Figure 5.2: Outcome and ambient air, soil and groundwater protection and noise abatement expenditures



All outcomes are equally weighted. The red lines represent the average EU level.

Source: Eurostat (ambient air, soil and groundwater protection and noise abatement expenditures, noise pollution) and EPI (PM2.5 exposure, PM2.5 exceedance, NOX emission drinking water).

5.1.3. Data for second-stage and spatial analysis

We use the same independent variables in the second-stage regression (and spatial regression models) as we do in Chapter 3, since ambient air, soil and groundwater protection and noise abatement is a subdomain of environmental protection (Eurostat, 2019). For a presentation of these data, see Section 3.1.4.

The correlation coefficients among the EPI PM2.5 exposure, PM2.5 exceedance, and NOX emission components, and the explanatory (control) variables of the second-stage and spatial analysis are displayed in Table A.5.1 in the Appendix.

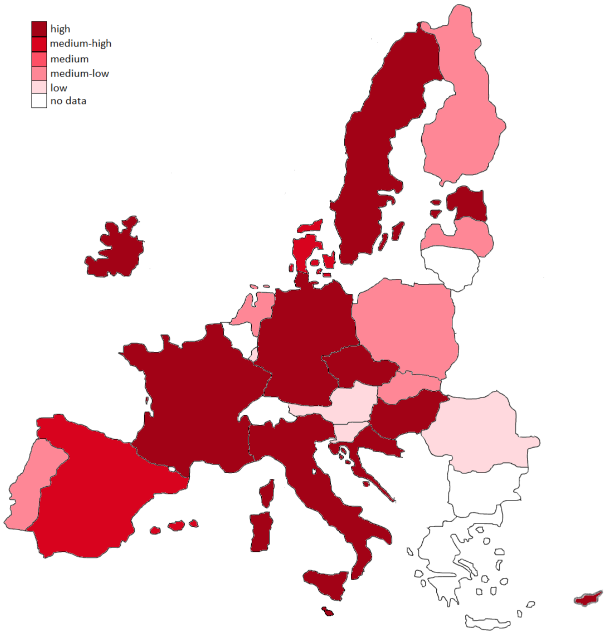
5.2. Results

We ran one DEA model (Model A) where outcomes are modelled as a function of input (ambient air, soil and groundwater protection and noise abatement expenditures). Our goal was to obtain estimates of Member States' efficiency in terms of ambient air, soil and groundwater protection and noise abatement and to compute Member States' budgetary waste rates to determine how many resources could be saved if Member States act efficiently.

5.2.1. Budgetary waste in ambient air, soil and groundwater protection and noise abatement expenditures

The estimated efficiency scores of Model A (outcome=f[input]) are shown in Figure 5.3 and Table A.5.2 (in the Appendix). We observed large differences in efficiency scores among countries. **The average Member State efficiency score is equal to 0.62, which corresponds to a budgetary waste rate of 38 percent.**

Figure 5.3: Efficiency estimations, Model A: outcome=f(input)



Source: Own estimates based on Eurostat data

The factors other than ambient air, soil and groundwater protection and noise abatement expenditures that impact the efficiency scores in the production of outcomes, are identified in a second-stage analysis.

We ran three models,[34] which differ in the number of explanatory variables considered. The regression output is shown in Table A.5.3 (in the Appendix). Two explanatory variables have a statistically significant impact on the efficiency scores in the most elaborated model. First, **road length** is positively associated with efficiency. Second, **urban population** and efficiency are positively correlated. This is in line with the hypothesis that citizens of urban areas are more exposed to pollution and may therefore exert political pressure to reduce pollution (Damania et al., 2003).

5.2.2. Economies of scale and cross-border spill-over effects

To answer the question of whether it would be beneficial to shift EU Member States' national ambient air, soil and groundwater protection and noise abatement expenditures to the EU level, we analyzed whether there are economies of scale and/or spill-overs.

Model A reveals **decreasing returns to scale for 22 Member States** and constant returns to scale for the remaining one for which we have data. On average, **the efficiency score of Member States would decrease with 54.4 percent** (see Table A.5.2 in the Appendix) **when moving to a larger**

[34] Model 1: GDP per capita, GDP growth, surface area, and population density; Model 2: explanatory variables Model 1 + industry value added, and urban population; Model 3: explanatory variables Model 2 + education, SPI, trade intensity, and road length.

scale. The decrease is relatively large because the scale efficiency of these countries is particularly low (0.46).

Table A.5.4 (in the Appendix) shows the output of the spatial analysis, which reveals **no statistically significant spill-over effects**; therefore, based on these results, spill-over effects as such are not an argument to shift ambient air, soil and groundwater protection and noise abatement expenditures to the EU level.

5.3. Robustness checks

We performed several robustness checks. Table A.5.5 (in the Appendix) provides an overview of the results. One striking result is that almost all robustness checks find, in contrast to the main analysis, evidence of spill-over effects. We discuss the other results below. Summarized, we conducted the following robustness checks:

1. *Alternative period*. In our main analysis we used 2018 data for each input and final outcome. Although the data seem relatively stable over time (and thus the impact of cyclical bias is expected to be negligible), we instead used two-year average (2017–2018) data for inputs[35] as a robustness check. The results are robust (see Row (2) of Table A.5.5 (in the Appendix)).
2. *Alternative input*. In our main analysis we used ambient air, soil and groundwater protection and noise abatement expenditures as a percentage of GDP as our input. As a robustness check, we used ambient air, soil and groundwater protection and noise abatement expenditures as a percentage of total public expenditures. The results are robust (see Row (3) of Table A.5.5 (in the Appendix)).
3. *Alternative outcome*. In our main analysis we used all outcome measures as outputs. As a robustness check, we ran DEA models for each outcome related to ambient air separately. The results are robust (see Rows (4) to (6) of Table A.5.5 (in the Appendix)).
4. *Keep outliers*. Because DEA models are sensitive to outliers, we dropped them in our main analysis. As a robustness check, we did not drop the outliers. The results are robust (see Row (7) of Table A.5.5 (in the Appendix)).

5.4. Conclusion

In this chapter we performed a benchmarking analysis on **ambient air, soil and groundwater protection and noise abatement expenditures.**[36] We found an average Member States' budgetary waste rate of 38 percent. This means that the same level of pollutants could be achieved with 38 percent fewer resources assuming that, if resources would be allocated to the EU level, the EU would operate on the efficient production function as estimated using actual production by Member States.

Next, we found that the majority of the Member States are operating under large decreasing returns to scale. As a result, shifting ambient air, soil and groundwater protection and noise abatement expenditure to the EU level would result in an **efficiency loss** of **54.37 percent**.

Finally, we found **no** evidence for the existence of **significant spill-over effects**.

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[35] Unfortunately, it is not possible to replace our final outcome (EPI components) by data averaged over multiple years because EPI scores of different years are not comparable due to changes in underlying methodology. Furthermore, EPI data are not available for 2017.

[36] Given the scope of this project, it was only possible to analyse final outcomes.

In sum, it would not be beneficial to shift the domain of ambient air, soil and groundwater protection and noise abatement to the EU level since doing so would result in a large efficiency loss and there are no spill-over effects that have to be internalized. Although air pollution is a cross-border problem and there are reasons to believe that common action is necessary to address it, it is also believed that local circumstances should be considered when designing and implementing legislation to reduce air pollution. This is more feasible using national/local legislation (EPRS, 2021; United Nations Environment Programme, 2021).

6. Concluding remarks

In this research paper, we adopt an input-oriented DEA approach to calculate a measure of budgetary waste (that is, how many resources could be saved if Member States acted efficiently?) and to estimate economies of scale. The former could be an argument for common action at the EU level, if the EU would operate on the efficient production function as estimated using actual production by Member States. By assigning environmental expenditures to the EU level, returns to scale could be exploited, which would result in efficiency gains as well. Spatial regression analyses are used to establish whether there are cross-border spillover effects that could be internalized.

The analyses were conducted for total environmental protection expenditures and two selected subdomains: (1) wastewater management and (2) ambient air, soil and groundwater protection and noise abatement. In our applications, we generally found **high budgetary waste rates**, ranging from 38 percent (ambient air, soil and groundwater protection and noise abatement) to no less than 82 percent (wastewater management). When focusing on **intermediate outputs**[37], we always found that efficiency would increase if the scale of operations would enlarge, and we always found evidence of spillovers. In other words, the results suggest that **shifting spending to the EU level would be beneficial** for solar, wind, and hydro energy production and circular material use (that is, Application 1, see Chapter 3) and the availability of wastewater collecting systems (Application 2, see Chapter 4).

When focusing on **final outcomes**[38], results are somewhat mixed. There is evidence of spill-over effects in total environmental spending, but not spending on wastewater management and ambient air, soil and groundwater protection and noise abatement. This indicates that **spill-over effects in environmental spending are coming from other subdomains**. Therefore, future research should analyze other aspects of environmental spending as well. A larger scale would not increase efficiency of final outcomes in any of the applications. However, outcomes depend not only on environmental expenditures, but also on other factors such as economic, social, political, and other geographical characteristics of a country. Our results confirm this.

The fact that we find, for example, spill-overs in total environmental spending but not in the two selected subdomains (wastewater management and ambient air, soil and groundwater protection and noise abatement) confirms the hypothesis that **not all subdomains of environmental spending necessarily have a positive budgetary savings ratio**. However, in light of the EU's principle of homogeneity (i.e. existence of common rules) and creating efficiency competence packages at the EU level, one could argue in favor of transferring coherent packages of spending to the EU level. More research is required in order to assess which subdomains of environmental spending (and potentially which elements of wastewater management and ambient air, soil and groundwater protection and noise abatement) could lead to budgetary savings.

In this research paper, it is important to note that efficiency gains are only one part of the impact of transferring competences to the EU level. Also noteworthy is the provision of **additional public goods** (for instance, new approaches and instruments to tackle wastewater, to tackle pollution, etc.), but also the **reduction in administrative costs** by having one administration instead of 27 administrative services at the Member State level. Because such costs are not included in the environmental expenditure data, these effects are not covered by the analyses in the present paper. Furthermore, the economic literature has clearly shown that **tackling externalities becomes more efficient at a higher level of government**. Although our scale effects partly measure these effects,

[37] More specific outputs needed to produce final outcomes (e.g. green energy production, circular material use).

[38] More general outputs (e.g. Environmental Performance Indicator).

other possible effects, such as enhanced innovation, can be generated by additional spending (that is, the production frontier could shift to a higher level than that achieved by the best-performing Member State).

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A.3. Appendix to Chapter 3

Table A.3.1: Environmental quality – Explanatory variables in the literature

Environmental quality indicator	Lamla (2009)	Co2[39]		So2[40]		BOD[41]		Gassebner et al. (2011)	Air pollution[42]	
Expl. Var.	Proxy	% sign	β	% sign	β	% sign	β	Proxy	% sign	β
GDP per capita	Log of real GDP per capita	76%	2.4610	70%	2.7336	36%	1.0210	Log of GDP per capita	92%	1.577
GDP growth	GDP growth rate	17%	0.0296	2%	−0.0010	8%	−0.0084	GDP growth rate	9%	0.001
Surface area	Land area (km²)	41%	0.0000	58%	0.0000	5%	0.0000			
Population density	Log of population per hectare	7%	0.0608	15%	−0.1293	3%	−0.0460	Log of population per hectare	55%	0.493
Education	Gross primary school enrollment (in %)	36%	−0.0034	11%	−0.0063	6%	0.0026	Gross primary school enrollment (in %)	16%	0.002
SPI								Democracy Score	12%	-0.005
Industry	Manufacturing value added (% of GDP)	2%	−0.0006	1%	0.0014	13%	−0.0048	Manufacturing value added (% of GDP)	42%	0.007
Trade intensity	(Import + export)/GDP	7%	−0.0003	5%	0.0025	11%	0.0008	(Import + export)/GDP	17%	0.001
Transport										
Urban population	Urban population (% of total)	24%	0.0010	36%	0.0072	23%	0.0032	Urban population (% of total)	21%	0.006

39 CO_2: Log of carbon dioxide (CO_2) emissions in metric tons per capita.

40 SO_2: Log of sulphur dioxide (SO_2) emissions in metric tons per capita.

41 BOD: Log of biochemical oxygen demand (BOD) in grams per day per capita.

42 Air pollution: Log of carbon dioxide (CO_2) Emissions (metric tons) per capita.

Table A.3.1: Environmental quality – Explanatory variables (continued)

	Gassebner et al. (2011)		Neumayer (2003)										
Environmental quality indicator	Water pollution[43]			CO_2[44]		SO_2[45]		NO_2[46]		CO[47]		VOC[48]	
Expl. Var.	% sign	β	Proxy	s.l.	β	s.l.	β	s.l.	β	s.l.	β	s.l.	β
GDP per capita	91%	1.792	Log of GDP per capita	1%	0.826	1%	2.001	1%	1.216	5%	0.422	1%	0.655
GDP growth	5%	-0.002											
Surface area													
Population density	7%	0.123											
Education	7%	0.002											
SPI	17%	0.011											
Industry	45%	0.010	Share GDP from manufacturing	NS	0.335	NS	1.436	1%	0.926	NS	0.110	NS	0.455
Trade intensity	10%	0.001											
Transport			Per capita vehicle use	5%	0.096	5%	0.444	1%	0.274	5%	0.276	1%	0.511
Urban population	70%	0.019											

Proxy: definition of the variable used in the concerned study
% sign: the percentage of regressions in which the respective variable is significant at a 5% significance level
s.l.: level on which the respective variable is significant (NS: Not Significant)
β: coefficient
Source: Lamla (2009), Gassebner et al. (2011) and Neumayer (2003)

43 Water pollution: log of biochemical oxygen demand (BOD) (grams per day) per capita.

44 CO_2: Log of carbon dioxide (CO_2) per capita.

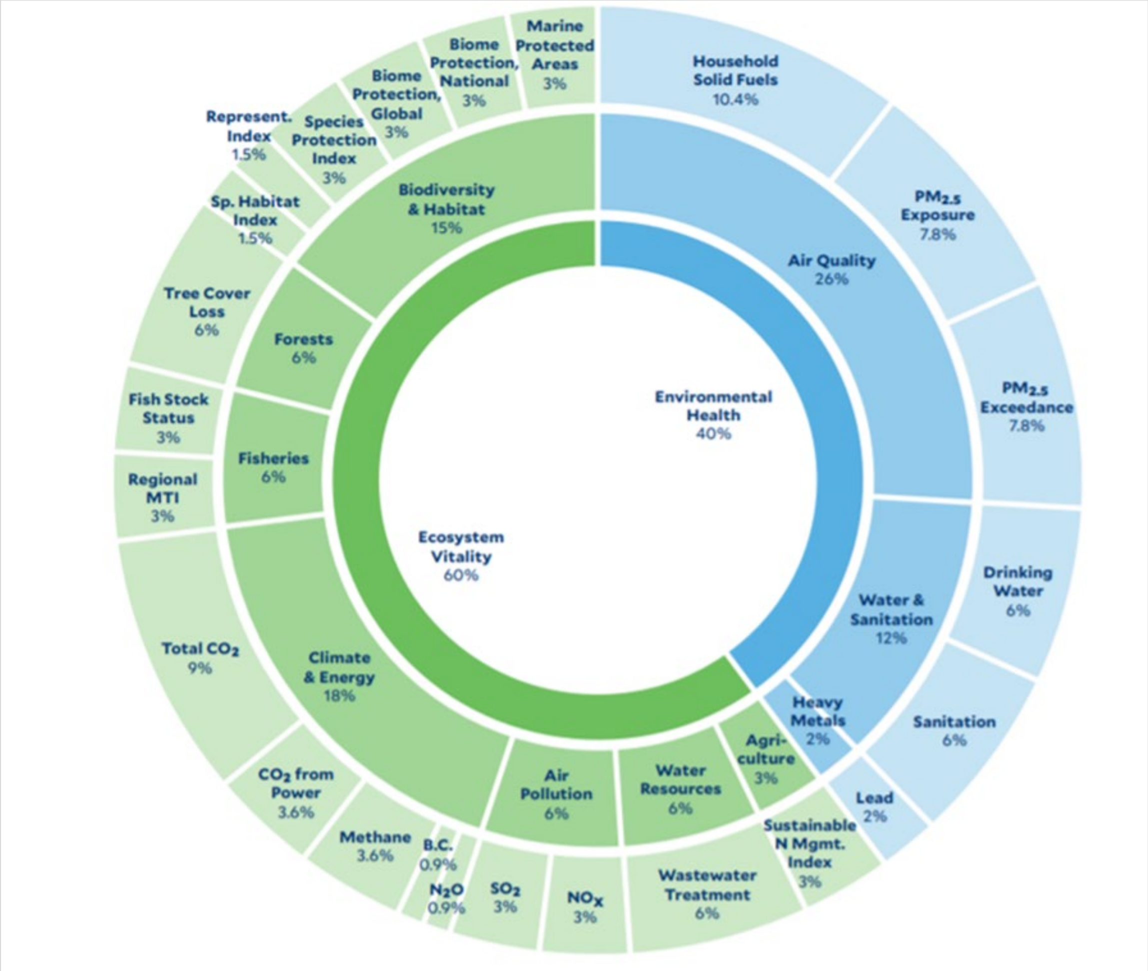
45 SO_2: log of sulphur dioxide (SO_2) per capita.

46 NO_2: log of nitrogen oxide (NO_2) per capita.

47 CO: log of carbon monoxide (CO) per capita.

48 VOC: log of volatile organic compound (VOC) per capita.

Figure A.3.1: Composition Environmental Performance Index (EPI)



Source: Wendling et al. (2018)

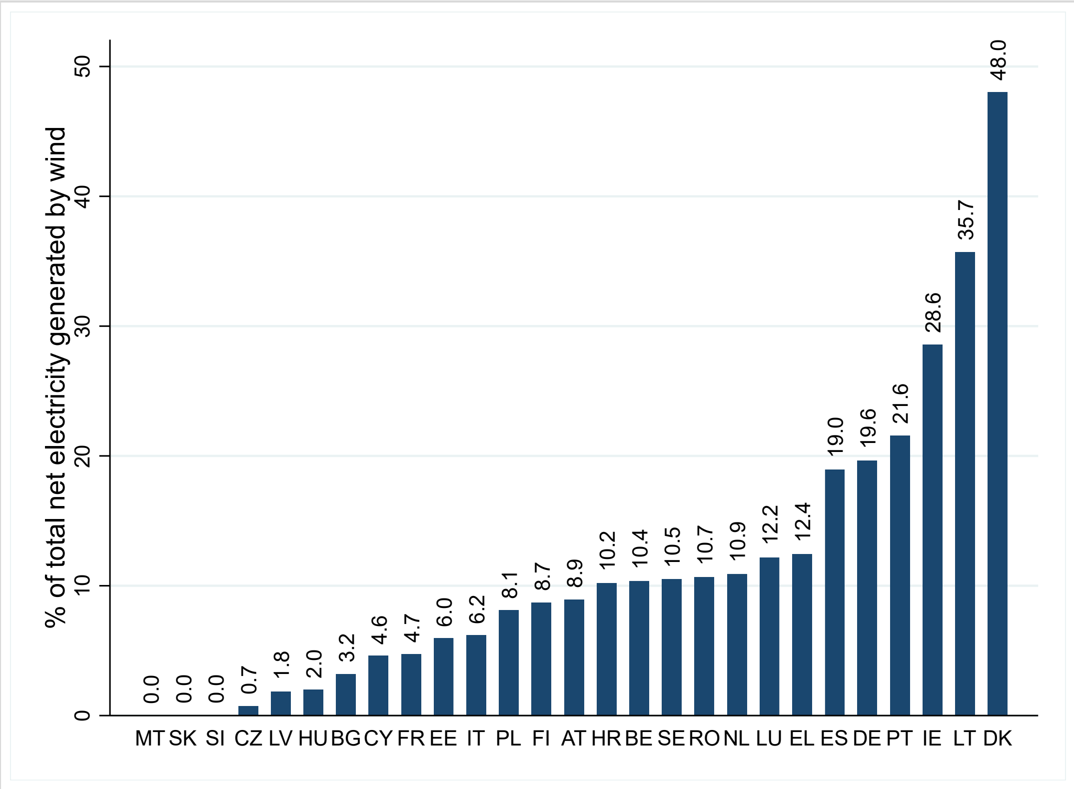
Table A.3.2: Values of intermediate outputs and aggregate index

Country	Wind energy	Solar energy	Hydro energy	Circular material use	Aggregate index
AT	8.93	0.00	56.74	11.10	38.39
BE	10.37	5.04	1.79	19.90	18.55
BG	3.18	2.50	11.25	2.50	9.72
CY	4.60	3.97	0.00	2.80	5.69
CZ	0.73	2.83	3.23	8.00	7.40
DE	19.62	8.08	3.51	11.70	21.45
DK	48.03	3.29	0.05	8.10	29.74
EE	5.96	0.00	0.17	13.50	9.81
EL	12.42	7.48	11.44	3.30	17.32
ES	18.96	4.65	13.82	9.30	23.36
FI	8.69	0.13	19.52	5.90	17.12
FR	4.74	1.75	12.45	19.50	19.22
HR	10.19	0.52	57.94	5.00	36.83
HU	1.98	2.00	0.73	7.00	5.85
IE	28.56	0.00	3.15	1.60	16.66
IT	6.18	8.17	17.58	18.80	25.37
LT	35.70	2.51	29.55	4.30	36.03
LU	12.18	5.16	61.27	10.80	44.70
LV	1.85	0.00	37.20	4.70	21.87
MT	0.00	.	0.00	8.30	.
NL	10.91	2.15	0.08	28.90	21.02
PL	8.10	0.19	1.53	9.80	9.81
PT	21.57	1.68	23.22	2.20	24.34
RO	10.66	2.99	30.06	1.50	22.61
SE	10.50	0.00	38.49	6.60	27.80
SI	0.04	1.66	31.61	10.00	21.66
SK	0.02	2.47	16.18	4.90	11.79
Total	11.28	2.66	17.87	8.89	20.31

INTERMEDIATE OUTPUTS: Wind energy – Percentage of total net electricity generated by wind; solar energy – Percentage of total net electricity generated by sun; hydro energy – Percentage of total net electricity generated by water; circular material use – The percentage of material recovered and fed back into the economy. **AGGREGATE INDEX:** The intermediate outputs wind, solar, and hydro energy are combined into one composite indicator: "green energy" (percentage of total net electricity generated by wind, sun and water). Green energy and circular material use are equally weighted.

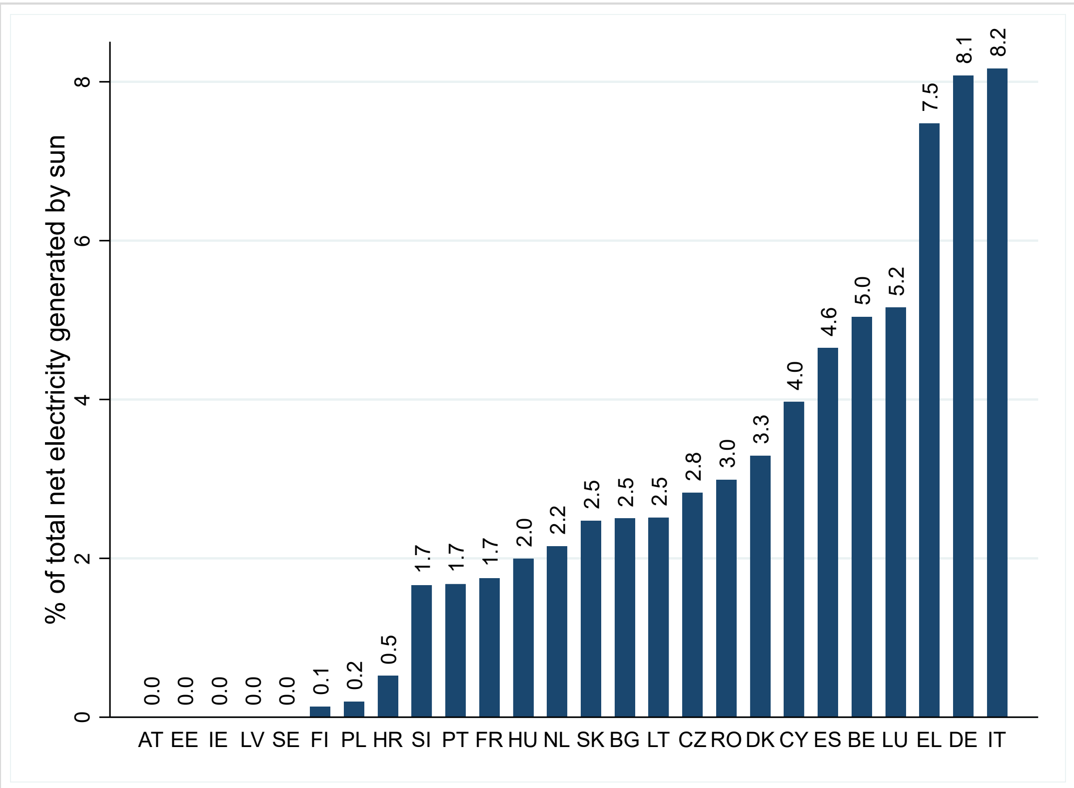
Source: Eurostat (Wind energy, solar energy, hydro energy, circular material use)

Figure A.3.2: Percentage of total net electricity generated by wind, 2018



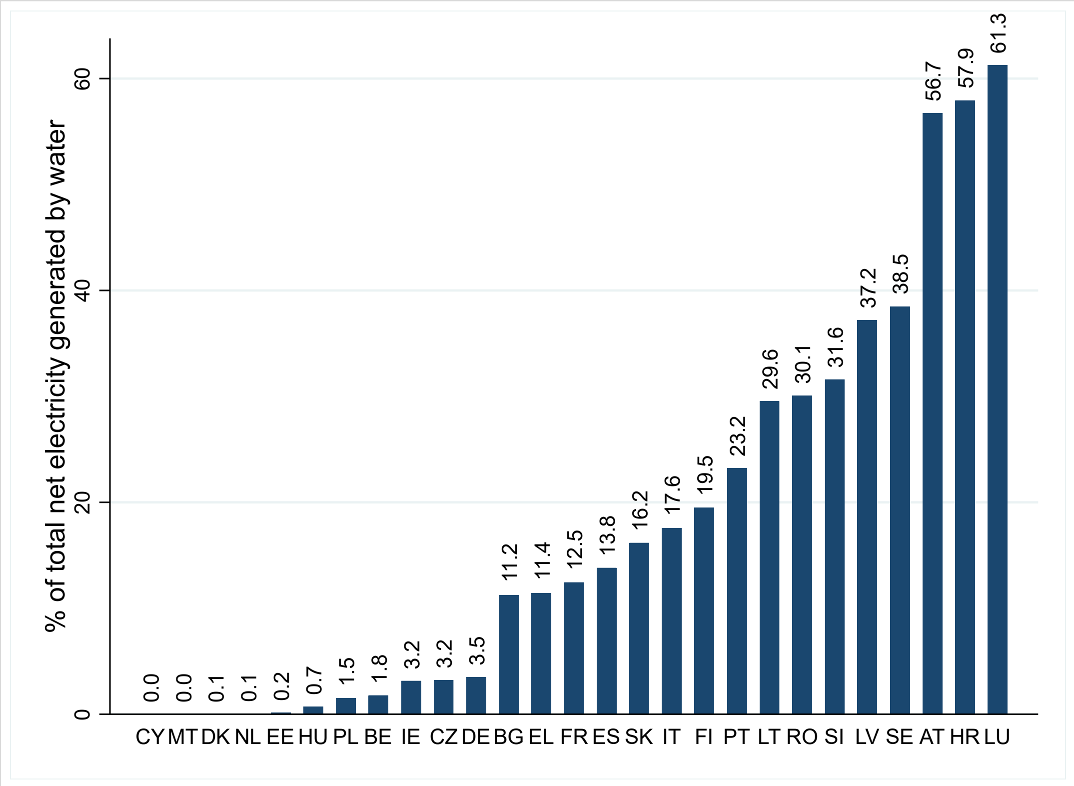
Source: Eurostat

Figure A.3.3: Percentage of total net electricity generated by sun, 2018



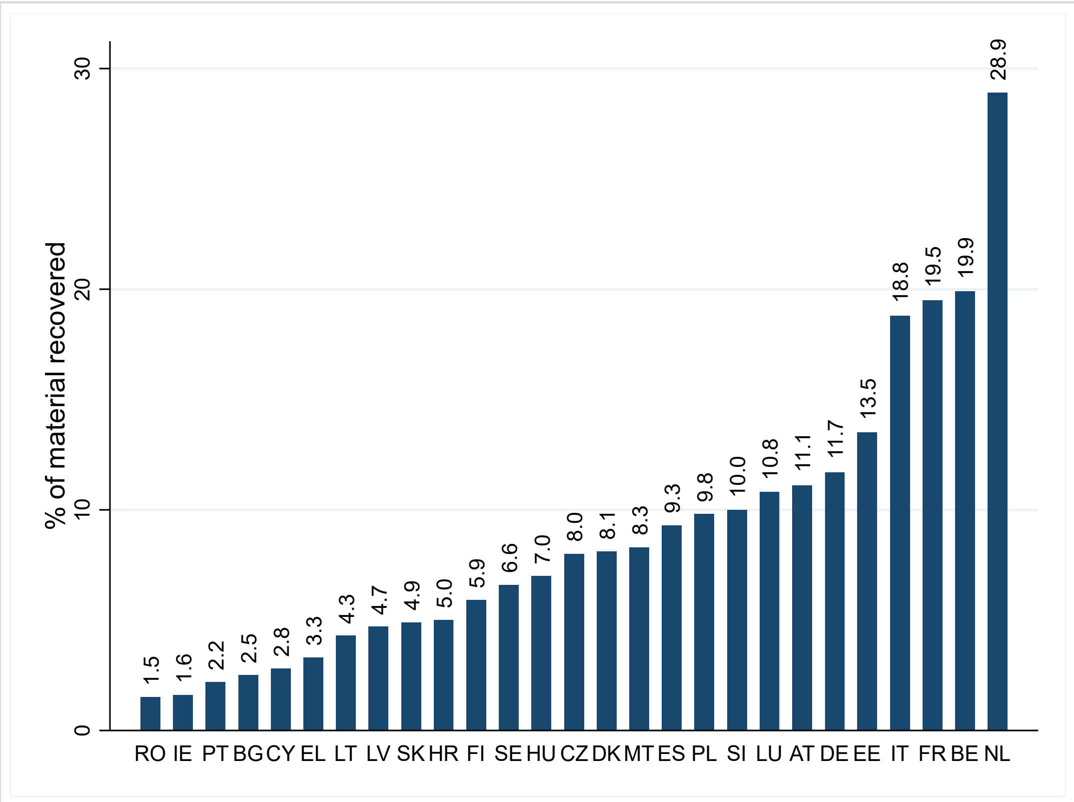
Source: Eurostat

Figure A.3.4: Percentage of total net electricity generated by water, 2018



Source: Eurostat

Figure A.3.5: Circular material use, 2018



Source: Eurostat

Table A.3.3: Variable description second-stage analysis

Variable	Definition
GDP per capita	Ratio of real GDP to the average population of a specific year, in €.
GDP growth	GDP growth rate in terms of volume, in percentage. The GDP at current prices are valued in the prices of the previous year and the thus computed volume changes are imposed on the level of a reference year.
Surface area	The area that includes land area and inland waters, in 100km².
Population density	Ratio of the annual average population to the land area, in inhabitants per km².
Education	15–64-year-old population with tertiary education, as a percentage of the total 15–64-year-old population.
Social Progress Index	Indicator of the extent to which countries meet the social and environmental needs of their citizens, measured on a scale from 0 to 100.
Industry value added	Value added by industry (including construction), as a percentage of GDP.
Trade intensity	Ratio of imports plus exports to GDP.
Road length	Length of roads (state, provincial, communal roads), in 100 km.
Urban population	Percentage of total population that lives in urban areas.

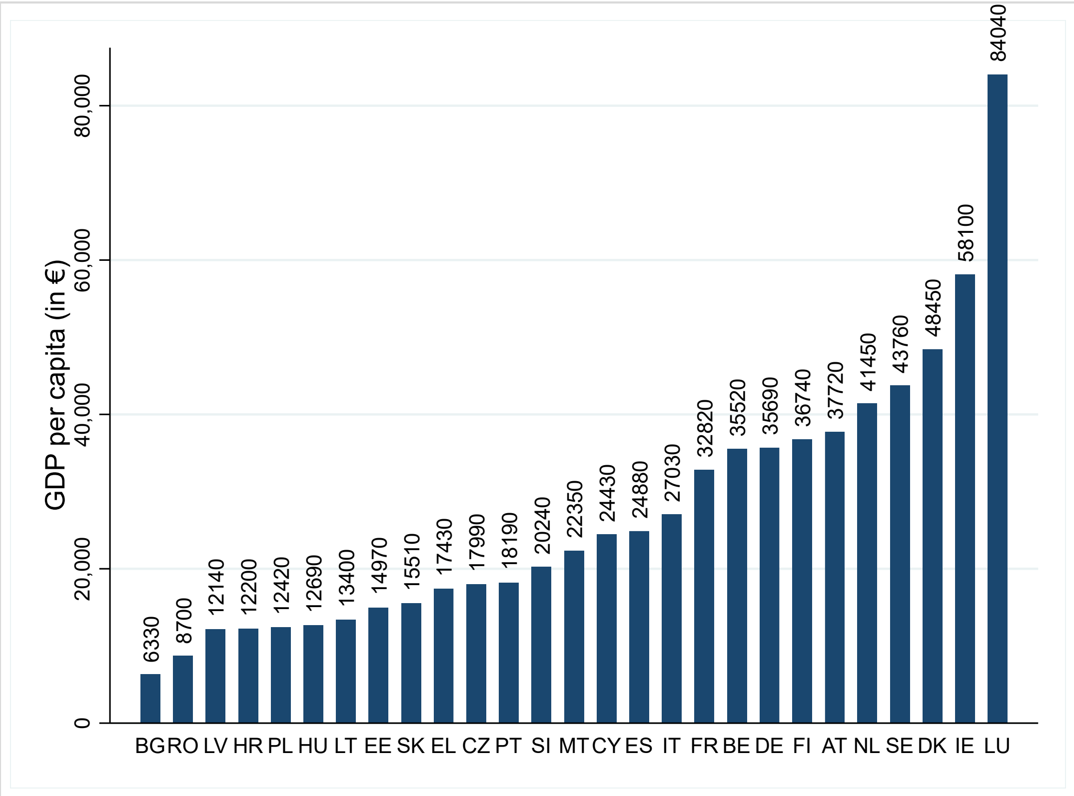
Source: Eurostat (GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data.

Table A.3.4: Descriptive statistics second-stage analysis

	N	Mean	Std. dev.	Min.	Max.
GDP per capita	27	27,229.26	17,509.09	6,330.00	84,040.00
GDP growth	27	3.32	1.86	0.90	9.00
Surface area	27	1,545.49	1,631.17	3.20	5,490.87
Population density	27	179.89	293.76	18.10	1,548.30
Education	27	29.40	7.08	15.50	40.50
SPI	27	84.46	4.33	74.51	89.96
Industry value added	27	22.33	6.25	11.77	37.03
Trade intensity	27	1.35	0.67	0.60	3.60
Road length	27	1,952.27	2,639.49	28.55	10,921.03
Urban population	27	73.37	13.15	53.73	98.00

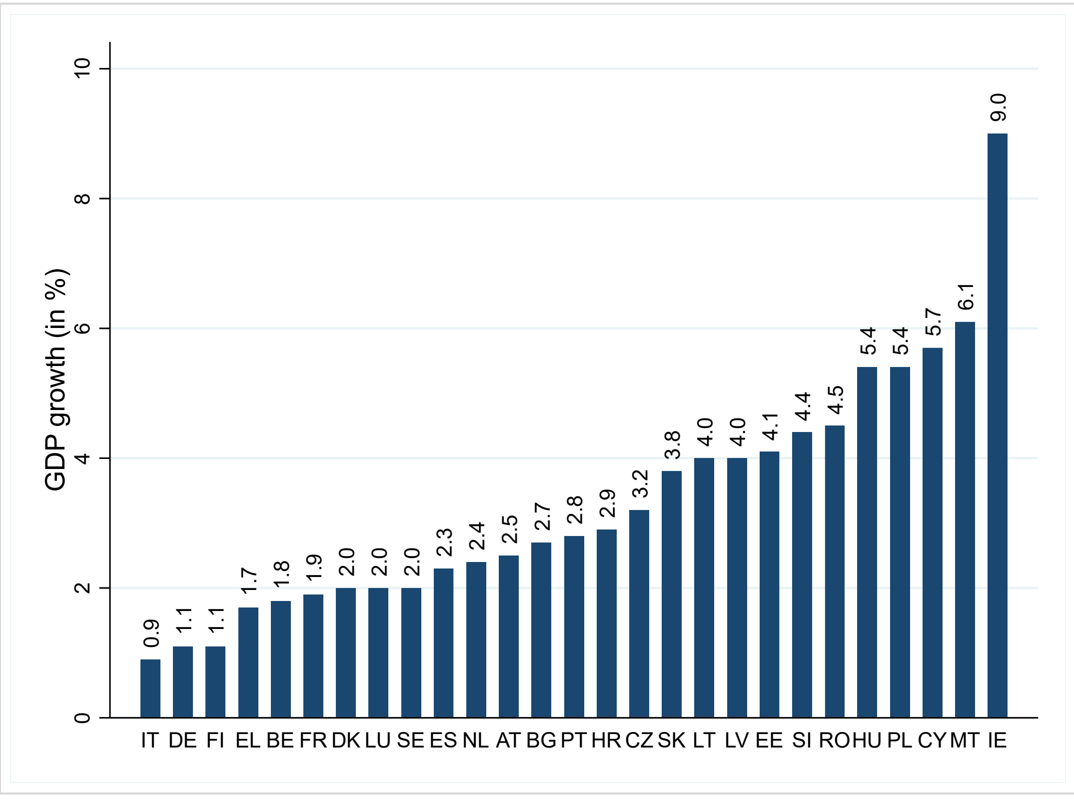
Source: Eurostat (GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data. All analyses use 2018 data.

Figure A.3.6: GDP per capita, 2018



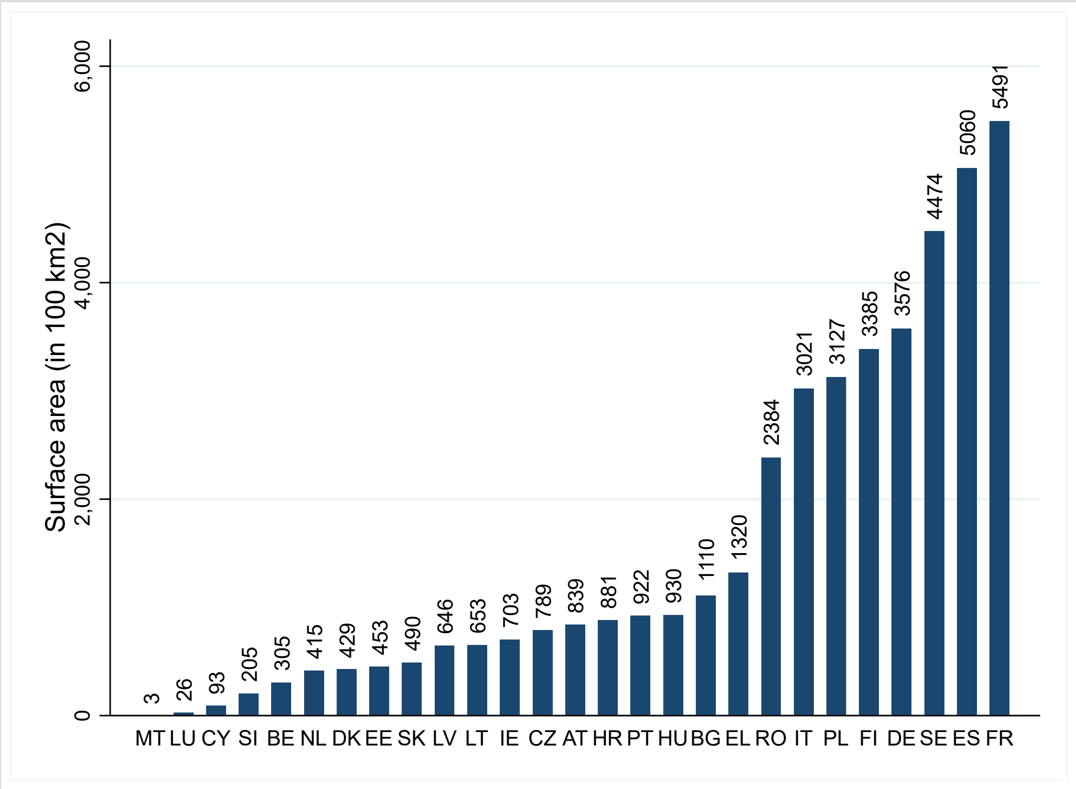
Source: Eurostat

Figure A.3.7: GDP growth, 2018



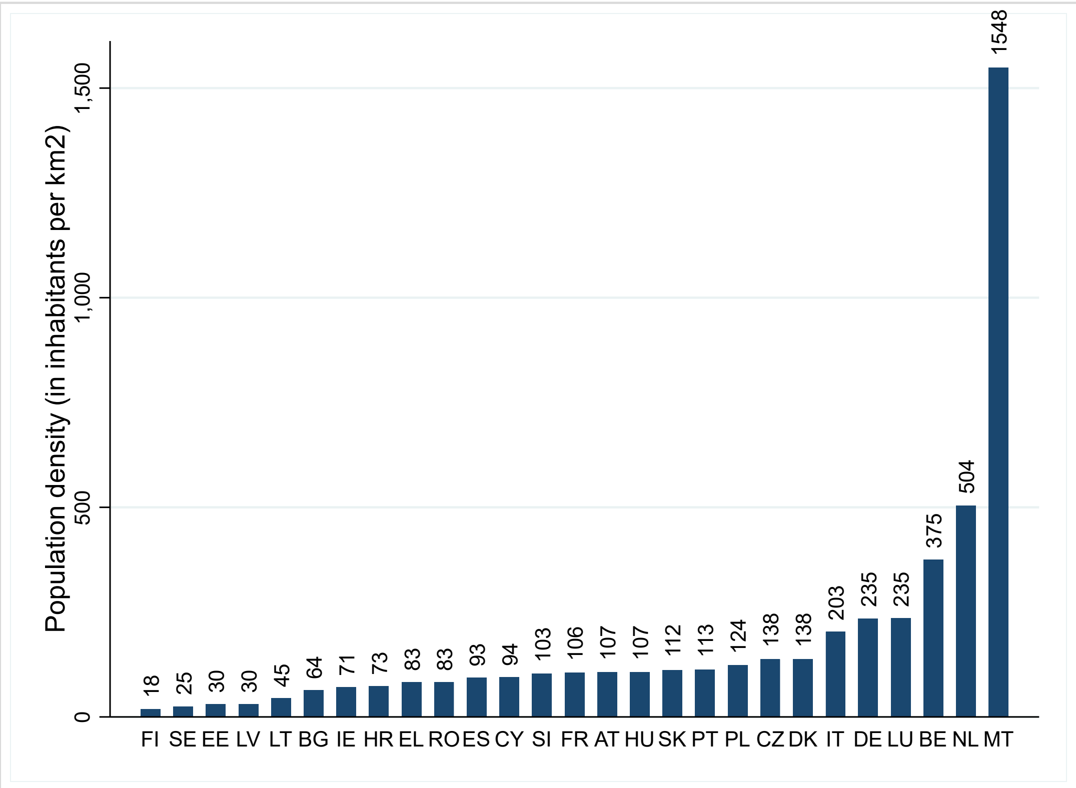
Source: Eurostat

Figure A.3.8: Surface area, 2018



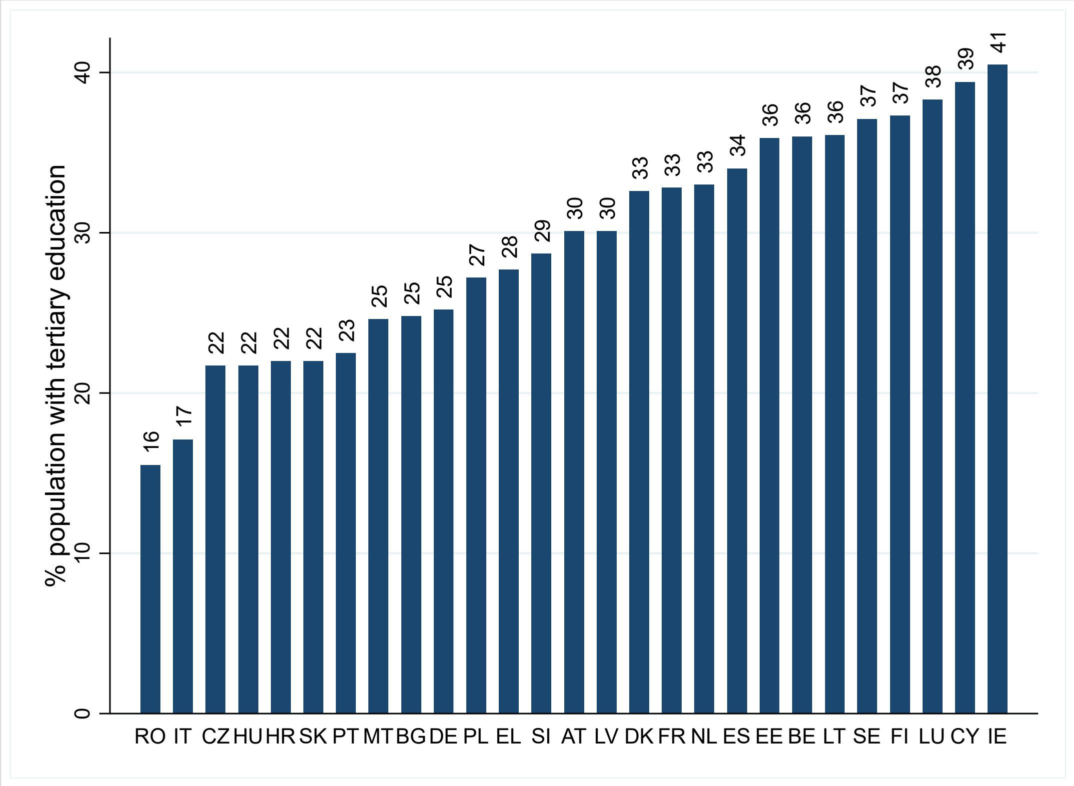
Source: The World Bank

Figure A.3.9: Population density, 2018



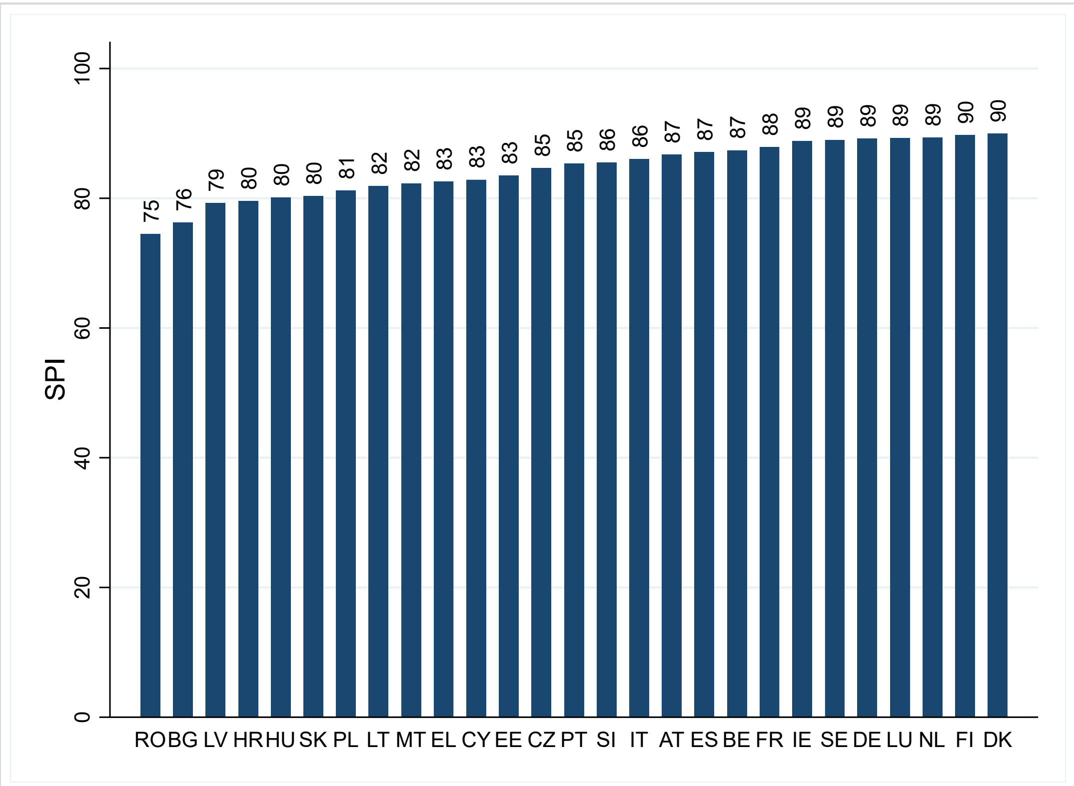
Source: Eurostat

Figure A.3.10: Education, 2018



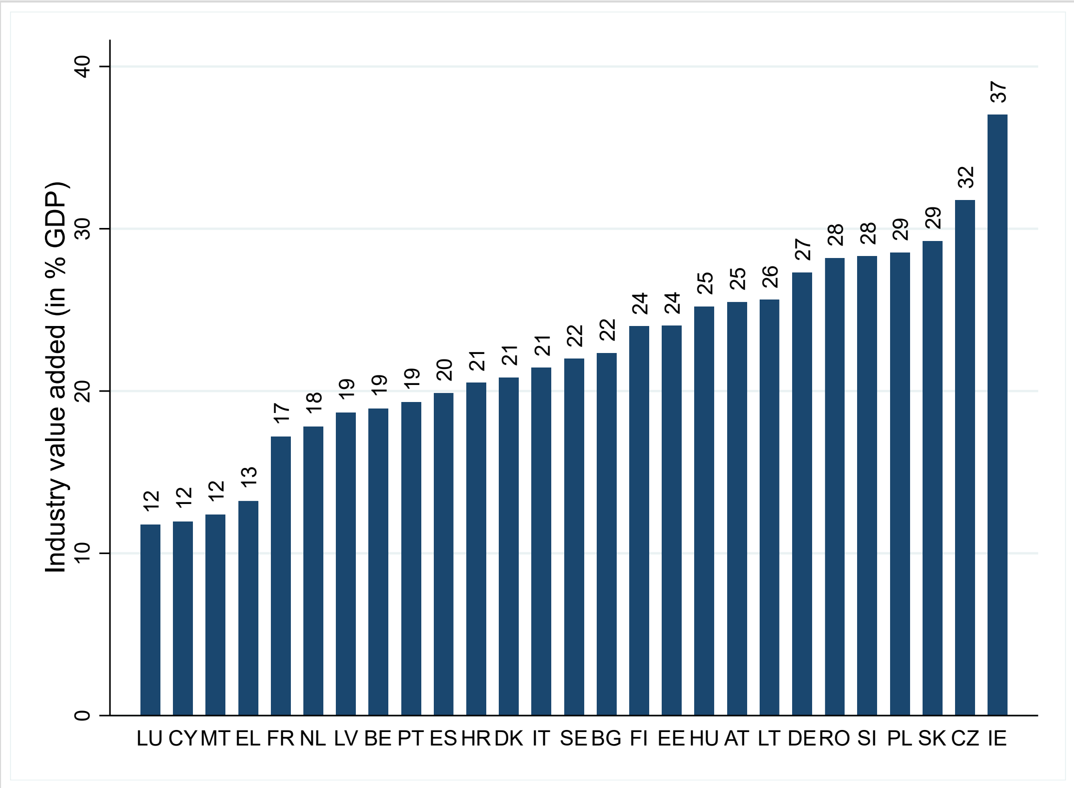
Source: Eurostat

Figure A.3.11: Social Progress Index, 2018



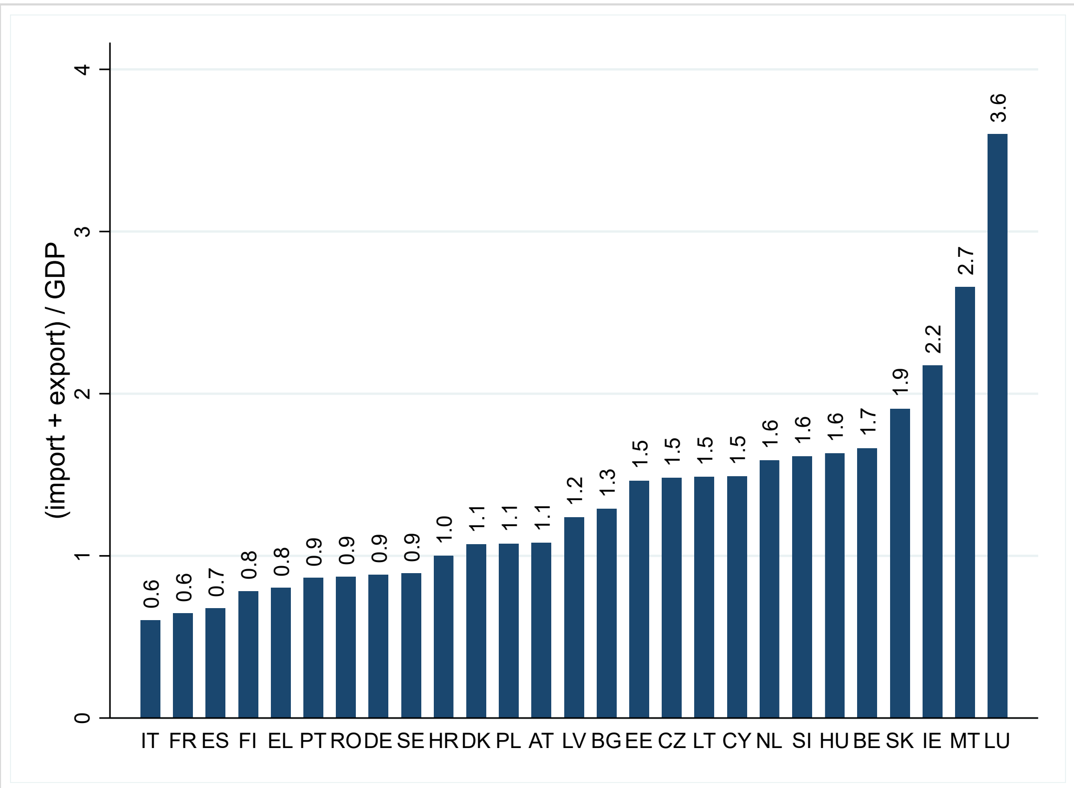
Source: Deloitte

Figure A.3.12: Industry value added, 2018



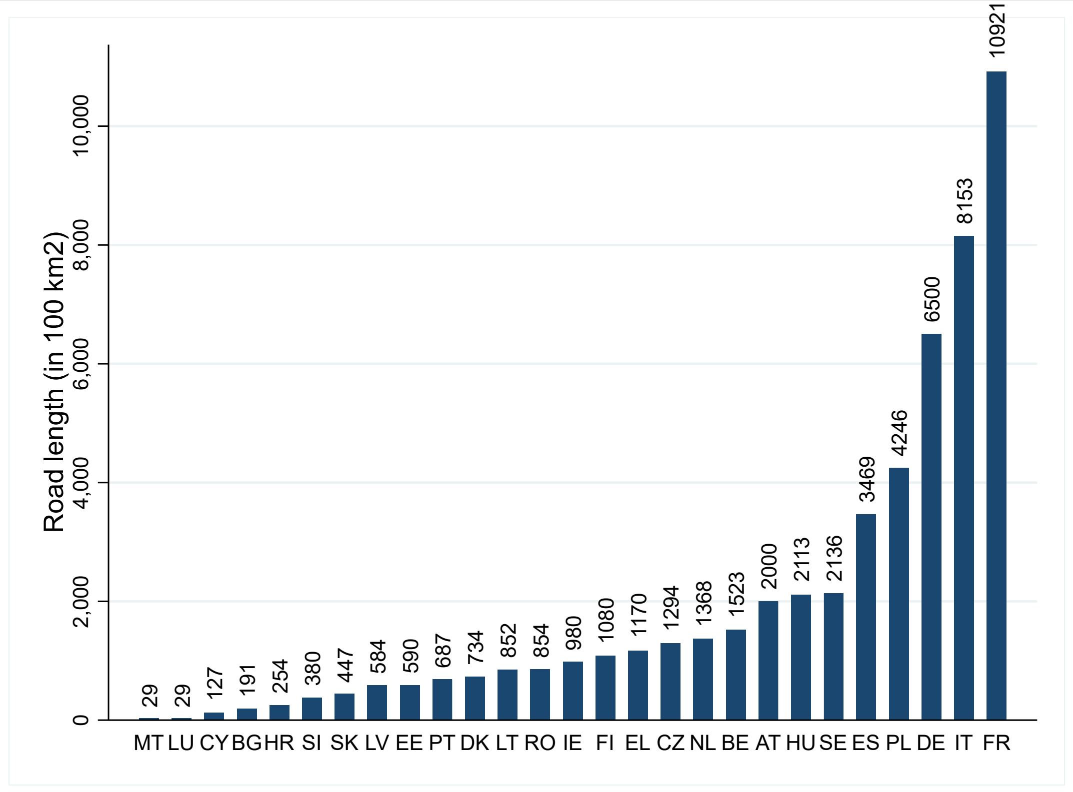
Source: The World Bank

Figure A.3.13: Trade intensity, 2018



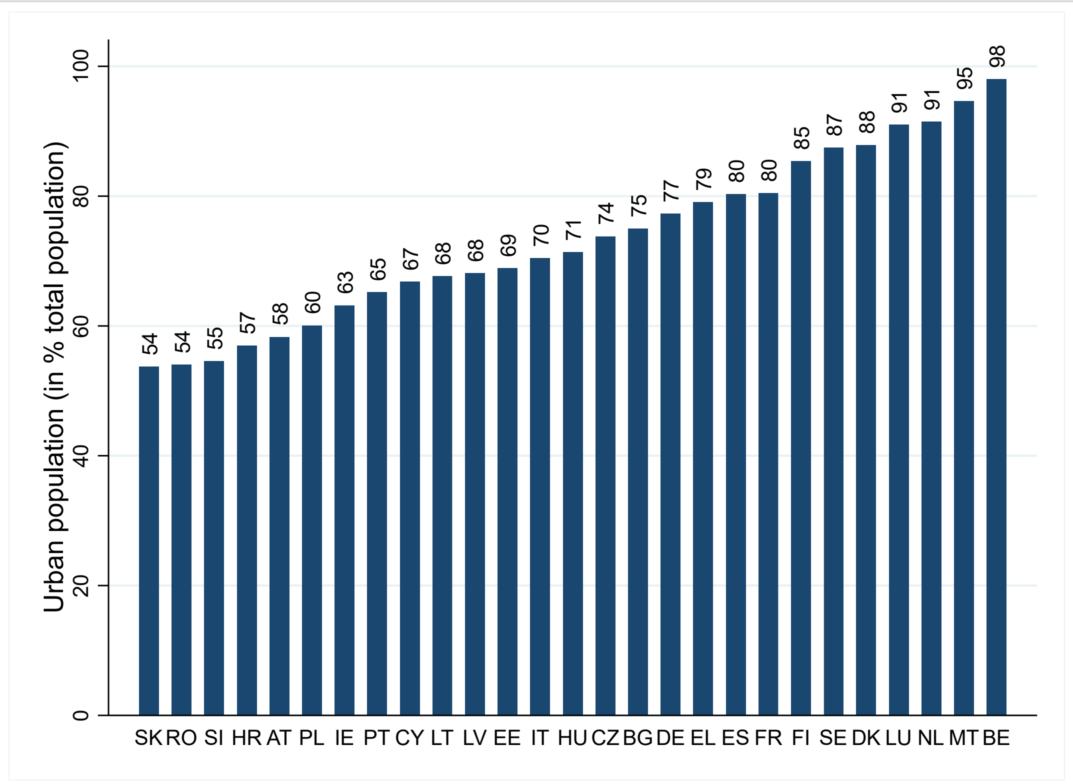
Source: Eurostat ((import + export)/GDP)

Figure A.3.14: Road length, 2018



Source: Eurostat

Figure A.3.15: Urban population, 2018



Source: The World Bank

Table A.3.5: Correlation analysis explanatory variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) GDP per capita	1.000									
(2) GDP growth	-0.157	1.000								
(3) Surface area	0.005	-0.386**	1.000							
(4) Population density	0.082	0.177	-0.241	1.000						
(5) Education	0.581***	0.080	-0.014	-0.123	1.000					
(6) SPI	0.788***	-0.354*	0.231	0.045	0.570***	1.000				
(7) Industry value added	-0.158	0.345*	0.072	-0.375*	-0.192	-0.079	1.000			
(8) Trade intensity	0.457**	0.416**	-0.622***	0.453**	0.263	0.053	-0.136	1.000		
(9) Road length	0.058	-0.354*	0.744***	-0.083	-0.143	0.292	0.026	-0.467**	1.000	
(10) Urban population	0.502***	-0.405**	0.107	0.469**	0.404**	0.538***	-0.553***	0.219	0.081	1.000

**** p<0.01, ** p<0.05, * p<0.1*

Source: Own estimates based on Eurostat (GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data

Table A.3.6: Pairwise correlation EPI and explanatory variables

	EPI
GDP per capita	0.721***
GDP growth	-0.339
Surface area	0.328
Population density	0.318
Education	0.427**
SPI	0.773***
Industry value added	-0.320
Trade intensity	0.058
Road length	0.363
Urban population	0.633***

Source: Own estimates based on EPI (EPI), Eurostat (GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data.

Table A.3.7: EU countries efficiency scores (Model A)

Country	θ_{VRS}	θ_{CRS}	SE	rts	% Change
Austria	0.93	0.82	0.88	drs	-12.27
Belgium	0.26	0.25	0.97	drs	-3.48
Bulgaria	1.00	1.00	1.00	crs	0.00
Croatia	0.21	0.20	0.96	irs	3.54
Cyprus	0.32	0.32	0.98	drs	-1.88
Czechia	0.17	0.17	1.00	irs	0.25
Denmark	1.00	0.52	0.52	drs	-47.53
Estonia	0.16	0.15	0.95	irs	5.22
Finland	1.00	0.96	0.96	drs	-3.86
France	1.00	0.30	0.30	drs	-69.58
Germany	0.48	0.47	0.96	drs	-3.78
Greece	0.19	0.18	0.98	drs	-2.23
Hungary	0.33	0.32	0.96	irs	4.19
Ireland	0.38	0.35	0.93	drs	-7.37
Italy	0.35	0.34	0.97	drs	-3.35
Latvia	0.41	0.40	0.97	irs	2.55
Lithuania	0.40	0.40	0.99	drs	-0.62
Luxembourg	0.61	0.52	0.84	drs	-15.61
Malta	0.25	0.15	0.59	drs	-41.42
Poland	0.34	0.32	0.94	irs	5.51
Portugal	0.71	0.70	0.98	drs	-1.62
Romania	0.29	0.28	0.95	irs	4.52
Slovakia	0.16	0.15	0.99	drs	-1.13
Slovenia	0.39	0.39	1.00	irs	0.41
Spain	0.27	0.26	0.96	drs	-3.78
Sweden	0.36	0.23	0.63	drs	-37.29
Total	0.46	0.39	0.89		-8.87

The columns are: θvrs - total technical efficiency with variable returns to scale, θcrs - total technical efficiency with constant returns to scale, rts - returns to scale, SE - Scale efficiency, % change - % change in total efficiency moving from crs to vrs (+ for irs, - for drs).
Outliers: /
Missing data: /
Source: Own estimates based on EPI (EPI) and Eurostat data (Environmental expenditures)

Table A.3.8: Second-stage analysis

	(1)	(2)	(3)
GDP per capita	0.000	0.000	0.002*
	(0.000)	(0.000)	(0.001)
GDP growth	-4.877	-4.318	-5.696
	(3.493)	(4.196)	(5.670)
Surface area	0.002	0.001	-0.007
	(0.004)	(0.004)	(0.007)
Population density	-0.012	-0.016	0.023
	(0.021)	(0.027)	(0.038)
Industry value added		-0.059	0.908
		(1.204)	(1.374)
Urban population		0.170	0.146
		(0.760)	(0.836)
Education			1.548
			(1.578)
SPI			-4.424
			(3.497)
Trade intensity			-33.958*
			(19.318)
Road length			0.002
			(0.004)
Constant	50.705	40.027	370.693
Observations	26	26	26
Pseudo R2	0.027	0.027	0.042

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Dependent variable: efficiency scores DEA Model A (%)
Source: Own estimates based on EPI (EPI), Eurostat (Environmental expenditures, GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data

Table A.3.9: EU countries efficiency scores (Model B)

Country	θ_{VRS}	θ_{CRS}	SE	rts	% Change
Austria	1.00	1.00	1.00	crs	0.00
Belgium	1.00	0.69	0.69	drs	-30.83
Bulgaria	1.00	0.89	0.89	irs	11.41
Croatia	0.36	0.33	0.91	drs	-8.90
Cyprus	0.41	0.36	0.88	irs	12.20
Czechia	0.25	0.23	0.90	irs	9.99
Estonia	0.33	0.28	0.85	drs	-14.73
Finland	1.00	0.83	0.83	irs	16.79
France	1.00	0.67	0.67	drs	-33.29
Germany	1.00	1.00	1.00	crs	0.00
Greece	0.40	0.40	1.00	irs	0.18
Hungary	0.44	0.38	0.86	irs	14.23
Italy	1.00	1.00	1.00	crs	0.00
Latvia	0.51	0.38	0.75	irs	24.77
Luxembourg	1.00	1.00	1.00	crs	0.00
Poland	0.46	0.43	0.94	irs	5.84
Portugal	1.00	1.00	1.00	crs	0.00
Romania	0.44	0.41	0.93	irs	7.32
Slovakia	0.18	0.15	0.81	irs	18.57
Slovenia	0.60	0.58	0.96	irs	3.76
Spain	0.49	0.47	0.98	drs	-2.24
Sweden	0.26	0.23	0.89	irs	11.10
Total	0.64	0.58	0.90		2.10

The columns are: θvrs – total technical efficiency with variable returns to scale, θcrs – total technical efficiency with constant returns to scale, rts – returns to scale, SE – Scale efficiency, % change – % change in total efficiency moving from crs to vrs (+ for irs, - for drs).
Outliers: The Netherlands (circular material use, expenditures), Denmark, Lithuania, Ireland (wind energy)
Missing data: Malta (solar energy)
Source: own estimates based on Eurostat data (Environmental expenditures, wind energy, solar energy, hydro energy, circular material use)

Table A.3.10: Spatial analysis

	(1)	(2)
Expenditures	2.479** (1.073)	4.474*** (1.597)
Expenditures ×contig	3.509 (6.448)	10.455** (4.097)
Observations	676	572

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1
Dependent variable: efficiency scores DEA Model A (%) (column (1)): efficiency scores DEA Model B (column (2))
The following variables are included as control variables for both Countries i and j: GDP per capita, GDP growth, surface area, population density, education (percentage of people with tertiary education), SPI, industry value added, trade intensity, road length, urban population.
Source: Own estimates based on EPI (EPI), Eurostat (Environmental expenditures, GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data

Table A.3.11: Robustness checks

Description	θ_{VRS}	% change	Spill-overs?
(1) Main results Model A	0.46	-8.87	Yes
(2) Main results Model B	0.64	2.10	Yes
(3) Robustness check: 2017–2018 data instead of 2018 data – Model A	0.49	-1.05	Yes
(4) Robustness check: 2017–2018 data instead of 2018 data – Model B	0.67	2.67	Yes
(5) Robustness check: environmental expenditures as a percentage of total public expenditures – Model A	0.42	-1.03	Yes
(6) Robustness check: environmental expenditures as a percentage of total public expenditures – Model B	0.63	4.30	Yes
(7) Robustness check: total green energy – Model B	0.57	11.59	Yes
(8) Robustness check: decompose EPI in environmental health and ecosystem vitality – Model A	0.49	-13.07	Yes
(9) Robustness check: EPI 2016 data instead of EPI 2018 data – Model A	0.39	-3.90	Yes
(10) Robustness check: keep outliers – Model A	0.45	-8.65	Yes
(11) Robustness check: keep outliers – Model B	0.67	0.69	Yes

Model A: Outcome = f(input)
Model B: Intermediate output = f(input)
Source: Own estimates based on EPI (EPI), Eurostat (Environmental expenditures, GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data.

A.4. Appendix to Chapter 4

Table A.4.1: Variable description second-stage analysis (additional variables)

Variable	Definition
Nitrogen consumption	Annual nitrogen consumption, in 100 tons.
Phosphorus consumption	Annual phosphorus consumption, in 100 tons

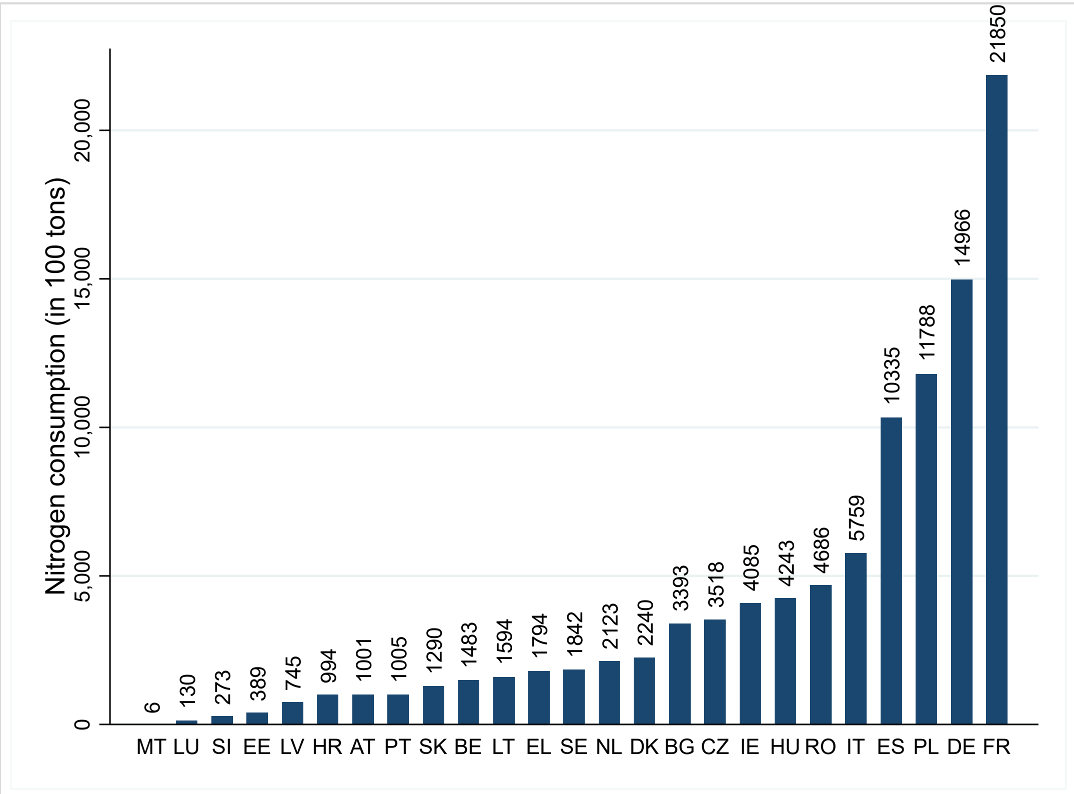
Source: Eurostat (Nitrogen consumption, Phosphorus consumption)

Table A.4.2: Descriptive statistics second stage analysis (additional variables)

	N	Mean	Std. dev.	Min.	Max.
Nitrogen consumption	25	4,061.31	5,302.79	5.86	21,850.15
Phosphorus consumption	25	448.57	566.79	0.40	1,919.21

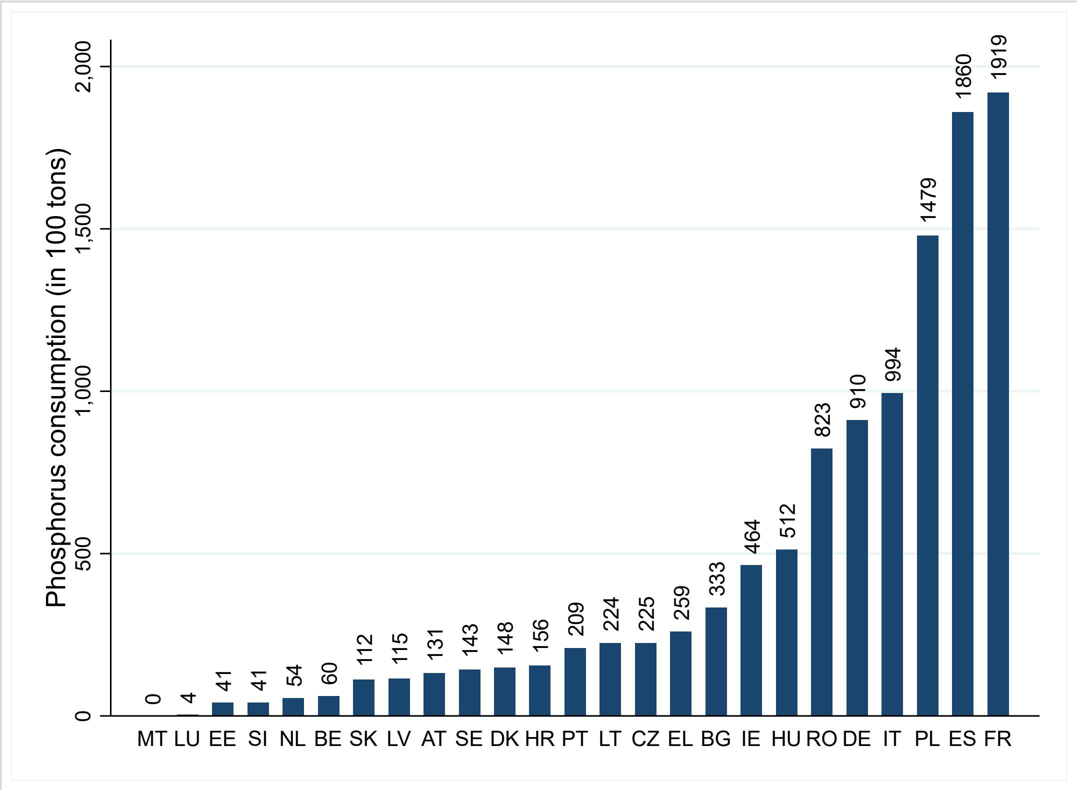
Source: Eurostat (Nitrogen consumption, Phosphorus consumption)

Figure A.4.1: Nitrogen consumption, 2018



Source: Eurostat

Figure A.4.2: Phosphorus consumption, 2018



Source: Eurostat

Table A.4.3: Pairwise correlation EPI wastewater treatment component and explanatory variables

Variables	EPI wastewater treatment component
GDP per capita	0.406**
GDP growth	-0.509*
Surface area	0.209
Population density	0.308
Industry value added	-0.205
Urban population	0.688***
Nitrogen consumption	0.134
Phosphorus consumption	0.062

Source: Own estimates based on EPI (EPI), Eurostat (GDP per capita, GDP growth, population density, nitrogen consumption, phosphorus consumption), and the World Bank (Industry value added, surface area, urban population) data

Table A.4.4: EU countries' efficiency scores (Model A)

Country	θ_{vrs}	θ_{crs}	SE	rts	% Change
Austria	0.72	0.01	0.02	drs	-98.22
Belgium	0.10	0.01	0.12	drs	-88.38
Bulgaria	1.00	1.00	1.00	crs	0.00
Croatia	0.01	0.01	0.92	irs	7.82
Czechia	0.02	0.00	0.22	drs	-77.55
Denmark	1.00	0.11	0.11	drs	-89.20
Estonia	0.09	0.02	0.18	drs	-82.28
France	0.02	0.01	0.25	drs	-75.41
Germany	1.00	0.01	0.01	drs	-98.98
Greece	0.14	0.02	0.13	drs	-87.46
Hungary	0.01	0.01	0.99	irs	0.54
Ireland	0.00	0.00	0.97	irs	2.92
Italy	0.27	0.04	0.13	drs	-86.91
Latvia	0.14	0.03	0.18	drs	-81.57
Lithuania	0.11	0.11	1.00	irs	0.47
Luxembourg	0.39	0.00	0.01	drs	-99.36
Malta	1.00	0.00	0.00	drs	-99.73
Netherlands	0.72	0.00	0.00	drs	-99.64
Poland	0.01	0.00	0.98	irs	1.68
Portugal	0.01	0.01	1.00	irs	0.12
Romania	0.01	0.01	0.89	irs	10.62
Slovakia	0.01	0.01	0.96	irs	4.24
Slovenia	0.01	0.00	0.94	irs	5.78
Spain	1.00	0.01	0.01	drs	-99.11
Sweden	0.07	0.01	0.08	drs	-91.84
Total	0.31	0.06	0.44		-52.86

The columns are: θvrs – total technical efficiency with variable returns to scale, θcrs – total technical efficiency with constant returns to scale, rts – returns to scale, SE – Scale efficiency, % change – % change in total efficiency moving from crs to vrs (+ for irs, - for drs).
Outliers: Cyprus (EPI-component wastewater treatment)
Missing data: /
We dropped Finland because it was not possible to calculate its efficiency score due to a lack of production (expenditure = 0)
Source: own estimates based on Eurostat data (Wastewater management expenditures) and EPI data (wastewater treatment)

Table A.4.5: Second–stage analysis

	(1)	(2)	(3)	(4)
GDP per capita	0.000	0.000	0.000	0.000
	(0.001)	(0.000)	(0.001)	(0.001)
GDP growth	-6.581	-7.362	-9.322	-11.769*
	(5.207)	(4.797)	(6.334)	(6.508)
Surface area		0.003	0.002	-0.006
		(0.005)	(0.005)	(0.010)
Population density		0.097**	0.096**	0.094**
		(0.042)	(0.046)	(0.043)
Industry value added			1.746	2.266
			(2.007)	(2.046)
Urban population			0.613	0.836
			(1.004)	(1.001)
Nitrogen consumption				-0.002
				(0.004)
Phosphorus consumption				0.044
				(0.042)
Constant	46.004*	31.030	-41.875	-61.645
	(25.422)	(26.543)	(91.630)	(92.623)
Observations	25	25	25	25
Pseudo R^2	0.011	0.046	0.050	0.055

Standard errors are in parentheses
**** p<.01, ** p<.05, * p<.1*

Dependent variable: Efficiency scores DEA Model A (%)
Source: Own estimates based on EPI (EPI), Eurostat (Wastewater management expenditures, GDP per capita, GDP growth, population density, phosphorus consumption, nitrogen consumption), and the World Bank (Industry value added, surface area, urban population) data

Table A.4.6: EU countries efficiency scores (Model B)

Country	θ_{vrs}	θ_{crs}	SE	rts	% Change
Austria	0.12	0.12	1.00	crs	0.00
Belgium	0.11	0.11	0.99	irs	1.37
Czechia	0.04	0.03	0.89	irs	11.16
Denmark	1.00	1.00	1.00	crs	0.00
Estonia	0.14	0.13	0.93	irs	7.49
France	0.05	0.04	0.88	irs	12.12
Germany	0.09	0.09	0.98	irs	1.71
Greece	0.16	0.16	0.97	irs	3.12
Hungary	0.07	0.06	0.87	irs	12.51
Ireland	0.04	0.04	0.96	irs	3.78
Latvia	0.25	0.25	1.00	crs	0.00
Lithuania	1.00	0.86	0.86	irs	13.67
Luxembourg	0.02	0.02	0.99	irs	0.89
Netherlands	0.02	0.02	1.00	crs	0.00
Poland	0.05	0.05	0.98	irs	2.40
Portugal	0.09	0.08	0.91	irs	8.85
Slovakia	0.12	0.11	0.94	irs	6.13
Slovenia	0.05	0.05	0.98	irs	1.73
Spain	0.08	0.07	0.93	irs	6.53
Sweden	0.05	0.04	0.92	irs	8.07
Total	0.18	0.17	0.95		5.08

The columns are: θvrs – total technical efficiency with variable returns to scale, θcrs – total technical efficiency with constant returns to scale, rts – returns to scale, SE – Scale efficiency, % change – % change in total efficiency moving from crs to vrs (+ for irs, - for drs).
Outliers: /
Missing data: Bulgaria, Croatia, Cyprus, Italy, Malta, Romania (connected)
We dropped Finland because it was not possible to calculate its efficiency score due to a lack of production (expenditure = 0)
Source: Own estimates based on Eurostat data (Wastewater management expenditures, connected)

Table A.4.7: Spatial analysis

	(1)	(2)
Expenditures	8.822	7.764**
	(5.869)	(3.869)
Expenditures x contig	-23.180	-23.673
	(36.567)	(19.897)
Observations	650	520

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Dependent variable: Efficiency scores DEA Model A (%) (column (1)): efficiency scores DEA Model B (Column (2))

The following variables are included as control variables for both Countries i and j: GDP per capita, GDP growth, surface area, population density, education (percentage of people with tertiary education), SPI, industry value added, trade intensity, road length, urban population, nitrogen consumption, phosphorus consumption.

Source: Own estimates based on EPI (EPI), Eurostat (Wastewater management expenditures, GDP per capita, GDP growth, population density, phosphorus consumption, nitrogen consumption), and the World Bank (industry value added, surface area, urban population) data

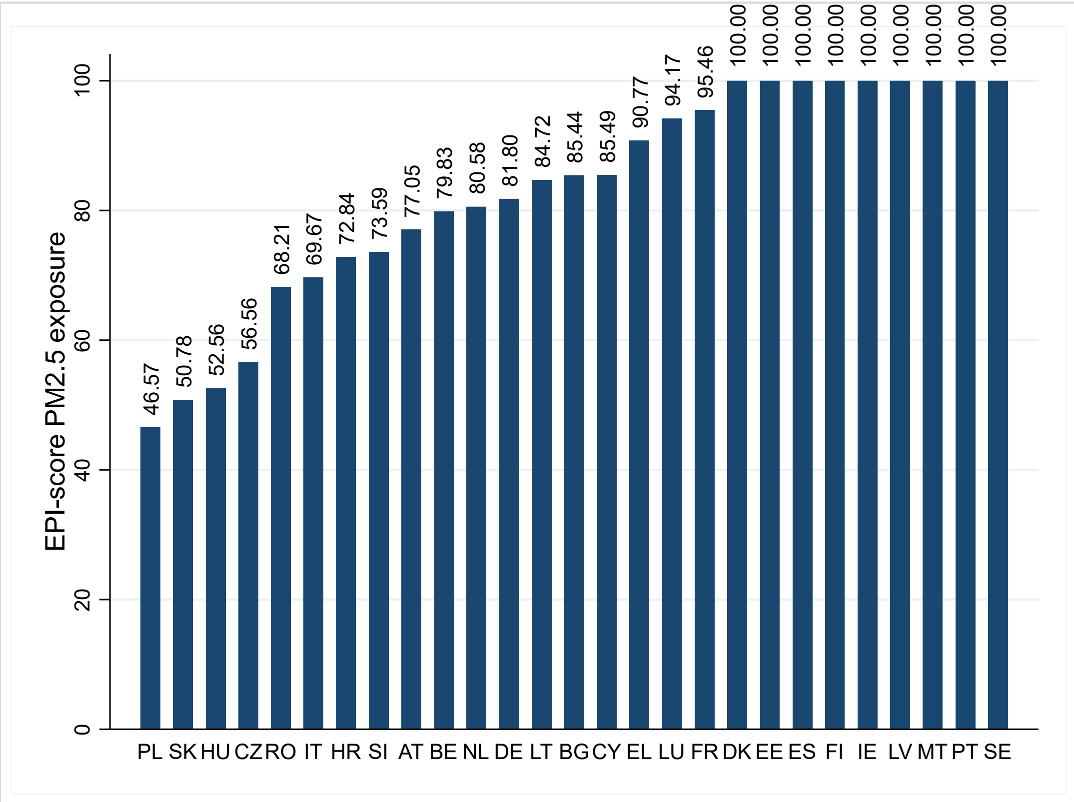
Table A.4.8: Robustness checks

Description	θ_{VRS}	% change	Spill-overs?
(1) Main results Model A	0.31	-52.86	No
(2) Main results Model B	0.18	5.08	Yes
(3) Robustness check: 2017–2018 data instead of 2018 data – Model A	0.35	-24.26	Yes
(4) Robustness check: 2017–2018 data instead of 2018 data – Model B	0.18	-0.45	Yes
(5) Robustness check: wastewater management expenditures as a percentage of total public expenditures – Model A	0.29	-46.68	No
(6) Robustness check: wastewater management as a percentage of total public expenditures – Model B	0.16	8.47	Yes
(7) Robustness check: keep outliers – Model A	0.30	-50.23	No
(8) Robustness check: keep outliers – Model B	0.18	5.08	Yes

Model A: Outcome = f(input)
Model B: Intermediate output = f(input)
Source: Own estimates based on EPI (EPI), Eurostat (Wastewater management expenditures, GDP per capita, GDP growth, population density, phosphorus consumption, nitrogen consumption), and the World Bank (Industry value added, surface area, urban population) data

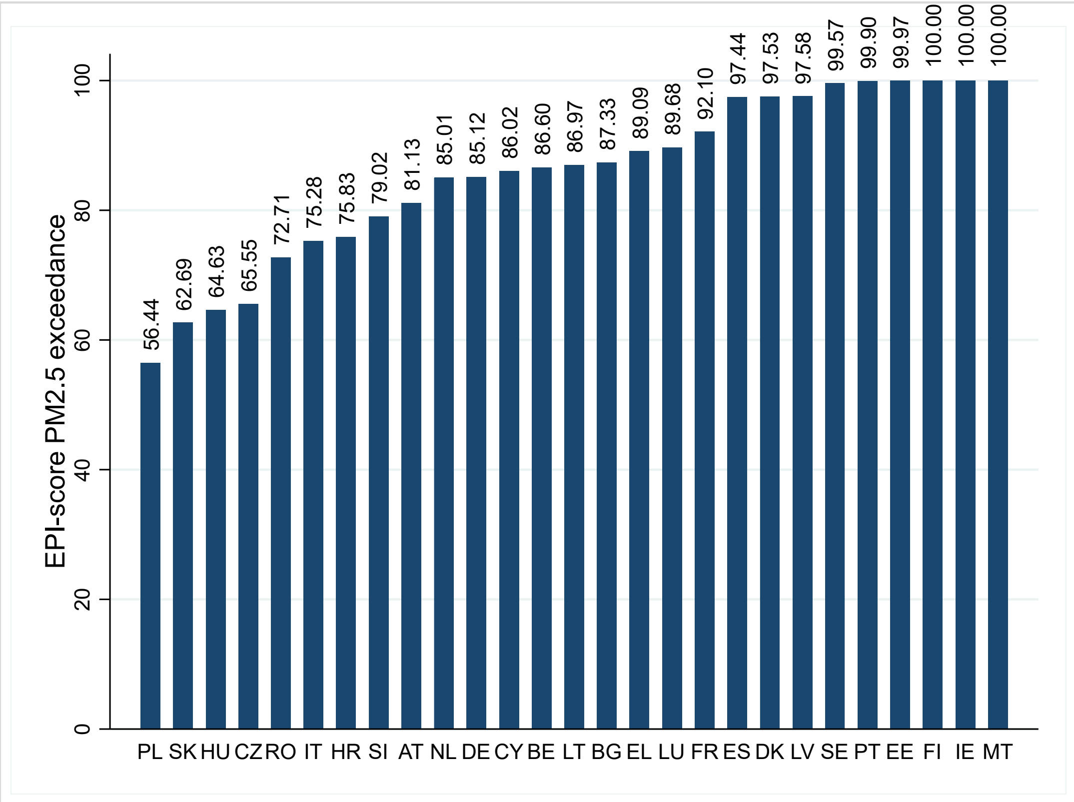
A.5. Appendix to Chapter 5

Figure A.5.1: PM2.5 Exposure, 2018



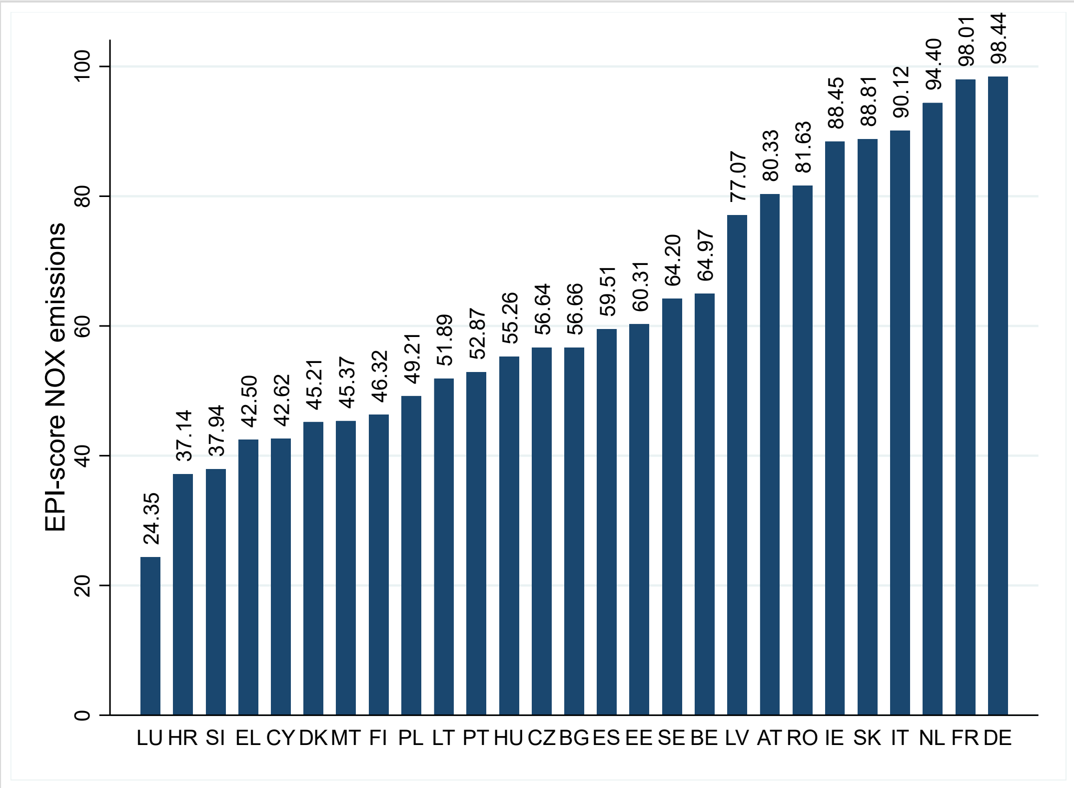
Source: EPI

Figure A.5.2: PM2.5 Exceedance, 2018



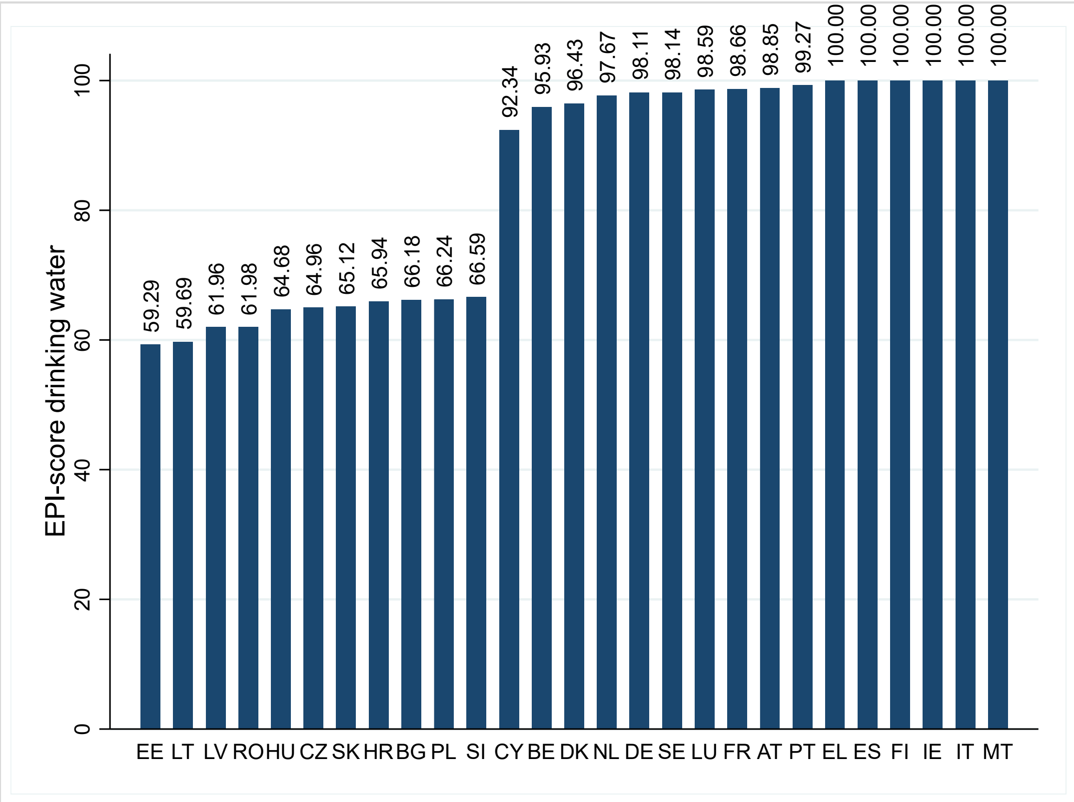
Source: EPI

Figure A.5.3: NOX Emissions, 2018



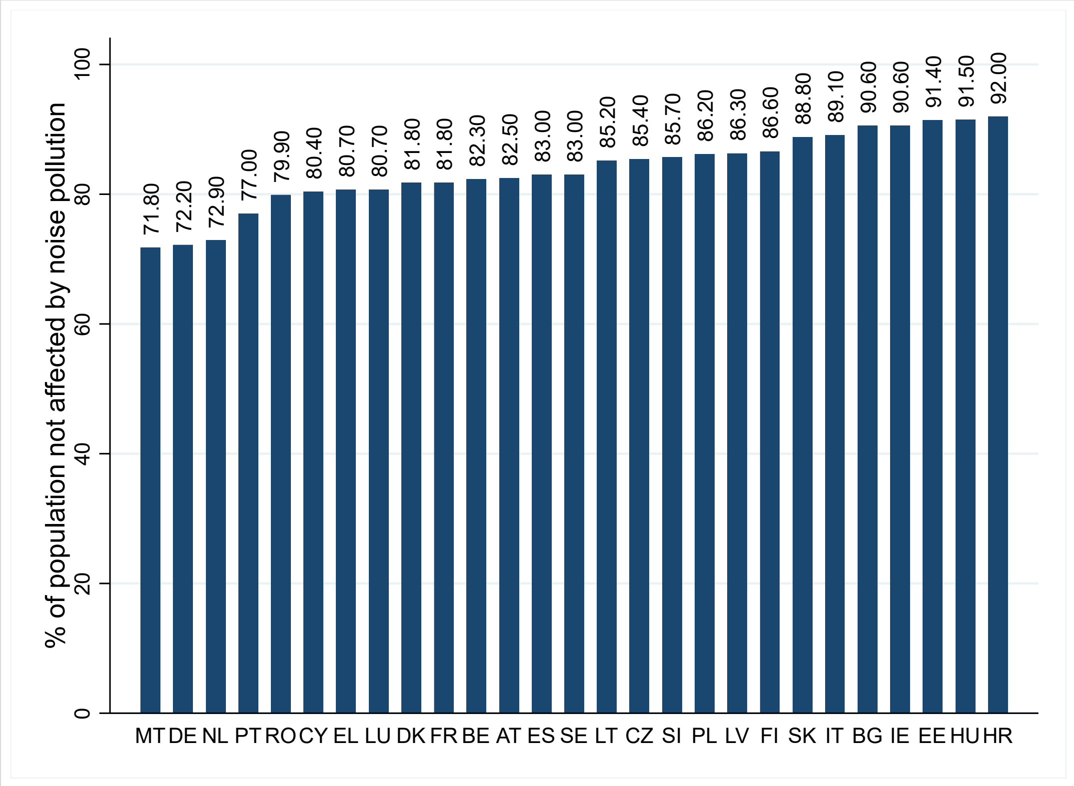
Source: EPI

Figure A.5.4: Drinking Water, 2018



Source: EPI

Figure A.5.5: Noise pollution, 2018



Source: Eurostat

Table A.5.1: Pairwise correlation EPI PM2.5 exposure, PM2.5 exceedance, and NOX emission component and explanatory variables

	PM2.5 Exposure	PM2.5 Exceedance	NOX Emission
GDP per capita	0.398**	0.378*	0.005
GDP growth	-0.130	-0.106	-0.062
Surface area	0.099	0.071	0.354
Population density	0.117	0.148	-0.053
Industry value added	-0.440**	-0.391**	0.351*
Urban population	0.479**	0.493***	-0.111
Education	0.586***	0.587***	-0.169
Social progress index	0.422**	0.437**	0.110
Trade intensity	0.019	0.022	-0.307
Road length	-0.094	-0.121	0.561***

*** p<.01, ** p<.05, * p<.1

Source: Own estimates based on EPI (EPI), Eurostat (GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data

Table A.5.2: EU countries efficiency scores (Model A)

Country	θ_{vrs}	θ_{crs}	SE	rts	% Change
Austria	0.15	0.07	0.44	drs	-56.21
Croatia	1.00	0.45	0.45	drs	-55.10
Cyprus	1.00	0.58	0.58	drs	-42.35
Czechia	1.00	1.00	1.00	crs	0.00
Denmark	0.69	0.34	0.49	drs	-51.24
Estonia	1.00	0.06	0.06	drs	-94.43
Finland	0.33	0.16	0.49	drs	-51.24
France	1.00	0.14	0.14	drs	-85.66
Germany	1.00	0.07	0.07	drs	-93.27
Hungary	1.00	0.50	0.50	drs	-49.66
Ireland	1.00	0.49	0.49	drs	-51.24
Italy	1.00	0.33	0.33	drs	-67.21
Latvia	0.28	0.14	0.49	drs	-51.24
Luxembourg	0.17	0.08	0.48	drs	-51.61
Malta	0.85	0.42	0.49	drs	-51.24
Netherlands	0.21	0.04	0.19	drs	-81.00
Poland	0.27	0.23	0.84	drs	-15.73
Portugal	0.28	0.14	0.49	drs	-51.24
Romania	0.06	0.03	0.47	drs	-52.94
Slovakia	0.39	0.16	0.40	drs	-59.69
Slovenia	0.12	0.08	0.64	drs	-35.83
Spain	0.66	0.32	0.49	drs	-51.24
Sweden	0.82	0.40	0.49	drs	-51.24
Total	0.62	0.27	0.46		-54.37

The columns are: θvrs – total technical efficiency with variable returns to scale, θcrs – total technical efficiency with constant returns to scale, rts – returns to scale, SE – Scale efficiency, % change – % change in total efficiency moving from crs to vrs (+ for irs, - for drs).
Outliers: Belgium, Greece (expenditures)
Missing data: Bulgaria, Lithuania (expenditures)
Source: Own estimates based on Eurostat data (ambient air, soil and groundwater protection and noise abatement expenditures, noise pollution) and EPI data (PM2.5 Exposure, PM2.5 Exceedance, NOX Emissions, Drinking Water)

Table A.5.3: Second-stage analysis

	(1)	(2)	(3)
GDP per capita	-0.000 (0.001)	-0.001 (0.001)	-0.001 (0.001)
GDP growth	7.217 (7.900)	10.056 (8.326)	19.306 (12.062)
Surface area	0.008 (0.008)	0.004 (0.008)	-0.014 (0.012)
Population density	0.000 (0.039)	-0.040 (0.053)	-0.101 (0.070)
Industry value added		0.707 (2.485)	-0.575 (2.909)
Urban population		1.952 (1.633)	3.056* (1.705)
Education			-1.615 (3.518)
SPI			3.532 (6.826)
Trade intensity			5.635 (30.782)
Road length			0.018* (0.008)
Constant	38.946 (46.600)	-94.675 (134.290)	-412.15 (487.585)
Observations	23	23	23
Pseudo R^2	0.009	0.017	0.071

Standard errors are in parentheses
*** p<.01, ** p<.05, * p<.1

Dependent variable: efficiency scores DEA Model A (%)
Source: Own estimates based on EPI (EPI), Eurostat (ambient air, soil and groundwater protection and noise abatement expenditures, GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data

Dependent variable: efficiency scores DEA Model A (%)
Source: Own estimates based on EPI (EPI), Eurostat (ambient air, soil and groundwater protection and noise abatement expenditures, GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data

Table A.5.4: Spatial analysis

	(1)
Expenditures	3.347
	(3.043)
Expenditures x contig	-9.671
	(24.271)
Observations	575

Dependent variable: Efficiency scores DEA Model A (%)
Following variables are included as control variables for both Countries i and j: GDP per capita, GDP growth, surface area, population density, education (percentage of people with tertiary education), SPI, industry value added, trade intensity, road length, urban population.
Source: Own estimates based on EPI (EPI), Eurostat (ambient air, soil and groundwater protection and noise abatement expenditures, GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data

Table A.5.5: Robustness checks

Description	θ_{VRS}	% change	Spill-overs?
(1) Original Model A	0.62	-54.37	No
(2) Robustness check: 2017–2018 data instead of 2018 data – Model A	0.62	-49.93	Yes
(3) Robustness check: ambient air, soil and groundwater protection and noise abatement expenditures as a percentage of total public expenditures – Model A	0.71	-57.39	Yes
(4) Robustness check: one outcome (PM2.5 exposure) – Model A	0.42	-34.96	Yes
(5) Robustness check: one outcome (PM2.5 exceedance) – Model A	0.41	-40.39	Yes
(6) Robustness check: one outcome (NOX emissions) – Model A	0.38	-18.78	No
(7) Robustness check: keep outliers – Model A	0.57	-54.35	Yes

Model A: Outcome = f(input)
Model B: Intermediate output = f(input)
Source: Own estimates based on EPI (EPI), Eurostat (ambient air, soil and groundwater protection and noise abatement expenditures, GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data

Model A: Outcome = f(input)
Model B: Intermediate output = f(input)
Source: Own estimates based on EPI (EPI), Eurostat (ambient air, soil and groundwater protection and noise abatement expenditures, GDP per capita, GDP growth, population density, education, road length, trade intensity ((import + export)/GDP), Deloitte (Social Progress Index), and the World Bank (Industry value added, surface area, urban population) data

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Linking national spending on the environment with the effects it has on the environmental performance of EU Member States allows for a better assessment of the effective quality of budgetary interventions. In this analysis, based on the detailed research paper in the Annex, we discuss under what circumstances some public environmental expenditure could be spent more efficiently at EU rather than at national level. We estimate that this transfer towards a more efficient level of governance would allow Member States to save between €20 billion and €26 billion of budgetary spending per year. In the present exacerbated economic, social and environmental crisis, we conclude that reducing budgetary waste and improving the way public money is spent should be fully integrated to achieve more sustainable development.

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